Electrical Grids and Storage Criteria

Development of Eligibility Criteria under the Climate Bonds Standard & Certification Scheme

DRAFT FOR CONSULTATION

Document version and notable changes	Date
Issued as draft for public consultation	May 2021

Climate Bond Certified

Definitions

Climate Bonds Initiative (CBI): An investor-focused not-for-profit organisation, promoting large-scale investments that will deliver a global low carbon and climate resilient economy. The Initiative seeks to develop mechanisms to better align the interests of investors, industry and government so as to catalyse investments at a speed and scale sufficient to avoid dangerous climate change.

Climate Bond: A climate bond is a bond used to finance – or re-finance - projects needed to address climate change. They range from wind farms and hydropower plants, to rail transport and building sea walls in cities threatened by rising sea levels. Only a small portion of these bonds have been labelled as green or climate bonds by their issuers.

Certified Climate Bond: A Climate Bond that is certified by the Climate Bonds Standard Board as meeting the requirements of the Climate Bonds Standard, as attested through independent verification.

Climate Bonds Standard (CBS): A screening tool for investors and governments that allows them to identify green bonds where they can be confident that the funds are being used to deliver climate change solutions. This may be through climate mitigation impact and/ or climate adaptation or resilience. The CBS is made up of two parts: the parent standard (Climate Bonds Standard V3) and a suite of sector specific eligibility Criteria. The parent standard covers the certification process and pre- and post-issuance requirements for all certified bonds, regardless of the nature of the capital projects. The Sector Criteria detail specific requirements for assets identified as falling under that specific sector. The latest version of the CBS is published on the Climate Bonds Initiative website.

Climate Bonds Standard Board (CBSB): A board of independent members that collectively represents $34 trillion of assets under management. The CBSB is responsible for approving i) Revisions to the Climate Bonds Standard, including the adoption of additional sector Criteria, ii) Approved verifiers, and iii) Applications for Certification of a bond under the Climate Bonds Standard. The CBSB is constituted, appointed and supported in line with the governance arrangements and processes as published on the Climate Bonds Initiative website.

Climate Bond Certification: allows the issuer to use the Climate Bond Certification Mark in relation to that bond. Climate Bond Certification is provided once the independent Climate Bonds Standard Board is satisfied the bond conforms with the Climate Bonds Standard.

Green Bond: A Green Bond is where proceeds are allocated to environmental projects. The term generally refers to bonds that have been marketed as "Green". In theory, Green Bonds proceeds could be used for a wide variety of environmental projects, but in practice they have mostly been the same as Climate Bonds, with proceeds going to climate change projects.

Grid assets and projects: Assets and projects relating to the transmission and distribution, and storage of electricity.

Technical Working Group (TWG): A group of key experts from academia, international agencies, industry and NGOs convened by the Climate Bonds Initiative. The TWG develops the Sector Criteria - detailed technical criteria for the eligibility of projects and assets as well as guidance on the tracking of eligibility status during the term of the bond. Their draft recommendations are refined through engagement with finance industry experts in convened Industry Working Groups and through public consultation. Final approval of Sector Criteria is given by the CBSB.

Industry Working Group (IWG): A group of key organisations that are potential issuers, verifiers and investors convened by the Climate Bonds Initiative. The IWG provides feedback on the draft sector Criteria developed by the TWG before they are released for public consultation.

The Climate Bonds Initiative gratefully acknowledges the Technical and Industry Working Group members who supported the development of these Criteria. Members are listed in Appendix 1. Special thanks are given to Ian Walker, the lead specialist coordinating the development of the Criteria through the Technical Working Group, and Arna Sigurdardottir and Foaad Tahir, also providing support.

This paper was prepared by Ian Walker and Arna Sigurdardottir of Element Energy and Chris Moore of the Climate Bonds Initiative.

Table of Contents

1 Introduction

1.1 Overview

This Criteria Document provides serves as a reference document to the Criteria Document for the Electrical Grids and Storage Criteria (hereafter referred to as the Grids and Storage Criteria). The purpose of the Background Document is to provide an overview of the key considerations and issues that were raised during development of the Grids and Storage Criteria.

The Criteria are developed through a consultative process with Technical Working Groups (TWGs) and Industry Working Groups (IWGs), and through public consultation. The TWGs comprise academic and research institutions, civil society organizations, multilateral banks and specialist consultancies whereas IWGs are represented by industry experts including potential bond issuers and investors. A period of public consultation offers the opportunity to any member of the public to comment on the Criteria. This document aims to capture these various dialogues and inputs and substantiate the reasoning behind the Grids and Storage Criteria.

This Background Document begins with an introduction to the challenges in financing a low carbon and climate resilient world and the role that bonds can play in meeting this challenge, particularly through the standardization of green definitions. This is followed by Section 2, which introduces the grids (electricity transmission, distribution and storage) sector and the implications of climate change on the sector in terms of both emissions and climate risks. Section 3 explains the principles and boundaries of Grids and Storage Criteria development. Section 4 synthesizes the discussions arising from the TWGs, IWGs, and public consultation and presents the resulting Criteria.

Supplementary information available in addition to this document include:
1. Grids and Storage Criteria Brochure[1]: a 2-page summary of the Grids and Storage Criteria.
2. Grids and Storage Criteria Document: the complete Criteria requirements.
3. Climate Bonds Standard V3: the umbrella document laying out the common requirements that all Certified Climate Bonds need to meet, in addition to the sector-specific Criteria (V3 is the most recent update version).
4. Climate Bonds Standard & Certification Scheme Brochure: an overview of the purpose, context and requirements of the Climate Bonds Standard & Certification Scheme.

For more information on the Climate Bonds Initiative and the Climate Bonds Standard & Certification Scheme, see https://www.climatebonds.net/standard.
For the documents listed above, see https://www.climatebonds.net/standard/grids

1.2 Funding needs of a low-carbon and climate resilient economy

The current trajectory of climate change, expected to lead to global warming of 2.7 - 3.1°C by 2100[2], poses an enormous threat to the future of the world's nations and economies. The effects of climate change and the risks associated with a greater than 1.5ºC rise in global temperatures by the end of the century are significant: rising sea levels, increased frequency and severity of hurricanes, droughts, wildfires and typhoons, and changes in agricultural patterns and yields. Avoiding such catastrophic climate change requires a dramatic reduction in global greenhouse gas emissions.

To ensure sustainable development and halt climate change, all future infrastructure, both built and nature-based, needs to be low-carbon and resilient to climate change, without compromising the kind of economic growth needed to improve

1 This will be published once criteria are finalised following public consultation
2 According to Climate Tracker, under current policies we could expect 2.7-3.1ºC. In the absence of policies this rises steeply to 41.-4.8 ºC: http://climateactiontracker.org/global.html

the livelihoods and wellbeing of the world's most vulnerable citizens. Global infrastructure investment is expected to amount to USD 90 trillion over the next 15 years, which is more than the entire current infrastructure stock.[3]

Ensuring that the infrastructure built is low-carbon raises the annual investment needs by 3–4%.[4] The IEA further estimates that an additional USD 1.1 trillion will need to be invested annually in both supplying power and altering how end users consume power between now and 2040 to meet the IEA Sustainable Development Scenario (compatible with a 1.5ºC scenario)[5]. Climate adaptation needs add another significant amount of investment, which is estimated at USD 280–500 billion per annum by 2050 for a 2ºC scenario.[6] These estimates would likely increase in a higher warming scenario.

According to the Task Force on Climate-related Financial Disclosures (TCFD), there are two broad channels through which climate change can present risks to business activities and assets[7]:

1. Physical risk: the risk of impacts from climate- and weather-related events, such as floods and storms that damage property or disrupt supply chains and trade;
2. Transition risk: the financial risks that could result from the process of adjustment towards a lower-carbon economy. These include sudden shifts in demand; legal risk due to parties who have suffered loss or damage seeking compensation; and changes in policy favouring lower carbon technologies.

These could prompt a reassessment of the value of a large range of assets as costs and opportunities become apparent, and widespread inadequate information on these risks could even threaten the stability of the financial system. Risks to financial stability will be minimised if the transition to a low carbon and climate resilient economy begins early and follows a predictable path, thereby helping the market anticipate a smooth transition to a 1.5ºC warming world.

1.3 Green bonds are critical to mobilising the capital required

Traditional sources of capital for infrastructure investment, such as governments and commercial banks lending, are insufficient to meet capital requirement needs to 2030. Institutional investors, particularly pension and sovereign wealth funds, are increasingly looked to as viable actors to fill these financing gaps.

Capital markets enable issuers to tap into large pools of private capital from institutional investors. Bonds are appropriate investment vehicles for these investors as they are low-risk investments with long-term maturities, making them a good fit with institutional investors' liabilities (e.g. pensions to be paid out in several decades).

Bond financing works well for low-carbon and climate-resilient infrastructure, particularly for refinancing projects and assets post-implementation, as capital markets also facilitate risk management. Across investors and financial markets, different entities face different types and severities of risks related to climate change, depending on many factors including degree of long-term exposure, likelihood of negative climate impacts, and ability to mitigate impacts or shift positions.

Bonds offer relatively stable and predictable returns, and long-term maturities. This makes them a good fit with institutional investors' investment needs. Labelled green bonds are bonds with proceeds used for green projects, mostly climate change mitigation or adaptation projects, and labelled accordingly. The rapid growth of the labelled green bond market has shown in practice that the bond markets provide a promising channel to finance climate investments.[8]

The green bond market can reward bond issuers and investors for sustainable investments that accelerate progress toward a low carbon and climate resilient economy. Commonly used as long-term debt instruments, green bonds are issued by governments, companies, municipalities, commercial and development banks to finance or re-finance assets or activities with environmental benefits. Green bonds are in high demand and can help issuers attract new types of investors.

3 New Climate Economy (2016). Better Growth, Better Climate.
4 New Climate Economy (2016). The Sustainable Infrastructure Imperative: Financing for Better Growth and Development.
5 International Energy Agency, 'World Energy Outlook 2018', (November 2018), available at: https://www.iea.org/weo2018/
6 UNEP (2016). The Adaptation Finance Gap Report.
7 TFCD's 'Recommendations of the Task Force on Climate-related Financial Disclosures': https://www.fsb-tcfd.org/publications/final-recommendations-report/
8 See Climate Bonds Initiative's 'State of the Market' Report for more information: https://www.climatebonds.net/files/reports/cbi_sd_sotm_2020_04c.pdf

Green bonds are regular bonds with one distinguishing feature: proceeds are earmarked for projects with environmental benefits, primarily climate change mitigation and adaptation. A green label is a discovery mechanism for investors. It enables the identification of climate-aligned investments with limited resources for due diligence. By doings so, a green bond label reduces friction in the markets and facilitates growth in climate aligned-investments.

However, today it is estimated that green bonds account for only 2% of the total global bonds outstanding[9] in a global bond market of nearly USD 130 trillion[10]. The potential for scaling up is tremendous, while more market tools and labels are becoming commonplace. Social bond and Sustainability bond issuance increased considerably in 2020, for instance[11].

1.4 Introduction to Climate Bonds Initiative and the Climate Bonds Standard

The Climate Bonds Initiative is an investor-focused not-for-profit organisation whose goal is to promote large-scale investments through green bonds and other debt instruments to accelerate a global transition to a low-carbon and climate-resilient economy.

Activating the mainstream debt capital markets to finance and refinance climate-aligned projects and assets is critical to achieving international climate goals, and robust labelling of green bonds is a key requirement for that mainstream participation. Confidence in the climate objectives and the use of funds intended to address climate change is fundamental to the credibility of the role that green bonds play in a low carbon and climate resilient economy. Trust in the green label and transparency to the underlying assets are essential for this market to reach scale but investor capacity to assess green credentials is limited, especially in the fast-paced bond market. Therefore, the Climate Bonds Initiative created Climate Bonds Standard & Certification Scheme, which aims to provide the green bond market with the trust and assurance that it needs to achieve scale.

The Climate Bonds Standard & Certification Scheme is an easy-to-use tool for investors and issuers to assist them in prioritising investments that truly contribute to addressing climate change, both from a resilience and a mitigation point of view. It is made up of the overarching Climate Bonds Standard detailing management and reporting processes, and a set of Sector Criteria detailing the requirements assets must meet to be eligible for certification. The Sector Criteria cover a range of sectors including solar energy, wind energy, marine renewable energy, geothermal power, low carbon buildings, low carbon transport, and water. The Certification Scheme requires issuers to obtain independent verification, pre- and post-issuance, to ensure the bond meets the requirements of the Climate Bonds Standard.

1.5 Process for Sector Criteria Development

The Climate Bonds Standard has been developed based on public consultation, road testing, review by the assurance roundtable and expert support from experienced green bond market actors. The Standard is revisited and amended on an annual basis in response to the growing green bond market. Sector specific Criteria, or definitions of green, are developed by TWGs, made up of scientists, engineers and technical specialists. Draft Criteria are presented to IWGs before being released for public comment. Finally, Criteria are presented to the Climate Bonds Standard Board for approval (see diagram below).

[9] https://www.fitchratings.com/research/fund-asset-managers/global-green-bond-fund-dashboard-1h20-24-09-2020
10 https://www.icmagroup.org/Regulatory-Policy-and-Market-Practice/Secondary-Markets/bond-market-size/
11 See Climate Bonds Initiative's 'State of the Market' Report for more information: https://www.climatebonds.net/files/reports/cbi_sd_sotm_2020_04c.pdf

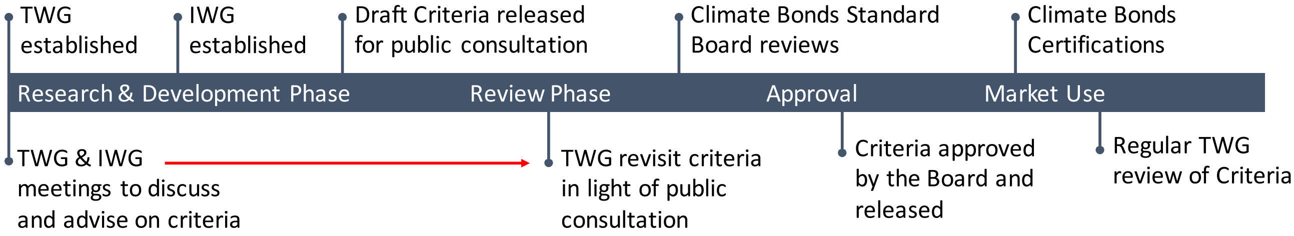

Figure 1: process for developing Climate Bonds Standard Sector Criteria

To date, Sector Criteria for the following sectors are available for certification:

- Wind
- Solar
- Geothermal
- Marine renewables
- Transport
- Water
- Buildings
- Agriculture and Protected Agriculture
- Hydropower
- Bioenergy
- Waste management
- Shipping

Sector Criteria for Cement, Steel and Chemicals are under development.

1.6 Revisions to these Criteria

As part of the Climate Bonds Initiative's goal to accelerate a global transition to a low-carbon, resilient economy, the Grids and Storage Criteria seek to maximize viable bond issuances with verifiable environmental outcomes. This guidance should be recognised as the first set of sector-specific guidance for electricity transmission, distribution and storage. All groups and individuals involved recognise the breadth and complexity of this sector and emphasise that this guidance should be a foundation on which to encourage increased transparency and consistency in application of scientific best practices and data in the context of bond issuances. Note that Climate Bonds Initiative expects that the Grids and Storage Criteria may be refined over time, however any approvals given will not be removed or changed retroactively. These eligibility criteria should be recognized as a starting point.

These Criteria will be reviewed two years after launch, or potentially earlier if the need arises, at which point the TWG will take stock of issuances that arise in the early stages and any developments in improved methodologies and data that can increase the climate integrity of future bond issuances. After the first review, the Criteria will be reviewed again periodically on a needs basis as technology and the market evolves. As a result, the Criteria are likely to be refined over time, as more information becomes available.

2 Sector Overview

2.1 What are Electrical Grids and Storage?

Electrical Grids

Electrical grids, comprising transmission and distribution systems, are the critical infrastructure that connect power generation with electricity consumers. Transmission systems carry power at high voltage, often over long distances, connecting electricity generators (e.g. power plants) with electricity distribution networks. The majority of end-users, such as homes and businesses, are connected to the distribution networks, which are more localized and distribute electricity at lower voltages than the transmission system. The transmission and distribution systems each consist of large numbers of physical assets. This is principally cables, transformers and switchgear that carry power, convert between voltage levels and provide connections between different parts of the system and to end-users.

Global investment in electrical grids stood at around $275bn in 2019, the bulk of which was in the distribution network (around 65-70%)[12]. The US and China accounted for $150bn of this total investment, with around $50bn of spending in Europe and $18bn in India. While conventional network assets as described above still make up the majority of the investment, a growing proportion of spending is shifting toward digital grid technologies, which accounted for around 15% of total investment in 2019.

In addition to the network assets, the wires, transformers and so on, grids are increasingly being monitored and actively controlled, requiring control devices and communications infrastructure. Grid investments could include investment in monitoring, control and communication systems.

Transmission and distribution grids are usually considered to be natural monopolies, with high barriers to entry due to high costs of power generation facilities and transmission lines, and historically large economies of scale. Grids serving different regions within these systems are usually operated by regulated utilities, which in some countries are privately-owned and in others are state-backed entities. Investment and ownership of the assets making up the transmission and distribution systems will usually be by these regulated utilities.

Electricity Storage

Electrical energy storage is the conversion of electrical energy into a different form, such as potential or chemical energy, in order to convert it back to electrical energy at a point in the future. This can be carried out by a wide array of technologies or practices. For example, batteries, capacitors, flywheels, compressed air, pumped hydropower, and hydrogen. Section XX outlines the storage technologies outside the scope of these Criteria. The consideration of electricity storage in the Grids and Storage criteria is focused on battery, compressed air, and flywheel storage technologies.

The level of investment in energy storage technologies has been steadily increasing over much of the last decade, although for the first time saw a drop in 2019. Total investment in battery storage exceeded $4bn13, with an approximately even split between grid-scale and behind-the-meter battery storage technologies. Europe is a leader in battery storage investment, in both grid-scale and behind-the-meter technology, with the US, China, Japan, Korea and Australia also strong markets for battery technology.

Whereas investment in transmission and distribution assets will normally be by regulated utilities, electricity storage tends to be treated similarly to generation and is not usually a regulated asset. Indeed, in some countries, such as the UK, network operators are not allowed to own storage assets. There may therefore be a wide variety of organisations that look to use bond proceeds for investment in electricity storage assets.

12 IEA World Energy Investment 2020: Power Sector (https://www.iea.org/reports/world-energy-investment-2020/power-sector#abstract)
13 IEA, World Energy Investment Report 2020, https://www.iea.org/reports/world-energy-investment-2020/power-sector?utm_content=buffer61c85&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer

2.2 Future of electrical grids and storage

Traditionally grids have been developed as passive systems, designed to transport power in one-direction from large power stations connected to the transmission system, through the network of cables and transformers to large numbers of end-users, the majority of which will be connected to the distribution network at lower voltage levels.

This is changing with the decarbonisation of electricity grids through the connection of increasing capacities of low carbon and renewable generation. This often includes smaller, more distributed generators, some of which are embedded in the distribution networks and include generation installed at customer sites (e.g. rooftop solar installed on the roofs of homes and businesses).

Decarbonisation of the power sector greatly magnifies the need for electricity networks, which can manage dynamic power flows. A low-carbon electricity system is typically one which must prepare for a high degree of utility-scale intermittent renewables penetration and flexibility in matching demand and supply. It may also imply: (i) greater decentralisation of generation resources in the hands of households and municipalities, resulting in the need to manage bi-directional power flows; (ii) the incorporation of demand response measures.

Utility-scale battery storage is one strategy for dealing with intermittency that has been receiving increasing attention and investment. Utility-scale typically refers to batteries of a size from a few MWhs to hundreds of MWh. As lithium-ion battery prices have tumbled, this technology has taken an increasing share of the global grid-scale battery market, achieving nearly 90% market share by capacity of new additions in 2016 (corresponding to 1.62 GW of added capacity)[14]. Grid-scale batteries can be installed to provide a variety of services, including power-oriented applications such as frequency response, which require high power output for a short duration, to more energy-oriented applications, such as network peak shaving, arbitrage and co-location with intermittent renewables to provide output firming. Behind-the-meter battery systems are installed at a customer's site and are significantly smaller in capacity (often installed within commercial premises or in the residential sector). The most likely use cases for behind-the-meter storage are to maximise own-use of onsite renewable energy systems, e.g. rooftop solar, arbitrage and for reliability purposes. While behind-the-meter storage is usually owned by the customer, it can still be beneficial to the network operator. For example, in parts of the network with high penetration of photovoltaics, distributed behind-the-meter batteries can help to reduce reverse power flows at times of high solar output and low demand on the low voltage system.

A further strategy for better integration of intermittent renewables is greater connectivity across a large geographical region, smoothing out differences in meteorological conditions in different areas. The best renewable resources can often be located far from population centres; for example, in desert areas, or off remote windy coasts. The UK may one day be connected to the geothermal and hydropower resources of Iceland via the world's longest subsea cable. Long-distance interconnection or 'mega-grids' are frequently discussed as a means of making the best use of renewable resources, and advances in ultra-high voltage transmission technology have made transcontinental transmission feasible[15]. While plans for connecting Europe to the vast solar resource of North Africa have been shelved due to political risk, mega-grids connecting China with Siberia and Central Asia or even Europe are a current topic of discussion[16][17].

14 IRENA, 2019, Utility-scale batteries: Innovation landscape brief, www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Utility-scale-batteries_2019.pdf
15 The economist. 2017. Rise of the supergrid: Electricity now flows across continents, courtesy of direct current. Available from: https://www.economist.com/news/science-and-technology/21714325-transmitting-power-over-thousands-kilometres-requires-new-electricity. Accessed on 17.05.2018.
16 Ardelean, M., & Minnebo, P. 2017. JRC science for policy report; A China-EU electricity transmission link; Assessment of potential countries and routes. Available from: https://ses.jrc.ec.europa.eu/sites/ses.jrc.ec.europa.eu/files/publications/jrc110333_intercon_report_v03.pdf. Accessed on 17.05.2018.
17 Financial Times. 2017. China plans super-grid for clean power in Asia. Available from: https://www.ft.com/content/e808a542-d6c6-11e7-8c9a-d9c0a5c8d5c9. Accessed on 17.05.2018

2.3 Electrical Grids and climate change

Electrical grids are a key enabler of the decarbonization of energy systems[18]. A wide range of energy uses can be decarbonized by the use of electricity in place of fossil fuels; for example in transport, heating and industrial processes, provided that the electricity is generated from low carbon or renewable resources. Modern electricity transmission and distribution grids are needed to connect these new sources of generation and to cope with the growing electricity demands associated with increased electrification. Simultaneously, they must maintain high levels of system security, reliability, safety and low losses.

The potential for grid investments to contribute to greenhouse gas mitigation largely rests on their ability to:

1. Connect utility-scale renewable resources to the grid;
2. Accommodate and/or encourage low-carbon decentralised resources;
3. Upgrade the grid network with flexibility measures to be able to better handle intermittency, bi-directional flows, demand response measures and more dynamic and finer-grained matching of supply and demand (smart grids, internet of energy, etc.); and
4. Enable electrification of other sectors

The technologies required to achieve these objectives will include traditional grid assets, such as cables and transformers, to increase capacity for connection of new demands and to carry power from locations of strong renewable resources to the centres of electricity demand (note that in addition to high-voltage AC transmission, the demand for long-distance, low loss transmission may lead to an increasing role for HVDC technology). Alongside the build of increased capacity, the transition to smart grids will require investment in technologies for the automation and control of networks, communications systems and digitalisation. Smart grids will also be necessary to enable decarbonisation in the most efficient and cost-effective way.

In general, investment in building sufficient network capacity and facilitating smarter network management is considered to be crucial to achieving energy system decarbonisation and hence there is a strong rationale for broad eligibility of grid investments with respect to the Climate Bonds Grids and Storage Criteria.

2.4 Electricity storage and climate change

The benefits of storage in clean energy systems are regularly discussed (e.g. grid support, balancing intermittency, daily peak shifting, seasonal storage, etc.). However, it should be acknowledged that research by systems modellers shows that storage does not always reduce the GHG emissions of the electrical grid as a whole[19]. In fact, associated emissions of storage seem to depend on the relative carbon intensities of: i) the electricity used to charge the storage, and (ii) the generation that the stored electricity displaces. To determine the impact of storage on emissions in any particular grid is likely to require modelling of the dispatch of grid generation and the operation of storage within the system. However, the potential for electricity storage to increase emissions is diminished as the overall carbon intensity of the grid reduces. The benefits of storage, in terms of facilitating increased penetration of renewables and managing peak demands, are therefore expected to outweigh any potential increase in emissions.

There is limited literature on the lifecycle impacts of electricity storage technologies. These indicate that pumped storage hydropower is probably the lowest carbon forms of storage, while batteries have a higher GHG impact, partly due to the lower number of cycles which they are able to withstand[20] (see Table 1). Battery lifecycle GHG emissions are highly sensitive to the carbon intensity of the grid of the country of manufacture. Compressed air has lower GHG emissions when paired with fossil fuel energy, and for this reason does not compare well to other storage technologies in low carbon grids[21]. Note

18 https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/energy-resources/deloitte-ch-en-eurelectric-connecting-the-dots-study.pdf
19 Hittinger, E., Azevedo, I., 2015, Bulk Energy Storage Increases United States Electricity Systems Emissions, Environ. Sci. Technol. 2015, 49, 3202-3210
20 Hiremath, M., Derendorf K. and Vogt T. 2015. Comparative Life Cycle Assessment of Battery Storage Systems for Stationary Applications", Environ. Sci. Technol. 2015, 49, 4825–4833.
21 Denholm, P. and Kulcinski, G.L. 2004. Life cycle energy requirements and greenhouse gas emissions from large scale energy storage systems', Energy Conversion and Management 45: 2153–2172.

that these are indicative figures from the few sources we have been able to access to date, and do not constitute a review. We have presented an interpretation of quantitative results (rather than the figures themselves) for any study which includes the carbon-intensity of the electricity used to charge the battery, as this would clearly be a dominating factor (right-hand column).

Table 1. Energy stored on investment (ESOI) and lifecycle GHG emissions of different storage technologies[22, 23].

Storage technology	ESOI[1]	$kgCO_2e/kWh$ storage capacity	gCO_2e/kWh electricity discharged
Compressed air	240		lower than other storage technologies in carbon-intensive grids
Pumped hydropower	210		lower than battery; lowest of all in low carbon grids
Lithium-ion battery	10	40-270	lower than other battery technologies
High temperature sodium-sulphur battery	6		
Vanadium redox flow battery	3	183	
Zinc-bromide hybrid flow battery	3		
Lead-acid battery	2	52	marginally higher than other battery technologies

Note: ESOI is the amount of energy stored in a storage device over its lifetime divided by the energy required to produce that device.

2.5 Investment need

Substantial investment in electricity grid infrastructure will be required to support increasing electrification of energy demands, including transport and heating, and greater penetration of renewable energy sources. Investment will be required to increase network capacity at both transmission and distribution levels, involving the deployment of ‘conventional’ grid assets such as transformers and cables. Better utilisation of existing network capacity will also be required if increased demands on electricity grids are to be met in the most cost-effective way. This is expected to drive increasing investment in network automation, monitoring, communications and control systems. This will in turn enable more active management of networks, which have traditionally been operated in a passive way. Flexibility, including demand side management and electricity storage, is expected to play an increasing role in the management of networks, resulting in growing investment in flexibility services.

In contrast to the need for investment, the actual investment in grids globally has fallen over recent years. The IEA’s World Energy Investment 2020 report[24] recorded the third consecutive year of declining investment in grids in 2019 with total investment at around $275bn, a reduction of 7% compared to 2018, with a further fall predicted in 2020 as the Covid-19 pandemic weakens public finances. The drop has largely been driven by declining investment in distribution networks, while investment in transmission grids, which contributes around 30% of network investment globally, had been growing steadily over a five-year period to 2018[25], but also dropped in 2019. Despite the overall reduction, grid investment in the United States, Europe and India has been increasing, but this has been offset by reduced spending in China and other regions.

22 , S., Schmidt, O. and Gambhir, A. 2016. ‘Electrical energy storage for mitigating climate change’, Grantham Institute Briefing paper No 20, Imperial College London; 2 Baumann, M., Peters, J.F., Weil, I.M., Grunwald, A. 2016. CO2 Footprint and Life-Cycle Costs of Electrochemical Energy Storage for Stationary Grid Applications’, Energy Technology 5(7):1071-1083; 3.
23 Romare, M. and Dahllof, L. 2017. The Life Cycle Energy Consumption and Greenhouse Gas Emissions from Lithium-Ion Batteries’, IVL Swedish Environmental Research Institute.
24 https://www.iea.org/reports/world-energy-investment-2020/power-sector?utm_content=buffer61c85&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer
25 https://www.carbonbrief.org/iea-low-carbon-spending-must-more-than-double-to-meet-climate-goals

The expected shift in investment from conventional grid infrastructure to digital grid technologies has been observed, with increasing spending on smart meters, network automation and EV charging infrastructure. Investments in smart network technologies made up more than 15% of total investment in grids in 2019.

The IEA World Energy Investment report notes that the current trajectory of grid spending is at risk of falling short of that needed to support growing renewables and electrification. The IEA Net Zero by 2050 report estimates that an annual spending of USD 820 billion on electrical grids will be needed by 2030 to limit global warming to 1.5°C above pre-industrial levels[26], nearly a 300% increase on 2019 levels.

2.6 Bonds in the sector

Of the more than USD 150bn of green bonds that Climate Bonds has Certified since the establishment of the Standard, 46% (USD 69bn) of cumulative issuance relates to energy generation[27]. Many of the renewable energy projects represented by this number will include necessary dedicated connections and transmission lines. However, there is considerable further grid investment that might not directly connect to renewable energy. These might be financing upgrades or extensions to T&D networks, or development of smart grids and storage facilities. In 2019 alone, there was a total of USD 248bn investment into T&D infrastructure[28], although this is not limited to bond financing. In any case, grid infrastructure represents a pool of assets and activities which can absorb large amounts of finance that can be structured through certified green bonds.

It is not clear how many outstanding bonds are aligned with grid infrastructure. Issuance of Transmission Line Project Bonds equalled USD 3.8bn in 2016 alone. Between 2010 and 2017 Transmission Line Project Bonds accounted for approx. 16% of all Power-related Project Bond issuances by volume, and roughly 4% of the total Project Bond market29. Table 2 meanwhile provides recent examples of bonds in the grid sector.

Table 2. Examples of recent bonds in the grids sector.

Issuer	Year	Description	Credentials
TenneT Holdings	2020	EUR 1.35bn bond, eligible projects for funding: connection of large-scale offshore wind to the onshore electricity grid and enhancing the onshore transmission capacity for renewable energy[30]	ISS Corporate Solutions second opinion
National Grid	2020	EUR 500mn bond, eligible projects for funding: connection infrastructure of wind farms to the grid, reduction of electricity grid losses or financing clean transport infrastructure[31]	DNV-GL second opinion
Niagara Mohawk Power Corporation (NIMO) / National Grid	2020	USD 600mn bond, used to finance renewable energy, energy efficiency, clean transportation, pollution prevention, environmentally sustainable management of living natural resources and land use[32]	N/A

26 https://www.iea.org/reports/net-zero-by-2050
27 https://www.climatebonds.net/2020/11/new-milestone-climate-bond-standard-certifications-pass-150bn-record-24-market-share-2020
28 https://www.iea.org/reports/world-energy-investment-2020/power-sector
29 https://www.ca-cib.com/sites/default/files/2017-07/Project%20Bond%20Focus%20-%20Issue%206%20-%20Power%20Transmission%20%28VF%29.pdf
30 https://renews.biz/64490/tennet-raises-green-bond-financing-to-10bn/
31 https://www.nationalgrid.com/uk/stories/grid-at-work/national-grid-launches-green-bond-fund-sustainability-projects
32 https://www.nationalgrid.com/stories/grid-at-work-stories/us-green-bond-helps-fund-clean-energy-projects

Issuer	Year	Description	Credentials
Fingrid	2017	€100mn bond, linked to connections for renewable energy, reductions in network losses, interconnections, and smart grid development[33]	Cicero second opinion
Iberdrola	2021	EUR 2bn, 15-year green bond to finance the construction, operation and development of renewable energy, as well as general financing of smart grids, storage solutions and network development[34]	Vigeo Eiris second opinion
E.ON	2019	EUR 1.5bn bond, eligible projects for funding: renewable energy generation and connection, upgrades and refurbishments to its electrical grids, including smart grid investments, energy efficient replacements, the deployment of smart meters[35]	Sustainalytics second opinion
Rural Electrification Company (REC)	2017	USD 450mn 10-year bond, funding generation and distribution of solar, wind and biomass assets, as well as sustainable water and waste management projects[36]	Climate Bond Certified
NTPC	2016	INR 20bn (USD299mn), 5-year bond, eligible projects for funding: renewable energy connection and transmission[37]	Climate Bond Certified
FlexiGroup Limited	2019	AUD 90mn (USD 70mn) green bond issuance to finance the deployment of rooftop solar PV systems and small-scale energy storage systems[38]	Climate Bond Certified
Difebal S.A. / Terna	2017	USD 81mn, 30-year green bond used to directly connect renewable energy and construct and operate transmission lines	Vigeo Eiris

33 https://www.fingrid.fi/globalassets/dokumentit/en/investors/green-financing/fingrid---green-bonds-framework----3-october-2017.pdf
34 https://www.iberdrola.com/press-room/news/detail/iberdrola-completes-largest-green-hybrid-bond-issue-history-billion-euros
35 https://www.eon.com/en/about-us/media/press-release/2019/2019-08-21-eon-successfully-raises-green-bonds.html
36 https://www.climatebonds.net/certification/rural-electrification-corporation
37 https://www.climatebonds.net/certification/ntpc
38 https://www.energy-storage.news/news/important-market-development-energy-storage-included-in-australian-climate

3 Principles and Boundaries of the Sector Criteria

3.1 Guiding principles

The Climate Bond Standard needs to ensure that the Grid and Storage assets and projects included in Certified Climate Bonds deliver on GHG mitigation potential and climate resilience benefits, in line with best available scientific knowledge and compatible with the goals of the Paris Agreement. At the same time, the Grids and Storage Criteria need to be pragmatic and readily usable by stakeholders in the market, to maximise engagement and use. High transaction costs run the risk of reducing uptake of a Standard in the green bond market. Keeping the costs of assessment down while maintaining robust implementation of the criteria is important. Table sets out the principles guiding the development of the Grids and Storage Criteria to meet and balance on these two goals.

Table 3. Key principles for the design of a Climate Bond Standard Grids and Electricity Storage Criteria

Principle	Requirement for the Criteria
Level of ambition	Compatible with meeting the objective of 1.5ºC or less temperature rise above pre-industrial levels set by the Paris Agreement, and with a rapid transition to a low carbon and climate resilient economy.
Robust system	Scientifically robust to maintain the credibility of the Climate Bond Standard.
"Do not reinvent the wheel"	Harness existing robust, credible tools, methodologies, standards and data to assess the low carbon and climate resilient credentials of any technology, endorsed by multiple stakeholders where possible.
Level playing field	No discrimination against certain groups of producers or geographies.
Multi-stakeholder support	Supported by key stakeholders; those within the relevant industry, the financial community and broader civil society.
Continuous improvement	Subject to an evolving development process with the aim of driving continuous improvement and credibility in the green bond market.
Technology agnostic	The Climate Bonds Standard avoids picking 'winners and losers' in terms of technologies – a task beyond its mandate and capacity.

In addition to the overarching principles outlined in the table above, the following additional guiding principles for grids and storage were considered when developing the Criteria.

Any Criteria developed for the Electrical Grids and Storage sector should be:

- **Inclusive** – As a general principle, modern, robust grid infrastructure is an enabler of decarbonisation, hence eligibility criteria should be broadly inclusive
- **Simple** – Any Criteria developed should be easy to apply
- **Accessible** – Demonstration of eligibility of any Criteria should be accessible by the use of public datasets
- **Robust** – Energy systems across the world are undergoing rapid changes. Criteria developed should allow for these changes and not rely on parameters that will become outdated or obsolete in the near future

3.2 Potentially eligible assets

The following grid and storage assets are potentially eligible for inclusion in a Certified Climate Bond, subject to meeting the eligibility Criteria discussed in this document and summarized in the associated Grids and Storage Criteria document.

- Electrical grid networks:
    - Transmission and distribution lines
    - Transformers and conductors
    - Interconnectors
    - Control, monitoring and communication systems and software
- Battery, compressed air and capacitor storage
- Dedicated infrastructure such as equipment housing infrastructure

3.3 Assets out of Scope

Pumped Hydropower Storage is out of scope of these criteria. Such assets and activities fall under the scope of the Climate Bonds Standard Hydropower Criteria.

Hydrogen storage is not within the scope of these Criteria. While hydrogen can act as an electricity storage medium, it has many other applications and is expected to play a crucial role in decarbonisation of multiple sectors, including industry and transport. Climate Bonds Initiative acknowledge the diverse role that Hydrogen can play and will therefore develop a comprehensive set of criteria to address Hydrogen in future.

4 Discussion and Eligibility Criteria

4.1 Overarching considerations

The purpose of the Grids and Storage Criteria, like all Sector Criteria developed for the Climate Bonds Standard & Certification Scheme, is to certify assets and projects that are aligned with a low carbon economy and are climate resilient. Overarching principles and considerations for alignment with these objectives apply to all Grids and Storage applications in scope and are discussed in this section.

4.1.1 The overarching principles of the Grids and Storage Criteria

The overarching objectives of the Grids and Storage Criteria are as follows:

- Support the integration of renewable energy into the power grid
- Support the transition from carbon-intensive energy supply, via electrification and parallel development of low carbon power generation capacity
- Support grid management technology used for integrating low carbon emission generation and demand side energy savings
- Decrease direct emissions from transmission and distribution (T&D) infrastructure

Electrical grids have limited direct emissions impact. However, they are a key enabler of increased penetration of renewable energy into a wide variety of energy end uses. The general principle applied in developing the Grids and Storage Criteria is that electrification can greatly contribute to climate change mitigation and therefore that investment in transmission and distribution infrastructure is to be encouraged. The criteria are therefore designed to be inclusive, such that the majority of investments in modern grid infrastructure, including associated control systems, are eligible. The exclusions to this are if the investment is directly financing infrastructure that increases the capacity of high carbon intensity electricity production plants connected to the system, where high carbon intensity is defined as generation that exceeds a certain threshold level, or if the grid system as a whole does not demonstrate an adequate rate of decarbonisation.

The same overarching principles are applied to electricity storage, in terms of supporting integration of renewable energy, supporting transition from carbon intensive energy supply via electrification and supporting grid management technology used for integrating low carbon generation and demand side energy savings.

Storage can increase carbon emissions in electricity systems.[39],[40] The efficiency loss in electrical storage systems results in an increased requirement for generation to meet demand (unless the electricity stored would have otherwise been curtailed). If the additional generation results in greater emissions than displaced by the discharged electricity, then emissions will be increased. If the storage is used for arbitrage and is charged by more carbon intensive electricity than the electricity that is displaced when the storage is discharged, then emissions will also be increased.

Storage can however increase the integration of low carbon energy generation into electricity systems and, as the capacity of renewable generation connected to an electricity system increases with associated increased curtailment, storage can be expected to reduce emissions. Hence, the overarching principle adopted to storage is that if the storage is deployed within a grid that is decarbonising, as defined within the Grids and Storage Criteria, then the storage deployed within that system is also eligible.

39 https://pubs.acs.org/doi/abs/10.1021/es505027p
40 https://www.nature.com/articles/nenergy20171.epdf?sharing_token=ABC-sfxS_si1qioORuWP09RgN0jAjWel9jnR3ZoTv0PZncHjYV6mdy8s1m8MlS8Q6iSBxwzscJTnHo0ustfXYEdKYZAdxtcfCIju9HpK-sBn74YVf7M760kXn2Fi1elK35plmG_RRuFy5NF32Aah5zTSYaRZn5Yz-zwTkyWGu89g6uQrKz6ymV5-t33ptT3jE3H9AD2rDt2OR1czM5kALA%3D%3D&tracking_referrer=www.vox.com

4.2 Definitions and key terms

System
The term System is used in this section to reference the transmission or distribution network control area of the network or system operator(s) where the discussed activity takes place.

Direct connection or expansion
A direct connection or expansion of an existing direct connection to production plants includes infrastructure that is indispensable to carry the associated electricity from the power generating facility to a substation or network.

4.3 Leveraging existing best practice standards

In all Climate Bonds Standard Sector Criteria, the aim is to leverage existing schemes and initiatives that are in use in the sector in question. This is because:

- Significant industry effort has already gone towards designing and implementing these schemes
- Many have been through multi-stakeholder development processes and periods of public consultation
- It is very likely that some established schemes and initiatives check similar requirements to those that the Climate Bonds Standard Grid Criteria require are fulfilled

The EU taxonomy[41] was identified as a key industry best practice certification body to be leveraged by the Grids and Storage criteria. The EU taxonomy define specific Mitigation Criteria for Transmission and Distribution of Electricity and for Storage of Electricity. After careful consideration, the TWG decided to adopt the EU taxonomy as the Climate Bonds Criteria for Grids, and to adapt the Transmission and Distribution Mitigation Criteria as the basis for the Climate Bonds Storage Criteria. A detailed discussion on the assessment of options can be found in the following section.

4.4 Eligibility criteria for Mitigation – assessment of options

The Climate Bonds eligibility criteria for Grids and Storage should align with the overarching principles and support a transition from carbon-intensive energy supply to a low-carbon future. Since grids have limited direct emissions impact, the Grids and Storage Criteria should define eligible grids as those that either have a high proportion of renewable generation connected to it already, are on a trajectory to, or have the ambition to adopt more low-carbon generation. This should avoid setting overly stringent constraints as investment in T&D infrastructure is to be encouraged in general.

In line with the aim to leverage existing work as far as possible, the EU taxonomy was considered as a baseline for the development of eligibility criteria. The TWG identified shortcomings of the EU taxonomy and several possible routes were explored that involved either new alternative methodologies or changes to the EU taxonomy to solve some of the issues identified. However, the conclusion was that none of these alternative options represented a clear improvement to the EU taxonomy. Reasons for this varied, either being impractical, overly stringent, or not robust. These alternatives and reasons are discussed below.

4.4.1 Adopting the EU taxonomy Criteria for the Transmission and Distribution of Electricity

The underlying philosophy of the EU taxonomy is that the electrification of assets and sectors is crucial to meeting Paris Goals of keeping global warming to 1.5-degrees Celsius. The grid is the key enabler of this[42] and therefore generally can be

41 https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en
42 https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/energy-resources/deloitte-ch-en-eurelectric-connecting-the-dots-study.pdf

seen favourably in terms of its role in decarbonisation[43]. At the same time, grid investment has fallen in recent years[44],[45]. Some grid infrastructure can be up to 50 years old[46]. This ageing infrastructure is not sufficient to meet the challenges of increasing electrification and renewable energy generation, or to withstand future changes in climate.

The EU taxonomy's approach recognises that most grid infrastructure can be defined as green, though with notable exceptions. A list of automatically eligible activities describes pure-play green activities. Additional criteria then determine whether a system is on a pathway to full decarbonisation. If so, any grid investment in this system is eligible. These Criteria are as follows:

"A System is deemed to be on a trajectory to full decarbonisation if either

- *more than 67% of newly connected generation capacity in the System is below the generation threshold value of 100 gCO2e/kWh measured on a Product Carbon Footprint[47] (PCF) basis, over a rolling five-year period; or*
- *the average System grid emissions factor is below the threshold value of 100 gCO2e/kWh measured on a PCF basis, over a rolling five-year average period."*

This adds to the automatic exclusion of direct connections to plants with emission intensities of 100g CO2e/kWh or greater (in essence, fossil fuel power). The TWG therefore considered that these Criteria have the crucial elements which prevent certification of grid assets and activities which are likely not contributing to decarbonisation.

This system approach is a realistic and attainable threshold for many countries. However, it still screens out countries or Systems where changes to the energy system are clearly not aligned with Paris Goals.

The TWG recognised that the system approach does not provide certainty that a particular grid or system is on a trajectory to Paris alignment or approximately to net zero by 2050. However, the TWG considered that a system can be assumed to be on a pathway to decarbonisation if a large majority of added generation is clean (i.e. below a threshold emissions factor). Investment in these decarbonising grids will deliver further decarbonisation as energy end-uses increasingly electrify and will also facilitate increasing penetration of renewable generation in future.

The conclusion was to adopt the EU taxonomy criteria for the transmission and distribution of electricity.

The EU taxonomy list of automatically eligible assets

The EU taxonomy includes a list of activities that are always eligible, irrespective of whether the System is on a pathway to full decarbonisation. The TWG were in agreement that this list captured key activities that would be considered climate aligned but discussed some proposed additions to the list. These included activities dedicated to diminishing technical losses and/or improving the efficiency of grids, as well as avoidance of nontechnical losses. In all cases, the TWG emphasised the difficulty and ambiguity of determining if a standalone investment into these issues were beyond improvements expected from business-as-usual replacements. A threshold for efficiency improvements could be set, but such Criteria would not be robust as standards vary between countries.

The conclusion was to adopt the EU taxonomy whitelist of activities that are always eligible.

43 https://www.act.is/macro-forum-the-street-view/street-view-articles/grid-modernisation-a-key-enabler-for-energy-transition/
44 https://www.carbonbrief.org/iea-low-carbon-spending-must-more-than-double-to-meet-climate-goals
45 https://www.iea.org/reports/world-energy-investment-2020/power-sector?utm_content=buffer61c85&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer
46 https://www.greenbiz.com/article/time-right-rethink-grid
47 For electricity and heat generation activities, an ISO 14067 or a GHG Protocol Product Lifecycle Standard compliant Product Carbon Footprint (PCF) assessment including measurement of fugitive emissions is required.

4.4.2 Using historic grid factors and trajectories to determine system eligibility

A principle of Climate Bonds Criteria is that they align with the Paris Agreement. That is, they identify assets and activities aligned with a 1.5-degree warming scenario as set out by the IPCC. Hence, one option explored by the TWG would be to distinguish between those systems that are on a pathway to full decarbonisation from systems that are decarbonising more slowly. Such a feature would recognise how clean the system already is and how quickly it is decarbonising, to test alignment with the Paris agreement.

A proposed solution was to use a grid emissions factor as a metric to determine a grid's eligibility. The grid factor was defined as the CO2 emissions from coal, gas and oil associated with the generation of 1 kWh of electricity and heat, measured in gCO2/kWh. The IEA provided various data[48] including:

a) CO_2 emissions from electricity and heat by energy source (coal, oil, and gas), by year and by country
b) Total electricity and heat production, by year and by country
c) CO_2 intensity of power indices, by year and by country
d) Trajectories for the grid factor for certain regions and countries aligned with their Sustainable Development Scenario (SDS), which reflects a 1.5-degree warming scenario[49]

The proposed methodology used these data to determine a country's historic grid factor trajectory and extrapolate this to 2040. At the same time, a target trajectory was set for a country by using the same percentage target set by the IEA in their SDS (point d) for the World (83% reduction compared to 2019 values by 2040). If the country's trajectory was as ambitious as this trajectory, then the system would be determined to be Paris-aligned.

Several countries were tested against this methodology by considering their grid factor over the past 10 years and a linear extrapolation of that trajectory to 2040. Figure 2 demonstrates the eligibility of eight examples tested. Should a grid factor's actual rate-of-change exceed the target rate-of-change, the grid is deemed eligible. Of the eight examples shown in the figure, only three were eligible, the United Kingdom, Kenya, and Norway.

48 https://www.iea.org/data-and-statistics?country=CHINAREG&fuel=Energy%20supply&indicator=TPESbySource
49 https://www.iea.org/data-and-statistics/charts/carbon-intensity-of-electricity-generation-in-selected-regions-in-the-sustainable-development-scenario-2000-2040

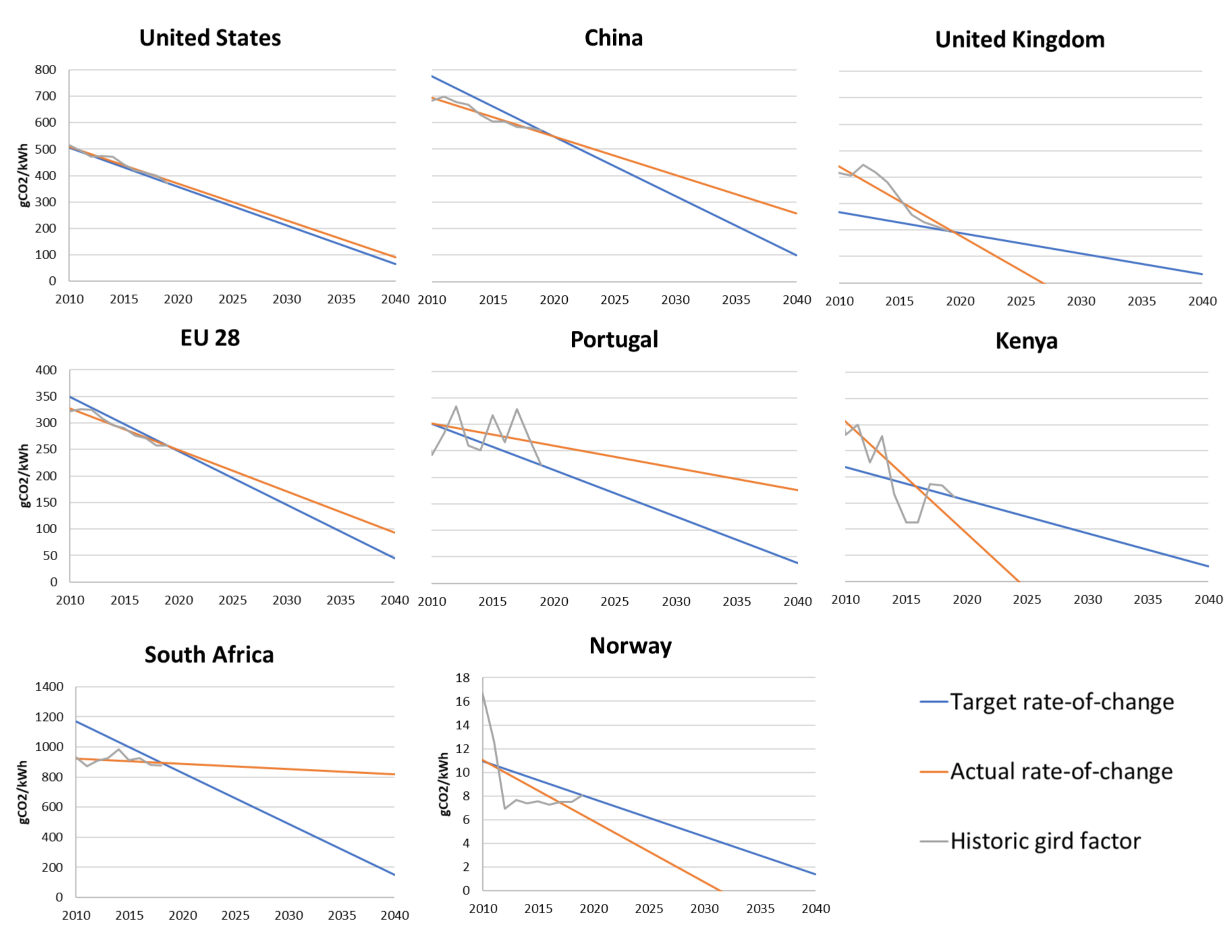

Figure 2: Testing of alternative criteria: Historic grid factors and trajectories to determine system eligibility. Three countries out of eight examples are eligible, i.e., the actual rate-of-change exceeds the target rate-of-change.

The TWG decided this was an unsuitable methodology to use for these Criteria for the following reasons:

- Overly stringent: the TWG were supportive of an approach which facilitates grids being generally eligible except for clear unacceptable cases. However, the reality is that many if not most national grid factors are not on the required pathway to Paris-aligned levels. This is down to a lack of added renewable energy capacity and existing higher carbon power infrastructure with higher capacity factors in places[50]. If few grids would meet the criteria, this would be contrary to the principle of being inclusive.
- Inaccurate projections of future grid emission factors: the TWG stressed that energy systems are experiencing a period of rapid and, crucially, unpredictable change[51,52]. The plummeting cost of renewable energy today[53] has meant that they are exceeding expectations from even 5 years ago. In other words, drawing a straight-line trajectory to 2040 using historic changes in grid factor would likely not be the trajectory of change witnessed. This goes the other way, too. As grids get cleaner, it becomes harder to lower the grid factor further. This is because the very high carbon plants such as coal, where decommissioning brings the greatest emissions savings, will have already been closed. After this, gas plant closures would bring smaller reductions due to their lower emissions compared to coal. Therefore, determining eligibility with such a methodology would not be robust.
- Lack of robust target: applying an 83% reduction target based on the IEA's world target trajectory would be an approximate target for other countries. The same IEA model shows that certain regions differ in their percentage change, with differing rates of change down to 2040.

[50] https://www.energy.gov/ne/articles/what-generation-capacity
[51] https://www.mpg.de/11825144/socio-technical-energy-systems
[52] https://www.iea.org/reports/world-energy-outlook-2020
[53] https://www.irena.org/newsroom/articles/2020/Jun/How-Falling-Costs-Make-Renewables-a-Cost-effective-Investment

4.4.3 Using the International Finance Institutions (IFI) methodology for grid factor

IFIs utilise a methodology[54] for determining a country grid factor for the purposes of then determining an individual project's impact on grid emissions. The rationale for consideration of this approach was that it provides open access and robust data, reliably sourced from the IEA and based on CDM methodologies.

Publicly available data provides the Operating Margin (OM) and Combined Margin (CM) for virtually all countries. The CM is calculated by combining the OM and the Build Margin (BM). The BM is not available publicly as it is sourced by the IFIs from proprietary IEA data. The OM represents the emissions factors of the most carbon intensive plants (usually coal) in the country, with the average taken from the years 2013 – 2015. The BM represents the average emissions factor of a grid between the years 2018 – 2025 based on the IEA's Stated Policies Scenario. The logic was thus that the OM provides some historic grid emissions data, while the BM defines how the emissions of the grid are changing over time out to 2025. In other words, there is a starting point and a rate of change (or a trajectory).

The TWG decided this was unsuitable for the following reasons:

- Not robust: OM is not representative of the entire emissions intensity of a country's energy system, being marginal power. It doesn't provide a full representation of the merit order and how the system as a whole develops. It is restricted by assumptions made based on capacity factors, when in reality this is also changing. Certain offshore wind farms have much higher capacity factors than previously seen[55]. In systems with high amounts of wind and solar power, marginal power becomes even more problematic.
- Lack of robust trajectory: the reality of using this approach to plot a trajectory similar to the methodology discussed in section **Error! Reference source not found.** means that the historic grid emissions (OM) will appear higher than the reality. Meanwhile, the CM would be more representative (and lower) and therefore result in a country's trajectory appearing steeper towards decarbonisation than is the case.

4.4.4 Using generation as a metric rather than capacity

The TWG were in strong agreement that capacity (in MW, for example) does not provide a full picture of an energy system. Fossil fuel power generally has higher capacity factors than renewable energy. In other words, an installed capacity of 100 MW of gas and 100 MW of wind energy does not mean there is equal generation of both – there will likely be more generation using gas which typically has a higher capacity factor.

With reference to the EU taxonomy, this means that 67% of added capacity being low carbon energy does not equal 67% of added generation being low carbon. A proposed solution was to consider added generation (for example MWh) rather than added capacity (MW).

The TWG determined that while these differences are important to note, the methodology was deemed unsuitable for a number of reasons:

- Overly stringent: due to the characteristics of generation vs capacity noted above, a system will be far less likely to meet a threshold based on generation. This would be the case if the same threshold was kept (67%). Therefore, fewer countries that need grid investment would likely meet these Criteria. The objective of inclusivity would therefore not be met.
- Difficulty in determining an alternative threshold: Determining a lower threshold also based on generation would make the threshold less stringent, but there is little precedent for what number could be chosen. Equally, choosing a lower threshold for this reason would essentially do the same thing as capacity – filter out the systems that are going in the wrong direction.
- Based on what was found in testing the EU taxonomy, capacity data is generally slightly more recent: there is a greater delay in data reporting for generation as opposed to capacity. In most cases, generation data from publicly

54 https://unfccc.int/climate-action/sectoral-engagement/ifis-harmonization-of-standards-for-ghg-accounting/ifi-twg-list-of-methodologies
55 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Oct/IRENA_Future_of_wind_2019.pdf

available sources is not present for the most recent two to three years. For capacity, on the other hand, there is still a delay but seemingly there is usually an additional recent year available. With the rapid change in capacities and generation being seen in many countries, this extra year of data could be crucial to a system being eligible. A country that might meet the criteria because its most recent year included a large increase in solar capacity, for example, would not meet the criteria if the data for that year were not available. The Criteria should aim to avoid unfairly penalising such systems.

4.4.5 Other criteria options discussed for Grids

All grid infrastructure as automatically eligible

As the TWG were supportive of an inclusive approach which generally recognises grid infrastructure and electrification as a green enabler, there were suggestions that this could even set all T&D infrastructure as eligible.

However, such Criteria would be weaker than the EU taxonomy and therefore would not meet the CBI principle of being best practice in the market. As such, the Criteria would need to be at least as strong if not stronger than the EU taxonomy.

Considering transmission and distribution separately

The TWG discussed considering transmission systems and distribution systems separately due to their different natures. Improvements on the distribution side are vital for the electrification of economies and it can be argued that such electrification will assist in the climate goals. On the other hand, the transmission network can either transport electricity generated from high-polluting fossil fuel power stations or electricity from renewable (or other low carbon) sources and could either be beneficial to the climate or not. Criteria were discussed that considered all distribution grid activities to be eligible but set some constraints on transmission grids.

While the TWG agreed that in some cases these sectors could be considered separately, such Criteria would be weaker than the EU taxonomy and therefore would not meet the CBI principle of being best practice in the market.

Considering national commitments to decarbonisation

Many of the options discussed for the Grids and Storage criteria included reference to past performance and some suggestions (such as that in Section **Error! Reference source not found.**) included future trajectories based on historic values. The TWG agreed that past performance is not necessarily an indicator for the future and therefore, an approach that considers national commitments to decarbonisation was discussed. Such Criteria would compare these commitments to specific targets to test alignment to the Paris agreement.

Such Criteria would not meet the CBI principle to rely on action not promises and was therefore deemed unsuitable by the TWG. Moreover, not many countries have such commitments and for that reason, such criteria would be unfair to grid operators in those countries that do not.

4.4.6 Criteria options discussed for Storage

In the EU taxonomy, all electricity storage activities are eligible with the rationale that electricity storage can support the integration of renewable energy systems into electricity grids, balance electricity generation, contribute to energy security, supplement demand response and flexible generation, complement grid development and contribute to the decarbonisation of other economic sectors. According to the EU taxonomy, all additional storage capacity should be beneficial to the EU climate mitigation objectives. While this may be true in theory, the TWG raised concerns over the climate impacts associated with the addition of storage to grids that are not yet fully decarbonised, where the deployment of energy storage can in fact increase emissions[56][57].

Instead of adopting the EU taxonomy for Electricity Storage, the TWG concluded to take a conservative approach, applying constraints to the storage activities that would be eligible under the Criteria. The resulting Criteria are based on the EU taxonomy for Transmission and Distribution grids, with the rationale that any electricity storage activity in a grid that is on a trajectory towards decarbonisation should be eligible, otherwise not.

4.5 Adaptation & Resilience Requirements

The IPCC defines adaptation as: *"The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects."* [58].

The IPCC defines resilience as: *"The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation."* Capacity for adaptation and for resilience will depend on available assets and their distribution within a population as well as institutional infrastructure.

The Climate Resilience Principles further offers the below definition to inspire investors and issuer engagement:
Climate resilience investments improve the ability of assets and systems to persist, adapt and/or transform in a timely, efficient, and fair manner that reduces risk, avoids maladaptation, unlocks development and creates benefits, including for the public good, against the increasing prevalence and severity of climate-related stresses and shocks.

To meet the requirements for Climate Bonds Certification, bond issuers must demonstrate that they have consider the climate risks associated with their investment over the operational lifetime of the assets, taken appropriate measures to mitigate those risks in the face of the uncertain impacts of climate change and have assessed the resilience benefits that the investment can provide to the wider system. Furthermore, the assessment should demonstrate that the investment will maximise climate resilience benefits to the system itself.

Specifically, issuers must demonstrate that for the assets and activities finance via the bond they:

- Understand the climate risks faced by the asset, activity or system in question;
- Have addressed those risks by undertaking risk-reduction measures and adopting flexible management plans that take account of inherent uncertainties around climate change, ensuring that the asset, activity or system is robust, flexible and fit-for-purpose in the face of that uncertainty;
- Can deliver resilience benefits over and above addressing identified risks (for system-focused investments); and
- Are undertaking regular (re)evaluation of the asset and/or system's climate resilience performance, adjusting to risk reduction measures over time as needed.

4.5.1 Adaptation & Resilience in grids and storage

Grids and storage will need to adapt and be resilient to climate change to ensure stable provision of electricity to different facets of society into the future. Climate is a major factor affecting the smooth running of transmission and distribution

56 Hittinger and Azevedo (2015). Bulk energy storage increases United States electricity system emissions.
57 Arciniegas and Hittinger (2018). Tradeoffs between revenue and emissions in energy storage operation.
58 Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability.Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field CB et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32. http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf

infrastructure, with temperature highly affecting the efficiency of electricity transfer. Equally, T&D infrastructure is highly susceptible to storm events.

Climate risks

Climate Bond Standard Sector Criteria focus on resilience to physical climate risks. Climate-related risks[59] can be expressed as the probability of a climate hazard occurring, i.e. the variability or uncertainty of an expected outcome. Climate hazards vary in terms of severity and frequency and include both chronic (associated with long-term shifts in climate patterns, such as rising sea levels from higher temperatures) and acute (event-driven, such as extreme weather events).[60]

Investments particularly susceptible to climate risk are those with[61]:
• long-lived, fixed assets;
• locations or operations in climate-sensitive regions (e.g., coastal and flood zones);
• reliance on availability of water; and
• value chains exposed to the above.

The Climate Resilience Principles provide the definitive minimum list of physical climate hazards to be considered for the Grids and Storage Criteria (Table 6).[62]

59 See also the general classification of climate risks by European Bank for Reconstruction & Development (EBRD) and Global Centre on Adaptation (GCA). "Advancing TCFD Guidance on Physical Climate Risk and Opportunities". 2018. https://s3.eu-west2.amazonaws.com/ebrd-gceca/EBRD-GCECA_draft_final_report_full_2.pdf
60 Climate Resilience Principles: A framework for assessing climate resilience investments. Climate Bonds Initiative. https://www.climatebonds.net/files/files/climate-resilience-principles-climate-bonds-initiative-20190917.pdf
61 https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-2017-TCFD-Report-11052018.pdf
62 https://ec.europa.eu/info/sites/info/files/business_economy_euro/banking_and_finance/documents/190618-sustainable-finance-tegreport- taxonomy_en.pdf and https://www.climatebonds.net/files/files/climate-resilience-principles-climate-bonds-initiative-20190917.pdf

Table 6. Classification of climate-related hazards

	Changes in climate patterns and in the frequency/severity of climate-related events that are:			
	Temperature-related	Wind-related	Water-related	Solid mass-related
CHRONIC	Changing temperature (air, fresh water, marine water)	Changing wind patterns	Changing precipitation patterns and types (rain, hail, snow/ice)	Coastal erosion
	Heat stress		Precipitation and/or hydrological variability	Soil degradation
	Temperature variability		Ocean acidification	Soil erosion
	Permafrost thawing		Saline intrusion	Solifluction
			Sea level rise	
			Water stress	
ACUTE	Heat wave	Cyclone, hurricane, typhoon	Drought	Avalanche
	Cold wave/frost	Storm (including blizzards, dust and sandstorms)	Heavy precipitation (rain, hail, snow/ice)	Landslide
	Wildfire	Tornado	Flood (coastal, fluvial, pluvial, ground water)[42]	Subsidence
			Glacial outburst[43]	

4.5.2 Climate risk and resilience evaluation tools and methodologies

No standard methodologies or tools for climate risk assessment and evaluation of resilience measures that are specific to electricity grids and storage have been identified. There are a range of global climate models that simulate key aspects of the Earth's climate and make predictions of likely outcomes, for example in terms of temperature change, under different emissions scenarios[63]. These models, some of which provide predictions at reasonably high spatial resolution, could be used to provide predictions of the increase in average and extreme temperatures to feed into climate impact assessments. For example, in the UK, National Grid (the transmission network operator) used future climate scenario projections produced by the UK Met Office (UKCP09[64]) to feed into their assessment of climate risks to the UK transmission system and reporting to government[65].

In the absence of specific methodologies for the assessment of climate change risk & resilience impacts and benefits related to assets and activities in the Grids and Electricity Storage sector, bond issuers may wish to explore the use of more

63 Hayhoe et al., Climate Models, Scenarios, and Projections, in CLIMATE SCIENCE SPECIAL REPORT: FOURTH NATIONAL CLIMATE ASSESSMENT, VOLUME I 133, 134 (D.J. Wuebbles et al., eds., 2017), https://perma.cc/HB9P-F8EL.
64 UKCP09: Land and marine past climate and future scenario projections data for the UK, Centre for Environmental Data Analysis, data.gov.uk/dataset/fd2b1c2d-3156-4eed-98c1-12155878cdc2/ukcp09-land-and-marine-past-climate-and-future-scenario-projections-data-for-the-uk
65 National Grid, 2016, Climate Change Adaptation Reporting: Second Round Response

generalised climate risk assessment tools, such as those provided in the Climate Bond Initiative Climate Resilience Principles (CRP) Technical Annex[66].

Box 1. Optional Guidance for item 2 in the checklist: Key physical climate hazards assessment.

- Users can choose to apply climate scenarios based on representative concentration pathway (RCP) 4.5 and 8.5 or similar scenarios to ensure consideration for worst case scenario.
- A broad range of models can be used to generate climate scenarios.
- Time horizons for assessing climate risk in grids can be based on annual seasonal forecasts and every ten years for the lifetime of the assets and projects. Where accurate assessments of climate variability for specific locations are not possible, use worst-case scenarios.
- Risks can be characterized by the associated annual probability of failure or annual costs of loss or damage.
- For risk assessment, the TCFD The Use of Scenario Analysis in Disclosure of Climate Related Risks and Opportunities is recommended.

Resources for carrying out a risk assessment:

Platforms
- EU Climate Adapt and GRaBS Assessment Tool
- World Bank Climate Change Knowledge Portal

Tools and frameworks
- Climate Change in Los Angeles County: Grid Vulnerability to Extreme Heat[66]
- USAID Climate Risk Screening and Management Tools
- African Development Bank Climate screening and adaptation review and evaluation procedures
- CEDRIG tool (Climate, Environment and Disaster Risk Reduction Integration Guidance) of the Swiss Development Corporation
- WWF Water risk filter
- WRI Aqueduct atlas
- WBCSD Water tool
- SASB Good practice standards

Climate data
- IRI Climate Data Library
- Global Circulation Model GCM) Downscaled Data Portal: http://ccafsclimate.org/data_spatial_downscaling/
- MarkSim GCM, http://gismap.ciat.cgiar.org/MarkSimGCM/, which can provide characteristic daily data for current or future conditions (using Coupled Model Intercomparison Project Phase 5 (CMIP5) GCM data) by pointing and clicking on the map and choosing the GHG scenario/model/year.
- IPCC Working Group 1 is producing an online atlas. Until that is available the CIAT climate Wizard is a resource, although it uses older CMIP3 data.

66 https://www.climatebonds.net/files/files/CBI%20Climate%20Resilience%20Principles%20-%20Technical%20Annex.pdf

Box 2. Optional guidance for item 4 in the checklist: Monitoring and evaluation in Adaptation and Resilience Checklist for grid and storage infrastructure.

Resources for indicators of climate risks include: Papic et al. (2020).

Resources for monitoring and evaluation of adaptation include

- Monitoring and Evaluation Framework, NAMA (Nationally Appropriate Mitigation Action) Facility www.nama-facility.org/fileadmin/user_upload/publications/documents/2018-11_doc_nama-facility_me-framework.pdf. Guidance for NAMA Support Projects funded by the NAMA facility for formative evaluation for relevance, efficiency, effectiveness, sustainability and impact.
- Making Adaptation Count: Concepts and options for monitoring and evaluation of climate change adaptation www.wri.org/publication/making-adaptation-count. Report providing a theory-of-change-based and "learning by doing" framework for tracking adaptation achievements and setbacks for projects with development objectives.
- Sendai Framework for Disaster Risk reduction.

67 Climate Change in Los Angeles County: Grid Vulnerability to Extreme Heat

Appendix 1: Technical Working Group members

Members of the Grids Technical Working Group

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- John Sinner, Independent, formerly of the European Investment Bank (EIB)
- Mark Barrett, University College London (UCL)
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Appendix 2: Industry Working Group members

Members of the Grids Industry Working Group

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- Enno Dykmann, Alliander (The Netherlands)
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