Sustainability criteria for biofuels

A review of sustainability frameworks and the role of certification schemes

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About Smart Freight Centre

Smart Freight Centre is an international non-profit organization focused on reducing greenhouse gas emissions from freight transportation. Smart Freight Centre's vision is an efficient and zero emission global logistics sector. Smart Freight Centre's mission is to collaborate with the organization's global partners to quantify impacts, identify solutions, and propagate logistics decarbonization strategies. Smart Freight Centre's goal is to guide the global logistics industry in tracking and reducing the industry's greenhouse gas emissions by one billion tonnes by 2030 and to reach zero emissions by 2050 or earlier, consistent with a 1.5°C future.

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Contents

Tables

Figures

Executive Summary

The 'Sustainability criteria for biofuels' report is part of Smart Freight Centre's series on biofuels, where we address different perspectives on impact, greenhouse gas emissions and implementation challenges of biofuels as a decarbonization solution. The full series is available here.

Introduction to the report

The use of biofuels as an emissions-reduction solution in the road freight sector requires an understanding of wider sustainability issues in addition to its impact on greenhouse gas emissions. In particular, the concern is that the agricultural activity used to grow biomass may cause harm to the local community and environment. This applies primarily to certain feedstock grown on dedicated land, which is currently the main feedstock type used to produce biofuel in the EU. Shippers may not necessarily be aware of these issues and have the risk of indirectly violating their sustainability commitments if biofuels are integrated into their transport operations.

This study has two main aims:

- Compare and contrast principles used in existing sustainability frameworks, which serves to explore wider sustainability topics beyond the well-addressed GHG lifecycle topic.
- Understand how these frameworks are used and complied with, specifically via certification.

A definition of sustainability often derives from the definition of sustainable development by the United Nations, that is "meeting the needs of the present without compromising the ability of future generations to meet their own needs", and accounts for the effects of human activity from economic, environmental, and social perspective. Sustainability must be defined and operationalized in context. It is often expressed as a set of principles, criteria and indicators addressing a particular sustainability issue.

The sustainability frameworks reviewed in this work have diverse coverage in terms of transport mode, geographical scope, and purpose. These are from the Sustainable Shipping Initiative, Low Carbon Fuel Standard (LCFS), Renewable Energy Directive II (RED II), Roundtable on Sustainable Biomaterials (RSB), Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), Energy Transitions Commission, and the International Sustainability and Carbon Certification (ISCC). The frameworks have three main purposes: to serve as guidance and information about sustainability issues, provide criteria and indicators in legislation, and in sustainable fuel certification schemes. Thus, they also have different coverage and definitions of sustainability. Further, the frameworks may provide different principles, criteria and indicators although addressing the same issue.

Sustainability issues in biofuels

Fifteen issues were identified, which fall under the environmental, social, and economic sustainability categories, and a general category.

- **Environmental**: greenhouse gas emissions (GHG); short lived climate forcers (SLCF) emissions; air quality; carbon source; electricity or energy source; water; sustainable resource use; soil health; and ecological impacts.
- **Social**: social equity; social, labor, and human rights; food security; health, safety and security.
- **Economic**: economic well-being.
- **General**: continuous improvement.

It is important that other types of factors leading to climate change are considered, besides GHG emissions, such as SLCF emissions, carbon source and electricity or energy source. Not every framework has the same coverage or include them in the same way.

An issue surrounded by confusion – due to the lack of transparency and difficulty to measure - is the impact from land use change on the carbon stock depending on the carbon source, in other words, the feedstock. Carbon sources associated with the release of carbon from soil or with the reduction of absorption potential, such as in peatland and forests, should be avoided. In some regions, especially in rural and poor regions, the use of crops or the land itself for biofuel feedstock may impact the price and availability of food. A consequence of this is the impact on food security of the community and indirect land use change if other food agricultural land use change is caused. Emissions caused by indirect land use change, while not included in lifecycle emissions accounting, should nevertheless be accounted for separately.

Other sustainability issues are mostly localized within the community or region and are caused by the practices in agricultural and chemical sector, during the feedstock cultivation and fuel production stages, respectively. Several issues, such as the water, land use and health, and safety and security issues, have both a physical environmental aspect and a social aspect to them. Agricultural chemical production practices can lead to runoff, which may affect the ecosystem and the communities that depend on them; however, good agricultural and chemical sector practices can easily mitigate many of these issues.

Finally, it is important that the economic well-being of the entire community improves, but also among marginalized groups and those who are employed in the agricultural and chemical sector. These are issues that are very difficult to monitor and evaluate, even by certification schemes. Nevertheless, these are vital for the flourishing of the community and to ensure that the supply of biofuel feedstock continues.

The role of certification schemes

To understand the role of certification schemes, we reviewed 8 different policies: the RED II, CORSIA, the Renewable Transport Fuel Obligation (RTFO), Queensland's Biofuels Mandate (QBM), North South Wales Biofuels Regulation (NSW BR), Brazil's RenovaBio, California's LCFS and the US Federal Renewable Fuel Standard (RFS). The adoption of sustainability criteria for biofuels in legislative frameworks across the world are not harmonized, neither in terms of the scope of biofuels industry, nor in terms of the aspects included. The discrepancy can occur even in the same country, as in the case of Queensland's Biofuels Mandate and North South Wales Biofuels Regulation in Australia, or in comparison between California's Low Carbon Fuel Standard (LCFS) and the US Federal Renewable Fuel Standard (RFS). It was also found that some countries had some form of biofuel legislation but did not require GHG emissions calculation nor any sustainability criteria.

Most of the legislation looked at in the study applied only to the road vehicle fuels, except CORSIA, which is used for the aviation sector and the LCFS, which also applies to jet fuel. No equivalent standard or legislation was found for the maritime sector, although the EU's Monitoring, Reporting and Verification Regulation mandates the registration of CO_2 emissions of certain maritime vessels, and the IMO Data Collection System requires the registration of fuel consumption. There are several developments on the horizon that intend to introduce sustainability criteria for renewable maritime fuels, such as the EU's FuelEU Maritime and the work by IMO's Intersessional Meeting of the Working Group on Reduction of GHG Emissions from Ships.

Nevertheless, in the absence of globally harmonized criteria, there is space for 3rd party certification standards to be developed, both to harmonize the criteria across the transport chain, as well as to reduce barriers to the supply of biofuels to different markets.

The review of the legislative requirements also showed discrepancy in how the sustainability criteria and GHG emissions reporting should be verified. The RenovaBio, LCFS and RFS rely primarily on accredited verifiers and their own verification procedures. The other policies allow for 3rd party voluntary schemes or mandate certification by a 3rd party certification scheme. EU RED II and RTFO explicitly allow for approved voluntary schemes to prove compliance with the sustainability criteria. Eleven out of the twelve approved voluntary schemes for the RED II and RTFO are the same. CORSIA only allows for two certification schemes provided by the largest certification scheme providers, the International Sustainability and Carbon Certification (ISCC) and the Roundtable on Sustainable Biomaterials (RSB). Some of the certification schemes are favored by different countries or specific types of feedstocks, such as sugar cane (Bonsucro EU) or palm oil (RSPO).

Conclusion

The study highlights the need for a consistent and interoperable sustainability criteria framework for the transport sector. The frameworks mandatory for road biofuels are limited in scope, compared to the one applied in the aviation sector by the International Civil Aviation Organization (ICAO), which is set to become mandatory beginning in 2027 There are currently no mandatory frameworks applied in the maritime sector. The use of a common sustainability framework, if not a cross-compatible certification scheme, will support multimodal transport operators that operate globally. It should have broad acceptance and buy-in from the different markets and address the issues arising in the wide variety of biofuels and blends used by all transport modes.

While the development and auditing of certification schemes have their challenges, a good and reputable certification scheme and auditing company may provide biofuel buyers, the confidence that wider sustainability criteria are met. Food supply chain actors, in particular, should be mindful that the use of biofuel do not interfere with the sustainability commitments made for their food supply chain, especially when there could be potential conflicts between the production of fuel and food. On the other hand, they may use their influence and purchasing power to push the transport and fuel industry to higher levels of accountability.

Finally, while the study focused on sustainability of biofuels, it is important to raise the question of wider sustainability impacts of other types of fuels, such as the more prominent ones: renewable electricity and hydrogen. The production of these fuels is highly industrialized and often, but not necessarily, located where they are to be used, in contrast to feedstock, that can be cultivated in developing countries and used elsewhere. Furthermore, the wider impacts of the zero-emissions vehicle production should also be considered. Further research could cast light on how the sustainability issues of the full fuel and vehicle lifecycles measure up side-by-side, in order to inform us of the impact of the transport sector's decarbonization transition.

1 Introduction

The ‘Sustainability criteria for biofuels’ report is part of Smart Freight Centre’s series on biofuels, where we address different perspectives on impact, greenhouse gas emissions and implementation challenges of biofuels as a decarbonization solution. The full series is available here.

While the focus of Smart Freight Centre has always been about reducing the emissions of greenhouse gases (GHGs) in the freight transport sector, when the impact of biofuel is explored, broader issues of sustainability also need to be addressed. The main point of controversy about biofuels is this. If unregulated, agricultural activity to grow biomass used in biofuel production may cause harm to the community and environment. Shippers may not necessarily be aware of how biofuel is produced upstream. Hence, shippers (and carriers) must ensure that the procurement of biofuels introduced in their decarbonization efforts do not indirectly violate the sustainability commitments made in their main procurement activities.

This study has two main aims:

- Compare and contrast criteria used in existing sustainability frameworks, which serves to explore wider sustainability topics beyond the well-addressed GHG lifecycle topic.
- Understand applicability of the frameworks to different stakeholders and how it can be addressed, specifically via the need for certification.

The first part of the study reviews seven sustainability frameworks diverse in terms of purpose, application, and jurisdiction. The criteria included in each framework that addressed similar issues were discussed together, in terms of their principles, the criteria used to express the principle, and the indicators used to evaluate the criteria.

The second part of the study provides a suggestion on how certification schemes may be selected depending on the applicability to the user’s needs. The work conducted within our study focused on legislative requirements on biofuels globally.

The outcome of this study is expected to support the development of a sustainability framework relevant to the global transport sector, and conceptually aligned with the work of Smart Freight Centre. Further, it identifies the issues that are relevant for the procurement of sustainable biofuel-based transport, thus enabling a coherent commitment to sustainability – from sustainable supply chains to sustainable freight transport.

In the next two sections, an overview of the biofuel production pathways and the importance of sustainability criteria frameworks are presented.

2 Biofuel lifecycle perspective

In understanding the sustainability of biofuels, especially with respect to its feedstock cultivation and production, biofuels can be differentiated into three main categories[i] (ETC, 2021).

- Feedstock grown on dedicated land: energy crops, food crops or forest material.
- Feedstock sourced from waste and residue: forest and agriculture production waste or municipal and industrial waste.
- Feedstock from aquatic sources, i.e., algae.

Figure 1 illustrates the lifecycle of the biofuel from feedstock cultivation (including land preparation) to processing and transport until its end-use. Ascertaining the GHG emissions from well-to-tank (WTT) is complicated, especially when considering carbon credits assigned to various feedstock (e.g. wet manure is given credit for avoided direct methane emissions) and the impacts of indirect land-use change (iLUC) (Smart Freight Centre & ifeu, 2021). Tank-to-wheel[ii] (TTW) emissions, on the other hand, only include non-CO_2 emissions by convention. Only certain fuel pathways may result in well-to-wheel (WTW) GHG savings. These allow for decarbonization of transport, where alternative low or zero-carbon fuels are not feasible.

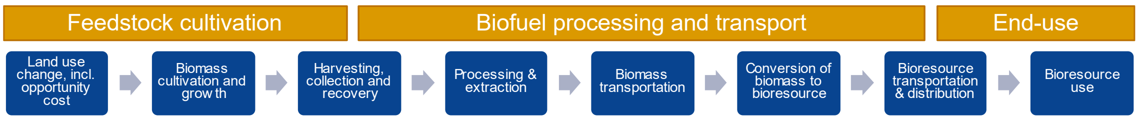

Figure 1 Biofuel lifecycle from feedstock cultivation to biofuel use (Source: adapted from ETC, 2021)

Nevertheless, as lifecycle GHG emissions need to be considered in the use of biofuels, so also may other impacts that occur, especially in the stage of feedstock cultivation (or production). This stage is predominantly agricultural activity, strongly related to land management and agricultural practices, which may also lead to other types of unintended impacts on the local economy, environment, and community.

3 Sustainability criteria frameworks

A sustainability criteria framework makes sustainability defined for a particular activity or industry functional. A definition of sustainability often derives from the basic definition of sustainable development, that is "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987) and accounts for the effects of human activity from three different perspectives: economic, environmental and social.

The application of the sustainability paradigm is strongly context- and sector-specific, such that the impacts and emphasis could vary wildly (UNCTAD, 2018). For instance, sustainable freight and maritime transport are widely accepted as being transport infrastructure and services that are safe, economically efficient and competitive, socially inclusive, accessible, reliable, transparent, affordable, fuel-efficient, environmentally friendly (land, air and water), respectful of land and marine resources, low-carbon and resilient to shocks and disruptions including those caused by climate change and natural disasters (SSI & CBS Maritime, 2021; UNCTAD, 2017). In contrast, a definition of sustainable biomass supply is "material that is renewable, has a lifecycle carbon footprint equal or close to zero (including emissions related to indirect land-use change), and for which the cultivation and harvesting practices used are mindful of ecological considerations, such as biodiversity and health of the land and soil, as well as social aspects" (ETC, 2021).

These high-level definitions often need to be expressed in principles (i.e., explaining why a sustainability issue is relevant and what is the goal), criteria (i.e. conditions(s) to meet the principle) and indicators (i.e. how the criteria are measured or evaluated). The sustainability criteria framework presents how the principles, criteria and indicators fit together to serve a specific purpose. The extent to which these are developed depends on the purpose of the framework.

This study reviewed seven diverse frameworks in purpose, application, and jurisdiction. These are summarized in Table 1. The three main purposes identified in the desk review:

- To serve as guidance and information about sustainability issues
- To provide criteria and indicators in legislation
- To provide criteria and indicators for a certification scheme

Table 1 Overview of frameworks studied

Framework	Mode and fuel	Geographical	Purpose
Sustainable Shipping Initiative (SSI) (SSI & CBS Maritime, 2021)	Maritime	Global	Guidance
Low Carbon Fuel Standard (LCFS) (CARB, 2018)	Road, all fuels inc. biofuels	California	Legislation - Credit market scheme for fuel suppliers
RED II (RED II, 2018)	All modes	Europe	Legislation - EU Member States quota of renewable energy
Roundtable on Sustainable Biomaterials (RSB) (2016)	All modes using biofuels	Global	Certification
Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) (ICAO, 2021c)	Air transport	Global	Legislation - Eligible fuels for ICAO emissions offset scheme
ETC (2021)	All modes using biofuels	Global	Guidance
International Sustainability and Carbon Certification (ISCC) (2020)	All modes using biofuels	Global	Certification

Guidance documents often allow for the inclusion of a very broad set of issues, as they often serve to recommend the consideration of sustainability issues in their target industry. In contrast, in legislation and certification schemes, sustainability criteria and indicators need to be clear and practical to serve in the assessment framework. They also tend to be more narrowly or conservatively defined to the main aims of the framework.

In the next section, the sustainability issues and themes raised in the frameworks are presented.

4 Sustainability themes

Fifteen unique sustainability issues have been identified and classified under four main sustainability categories: environmental, social, economic, and general. An overview is presented in Table 2. One notes that coverage of the issues may vary between the different frameworks. This should not be taken as an indication of a better framework but should be considered a reflection of the function of the framework within its broader context, as well as how the framework was developed. For instance, a framework used in legislation, such as the LCFS and RED II, is often narrowly defined to address specific regulatory needs (e.g., low carbon or renewable fuels) and to ensure it does not overlap with other legislation, such as those dealing with air pollutant emission standards or labor rights within the country. In contrast, frameworks proposed in guidance documents, such as the SSI, serves to explore and guide thinking in the field, and thus can afford to be more comprehensive than legislation and certification schemes. Certification schemes, especially ones that have a global scope, will address issues pertinent by the stakeholders (or clients) and may result in quite different issues covered in geographically bound legislation.

Another aspect to bear in mind is that these frameworks may also differ in how they address each issue, especially in terms of criteria, indicators and the underlying methods used to evaluate the indicators. The following sections will discuss each theme with respect to those aspects, as well as relevant details about the definitions, the impact, and other practicalities.

Table 2 Overview of sustainability issues addressed in the seven frameworks

Category	Sustainability Issue	SSI	LCFS	RED II	RSB	CORSIA	ETC	ISCC
	GHG emissions	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Short Lived Climate Forcers emissions	Yes						
	Air quality	Yes	Yes		Yes	Yes		Yes
	Carbon source	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Environmental	Electricity/energy source	Yes	Yes	Yes	Yes			Yes
	Water	Yes			Yes	Yes		Yes
	Sustainable resource use	Yes			Yes	Yes		Yes
	Soil health	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Ecological impacts	Yes		Yes	Yes	Yes	Yes	Yes
	Social equity	Yes			Yes	Yes		
Social	Social, labour and human rights	Yes			Yes	Yes		Yes
	Food security	Yes			Yes	Yes	Yes	
	Health, safety and security	Yes			Yes			
Economic	Economic well-being	Yes			Yes			Yes
General	Continuous improvement	Yes	Yes		Yes			Yes

4.1 Greenhouse Gas Emissions

The Kyoto Protocol greenhouse gases (GHG) include carbon dioxide, perfluorocarbons, nitrous oxide, nitrogen trifluoride, hydrofluorocarbons, sulphur hexafluoride and methane. The global warming impacts of these GHGs are expressed as CO_2-equivalent.

Although biofuels are considered, by convention, to have zero TTW CO_2 emissions, they may still produce other high global warming potential GHGs, such as methane or nitrous oxide. In the production and transportation of the fuel, i.e., in the WTT stage, GHGs might be produced from land-use change impacts, the release of soil carbon stock, and in the processing and distribution of the fuel.

The frameworks generally consider the WTW lifecycle GHG emissions in their definitions, except the ETC that only considers the WTT stage. ETC focuses primarily on the production of feedstock and thus does not consider the use of the fuel. The frameworks express the reduction in lifecycle GHG emissions, either in absolute terms (e.g., used in SSI), or percentage (e.g. used in CORSIA and RSB).

Despite how similar some of the definitions are, the level of ambition and precision expressed in the criteria can vary. For example, SSI and ETC provide a general emission reduction target, whereas RSB provides further detailed requirements for boundary-setting and compliance with local and regional regulations.

GHGs emissions, which can be directly or indirectly released along the lifecycle of biofuels, contribute to climate change and the associated effects on the world. Other impacts, such as air pollution, are also related to the release of GHGs into the atmosphere and are treated in sustainability issues of air quality and SLCF emissions.

To understand the extent of these impacts, the Global Bioenergy Partnership (GBEP) (2011) considers the following key aspects for the calculation of GHG emissions from the production and use of biofuels.

- The scope of the lifecycle analysis: The model used should cover the full life cycle of the fuel and be appropriate for the region of interest. There are life-cycle databases with global coverage such as GEMIS, EcoInvent or GaBi or national alternatives, such as GREET (US), GHGenius (Canada).
- Allocation of impacts to bioenergy: When several products are generated, emissions can be allocated according to different approaches. Some common physical allocation approaches are the mass and energy allocation. CORSIA and RED II propose an energy allocation methodology, based on lower heating value. RSB (2017) uses economic allocation, although it is considered to be less precise due to possible price fluctuations of raw materials and final products.
- Estimation of GHG emissions from land-use change: Primary data for land-use change from Intergovernmental Panel on Climate Change (IPCC) report on land to land for bioenergy crops, as well as measurements of the biogenic carbon on the land before and after the land-use change is preferred. In the cases where the share of land dedicated to bioenergy crops, or the biogenic carbon changes are unknown, appropriate estimates and IPCC default values are to be used. A good resource to use is the agri-footprint database from Blonk (Blonk Sustainability, 2022).
- Inclusion of potential soil organic carbon storage: Soil organic carbon net changes should be included as part of the lifecycle assessment. Attribution is particularly challenging as bioenergy crops are normally grown in rotation with other crops, the rotation periods might vary depending on the market and climate conditions.

4.2 Short-Lived Climate Forcers (SLCF) Emissions

Short-lived climate forcers (SLCF), sometimes called short-lived climate pollutants, are gaseous or air-borne particulates that have a strong impact on the climate, although it remains in the atmosphere for a much shorter period than carbon dioxide. They may also have impacts on air quality, thus affecting health and agriculture. The IPCC considers the following to be SLCFs: black carbon, organic carbon, particulate matter 2.5 microns or smaller, nitrogen oxide, carbon monoxide, non-methane volatile organic compounds (including biogenic volatile organic compounds, sulphur dioxide, ammonia, methane, and halogenated compounds. Nitrogen oxides to ammonia (from the list) are considered precursors to ozone or other aerosols.

Only the SSI considers the SLCF a unique sustainability issue. Other frameworks may include some of the compounds as GHG emissions, such as nitrogen oxides, methane, and halogenated compounds, or under air quality issues.

In terms of impacts, short-lived climate forcers (primarily Black Carbon, methane and hydrofluorocarbons) are estimated to contribute 0.6 C to global warming by 2050 (UNEP & WMO, 2011). Black carbon is estimated to have from 460 to 1,500 times the warming potential than carbon dioxide per unit mass. A model of global energy-related emissions estimated that about 26% was due to fuel combustion in transport. On-road and off-road (i.e., rail, maritime) diesel engines are the main contributors.

To facilitate the measurement of these emissions, the IPCC Task Force on National Greenhouse Gas Inventories is developing a methodology report on SLCFs, which will provide guidance on making an inventory of these pollutants. Many of the pollutants as mentioned earlier have already been addressed under different headings (i.e., lifecycle GHG emissions and air quality) and have a well-established estimation methodology. Smart Freight Centre also provides a Black Carbon Methodology for the Logistics Sector as a companion to the GLEC Framework methodology (Smart Freight Centre, 2017).

4.3 Air quality

The EU considers sulphur dioxide, nitrogen dioxide, nitrogen oxides, particulate matter and carbon monoxide to be relevant to air quality issues (Air Quality Directive, 2008). Additionally, ISCC considers under this category volatile organic compounds, particulate matter, dioxins, and other substances, such as heavy metal, ammonia or dust.

Air quality is a major concern in the transport system, as air pollutants are normally emitted during combustion and have a negative impact on the environment and human health. Areas with high population density and high levels of traffic are particularly exposed to related health problems, hence fuels, which can reduce these emissions will drastically improve the lives of residents. Despite its important impacts on the environment and human health, there is not a consensus on how to account for these emissions. An agreement on the definition of most important impacts would be needed, as well as how to combine them in a common indicator which comprises all impacts. According to GBEP, the measurement of air quality presents several challenges and requires the work of experts from different disciplines.

Air quality should be considered from a full life cycle perspective, considering upstream emissions from the production, processing, and distribution of the biofuels, as well as the emissions from combustion. Both upstream and downstream emissions can be derived from literature (Franke et al., 2013) and models (e.g., GEMIS and GREET). Air toxics (e.g., heavy metals, polycyclic aromatic hydrocarbons, etc.) would only be accounted for in the direct emissions from combustion, where they are more relevant. The impacts are differentiated by where they occur, e.g. an emission close to ground in a densely populated area will receive a higher impact factor than one in a remote area or at a high altitude. Some life cycle impact assessment methods for air pollution modelling include EcoInvent, GaBi and ProBas.

4.4 Carbon Source

The carbon source sustainability issue is defined as the release of carbon to the atmosphere when biofuel crops replace the original vegetation growing in soil with high carbon stock: when replacing the native vegetation, the soil loses the ability to sequester carbon. This effect is particularly relevant when substituting forests, which have a higher carbon-sequestering capacity than any other land use. This process is long-term but might significantly contribute to the release of carbon to the atmosphere, thus contribute to GHGs and climate change. Further, annual emissions from drained peatland are estimated to be equivalent to 5% of global anthropogenic GHG emissions (IUCN, 2021).

Although the different frameworks provide similar definitions of this issue, they do not have a common approach in terms of the criteria. For example, LCFS only require the disclosure of emissions due to change in soil carbon stock, whereas RED II, SSI and CORSIA make an explicit requirement not to grow biofuel crops in land with high carbon stock. RSB incorporates both requirements.

In terms of measurement, GBEP mentions that the main challenge is the limited amount of data for many regions. Difficulties in the measurement/ modelling of soil carbon include its high variability depending on soil and climate conditions and the necessity of monitoring soil for long periods to identify the effect of bioenergy production. Other challenges include data availability on soil improvement measures and attribution. Attribution is particularly challenging as bioenergy crops are normally grown in rotation with other crops and the rotation periods might vary depending on the market and climate conditions.

Information on the global availability of measurements can be found at the FAO (Global Symposium on Soil Organic Carbon et al., 2017). GTAP Agro-Ecological Zone Emission Factors (Plevin et al., 2014) provides a global model which matches land use change associated with biofuel production with carbon releases from soil and biomass.

4.5 Electricity/Energy Source

The definitions used here by the SSI and LCFS focus on two different uses of electricity. The SSI and RSB focus on the use of electricity in the production of fuels such as electrofuels (e.g., hydrogen-based) or biofuels (i.e., in supplying energy to biofuels processing plants). Both also require the use of renewable energy sources. In contrast, the LCFS includes on the lifecycle carbon intensity of electricity used to charge an electric vehicle, as well as during biofuel production.

Consideration of electricity source is already an integral aspect of lifecycle emission calculations, which is what the definitions emphasize, albeit for different types of energy sources. In this sense, the main impacts of electricity and energy use are covered under the lifecycle GHG calculations. The SSI criteria adds the condition to also increase renewable energy capacity in the production location of the fuels, which has wider energy sector benefits, but is also more difficult to comply with. Similarly, RED II sets a minimum share of renewable energy within the transportation sector that needs to be reached.

Regarding its measurement, the estimation of carbon intensity of electricity is transparent and can be obtained from national and regional statistics. The values should include the lifecycle GHG emissions of the electricity generation and not just the combustion only.

4.6 Water

Water is consistently defined across sources in terms of quality and quantity as a relevant environmental issue in the assessment of biofuel production. Some initiatives, like ISCC and RSB, also regard it from a social perspective, making reference to water quality and quantity for human consumption. In this sense, water quality and availability are key for both the protection of natural ecosystems and human subsistence; for direct consumption and the irrigation of food crops, especially in regions where this resource is scarce. Growing bioenergy crops might compromise the availability and quality of the water, as it might shift its use from the population, the growth of food crops, and it could require the use of fertilizers and chemicals which deteriorate its quality.

For an accurate measurement of water use, GBEP highlights the importance of setting appropriate timeframes for measurement as well as relevant reference values. In particular, the water level of watersheds or reservoirs over average and dry years could be used to establish a point of reference.

For estimating the impact on water quality, the contribution of bioenergy crops to the pollutant loading must be precisely calculated. For this, an attributional approach can be taken, where the impact of agricultural and non-agricultural activities must be first estimated and then the share of bioenergy agriculture concerning other agricultural activities. There are tools that allow modelling water consumption and levels of pollutants, such as Soil & Water Assessment Tool (SWAT, 2020) and the Global Climate, Land, Energy & Water Strategies model (UNITE, 2020).

4.7 Sustainable Resource Use

The issue focuses on avoiding resource depletion for present and future generations, using a ‘closed-loop approach’ to resources, which includes reuse, recycling, recovery and waste management. SSI keeps the scope general, which could refer to all resources used in production (e.g., land, water, fertilizer, etc.). Both the RSB and ISCC specify that residues, wastes, and byproducts shall be reused or recycled, if not used for energy production. RSB includes the criteria for reusing and recycling wastewater.

Adherence to these principles aims to reduce the impact of waste (by reducing what is finally considered waste), reduce costs (by reducing procurement) and improve the associated lifecycle GHG emissions (especially if co-products are produced). The SSI's definition also refers to a closed-loop approach, which is linked to circular agriculture (Bianchi et al., 2020).

One should note that the biodiesel industry already practices circularity, besides just recycling wastewater. For instance, biodiesel production produces a significant amount of glycerin, which is used in further industrial processes.

4.8 Soil Health

The different initiatives/directives point out that biofuels should preserve soil health and not compete with other relevant uses of land, including climate and biodiversity protection, and human use. This sustainability issue addresses diverse impacts on biodiversity and various aspects of soil health. These are addressed by sustainable land management as well as sustainable agricultural practices.

The SSI provides a broad perspective on these impacts, but the other frameworks are more narrowly defined. Both the RED II and ETC includes references to biodiversity. CORSIA, RSB and ISCC limit the definitions to maintaining or enhancing soil health and mitigating soil degradation. Since aspects of carbon stock and biodiversity are addressed elsewhere, this section focuses on maintaining soil health.

Considering biofuels deriving from agricultural produce, the issue of land-use impacts and soil quality or health is critical in the long-term productive cultivation of feedstock, as well as for any other type of crop the land will be used for. The GBEP classifies five interrelated factors that contribute to soil degradation: loss of organic matter; soil erosion; accumulation of mineral salts due to inadequate drainage; soil compaction and loss of plant nutrients.

Land use is required for growing bioenergy crops, where relevant competing uses include food crops, natural ecosystems and forests, and human habitation. The use of land for growing bioenergy crops could involve negative effects on soil health, as well as having potentially negative impacts on biodiversity.

According to GBEP, the main challenges for measuring land-use change are attribution, the timescale, land typologies and categorization, availability of data and not a clear definition or consensus on what land-use change is. Bioenergy crops are usually grown as secondary crops[iii], which might have varying rotation periods and land area required. Data over long periods is required to understand long-term trends for the impact of seasonality and market signals in land-use change. A clear consensus on how land-use change is defined is needed, as well as appropriate use of the terms wastes and residues, as both are considered to involve zero land-use change.

Concerning soil health, the RSB provides the RSB Soil Impact Assessment Guidelines (RSB, 2018c) which supports the development of a soil management plan. ISCC also provides detailed criteria that can be easily assessed, particularly focused on a soil management plan and the use of best practices. GBEP presents several means for objectively testing various aspects of soil quality.

4.9 Ecological Impacts

Under ecological impacts, the different initiatives/directives mainly cover the preservation of biodiversity across the lifecycle of biofuels, particularly in the production of fuels and in the disposal of wastes and by-products. Mention is made to the preservation of primary forests or forests with high biodiversity in RED II, ETC, and ISCC due to their high ecological value.

The level of detail of the different initiatives/directives varies. For example, RSB provides a detailed list of criteria to be covered, whereas CORSIA and ETC provides a more general definition. Some of the criteria overlap with sustainable resource use, land use and or carbon stock. However ecological impacts look more particularly at the preservation of biodiversity and ecosystems.

The issue revolves around ensuring that biodiversity (especially rare, threatened, and endangered species) and the ecosystem that supports it is protected. Several of the frameworks, i.e., RED II, RSB, CORSIA, ETC and ISCC, include provisions that do not permit the use of biomass from areas with high biodiversity or conservation value. RSB specifies that biomass should only be harvested from forests with the Forest Stewardship Council certification. RED II mention that biomass can be harvested from forests, which are well monitored and have enforcement systems in place to ensure legal harvesting, forest regeneration and soil carbon conservation. Several frameworks, RSB, CORSIA, and ISCC also mention control of types of species and microorganisms introduced to the land. General operational practices, such as soil management and waste management, are also listed as criteria by RSB, CORSIA and ISCC.

With general relevance to certain types of fuels, the production and use of biofuels can have detrimental effects in natural ecosystems and biodiversity, especially when substituting land of high ecological value with bioenergy crops, or when byproducts, wastes and residues generated in the production or disposal of biofuels are not appropriately handled. For example, agricultural practices and the overuse of pesticides could have a significant negative impact in local natural ecosystems. This is strongly regional, i.e., depending on where the feedstock is produced, and shows a stark contrast between activity on existing and new agricultural land.

In accordance with the GBEP, the main challenges in the assessment of ecological impacts are data availability, difficulties in measurements from nationally recognized areas and habitat corridors:

- Data availability is a challenge as, although data is normally available for national protected areas, in some countries not all areas of high ecological value have been identified and mapped.
- In nationally recognized areas, although data is normally available, land use change is usually prohibited. For measuring impacts in biodiversity, other areas with high biodiversity value should be accounted for.
- Habitat corridors, despite their importance in connecting areas of high biodiversity value, are now not accounted for when measuring this indicator.

To estimate the impact on biodiversity, some proxies could be the change in the number of endangered and vulnerable species, the percentage of remaining native vegetation, or the percentage of land managed with wildlife-friendly techniques.

4.10 Social equity

The topic of social equity is covered by the SSI, RSB and CORSIA. The RSB focuses on the social and economic development of affected communities including women, youth, and indigenous people. The definition of SSI and CORSIA is more general but aims at improving social equity or socio-economic conditions of local producers, communities, and stakeholders. Note that is closely related to the section on social, labor, and human rights.

Social equity is a characteristic of a community with little to no disparity, marginalization, or discrimination, and conversely has high social and political inclusion (Brandi Blessett et al., 2017). A lack of social and political inclusion may lead to low pay and standard of living, job security, social mobility and safety and rights protections (S Brodt et al., 2011). Ultimately, these may lead to poverty and health issues.

The RSB's Rural and Social Development Guidelines (RSB, 2018b) provides operators and auditors with information and guidance on how to assess the work done to comply with the requirements. They require that the operators work with the affected communities and vulnerable households in developing the development plan and ensuring inclusivity in the business model.

4.11 Social, labor, and human rights

This issue focuses on labor, human and land rights that affect workers, as well as the communities in the area. SSI, RSB and ISCC specify, under labor rights, decent working conditions, promoting the well-being of workers, fair wages, and the freedom to bargain collectively. RSB specify, under human rights, issues such as forced labor, child labor, and discrimination. SSI, RSB, CORSIA and ISCC include respecting land rights, especially through the process of Free Prior and Informed Consent. It is worth noting that specific national or regional legislation may also cover some of these issues, especially for modern slavery, child labor, and labor rights/conditions.

The impact of not protecting these rights affect poor and rural communities and strongly leads to exploitation, social inequity, poverty, and unsafe working conditions. In particular, land use rights of local populations could be infringed for the acquisition of fields for bioenergy crops, especially when informal land tenure systems are in place and due to the sensitivity (possible lack of transparency) in collecting data.

The GBEP provides several indicators to measure the various aspects of this issue, such as changes in income, change in unpaid time spent by women and children collecting biomass, and incidence of occupational injury, illness, and fatalities. Furthermore, measuring the impact of biofuel production on land rights presents some difficulties, including data availability, the lack of consensus in the definition of what is “new bioenergy production” and the sensitivity of tenure-related information. Still, two proxies to estimate the impact on land rights are proposed:

- Monitoring of good practices
- Evidence of land claims/disputes/conflicts

To assess the contribution to social development and the respect of land use rights, RSB sets a series of minimum requirements which could also be used as proxies for assessing social equality. Requirements for social development cover different aspects like job creation or social benefits to local communities. Requirements for land use rights include the evidence of legitimate disputes, involuntary resettlements or sold land on a willing basis. These requirements could be formulated as close questions for the evaluation of this sustainability issue.

4.12 Food security

The definitions offered by SSI, RSB, CORSIA focus on the potential impact of fuel production on food security, especially it may replace staple crops or cause a diversion of exports and local food price increases. The ETC defines it in terms of price and availability of food. RSB and CORSIA include in their definitions the promotion or enhancement of food security in the food-insecure regions.

Biofuels, especially if supported with subsidies (IFPRI, 2008) may be more economically attractive to produce than food. Biofuels impact the price and availability of food in rural and poor regions in three distinct ways: increase in the share of domestic crops diverted from food use, competition for production inputs (i.e., land, water and fertilizer) resulting in a price change, and reliance on food imports (Brinkman et al., 2020; Global Bioenergy Partnership et al., 2011). Rural and poor communities already spend a large proportion of their income on food. The influence of biofuel production could exacerbate the situation.

The RSB provides a detailed set of guidelines on how to assess compliance with their principle in the RBS Food Security Guidelines (RSB, 2018a). The main approaches to measure the compliance are based on food consumption status (i.e., calorific or nutritional), indicators on the availability, access, utilization and stability, and via modelling the aforementioned impacts. These are obtained via detailed data collection at the household level or from secondary sources, such as health survey statistics.

4.13 Health, safety, and security

Health, safety, and security is considered by SSI and RSB across the full life cycle of the biofuels. In biofuels sourcing and processing, safe and secure work conditions should be guaranteed. In the processing, use and disposal, correct handling of wastes and byproducts needs to be in place to avoid noxious effects on human health.

By nature, all biofuels are flammable. Some hazards are important to be aware of at biofuel production sites, such as fire and explosion hazards, chemical reactivity hazards and toxicity hazards (Occupational Safety & Health Administration, n.d.). These can also have short- and long-term impacts on productivity for example if the workforce and community are regularly affected by the hazards which affect their health Nevertheless, it should be noted that neat biodiesel “contains no hazardous materials and is generally regarded as safe” (Alleman et al., 2016). Biogas can be toxic when it contains a high level of hydrogen sulphide, which must be limited to avoid negative impacts in health and the environment.

There is currently no consensus on the assessment of health, safety and security for the production, distribution, and use of biofuels. Different countries have different requirements. RSB sets some minimum requirements which include:

- Training about work-related safety and security, work-related risks, manipulation of hazardous substances, other relevant aspects
- Implementation and maintenance of procedures related to emergencies and accidents
- Maintenance of records and adjustment of procedures
- Availability of emergency materials (e.g., of first aid kits, fire extinguishers) in sufficient quantity and quality
- Protective equipment for workers appropriate to their respective jobs
- Appropriate infrastructure to meet employees' basic needs

Additionally, GBEP refers to the importance of insurance regimes, discouragement of informal jobs, obtaining good quality data and conducting surveys.

4.14 Economic well-being

This issue is defined in three different ways, though the SSI and RSB are more similar. SSI emphasizes that the operations in WTT should improve the economic well-being of the actors and stakeholders in that region, whereas RSB emphasizes the same but only in regions of poverty, which are defined based on UNDP Human Development indices. Further, RSB adds that special groups – women, youth, indigenous communities and the vulnerable – should be actively encouraged to participate in the operations, thus providing jobs. In contrast, the ISCC focuses on the business viability of only the farm or plantations and encourages it to develop through a sustainable business plan incorporating risk.

Economically viable biofuel production can “aid in economic and rural development by stimulating the agriculture sector” (Hartley et al., 2019). Furthermore, if the benefits are spread, via job creation, to communities and stakeholders, especially to the vulnerable groups, socio-economic inequality will reduce there.

Economic improvement can be easily measured and tracked in monetary and accounting terms. Development of a sound business plan is also relatively easy to accomplish with the right support.

4.15 Continuous improvement

SSI provides a broad principle, asking that sustainability performance of all operations in the well-to-wake lifecycle continually improves. RSB and ISCC focus on the well-to-tank stage, but also adopts a broad sustainability perspective, much like the SSI. The LCFS aims for a year-on-year reduction of carbon intensity threshold values, which is the goal set for the state.

Continuous improvement sits in contrast with simply fulfilling a requirement and halting progress. As many sustainability criteria are “soft”, there will always be important ways to improve, thus positively affecting the environment, community, and economy.

The RSB and ISCC emphasize record-keeping, rather than strictly requiring evidence of improvement. RSB also asks for a grievance mechanism to ensure that records about the complaints to the operators are preserved. Both are strictly speaking not an indicator of continuous improvement, but important elements in tracking the improvement. ISCC provides suggestions on what areas of continuous improvement can be easily monitored. Notably the RSB requires operators to develop an Environmental and Social Management Plan, which will be used by auditors annually to monitor emergent issues, propose mitigation measures and track progress.

Summary

Many of the sustainability issues identified in this report relate to factors contributing to climate change, such as GHG emissions, SLCF, Carbon Source and Electricity/energy source. Nevertheless, there are differences between the frameworks as to what extent they are included. Besides these, the other sustainability issues encompass other potential adverse effects of biofuel production on the environment, human health, or social and economic conditions. Most of the sustainability issues are impacts caused by the practices in the agricultural and chemical sector or more specifically, the feedstock cultivation and fuel production stages, respectively. These focus on the impacts at the location of feedstock cultivation and fuel production, as opposed to climate change which is a global phenomenon. Several of the impacts, such as water and land use, have both a physical environmental and a social aspect to them. Agricultural chemical production practices can lead to runoff, impacting land and water. Water and land can both be physically polluted. They can also influence the community, when water scarcity affects sources for human consumption, or if land rights are not respected. The air quality issue is closely linked to GHG emissions issue in that air pollutants are produced primarily from fuel combustion or open-air burning. However, it differs in that it is linked to both health-related and ecological impacts. Continuous improvement is a general principle to gradually improve all aspects of sustainability.

The frameworks generally treat each sustainability issue that they cover as equally requisite. Nevertheless, as lifecycle GHG emissions reduction is considered the primary sustainability aim of introducing biofuels, meeting the set thresholds or targets are considered first, before assessing how the other aspects fare.

Table 3 summarizes at which stages the sustainability issues must be addressed according to the frameworks presented. It also illustrates the wide range of issues that the demand for fuel causes in upstream activities. To achieve complete lifecycle sustainability, the key actors in each respective stage must also be engaged. Schemes, such as CORSIA and RED II, limit the type of biofuels in the final stage, which helps to reduce certain types of upstream impact, such as carbon emissions from direct and indirect land use change during feedstock cultivation.

Table 3 Lifecycle stage for sustainability issue

SUSTAINABILITY ISSUE	FEEDSTOCK CULTIVATION	FUEL PRODUCTION	FUEL USE
Greenhouse gas emissions	xx	x	xx
Short-lived climate forcers			xx
Air quality	xx	x	xx
Carbon source	xx		
Electricity/energy source		xx	x
Water	xx	x	
Sustainable resource use	xx	x	
Soil health	xx		
Ecological impacts	xx		
Social equity	xx	x	
Social, labor and human rights	xx	xx	
Food security	xx		
Health, safety, and security	x	xx	
Economic well-being	xx	xx	
Continuous improvement	xx	x	xx

* x is important; xx is very important, <blank> not important

5 Selecting a certification scheme

In selecting a biofuel certification scheme, three major steps have been identified, based on the study “How to select a biomass certification scheme?”[iv] (Peter Vissers et al., 2011). The steps are outlined in the Figure 2. It is not in the scope of this study to address all the concerns, rather the focus is on steps 3.2.2 and 3.2.3, which are deemed most crucial to address and update compared to the 2011 report.

The two criteria correspond with the following two questions:

- What legal requirements apply to the market to which the biofuel is being supplied?
- Which certification schemes will support compliance with the legislation?

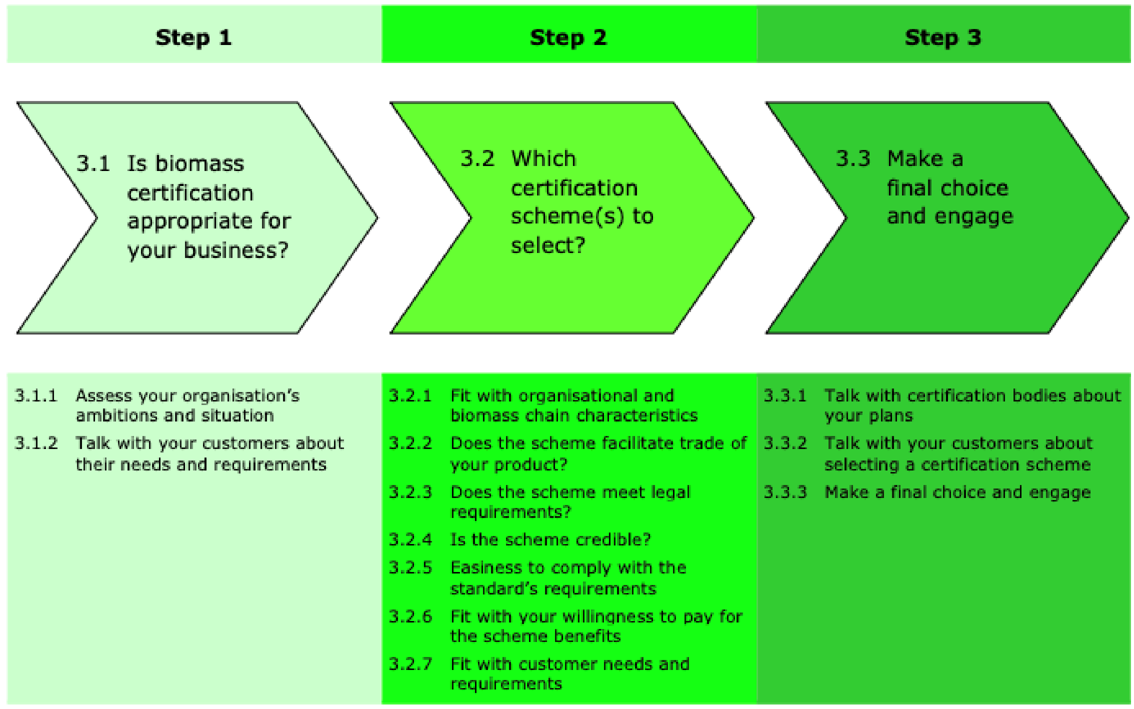

Figure 2 Steps to select a biomass certification scheme (Source: Peter Vissers et al., 2011)

5.1 What legislations apply when supplying biofuels to a particular market?

Biofuels markets have requirements to ensure that biofuels that are introduced to the market provide the GHG benefits that supplier claim they should. Many also acknowledge and aim to reduce the impact that biofuel production could have on the environmental and social sustainability of the location of origin. These are introduced through the so-called sustainability criteria discussed previously. The results of a search for legislation that regulates the import, sale, and use of biofuels for transport and the areas of sustainability it covers are presented in Table 4. The jurisdiction ranges from regional (e.g. Queensland’s Biofuels Mandate, NSW Biofuels Regulation, LCFS) to national/supranational (i.e. RTFO, RenovaBio, RFS and EU RED II) and sectoral (i.e. CORSIA).

Table 4 Legislations regulating the import and use of biofuels for transport

Legislation	Function and jurisdiction	Sustainability issue covered			
		Greenhouse gas	Feedstock/ production	Other Environmental	Social
EU RED II Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources	All biofuels produced in and imported to EU that count to Member State's obligations for renewable energy in transport.	Yes	Yes	Yes	
RTFO UK Renewable Transport Fuel Obligation	Fuel suppliers claiming Renewable Transport Fuel Certificates for 'Renewable Fuels' (biofuels) in the UK that count towards their obligations for renewable fuels. (Department of Transport UK, 2021)	Yes	Yes	Yes	Yes
Queensland's Biofuels mandate under Liquid Fuel Supply Regulation 2016 and the Liquid Fuels Supply Act 1984.	Petrol and diesel sellers/wholesalers in Queensland, Australia to comply with minimum biofuel sales (Business Queensland, 2018).	Yes	Yes	Yes	Yes
NSW Biofuels Regulation (No 2) 2016	Fuel wholesalers selling biofuel in New South Wales, Australia to meet minimum biofuels sale requirements. Biofuels require compliance with sustainability standard (NSW government, 2007, 2016).	Yes	Yes	Yes	Yes
RenovaBio Brazil's National Biofuels Policy	Biofuel producers applying for decarbonization credits Certificate of Efficient Production of Biofuels, which are to be purchased by fuel distributors in Brazil (Collegiate Board of the National Agency Of Petroleum, Natural Gas, And Biofuels, 2018).	Yes	Yes	Yes	
LCFS California's Low Carbon Fuel Standard	All low & zero-carbon fuels supplied to California issued credits according to carbon intensity. Fuel suppliers must meet LCFS carbon intensity standards (CARB, 2018).	Yes	Yes		
RFS USA's Renewable Fuel Standard Program under Energy Policy Act of 2005	Biofuels refiners or importers of gasoline or diesel apply for renewable identification numbers (RIN), which are credits used to demonstrate compliance with renewable volume obligation. (US EPA, 2015)	Yes	Yes		
CORSIA ICAO's Carbon Offsetting and Reduction Scheme for International Aviation	Eligible fuels to reduce offsetting requirements. Voluntary for ICAO members, currently 107 States. (ICAO, 2021a)	Yes	Yes	Yes	Yes

All the legislations require the calculation of lifecycle GHG emissions, whether using unspecified methods, the legislation's adopted calculation methods or globally recognized methods (e.g. RSB's lifecycle GHG emissions methodology, ISO 14040, ISO 14044 and, ISO 14067). Examples of own calculation methods include LCFS's use of four different methods to calculate direct carbon intensity of fuel production and use and of crude production and transport to refinery, indirect land use change emissions, and carbon release from soil and biomass (CARB, 2019) and RenovaBio's RenovaCalc (Ministério de Minas e Energia, 2020), which is an attributional LCA. Most also consider environmental concerns, outside GHG emissions, and social concerns.

Other legislations were found that regulate the uptake of biofuels in transport by mandating the minimum volume sold, namely, Canada's Renewable Fuel Regulations (Environment and Climate Change Canada, 2021) and Japan's Sophisticated Methods of Energy Supply Structure Act (Daisuke Sasatani, 2020). Both do not require the calculation or specification of any of the criteria outlined in Sustainability themes section. However, the upcoming Canadian Clean Fuel Standard directive, which mandates fuel suppliers to reduce the carbon intensity of fuel they supply and establishes a carbon credit market, will also include the land use and biodiversity criteria for biofuels (Environment and Climate Change Canada, 2022).

The schemes outlined here mostly applies to fuels for road vehicles, except CORSIA, which is used for the aviation sector. Sustainable aviation fuels can also generate credits under the LCFS on an opt-in basis. No equivalent standard or legislation was found for the maritime sector, although the EU's Monitoring, Reporting and Verification (MRV Regulation, 2015) requires certain maritime vessels to calculate and register their CO_2 emissions and the IMO Data Collection System requires registration of fuel consumption (IMO, 2018). Additionally, fuels used in the aviation and maritime sectors may opt in to be counted as renewable and contribute to the targets under RED II, and aviation fuels may opt in to meet targets under the LCFS. The FuelEU Maritime proposal seeks to require renewable maritime fuels to be compliant with the same sustainability criteria outlined in the RED II. The IMO Intersessional Meeting of the Working Group on Reduction of GHG Emissions from Ships (ISWG-GHG) is currently developing GHG LCA guidelines, which will include sustainability criteria (IMO, 2021).

In the absence of legislation, there is also space for 3rd party certification standards to be developed to guide the maritime and inland waterway sector in selecting sustainable fuels. As discussed previously, the criteria should extend beyond lifecycle GHG emissions to avoid impacts on communities and the environment where the feedstock and fuel is produced.

5.2 Which certification schemes support compliance with the legislation?

This section identifies the schemes that meet the sustainability requirements set in the legislation (Table 5). RenovaBio, LCFS and RFS focus primarily on GHG emissions, with the exception of several sustainable land criteria applied by RenovaBio, and therefore rely primarily on their verification system and accredited verifiers (or 3rd party quality assurance, as in RFS). The RED II and RTFO mention explicitly the certification schemes that qualify as voluntary schemes to prove compliance with sustainability criteria. CORSIA only approves two certification schemes at this point. QBM explicitly mentions the certification schemes in the table but also allows for their equivalent. NSW Biofuel Regulation (BR) only allows for the two mentioned in the table.

Table 5 Certification schemes applicable to legislations

	Legislation							
Schemes	EU RED II	CORSIA	RTFO	QBM	NSW BR	RenovaBio	LCFS	RFS
Accredited verifiers						x	x	x
ISCC EU, PLUS	x		x	x				
ISCC CORSIA		x						
RSB EU RED	x		x					
RSB Global				x	x			
RSB CORSIA		x						
2BSvs	x		x					
Better Biomass	x		x					
KZR INiG	x		x					
REDcert	x		x					
Red Tractor	x		x					
RTRS EU RED	x							
SQC	x		x					
TASCC	x		x					
UFAS	x		x					
SURE	x							
Bonsucro EU			x					
RSPO				x				
BMP				x				
ISO13065:2015					x			

The two most widely accepted certification schemes are based on ISCC and RSB standards. However, one should note that there are minor differences, especially in GHG calculation methodology when comparing schemes targeting the EU and others. Several are also country-focused France (2BSvs), Netherlands (Better Biomass), Poland (KZR INiG), UK (Red Tractor, SQC, TASCC, and UFAS) and Australia (BMP). The Better Biomass is based on the NEN standard NTA 8080-1 (NEN, 2015), which may bear resemblance to the ISO 13065.

The overall picture shows that biofuels producers/suppliers will need to apply for several certification schemes to access the markets addressed above. Hence, it might help to facilitate interoperability and reduce barriers to market, if sustainability requirements set by different legislation were based on equivalent principles and criteria and if different certification schemes are allowed to be used in the same value chain. Additionally, Brazil, the US and California could expand their sustainability criteria scope by relying on 3rd party certification schemes.

It should also be noted that a fuel supplier can always adhere to a voluntary scheme, even if it is not recognized by a specific legislation. Although not the same benefits in terms of recognition could be applied, it could be used to prove sustainability efforts beyond compliance.

6 Conclusion

The report provides an overview of the sustainability issues associated with biofuel production. Biofuel production, especially using crops as feedstock, run the risk of impacting the environment and the local community negatively where the feedstock is cultivated. The sustainability issues highlighted provide a brief overview of some of these impacts, as well as how they are addressed in guidance literature, in legislation and in certification schemes.

There is a discrepancy between wider sustainability criteria introduced by legislation and those used in fuel certification schemes. This discrepancy may be in terms of coverage of issues, specific criteria used to evaluate a certain issue, the type of indicator used, and the quantitative methods used for the indicator. Voluntary or national certification schemes supplement legislation action by addressing local stakeholder concerns or national sustainability schemes.

In the light of the findings of this study, the need for a consistent and interoperable sustainability criteria framework applied in the transport sector is made evident. Currently, frameworks mandatory for road-based fuel in the US and the EU are limited compared to the one applied in the aviation sector by ICAO, which will become mandatory globally from 2026 to 2035. No mandatory frameworks are currently applied in the maritime sector. The use of a common sustainability framework, if not a cross-compatible certification scheme, will support multimodal transport operators that operate globally. Such a framework/scheme should have the same level of buy-in that ICAO has (i.e., currently 107 countries) and aims to achieve (i.e. all ICAO members). Further, it should address the wide variety of fuels and blends used in the different modes (i.e., road, rail, maritime and aviation), as well as the specific sustainability issues that may raise.

The development and auditing of a certification scheme has its challenges, especially in translating commitments on paper to real-world impact with an adequate level of assurance (Serafini, 2016), and some disadvantages, such as the cost of certification placing a barrier to small producers (UNCTAD, 2008). Notwithstanding, the use of a good and reputable certification scheme may provide biofuel buyers – whether carriers or shippers indirectly - the confidence that wider sustainability criteria are met.

A cursory glance at the sustainability commitments made by food supply chain actors point to overlaps with some of the issues that biofuel producers relying on feedstock produced on agricultural land also face[v]. Shippers should be mindful of fuel procurement that does not align with the sustainability commitments made for their supply chain, especially if promoted for *sustainability* purposes. On the other hand, shippers may use their influence and purchasing power to push the transport and fuel industry to higher levels of accountability, by integrating sustainable fuel procurement with their own CSR promotion and activity. For instance, Nestlé (2013) commits to avoiding the use of first-generation liquid crop-based biofuels, as well raise awareness and advocate for sustainability of biofuels.

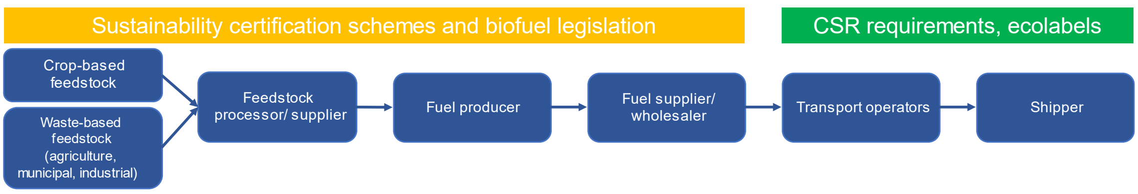

Figure 3 Alignment of sustainability commitments from supply chain to biofuel-based transport

As the impacts of biofuel production is considered, it would also be beneficial to raise the question of wider sustainability impacts of non-bio-based low emissions fuels, such as electricity and hydrogen, used in battery electric and fuel-cell vehicles. The production of renewable electricity and hydrogen are fundamentally different than production of biofuels. The production of these fuels is highly industrialized and often, but not necessarily, located where they are to be used, in contrast to feedstock, that can be cultivated in developing countries and used elsewhere. Nevertheless, the construction and operation of solar and wind farms have a significant impact on its environment, simply due to the size and scale of the facilities. Wind turbines are often criticized for its impact on vulnerable bird species. Visual pollution to scenic landscapes affects the conservation value of the area. Issues with land rights in large energy farms, like that faced in feedstock cultivation, may also appear. Similar lifecycle analysis of impacts in the production of batteries and fuel-cell systems, critical in zero emission vehicle systems, have also highlighted issues regarding human rights and water pollution, especially where rare metals are mined. Further research could cast light on comparing the sustainability issues of these fuel and vehicles from the perspective of countries currently leading the way in the use of these technology.

Appendix I: Definitions of sustainability

Greenhouse Gas Emissions

SSI	Principle: Zero and low carbon marine fuels should generate zero or close to zero GHG emissions on a well-to-wake lifecycle basis over a timescale consistent with achieving the temperature goals of the Paris Agreement Criterion: Zero and low carbon marine fuels shall achieve zero GHG emissions or significant net GHG reductions i.e., total GHG values over the well-to-wake lifecycle of the zero and low carbon marine fuel over a timescale consistent with achieving the temperature goals of the Paris Agreement Indicator: WTW GHG emissions
LCFS	Criterion: Reduce carbon intensity of transportation fuel pool by at least 20% by 2030 (versus 2010). Indicator: Carbon intensity is expressed in grams of carbon dioxide equivalent per megajoule of energy provided by that fuel, for the full life cycle of the fuel. (WTW gr CO_2e/MJ). LCFS sets carbon intensity benchmarks for different types of fuels, which are increasingly more restrictive, as to reach a 20% reduction by 2030 with respect to 2019 benchmark.
EU RED II	Criterion: Production of biofuels and biogas for transport has the potential for delivering substantial greenhouse gas emissions savings compared to fossil fuels based on a life-cycle assessment of emissions. The greenhouse gas emission savings from the use of biofuels, bioliquids and biomass fuels taken into account shall be at least 65 % for biofuels, biogas consumed in the transport sector, and bioliquids produced in installations starting operation from 1 January 2021. An installation shall be considered to be in operation once the physical production of biofuels, biogas consumed in the transport sector and bioliquids. The greenhouse gas emission savings from the use of biofuels, biogas consumed in the transport sector, bioliquids and biomass fuels used in installations producing heating, cooling and electricity shall be calculated in accordance with Article 31. Indicator: Percentage Reduction in WTW GHG emissions compared to fossil fuels.
RSB	Principle: Biofuels contribute to climate change mitigation by significantly reducing lifecycle GHG emissions as compared to those of fossil fuels. Criterion: a) Biofuels shall meet all applicable GHG reduction requirements set by national and/or regional and/or local regulations. b) Lifecycle GHG emissions of biofuel shall be calculated by using system boundaries from Well to Wheel, including GHG emissions from land-use change, including, but not limited to above and below-ground carbon stock changes and incentivizing the use of co-products, residues and waste in such a way that the lifecycle GHG emissions of the biofuel are reduced. c) Biofuels shall have on average 50% lower lifecycle greenhouse gas emissions relative to the fossil-fuel baseline (60% for new installations). Indicator: WTW GHG relative to the fossil-fuel baseline.
CORSIA	Principle: CORSIA SAF should generate lower carbon emissions on a life cycle basis. Criterion: CORSIA SAF will achieve net greenhouse gas emissions reductions of at least 10% compared to the baseline life cycle emissions values for aviation fuel on a life cycle basis. Indicator: WTW GHG emissions (Functional units are gCO_2e/MJ).
ETC	Criterion: The carbon footprint related to production, collection, transportation, and processing of the biomass should be reduced to close to zero. Indicator: Carbon footprint

ISCC	Criterion: Efforts are made to reduce fossil energy consumption, thus lower greenhouse gas and air pollution emissions.

Short-Lived Climate Forcers (SLCF) Emissions

SSI	Principle: Zero and low carbon marine fuels for use in the maritime industry should generate zero or close to zero SLCF emissions on a well-to-wake lifecycle basis over a timescale consistent with achieving the temperature goals of the Paris Agreement. Criteria: Zero and low carbon marine fuels shall achieve zero SLCF emissions or significant net SLCF reductions i.e., total SLCF values over the well-to-wake lifecycle for the zero and low carbon marine fuel over a timescale consistent with achieving the temperature goals of the Paris Agreement. Indicator: SLCF emissions

Air quality

SSI	Principle: Impacts across the lifecycle of zero and low carbon marine fuels should avoid negative effects on air quality. Criteria: Air pollutants across the well-to-wake lifecycle stages of the zero and low carbon marine fuel shall be minimized or eliminated.
LCFS	Criterion: Provides a collective contribution to the improvement of air quality through the transformation and diversification of the fuel mix and reduction of petroleum dependency.
RSB	Principle: Air pollution from the operations is minimized along the supply chain. Criterion: a) Air pollution emission sources from the operations shall be identified, and air pollutant emissions minimized through an air management plan. b) Operations shall avoid and, wherever possible, eliminate open-air burning of residues, wastes or by-products, or open-air burning to clear the land.
CORSIA	Principle: Production of CORSIA SAF should minimize negative effects on air quality. Criterion: Air pollution emissions will be limited.
ISCC	Criterion: Efforts are made to reduce fossil energy consumption and thus reduce air pollution emissions. The reduction or minimization of the following pollutants should be implemented, recorded and monitored by the system user: carbon monoxide, nitrogen oxides, volatile organic compounds, particulate matter, sulphur compounds, dioxins, other substances recognized as potentially harmful for the environment or human health (e.g. heavy metals, ammonia or dust).

Carbon Source

SSI	Principle: The source(s) of carbon (e.g., feedstock) used in the production of zero and low carbon marine fuels should be disclosed. The feedstock should be derived from a source with the lowest negative impacts according to the best available techniques and eliminate or minimize lifecycle GHG emissions and carbon intensity. Criteria: The source of carbon (e.g., the feedstock) used in the production of the zero and low carbon marine fuel shall be fully disclosed. The disclosure shall include, but should not be limited to, origin, production process, quantity and carbon intensity. The source may not be carbon of fossil origin, nor obtained from land with high carbon stock, and should provide a climate benefit compared to fossil fuels.
LCFS	Criterion: The carbon source of the fuel in question must be included in the calculations in order to ascertain whether this constitutes a short or long circuit carbon release (e.g. for vehicles fueled by biofuels [short circuit], tailpipe emissions are not considered part of accounting).

RED II	Criterion: Biofuels from waste or agricultural residues must be sourced from land where soil carbon and soil quality are monitored and managed to minimize impacts.
RSB	Criterion: Minimum requirements for each of the criteria included in RSB are provided and allocated by feedstock, therefore feedstock disclosure is required to ensure the correct minimum requirements are met for each criterion.
CORSIA	Principle: CORSIA SAF should not be made from biomass obtained from land with high carbon stock. Criterion: CORSIA SAF will not be made from biomass obtained from land converted after 1 January 2008 that was primary forests, wetlands, or peatlands and/or contributes to the degradation of the carbon stock in primary forests, wetlands, or peatlands as they have high carbon stocks. In the event of land-use conversion after 1 January 2008, as defined based on the Intergovernmental Panel on Climate Change (IPCC) land categories, direct land-use change (DLUC) emissions will be calculated. If DLUC's greenhouse gas emissions exceed the default Indirect land-use change (ILUC) value, the DLUC value will replace the default ILUC value
ETC	Criterion: Where production of biomass would trigger a direct or indirect change in land use, the carbon stocks associated with the land before conversion and the opportunity cost of carbon that could be sequestered if biomass were not extracted, must be accounted for. Such changes can result in substantial carbon emissions if land with significant carbon stocks (e.g., peatlands or other natural landscapes with high soil carbon) are converted for biomass production, or if biomass production displaces other activities (e.g., food production) on those lands. To achieve a net reduction in GHG emissions, the use of the land for bioenergy or biomaterials must result in lower GHG emissions overall than would have been emitted otherwise. Additionally, new biomass production cannot provide an immediate offset because plants must capture carbon through growth before they can be harvested for use.
ISCC	Criterion: Raw material shall not be obtained from land with high carbon stock, namely land that had one of the following statuses in January 2008 and no longer has this status: wetlands, continuously forested areas, other (sparsely) forested areas.

Electricity/Energy Source

SSI	Principle: The source of renewable electricity/energy consumed in support of producing hydrogen-based zero and low carbon marine fuels should be disclosed. Hydrogen-based zero and low carbon marine fuels should be produced from renewable energy sources and use the best available techniques to eliminate or minimize lifecycle GHG emissions. Criteria: The primary source of electricity/energy consumed for the production of hydrogen-based zero and low carbon marine fuel shall be disclosed. The information shall include, but should not be limited to, origin, production process, and quantity. The production of hydrogen should be based on renewable energy sources. Furthermore, there should be an element of additionality, meaning that the fuel producer is adding to the deployment or financing of renewable energy sources.
LCFS	Criterion: Carbon intensity of electricity generated in California is calculated using CA-GREET (using a 2017 average), emissions include upstream fuel for generating electricity, actual emissions from electricity generation and an adjustment for transmission line losses. Indicator: Carbon Intensity (WTW)
RED II	Criterion: Ensure that the share of renewable energy within the final consumption of energy in the transport sector is at least 14 % by 2030 (minimum share).

	The energy content of all types of energy from renewable sources supplied to all transport sectors, including renewable electricity supplied to the road and rail transport sectors, shall be taken into account.
ISCC	Criterion: Energy consumption should be as efficient as possible to protect the climate. To achieve this, fossil fuel reduction and the use of renewable energies, e.g. biofuels, biogas, solar or wind energy, on the farm or plantation are encouraged. A plan should be in place to improve the efficiency of fossil energy use and the increased usage of renewable energies.

Water

SSI	Principle: Impacts across the lifecycle of zero and low carbon marine fuels should maintain or enhance water quality and availability, and respect water use rights. Criteria: Operations in the well-to-tank lifecycle stages of the zero and low carbon marine fuel shall minimize water usage; avoid contamination, pollution and spillage; maintain or enhance the quality, quantity, usage and conservation of water resources; and respect formal or customary water rights.
RSB	Principle: Operations maintain or enhance the quality and quantity of surface and groundwater resources, and respect prior formal or customary water rights. Criterion: a) Operations shall respect the existing water rights of local and indigenous communities. b) Operations shall include a water management plan which aims to use water efficiently and to maintain or enhance the quality of the water resources that are used for the operations. c) Operations shall not contribute to the depletion of surface or groundwater resources beyond replenishment capacities. d) Operations shall contribute to the enhancement or maintaining of the quality of the surface and ground-water resources.
CORSIA	Principle: Production of CORSIA SAF should maintain or enhance water quality and availability. Criterion: CORSIA SAF production will respect the existing water use rights of local and indigenous communities.
ISCC	Principle: Use of best practices to maintain and improve water quality and quantity. Criterion: Respect existing water rights and justify irrigation in the context of social and environmental sustainability. Application of good agricultural practices to reduce water usage and to maintain and improve water quality.

Sustainable Resource Use

SSI	Principle: Impacts across the lifecycle of zero and low carbon marine fuels should avoid resource depletion and ensure the resource potential to meet the needs of present and future generations. Criteria: Operations in the well-to-tank lifecycle stages of the zero and low carbon marine fuel shall avoid negative land use impacts (maintain soil health; avoid/reverse soil degradation; maintain carbon stocks; avoid forgone carbon sequestration; enhance biodiversity and ensure no impacts on high biodiversity areas), address the risks related to land use change, leakage, hierarchy and apply good agricultural practices.
RSB	Principle: Operations implement practices that seek to reverse soil degradation and/or maintain soil health. Criterion: a) Operators shall implement practices to maintain or enhance soil's physical, chemical, and biological conditions.
CORSIA	Principle: Production of CORSIA SAF should promote responsible management of waste and use of chemicals.

	Criterion: Operational practices will be implemented to ensure that waste arising from production processes as well as chemicals used are stored, handled and disposed of responsibly. Responsible and science-based operational practices will be implemented to limit or reduce pesticide use.
ISCC	Principle: 2.10 Use of best practices in waste and energy management.

Soil Health

SSI	Principle: Impacts across the lifecycle of zero and low carbon marine fuels should not result in negative land use impacts and shall apply good agricultural practices. Criteria: Operations in the well-to-tank lifecycle stages of the zero and low carbon marine fuel shall avoid negative land use impacts (maintain soil health; avoid/reverse soil degradation; maintain carbon stocks; avoid forgone carbon sequestration; enhance biodiversity and ensure no impacts on high biodiversity areas), address the risks related to land use change, leakage, hierarchy and apply good agricultural practices.
RED II	Criteria: Biofuels, bioliquids and biomass fuels produced from agricultural biomass shall not be made from raw material obtained from land that was declared in January 2008 to have a high biodiversity value, with high carbon stock or which was undrained peatland, unless evidence is provided that the cultivation and harvesting of that raw material meet strict criteria (e.g. in the case of peatland, it should not involve drainage of previously undrained soil).
RSB	Principle: Operations implement practices that seek to reverse soil degradation and/or maintain soil health. Criterion: a) Operators shall implement practices to maintain or enhance soil's physical, chemical, and biological conditions.
CORSIA	Principle: Production of CORSIA SAFs should maintain or enhance soil health. Criterion: Agricultural and forestry best management practices for feedstock production or residue collection will be implemented to maintain or enhance soil health, such as physical, chemical and biological conditions.
ETC	Criterion: Any biomass production should consider competing alternative uses of land – for human habitation, food production, habitat conservation, and climate mitigation. These alternatives define an opportunity cost to use of the land and a baseline for carbon emissions (whether source or sink) against which use of the land for bioenergy and biomaterials should be judged. Land available for additional biomass production is therefore restricted to a highly limited supply of marginal/degraded land or to crop- and pastureland that can be released from its current use.
ISCC	Principle: Use of best practices to maintain and improve soil fertility. Use of best practices in fertilizer application.

Ecological Impacts

SSI	Principle: Impacts across the lifecycle of zero and low carbon marine fuels should avoid negative ecological impacts, maintaining or enhancing biodiversity (including rare, threatened or endangered species and high conservation value habitats), ecosystems, soil, ecosystem services and conservation. Criteria: Operations in the well-to-wake lifecycle stages (including waste management and use of chemicals) of the zero and low carbon marine fuel shall avoid negative impacts on, and shall maintain or enhance biodiversity (including rare, threatened or endangered species and high conservation value habitats), ecosystems, soil, ecosystem services, conservation values.

RED II	Criteria: Biofuels, bioliquids and biomass fuels produced from agricultural biomass shall not be made from raw material obtained from land with a high biodiversity value, namely land that had one of the following status in or after January 2008, whether or not the land continues to have that status: -Primary forest and Highly biodiverse forest. When biofuels, bioliquids and biomass are sourced from forest biomass, appropriate monitoring and enforcement systems must be in place to ensure legal harvesting, forest regeneration and soil carbon conservation.
RSB	Principle: Operations avoid negative impacts on biodiversity, ecosystems, and conservation values. The use of technologies in operations seeks to maximize production efficiency and social and environmental performance, and minimize the risk of damages to the environment and people. Criterion: - The RSB addresses the risks of deforestation and unsustainably managed forests by requiring operators to source forestry residues only from sustainably managed forests. Operators are therefore required to provide evidence that forestry residues are sourced from forests with a valid Forest Stewardship Council certification or any certification scheme with equivalent sustainability requirements as approved by RSB. a) Conservation values of local, regional or global importance within the potential or existing area of operation shall be maintained or enhanced. b) Ecosystem functions and services that are directly affected by the operation shall be maintained or enhanced c) Operations shall protect, restore or create buffer zones. d) Ecological corridors shall be protected, restored or created to minimize fragmentation of habitats e) Operations shall prevent invasive species from invading areas outside the operation site. a) The technologies used in operations including genetically modified plants, micro-organisms, and algae, shall minimize the risk of damages to environment and people, and improve environmental and/or social performance over the long term. b) Micro-organisms used in operations which may represent a risk to the environment or people shall be adequately contained to prevent release into the environment. c) Good practices shall be implemented for the storage, handling, use, and disposal of biofuels, fertilizers and chemicals. d) Residues, wastes and byproducts from feed-stock processing and biofuel or biomaterial production units shall be managed such that soil, water and air's physical, chemical, and biological conditions are not damaged.
CORSIA	Principle: Production of CORSIA SAF should maintain biodiversity, conservation value and ecosystem services. Criterion: Criterion 6.1: CORSIA SAF will not be made from biomass obtained from areas that, due to their biodiversity, conservation value, or ecosystem services, are protected by the State having jurisdiction over that area, unless evidence is provided that shows the activity does not interfere with the protection purposes. Criterion 6.2: Low invasive-risk feedstock will be selected for cultivation and appropriate controls will be adopted with the intention of preventing the uncontrolled spread of cultivated alien species and modified microorganisms. Criterion 6.3: Operational practices will be implemented to avoid adverse effects on areas that, due to their biodiversity, conservation value, or ecosystem services, are protected by the state having jurisdiction over that area.
ETC	Criterion: Areas of high biodiversity, such as natural forests, should be strictly avoided. High-intensity land management can impact biodiversity, therefore presenting a trade-off between biomass production and leaving the land to nature. However, some land-use models can mitigate these trade-offs.

ISCC	Principle: Raw material shall not be obtained from land with high biodiversity value, namely land that had one of the following status in or after January 2008, whether or not the land continues to have that status: Primary forests and wooded land, Areas designated by law or by the relevant competent authority for nature protection purposes, Areas for the protection of rare, threatened or endangered ecosystems or species, Highly biodiverse grassland ,Use of best practices to maintain and improve soil fertility. Natural vegetation areas around springs and natural watercourses are to be maintained or re-established.

Social equity

SSI	Principle: Impacts across the lifecycle of zero and low carbon marine fuels should contribute to social equity in communities where the operations leading to, and including, the production of low and zero-carbon fuel takes place. Criteria: Operations in the well-to-tank lifecycle stages of the zero and low carbon marine fuel shall contribute to the social equity of local producers, communities and stakeholders.
RSB	Principle: In regions of poverty, operations contribute to the social and economic development of local, rural and indigenous people and communities. Criterion: a) In regions of poverty, the socio-economic status of local stakeholders impacted by the operations shall be improved. b) In regions of poverty, special measures that benefit and encourage the participation of women, youth, indigenous communities and the vulnerable in the operations shall be designed and implemented.
CORSIA	Principle: Production of CORSIA SAF should contribute to social and economic development in regions of poverty. Criterion: CORSIA SAF production will strive to, in regions of poverty, improve the socio-economic conditions of the communities affected by the operation.

Social, labor and human rights

SSI	Principle: Impacts across the lifecycle of zero and low carbon marine fuels should respect and uphold the social, labor and human rights of affected populations including indigenous rights and title. Criteria: Operations in the well-to-tank lifecycle stages (including operations in the extractive industries) of the zero and low carbon marine fuel shall not violate labor or human rights of the affected populations, shall promote decent work conditions and workforce well-being, and shall not violate land-use rights (through e.g., ensuring Free Prior Informed Consent (FPIC) as recognized in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP)).
RSB	Principle: Operations do not violate human rights or labor rights, and promote decent work and the well-being of workers. Operations respect land rights and land-use rights.

	Criterion: a) Workers shall enjoy the freedom of association, the right to organize, and the right to bargain collectively b) No slave labor or forced labor shall occur. The participating operator shall not be engaged in or support the use of forced, compulsory, bonded, trafficked or otherwise in-voluntary labor as defined in ILO Convention 29. c) No child labor shall occur, except on family farms and then only when work does not interfere with the child's schooling and does not put his or her health at risk. d) Workers shall be free of discrimination of any kind, whether in employment or opportunity, with respect to gender, age, wages, working conditions, and social benefits. e) Workers' wages and working conditions shall respect all applicable laws and international conventions, as well as all relevant collective agreements. Where a government-regulated minimum wage is in place in a given country and applies to the specific industry sector, this shall be observed. Where a minimum wage is absent, the wage paid for a particular activity shall be negotiated and agreed on an annual basis with the worker. Men and women shall receive equal remuneration for work of equal value. f) Conditions of occupational safety and health for workers shall follow internationally-recognized standards g) Operators shall implement a mechanism to ensure the human rights and labor rights outlined in this principle apply equally when labor is contracted through third parties. h) Operators shall implement and maintain a transparent and easily accessible grievance mechanism, open for all workers and contracted workers. a) Existing land rights and land-use rights, both formal and informal, shall be assessed, documented, and established. The right to use the land for the operations shall be established only when these rights are determined. b) Free, Prior, and Informed consent shall form the basis for all negotiated agreements for any compensation, acquisition, or voluntary relinquishment of rights by land users or owners for operations.
CORSIA	Principle: Production of CORSIA SAF should respect human and labor rights. Production of CORSIA SAF should respect land rights and land-use rights including indigenous and/or customary rights. Criterion: CORSIA SAF production will respect human and labor rights. CORSIA SAF production will respect existing land rights and land use rights including indigenous peoples' rights, both formal and informal.
ISCC	Principle: Safe Working Conditions: Training and competence; Prevention of and handling with accidents; Compliance with human, labor and land rights; Rural and social development; Employment conditions. The Legitimacy of land use. The producer should be able to prove that the land is being used legitimately and that traditional land rights have been secured. Documents must show legal ownership or lease, history of land tenure and the actual legal use of the land. The producer must identify and respect existing land rights (see Principle 1). The rights of indigenous people must be respected. The process of Free Prior and Informed Consent (FPIC) is applied in the case of new land acquisitions.

Food security

SSI	Principle: Impacts across the lifecycle of zero and low carbon marine fuels should respect and uphold the right to adequate food and should not disadvantage food security. Criteria: Operations in the well-to-tank lifecycle stages of the zero and low carbon marine fuel shall avoid negative impacts on food security (such as the replacement of staple crops, diversion of exports and local food price increases).
RSB	Principle: Operations ensure the human right to adequate food and improve food security in food-insecure regions.

	Criterion: a) Operations shall assess risks to food security in the region and locality and shall mitigate any negative impacts that result from their operations. b) In food-insecure regions, operations shall enhance the local food security of the directly affected stakeholders.
CORSIA	Principle: Production of CORSIA SAF should promote food security in food insecure regions. Criterion: CORSIA SAF production will, in food-insecure regions, strive to enhance the local food security of directly affected stakeholders.
ETC	Criterion: and any impacts of biomass production for energy and materials on the price and availability of food are also important.

Health, safety, and security

SSI	Principle: Operations in the well-to-tank lifecycle stages of the zero and low carbon marine fuel (including the end-of-life treatment and/ or disposal of fuel by-products and waste streams, production plants and equipment) should minimize health, safety and security risks to the workforce, communities and the natural environment. Criteria: Health, safety and security risks (including noise, odor and dust) throughout the well-to-wake lifecycle of the zero and low carbon marine fuel shall be addressed by avoidance, mitigation and adaptation through risk assessments, safety management, guidance and training on e.g., accidents, as well as ecological and health impacts of spillage/discharge.
RSB	Criteria: Conditions of occupational safety and health for workers shall follow internationally recognized standards. Wastes and byproducts should be appropriately handled to prevent any damage to human health.

Economic well-being

SSI	Principle: Impacts across the lifecycle of zero and low carbon marine fuels should contribute to the economic well-being of local producers, communities and stakeholders where the operations leading to, and including, the production of low and zero-carbon fuel takes place. Criteria: Operations in the well-to-tank lifecycle stages of the zero and low carbon marine fuel shall contribute to the economic well-being of local producers, communities and stakeholders where the production of low and zero-carbon fuel takes place.
RSB	Principle: In regions of poverty, operations contribute to the social and economic development of local, rural and indigenous people and communities. Criterion: - a) In regions of poverty, the socio-economic status of local stakeholders impacted by the operations shall be improved. b) In regions of poverty, special measures that benefit and encourage the participation of women, youth, indigenous communities and the vulnerable in the operations shall be designed and implemented.
ISCC	Principle: Principle 6 Good management practices and continuous improvement. Principle 6.1 Economic stability: Business plan refers to social well being through economic sustainability. Criterion: Farms or plantations shall develop and implement a business plan that reflects a commitment to long-term economic viability. It includes plans and activities to support the long-term economic viability of the farm or plantation. It shall take into account social and environmental principles, e.g. the sustainable optimization of yield and input efficiency. Market requirements as well as risk mitigation strategies (e.g. of drought, price fluctuations) can also be included.

Continuous improvement

SSI	Principle: Operations in the well-to-wake lifecycle stages of zero and low carbon marine fuels should continuously improve through innovation, adopting a proactive approach to enhancing their sustainability performance. Criteria: Innovation in the well-to-wake lifecycle stages of the zero and low carbon marine fuel (explicitly including end-of-life treatment and/or disposal of fuel by-products and waste streams, production plants and equipment) shall contribute to the continuous improvement of the fuel's sustainability performance.
LCFS	Criteria: Graded reduction of carbon intensity up to 2030. Indicator: WTW (gCO2e/MJ)
RSB	Principle: Sustainable operations are planned, implemented, and continuously improved through an open, transparent, and consultative impact assessment and management process and economic viability analysis. Criterion: - a) Operations shall undertake an impact assessment process to assess impacts and risks and ensure sustainability through the development of effective and efficient implementation, mitigation, monitoring and evaluation plans. b) Free, Prior & Informed Consent (FPIC) shall form the basis for the process to be followed during all stakeholder consultation, which shall be gender sensitive and result in consensus-driven negotiated agreements. c) Operators shall implement and maintain a transparent and easily accessible grievance mechanism for directly affected local communities. d) Biofuel operators shall make adequate resources available to ensure compliance with the RSB Standard.
ISCC	Principle: Principle 6 Good Management Practices and Continuous Improvement. 6.2 Management: Establishment of a recording system for each unit of production; Commitment of continuous improvement for each unit of production; Records are kept for the description of the areas in use; Subcontractors must fully comply with the ISCC sustainability requirements. Criterion: For continuous improvement: the management regularly monitors and reviews all activities and takes actions to continuously improve the management with respect to an environmental, social and economic sustainable development. Continuous improvement can include (but is not limited to) a reduction of plant protection product application, more efficient fertilizer management, waste reductions, energy consumption and greenhouse gas emissions, social impacts and yield performance.

Notes

[i] Other categorizations exist, such food-based and advanced biofuels (EC, 2016), 1st, 2nd and 3rd generation biofuels (Lee & Lavoie, 2013), or specific to the conversion pathways, e.g. ASTM D4054+s categories (ICAO, 2021b). The categorization used here clearly shows the competition for land and food-crops, which is crucial in understanding the sustainability of biofuels.

[ii] The maritime sector may use the term tank-to-wake, which for our purposes should be considered synonymous with the tank-to-wheel convention.

[iii] A crop succeeding one already harvested during a growing season or a regrowth of the harvested.

[iv] The study published in May 2011 funded by the NL Agency under the framework of the Netherlands Programmes Sustainable Biomass provides brief guidelines to support biomass actors to select an appropriate biomass certification standard, which were used to prove compliance with regulations or simply to distinguish their products from others (Peter Vissers et al., 2011).

[v] A review of sustainability criteria in the agrifood supply chain lists themes, such as local living conditions, labor rights, land rights, food security, end-of-life valorization (i.e. circular economy), and other environmental issues (Gold et al., 2017).

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