



Review

Green finance for energy transition, climate action and sustainable development: overview of concepts, applications, implementation and challenges

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Abstract: The solutions to mankind's greatest problems today lie in the simultaneous development, adoption and deployment of a combination of technological, socio-political, cultural and financial initiatives and mechanisms. The present work serves as a brief compilation of concepts and information pertaining to the broad domain of green finance, particularly for a readership with non-financial background. Green finance indicates the deployment of private and public capital towards projects that not only prevent environmental degradation and related impacts such as climate change and air pollution but also generate a host of social benefits and adequate financial returns for the investors. Thus, green finance embodies several cross-cutting concepts. The various global events leading to the development of the current state of green finance, the typical forms and instruments involved, the regulatory framework and issuance process for these instruments and the various international agencies and organizations developing and making use of green finance schemes for identified beneficiary projects are briefly described in this work. Financial disclosures and the role of regulators and investors in strengthening green finance schemes are discussed, along with a summary of the current thought leadership and current academic research in this domain. The challenges in green finance are also enumerated and a few perspectives for the future are presented.

Keywords: green finance; sustainable finance; impact investing; climate change mitigation and adaptation; energy transition

JEL Codes: Y2, Q42, Q54, Q56, P28, G11

Abbreviations: ADB: Asian Development Bank; CDP: Carbon Disclosure Project; COP: Conference of Parties; EBRD: European Bank for Reconstruction and Development; ESG: Environmental, Social, Governance; IEA: International Energy Agency; IPCC: Intergovernmental Panel on Climate Change; GHG: Green House Gas; NDC: Nationally Determined Contributions; OECD: Organization for Economic Co-operation and Development; REDD: Reducing Emissions from Deforestation and Forest Degradation; SDG: Sustainable Development Goal; TCFD: Task Force on Climate-related Financial Disclosures; UNCTAD: United Nations Conference on Trade and Development; UNEP: United Nations Environmental Program; UNEP FI: United Nations Environment Programme Finance Initiative; UNFCCC: United Nations Framework Convention on Climate Change; UNGC: United Nations Global Compact; WRI: World Resources Institute; WWF: World Wildlife Fund.

1. Introduction

1.1. Conceptual basis for green finance

Mankind today is facing some of the biggest challenges including climate change, pollution, environmental degradation, loss of biodiversity, water crisis and associated humanitarian issues such as poverty, lack of employment, forced migration, hunger, lack of healthcare infrastructure and education and armed conflict in many parts of the world (Emmerij et al., 2001). In fact, the Global Risk report has consistently identified climate change, biodiversity loss and such environmental issues as the most significant risk on a global level (WEF, 2021). The financial sector has a crucial role in empowering mankind to overcome these massive problems. It is not adequate to only develop the technologies and policy frameworks necessary to address these problems. Inadequate financial resources to deploy these solutions at scale for the priority action areas are a major impediment towards managing these problems and ensuring inclusive and sustainable growth for all, while staying within the limits of the planetary boundaries (Steffen et al., 2015).

In order to serve as the vanguard for climate action, sustainable development and green recovery, the financial sector has developed strategies and innovative measures to ensure adequate amounts of capital are made available towards projects with social and environmental benefits while also progressively diverting funds away from unsustainable projects and industries with huge negative impacts upon the environment and mankind, particularly those that aggravate climate change effects. Green finance is one such innovative concept aligned with the financial sector's responsibility in meeting the mega challenges of today, in a way that ensures both business and societal value creation without harming the environment (Thomson, 2021). Currently there is increasing understanding of the complex and dynamic interlinkages between running of businesses, impacts on society and the environmental dimensions of these activities. It is this awareness that has made green finance one of the cornerstones in the financial world today, when it comes to ensuring its alignment with meeting the Paris Agreement goals and objectives. The broad objective of green finance is therefore to decouple inclusive, economic growth from environmental degradation.

1.2. Motivation and scope

There are a number of mechanisms being adopted globally for climate change mitigation and adaptation efforts in different sectors, as this is a threat that tends to jeopardise the attainment of all other sustainable development objectives (Ravindranath and Sathaye, 2002; Knittel, 2016). These are primarily based on (i) technological interventions, particularly those that are applicable to the energy and industrial sectors and clean energy transition (e.g., carbon capture technology deployment, increased use of renewable and other clean and low carbon energy sources (Osman et al., 2021), (ii) implementation of natural and nature-based solutions such as increasing forest cover and promoting afforestation as forms of negative emissions ‘technology’, using the oceans and wetlands and soil cover as natural carbon sink and enhancing these capabilities through technology (Law et al., 2018) and (iii) financial actions (e.g., imposing carbon taxes or practising carbon emissions trading; enforcing climate related disclosures in the financial and industrial sector to enable potential investors to make informed choices (Calel and Dechezlepretre, 2016). Many of these mechanisms are now being formally ratified into carbon legislation (Moore, 2012) and mandatory/legally binding climate risk disclosures in some countries.

This work is motivated by the third aspect that is crucial for attainment of net zero emissions across sectors: the depth and breadth of financial actions necessary for climate change management and sustainable, inclusive development for all. This work attempts to provide an insight into the key concepts of green finance, including the historical evolution of the concept through significant global events and initiatives, the mechanisms of green finance currently in use, the various institutions and organizations involved in deploying and managing green finance programs, the types of projects under these schemes in different regions of the world, specific examples and success stories, the current challenges and future outlook for this domain. It also describes briefly current academic research areas, research gaps and thought leadership in this field along with some of the recent innovations in this sector. A brief perspective on the inclusion of nuclear power projects under green finance schemes is also included to highlight some of the conflicting thought processes in green finance.

This work is pedagogical in nature and is meant to complement the undergraduate curricula in economics, finance, sustainable energy and engineering and related disciplines. It aims to contribute to awareness-building in this domain by synthesizing various kinds of information and insights in academic and grey literature on green finance. It also attempts to serve as a concise and not a very highly technical bibliographic review cum primer on the various aspects of green finance to newcomers in this field, particularly those belonging to or having non-financial educational or professional backgrounds.

2. Preliminary concepts and definitions

2.1. Terminology

Green finance refers to a broad category of activities, products, services (including financial risk management related to climate and environment), instruments and mechanisms in the financial domain that are linked to investments in business and industrial activities that can create sustainable, positive impact on the society and the environment, including land, water, biodiversity resources, air and people (Sachs et al., 2019). It is an emerging cross-cutting domain in finance and represents an amalgamation of concepts from traditional financing in the business world, fiduciary duty in development and deployment of new technologies for a low-carbon economy, sustainable development, climate change

management and preservation of the natural world (Migliorelli and Dessertine, 2019). It is a segment of the general principles of green economy and sustainable finance.

Table 1. Glossary of terms related to modes of green finance (Sachs et al., 2019; Ramiah and Gregoriou, 2016; Wabnitz and Blasiak, 2019; Linnenluecke et al., 2016).

Serial No.	Term	Explanation
1	Green finance	Generic term implying use or diversion of financial resources to deploy and support projects with long term positive impact on the environment
2	Sustainable finance	Finances deployed in support of projects that ensure just, sustainable and inclusive growth or attainment of one or more sustainable development goals
3	Climate finance	Finances deployed in support of low carbon and climate resilient projects that help in climate change mitigation and adaptation efforts, particularly in the energy and infrastructure sectors
4	Carbon finance	Financial instruments based on economic value of carbon emissions which an organization cannot avoid but which it offsets by funding other compensatory projects that contribute to carbon emissions reduction
5	Impact investing	Investing in projects that solve a social or environmental problem; the focus is on the positive impact rather than the means used to produce that impact
6	ESG investing	Investments considering the broad range of environmental (e.g. climate change, pollution biodiversity loss), social (e.g. working conditions, human rights, salary or compensation structures) and governance (e.g. board composition, diversity and inclusion, taxes) characteristics of the projects or companies being invested in; ethical and business sustainability considerations are integral part of financing
7	Adaptation finance	Finance for projects that help a region or industry to adapt to the effects (existing or foreseen) of climate change and avoid climate related risks to the business
8	Ocean finance	Financing for preservation, sustainable development and growth of the blue or ocean-based economy; of particular relevance to island nations and coastal communities
9	Environmental finance	Financial instruments to create environment friendly and technologically feasible outputs through businesses, while including the possible impacts of environmental degradation on the viability of the projects over the long term
10	Transition finance	Financial initiatives that help companies with large carbon footprints to gradually shift to net zero emissions operations
11	Microfinance schemes	Initiatives to enable access to capital by individuals or communities or small enterprises working on environmental or social development projects, often in the rural areas

Green finance is possibly most simply understood as a set of strategies and methods to acquire or raise and allocate funds (both private and public sector as well as philanthropic contributions) to bridge the enormous investment gap in creating and maintaining new, climate resilient, sustainable

infrastructure that also makes sound business sense, as indicated by UNEP. This will help nations to solve multiple societal challenges, meet their climate action commitments and nationally determined contributions aligned with the Paris Agreement, and attain the seventeen United Nations Sustainable Development Goals (UN SDGs) within the current decade from 2021 to 2030 (Volz, 2018; Nawaz et al., 2021). But its implementation needs a lot of innovation across cross-disciplinary domains technology, policy, business practices, legal and regulatory frameworks, multi-stakeholder/investor engagement and collaborations at local, regional, national and international levels and development of novel deployment pathways. It is well understood that public sector funding will not be adequate to bridge this investment gap and private sector funding will have to be mobilized at massive scales in order to accomplish these goals within the stated timelines (Patel, 2011). It is also evident that technology development alone will not address global challenges, unless fiscal resources are also available to deploy them at scale. Broadly speaking, this resource mobilization for sustainable climate action is what green finance mechanisms primarily attempt to accomplish.

A number of terms are commonly used to broadly express the concept, forms and types of green finance and investment. There are often no precise, formal definitions of these terms and overlaps and interconnections in the scope and significance of these various forms of green finance are possible. In general these instruments tend to conform to criteria that exclude certain categories of projects that are negatively viewed by investors, such as funding of new fossil fuel power plants in view of their damaging impact on nature and support and endorse those which are perceived to ‘do no harm’ to the natural world and which help create multi-dimensional benefits over and above environmental preservation (CBI, 2016). In Table 1, a brief glossary is presented to show the differences and the interlinkages between these allied concepts or financial mechanisms.

There are some general features common to all the green finance modes described in Table 1. Almost all the green finance instruments are based on long term investments such as in the insurance and pension funds, since climate change and development issues remain relevant over long time frames. Most of them are debt based or fixed income instruments such as bonds and loans, as described later, though equity instruments are also growing in importance (Kazlauskiene and Draksaite, 2020). Many of the projects involving green infrastructure creation and operation involve public-private partnerships in the business model. One common challenge that they face is the tracking and measuring of the impacts of some of these instruments, which could be difficult in quantitative terms, such as the societal benefits of a social bond funded project. Thus, enhanced impact data collection methods and new indicators or metrics are needed for all schemes in this domain.

2.2. Historical development of green finance concepts

The need to preserve the environment while pursuing activities for human development and progress was first recognized in the NEPA of USA in the 1960s (Rome, 2003). The concept of Socially Responsible Investment, which has now evolved into the Environment, Social, Governance (ESG) concept of the modern corporate world, also started gaining traction during this time frame (Boffo and Patalano, 2020). The idea that business activities for human development should not and need not be at odds with respect to environmental protection principles gained more formal and widespread recognition in the Stockholm Conference of 1972 (Brunnée, 2009). This was also the time when the environmental protection movement also started taking shape and acquiring global support (e.g., Earth Day celebrations). Subsequent developments leading up to the current scenario of green finance and

sustainable investments are summarized in Table 2 below (CFR, 2020; BBC, 2013; Jackson, 2020; Kestin et al., 2020; Mensah and Casadevall, 2019; Stofleth, 2015; UNDP, 2020; UNFCCC, 2020).

Table 2. Historical evolution of sustainable and green finance concepts and initiatives.

Year	Development/Event	Significance
1969	National Environment Policy Act, USA came into force	First legal framework in the USA for environmental protection alongside human activities
1972	UN Conference on the Human Environment, Stockholm	The idea of human development while simultaneously ensuring protection of the environment was first proposed
1987	The World Commission on Environment and Development released the Brundtland Report entitled “Our Common Future”; Montreal Protocol established	The first formal definition of sustainability was provided and the limits of natural capital in meeting humans needs indefinitely was recognized; need to protect the ozone layer was affirmed
1988	Intergovernmental Panel on Climate Change (IPCC) was established	Collection of data-based evidence and quantitative assessment of climate change was initiated
1991	Carbon tax levied in Finland	The first country to implement carbon taxation as a measure to reduce emissions
1991	Establishment of Global Environmental Facility	Development and funding of projects to prevent environmental degradation and loss of natural capital
1992	United Nations Conference on Environment and Development (UNCED), Rio Earth Summit, Rio de Janeiro	The international community was urged to prioritize sustainable development through the outcome document Agenda 21
1994	United Nations Framework Convention on Climate Change came into force	Key principles for climate action by individual countries were developed
1997	Kyoto Climate Agreement	Recognition of the fact that emissions arising out of anthropogenic activities should be reduced
1997	Global Reporting Initiative (GRI) established by CERES and UNEP	First framework for voluntary sustainability reporting made available to business organizations
2000	Millennium Development Goals established	Focus on poverty and hunger reduction, preventing disease, improving water access and ensuring primary education for children
2000	Initiation of the Carbon Disclosure Project	Multi-national non-profit organization enabling companies to monitor and voluntarily report the environmental impacts of their activities, especially GHG emissions and overall carbon footprint
2000	Establishment of the UN Global Compact	Forum for private industry to make voluntary commitments on corporate sustainability and to report the action taken for it. Currently it has more than 9000 signatories across the world.
2002	World Summit on Sustainable Development (WSSD), Rio+10, Johannesburg	Plan of implementation for Agenda 21 was developed
2006	UN Principles for Responsible Investing launched	Set of investment principles for companies to apply to investment practice that takes care of sustainable development and environmental protection

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Year	Development/Event	Significance
2007	European Investment Bank issued first Green Bond/ Climate Awareness Bond	Proceeds of the bond were used to finance renewable energy and energy efficiency projects i.e., green projects
2009	Climate Bonds Initiative launched	Non-profit group working to mobilize fiscal resources in the form of bonds for deployment of climate change mitigation and adaptation solutions
2009	Global Impact Investing Network was launched	Non-profit membership organization with 330 members in 50 countries that builds industry infrastructure and supports projects related to the development of the impact investing industry
2010	Green Climate Fund established	Financial support to countries to enable concrete climate change mitigation and adaptation efforts through infrastructure development projects
2011	Sustainability Accounting Standards Board (SASB) was established	Establishment of industry specific disclosure standards for environmental, social and governance (ESG) issues
2012	United Nations Conference on Sustainable Development (UNCSD) or Rio+20 held	Green Economy and an institutional framework to achieve it were emphasized in the outcome document “The Future We Want” for national and international level action
2012	Sustainable Banking Network was launched	It is a voluntary community of financial sector regulatory agencies and banking associations from emerging markets of 43 Member countries who are working to integrate ESG principles into their operation and divert finances for climate action.
2013	Partnership for Action on Green Economy (PAGE)	Consortium of 5 UN Organizations to develop economic policies and practices for attainment of the UN SDGs, particularly focusing on inclusive growth
2014	Green Bond Principles were launched	Voluntary guidelines on green bond markets were issued by International Capital Market Association (ICMA), aimed at making the mechanism transparent
2015	Addis Ababa Action Agenda was drawn up	Policy actions and funding and financing mechanisms were identified to achieve the Sustainable Development Goals
2015	UN SDGs formulated	Blueprint for global sustainable development adopted by all UN Member States
2015	Paris Agreement drafted	All nations agree to take action to reduce GHG emissions drastically to keep global temperature rise below 2 deg C from pre-industrial levels
2015	Task Force on Climate-Related Financial Disclosures (TCFD) established	Market driven initiative to encourage disclosures of climate change related financial risks to be made by banks and other financial organizations to the stakeholders
2016	Inclusion of Article 173-VI in the French Energy Transition Law and its implementation decree	Mandated compulsory carbon disclosures and carbon related financial risk reporting by listed companies and carbon reporting for institutional investors
2017	Business & Sustainable Development Commission report issued	Identification of mechanisms by which the business world can be modified to meet the SDGs. It focuses on setting business strategy and transforming markets synergistically with global development.

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Year	Development/Event	Significance
2017	Finalization of the Hamburg Principles by G20 nations	Principles to be adopted by World Bank and multilateral development finance institutions to increase private sector funding in meeting sustainable development objectives in emerging economies round the world
2017	Science based targets initiative (SBTI) launched as a joint effort between CDP, UNGC, WRI, WWF	Enabling private industry to take climate action to limit global temperature rise to less than 1.5°C by setting scientifically defined emissions reduction targets
2017	Creation of the Network for Greening the Financial System (NGFS)	A network of 89 central banks and other financial institutions to accelerate the deployment of finance towards sustainable development and economic growth
2017	Climate Action 100+	Consortium of one hundred large industrial organizations working together to establish low carbon industrial practices for climate change management
2018	European Union Action Plan on Sustainable Finance was launched	Plan of action for sustainable investments and for financing the European Green Deal; incorporates taxonomy, disclosures, industry benchmarks and sustainability preferences
2018	Sustainable Blue Economy Finance Principles were launched	Developed by European Commission, WWF, WRI and EIB as a framework of 14 principles for banks, insurers and investors to finance a sustainable blue economy as part of meeting UN SDG 14
2018	World's first sovereign Blue Bond issued by Seychelles	For use in financing ocean and marine-based projects that have positive economic, environmental and climate benefits, along the lines of Green Bonds
2019	Abu Dhabi Declaration adopted at 18 th UNIDO General Conference	Advocating for and supporting multilateralism and international cooperation to attain the UN SDGs
2019	UN convened Net Zero Asset Owner Alliance was formed	A group of private institutional investors made public commitment to transition their investment portfolios to net zero emissions by 2050, as per ESG principles and the Paris Agreement. These are over and above those made by national governments.
2019	Sustainability Linked Loans Principles were issued	Joint guidance issued by Loan Market Association, Loan Syndications and Trading Association and Asia Pacific Loan Market Association to define framework of green loans and sustainability related loans
2019	The Principles of "Investing for Impact: Operating Principles for Impact Management" were issued by IFC	Framework for institutional investors (currently 127 signatories) to finance projects that create measurable, sustainable, positive impact across diverse investment portfolios, asset types, sectors, and geographies
2019	European Union launched the International Platform on Sustainable Finance	Serves as a forum for dialogue between public policy makers in member states to develop sustainable finance regulatory mechanisms

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Year	Development/Event	Significance
2019	European Green Deal was initiated	Policy framework to make the European Union climate neutral by 2050 via a just and inclusive energy transition; goal is to reduce emissions by 55% by 2050 at least.
2020	Asia's first offshore Blue Bond issued by Bank of China	Intended for financing of marine related green projects for a sustainable blue economy
2020	EU Sustainable Finance Taxonomy was created to facilitate responsible investing	Defining terms and conditions of projects to help potential investors understand whether the projects are sustainable, environmentally benign and climate positive or not
2021	Climate related disclosures of the financial sector made mandatory by law in New Zealand	First country to pass a law requiring the financial institutions to disclose the impacts of climate change on their activities and performances
2021	Sustainable Finance Disclosure Regulation (SFDR) along with Taxonomy Regulation were introduced by the European Commission	The regulation makes it mandatory to follow ESG disclosure obligations (including sustainability risk and potential harmful impacts of certain financial products) by asset managers and other financial markets participants
2021	Task Force on Nature Related Financial Disclosures launched	It provides a framework for financial institutions and the corporate sector to understand, identify and report on nature and biodiversity-related risks material to their business and operations, in line with the climate change related TCFD framework
2021	French green budget for 2021	Assessment of the environmental effects (related to climate change, pollution and biodiversity loss) of budgeted national government spending in the year 2021 and adoption of green fiscal measures more extensively

The above table indicates the especially large number of initiatives aligned with sustainability, climate action and green finance that have emerged in the last few years, particularly in the wake of the signing of the Paris Agreement in 2015. The COVID-19 pandemic has been a major turning point as well and it has given an impetus to the philosophy of green finance as the preferred mechanism for nations to avoid the business-as-usual method of functioning, build back better through green recovery policies aimed at climate positive, inclusive and sustainable growth of the economy (ADB, 2021). These initiatives are expected to gain more momentum and practical action in the near term, as investors demand greater transparency and accountability about the nature and impact of investments and as they become increasingly interested in financing projects that offer good returns and numerous social and environmental benefits at the same time (Netto et al., 2021).

2.3. Green finance in context of sustainable development and climate action

It has been estimated that investments of the order of several trillions of dollars every year would be needed to finance climate action and achieve the UN SDGs by 2030 (Barua, 2020). Another estimate states that finances of the order of 300 to 500 billion dollars per year would be required between 2030 and 2050 to establish climate resilient infrastructure (Adhikari and Chalkasra, 2021). The Paris Agreement, 2015 in its article 9 also includes the commitment from advanced nations of providing 100

billion dollars per year by 2020 to developing countries to fund their climate action programs (UNFCCC, 2016) but this has so far not been achieved as planned. These figures are much greater than the current public revenues available within a country or by cross-border financial flows at the global level, via mechanisms like foreign direct investments in developing countries. Green finance schemes attempt to fill this investment gap through a number of instruments that involve the entire capital market, as discussed in the next section. Engagement with governments, the general public and the financial sector is a crucial element in all these attempts. ICMA has created a framework that maps each target under SDGs to a specific element of the Green Bonds Principles to enable investors in green finance instruments to gain clarity on where the finances are being diverted (ICMA, 2019).

Despite rapid rise in green financial flows in practically every region of the world, there still remains a large investment gap that must be overcome in order to meaningfully manage a just, sustainable energy transition, economic development and widespread climate action. Estimates of this investment gap are provided by recent literature such as the UNEP Adaptation Gap Report, 2020 (UNEP, 2021) which indicates that in developing countries, the climate adaptation finance gap currently stands at US \$70 billion, which could go up to \$300 billion by 2030 and \$500 billion by 2050. Similarly, the UNCTAD's World Investment Report estimates that there is an SDG financing gap of about US \$2.5 trillion dollars per year (UNCTAD, 2021).

3. Instruments and mechanisms of green finance

3.1. Taxonomy in green finance

Green finance taxonomy indicates a definition and classification framework related to the type and nature of projects or economic activities that are eligible for financing under green finance schemes or allied policies. It is an important part of the regulations for the green finance market and enables investors and/or asset managers to decide what is really green and how far it is aligned with sustainable development, growth and preservation of the environment. Most financial institutions use their own taxonomy (depending on prevailing regional legal/regulatory frameworks) to identify, select and finance green projects and this may be highly dependent on the market or jurisdiction in which they are operating. Taxonomies are often used to screen in or out certain projects for finance and there is significant interest today in developing harmonized taxonomies for the international financial markets, cross-cutting across borders and legal regimes. The most well-known of these taxonomies include the EU Sustainable Finance Taxonomy, ASEAN Capital Markets Forum guidelines and the Green Bonds Endorsed Project Catalogue from China (WBG, 2020; Pfaff et al., 2021). The most common types or classes of projects financed by green investment mechanisms (i.e., the common features in most of the current taxonomies) at present are indicated in Table 3. Clean energy, energy efficiency, climate resilient low carbon infrastructure, water, forestry and agriculture are some of the most common domains attracting green finance flows.

In the wake of the COVID-19 pandemic, several nations have announced stimulus packages to ensure economic recovery and there are many initiatives in these packages in line with green finance principles (IPU, 2021). The core idea is to build back better and ensure sustainable and inclusive recovery, after this global crisis.

Table 3. Typical projects qualifying for green finance.

Serial No	Type of project/sectors
1	Renewable and green energy deployment for emissions reduction across sectors, improving energy access and affordability among less developed communities or nations
2	Energy efficiency and savings and optimized water use projects in the built environment, green and sustainable building projects (new or retrofit)
3	Clean mobility (urban and rural) and transportation services
4	Ecological protection and ecosystem services, smart forestry and agriculture practices, land use applications, regenerative agriculture related projects, nature-based solutions and natural capital preservation
5	Integrated water resources management, sanitation services and waste water treatment and re-use
6	Climate resilient urban infrastructure development, waste management initiatives, resource conservation, recycling and circular economy projects

The World Bank Group has issued a guidance framework (WBG, 2020) on creating a national green taxonomy and it also provides a comparative assessment of such existing taxonomies in countries such as Bangladesh, China, Mongolia and the European Union. Some include general guidance principles whereas others explicitly spell out specific types of projects that may be considered for green financing. The more granular a taxonomy, the clearer and more useful it becomes for its users to apply it for project screening.

3.2. Common instruments of green finance

Instruments of green finance refer to the actual mechanisms by which capital is raised or mobilized to support deployment of green projects, such as those identified in Table 3, with expectations of earning a reasonable return on the amounts invested. The issuers of these instruments could be banks, governments, private investment institutions, insurance industry. The common instruments in today's green finance markets are indicated in Table 4. Some of these are more asset or project focused, whereas some are related to the overall impact they create (such as meeting SDGs or helping in energy transition or climate transition). In the COVID-19 scenario, these instruments are also being linked to the post pandemic, green recovery. These are issued by large central banks, development finance institutions and also private financial institutions.

Green bonds remain the most popular form of green finance in the primary capital market, out of the ones listed above. According to some estimates, the global green bond issuance has exceeded US \$1 trillion by the end of 2020, with USA, Germany and France leading the list of issuing countries (Amundi and IFC, 2021). Most of the finances are deployed for renewable energy projects at the global level, since the clean energy transition is widely viewed as the backbone of all sustainable development and decarbonization efforts (IRENA, 2020). Most green bonds are issued by the banking sector (Hesary-Taghizadeh et. al., 2021) but there are increasing numbers of non-banking firms which are joining the list of issuers today, in response to climate crisis and environmental degradation concerns of investors. The not-for-profit group Climate Bonds Initiative, headquartered in London provides valuable and current information about green bonds and related instruments, including defining taxonomy and providing verification services to issued bonds (CBI, 2021). An updated list of green and related bonds issued in the last few years in different countries of the world is also maintained by them.

Table 4. Common green and sustainable finance instruments (Larsen, 2019; Rado and Filkova, 2019).

Serial No.	Instrument	Salient features
1	Green bonds	Debt or fixed income instrument labeled green by the issuer and used to raise capital for climate and environmentally beneficial projects, in line with the voluntary framework of Green Bonds Principles.
2	Green loans/ Concessional debt	Lending of capital dependent on the environmental and resource utilization criteria and characteristics of the projects.
3	Sustainability bonds	Bonds whose proceeds are used to finance or re-finance a combination of both green and socially meaningful projects directed towards a specific population.
4	Climate bonds	Fixed income climate aligned financial instruments that support endeavors with positive impact on climate, in line with Green Bonds Principles.
5	Social bonds	Financial instruments that aim to support ventures in education, health and food security, towards creating positive social impact.
6	Carbon pricing	An economic cost applied to carbon emissions related to an industrial activity, generally in the form of a tax. The proceeds recovered by these mechanisms can be used to develop and deploy environment friendly technologies. Current day carbon markets operate via several mechanisms, described later.
7	Blended finance	Combination of development finance (from public and private sources) and voluntary, philanthropic contributions towards mobilizing additional financial flows for sustainable development in developing and emerging economies.
8	Grants	Financial assistance from the private industry (generally) towards environmentally and socially impactful projects.
9	Sustainability linked bonds	Bonds issued for general corporate uses but with specific sustainability linked indicators incorporated in the financial characteristics of the instruments.
10	Blue bonds	Debt finance instruments issued specifically to support measures for protecting the ocean and ocean-based communities, island nations and preserving sustainable ocean economy.
11	Sovereign bonds	A debt security issued by a national government to meet part of its expenditures on various projects including those linked to sustainable development and environmental preservation.
12	Transition bonds	These instruments can be either green bonds or sustainability-linked bonds that are issued by corporate sector looking to align their financing strategy to their climate transition and decarbonization strategies.
13	Green securitization	It indicates conversion of illiquid green assets (e.g., green buildings) into tradable financial instruments (debt). They are commonly used to re-finance green loans and mortgages.
14	Green Derivatives	It is a financial arrangement for mitigating and managing risk in some kinds of green investments by assigning a value to a green asset.
15	Green Sukuk	It is an Islamic financial instrument that finances projects with environmentally positive impacts, in compliance with the Shariah principles
16	Green/ eco- friendly insurance products	These include insurance products that invest a part of their proceeds into green projects or which help any damaged assets to be replaced by more sustainable and environmentally friendly assets.

An overview of the trends and drivers of green product demand is available in literature and current growth in this domain may be taken as further intensification and consolidation of these trends, particularly in the post pandemic world (NATF and UNEP FI, 2007). Bibliometric analysis performed by Chitimiea et al. (2021) indicates that the global financial crisis of 2008 was possibly the first major driver of investor interest in green finance, with yet another massive boost being received after 2015 and the signing of the Paris Agreement. Currently investor awareness about climate change and their preference for organizations that are adopting green business principles and establishing strong ESG performance are fueling the demand for green finance products.

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3.3. Green finance issuance framework, standards, certification, labeling and other regulatory considerations

The issue of a green bond or any such instrument by a financial organization or corporate entity is typically based on the following sequence of actions, in accordance with the voluntary Green Bonds Principles (KPMG, 2016; IFC, 2021):

1. Assessment of financing options for the project, with particular emphasis on sustainability objectives and green credentials associated with the project.
2. Defining the selection criteria for a green project based on existing or new taxonomy.
3. Labeling a green bond by the issuer (in line with Green Bonds Principles and similar voluntary standards designed to encourage transparency) and defining how the bond proceeds will be used, tracked and monitored over the maturity duration.
4. Information disclosure and credit rating of the bond via appropriate agencies.
5. Bond issue and proceeds allocation to selected project(s).
6. Defining bond performance indicators and measuring, reporting and communicating them to relevant stakeholders with transparency and due diligence.

Green and sustainable finance have their specific ISO standard under development (under ISO/TC 322 committee) (ISO, 2021). This will be complemented by other existing standards on environmental management and financial sector services. It is expected to complement and possibly create harmonized definitions of green finance and projects that may be so financed, integration of sustainability considerations in the financial sector's activities and alignment with the UN SDG targets and indicators.

After a green finance instrument such as a green bond is issued, the objectives and use-of-proceeds stated by the issuer is often verified and certified by independent agencies by comparison with certain standards. The most widely known mechanisms for verification are the Climate Bonds Initiative Climate Bonds Standards, Green Bond Assessment and Verification Guidelines, European Union Green Bonds standards and ASEAN Green Bonds Standards (Tolliver et al., 2021).

3.4. Carbon financing, markets and their linkage to green finance

The carbon market or carbon finance is a policy lever or special form of financial arrangement intended to ultimately reduce carbon emissions from various sectors and shift energy usage and operations towards environmentally benign forms (Höhne et al., 2015). It is considered one of the earliest mechanisms of green finance and it takes many forms in actual implementation. In many countries, there are sound legal provisions and regulatory mechanisms (often called carbon or climate legislation) governing the implementation and action of this market. It merits special attention in the implementation of green finance and an overview of the methods to create and maintain a carbon market is provided in Table 5 below.

Carbon legislation refers to the creation of laws and legal frameworks to support climate positive actions by individuals and industries, mainly by reducing carbon emissions from different sources by all viable mechanisms. It is estimated that there are currently more than 1200 laws, policies and regulations related to climate action globally from over 164 countries and this number is poised to increase as even the least developed nations (which are also most vulnerable to climate change) are now developing their strategies for climate action. Legislative support is a strong enabler of clean energy technologies and policies and is crucial for meeting the targets agreed upon by countries with respect to the Paris Accord, 2015. Some such examples from the largest carbon emitting nations or regions of the world are indicated in Table 6 below.

The final objective of all these mechanisms is to cause a shift in the carbon intensive operations of a company by creating a financial penalty for the emissions in any segment of their value chain. The funds acquired from these mechanisms are best used to develop clean energy and sustainable development related projects, thereby creating a direct link with green finance policies. International cooperation is also a necessity in order to have effectively functioning carbon markets. Along with the carbon market, carbon accounting methods (physical and financial accounting) in processes and industries and investment portfolios related to those processes have also been developed for accurately estimating carbon emissions and hence the worth of those emissions along the entire value chain of an organization and these tools are routinely used by financial institutions now (Bird et al., 2010).

The value of carbon tax or the price of carbon emissions is decided on the basis of the social and environmental costs of carbon i.e., the impacts on the ambient, nature, soil, water, climate and human health etc. due to carbon emissions and the associated negative impacts arising from it. Some nations with mandatory carbon taxing systems are the United Kingdom, Australia, Canada, Chile, Switzerland, Norway, Sweden, Finland and New Zealand, ranging between US \$15 to 130 per ton of CO₂ emitted.

Emissions trading schemes exist in many more nations, including the recently launched scheme in China (IEA, 2020). Worldwide, there is increasing momentum to develop more stringent carbon legislation as an effective means for implementing climate change mitigation and adaptation practices.

Table 5. Carbon market instruments (Essl et al., 2018; Hartman and Broom, 2020).

Serial No.	Carbon market mechanism	Salient features
1	Carbon price/tax	Form of indirect tax levied by the government on carbon emissions associated with industrial activities (such as fossil fuel usage) so that the hidden cost of these emissions is adequately quantified.
2	Carbon emissions trading	Trade agreements within and between countries regarding sale of financial credits associated with their carbon emissions due to industrial and commercial activities, similar to trade of any other commodity. Countries that have spare emission units out of those granted to them annually can sell them to countries that are exceeding their annual limit. The ultimate aim is to reduce or eliminate these emissions
3	Carbon border adjustment mechanisms	These are taxes on imports and rebates on exports that account for variance in carbon pricing policies across different countries. It is proposed to be deployed in the European Union by 2023. This mechanism has been criticized for being unfair to goods and services originating in the fossil fuel dependent developing countries and it can also create difficulties for industries in the European Union to find alternative sources of cheap and abundant raw materials that it has so far procured from the emerging and developing economies.
4	Carbon offsets	Compensatory financial activity for activities causing carbon or other green house gas emissions elsewhere (e.g., fossil fuel burning countries investing in renewable energy projects in proportion to their total annual emissions)
5	Carbon contract for differences	Carbon Contracts for Differences (CCfDs) is a mechanism for governments to guarantee investors in climate positive technologies and practices a fixed price that rewards CO ₂ emission reductions above the current price of carbon or emissions trading. But investors are liable for payment if the carbon price exceeds the contract's strike price.
6	Carbon credits and cap-and-trade arrangements	A permit or tradable certificate granted to a company to emit a certain amount of CO ₂ and other GHGs (i.e., a cap on total emissions). One credit is expressed as one ton of CO ₂ emitted. Companies who cannot avoid a certain amount of emissions in their working pay some other entity to reduce their emissions or invest in carbon capture technologies. It requires a standard method or framework for verifying and validating the credits and offsets of carbon emissions.

Table 6. Examples of carbon legislation (Robles, 2015; Evans, 2017; GRICCE, 2020).

Serial No	Country/Region	Features of Carbon Legislation
1	European Union	Multiple legislations have been passed (from as early as 1999) regarding energy efficiency of buildings and products, alternative fuels and promotion of renewable energy, ecolabeling practices for goods, taxation of energy products, agriculture and forestry practices, financing for sustainable development and financial disclosures related to sustainability, directives for EU wide emissions trading. The Nordic countries are particularly pro-active in these domains. The latest development (December 2020) is that the EU has a new binding commitment to reduce its carbon emissions by 55% within 2030, as part of the European Green Deal.
2	India	India introduced the Energy Conservation Act in 2001 and the Clean Energy Cess Rules in 2010 (for creating a National Clean Energy Fund). The Compensatory Afforestation Fund Act was introduced in 2016 to enable forest cover preservation as a means of Carbon Sequestration. India does not yet have any legally binding commitments in line with its pledges to the Paris Agreement but it does have a National Action Plan on Climate Change and a Coal cess was introduced in 2010. A number of national targets have also been indicated for deployment of renewables.
3	China	China has ratified an Energy Conservation Law and a Renewable Energy Act along with National strategy and plan for climate change mitigation. Like India, it too has ambitious climate action targets mainly based on rapid and extensive deployment of renewable energy sources.
4	USA	The American Recovery and Reinvestment Act of 2009 promotes energy efficiency measures and increased share of renewables. Currently there is no national level carbon taxation but 11 states have individual carbon pricing policies in place, based on a cap-and-trade program.
5	Brazil	A number of laws have been enacted for energy conservation, renewables deployment, protection of rainforests (under the REDD+ framework), establishing National Fund on Climate Change, biofuels including bio-diesel usage. Several National plans have been formulated for climate change mitigation and adaptation.
6	Russia	One law on energy saving and energy efficiency improvement was enacted in 2009. A number of national decrees and policies governing national energy strategy, climate action, reduction of gas flaring, renewables promotion and GHG reduction are also in place.
7	Japan	The Act of Promotion of Global Warming Countermeasures (1998, updated in 2016) and the Climate Change Adaptation Act (2018) are two crucial legal measures adopted in Japan for emissions reduction and climate action. Other acts include promotion of renewables and using off-shore areas for deployment of renewables and improvement in building energy efficiency and disaster resilience.

4. The implementing agencies and organizations

Several multi-national and multi-lateral agencies (government, private sector) and organizations are currently engaged in the development and implementation of green finance initiatives and the associated regulatory frameworks and standards. Some of these organizations have a regional focus while the others have global presence, with respect to the projects financed by them. Table 7 compiles some of the current information in these initiatives, from the public websites of the respective organizations and other sources in the public domain. More specific region-wise project examples are provided in the next section and greater details about each such project are available on the respective websites.

Table 7. Green finance activities in major international organizations.

Serial No.	Institution	Nature of institution	Recent initiatives undertaken in green finance
1	World Bank Group (WBG)	Development finance institution	Launched the “Strategic Framework for Development and Climate Change” to help developing nations with climate change mitigation and adaptation; issued World Bank Green Bonds worth about 16 trillion dollars and triple A credit quality so far under this framework
2	Inter American Development Bank (IDB)	Development finance institution	Launched the Green Finance LAC Platform, Green Bond Transparency Platform and Financial Innovation Lab to coordinate green finance deployment efforts in the Latin American and Caribbean region
3	Asian Development Bank (ADB)	Development finance institution	Launched Green Bonds Framework for mitigation and adaptation efforts in its member countries in Asia Pacific region
4	European Investment Bank (EIB)	Development finance institution	First Climate Awareness Bond was launched in 2008 and first Sustainability Awareness Bond was issued in 2017; involved in financing the European Green Deal, creation of the EU Taxonomy and related frameworks for climate action
5	International Monetary Fund (IMF)	Development finance institution	Working to develop green finance standards and climate related stress tests; research on economic dimensions of climate change
6	International Finance Corporation (IFC)	Development finance institution	Largest development institution allied with private sector financial organizations to support climate resilient and socially and environmentally responsible development in the emerging economies; developing methods for ESG integration in financial institutions
7	African Development Bank (AfDB)	Development finance institution	Green bond and climate finance programs with special focus on the African region
8	European Bank for Reconstruction and Development (EBRD)	Development finance institution	Issue of Green Economy Transition, 2020–25 as a roadmap, with pledge to have nearly complete operation in green finance domain (majority green bank)

Continued on next page

Serial No.	Institution	Nature of institution	Recent initiatives undertaken in green finance
9	Asian Infrastructure Investment Bank	Development finance institution	Sustainable bonds for infrastructure development; launch of climate change investment framework in 2020 under collaboration with Amundi (a European asset management company); initiatives on sustainable cities and transport
10	Islamic Development Bank	Development finance institution	Development of Sustainable Finance Framework, 2019 in compliance with tenets of Islam; raised 2.5 billion USD with Sustainability Sukuk to finance green and social development projects
11	International Investment Bank	Development finance institution	Investments in green bond issuances in various geographies
12	CAF Development Bank of Latin America	Development finance institution	Regional financial institution working for the Latin American region's sustainable development
13	Nordic Investment Bank	Development finance institution	Own green bond initiatives and investment in social and sustainability bonds in Nordic-Baltic region
14	Council of Europe Development Bank	Development finance institution	Exclusively social mandate for potential investment in development projects in its member states
15	United Nations Environmental Program-Finance Initiative	Supranational organization	Developed Principles of Responsible Banking, Investment and Insurance which as serve as voluntary standards for the financial sector to align with environment, nature and climate positive projects
16	Green Climate Fund	Multi-lateral funding initiative	Provides funding to developing countries and emerging economies to create climate positive and resilient infrastructure for sustainable and inclusive development
17	Multilateral Investment Fund	Multi-lateral funding initiative	Initiative of IDB Group catering to the private sector of the Latin American and Caribbean countries
18	Millennium Science Initiative	Multi-lateral funding initiative	Initiative of the World Bank Group to support Science and Technology led innovations for Uganda and other African nations
19	European Fund for Strategic Investments	Multi-lateral funding initiative	Special account maintained by EIB Group to support European Union efforts at long term economic growth and maintenance of competitive advantage at global level
20	Environmental Defense Fund (EDF)	Research based multi-lateral funding initiative	Non-profit organization for policy advocacy based on science and economics to drive investments in climate change management solutions
21	Global Environmental Facility (GEF)	Multi-lateral funding initiative	program developed by the World Bank Group for strategic investments for tackling crises such as climate change and environmental degradation
22	Adaptation Fund	Multi-lateral funding initiative	Providing funds to developing countries for climate change mitigation and adaptation projects

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Serial No.	Institution	Nature of institution	Recent initiatives undertaken in green finance
23	Climate Investment Funds	Multi-lateral funding initiative	Providing funding to projects on clean technologies, improvement energy access, climate change resilience, and management of sustainable forests in developing and middle-income countries
24	Special Climate Change Fund (SCCF)	Multi-lateral funding initiative	Initiative under UNFCCC and operated by GEF to provide funding to projects on climate change adaptation, mitigation and resilience

5. Green finance in action

5.1. Examples of recent projects under green finance in different regions

The enormous amounts of capital currently flowing into green finance schemes have led to a significant diversity in the number and types of projects being financed by them. A few examples are provided in this section. As stated in Section 2.1, Table 3 most of the beneficiary projects belong to the category of green and renewable energy infrastructure creation for various sectors like buildings, transport and energy efficiency mechanisms. There is also growing momentum in nature preservation and preventing bio-diversity loss.

Asia (particularly South East Asia) is one of the most active regions when it comes to deployment of green finance-based projects. This is not surprising given that the region has some of the most important emerging economies and markets in the world and it is trying to break free from its dependence of fossil fuel led development and growth. Among some recent projects financed by the Asian Development Bank under green finance schemes are initiatives like the 100 MW(e) Cambodia Solar Park Project of 2019 (USD 26.7 million total investment), Waste to Energy Project of Greater Male (USD 151.13 million total investment), investments in Green, Sustainability and Social Bonds issued by Georgia (USD 20 million), Thailand (more than USD 1.67 billion), and support to Indonesia (for issuance of transition bonds) and Philippines (for blue bond issuance and ocean economy development) (Mehta and Andrich, 2021). The Bank has also launched the ASEAN Catalytic Green Finance Facility (ACGF) to support environment, climate and sustainability linked projects, particularly in the context of economic recovery of the ASEAN from the impacts of COVID-19 pandemic (ADB, 2021).

In Central Asia (i.e., countries including Kazakhstan, Turkmenistan, Uzbekistan, Kyrgyz Republic and Uzbekistan), examples of such projects include those funded by the Green Climate Fund, Global Environment Facility and the Clean Development Mechanism along with significant contributions from domestic investors (CAREC, 2020). The focus areas are energy transformation, hydropower development, food and agriculture, water management and hydro-meteorological systems such as flood warning. About USD 37 billion have been invested in this region under these initiatives, as per reports in 2020.

Green finance initiatives in India are linked to projects such as renewable energy deployment (in line with India's ambitious targets of having 450 GW installed renewable electricity capacity), small hydropower projects, clean and sustainable transport and agriculture, land use and ecosystem-based projects (Ghosh et al., 2021). According to Acharya et al (2020), the total green finance flows in India amounted to USD 38 billion in the financial years 2016-18, a lion's share of which came from domestic

commercial banks, public sector corporations and government contributions. Foreign direct investment had only about 5% contribution. Above 80% of investments have been directed to power projects, energy efficiency measures, including grid modernization and digitalization efforts.

In the Middle East, green bonds issuance has attained a value of USD 6.4 billion by the middle of 2021, with bonds being issued in multiple currencies by regional and international banks and other financial institutions (Darasha, 2021). These funds are directed towards green recovery and development of ESG assets. There are about 12 climate funds supporting climate change management efforts in this region, with Clean Technology Fund, Green Climate Fund and Global Environmental Facility leading the way with a total approved pool of USD 1317 million, as indicated by data from 2003 to 2019 (Watson and Schalatek, 2020). Egypt and Morocco have received the greatest share of these funds so far, mostly for clean energy and water resources management related initiatives. Green sukuk and bonds have been issued by regional institutions such as First Abu Dhabi Bank in 2017, Majid Al Futtaim (MAF) and Islamic Development Bank (IsDB) in 2019, and Saudi Electricity Company, Qatar National Bank (QNB) and the Arab Republic of Egypt as well as the Etihad Airways (Etihad) transition sukuk in 2020 (Clifford Chance, 2021).

The Latin American region is yet another region that can benefit from green finance initiatives in order to preserve its bio-diversity and support sustainable growth by making use of its natural resources. It is also crucial in view of the extreme climate vulnerability of many countries in this area. The platform 'Green Finance for Latin America and the Caribbean' was created in 2016 and it provides knowledge and information about these initiatives, which are mainly administered by the World Bank, IFC and Inter-American Development Bank with its subsidiaries in this region. As of 2019, the largest regional economies of Brazil and Mexico have received more than 50% of total green finance flows, while Chile was the first country in this area to issue a sovereign green bond (CBI, 2019). A total of USD 12.6 billion in green bonds was issued by the middle of 2019 in these countries, mainly directed to the energy sector, land use, industry and transport. The Latin American Investment Facility (LAIF) is a regional blending facility supported by the European Union to combine EU and regional financial resources towards sustainable and climate positive projects in this region, focusing on water supply, urban development, waste management and sustainable energy. An updated list of these projects in each country is available on their website (<https://www.euiaif.eu/en/about-laif>). Similar facilities are also present for Africa, Asia and the Pacific region. The Clean Technology Fund, Amazon Fund, GCF and GEF have provided more than USD 2760 million in funding in this region over the time period from 2003 to 2018 for mainly energy and REDD+ activities (Watson and Schalatek, 2019a).

The Sub-Saharan Africa region contributes very little to global climate change in terms of carbon emissions but it is bearing the brunt of the impacts caused by developed nations and advanced economies. This region also has some of the least developed countries and conflict afflicted zones of the world, making them especially vulnerable to anthropogenic climate change, poverty, hunger and disease. Watson and Schalatek (2019b) report that most green finance projects focus on climate change mitigation and adaptation in this region along with sustainable forestry and REDD+ initiatives. The Green Climate Fund, the Least Developed Countries Fund and the Clean Technology Fund are the three largest contributors of green finance to this region in the period from 2003 to 2018. The urbanization potential of this region along with rapid population growth requires cities to be made more climate resilient and it is estimated by a recent scoping study that USD 50 billion per year by 2050 would be required to enable this transition and close the infrastructure gap that currently exists (Com SSA, 2019).

5.2. Performance indicators and impact assessment of green finance initiatives

The performance of a green finance instrument is assessed against standards set by specific organizations and regulators. For example, the Green Bonds Principles (ICMA, 2019) is the framework often used by investors to evaluate the nature and authenticity of a possible green investment and use-of-proceeds.

Once an investment has taken place in a green scheme, a common practice is to link its performance to certain indicators, which in turn are in some way linked to the returns on investment. Green finance schemes are no exceptions. There are important indices such as the Solactive Green Bond Index, Bloomberg Barclays MSCI Green Bond Index family, the S&P Dow Jones Index family, that compare the performance of a green bond against other capital market metrics or benchmark indices over time, within the bond maturity period, which could be anywhere from 5 to 15 years (Perlovsky and DeMarco, 2021; Liaw, 2020). The yield from a green bond may or may not exceed that from a conventional bond from the same issuer, thus current research demonstrates that there is no uniform or generic conclusion regarding the performance of these instruments compared to other bonds. But in general, the green finance market has grown enormously in the last few years and its performance has been stated to be satisfactory, from the investor perspective. There is increasing investor demand for such products as climate action and climate risk assessment in investments becomes a crucial part of any kind of corporate or government activity, particularly for infrastructure investments.

Among non-financial performance indicators for green finance products, an estimate of avoided or saved CO₂ or other GHG emissions by deployment of a green project is one of the commonly used metrics (2DII, 2016). The use of sustainability indicators and corporate sustainability reporting to track green finance performance is also possible. But these approaches require a lot more data to be collected and provided by the project developers and integrating them with financial performance is still challenging.

6. Current academic research agenda in green finance

Academic research on green finance focuses on evaluating quantitatively the relation between green financing mechanisms and environmental protection, climate action, sustainable development. Significant attention is now being paid to establishing innovative metrics for monitoring and measuring the effectiveness and impact of green finance schemes and how they compare in terms of returns with other financial instruments not explicitly labeled green. The role of digital technologies and inclusive green finance, data analytics in green finance is another area of research, where the role of quality and reliable data is regularly highlighted. In Table 8 below, some of the most common research themes or keywords appearing in green and climate finance related research articles, webinars, conferences and more than forty (not in any specific order) reputed peer reviewed SCOPUS indexed English language journals (dealing with energy, climate change, investments and finance related subject matter) in the last few years (2016 onwards till date) are indicated. This is not to be construed as a full bibliometric or scientiometric study on green finance as performed by some researchers (Zhang et al., 2019; Sarma and Roy, 2020; Akomea-Frimpong et al., 2021; Cai and Guo, 2021) but a general indication of current academic and policy research trends, opportunities and thought leadership in this domain to interested readers.

Despite great interest in industry and economy regarding green finance mechanisms, academia has only recently begun to address various research questions in this domain. The list of journals provided in the first column of Table 8 indicates some of the most active and relevant media for

academic work in this field and their potential to serve as source of more detailed information for readers. The second column indicates the key themes of research interest in academia and industry, as evident from recent publications in the journals listed (one-to-one correspondence between journal name and research direction is not implied, only a generic list is provided). But the fact still remains that most of the work in this domain has been led by financial institutions, consultancies, standard setting organizations and non-governmental entities, as is evident from the other literature cited in this work. The situation is improving these days as climate science, policy research and business decisions are becoming more and more intertwined, requiring better understanding of these issues through academic research.

Table 8. Current academic research areas in green finance (2016-till December 2021).

Name of Journal	Major Research Directions
The Energy Journal	Green finance for achieving the Sustainable Development Goals
Ecological Economics	Impact Assessment of Green Finance schemes through
Climatic Change	statistical/econometric analysis
Sustainability	Use of data/big data analytics in evaluation/verification of green
International Review of Financial Analysis	finance/green investment performance
Financial Analysts Journal	Use of Artificial Intelligence and Machine Learning in green
The Journal of Portfolio Management	finance performance assessment and identification of green
Nature Climate Change	washing practices in corporate sector
Foundations and Trends in Finance	Role of various financial institutions in green finance deployment
Journal of Management	through case studies or firm level/country wide/region wide
Journal of Accounting Research	analysis
Journal of Accounting and Economics	Financing and green innovation/green manufacturing
Accounting Review	Green finance opportunity, green microfinance, assessment in
Journal of Financial Intermediation	different regions/industries
Journal of Monetary Economics	Green digital finance and financial inclusion policies
Review of Finance	Regulatory and legal frameworks for green finance, harmonized
Journal of Financial and Quantitative Analysis	standards development
Review of Asset Pricing Studies	Finance for urban resilience and climate action plans of cities
Review of Corporate Finance Studies	Tools and methodologies for assessment of financial materiality
Annual Review of Financial Economics	Quantitative studies on climate risk/carbon risk in finance
Critical Finance Review	Green/ESG finance, capital markets and COVID-19 pandemic
Journal of Corporate Finance	recovery measures
Journal of Financial Stability	Green financial indices and metrics for performance assessment,
Review of Development Finance	methods for sustainability analysis in finance, green finance cost-
International Review of Environmental and	benefit analysis
Resource Economics	Mutual funds, stock markets and their green finance characteristics
Nature Energy	Environmental policies and green bonds pricing strategy
Renewable Energy	Risk assessment, carbon/climate risk in green finance
Energy Policy	Climate exchanges
Energy Strategies Review	Financing losses/damages due to climate change effects

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Name of Journal	Major Research Directions
Energy Economics	Green finance/environmental finance/energy finance for the
Solar Energy	Energy Transition
Renewable and Sustainable Energy Reviews	Finance for green start-ups/clean tech/climate tech companies
Journal of Cleaner Production	Financing circular economy practices
Climate Policy	Socially responsible investment, banking and insurance
Joule	Green principles in Islamic finance
Applied Energy	Green finance and profitability for investing companies
Energy	Finance and linkage with climate change pathways
Energy and Environmental Science	Comparison of the performance of green and
IEEE Transactions on Sustainable Energy	traditional/conventional financial instruments
IEEE Transactions on Power Systems	
Energy Conversion and Management	
Environmental Innovation and Societal Transitions	
Energy for Sustainable Development	
Journal of Sustainable Finance and Investment	

7. Risk elements and disclosures in green finance

Risk elements in conventional financial practice also extend to the field of green finance. There are some additional considerations linking climate and social issues with the financial domain that are discussed in this section briefly.

7.1. ESG integration in finance

Businesses now recognize that environmental issues such as climate change produce materially significant impacts on their operations and the profitability of their ventures. Thus, deriving business insights, particularly risks in business from climate sciences is an important area today. Along with it, the impact of businesses on society is also a crucial metric now, particularly for the investors. For example, the groups of financial institutions who are signatories to the UN supported initiative named Principles of Responsible Investing (PRI) ensure investor alignment with and incorporation of ESG principles in management of their portfolios. Thus, evaluation of the materiality of climate related risks to business (which are further categorized as physical risks such as extreme weather events, natural disasters, etc and transition risks such as changing environmental laws, increasing carbon taxes, etc) and the societal impacts of business are important components of corporate risk analysis today. In addition, investors are also keen about the governance and corporate practices of a company as part of a holistic evaluation of an investment option. Investor demands for greater transparency from the businesses regarding climate risks as well as the societal and governance issues in their existing portfolio of operations and projects have also grown massively in recent times. This is what has made climate and ESG related reporting and disclosure an extremely important segment of corporate reporting activities today (Khetan et al., 2020).

7.2. Climate related financial risk and corporate disclosures

Today, one set of activities in green finance is concerned with linking insights from climate science (e.g., IPCC RCPs and CO₂ levels or temperature rise trajectories) to the potential impacts on business performance i.e., business risks. This is performed through the evaluation frameworks like the Network on Greening of the Financial Systems (NGFS), in which essentially climate risks in the operation of financial institutions are quantified (NGFS, 2020).

The other set of activities is related to voluntary financial disclosures on climate change effects on business and climate risk exposure as an extension of the legally binding financial reporting that is already practised by all corporate entities on an annual basis. Some of these initiatives are listed in Table 2 of this study. One of the earliest examples is the Carbon Disclosure Project or CDP that required participants (cities or companies) to disclose the extent of greenhouse gas emissions from their businesses via responses to a questionnaire, based on which scores were assigned to them (CDP, 2020). Later, the Task Force on Climate Related Financial Disclosures (TCFD) published a set of disclosure requirements in 2017 for the financial institutions such as banks but this framework is gradually being used by the non-financial sectors as well (TCFD, 2017). These disclosures also cover governance and business strategy for managing climate change impacts and can therefore complement annual sustainability reports as well. One of the most fundamental disclosures pertains to declaration of carbon emissions intensity of the business operations and these emissions can be classified into three Scopes depending on how they originate.

Climate related financial disclosures are a specific part of corporate sustainability reporting and disclosures, which include other themes such as land, water and energy use to sustain a given portfolio of operations, emissions and waste generation associated with those operations and the impacts on nature and biodiversity, labour and human rights issues linked to the projects and so on. Some of the most well-known frameworks for voluntary reporting on these issues are the Global Reporting Initiative (GRI) and Sustainability Accounting Standards Board (SASB) (Siew, 2015). Frameworks like TCFD complement the corporate reporting done under these general sustainability reporting frameworks.

Corporate disclosures regarding carbon emissions in their associated value chain have been found to have an impact of how the organizations are valued by the capital markets and investors. An analysis of voluntary carbon emission data provided by companies between 2006 and 2008 by Matsumura et al. (2014) identified that for an extra thousand metric tons of carbon emissions by a firm, its market value decreases by an average of \$212,000, for reasonably large sized organizations. But the initiative of voluntarily disclosing carbon emissions themselves has a positive effect on firm valuation. Using more recent data and statistical analysis, Lee et al. (2021) have identified a similar positive correlation between firm value and voluntary carbon disclosures. Firms participating in emissions trading scheme also been seen to enjoy enhanced non-business income, as established by a recent analysis of Chinese firms by Liu et al. (2021).

Other than carbon disclosures, ESG disclosures and their usefulness in determining firm valuation has been studied extensively. For example, Abdi et al. (2021) examine the performance of airline companies vis-à-vis their ESG scores and attempt to establish linkage with the corresponding financial performance. But these analyses are highly dependent on the assigned ESG score which third party agencies provide. Given the fact that there still are no globally harmonized frameworks for assessing the quality and worth of ESG disclosures made by organizations and the fact that different rating agencies can have widely different and subjective criteria for assigning ratings to the disclosing

organizations, the usefulness of these metrics to researchers and potential investors can be questionable at times (Abhayawansa and Tyagi, 2021). Berg et al. (2021) also highlight the lack of transparency regarding sources of firm level ESG data, verifiability of data and potential discrepancies in the data analysis process as causes that reduce the usefulness of corporate disclosures, be it in academic studies or in investment decisions.

7.3. Climate related litigation

The publication of the fourth IPCC Assessment Report and the signing of the Paris Agreement caused a major increase in climate related lawsuits against the corporate sector (fossil fuel companies and electricity utilities) and the national governments in several countries (Nosek, 2018). Climate litigation is often thought of as an important way to enforce climate action. In line with the growing legal frameworks associated with the environment and particularly focused on climate change mitigation and adaptation (as described earlier in Section 2.4), companies are also at greater risk of facing climate related litigation by concerned investors and other stakeholders depending on how they are carrying out their business operations. Maintaining transparency and avoiding such litigation is also another reason why businesses need to understand climate related risks and impacts of their operations and project portfolios. Up to July 2020, about 1550 climate related cases have been filed in 38 countries, with about 75% cases filed in the US alone, followed by Australia, United Kingdom and the European Union (UNEP, 2020). Most of the cases pertain to prevention of fossil fuel extraction and use, greater transparency in climate related disclosures and enhancing enforcement of climate change related laws.

In USA, the Massachusetts versus Environmental Protection Agency (EPA) case in 2007 is considered a landmark case that identified the US EPA's failure in monitoring and reducing GHG emissions from public sector projects (Ganguly et al., 2018). One of the earliest and most well-known examples of climate litigation outside USA is that of the Urgenda Foundation versus State of the Netherlands in 2015 (Viglione, 2020). In this case, a group of Dutch citizens led the Dutch Supreme Court to make 25% emissions reduction from 1990 levels mandatory. A recent landmark judgment in this domain has been the Dutch court order against Royal Dutch Shell Plc, requiring it to reduce emissions by 45% within 2030 as opposed to its 25% target in the same time frame (Baazil et al., 2021). Several more examples of climate related lawsuits have been recently compiled (UNEP, 2020), thus establishing that this is indeed a business risk that companies must seriously consider as part of their planning process. It must also be mentioned that climate related cases are also filed against the government rules and policies by businesses seeking exemptions and concessions for their operations which would otherwise be hampered by the climate or environmental legislation in place.

8. Barriers and the way ahead for green finance

Green finance deployment has seen a massive surge in recent times but there are still challenges to be overcome in order for this financial service to truly meet its intended objectives. The major challenges are described in Table 9 below. It is evident that significant intervention from the financial regulators and other institutional participants is needed to resolve these difficulties and make the green finance universe streamlined and more impactful.

Table 9. Challenges in green finance.

Serial No	Challenge	Description	The way forward
1	Green washing (Netto et al., 2020)	It refers to the general practice of making a company's operations, products and services seem more environmentally friendly, socially acceptable and sustainable, mainly with the objective of deceiving the customers and regulators.	Issue of anti-green washing guidelines by financial regulators/governments (Department for Environment, Food and Rural Affairs, 2011)
2	Lack of data	Detailed quantitative or quantifiable information about funds raised through green finance schemes and the use-of-proceeds in actual projects are not available from all institutions that are involved in these schemes, thus making it difficult to analyze the true extent of deployment of these schemes	Regulators must make disclosures mandatory with clear definitions and details of what must be included in the reports every year.
3	Difficulty of quantifying and monitoring impact of green finance schemes	Metrics or indicators that can specifically quantify the impact of projects financed by green schemes or instruments are not easily available for all kinds of projects across geographies	Academic research is needed to develop quantifiers and performance indicators for green finance and allied mechanisms, over and above traditional financial metrics like bond yields. Industry and academia must also be more closely aligned so that the academic results benefit industry.
4	Lack of harmonization in rating standards and reporting frameworks for green finance schemes	The lack of consensus or uniform rating standards regarding what kind of financial disclosures should be made by companies operating in the green finance domain, how they should incorporate ESG and related criteria in their investment and operations decision-making affects or limits the usefulness of the disclosure reports that the companies issue, for stakeholders concerned. This also increases possibilities of green washing.	Regulators need to define the framework for standards and reporting in order to truly make the information decision-useful. Attempts at globally harmonized frameworks are being made by standard setting organizations, but it may take significant time to arrive at consensus.
5	Valuation of natural capital and biodiversity	Other than climate change, understanding and integration of the risks of damage to nature and loss of biodiversity in general business risk analysis is inadequate today. Certain industries such as those related to agriculture, food processing and ecosystem services are very susceptible to such risks.	Guidelines on valuation of natural climate and tools to integrate nature related risks into decision making are required; some attempts at defining the necessary frameworks have been made recently (Tinch, 2018).

Other than the issues mentioned in Table 9, concerns regarding fiduciary responsibility tend to hold investors and asset managers back from getting involved in green finance projects, especially when the cost-benefit aspects are not articulated well enough. This is in part due to the lack of objective research and academic assessments in journals that has long plagued the green finance domain (Diaz-Rainey et al., 2017). But this situation is changing now, which will help overcome several information related shortcomings in green finance.

9. Green finance for nuclear power projects-some perspectives

Table 3 in this study indicates the type of projects commonly financed by green finance schemes. Nuclear power projects are considered mega-projects and are historically not financed by such mechanisms, even though like renewables they represent very low carbon emission sources of heat and electricity. They are capable of not only clean, stable and reliable electricity supply to various sectors but also providing support to plants supplying various non-electric products and services such as fresh water, industrial and district heating, clean hydrogen and other green fuels/energy carriers and so on. In electric grids increasingly fed by variable renewables, nuclear reactors add inertia and provide grid stability. These processes diversify the role of the nuclear industry in enabling climate action and sustainable development, and need to be viewed similarly to other green energy initiatives. Nuclear power projects produce significant positive impacts on economic development as well (local industrial growth, stable employment, etc), like other low carbon energy and industrial technologies, and these are expressed quantitatively in terms of positive economic multipliers (having values greater than unity) associated with investments in these projects (Batini et al, 2021).

But owing to the highly political nature of nuclear power, misplaced risk perception and the burden of negative public opinion against these projects (particularly due to concerns about compromises in safety, security, proliferation and nuclear waste management), along with long project development and deployment timelines plus the enormous capital investments that these projects require, they are typically considered as projects with significant financial risks by investors and financiers, particularly private ones. Thus, green finance schemes (even from large multilateral development finance institutions) have traditionally harbored a negative point of view towards nuclear power projects and stayed away from financing them, despite their having several “green” characteristics. Therefore, deployment of new projects depends on political willingness in the country in question and the availability of government support and funding for them. One exceptional but positive example in this case is provided by the activities of the European Bank for Reconstruction and Development (EBRD), which manages seven funds directly dealing with nuclear facilities management including nuclear safety, remediation and decommissioning in Europe, particularly in Russia and Eastern European countries, including the Chernobyl site (Holovko, 2017).

In recent times, with greater recognition of the dangers of climate change and the need to ensure sustainable development for all, the role of nuclear power is being re-evaluated by various governments round the world. There is greater support for the deployment of such projects in many nations including developing nations and many novel initiatives including the development of advanced, inherently safe and accident tolerant nuclear reactors are being made globally. This includes small, modular reactors and micro-reactors (SMRs), more than 70 designs of which are currently being considered and some are expected to be deployed within the current decade (IAEA, 2020). Nuclear-renewable hybrid energy systems are also being studied for specific applications, including in remote

communities. One of the Net Zero scenarios postulated by Bloomberg NEF has upto 66% of nuclear power in the global energy mix and it envisages deployment of SMRs alongside renewables, providing heat, electricity and clean hydrogen (Bloomberg NEF, 2021).

The importance of nuclear heat and electricity in decarbonizing multiple sectors, particular via nuclear cogeneration projects is also better understood now, which may attract more institutional investors towards them through the creation of new business models and value propositions (NREL, 2020). New financing models are also being explored for them and it is possible that even some form of green finance will become available to them. One important step forward in this regard has been the issuance of the JRC report on nuclear power, which concludes that nuclear power projects do not harm the ambient and are therefore fit for inclusion under green energy and related taxonomies (EURATOM, 2021). Consideration of nuclear power projects as an investible asset class with positive ESG characteristics has recently been advocated by the Generation IV International Network, a consortium of nations working on and supporting deployment of advanced nuclear reactor technologies (GIF, 2021). A science backed approach towards nuclear energy and its benefits with regards to climate action and sustainable development can go a long way in shaping favorable and technology-neutral policies and de-risking it for potential green investors to accelerate its deployment.

10. Concluding remarks and future perspectives

Green finance and associated environmentally and socially responsible financial mechanisms are an important mechanism in solving the multiple mega problems that mankind is facing today due to environmental degradation and anthropogenic climate change. They can act by causing shifts in the fundamental manner of doing business today, by decoupling damage to environmental systems from economic growth and development. They enable development and deployment of systems and technologies that address these social and environmental issues at large scale, create pathways for sustainable and inclusive development and support climate change management strategies at local, regional, national and international levels. These financial products represent ever-increasing investor interest in socially responsible projects that go beyond the mandate of not harming the environment but in also restoring and regenerating it, while producing tangible socio-economic benefits for the concerned stakeholders.

This pedagogical study discusses the various instruments of green finance, the projects that can be brought under the purview of these instruments and the organizations involved in developing and deploying these instruments and associated financial regulations, standards and reporting frameworks. It also discusses the weaknesses and challenges that these schemes are still facing and summarizes current academic research agenda in this domain. The green finance domain is vast and has strong linkages to ESG themes; Therefore, it is growing and widening its scope every day. New research is also needed to better understand these diverse roles and quantify their actual long- and short-term impacts with the expected ones.

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Conflict of interest

The author declares no conflict of interest.

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