Bioenergy Criteria

Background document

Draft for public review

Revision	Date	Summary of Changes
2	10 November 2025	Provisions for new default methane values for standard and best-practice scenarios to be included in LCA GHG calculations. A feedstock-agnostic approach was introduced for eligible biomass based on robust sustainability requirements. The sustainability criterion for the biomass feedstock has been split from the adaptation and resilience requirement for the sake of clarity. Inclusion of facilities for electricity generation from biomass withing the scope of the criteria. Establishment of a temporal trajectory for GHG emission savings, reaching close to 0 in 2050. Clarification of the definition given for aligned product/asset, biomass, biomass-based fuel, bioenergy, eligible project/asset, certified project/asset, bioenergy biomass-based fuel, intermediate biomass energy product.
1.3	1 August 2022	Clarification that Bioenergy ‘Storage’ is within the scope as supporting infrastructure – i.e., providing the Bioenergy meets the overarching criteria (with Storage included in LCAs). Addition of Supporting Infrastructure section (section 3.4) which was previously absent
1.2	23 March 2021	Feedstock certification best practise standards list updated to included CBI Agriculture criteria following analysis that it meets requirements in Appendix 2. Removal of indication that a part 2 might be developed (that could have been for woody biomass feedstocks). This will not now be done.
1.1	28 July 2020	Issue for Public Consultation Swap ‘bioenergy’ to ‘electricity’ in table 2.
1	July 2019	Publication of first criteria

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Definitions

Adaptation and Resilience Criteria: Rules or principles for evaluating and preventing physical climate risk and assessing the vulnerability of an asset or entities to the effects of climate changes, which aim to reduce of this vulnerability. These rules generally guarantee that the activities don't do any significant harm to other assets within their system boundaries which covers the area affected by the activity.

Aligned product/asset: A product/asset that meet the different requirements developed in the criteria.

Applicant: The term or name for any potential bond issuer, or non-financial corporate entity, that might seek certification under the Electrical Utilities Criteria.

Bioenergy: renewable energy derived from biomass.[1]

Bioenergy product: a product that provides energy derived from biomass, including electricity, heat, cooling and biomass-based fuels in solid, liquid, or gaseous form.

Biomass: material of biological origin, excluding material embedded in geological formations and transformed into fossil.[2]

Biomass-based fuel: consumable products derived from raw biomass that can be used in a variety of energy applications, such as electricity generation, heat and cooling production, and transportation. Biomass-based fuels can be solid, liquid, and gaseous (see Annex 1 for non-exhaustive list).

Certified project/asset: An eligible project/asset that has demonstrated compliance with the specific requirements set out in the criteria (Table 1) and therefore has been approved for certification.

Certified entity: The entity or part thereof which is being certified under the Climate Bonds Standard. Currently, entity Certification is limited to non-financial entities or segregated segments thereof, for which the Climate Bonds Initiative has Climate Bonds Standard Sector Criteria for entity Certification.

Climate Bond Certification: allows the applicant to use the Climate Bond Certification mark in relation to that bond. Climate Bond Certification is provided once the independent CBSB is satisfied the bond complies with the CBS.

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

Climate Bonds Standard (CBS): A screening tool for investors and governments that allows them to identify green bonds, the proceeds of which 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 (CBS v4.0) 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 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 CBS, including the adoption of additional sector Criteria, (ii) Approved verifiers, and (iii) Applications for Certification of a bond under the CBS. The CBSB is constituted, appointed, and supported in line with the governance arrangements and processes as published on the Climate Bonds website.

Climate change: A change in global or regional climate patterns attributed to the increased levels of CO_2 in the atmosphere, produced mainly by the combustion of fossil fuels.

Climate goals: Objectives that aim to reduce GHG emissions to limit the global temperature increase to 2.0-degree or even 1.5-degrees above pre-industrial levels.

[1] International Energy Agency (IEA).
[2] Food and Agriculture Organization of the United Nations (FAO).

Climate mitigation performance targets: The performance targets that define the measurable climate mitigation performance to be achieved.

Climate resilience and adaptation: Measures or assessments related to protecting communities or ecosystems from the effects of climate change. Adaptation refers to protection, while resilience is the ability to adapt and recover from the impacts of climate change.

Climate targets: Limits established by scientists and policymakers in plans to combat climate change.

CO_2 equivalent: A unit to measure the effect of all greenhouse gases according to their global warming potential that expresses the warming effect of each greenhouse gas over a set period of time (usually 100 years) in comparison to CO_2. Thus, an amount of a GHG can be expressed by the amount of CO_2 that will have the equivalent warming effect over 100 years.

CO_2 geological storage: The process of keeping CO_2 in underground geologic formations, usually pressurising the carbon dioxide until it becomes a liquid.

Critical interdependencies: The asset or activity's boundaries and interdependencies with surrounding infrastructure systems. Interdependencies are specific to local context but are often connected to wider systems through complex relationships that depend on factors 'outside the asset fence' that could cause cascading failures or contribute to collateral system benefits.

Decarbonisation pathways: Transformation processes, strategies, or indications to be implemented in the energy sector aiming to reduce emissions and the use of fossil fuels. They involve measures such as shifting the energy mix, increasing energy efficiency, utilising the circular economy, or managing demand for energy.

Decarbonise: Move away from energy systems that produce carbon dioxide and other greenhouse gas emissions and remove the amount of carbon gaseous compounds in the atmosphere.

Eligible project/asset: Project/assets within the scope of these criteria (section 1.3).

Emission intensity: Volume of emissions per unit of a representative factor in the assessed sector, which in the bioenergy sector is MJ generated, so the emissions intensity is the grams of CO_2 eq per MJ: gCO_2e/MJ.

Emissions target: Limits that scientists set for the quantity of emissions to be aligned with the Paris Climate Agreement.

Fossil gas: It is a hydrocarbon fuel mostly composed by methane produced from the decay of organic material over millions of years.

Green bond: A bond where the proceeds are allocated to environmental projects or expenditures. 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 or expenditures, but in practice they have generally been earmarked for climate change projects.

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

Intermediate Biomass Energy Products: Semi-processed biomass-derived energy carriers that have undergone an initial conversion, pre-treatment, or upgrading step, but require further processing or refining before becoming final biomass-based fuels. Typical examples are biomass-derived oils from pyrolysis or hydrothermal liquefaction, solid bio-intermediates such as torrefied biomass, intermediate alcohols or syngas.

Investment period: The interval between the bond's issuance and its maturity date; otherwise known as the bond tenor.

Life-cycle emissions analysis (LCA): A methodology for assessing or accounting for environmental emissions associated with all the stages of the life cycle of a product or process, from the initial design phase to disposal or recycling.

Mitigation Criteria: Rules and principles containing thresholds, benchmarks, and milestones for sector activities whose objective is the reduction of the harmful effects of greenhouse gases emissions.

Mitigation technologies: Actions within technological processes implemented to reduce and curb greenhouse gas emissions.

Negative emissions: Processes in which more CO_2 is removed and stored from the atmosphere than added to it, so the final GHG emissions balance is negative. It can be achieved by natural processes or a variety of technological solutions. Negative emissions are necessary to meet the Paris Agreement.

Net-zero emissions: A situation where global greenhouse gas emissions from human activity are in balance with emissions reductions. To achieve this situation, human-caused emissions should be reduced as close to zero as possible.

Net-zero targets: Global policy instruments for international GHG reductions to achieve net zero emissions.

Non-fossil renewable gaseous and liquid fuels: Fuels produced using energy from other renewable energy sources.

Offsetting: A climate action that enables organizations to compensate for the emissions they put into the atmosphere, by supporting worthy projects that reduce emissions in other regions of the world.

Parent company/group: A company is considered a parent company of another entity (a subsidiary) if it exercises control over the subsidiary. The terms control and subsidiary have the meaning assigned to them under International Financial Reporting Standard 10 (IFRS 10). A parent group consists of the parent company and all the companies that the parent company exercises control over. Where the applicant does not belong to a group of companies, the term parent company applies to the applicant.

Paris Agreement: A legally binding international treaty on climate change adopted by 196 parties. Its overarching goal is to hold the increase in the global average temperature to well below 2-degrees above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5-degrees above pre-industrial levels.

Pathways: Science-based trajectories for different sectors indicating the way to achieve targets related to relevant indicators. In the bioenergy sector, these trajectories generally refer to the emission intensity.

Scope of emissions: Scope 1, 2 and 3 are terms devised by the GHG Protocol to categorise the different sources of carbon emissions an organisation creates in its own operations, and in its wider value chain.

Standards Criteria: Established principles to evaluate processes, assets, or entities aiming to achieve benchmarks, targets, or goals.

Sustainability-linked debt (SLD): Any debt instrument for which the financial and structural characteristics can vary depending on whether the issuer achieves predefined sustainability/ESG objectives. Such objectives are measured through predefined key performance indicators (KPIs) and assessed against predefined performance targets. Proceeds of SLD are intended to be used for general purposes.

Technical Working Group (TWG): A group of recognised experts from academia, international agencies, industry, and NGOs convened by Climate Bonds. The TWG develops the Sector Criteria, which are 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 (see below) and through public consultation. Final approval of Sector Criteria is given by the CBSB.

Transition targets: Thresholds, benchmarks, and milestones based on key assumptions and dependencies used by scientists and policymakers to develop a plan to achieve climate targets.

1 Introduction

1.1 Overview

This document serves as a reference document to the Criteria Document for Bioenergy. The purpose of this document is to provide an overview of the key considerations and issues that were raised during the development of the Bioenergy Criteria and provide the rationale for why requirements were chosen and set.

The Criteria were developed through a consultative process with Technical Working Groups (TWG) and Industry Working Groups (IWG), and thorough Public Consultation. The TWGs comprised academic and research institutions, civil society organizations, and specialist consultancies whereas IGWs are represented by industry experts including potential bond issuers and investors. A 60-days 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 Bioenergy Criteria.

Supplementary information will be made available in addition to this document, including:

Information to support issuers and verifiers is available at Bioenergy Criteria / Climate Bonds Initiative as follows:

- *Bioenergy Criteria. Applying for recognition as an approved proxy*
- *Bioenergy Criteria Frequently Asked Questions* (FAQs)
- *Bioenergy Criteria Public Consultation Feedback and Responses Summary*
- The Climate Bonds Standard contains the requirements of the overarching CBS
- The Climate Bonds Standard v4.3 Entity and Sustainability-Linked Debt Checklist documents provide further information on the cross-sectoral requirements for entity and SLD Certification respectively.

For more information on Climate Bonds and the Climate Bonds Standard and Certification Scheme, see www.climatebonds.net

1.2 The role of bioenergy in the goals of Paris Agreement.

The current trajectory of climate change, expected to lead to ag lobal warming of 2.2-3.4 by 2100[3]. According to Climate Change Tracker as of June 2025, there are 30 gigatonnes of remaining CO_2 budget and this budget would be exhausted in 2025.[4] The effects of climate change and the risk associated with the global warming are evident: 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.

Greenhouse gas emissions from the energy sector accounts for 76% of total greenhouse gas emissions[5] in 2022. In 2023, the Bioenergy sector accounts for up to 0,7 % of global CO_2 emissions[6] and up to of 2,7 % of total methane emissions, see 7,9 % of methane emissions associated to the energy sector[7].

Although bioenergy sector is not one the main sources of direct greenhouse gas emissions, bioenergy will have an important role in the clean energy transition and in the substitution of fossil fuels. Most scenarios aligned with the goals in the Paris Climate agreement indicate a bioenergy share between 15% and 25% in overall primary energy use in 2050. Bioenergy is called to be a leaver to decarbonise other hight emitting activities and a sink to offset emissions from other sectors.

Bioenergy will play an important role in the transition to a sustainable future for two main reasons:

1. Use of bioenergy will be important in hard to abate sectors as long-distance heavy-duty land transport, shipping and aviation. In addition, biomass for electricity can support the expansion of intermittent renewables such as solar PV and wind, main leavers for the decarbonization of the energy sector and consequently, other sector of the economy. Bioenergy

[3] Climate Action Tracker. Warming Projections Global Update. November 2024
[4] Climate Change Tracker.
[5] Climate Watch. Historical GHG emissions
[6] IEA World Energy Outlook 2024
[7] IEA Global Methane Tracker 2024

supply will increase up to 100 EJ in 2050 according to the IEA8, an increase of around 60% from the 60/70 EJ currently bioenergy supply.

2. Bioenergy combined with carbon capture and storage (BECCS), will contribute to the Net Zero future with negative emissions. Negative emissions will provide a pathway to offset residual emissions from hard-to-abate sectors, including agriculture.

However, bioenergy can have also a negative impact if not well addressed. Bioenergy development may potentially cause serious environmental alterations, not only related to greenhouse gas emissions but also affect water quality, biodiversity, soil organic carbon, food security, etc… In any analysis of bioenergy climate impacts, it is key to take a broad enough system boundary and to consider a credible reference system.

Thus, all these reasons underline the need of an assessment for a correct use of bioenergy and direct investments to sustainable bioenergy projects.

1.3 The role of bonds

Traditional sources of capital for infrastructure investment (government and commercial banks) are insufficient to meet these capital needs; institutional investors, particularly pension and sovereign wealth funds, are increasingly looked to as viable actors to fill these financial 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).

Binds financing works well for low-carbon and carbon-resilient infrastructure projects post-construction, as bonds are often used as refinancing instruments. Labelled Green Bonds are bonds with proceeds used for green projects, mostly climate change mitigation and/or adaptation projects, and labelled accordingly. The labelled growth of the green bond market has shown in practice that the bond markets can provide channel to finance climate investments.

The Green Bond market can reward bond issuers and investors for sustainable investments that accelerate process towards a low-carbon and climate-resilience economy. Commonly used as long-term debt instruments, Green Bonds are issued by governments, companies, municipalities, and commercial and development banks to finance or re-finance assets or activities with environmental benefits. Green Bonds are regular bonds with one distinguishing feature: proceeds are earmarked for projects with environmental benefits. Green Bonds are in high demand and can help issuers attract new type of investors.

A green label is a discovery mechanism for investors. If enables the identification of climate-aligned investments even with limited resources for due diligence. By doing so, a green bond reduce friction in the market and facilitates growth in climate-aligned investments.

Currently, Green Bonds only account for less than 0.4%[9] of a global bond market of USD187.8 trillion[10]. The potential for scaling up is tremendous. The market now needs to grow much bigger, and quickly.

1.4 Introduction of the Climate Bonds Standards (CBS)

Activating the mainstream debt capital markets to finance and refinance climate friendly 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 paly 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 credential is limited. Therefore, Climate Bonds created the Climate Bonds Standard & Certification Scheme, which aims to provide the Green Bond market with the trust and assurance to achieve the required scale.

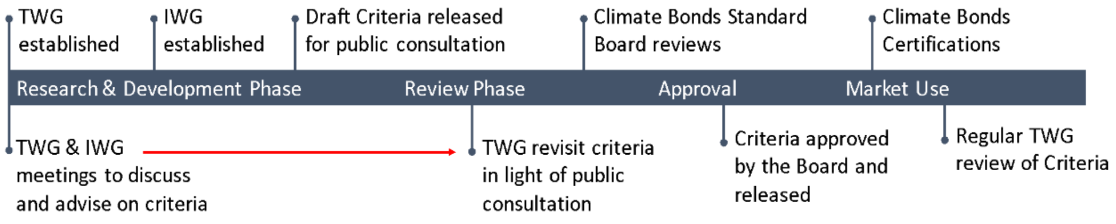
[8] IEA Net Zero Emissions for 2050 roadmap
[9] Green Bonds issued in 2024: 799.8 USD billions. Climate Bonds Initiative
[10] London Stock Exchange Group. The size of global markets in chart. 2024

The Climate Bonds Standard and 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 CBS detailing management and reporting process, and a set of a Sector Criteria detailing the requirements assets must meet to be eligible for certification. The Sector Criteria covers a range of sectors including solar energy, wind energy marine renewable energy, geothermal power, low carbon buildings, low carbon transport, water infrastructure, steel production, hydrogen production and delivery, forestry, agriculture, waste management, electrical utilities, geothermal power, electricity grids and storage…. The Certification Scheme requires issuers to obtain independent verification, pre- and post-issuance, to ensure the bond meets the requirement of the CBS.

1.5 Process for sector Criteria Development

The CBS has been developed based on public consultation, road testing, and review by the Assurance RoundTable (A group of verifiers) and expert support from experienced green bond market participants.

Figure 1. Criteria development process



Source: Climate Bonds Initiative

The standard is revisited and amended on annual basis in response to the growing climate aligned financed market. Sector Specific criteria are developed by TWG made of scientists, engineers, and technical specialists. Draft Criteria are presented to IWG before being released for public comment. Finally, Criteria are presented to the Climate Bonds Standard Board (CBSB) for approval (see diagram above, Figure 1)

Bioenergy-specific information to support applicants and verifiers is available at Bioenergy Climate Bonds Initiative as follows:

- *Bioenergy Background Paper* detailing how the criteria were chosen,
- *Bioenergy Frequently Asked Questions* (FAQs),
- *Bioenergy Criteria Public Consultation Feedback and Responses Summary.*

In addition, the following cross-cutting information to support applicants and verifiers is available as follows:

- The Climate Bonds Standard contains the requirements of the overarching CBS,
- The Climate Bonds Standard v4.3 Entity and Sustainability-Linked Debt Checklist documents provide further information on the cross-sectoral requirements for entity and SLD Certification respectively.

For more information on Climate Bonds and the Climate Bonds Standard and Certification Scheme, see www.climatebonds.net.

1.6 Structure of the document

The document support Bioenergy Criteria. It captures the issues raised and discussed by the TWG, as well as the arguments and evidence in support of the Criteria. It is structured as follows:

- Section 2: Detail information about the bioenergy sector that supports the scope of the criteria
- Section 3: Detail rationale for developing the mitigation criteria
- Section 4: Detail information for developing the adaptation and resilience criteria

2 Sector overview

2.1 The need for updating

Methane is a highly potent Greenhouse Gas, with a global warming potential of approx. 30-80 times that of CO2 over a 25–100-year period. Given the 2050 timeframe for net zero goals, special attention to Methane is warranted: the IEA estimates that rapid cuts in Methane emissions from fossil fuels can avoid up to 0.1 °C of global warming by mid-century. Across sectors, methane abatement finance has one of the highest ratios of global warming benefit per dollar of capital invested.

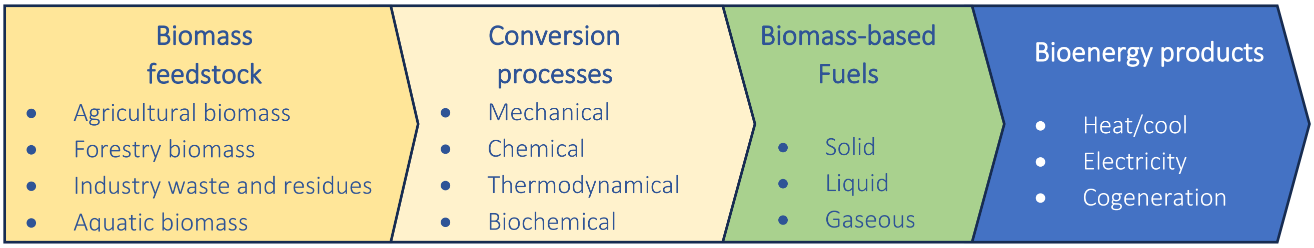
In recent years, traditional and labelled bonds, loans, and other debt instruments such as revolving credit facilities have been used as a channel used to fund abatement projects in various sectors: with the Energy sector historically seeing the largest share of Use of Proceeds. However, to date an extremely limited number of debt instruments and frameworks have made references to Methane abatement, which are both robust and actionable. A credible and practical framework for Methane abatement financing should be designed to deliver robust and real impacts to global warming, while creating a feasible ecosystem for the Issuers and Investors to participate. Guidance seeks to deliver actionable and credible methane abatement activities and targets, which should be considered best practices, agnostic of financing structure.

This new version of the Climate Bond Initiative's Bioenergy Criteria compiles best practices along biogas and biomethane value chain, promoting their implementation by linking them to the application of updated and mor accurate default values for methane emissions accounting.

2.2 Bioenergy products. Scope of the criteria.

Biomass is converted into bioenergy products through conversion processes. See Figure 2.

Figure 2. Bioenergy products production pathways.



Source: Climate Bonds Initiative based on IEA Bioenergy

Biomass is material of biological origin that can be used with different purposes. It can be used for energy purposes, converting the biomass source into biomass-based fuels and then, by burning these biomass-based fuels, energy can be obtained in the form of heat/cool and/or electricity or can directly burn in vehicle's engine to propel it.

Throughout this document a biomass-based fuel will be consumable products derived from raw biomass that can be used in a variety of energy applications, such as electricity generation, heat and cooling production, and transportation. Biomass-based fuels can be solid, liquid, and gaseous, see Table 1.

Table 1. Non-exhaustive list of bioenergy products.

Kind of biomass-based fuels	Examples
Solid biomass-based fuel	pellets, chips, briquettes, logs, and charcoal
Liquid biomass-based fuel	ethanol, biodiesel, renewable diesel and biojet fuel
Gaseous biomass-based fuel	biogas, biomethane and syngas

Bioenergy products will be a product that provides energy derived from biomass, including electricity, heat, cooling and biomass-based fuels in solid, liquid, or gaseous form.

According to the International Energy Agency (IEA), raw biomass is defined as organic material derived from plants and animals. See Table 2.

Table 2. Non-exhaustive list of biomass source[11]

Kind of biomass source for biomass-based fuels	Examples
Agriculture	Multipurpose crops, dedicated biomass crops, organic waste/residues from agriculture
Forestry	Woody biomass, organic waste/residues from forest and landscape management
Industry	Organic waste/residues from industry.

The following chapters will detail the stages of the bioenergy value chain, giving rationale for its inclusion in the criteria.

2.2.1 Biomass feedstock

A wide range of organic material can be used to produce bioenergy products, including crops, sawdust/wood shavings, forestry residues, firewood, low quality stem wood, post-consumer wood waste, green waste, food industry residues, organic municipal solid waste, sludge from wastewater treatment, manure, rice straw, perennial grasses, short rotation coppice…

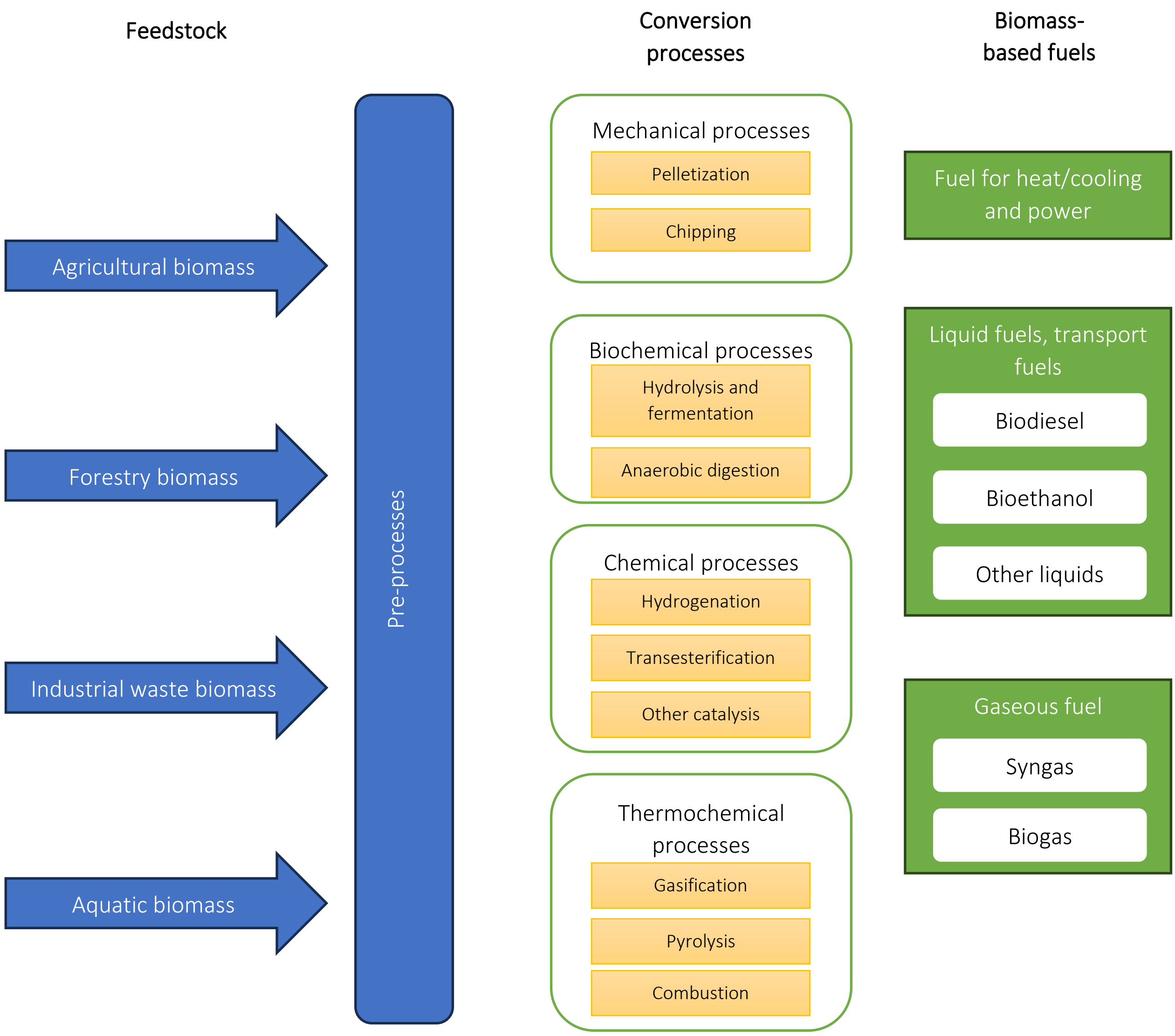
In the context of developing renewable biofuels technologies, biomass feedstock from algae is considered attractive feedstock with many advantages over traditional sources of biomass. Algae can be used to produce biomass-based fuels such as biodiesel, biomethane and bioethanol, among others. Algae are a promising renewable energy source due to their rapid growth rate, high photosynthetic efficiency, and ability to thrive in diverse environments. Algae can be cultivated in inland-ponds or in marine environments.

2.2.2 Biomass conversion processes

Conversion of organic matter to bioenergy products can be done through mechanical, chemical, thermochemical or biochemical processes. Traditional combustion of biomass is not considered in modern bioenergy. See Figure 3.

[11] IEA Bioenergy. Factsheet. What is bioenergy. November 2024

Figure 3. Biomass-based fuel production pathway



Source: Climate Bonds Initiative

2.2.3 Biomass-based fuels

Biomass-based products are usually drop-in fuels (mainly gaseous biomass-based fuels) that can be used in the existing assets without relevant modifications.

Biomass-based fuels for energy purposes are usually classified into three types – solid, liquid and gaseous.

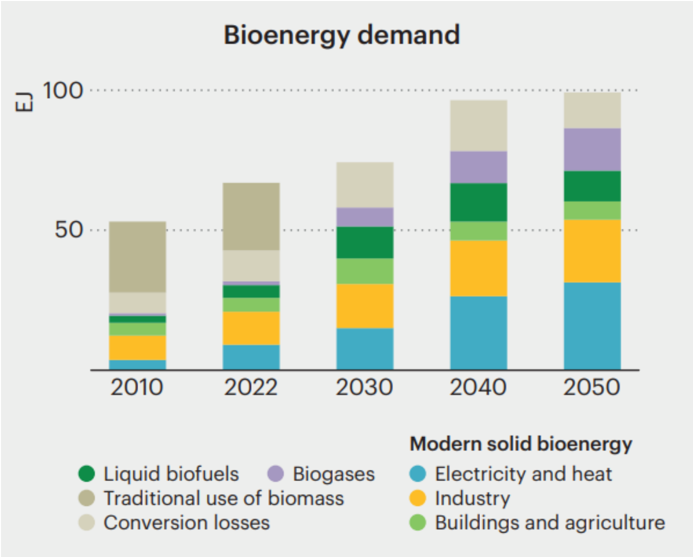
- Solid are typically produced from forest and landscape management residues, forest product manufacturing residues or agricultural residues. Solid biomass-based fuels can be used to generate heat in industry and buildings or to generate heat and/or electricity in power plants, combined heat and power (CHP) plants or district heating plants.
- Liquids are produced from agricultural energy crops, forest management and product manufacturing residues, agricultural residues and organic waste. Liquid biomass-based fuels are renewable alternatives for road; marine and aviation transport blended with liquid fossil fuels.
- Gaseous are produced from agricultural residues, organic waste and from forest management and product manufacturing residues. These biomass-based fuel can be used directly to generate heat and/or power. When upgraded it can also be injected into existing fossil gas pipelines or used by fossil gas vehicles.

2.2.4 Bioenergy end-uses[12]

Bioenergy, in addition with other low-carbon alternatives as hydrogen and hydrogen-based fuels, and technologies for negative emissions (carbon capture, utilization and storage (CCUS)) are critical to achieve net zero emission according to the International Energy Agency Net Zero Scenario (IEA NZE). Bioenergy with CCUS will scale up rapidly CO_2 atmospheric removals.

For the period 2022-2050, bioenergy and other fuel shifts (hydrogen not included) account for slightly less than 20%[13]. In the IEA NZE projections for total energy supply, solar energy will provide around 140 EJ in 2050, modern bioenergy almost 100 EJ and wind energy 85 EJ. See Figure 4. Electricity production will be the main purpose of bioenergy in this scenario, followed by liquid biofuels and biogases.

Figure 4. Bioenergy demand. 2010-2050.



Source: International Energy Agency. Net Zero Scenario by 2050

Solid bioenergy

Modern solid biomass is mostly used today for industrial purposes. However, the evolution of modern biomass in the future will lead power generation to account for 40% of the total biomass, ahead of industry (30%) and inputs to liquids or solids biofuels at 20%.

Liquid bioenergy

Modern liquid biofuel demand includes gasoline, diesel, marine and aviation fuels.

Gaseous bioenergy

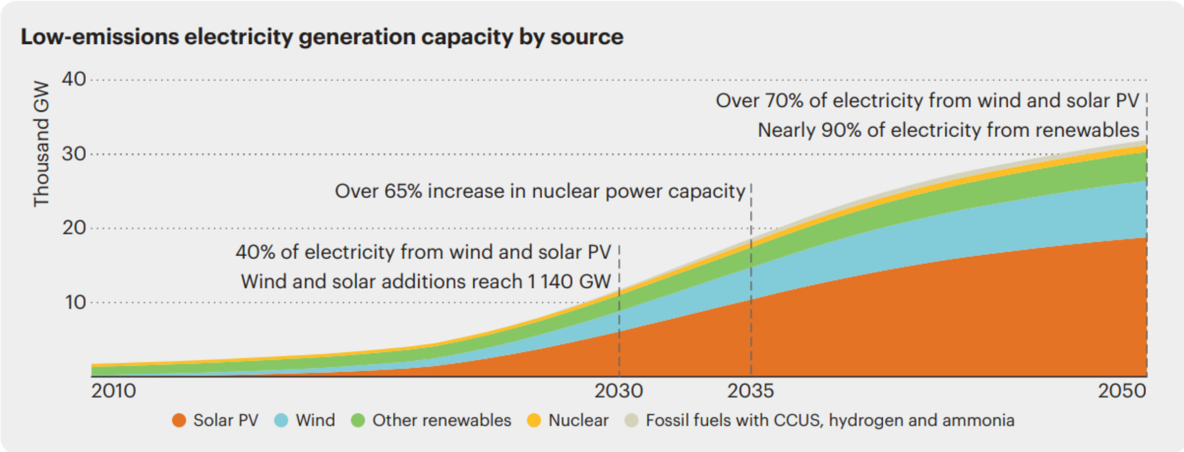
Modern gaseous bioenergy, including biogas and biomethane will play an important role in the power sector as it is the most cost-effective direct substitute for fossil gas

2.2.4.1 Biomass-based fuels for electricity

Renewable capacity for electricity generation leaded by solar PV and wind will raise the share of low-emissions sources in electricity generation from 39% in 2022 to 71% in 2030 and 100 in 2050. Solar PV and wind will account for 71% share in total generation, leaving 18% for other low-emissions sources, including bioenergy (4%), and fossil fuels with CCS, hydrogen and ammonia (11%)[14]. See Figure 5.

Figure 5. Low-emissions electricity generation capacity by source

[12] IEA Bioenergy Report 2023
[13] International Energy Agency. Net Zero Roadmap. A Global Pathway to Keep 1.5ºC Goal in Reach. 2023 Update.
[14] International Energy Agency. Net Zero Roadmap. A Global Pathway to Keep 1.5ºC Goal in Reach. 2023 Update.

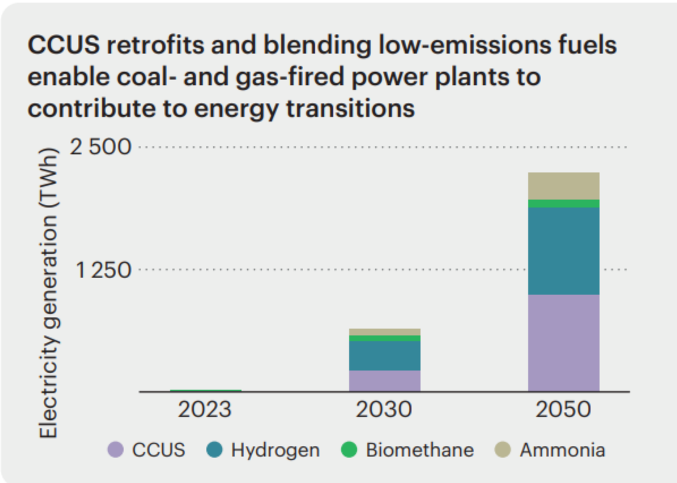


Source: International Energy Agency. Net Zero Scenario by 2050

The role of bioenergy in electricity generation is important due to the dispatchability of bioelectricity compared to solar PV and/or wind that are only available with favourable climate conditions and thus, not dispatchable. Also, due to some regional conditions where biomass source is easily available and abundant.

Biomass power plants apply different combustion technologies depending mainly on the type and quality of the biomass-based fuel they are using. In terms of its potential for cutting greenhouse gas (GHG) emissions, the cofiring of biomass in fossil fuel plants is very attractive. Only minor modifications are necessary to replace up to 50% of the coal with biomass-based fuels. Combined with carbon capture and storage (CCS) technology and other low-carbon fuels, this option can be seen as a mean to decarbonise young fossil fuel power plants. See Figure 6.

Figure 6. Decarbonization measures for fossil fuel power plants.



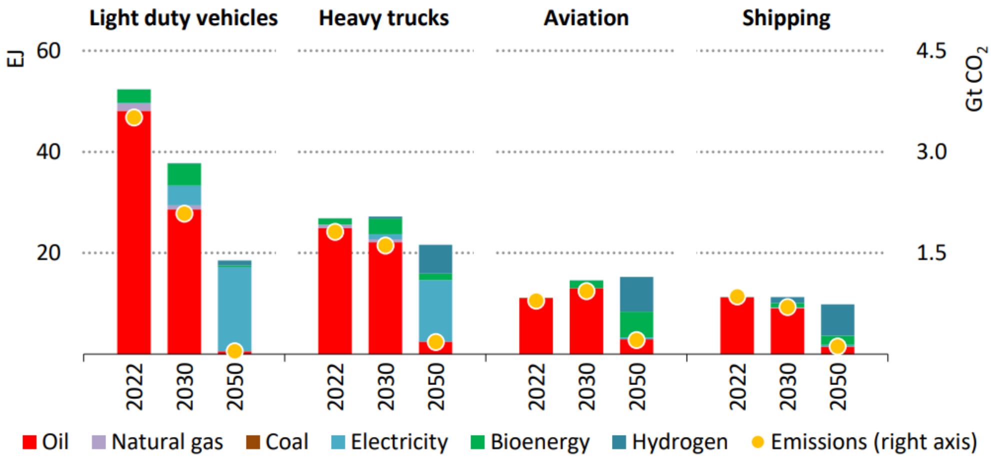
Source: International Energy Agency. Net Zero Scenario by 2050

Electricity from biomass-based fuels will be critical to decarbonize the electricity sector in emerging markets.

2.2.4.2 *Biomass-based fuels for transport*

Decarbonisation of transport relies mainly on electric vehicles and green electrification. See Figure 7.

Figure 7. Final energy consumption in transport by fuel for selected modes, 2022-2050.



Source: International Energy Agency. Net Zero Scenario by 2050

However, long-distance transport in large vehicles, airplanes or ships with high power requirements needs to be fuelled by energy carriers with high energy density. Liquid and gaseous biofuels (bioethanol, biodiesel, biogas, biomethane) produced from biomass, can provide low carbon intensity energy in the form required. Liquid biomass-based have physical and chemical properties comparable to current fossil fuel and can be easily stored on board; gaseous biomass-based fuels can be either compressed or liquified and reach higher energy density.

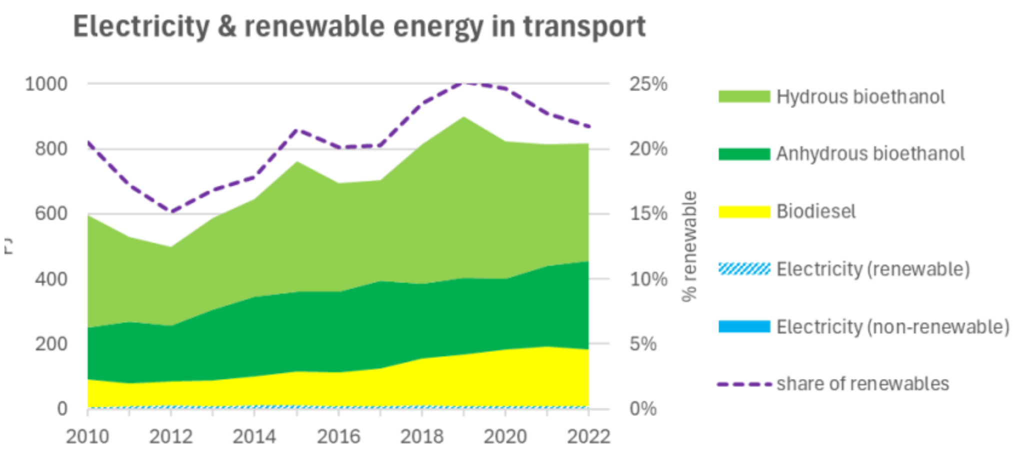
Most of the grown of modern bioenergy use in the NZE scenario come from the emerging market and development economies. Therefore, inclusion on biomass-based fuels as bioethanol or biodiesel for light-duty transport is important to reach carbon neutrality in transportation.

LIGHT-DUTY VEHICLES

Bioenergy will also account for light duty vehicles in countries where biomass supply and technology is available and electrification can be used for other decarbonisation purposes. Also, in countries where decarbonization of the grid is not achieved and thus electric vehicles won't have LCA GHG net-zero emissions.

In Brazil, where the use of biofuels in transport has grown steadily in the past 20 years, biofuels represent 22% of transport energy in 2022[15], see Figure 8. Bioethanol is the most important biofuel, used in fossil fuel vehicles, on average representing almost 40% by energy combined gasoline and ethanol use.

Figure 8. Renewable energy in the Brazilian transport sector. 2010-2022



Source: IEA Bioenergy. Brazil update 2024

[15] IEA Bioenergy. Implamantation of bioenergy in Brazil – 2024 update.

In the context of Brazilian or Indonesian road transport, biofuels are projected to reach 35% of final energy consumption by 2050[16]. India also has huge potential to increase the production and use of biomass-based fuels for transport, including environmental and socio-economic benefits beyond GHG emissions reduction. India is now the world's third largest producer and consumer of ethanol thanks to nearly tripling production over the period 2019-2024. It has potential to expand further.

Some crops as sugar beet, applicable in subtropical regions can achieve GHG savings up to 85-90% in best-practice plants with important socio-economic benefits as high yield potential, short crop cycles, low water footprints and rehabilitation of waste land.[17]

Globally, the evolution of biofuels in road transport in the IEA NZE will be 5% in 2022, 11% in 2030, 12% in 2035 and 3% in 2050[18]. The remaining proportion of biofuels for road transport can be very important for some countries where biomass is an important source of energy.

SAF-AVIATION

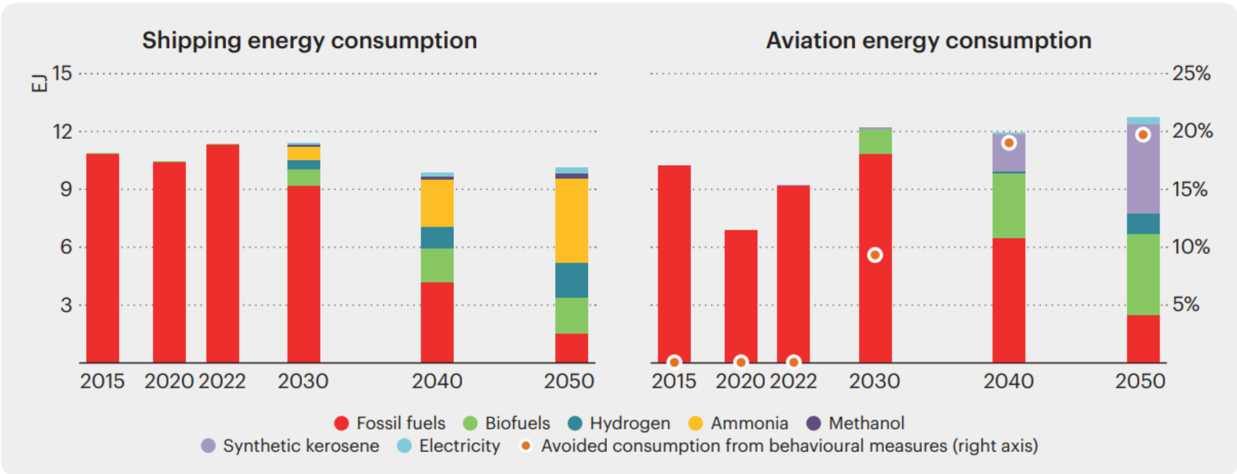
Aviation sector is predicted to steadily increase in terms of annual passenger-kilometres and need to achieve net zero emissions by 2050 to be aligned with the Paris Agreement goal. Whereas low-carbon alternative propulsion systems are at low-to-medium technology readiness levels, near-term GHG emissions reduction would have to come from the use of lower carbon intensity sustainable fuels (SAF). SAF can be based on biomass or on e-fuels synthesized from hydrogen and carbon dioxide. Hundreds of commercial flights are already operating on up to 50% blends of biojet fuel, demonstrating the technological maturity of flying on biofuels.

Bioenergy, hydrogen and hydrogen-based fuels ramp up from less than 1% of energy consumed today in shipping and aviation to almost 15% in 2030 and 80% by 2050 according to the IEA NZE[19]. The projections for biofuels in aviation are 0% in 2022, 10% in 2030, 22% in 2035 and 33% in 20250.

SHIPPING

Biofuels will also be important in the shipping transport accounting for 19% in the final energy consumption in 2050. See Figure 9.

Figure 9. Final energy consumption in shipping and aviation. 2015-2050



Source: International Energy Agency. Net Zero Scenario by 2050

2.2.4.3 *Biomass-based fuels for heat*

Heat is the most important form of energy used in industry. Bioenergy technologies can provide heat a t a wide range of temperatures. In 2020, the majority (86%) of renewable heat consumed in industry come from biomass-based fuels, equalling 9.4% of the industrial heat demand.

[16] IRENA, (2025), Brazil's biofuel industry. Lessons, challenges and opportunities. International Renewable Energy Agency.
[17] Global Biofuels Alliance. Bioethanol Webinar. Novemeber 2025.
[18] International Energy Agency. Net Zero Roadmap. A Global Pathway to Keep 1.5ºC Goal in Reach. 2023 Update.
[19] International Energy Agency. Net Zero Roadmap. A Global Pathway to Keep 1.5ºC Goal in Reach. 2023 Update.

Biomass-based fuels combustion systems also provide low temperature heat up to 100-degree for heating and hot water supply in buildings.

2.2.4.4 Biomass-based fuels for cogeneration

Heat and electricity can be produced in the same facility, by using the exhaust gases from a combustion chamber to produce heat. This heat can be used as heat or to generate steam in a heat exchanger (HX) which can be put into a turbine, operating a thermodynamical cycle to generate electricity.

The overall system efficiency can be increased compared to power plants without heat use from 30-40% to 80-90%. Thus, in situations where heat and electricity would be required at the same time and place, combined heat and power (CHP) plants can be a cost-effective solution.

3 Key considerations in the development of the Bioenergy Criteria for the Climate Bonds Standards

3.1 Mitigation criteria

3.1.1 Mitigation criteria for intermediate biomass energy products.

Conversion processes can involve intermediate stage where biomass is prepared before going to final conversion processes. These facilities are eligible under the Climate Bonds Bioenergy criteria. Biomass used must comply with the Sustainable Bioenergy Criteria (Section 3.2.2) and from the point of view of mitigation, the only requirement is to disclose the LCA GHG emissions following the methodologies accepted by the TWG (Table 10).

No LCA GHG emissions threshold is required as there is no fossil reference against which emissions could be compared. However, these reported emissions will be incorporated into the final bioenergy product made from these intermediate products.

3.1.2 Principle to set the mitigation criteria

Bioenergy products are a solution to decarbonise economic activities related to energy, including hard to abate emissions activities such as high temperature industrial processes, power produced from young fossil-based power plants or heavy-duty transport (freight land, aviation or shipping). See section 2.2.

Therefore, the main objective of the mitigation criteria is to reduce the emissions using or bioenergy products (biomass-based fuels for transport, heat/cool, electricity or cogeneration)

The philosophy behind the criteria to quantify the emissions reduction required is the following:

1. Set a reference value for emissions associated to the final energy product (heat/cooling, electricity or biofuel) produced with fossil fuels *(Fossil baseline),* AND;
2. Require a % of reduction to the emissions related to the final energy product produced out of biomass-based fuels *(Minimum % reduction)*.

The result will be a maximum LCA GHG emissions, expressed in gCO2e/MJ of final energy.

$$\textit{Maximum LCA GHG emissions } (gCO_2e/MJ) = \textit{Fossil baseline } (gCO_2e/MJ) \cdot (100 - \textit{Minimum \% reduction})$$

3.1.2.1 Final energy products in the scope of the criteria

Considering the projections of the bioenergy in the IEA NZE described in section 2.2, the bioenergy products that will be considered in the scope of these criteria are (See Table 3):

- *Biomass-based fuels for transport.* Modern liquid bioenergy accounts for 11 EJ in 2050 and biomethane for 15 EJ.
- *Heat/cooling.* Bioenergy for industry is expected to raise up to 22 EJ in 2050.
- *Electricity*. Projected to provide 30 EJ in the IEA NZE
- *Co-generation (CHP).*

Table 3. Bioenergy projections in the IEA NZE by 2050. 2022-2050.

Milestones	2022	2030	2035	2050
Total bioenergy supply (EJ)	**67**	**74**	**89**	**99**
Share of advanced feedstock	45%	80%	85%	90%
Modern gaseous bioenergy (EJ)	**1**	**7**	**9**	**15**
Biomethane	0	5	6	10
Modern liquid bioenergy (EJ)	**4**	**11**	**13**	**11**
Share of advanced biofuels	12%	40%	55%	75%
Modern solid bioenergy (EJ)	**35**	**55**	**65**	**73**
Electricity and heat	9	15	21	30
Industry	11	15	18	22
Buildings and agriculture	5	9	8	6
Traditional use of solid biomass (EJ)	**24**	**0**	**0**	**0**
Million people using traditional biomass for cooking	2 049	0	0	0

Source: International Energy Agency. Net Zero Scenario by 2050

3.1.3 Fossil baseline

The fossil baseline has calculated as the LCA GHG emissions associated to the combustion of fossil fuel to produces each energy product. The references consider the average blend of fossil fuels to produce the energy product.

The reference values for the emissions associated to fossil fuels are collected in Table 4. They are expressed in gCO_2e/MJ contained in the fossil fuel.

Table 4. Fossil baseline (gCO_2e/MJ) for final energy products

Final energy product		Fossil baseline gCO_2e/MJ
Transport	Land	94[20]
	Shipping	94[21]
	Aviation	89[22]
Heat/cooling		80[23] {124[24] for proved coal substitution}
Electricity		183[25]
Co-generation (CHP)		80 (heat) 123 (electricity)

These fossil baseline values are calculated on a life cycle basis. Life cycle basis includes emissions related to every stage in the life cycle of a fuel – form its production until it is used to fuel a vehicle. The scope of LCA should include:

- Fuel extraction
- Fuel processing
- Fuel transportation and storage
- Fuel final use

Transport has been divided into three transport modes underlining the differences in the fuel and technologies. However, as can be seen in Table 4, the fossil baseline is similar.

[20] Directive (EU) 2018/2001 of the European Parliament and of the Council. Annex V
[21] IMO. Interim Guidance on the use of biofuels under regulations 26, 27 and 28 of Marpol Annex VI.
[22] ICAO. CORSIA Methodology for calculating actual life cycle emissions value. June 2025
[23] Directive (EU) 2018/2001 of the European Parliament and of the Council. Annex V
[24] Directive (EU) 2018/2001 of the European Parliament and of the Council. Annex V
[25] Directive (EU) 2018/2001 of the European Parliament and of the Council. Annex V

Feedback from TWG members suggest considering different fossil baseline values for different world regions. However, Climate Bonds criteria aim to be global. The situation of different world regions has been included in the % of emissions reduction required to the biomass-based fuel as a temporal declining trajectory.

3.1.4 Minimum % emissions reduction

To decarbonise the energy sector using biomass-based fuel, emissions related to final product shall be reduced. The former Climate Bonds Bioenergy criteria require to every final product a minimum % of emissions reduction of 80%. TWG accorded that this value is too high for transport biomass-based fuels and is not achievable with current scalable bioenergy projects. TWG screened the most important international regulations for biomass-fuels whose % GHG savings are presented in Table 5.

Table 5. Minimum % of emissions reduction required in different international regulations/certification schemes.

% GHG savings for bioenergy products in different international regulations/certification schemes				
Bioenergy product	EU	UK	EEUU	CORSIA
Transport	65	65	20	10
Electricity	80	80	50	
Heat/cool	80		60	

3.1.4.1 Fossil baseline for transport sector.

Values from Table 5 shows that any regulation/certification schemes for biomass-based fuel requires more than 65% for the transport sector.

A temporal declining trajectory has been established considering the following rationale:

- Ending values: Reaching carbon neutrality by 2050. This goal is aligned with the Paris Agreement Goals, with 1.5-degree scenarios and with the ambition of the international transport organizations as IMO for shipping sector[26] or ICAO for aviation[27].
- Starting point: Global research has been conducted to determine the worst-case optimal conditions required and applied for biomass-based fuels. The lowest international emissions reduction % considered as green in 2025 have been applied as the starting point for the declining trajectory. This approach leaves some room to emerging markets, takes in consideration their local technical and economic circumstances and make the trajectory realistic enabling the transition to carbon neutrality.
- Intermediate values have been established to describe a technologically feasible trajectory, increasing the reduction as the technology is implemented.

Table 6 shows the declining trajectory for the transport sector.

Table 6. Minimum % emissions reduction for transport biomass-based fuels

Emissions reduction declining trajectory for TRANSPORT			
Transport sector	Road	Shipping	Aviation
Year	Minimum % of emissions reduction		
2025	50[28]	65[29]	50[30]
2030	60	70	60
2040	80	80	80
2050	Close to 100	Close to 100	Close to 100

[26] 2023 IMO strategy on reduction of GHG emissions from Ships. Reach net zero GHG emissions by 2050. 2023 IMO GHG Strategy
[27] ICAO's comittment to progress towards net-zero emissions from international civil aviation by 2050. ICAO's strategic plan for 2026-2050.
[28] 50% of GHG savings is required for biofuels in EEUU. EPA US. Renewable Fuel Standard.
[29] The IMO Interim Guidance on the use of biofules under regulations 26, 27 and 28 of Marpol Annex VI requires a mínimum % of emisisons reduction for low-carbon biofuels of 65%.
[30] 50% of GHG savings is required in EEUU for aviation low-carbon biofuels. Explained in IEA Bioenergy paper: Susan van Dyk and Jack Saddler. 2024. Progress in Commercialization of Biojet/Sustainable Aviation Fuels (SAF): Technologies and policies. Published by IEA Bioenergy. ISBN# 979-12-80907-36-3.

3.1.4.2 Fossil baseline for heat/cooling, electricity and cogeneration

Electricity generated from renewable sources is aimed to be below 100gCO_2e/kWh to be considered as low-carbon electricity in the Climate Bonds sector criteria. But electricity generation in a grid is a mix of different energy sources. Lifecycle GHG emissions from bioenergy for electricity range from 15 to 650 gCO_2e/kWh[31].

In the long-term solutions electricity from biomass-based fuels will play an important role as explained in section 2.2.4.1. Thus, as for transport sector a temporal declining trajectory has been established starting at a % of emissions reduction that can make the electricity pool reach the 100gCO_2e/kWh threshold and reaching close to 100% of emissions reduction in 2050 to be carbon neutral and thus aligned with the Paris Agreement Goals. The starting point leaves some room to emerging markets and takes in consideration their local technical and economic circumstances. Table 7 shows the declining trajectory for heat/cooling, electricity or cogeneration.

Table 7. Heat/cooling, electricity and cogeneration from biomass-based fuels minimum % of emissions reduction

Emissions reduction declining trajectory for HEAT/COOLING, ELECTRICITY AND COGENERATION	
Year	Minimum % of emissions reduction
2025	80
2030	85
2040	95
2050	Close to 100

Note: The % of emissions reduction associated with biomass-based fuel may not correspond to the % of emissions reduction in the final energy-related activity. The % of emissions reduction required in these criteria corresponds with life cycle emissions associated with biomass-based fuel, but the final activity (transport, heat/cooling production, electricity and cogeneration) could use a biomass-based fuel blended with another fuel. These criteria require a % of emissions reduction to the biomass-based fuel that would be equivalent to the % of emissions reduction from the final energy activity if a 100% biomass-based fuel mixture were used.

3.1.5 Maximum LCA GHG emissions

Applying the minimum % of emissions reduction to the fossil baseline, a threshold for the LCA GHG emissions can be obtained. See Table 8 and Table 9.

Table 8. Emissions intensity threshold for transport biomass-based fuels.

LCA GHG emissions threshold for transport biomass-based fuels				
Transport sector	Baseline (gCO_2e/MJ)	Minimum % of emissions reduction		LCA GHG emissions threshold for biomass-based fuels (gCO_2e/MJ)
Road	94 (gCO_2e/MJ)	2025	50	**47**
		2030	60	**37.6**
		2040	80	**18.8**
		2050	Close to 100	**Close to O**
Shipping	94 (gCO_2e/MJ)	2025	50	**39.2**
		2030	60	**28.8**
		2040	80	**18.8**
		2050	Close to 100	**Close to O**
Aviation	89 (gCO_2e/MJ)	2025	50	**44.5**
		2030	60	**35.6**
		2040	80	**17.8**
		2050	Close to 100	**Close to O**

[31] Amponsah et al.(2014). Greenhouse gas emissions from renewable energy sources: A review of lifecycle considerations.

Table 9. Emissions intensity threshold for heat/cooling, electricity and cogeneration produced from biomass-based fuels.

LCA GHG emissions threshold for heat/cooling, electricity and/or co-generation produced from biomass-based fuels.				
Energy products	Baseline (gCO_2e/MJ)	Minimum % of emissions reduction		LCA GHG emissions threshold for energy product (gCO_2e/MJ)
Heat/cooling	80 {124 for proved coal substitution}	2025	80	**16 {24.8}**
		2030	85	**12 {18.6}**
		2040	95	**4 {6.2}**
		2050	Close to 100	**Close to 0**
Electricity	183 (658.8 gCO_2e/kWh)	2025	80	**36.6**
		2030	85	**27.45 (98.82 gCO_2e/kWh)**
		2040	95	**9.15**
		2050	Close to 100	**Close to 0**
Cogeneration	80 (heat) 183 (electricity)	2025	80	**16/36.6**
		2030	85	**12/27.45**
		2040	95	**4/9.15**
		2050	Close to 100	**Close to 0**

3.1.5.1 Calculating emissions of a biomass-based fuel

The maximum LCA GHG emissions should be calculated on a life cycle basis including the emissions from the cultivation and extraction of raw materials, the biomass-based fuel conversion/production, transportation until the fuel is used to produce energy products.

GHG emissions calculation should be calculates as:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr}$$

Where:

E = total emissions from the production of the fuel before energy conversion

e_{ec} = emissions from the extraction and cultivation of raw materials

e_l = annualized emissions from carbon stock changes caused by land-use change

e_p = emissions from processing

e_{td} = emissions from transport and distribution

e_u = emissions from the fuel in use

e_{sca} = emissions saving from soil carbon accumulation via improved agricultural management

e_{ccs} = emissions savings from CO_2 captured and geological storage

e_{ccr} = emissions savings from CO_2 captured and replacement.

Note: CO_2 emissions captured for the plant in the growing process are neutralized by CO_2 emissions during the combustion of the biomass-based fuel. Therefore, both terms are not considered in the calculation of GHG emissions.

Issuers can use existing tools approved by legislative systems or voluntary standards. Table 10 propose robust tools to calculate GHG emissions from biomass-based fuels.

Table 10. Endorsed GHG calculations tools.

Name	Criteria	Origin
BIOGRACE II[32]	Biomass for electricity, heating and cooling	EU
RSB GHG Calculator[33]	Liquid biofuels	International
UK Solid and Gaseous Biomass Carbon Calculator[34]	Solid biomass and biogas used for heat and electricity generation	UK
GREET[35]	Alternative fuels in transport	US
RenovaCalc[36]	Ethanol, biodiesel, aviation biokerosene and biogas from waste	Brazil

3.1.6 LCA GHG emissions for biomass-based fuel used to produce heat/cooling, electricity or cogeneration.

These fossil baseline values include emissions related to every stage in the life cycle of a fuel – from its production until it is used to fuel a vehicle. However, issuers would like to certify only the production of biomass-based fuels to produce heat/cooling, electricity or cogeneration. In that case, fossil baseline should be recalculated considering a default energy efficiency value for each final use of the biomass-based fuel as detailed above. Emissions will be compared to the energy contained in the fuel.

Default energy efficiencies values to calculate the fossil baseline for biomass-based fuel are shown in Table 11.

Table 11. Default efficiency values (% respect the energy-contain of the fuel)

Final use	Energy efficiency
Heat/cooling	80
Electricity	40
Co-generation (CHP)	75 (35 for electricity + 40 for heat)

[32] http://www.biograce.net/home
[33] http://rsb.org/services-products/ghg-calculator/
[34] https://www.ofgem.gov.uk/guidance/uk-biomass-and-bioliquid-carbon-calculator
[35] https://greet.es.anl.gov/
[36] https://www.gov.br/anp/pt-br/assuntos/renovabio/renovacalc

Example of the calculation of the fossil baseline for a biomass-based fuel used to produce heat:

- The fossil baseline for heat is **80 gCO_2e/MJ** of heat produced. (F_b)
- The energy efficiency heat production is **80%,** means that with 1MJ of biomass-based fuel we can produce 0,8 MJ of heat. (η)
- Therefore, the fossil baseline in the production of the biomass-based fuel should be calculated as follows:

$$F_b' = F_b \cdot \eta$$

$$F_b' = 80 \cdot 0.8 = 64 gCO_2e/MJ$$

Where:

${F_b}'$ = New fossil baseline related to the energy contained in the fuel, including the default energy efficiency of the final use

F_b = Fossil baseline related to the energy contained in the final product.

η = estimated energy efficiency

The aimed % emissions reduction are still the same, i.e. 80% for heat generation. Thus, for 2025, LCA GHG emissions intensity threshold for heat (LCA_{t-h}) production will be:

- Fossil baseline: **64 gCO_2e/MJ (${F_b}'$)**
- Minimum % emissions reduction in 2025: **80%** ($\%$ ***emissions reduction***)

$$LCA_{t-h} = F_b' \cdot (1 - \frac{\%\, emissons\ reduction}{100})$$

$$LCA_{t-h} = 64 \cdot \left(1 - \frac{80}{100}\right) = 12.8\ gCO_2e/MJ$$

Applying this methodology to biomass-based fuels for heat/cooling production, electricity generation and co-generation (CHP) following values are obtained:

Table 12. LCA GHG emissions threshold for biomass-based fuel for heat/cooling production, electricity generation and co-generation (CHP)

LCA GHG emissions for biomass-based fuel for heat/cooling production, electricity generation and co-generation (CHP)				
Final use	Baseline (gCO_2e/MJ)	Minimum % of emissions reduction		LCA GHG emissions threshold for biomass fuel (gCO_2e/MJ)
Heat/cooling	64	2025	80	**12.8**
		2030	85	**9.6**
		2040	95	**3.2**
		2050	Close to 100	**Close to O**
Electricity	73.2	2025	80	**14.64**
		2030	85	**10.98**
		2040	95	**3.66**
		2050	Close to 100	**Close to O**
Cogeneration	32 (heat) 64.05 (electricity)	2025	80	**19.21**
		2030	85	**14.4**
		2040	95	**4.8**
		2050	Close to 100	**Close to O**

Note: For co-generation purposes, the maximum LCA GHG emissions required is calculated as follows:

Explanation of LCA GHG emissions thresholds for co-generation (CHP) from biomass-based products.

- Fossil baseline for heat in cogeneration in 2025: $80 \frac{gCO_2e}{MJ_h} \cdot 0.4 \frac{MJ_h}{MJ_f} = 32\ gCO_2e/MJ_f$
- Fossil baseline for electricity in cogeneration in 2025: $183 \frac{gCO_2e}{MJ_h} \cdot 0.35 \frac{MJ_h}{MJ_f} = 64.05\ gCO_2e/MJ_f$
- % GHG emissions reduction for cogeneration in 2025: 80 %
- LCA GHG emissions threshold for biomass-based fuel in cogeneration;

$$\frac{32gCO_2e}{MJ_f} \cdot 0.8 + \frac{64.05gCO_2e}{MJ_f} \cdot 0.8 = \frac{19.21gCO_2e}{MJ_f}$$

  - **16 gCO2e/MJ for heat (MJ_h).** See Table 9
  - **36.6 gCO2e/MJ for electricity (MJ_e).** See Table 9
- Energy efficiency:
  - 35% for heat **(0.35 MJ_h/MJ_f)**
  - 40% for electricity **(0.4 MJ_e/MJ_f)**

Emissions from 1MJ of biomass-based fuel in a co-generation (CHP) plant

- Emissions from heat generation: $\frac{5.6\ gCO2_2e/MJ_f}{0.35\ MJ_h/MJ_f} = 16gCO_2e/MJ_h \leq 16gCO_2e/MJ_h$ Criteria met
- Emissions from electricity generation: $\frac{5.6\ gCO2_2e/MJ_f}{0.4\ MJ_e/MJ_f} = 14gCO_2e/MJ_e \leq 36.6gCO_2e/MJ_e$. Criteria met

3.1.7 Methane emissions assessment. Specific methane emissions calculation guidelines for biogas and biomethane value chain.

Methane emissions are relevant in biomass-based fuels, mainly in the biogas and biomethane production. The Joint Research Centre (JRC) has released a recent study[37] addressing the methane emissions in the biogas and biomethane value chain.

TWG incorporates the results of the analysis. The aim is to promote the mitigation of methane emissions and to correct the identified of these emissions in current calculation methodologies. The criteria suggest the inclusion of these best-practise or direct measures for a better control of methane emissions.

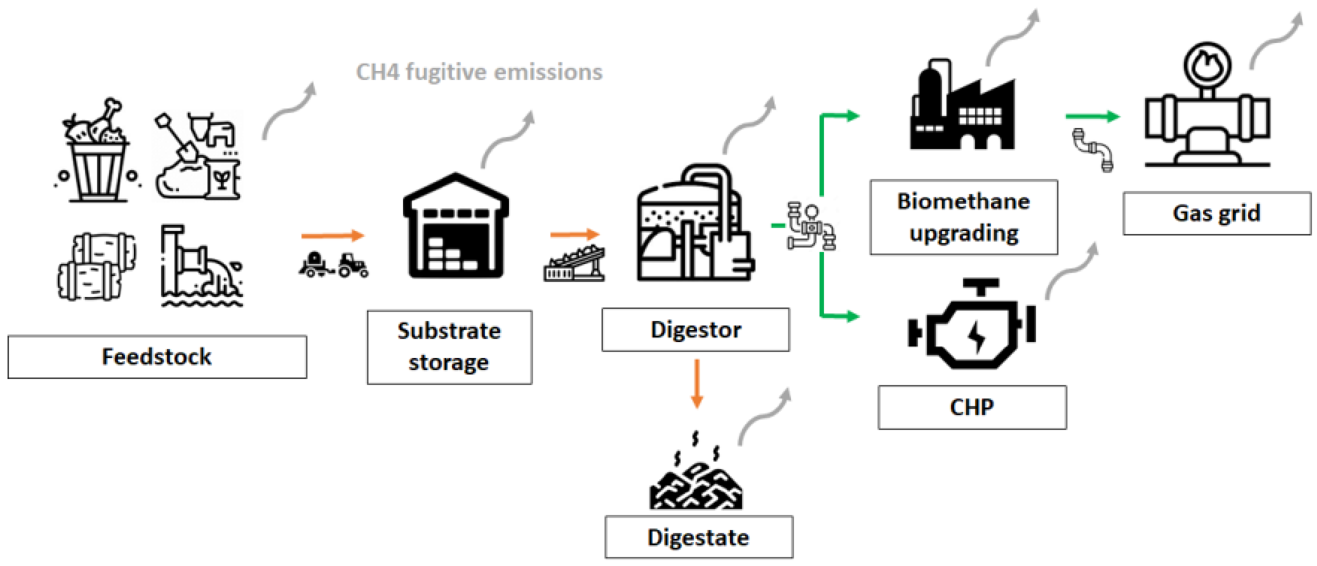
The study concludes that methane emissions included in calculation methodologies, as well as literature, have been underestimated. Some material emissions sources are not included, particularly fugitive and operational, and, in the case of those that are not measured, default values may be lower than reality.

The study also has evaluated best-practices proved in real projects and their corresponding methane emissions values.

Therefore, these Criteria will include an analysis identifying all the material source of methane within the biogas/biomethane value chain. (see Figure 10). All the emissions related to the identified sources must be included in the LCA GHG analysis.

[37] *Joint Research Centre, Buffi, M., Hurtig, O. and Scarlat, N., Methane emissions in the biogas and biomethane supply chains in the EU, Publications Office of the European Union, Luxembourg, 2024, JRC139485*

Figure 10: Short overview of the emissions for a traditional biogas value chain.



Source: JRC analysis

Next stages of biogas/biomethane value chain should be considered for methane emissions:

- Feedstock management
- Biogas/biomethane plant:
  - Biogas processing
  - Digestate management
  - Raw biogas upgrading
  - Biogas use in CHP
- Distribution

TWG propose three options for life cycle methane emissions accounting:

Option A – the use of actual values resulting from measurements and qualification of emissions made by an independent third-party. TWG should encourage issuers to move to this option.

Option B – The use of default values given in Table 13 for every relevant substage of the biogas/biomethane value chain. The use of the minimum default values given in Table 13, best-practice column, is conditioned to the use of the "best-practice" described below the table, section 3.1.7.1

Default values in the calculators cannot be lower than the standard practice column if no best practice have been applied and cannot be higher than the best-practice column in the case of best-practice implemented.

The use of other default values for methane emissions in biogas or biomethane value chain is not a viable option, except for the credits coming from emissions savings for improved agricultural management.

Option C – The use of a mix of actual and default values. The use of default values is affected by the same rules described in option B.

Table 13. Default values for methane emissions calculation (% refers to produced methane)[38]

Value chain stage	Substage	Default values for best-practices in the biogas/biomethane vale chain	Default values for standard practices in the biogas/biomethane value chain
Feedstock management	Storage	0.0% + access to credits[a]	0.0%
Plant	Biogas processing	0.5%	5.0%
	Digestate management. Composting or storage	0.1%	2.2% (silage) 2.5% (biowastes)[b] 10.0% (manure)
	Storage with RMP[c] measurement below the proposed default emission factor for standard digestate management	0.25·RMP	0.75·RMP
	Raw biogas upgrading	0.0%	0.2[d] / 1.0[e]/ 3.0%
Plant. Biogas use in CHP	Slippage of methane in the exhaust gas	1.7%	
Distribution	Piping, maintenance, leaks	0.0%	1.5%

a: The application of good practices allows the application of credit for avoided emissions.
b: Including sewage sludge from industrial wastewater treatment plants (sludge from municipal wastewater treatment plants is excluded from this CBI criteria)
c: Remaining Methane Potential
d: Technologies certified by the provider or measured to have < 0.2% of produced methane in the off-gas
e: Technologies certified by the provider or measured to have < 1% of produced methane in the off-gas

3.1.7.1 Best practice in biogas and biomethane value chain

The best practices required to be able to use the minimum default values set in Table 13 are described per each of the stages of the biogas and biomethane value chain. They were extracted from the best practices reported by Join Research Centre of the European Commission[39] and the Danish Energy Agency[40].

Feedstock management:

- Limit the storage and rest time; and
- Slurry is quickly moved to the foretank and quickly sent to the processing plant

Biogas/Biomethane plant:

- General requirement:
    - Follow a certified voluntary leakage and repair (LDAR) programme. The minimum requirements for this LDAR are listed in Table 14.
- Biogas processing:
    - Automatically activated flare connected to all pressure release valves and venting systems; and

[38] *Values for different parts of the biogas/biomethane plant are reported in European Commission, Joint Research Centre, Buffi, M., Hurtig, O. and Scarlat, N., Methane emissions in the biogas and biomethane supply chains in the EU, Publications Office of the European Union, Luxembourg, 2024, JRC139485. Standard value for distribution is based on the limit set by Bolivian Government in Reglamento de Distribución de Gas Natural por Redes (DS 1996, 14/05/2014) (in Spanish).*
[39] *Joint Research Centre, Buffi, M., Hurtig, O. and Scarlat, N., Methane emissions in the biogas and biomethane supply chains in the EU, Publications Office of the European Union, Luxembourg, 2024, JRC139485.*
[40] Ramboll, Scheutz, C., Pattern, J., Hinge, J., & Petersen, S. (2021). Targeted efforts to reduce methane loss from Danish biogas plants (Report No. 4.0). Danish Energy Agency

    - Installation of leak detection alarms or other detecting devices in closed environments

- Digestate management:
    - Storage:
        - Keeping the feedstock or digestate in an airtight environment (combined with time in digester and closed digestate storage) for at least 50 + x days, where "50" represents the minimum retention time of 50 days and "x" is the number calculated as additional 2 days for each mass percent of non-manure-based feedstock (max 150 days); or
        - storage with remaining methane potential (RMP) measurement below the proposed default emission factor, expressed in percentage of produced methane, for standard digestate management when the temperature inside the digestate storage remains below 20 °C during the whole storage period.
    - Composting: the whole process is done in complete closed environment, actively aerated cells in a closed environment, direct mixing and cooling of digestate with substrate at the exit of the air-tight section, monitoring and measurement of methane content in the off-gas.
- Raw biogas upgrading:
    - off-gas oxidation: combustion of off-gas is performed; or
    - no off-gas emitted: the CO_2 separated from the biogas is captured and no off-gases are released.
- Distribution:
    - Follow a certified voluntary leakage detection and repair (LDAR) program. The minimum requirements for this LDAR are listed in Table 14.[41]

[41] *Adapted from European Biogas Association (2020). Minimum requirements for European voluntary systems for self and external inspection of possible methane emissions on biogas and biomethane plants. EvEmBi Project Consortium; and European Commission, Joint Research Centre, Buffi, M., Hurtig, O. and Scarlat, N., Methane emissions in the biogas and biomethane supply chains in the EU, Publications Office of the European Union, Luxembourg, 2024.*

Table 14. Minimum requirements for methane Leak Detection and Repair (LDAR) system checklist for evaluating the issuer's adaptation and resilience performance in respect of bioenergy facility.

Area	Minimum Requirement
Ownership and purpose of the voluntary system	- The voluntary system should have a clear ownership - The voluntary system should have a clear purpose
System boundaries	The accepted boundaries of the system should be well described
Performing leak detections	- Self-control should be the focus of leak detection. Install detection systems for increased indoor methane concentrations and for pressure relief valve openings - Third-party revision for credibility is required
Quantifying emissions	- At least one monthly visual inspection (with no detecting instruments) of high-risk components (pressure relief valve, moving components) - At least once a year regular leak detection (and quantification) by an external professional. The methods to quantify emissions should be well described
Remedying of found leaks	- A maintenance and repair plan defining the intervals when components need maintenance and how to repair components that show leaks. - If the leaks exceed 2% of the annual production or 50 tonnes per year, a mandatory repair should be scheduled, and an additional test, within 6 months of the leak detection should confirm the effectiveness of the repair.
Reporting of emissions data	- A documentation system to report each inspection, leak detection, maintenance and repair - There should be an easy access to annual or periodical results with benchmark possibilities - Short term and long-term goals on leak detection performance and emission reduction should be set
Knowledge buildup and skills development	Training courses for introducing and maintaining leak detection programs should be organized or a written best management practice document available.

Adapted from recommendations by European Biogas Association (2020)[42] and European Commission, Joint Research Centre[43].

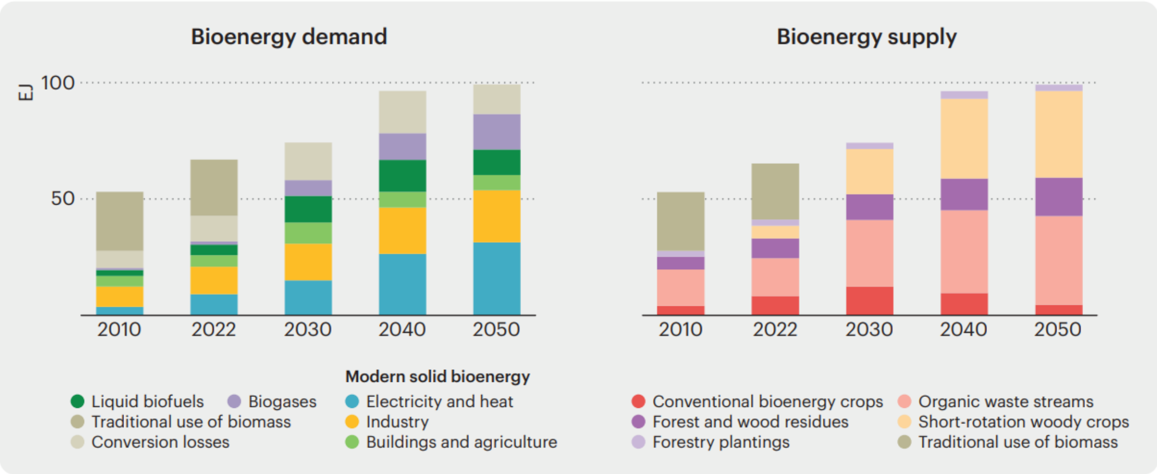
[42] European Biogas Association (2020). Minimum requirements for European voluntary systems for self and external inspection of possible methane emissions on biogas and biomethane plants. EvEmBi Project Consortium.

43 European Commission, Joint Research Centre43, Buffi, M., Hurtig, O. and Scarlat, N., Methane emissions in the biogas and biomethane supply chains in the EU, Publications Office of the European Union, Luxembourg, 2024.

3.2 Feedstock in scope. Agnostic approach

Bioenergy supply is projected to be around 100 EJ in 2050, according to the IEA NZE scenario[44]. This amount of energy should be supply by sustainable biomass feedstock. The scenario presented by the IEA also incorporates the bioenergy supply from the different biomass source. See Figure 11.

Figure 11. Bioenergy demand and supply in the net zero scenario by 2050. 2010-2050.



Source: Source: International Energy Agency. Net Zero Scenario by 2050

100 EJ is an important amount of energy and cannot be covered only using organic waste. Although organic waste streams represent the biggest share of biomass supply, followed by short-rotation woody crops and forest and wood residues. IEA NZE scenario considers that woody biomass will represent more than 50% of the biomass supply.

Other energy organizations as the World Bioenergy Association, also recognise the importance of woody biomass in bioenergy supply. See Table 15

Table 15. Global Potential of Biomass in 2012 and 2035 (in EJ)

Main sector	**Sub sector**	**2012 - Current**	**2035 - Range**	**2035 - Average**
Agriculture	Dedicated crops - Main product	3.5	26 - 34	30
	By products and residues including manure	2.1	30 - 38	34
	Total agriculture	5.6	56 - 72	**64**
Forestry		48.9	72 - 84	78
Organic waste		1.7	6 - 10	8
Total		56.2	134 - 166	**150**

Source: World Biomass Association. Global Biomass Potential towards 2035

Despite the differences in numbers, as they are different models, both estimations assume that woody biomass will play an important role (around 50%) of the total bioenergy supply.

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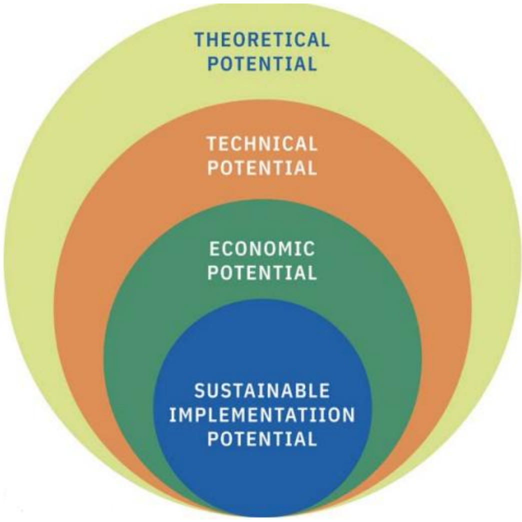
It is important to consider that biomass feedstock should meet sustainability requirements to be included in a low-carbon and climate-resilient economy. Figure 12 shows the distinction of biomass potential. The IEA, in the Bioenergy report 2023[45] establish that the sustainable implementation potential is estimated at between 60 and 120 EJ per year, pointing out that biomass potential is difficult to estimate.

Figure 12. Distinction of biomass potential



Source: IEA Bioenergy Report 2023

Therefore, TWG decided to have an agnostic approach regarding the biomass feedstock for biomass-based fuels production. The rationale was to not reject any type of biomass feedstock but request for strong and robust criteria covering all the relevant environmental and social important impacts associated with biomass feedstock.

According to the previous report from the World Bioenergy Association, solid biomass (including wood chips, pellets and traditional biomass) reaches 85% of total supply of biomass in 2021 (54 EJ globally). Liquids biofuels accounted for 7%, municipal and industrial waste sector accounted for 2-3% followed by biogas at 2%.[46] Therefore, TWG agreed with no exclusions for any type of biomass.

3.2.1 Feedstock classification

To address the potential environmental impacts of the biomass feedstock source, the TWG divided the potential biomass feedstock into four categories according to their characteristics:

- **Agricultural Biomass:** Biomass produced from agriculture, including algae if cultivated in land ponds and waste and residues from agriculture, aquaculture and fisheries.
- **Forestry biomass**: Any plant matter or tree material produced by forest growth that can converted to an energy source, including forestry residues (domestic forest biomass is excluded as it is covered by Climate Bonds municipal waste criteria)
- **Processing waste and residues biomass:** waste and residues other than agricultural, aquacultural, fisheries and forestry residues, i.e. industrial processing waste and residues. Include captured biogenic CO_2
- **Aquatic biomass:** Cultivated or harvested water-based plants or algae, and associated derivates.

Aquatic biomass has been included due to its energy potential. Among the possible biofuels options, Anaerobic Digestion (AD) to produce biogas from algae is considered one of the most viable technologies.

Table 16 shows some examples of feedstock included in this biomass source classification.

[45] International Energy Agency. Bioenergy Report 2023.
[46] World Bioenergy Association. Global Bioenergy Statistics Report. 2024

Table 16. Biomass feedstock source classification

Biomass feedstock type	Examples
Agricultural	Food and feed agricultural crops, such as corn or wheat Non-food agricultural crops cultivated in agricultural land, such as energy crops In-field agricultural residues, originating from a cultivation of a food or feed crop, such as cereal straw, rice straw, stalks, nutshell, bagasse (classified as processing residue if generated during processing); fruit tree cuttings and vineyard pruning. Intermediate crops, such as catch crops, cover crops or ley crops. Animal manure
Forestry biomass	Harvested woody biomass and grass Residues that are directly generated by forestry, e.g. residues that are left after logging operations: branches, stumps, treetops, barks, sawdust… (not including residues from related industries or processing)
Processing waste and residues biomass	Non-field agricultural residues, originating from the primary processing of a food crop in a factory such as rice husk, maize cob, nutshell and husks, peels, fruit seeds, bagasse, coffee husk, cocoa pods (classified as agricultural crops residue if directly generated by agriculture) Animal byproducts generated by slaughterhouses or other operations, and animal fats generated in a rendering process Other agrifood industry waste or residues such as brewery sludge and brewer's spent grain, grape marcs and wine lees, or solid waste and wastewater from diary industry Waste/residues from forest-based industries such as black and brown liquor from cellulose industry or paper sludge Crude glycerol from biodiesel production Bio-genic fraction of end-of-life tires. Captured bio-genic CO_2
Aquatic biomass	Microalgae (Chlorella, Scenedesmus, Nannochloropsis, Dunaliella) Cyanobacteria, often called "blue-green algae" (Spirulina, Synechocystis) Macroalgae, also called seaweeds (Kelp, Gracilaria, Ulva, Porphyra) Aquatic vascular plants (Duckweed, Water hyacinth, Cattail)

3.2.2 Sustainability criteria for feedstock classification

Biomass feedstock can have different environmental impacts from carbon sock in the soil, food security, indirect land use change, water quality or socio-economic impacts.

3.2.2.1 Agricultural biomass

The directive (EU) 2018/2001 of the European Parliament and of the Council requires some sustainability criteria for biomass-based fuel produced from agricultural biomass:

- Low-indirect land-use change risk assessment
- Monitoring and management plans to address the impacts on soil quality and soil carbon
- Biomass shall not be made from raw material obtained from land with a high biodiversity value
- Biomass shall not be made from land with high-carbon stock
- Biomass shall not be made from land that was peatland

TWG added stricter criteria to assess other environmental impacts:

- Conserve and protect water resources
- Air pollution and use of fertilizers
- Food security
- Circularity
- Socio-economic impacts
- Methane abatement best-practices

Table 17. Agricultural Biomass Criteria Principles

AGRICULTURAL BIOMASS CRITERIA PRINCIPLES					
A1	A2		A3	A4	A5
Indirect land use change (iLUC) risk management	Soil quality and soil carbon management		Conserving land with High-carbon stock	Conserve peatlands	Conserve high biodiversity areas
A6	A7	A8	A9	A10	A11
Conserve and protect water resources	Pollution	Food security	Socio-economic impacts	Circularity	Methane reduction

These principles are covered by different criteria listed in Table 18

Table 18. Criteria to cover the agricultural biomass principles:

Principle	Criteria
Indirect land use change risk management *(Specific criteria for food and feed crops, defined as starch-rich crops, sugar crops or oil crops produced on agricultural land as a main crop, excluding residues, waste or lignocellulosic material and intermediate crops, such as catch crops and cover crops, provided that the use of such intermediate crops does not trigger demand for additional land)*	Yield increase: Operators demonstrate that additional biomass was produced through an increase in yield, including multicrops, compared to a reference date, without any additional land conversion, OR; Unused/degraded land: Operators demonstrate that biomass was produced out of land that was not previously cultivated or was considered arable land, OR; For other cases different than yield increase and/or unused/degraded land, low iLUC should be proved by following the methodology described in Commission Imp Regulation (EU) 2022/996 or any other robust and publicly available guidance.
Soil quality and soil carbon management	Operators or national authorities have monitoring or management plans in place in order to address the impact on soil quality and soil carbon The soil management plan is developed and implemented with a focus on soil productivity, including retention of soil biomass levels, soil structure, salinity, pH and carbon sequestration The plan can outline crops and geographically appropriate practices such as no-till, only planting on suitable slopes, use of covers crops, crop rotation, tree hedges and contour planting, etc. The plan also includes adequate protection of riparian areas. The harvesting of agricultural waste and residues does not have a negative impact on soil quality and soil carbon stock
Conserving land with high-carbon stock	Feedstock obtained from land with high-carbon stock won't be accepted including wetlands, continuously forested areas and forested areas with 10-30% canopy cover
Conserve peatlands	Feedstock obtained from land that was peatland in January 2008 won't be accepted, unless evidence is provided that the cultivation and harvesting of that raw material does not involve drainage of previously undrained soil
Conserve high bio-diversity area	Feedstock obtained from land with high biodiversity won't be accepted including primary forests, old growth forests, high biodiverse grassland, heathlands, areas **designated by the relevant competent authority** for nature protection purposes and areas for the protection of rare, threatened or endangered ecosystems or species
Conserve and protect water resources	A complete assessment of water resource requirements and discharge impacts should be conducted, taking into considerations crop needs, soil water holding capacity, hydrological conditions, downstream human and environmental needs and uses, and impacts that the water use and discharge will have on the watershed, community health and regional ecology. A Water Management Plan is in place that addresses relevant risks and includes concrete measures to protect groundwater or local water bodies.

Principle	Criteria
Pollution: implement best-practices for the use of (Agro)chemicals, restrict air pollution and promote good air quality	Best practices to use water efficiently and to avoid the depletion of surface or groundwater resources beyond replenishment capacities Restrictions in case of water stress Operations shall contribute to the enhancement or maintaining the quality of the surface and groundwater resources Agrochemicals are properly used on site, judiciously and in a targeted fashion using available expertise. There is no use of hazardous agrochemicals listed as Classification I or II in the World Health Organization's Recommended Classification of Pesticides by Hazard. An Integrated Pest Management plan is developed and implemented, ideally incorporating biological controls. An Integrated Weed Management plan is developed and implemented, ideally including cultural and biological controls, appropriate rates of pre-and post-emergent applications, and appropriate altering of active ingredients A Nutrient management plan focused on optimal uptake and minimal loss of nutrients has been developed and is implemented. The plan can include soil and foliage testing (regularly and especially prior to fertilizer applications), use of variable rate technologies for fertilizer application, crop rotation, and use of cover crops and filter strips. Reduction and Reporting on NON-GHG pollutants Soil contamination through fertilizers is minimized by adapted management Pesticides shall only be used as part of Integrated Pest Management (IPM) in compliance with local legislation, chemical safety data sheets and industry best-practices. Banned pesticides shall not be used.
Food security	If the feedstock production is located in a country with low or moderate ranking on the Global Hunger Index (GHI)[47], according to the latest International Food Policy and Research Institute's publication, there is no further requirement. Otherwise, the issuer needs to assess whether the production of the sourcing feedstock is likely to have impacts on food security, and to establish corresponding mitigation and enhancement measures if the impacts are significant. Issuers can follow guidelines such as FAO's Bioenergy and Food Security Assessment, FSS or any other robust and publicly available guidance.
Socio-economic	Promote safe working conditions Positive impact on economic development of local communities Compliance with human and labour rights and responsible community relations Compliance with rights of indigenous peoples/land rights and tenure Wellbeing of local population: Operators should improve the socioeconomic conditions of the communities affected.
Circularity	Waste management includes reduction, reuse and recycling. Best practices addressed in a waste management plan and avoided use of landfills or on-site burning.
Reduction of methane emissions *(for biomass feedstock that can be naturally digested, namely, biomass feedstock to bu used for biogas/biomethane)*	Best practice for feedstock management include: a. Limit the storage and rest time b. Slurry is quickly moved to the foretank and quickly sent to the processing plant

TWG considers that these criteria are strong and robust enough and ensure that the biomass feedstock does not impact soil quality and carbon stock, or other impacts related to the ecosystem or local communities involved in the system.

[47] https://www.globalhungerindex.org

3.2.2.2 Forestry biomass

As an example of forest biomass with some environmental requirements, according to the World Bioenergy Association, in 2012, 85% of all the biomass used for energy originated from forest or trees, contributing with 49 EJ to the global energy supply. Additionally, 25-35 EJ of woody biomass can be supplied if some conditions are fulfilled[48]:

- Better use and management of existing forest
- Better use of the by-products or residues of trees in non-forest areas for bioenergy instead of dumping a huge share of this material as it done in many parts of the world today
- Planting of new forest in order to compensate for the losses of forest in some regions, to increase the global forest area again and use part of its additional production to energy.

Woody biomass is included in the different low-carbon scenarios to meet the bioenergy demand, but strong sustainability criteria must be required to ensure that woody biomass won't have negative impacts in soil quality, carbon sinks, local communities and other important and relevant impacts.

To ensure and address the conditions for biomass-based fuel from forest, the directive (EU) 2018/2001 of the European Parliament and of the Council requires some sustainability criteria to minimise the risk of using forest biomass derived from unsustainable production:

- Sustainable Forest Management (SFM)
- Land use, Land Use Change and Forestry (LULUCF)

TWG added stricter criteria to assess other environmental impacts:

- Socio-economic impacts.

Table 19. Forest biomass criteria principles

FORESTRY BIOMASS CRITERIA PRINCIPLES		
F1	F2	F3
Sustainable forest management	Land use, land use change and forestry	Socio-economic impacts

These principles are covered by different criteria listed in Table 20

[48] World Bioenergy Association fact sheet. Global Biomass Potential Towards 2035.

Table 20. Criteria to cover the forestry biomass principles

Principle	Criteria
Sustainable Forest Management	Legality of harvesting operations Forest regeneration in harvested areas Harvesting is carried out considering maintenance of soil quality and biodiversity Harvesting maintains or improves the long-term production capacity of the forest Areas designated by the relevant competent authority for nature protection purposes are protected with the aim to preserving biodiversity and preventing habitat destruction Feedstock obtained from land with high biodiversity won't be accepted including primary forests, old growth forests, high biodiverse grassland and heathlands, areas **designated by the relevant competent authority** for nature protection purposes and areas for the protection of rare, threatened or endangered ecosystems or species
Land use, land use change and forestry	Carbon stocks and sink levels in the forest are maintained or strengthened over the long term. Assessing monitoring and reporting forest carbon according with procedures given by FAO Global Forest Resources Assessment Guidelines[49], Verified Carbon Standards (VSC) Methodology for Improved Forest Management (VM0007)[50] or any other robust publicly available guidance.
Socio-economic	Promote safe working conditions Positive impact on economic development of local communities Compliance with human and labour rights and responsible community relations Compliance with rights of indigenous peoples/land rights and tenure Wellbeing of local population: Operators should improve the socioeconomic conditions of the communities affected.

3.2.2.3 Processes waste and residues.

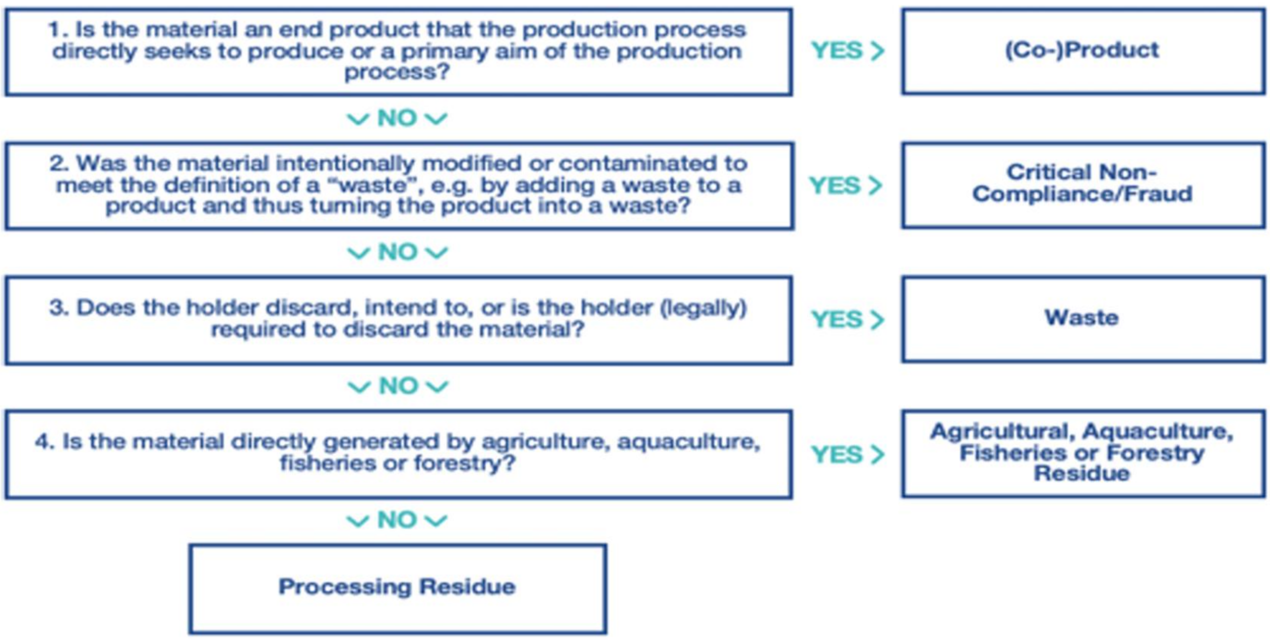
Waste and residues from industrial processes are not required to meet any sustainability criteria as they are considered waste. However, TWG agreed to include criteria to clearly defining waste. The criteria follow the process to determine if a material meets the definition of waste and residues established by ISCC.

"If evidence can be provided to the auditor demonstrating that competent national authorities have officially classified the respective material as waste or residues, e.g. on a positive list or by official decision that is not publicly available, the auditor must only verify that the material was not deliberately produced or intentionally modified or contaminated (steps 1 and 2 of the process)

[49] FAO. (2020). Global Forest Resources Assessment 2020: Terms and Definitions. Rome: Food and Agriculture Organization of the United Nations. https://www.fao.org/forest-resources-assessment

[50] Verra. (2015). VM0007: REDD+ Methodology Framework (REDD-MF), v1.6. Verified Carbon Standard. Washington, D.C. https://verra.org/methodologies

Figure 13. ISCC process to determine if a material meets the definition of waste or residues.



Source: ISCC

Process waste and residues must meet criteria for socio-economic impacts.

- Promoting safe working conditions; and
- Positive impacts on economic development of local communities; and
- Compliance with human labour rights and responsible community relations.

To prove evidence of compliance with these requirements the issuer can follow the methodology detailed by the International Sustainability and Carbon Certification (ISCC).

The issuer must communicate a declaration containing:

- A commitment to the ILO core labour standards
- Respect for the living wage
- Respect for the social environment
- respect for the legal and titles
- committing to solving social conflicts
- commitment to fair contract arrangements

3.2.2.4 Aquatic biomass

Aquatic biomass is deemed to play an important role on biomass-based fuel production. TWG wanted to address also the environmental impacts of aquatic biomass. Algae cultivated in land ponds fall under the agricultural biomass category.

Establishing parallel principles with agricultural biomass, some principles have been established in accordance with some certification schemes available today for sustainable algae production.

Table 21. Aquatic biomass criteria principles.

AQUATIC BIOMASS CRITERIA PRINCIPLES		
AQ1	AQ2	AQ3
Sustainable wild populations	Pollution	Socio-economic impacts

The accorded criteria to cover these sustainability principles are included in Table 22

Table 22. Criteria to cover the aquatic biomass principles

Principle	Criteria
Sustainable wild populations	Seaweed harvesting and farming must be conducted in a manner that does not lead to depletion of the exploited wild populations
	Seaweed shall be collected in accordance with the minimum size of collectable algae in consideration of the amount of algae resources.
	Seaweed harvesting and farming activities must allow for the maintenance of the structure, productivity, function and diversity of the ecosystem
Pollution	Avoid the use of prohibited substances
	Substances that turn into nutrients shall not be used
	Pest shall be controlled only by using a method of cultural control, physical control, biological control, or a combination of these methods.
Socio-economic	Promote safe working conditions
	Positive impact on economic development of local communities
	Compliance with human and labour rights and responsible community relations
	Wellbeing of local population: Operators should improve the socioeconomic conditions of the communities affected.

3.2.3 Best-practices standards and certification schemes used as proxies to meet the sustainable criteria for biomass feedstock

Provide compliance with the sustainability criteria that ensure that the biomass source for the production of biomass-based fuels do not impact the environment, the ecosystem and the communities involved in the system can proved through certification schemes available in the market.

A deep study of these certification scheme led to accept some of them and include them in the criteria as a proxy to meet the Sustainable Biomass Feedstock Criteria. Certification schemes are required to cover the sustainability biomass feedstock principles detailed in the previous section and some governance requirements listed in Table 23.

Table 23. Robustness check list for governance aspects

Option A	
Compliant with ISEAL Alliance's Code of Good Practice for Sustainability Systems (2023)	Standard gives accreditation
Option B	
Multi-stakeholder in involvement in standard development process	Stakeholder consultation in certification and auditing process
Multi-stakeholder participation in the standards system	Audits required annually
Scientific input in development of standard	Audit sample size specified
Transparency in public reporting	Sanction mechanisms in place
Transparency in communication of the standards documents and processes	Training of auditors
Complaints and appeals process	Training opportunities for users of the standard
Regular reviews and revisions of the standard	Standard gives accreditation

3.2.3.1 Agricultural biomass

For agricultural biomass, any certification scheme includes the methane emissions revision and best-practice adopted in the criteria. For that reason, in addition to being certified with some of the accepted certification schemes, the issuer must provide evidence of meeting the methane mitigation measures related to the biomass feedstock. These best practices are listed below:

Methane abatement best-practices
Best practices related to feedstock management:

- Limit the storage and rest time, AND;
- Slurry is quickly moved to the foretank and quickly sent to the processing.

Other certification schemes will not include some of the principles and criteria required. For those certification schemes that don't include this principles and criteria, requirements and methodologies to prove compliance are listed and must be met.

iLUC
iLUC risk management is required for food and feed crops. The Climente Bonds best-practice to comply with are:

- Yield increase: Operators demonstrate that additional biomass was produced through an increase in yield, including multicrops, compared to a reference date, without any additional land conversion, OR;
- Unused/degraded land: Operators demonstrate that biomass was produced out of land that was not previously cultivated or was considered arable land.

These criteria should be proved by following the methodology described in Commission Imp. Regulation (EU) 2022/996 or equivalent.

Socio-economic impacts
Climate Bonds best practices to comply with are:

- Promoting safe working conditions, AND;
- Positive impacts on economic development of local communities, AND;
- Compliance with human labour rights and responsible community relations, AND;

Approved certification schemes for agricultural biomass
There are a number of voluntary tools and certification schemes for biomass-based fuels from agricultural biomass. Climate Bonds Initiative screened the different tools to propose a list of voluntary standards that can be used as a proxy to meet the sustainability criteria detailed above. The voluntary tools must meet all the principles established and some governance requirements listed in Table 23.

The European Union funded a catalogue of sustainability certification schemes and labels, published in April 2023[51]. The catalogue is a useful guidance to study the sustainability and governance robustness of a certain number of certification schemes for biobased systems.

Table 24 shows different best practices standards and the Climate Bonds principles included. For those principles not included in the certification scheme, the issuer can provide separate evidence of meeting the criteria.

3.2.3.2 Forestry biomass

As outlined in this paper, biomass from forest account for more than 80 %[52] of the biomass supply with a potential to increase its contribution to the biomass supply to biomass-based fuels[53]. However, to be included as a sustainable feedstock, criteria have been defined to cover multiples environmental and ecosystem impacts.

Impacts from forest biomass have been big concern and many organisations have developed voluntary standards to cover and assess sustainable forestry biomass. As an example, FSC voluntary standard and certification system launched its first version in 1994. Table 25 Shows the TWG analysis over the different voluntary schemes and their relationship with the sustainability criteria detailed in section 3.2.2.2.

3.2.3.3 Processes waste and residues

As explained in section 3.2.2.3, no sustainability criteria is required for processes waste and residues biomass. Only socio-economic impacts must be considered and fulfilled.

3.2.3.4 Aquatic biomass

Aquatic biomass has been included as a feedstock source for bioenergy products. TWG agreed to establish certain sustainable criteria equivalent to those related to agricultural biomass. Based on this philosophy and considering the available best practices and certification schemes, the criteria for aquatic biomass have been presented in section 3.2.2.4. Table 26 shows the certification schemes usable as proxies to comply with the sustainability criteria for aquatic biomass.

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[51] Assessment from the Catalogue of sustainability certification schemes and labels by Sustainability Certification for Biobased System. Funded by European Union.
[52] World Bioenergy Association. Global Bioenergy Statistics Report 2024
[53] Ibid.

Table 24. Agricultural biomass voluntary tools and their compliance with Climate Bonds sustainability criteria.

Certification scheme	AGRICULTURAL BIOMASS: Biomass produced from agriculture, including algae if cultivated on land in ponds or in photoreactors, and residues from agriculture, aquaculture and fisheries									
	Criterion 1 ILUC risk management	Criterion 2 Soil quality and soil carbon management	Criterion 3 High-carbon stock area	Criterion 4 Peatland with drainage	Criterion 5 High Biodiversity value area	Criterion 6 Water use	Criterion 7 Pollution (air and fertilizers)	Criterion 8 Food security	Criterion 9 Socio-economic	Criterion 10 Circularity (waste)	Criterion 11 Methane abatement best-practises
ISCC[54]	Low ILUC risk feedstock criteria	Principle 1 (Criterion 1.4)	Principle 1 (Criterion 1.2)	Principle 1 (Criterion 1.3)	Principle 1 (Criterion 1.1)	Principle 2 (Criterion 2.9)	Principle 1 (Criterion 2.3 and 2.10)	Principle 4 (Criterion 4.1.4)	Principles 3,4 and 5	Principle 2 (Criterion 2.7)	CBI Criteria
RSB[55]	RSB low ILUC Biomass criteria	Principle 8 (Criterion 8.a)	Principle 7 (Criterion 7.a)	Principle 7 (Criterion 7.a)	Principle 7 (Criterion 7.a)	Principle 9	Principles 10 and 11 (Criterion 11.d)	Principle 6	Principles 4 and 5	Principle 11	CBI criteria
Better Biomass[56]	Criterion 6.3.3	Criterion 6.5.1.1 and 6.5.1.2	Criterion 6.2.2.	Criterion 6.2.2.	Criterion 6.4.1 and 6.4.2	Criterion 6.5.2.1 and 6.5.5.2	Criterion 6.5.1.1, 6.5.2.1, 6.5.3.1 and 6.5.3.2	Criterion 6.3.1	Criterion 6.6 and 6.7	Criterion 6.3.2, 6.5.4.1 and 6.5.4.2	CBI criteria
CORSIA	Not included	Principle 5	Principle 2	Principle 2	Principle 7	Principle 4 and 12	Principle 6 and 8	Principle 14	Principle 10, 11 and 13	Principle 8	CBI criteria
SBP	Not included	Principle 2 (Criterion 2.2.2, 2.2.3 and 2.2.4)	Principle 2 (Criterion 2.2)	Principle 2 (Criterion 2.2.1)	Principle 2 (Criterion 2.1 and 2.2)	Principle 2 (Criterion 2.2.5)	Principle 2 (Criterion 2.2.6 and 2.2.7)	Principle 4 (Criterion 4.2.3)	Principle 4	Principle 2 (Criterion 2.2.8)	CBI criteria
ClassNK	Not included	Theme 5	Theme 2	Theme 2	Theme 7	Theme 4 and 12	Theme 6 and 12	Theme 14	Theme 10, 11 and 13	Theme 8	CBI criteria
RSPO[57]	Not included	Criterion 7.4 to 7.6	Criterion 7.12	Criterion 7.7	Criterion 7.12	Criterion 7.8	Criterion 7.1, 7.2, 7.10, 7.11 and 3.4	Criterion 3.4, 4.3 and 4.5	Criterion 2.2, 4.4 to 4.8, 6.1 to 6.6 and 7.2	Criterion 7.3	CBI criteria
Bonsucro[58]	Not included	Criterion 4.2	Criterion 4.1.3	Criterion 4.1.3	Criterion 4.1	Criterion 4.3	Criterion 4.4, 4.5 and 5.2	Not included	Criterion 2.1 to 2.5 and 5.3 and 5.4	Criterion 5.3	CBI criteria
Better Cotton[59]	Not included	Criterion 3.1	Criterion 4.2	Criterion 2.1 and 4.2	Criterion 4.1 and 4.2	Criterion 2.1	Criterion 1.1 to 1.5, 1.8 to 1.9 and 3.1	Not included	Criterion 4.2, 6.1 to 6.21	Criterion 1.8 and 1.10	CBI criteria
SURE	Not included	Criterion 5.6.1 to 5.6.6	Criterion 5.4	Criterion 5.5	Criterion 5.1 to 5.3	Criterion 5.6.11 and 5.6.12	Criterion 5.6.7 to 5.6.9	Not included	Criterion 4.6.1	Not included	CBI criteria

[54] Assessment from the Catalogue of sustainability certification schemes and labels by Sustainability Certification for Biobased System. Funded by European Union.
[55] Ibid.
[56] Ibid.
[57] Ibid.
[58] Ibid.
[59] Assessment from the Catalogue of sustainability certification schemes and labels by Sustainability Certification for Biobased System. Funded by European Union.

Certification scheme	AGRICULTURAL BIOMASS: Biomass produced from agriculture, including algae if cultivated on land in ponds or in photoreactors, and residues from agriculture, aquaculture and fisheries										
	Criterion 1 ILUC risk management	Criterion 2 Soil quality and soil carbon management	Criterion 3 High-carbon stock area	Criterion 4 Peatland with drainage	Criterion 5 High Biodiversity value area	Criterion 6 Water use	Criterion 7 Pollution (air and fertilizers)	Criterion 8 Food security	Criterion 9 Socio-economic	Criterion 10 Circularity (waste)	Criterion 11 Methane abatement best-practises
2BSvs	Not included	Principle 4	Principle 5	Principle 6	Principle 3	Principle 8	Principle 8	Not included	Principle 9	Not included	CBI criteria
FSS*		Principle 11				Principle 10		Principle 2	Principles 2,4,5,6,8,9,13,14,15,16 and 17		

*FSS. Food security system is an independent voluntary scheme to cover food security impacts of biomass feedstock. It can be used in combination with other voluntary schemes that don`t included food security impact of the biomass.

Table 25. Forestry biomass voluntary tools and their compliance with Climate Bonds sustainability criteria.

Certification scheme	FORESTRY BIOMASS: Any plant matter or tree material produced by forest growth that can be converted to an energy source, including forestry residues (domestic forest biomass is excluded as it is covered by other ClimateBonds criteria)							
	Criterion 1 Sustainable Forest Management						Criterion 2 Land use, land use change and forestry (LULUCF)	Criterion 3 Socio-economic
	Legal harvesting	*Forest regeneration*	*Soil quality and Biodiversity*	*Capacity of the forest*	*Nature protection areas*	*High biodiversity areas*	*Carbon stocks and sinks maintained*	
PEFC	Criterion 6.3.1	Criterion 8.4.4	Criterion 8.4 and 8.5	Criterion 8.3.1, 8.3.3 and 8.3.4		Criterion 8.4.1, 8.1.5 and 8.1.6	Criterion 8.1.2 and 8.1.5	Criterion 6.3.3, 6.3.4 and 8.6
FSC[60]	Principle 1	Criterion 10.1 and 10.2	Criterion 10.6, 10.7, 10.8, 10.9 and 10.10	Criterion 5.2	Criterion 6.4 and 6.5	Criterion 6.9, 6.10, 6.11 and Principle 9	Criterion 6.3	Principles 2, 3 and 4
ISCC	Criterion 1.1	Criterion 1.1	Criterion 1.1	Criterion 1.1	Criterion 1.1	Criterion 1.1	Criterion 1.2	Principles 2, 3 and 4
SBP	Principle 1	Criterion 2.2.9 and 2.2.10	Criterion 2.2.3	Criterion 2.2.2	Criterion 2.1	Criterion 2.1	Principle 3	Principle 4

[60] Assessment from the Catalogue of sustainability certification schemes and labels by Sustainability Certification for Biobased System. Funded by European Union.

Table 26. Aquatic biomass voluntary tools and their compliance with Climate Bonds sustainability criteria.

Certification scheme	AQUATIC BIOMASS: Cultivated or harvested water-based plants or algae, and associate derivates		
	Criterion 1 Sustainable Wild Population	Criterion 2 Pollution	Criterion 3 Socio-economic
	High biodiversity areas	*Carbon stocks and sinks maintained*	
ASC-MSC JAS	Principle 1	Principle 2 Criterion 5.1, 5.3, 5.4, 5.6 and 5.7	Principles 4 and 5

4 An overview of the criteria for adaptation & resilience

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".[61]

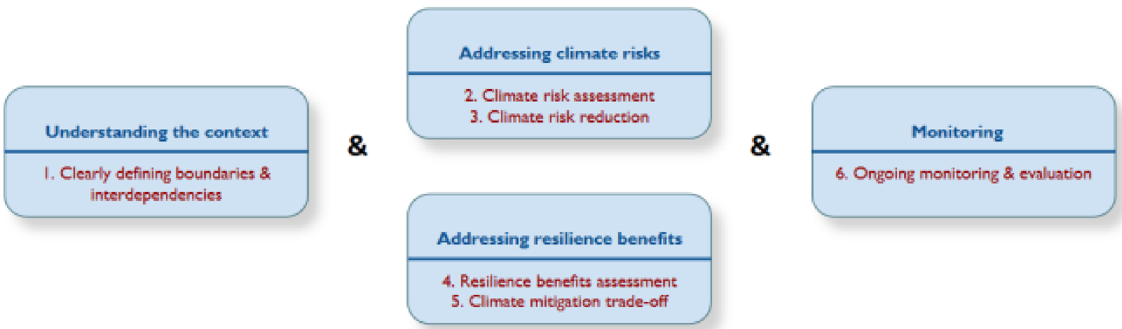
The IPCC defines resilience as: "The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning 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.

4.1 Key aspects to be assessed

Climate adaptation and resilience Criteria are designed to ensure that a project itself is resilient to climate change and that it does not affect the resilience of other sectors. The development of the requirements for the A&R component was based on CBI's "Climate resilience principles" document.[62] **¡Error! No se encuentra el origen de la referencia.** gives an overview of the six principles for r esilience. From the perspective of an entity, the Climate Adaptation and Resilience Criteria aim to assure that the entity will be able to provide its commodity taking into account the hazard risks associated with climate change without harming the resilience of other sectors or subsectors eventually connected within the boundaries of the entity.

Figure 14: The CBI's principles for Resilience.



Source: Climate Bonds Initiative

Although the principles provide a framework and serve as guidance for general aspects to consider, it is also recognised the challenges and limitations to assess the adaptation and resilience aspects in general. Such limitations include the lack of awareness of climate resilience benefits and a common language, robust data on climate risks and common methodologies for climate risk assessment, lack of capacity and interdependencies with other assets or actors in the supply chains. It is also acknowledged that A&R has inherent complexities which makes it harder to quantify and it can be very context specific, depending not only on location

[61] 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. www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf

[62] CBI (2019). Climate Resilience Principles. A framework for assessing climate resilience investments. www.climatebonds.net/climate-resilience-principles

but also on the type of asset, the type of risk looked at, the level of severity and frequency of the risk, and so on. The frequency and magnitude of the impacts are commonly underestimated by companies.

In the case of an entity owning and operating several assets, spread geographically an Adaptation and Resilience assessment of each asset may involve additional difficulties to assess the Criteria for each plant and for the whole entity as the addition of all the individual assets.

Adaptation and Resilience Criteria for entity's certification will ask the entity to hold and assessment considering the climate hazards to which will be exposed and vulnerable over its operating life including the measures identified and the plan to implement them to manage and mitigate the risks identified. The Criteria also requires ongoing monitoring and evaluation of the relevance of the risks and resilience measures and related projects adjustments as needed.

4.2 Practical considerations for this Component

Leverage existing tools

The A&R Component will require consideration of a highly complex and varied set of issues across the environmental and social spectrum for which data, methodologies and metrics may not be available. Qualitative methods based on verification lists or questionnaires have been proposed which can however be leveraged. It is not appropriate for Climate Bonds to commit resources to address these issues, and the guiding principle of simplicity shall be applied at this time. More robust criteria can be developed over time as more information is generated and integrated in the subsequent revisions of the Criteria.

However, it should be noted that existing methods do not always fully or explicitly cover the additional, often interrelated impacts connected to climate adaptation and resilience. Many of the risk assessments and management processes specified by existing guidelines will be a prerequisite for identifying A&R risks, but more may be needed to fully address them given that this is an emerging topic.

Minimise the assessment burden

In addition, there needs to be a balance between rigour and practicality. Any Criteria with a prohibitively expensive assessment burden will discourage certification. Any methodology adopted therefore need to avoid this.

Retrospective application

Finance raised in this sector may be for new, greenfield facilities, for retrofits or upgrades to existing facilities, or they may be a straight refinancing of an existing facility. Therefore, any proposal and associated approved assessment tool under this Component needs to be usable for both new and existing facilities.

This is not a straightforward issue; as in the case of refinancing, the facility may have been operating for a number of years. It may have been compliant with best practices in place at the time of its implementation but may not meet current best practice requirements. The selected methodology and tool will therefore need to be able to address and resolve any 'legacy issues' that may be identified.

Timeframes

Appropriate time horizons for climate resilience assessments need to be set for the assets and activities in scope. The criteria to base the time horizon for the assessments are set based on the typical lifetimes of assets in the sector which is 30 years on average.[63]

Disclosure

As part of the monitoring and evaluation principle, there are requirements for reporting and disclosing risks assessments. Currently there are a number of issues seen:

- a lack of alignment or harmonisation as reporting is often undertaken on a voluntary basis.
- the level of completeness can be low which leads to accusations of greenwashing.

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[63] Energy sources and power plants lifetime by type | Statista

- the frequency for reporting and updating the assessment varies (recognising that the time horizons for revisiting the assessments will likely depend on the level of risk of a facility: low risk facilities can have long time horizons, and high-risk facilities short time horizons). Depending on the severity of the risk the time horizon can be set.

Wider environmental and social risks

They are complex and interconnected and should be assessed under these Criteria, however the following points are noted:

- The Climate Bonds Standard is focused on climate impacts - including low GHG-compatibility (mitigation) and also climate adaptation and resilience. Defining resilience can be challenging. However, it is clear that many topics which have been a part of environmental and social assessments for a number of years overlap significantly with the resilience of affected populations and ecosystems and their ability to adapt to climate change.
- The most obvious example is the potential impact of climate change on hydrological conditions, and consequently water supply and local livelihoods. Another is climate change exacerbating ecological problems such as impaired species migration and algal blooms. Environmental and social impacts such as these, already complex and interconnected, become more so when climate change impacts and risks are taken into account, and there is a logic to addressing all key environmental factors, rather than trying to separate them out.

The Climate Bonds Standard does not usually address primarily social impact issues, these were discussed but not considered within scope.

4.3 Existing tools and guidelines considered

A range of existing tools and guidelines with the most potential to be leveraged for the Bioenergy Criteria are listed below, with a brief indication of whether they were taken forward for further consideration or not.

Risk Assessment and Climate Scenarios

- The ISO 14091:2021 Adaptation to climate change - Guidelines on vulnerability, impacts and risk assessment standard offers guidelines for assessing the risks related to the potential impacts of climate change.[64]
- Risks can be characterised 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.
- A broad range of models can be used to generate climate scenarios. Users should apply climate scenarios based on representative concentration pathway (RCP) 4.5 and 8.5 or similar / equivalent to ensure consideration for the worst case scenario. (The IPCC 'Shared Socioeconomic Pathways' to develop potential temperature scenarios. SSP5-8.5 is the highest warming pathway, SSP3-7.0 the second highest and so on).
- The IPCC Sixth Assessment report also provides an indication as to how different temperatures impact the likelihood and severity of different climate impacts.
- A framework for risk management for climate security. www.c2es.org/document/degrees-of-risk-defining-a-risk-management-framework-for-climate-security/
- Climate Change Risk Assessment Guidelines. www.ctc-n.org/system/files/dossier/3b/D4.2%20Climate%20change%20risk%20assessment%20guidelines.pdf

[64] www.iso.org/standard/68508.html

Annex I: TWG and IWG members

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Participation in IWG meetings does not necessarily reflect endorsement of the Criteria and serves to provide critical feedback on the usability-focused consultation process.

IWG Members			
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Acronyms

ASC-MSC Aquaculture Stewardship Council – Marine Stewardships Council

CHP Combined Heat and Power

CORSIA Carbon Offsetting and Reduction Scheme for International Aviation

gCO2e grams of equivalent carbon dioxide

FSC Forest Stewardship Council

FSS Food Security Standard

GHG Greenhouse gases

iLUC Indirect Land Use Change

ISCC International Sustainability and Carbon Certification

JAS Japanese Agricultural Standard

LDAR Leakage, Detection and Repair

LCA Life Cycle Analysis

LHV Low Heating Value

MJ Mega Joules

PEFC Programme for the Endorsement of Forest Certification

RMP Remaining Methane Potential

RSB Roundtable on Sustainable Biomaterials

SBP Sustainable Biomass Programme