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# EBIO – Biofuels through Electrochemical transformation of intermediate BIO-liquids

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# Description of the deliverable content and purpose

This deliverable presents the social impact assessment (SIA) carried out in EBIO, including the developed approach and final assessment results, for electrochemical conversion of fast pyrolysis oil into green fuels and biochemicals.

The assessment focuses on the potential implementation of the EBIO technology in a greenfield pyrolysis plant in Innlandet, Norway. Taking a case study approach allows consideration of the technology in a real-world context, even if it is at an early stage of development. We use data from a recently established fast pyrolysis plant in Sweden as a basis, together with data generated through the technological research and development in EBIO, macro-economic modelling, generic data from national statistics and pre-existing studies, and case-specific data based on consultation with local stakeholders.

Innlandet has rich forest resources and an existing wood industry, with both public and private stakeholders potentially interested in implementing the EBIO technology. The assessment addresses potential impacts in relation to five stakeholder categories; value chain actors, workers, users, local community or region, and wider society, considering the whole cycle, from feedstock production to end use in transport, and aims to identify social hotspots, or areas of risk and opportunities, that need to be considered in the onward efforts to develop and upscale the EBIO technology. We find positive potential impacts for value chain development, in terms of contribution to the regional skill mix, incentives and potential adopters, and the range of non-sustainable products that an EBIO biofuel plant in Innlandet potentially can replace. The results of the input-output modelling suggest a positive overall effect on employment, with significant value chain effects in the forestry and wood processing industry, benefitting Innlandet. Value-added at the national level is slightly reduced, but the effects of increased value-added from the biofuel production are almost as large as the negative effects on value-added in the petroleum-related sectors.

Furthermore, there are positive potential impacts on innovation capacity and regional attractiveness, as well as social acceptability. For workers, there are potential benefits in terms of fair wages. In terms of gender equality, the direct employment created may attract female workers, but the indirect employment effect will be mainly in sectors which remain male-dominated. Regarding the requirements or opportunities for workers to acquire new knowledge and skills, those directly employed are likely to benefit, whereas the sectors with increased indirect employment score lower than the national average. For the wider society, our assessment highlights the alignment with national decarbonisation strategies and potential to reduce the current import dependency of biofuels in Norway. A pyrolysis plant with EBIO technology in Innlandet may also enhance circular bioeconomy. Finally, the risk of indirect land use change is very limited, and no negative impacts on food security are anticipated. It should be noted however, that in a long-term perspective the availability of biomass could be a challenge, due to competing uses.

# Content

# Abbreviations

| | |
|---|---|
| BTG | Biomass Technology Group |
| CAPEX | Capital Expenditure |
| CEN | European Committee for Standardization |
| $CO_2$ | Carbon Dioxide |
| CPI | Corruption Perceptions Index |
| CSR | Corporate Social Responsibility |
| CSRD | Corporate Sustainability Reporting Directive |
| ESG | Environmental, Social, and corporate Governance |
| ETD | EU Energy Taxation Directive |
| ETS | EU Emission Trading System |
| EUR | Euros |
| EY | Ernst & Young |
| GHG | Greenhouse gas emissions |
| GJ | Gigajoule (unit of measurement for energy consumption) |
| GRI | Global Reporting Initiative |
| GROT | Tree tops, branches, and roots |
| GWh | Gigawatt hour |
| GWP | Global warming potential |
| IBGC | Brazilian Institute of Corporate Governance |
| IEA | International Energy Agency |
| ILUC | Indirect land use change |
| INN | Inland Norway University of Applied Sciences |
| IO | Input-output |
| KPI | Key Performance Indicator |
| LCA | Life Cycle Assessment |
| MJ | Megajoule (unit of measurement for energy consumption) |
| MNOK | Million Norwegian Kroner |
| NACE | Nomenclature of Economic Activities |
| NaOH | Sodium Hydroxide (lye) |

| | |
|---|---|
| NCE | National Centre of Expertise |
| NGO | Non Governmental Organisation |
| NIBIO | Norwegian Institute of Bioeconomy Research |
| NLF | Norwegian Truckowners' Association |
| NOK | Norwegian Kroner |
| NPV | Net Present Value |
| OECD | Organisation for Economic Co-operation and Development |
| OH | Hydroxide ion |
| OPEX | Operating Expense |
| PEFC | Programme for the Endorsement of Forest Certification |
| R&D | Research and Development |
| RED | Renewable Energy Directive |
| RFNBO | Renewable Fuel of Non-Biological Origin |
| SAF | Sustainable Aviation Fuel |
| SDS | Safety Data Sheet |
| SETAC | Society of Environmental Toxicology and Chemistry |
| SIA | Social impact assessment |
| S-LCA | Social Life Cycle Assessment |
| SPA | Structural path analysis |
| TRL | Technology Readiness Level |
| TWh | Terrawatt hours |
| UCO | Unknown Cooking Oil |
| UDHR | Universal Declaration of Human Rights |
| UN | United Nations |
| UNEP | United Nations Environment Programme |
| USD | United States Dollar |
| VA | Value-added |
| WtP | Willingness to Pay |

# 1. Introduction

EBIO has aimed to accelerate an economically viable, environment-friendly and socially acceptable process for transport fuel production from biomass. Specifically, the electrochemical conversion of two low-valued and industrially available bio-liquids, pyrolysis oil and black liquor, into green fuels, platform chemicals and high-added value compounds have been targeted.

The results from the technological research in the project, suggest the products will have a higher energy density and stability, lower averaged molecular weights, and less diverse oxygen functionalities in the molecules, compared to the original feeds. This allows better blending / mixing with existing refinery streams and shall result in higher overall yields (in terms of carbon in the product). Lab-scale research along the whole value chain (cradle to grave) has resulted in an integrated concept, which will be the prototype for a future fuel production system.

This report provides results from Task 1.4, Social Impact Assessment (SIA), which consists of a multi-criteria assessment of potential social impacts, including quantitative analysis of potential ripple effects in terms of value creation and employment, as well as qualitative assessment of other aspects of social sustainability. The assessment is carried out as a case-study, where we consider regional as well as wider social impacts of implementing the integrated concept for advanced biofuel production.

The following chapter provides a brief background, on the key concepts and the theoretical grounding of the study. Chapter 3 defines the goal and scope of the assessment, including the solution in focus, the region selected for the case-study, and the affected stakeholders. Chapter 4, subsequently, provides an overview of the developed assessment framework, with its main impact categories, subcategories, and specific indicators (which are further described in Annex 1 and 2). Chapter 5 gives an overview of the process and criteria for selection of impact categories, indicators, and assessment methods. In chapter 6, we describe the developed modelling framework, as well as the set-up of a new sector and alternative scenarios. Chapter 7 presents the results, structured according to stakeholder categories. Chapter 8 discusses the overall results and limitations of the assessment. We highlight potential benefits in terms of regional value creation and skill mix, innovation capacity and regional attractiveness, as well as the alignment with national decarbonisation strategies and potential to reduce the Norway's current import dependency of biofuels. However, we also note a high degree uncertainty, as the EBIO technology still is early-stage, and data availability is limited. Chapter 9, finally, provides a summary conclusion, with pointers for future research.

# 2. Background

## 2.1 Increasing focus on social sustainability

A transition towards a competitive low-carbon economy is necessary to address the issues of climate change, and Europe needs to develop and implement sustainable, renewable energy technologies. The transport sector in Europe is still heavily dependent on fossil fuels, making it both unsustainable and vulnerable (European Commission, 2016). Biofuels are expected to contribute significantly to a transition towards low-carbon transport, and Europe has long since started to promote biofuels in its transport sector (European Parliament and Council of the European Union, 2003). In recent years, the

European Union has also increased its focus on advanced biofuels, based on non-food biomass, and provided more specific sustainability criteria for the feedstocks (European Parliament and Council of the European Union, 2018).

In 2023 the ambitions regarding share of advanced biofuels were increased further (European Parliament and Council of the European Union, 2023). Member states need to implement the third version of the Renewable Energy Directive by May 2025, and the increased target for renewables in the transport sector will increase the volumes of biofuels needed by 2030 - with a new 29% energy target. Considering these changes, as well as the denominator expansion, more ambitious changes to sub-targets on Part A biofuels, the enlargement of the list of Annex IX feedstocks and additional demand from the maritime sector, a surge in demand for advanced and waste biofuels is expected (Transport and Environment, 2024). EBIO helps address this challenge, by developing a solution for valorisation of available low value biogenic oils that may substitute fossil-based fuels and chemicals and thereby contribute to a transition to a low-carbon economy.

At the same time, the European Green Deal points out the need for not only reducing the carbon footprint, but also preserving the world's natural resources, and provide future-proof jobs and skills training for the transition, to leave no one and no places behind (European Commission, 2019). These goals are accompanied by an increasing focus on the social dimension of sustainability. The Corporate Sustainability Reporting Directive (CSRD) states that risks related to social issues should be managed equally as environmental issues to enable just transition (European Parliament and Council of the European Union, 2022). Moreover, the EU has initiated work on a social taxonomy, for assessing and reporting on the impact of economic activities on social sustainability (Platform on Sustainable Finance, 2022).

However, among economic actors, social sustainability of the biobased economy in general and biofuels in particular has not received much attention, despite previous research pointing out the importance of addressing the social dimension of sustainability as well as the economic and environmental aspects (Kamali et al., 2018). While the social sustainability of products under development can be difficult to measure, it is possible and indeed necessary to assess potential social impacts to ensure their overall contribution to sustainable development and minimise negative consequences. The concept of social sustainability as such has been approached from various academic disciplines, and hence associated discipline-specific criteria, which make a generalised definition difficult to achieve. E.g., 'hard' social sustainability themes such as employment and poverty alleviation are complemented by 'soft' and less measurable concepts such as happiness, social mixing and sense of place (Colantonio, 2009). In practice, social sustainability assessment is often conducted through social impact assessment (SIA), which also may incorporate biophysical and economic variables. Overall, SIA can be defined as *"the process of identifying the future consequences of a current or proposed action(s), which are related to individuals, organisations and social macro-systems"* (Becker, 2001). According to previous research, a good SIA provides ''qualitative and quantitative indicators of social impact that can be understood by decision-makers and citizens alike'' (Burdge, 2003).

## 2.2. Conceptual underpinnings of the assessment

The assessment at hand is defined as a SIA, aiming to qualify and quantify the potential social impacts of implementing a fast pyrolysis plant with the EBIO technology in Innlandet county, considering the whole life cycle of the product, from feedstock to provision of end-products in the form of biofuels for use in transport. Potential impacts linked to alternative end-products, in the form of platform chemicals, are also briefly discussed. Thus, this SIA is a strategic assessment, where the aim is to shed light on potential benefits to society and thus promote the innovative technology as an element in sustainability transition, while also considering potential adverse impacts (Partidário 2015, 2016).

Our approach builds on the main concepts and categories in S-LCA (UNEP-SETAC 2009, 2020). Potential social impact is understood as the likely presence of a social impact, resulting from the activities of organisations linked to the life cycle and/or use of the focal product. While a full S-LCA requires extensive data and is difficult to validate, the conceptual framework provides a broad system perspective, including stakeholders and impacts at multiple levels, and at different geographical locations, depending on the value chain activities. It is therefore applied in this work, but in anticipation of limited data availability, and with concern to modify and link it to a specific case-study, we chose to define this assessment as a SIA, rather than a case of S-LCA.

S-LCA distinguishes between five stakeholder categories (workers, local community, society, consumers, value chain actors) and a set of main impact categories (including human rights, working conditions, health and safety, cultural heritage, governance, and socio-economic ripple effects). In addition, thirty sub-categories of social impact are listed (UNEP-SETAC, 2020). According to the guidelines, the selection of sub-categories should preferably reflect internationally recognised categorisations or standards or result from a multi-stakeholder process.

Still, neither S-LCA nor any other approach to SIA has become authoritative, and further method development is deemed necessary (Martin et al., 2018). We therefore conducted a state-of-the-art review on SIA for biofuels. Between December 2021 and March 2022, we assessed 45 studies, in terms of focus area, overarching assessment method, which stakeholders, impact categories and indicators that were considered, and any methodological challenges identified. The main and sub-categories of impacts from S-LCA were largely applied in the reviewed publications. However, some articles also emphasised the importance of social acceptability (Ahmad et al., 2021; Brinkman et al., 2019; Ekener et al., 2018; Falcone & Imbert, 2018), land use and land rights (Brinkman et al., 2019; Falcone & Imbert, 2018), and energy access and energy independence (Brinkman et al., 2019), instead of access to material and immaterial resources more broadly.

Both practitioners and policymakers, and previous research link bioeconomy innovations and regional development (see e.g., Refsgaard et al., 2021). On the other hand, several recent publications on bioeconomy innovations in sustainability transition question the actual positive implications of the bioeconomy (Allain et al., 2022; Bringezu et al., 2021). Against this background, we also consider regional innovation capacity and regional attractiveness as relevant impact categories.

Since not many databases exist (as expected for a new method), data collection is a central challenge in social sustainability assessment. Data may be collected from secondary sources like UN, OECD, or EU databases, provided by the industry, or collected directly. The UNEP-SETAC (2020) guidelines note that different contexts represent different challenges and need varying levels of assessment. Typically, an assessment may include generic assessment for life cycle stages that are not under the influence of the project partners, and specific assessment of activities within their sphere of influence. We thus apply both generic and site-specific data, based on local sources and consultation with stakeholders in the case region. In the following section, we define the scope of the assessment.

# 3. Scope

## 3.1 Goal

The goal of this SIA is to shed light on the potential benefits, risks and adverse impacts of the solutions developed in EBIO, if implemented full-scale. The focus is on the case where the EBIO process design for integration/add-on electrochemical systems is applied in a greenfield pyrolysis plant. We assume that the solution is implemented under the present (2024) conditions and consider social impacts of the technology both in a short- and longer-term perspective (2040), with a view to society's need and ambitions for sustainable energy transition.

Thus, the key question we address is: What are the potential total social impacts of implementing a value chain for production of advanced biofuels using EBIO technology in the selected case region?

## 3.2 Solution in focus

While EBIO has developed electrochemical conversion methods for upgrading two types of low-value bio liquids – pyrolysis oil and black liquor – this assessment focuses on the pyrolysis case. The electrochemical upgrading in EBIO aims to achieve a higher energy density and stability, which will allow for better blending with existing refinery streams than conventional upgrading methods. For our purposes, the process can be illustrated as in Figure 1.

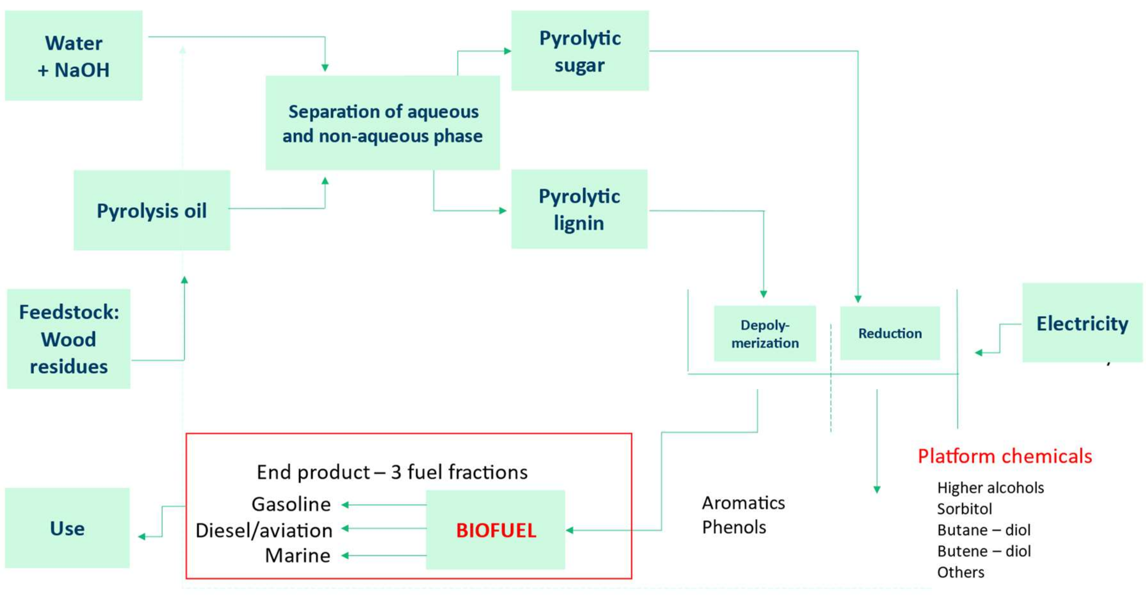


*Figure 1: Schematic illustration of the focal solution.*

Feedstock in the form of woody residues is entered into a fast pyrolysis plant, where it undergoes a thermochemical conversion into pyrolysis oil. The process results in some biogenic $CO_2$ emission and ash. A mix of sodium hydroxide and water, which results in heat and $OH^-$ ions, is subsequently added to the pyrolysis oil, to separate the aqueous and non-aqueous phase. From this, around 1/3 of cellulosic sugar and 2/3 of pyrolytic lignin is produced.

The electrochemical upgrading that is added results in a reduction of the cellulosic sugar to higher alcohols, and depolymerisation of the lignin, which provides aromatics and phenols that can be converted to biofuels. Limited amounts of hydrogen and oxygen are also generated in this phase. The fuel produced may be blended into gasoline and diesel or used as drop-in fuels in the form of renewable diesel and sustainable aviation fuel (SAF).

According to WP4 (Validation of the technology at lab scale and business plans) the solution is at technology readiness level (TRL) 3-4. This means that it is still under development, but the overarching key performance indicators (KPIs) for EBIO are:

- Carbon yield: EBIO targets a yield of at least 60% towards fuels, platform chemicals and high-value compounds.
- Cost effectiveness of the technology: Targeted production costs of bio-liquids to advanced biofuels below 1.5€/L (2020 benchmark) in the short term, less than 1€/L by 2030, and 0.8€/L beyond 2035 assuming stable feedstock and electricity prices.
- Value chain carbon footprint: Reduction of $CO_2$ emissions by 20 kg/GJ, based on applying electrochemical synthesis compared to producing hydrogen from natural gas resources; reduction by 100 kg/GJ compared to gasification.

The higher alcohols may eventually be used as platform chemicals. However, the end-product in focus in this assessment is fuel. In line with the guidelines for S-LCA, the use of the end-product is included within the system boundaries for this SIA.

In the case study, we assume that the above-mentioned process is implemented in a fast pyrolysis plant of the kind BTG recently designed for establishment in Finland and Sweden (Figure 2), at a suitable location in Innlandet.

*Figure 2: BTG pyrolysis plant in Gävle, Sweden, with capacity 40 000 tons of biomass per year. Source: https://www.btg-bioliquids.com/plant/pyrocell-gavle-sweden/*

The lay-out of one plant unit is typically 20 x 20 x 12 m, thus the overall lay-out with dryers and so on may be around 50 x 50 m. The investment is assumed to be around 40 million EUR, and the lifetime of the facility could be 20 years. The investment costs largely depend on the climatic region. A cold climate, as in Innlandet, requires additional insulation.

We assume that one plant unit is established, with the capacity to process 5 tons of dry biomass per hour (clean wood, for example from sawmills), resulting in around 3.5 tons of pyrolysis oil per hour. Such a plant requires a biomass availability of 40 000 tons per year, plus sufficient grid capacity to provide the electricity required for the electrochemical upgrading. The operating hours are set to 7 000 hours per year, and the needed manpower is assumed to be 10-15 employees per plant, mainly operators but also including two managers and technical staff.

The plant technology is modular, with scale-up by number rather than reactor volumes, e.g., if a capacity of 10 tons per hour is desired, there will be two plants. In the following, we refer to the kind of plant in focus of the assessment (i.e. like the one described above, but with EBIO technology implemented) as “EBIO biofuel plant”.

## 3.3 Case Innlandet

**Geography and natural resources**

Innlandet, a county in the south-eastern part of the country (Figure 3), is Norway’s largest agricultural region, measured in value creation. The production of milk, grains, vegetables, and meat employs 15,500 people across the value chains. 26% of the county's total area is productive forest, corresponding to 42% of Norway’s total harvest for sale, to a value of two billion NOK. Innlandet is also the county in Norway that has the highest number of agricultural properties (Statistics Norway, 2023a). 4% of the population is working in the primary sector, compared to 2% in Norway in total (Statistics

Norway, 2023d). 1,800 are employed in primary forestry, and when the employment in the timber and wood products industry is considered, the forest provides the basis for over 5 000 jobs scattered around the county (County Governor of Innlandet, 2023).

Innlandet is furthermore the least urbanised region in Norway, with 41% of the population living outside urban areas (Statistics Norway, 2023b). As EBIO has studied feedstocks that are typical side streams of wood processing industries and the aim has been to develop a technology that can be near-seamlessly integrated in the process design for new biorefineries, as well as within existing biorefineries, the richness in forest resources makes Innlandet interesting for a case study. In addition to rich forest resources, the industrial context in the region may provide favourable conditions for implementation of the EBIO technology.

*Figure 3: Map showing the location and extent of Innlandet county, Norway. Source: Google Maps.*

**Industry**

That a sizeable proportion works in the primary sector (Statistics Norway, 2023e), is reflected in the population's educational level and R&D activities. Innlandet is among the regions in Norway with lowest educational attainment (Statistics Norway, 2023c), least investment in R&D in companies (Statistics Norway, 2023h), and which seeks the least public funding for R&D (Statistics Norway, 2023g).

Still, Innlandet has developed a strong position in food technology and industry, breeding, agriculture, forestry, fish farming, wood mechanical industry and bioenergy. The county has a wide selection of businesses that work with (1) sawing, planing and impregnation of wood, (2) production of veneer sheets and other building and furniture boards of wood, (3) production of prefabricated houses, and (4) production of building materials (Sandberg et al., 2020). Moreover, the region hosts the Heidner

Biocluster, a national cluster including a high number of private sector actors, as well as leading knowledge institutions and key business associations within the bioeconomy (NCE Heidner Biocluster, 2020). The members engage in joint R&D projects, which have led to the establishment of new bioeconomy enterprises in the region. Also highly relevant is the Norwegian Wood Cluster, which aims to be an internationally leading cluster for wood-based industry.[1] In addition, there is the NCE Manufacturing, a National Centre of Expertise, which has its locus in the old industrial settlement of Raufoss, but currently includes more than 60 enterprises from different parts of the country.[2]

Much of the lumber from Innlandet is currently exported to Sweden and Finland (Statistics Norway, 2023f), so there is a big potential for increasing the value utilisation of the bio resources within the region. The BioNEXT project (Jåstad et al., 2021) points out that big investments in the Swedish and Finnish forest industry in recent years are likely to increase the annual demand for wood in the Nordics by about 20-25 million cubic meters. This means that there will be increased competition for the lumber, which investors in Norway must consider.

Currently, almost all liquid biofuel used in Norway is imported (Statistics Norway, 2023e).[15] Only small amounts of bioethanol (around 20 million litres per year) are produced domestically, by Borregaard. Apart from this, Silva Green Fuel has a demonstration facility at Tofte, Biozin Holding AS is working on an initiative linked to advanced bio-oil in Southern Norway,[3] and the Wood Cluster at Follum is keen to facilitate biofuel production in their vicinity. While an increase is expected, the future demand for biofuels in Norway will be strongly affected by the national and European policies regarding climate, energy and transport.

**Policies and framework conditions**

Norway is influenced by the EU's Renewable Energy Directive, even though it is not formally implemented in Norwegian law. In the revised version of the directive, RED III (European Parliament and Council of the European Union, 2023), the minimum share of 14% renewable energy in road and rail transport by 2030 is replaced by a requirement of minimum 13% GHG lifecycle emission reductions from all fuel and energy used in transport, with a 2.25% share of advanced biofuels by 2030 (Transport and Environment, 2023a). The principles of cascading use of biomass and minimising the use of whole trees and food and feed crops for energy production, are emphasised. The reduction of greenhouse gas emissions over the entire value chain, from raw material production to final use, must be at least 65%, when compared to fossil fuels. The biomass used as feedstock must not be associated with indirect land use change (ILUC).

The most recent national assessment of climate gas reduction measures (Norwegian Environment Agency, 2020) suggests that biofuels should amount to 40% of the energy use in Norwegian transport by 2030 (Norwegian Environment Agency, 2020). So far there are biofuel mandates for road (17%) and

[1] https://www.nwcluster.no/
[2] https://ncemanufacturing.no/om-oss
[3] Where an initial project with Shell was halted, but a new feasibility study has been started, in collaboration with Equinor and Bergene Holm, as one of the leading actors in the Norwegian lumber industry: https://biozin.no/bergene-holm-og-biozin-skal-studere-biodrivstoffprosjekt-med-equinor/

air transport (0.5%) (Norwegian Environment Agency, 2023). From 1. October 2023, there is also a requirement that 6% of the total volume of marine fuel traded in Norway shall be advanced biofuel (Norwegian Maritime Authority, 2023).

A national bioeconomy strategy was established as early as in 2016 (Norwegian Government, 2016). The bioeconomy and industrial processing of wood are further highlighted in the updated Roadmap towards a green industry in Norway (Norwegian Ministry of Trade, Industry and Fisheries, 2023), and circular bioeconomy is one of four focus areas in Norway's circular economy strategy (Norwegian Government, 2021). Several support mechanisms are available for biofuels initiatives, for example, through Enova, a state enterprise for the promotion of environment-friendly energy solutions, which has a large program for development of sustainable energy carriers.

The national bioeconomy strategy was followed by the "Bioeconomy Strategy for Innlandet 2017-2024" (Hedmark and Oppland counties, 2017).[4] This strategy emphasised the need to enable regional knowledge and competence-building through research and development collaboration with national and international research institutions. Innlandet strive to be attractive for entrepreneurs and innovative milieus aiming at bio-based value creation; to be a leading region in development of sustainable and knowledge-based production and use of bioresources; facilitate collaboration between stakeholders; and ensure visibility and communication between business and society.

Bio Valley is a wider regional partnership, which also includes the county administration and the Association of Norwegian Enterprises, Innovation Norway, and other relevant associations, and seeks to be a driver for investment, knowledge sharing, and creating favourable framework conditions for the bioeconomy in Innlandet (Biovalley, 2022). Increased utilisation and value creation from the side streams of the forestry and wood industry is a priority area.

Bio Valley was recently complemented by Innlandsporteføljen (the Innland Portfolio), a co-development initiative operated by the county authority, county governor, Innovation Norway, and the consultancy Ernst & Young, where the aim is to identify and groom the most innovative, profitable, and circular innovation projects in Innlandet. The initiative provides selected bio-hub projects with guidance and financial support, and the first hubs were selected in June 2023 (EY, 2023).

## 3.4 Stakeholders affected

In line with S-LCA, we see a stakeholder category as a category of people (organised in associations or enterprises, or as individuals), that can be affected by the activities involved in the life cycle of the product under consideration. Thus, the list of stakeholder categories considered in our case are the value chain actors, workers, users, the local community, and the wider society.

In accordance with the scope and selected case, the stakeholders involved in the assessment were mainly the project partners and stakeholders related to the case in Innlandet. A broad set of stakeholders in Innlandet was initially identified. These included actors in industry, education, research

[4] The former Hedmark and Oppland counties were merged into one county, Innlandet, in 2019.

and development, consultancy, policymakers and actors representing public initiatives, representatives of the financial sector, interest organisations, prospective users, workers, and the local community. In our case, the category “industry” embraces multiple actors in lumber and wood processing industry, and producers of wood products, industry clusters and member organisations, actors in biotechnology (Arbaflame[5]), and actors in bioenergy (Obio[6], Glocal green[7], Silva Green fuel[8]). The category “policy actors and actors representing public initiatives” includes innovation facilitators, public innovation initiatives (BioValley[9], Sirkulære Solør[10]) and public facilitators (Enova[11], Innovation Norway[12], Siva[13]). “Education, research and development” is represented by Inland Norway University of Applied Sciences, the Norwegian University of Life Sciences (NMBU[14]), and the Norwegian Institute of Bioeconomy Research (NIBIO[15]). From the financial sector, we identified two as particularly relevant (Våren, Investinor[16]). Of non-governmental organisations (NGOs), we identified two environmental organisations (e.g., Bellona[17], Zero[18]) as the most central, and in terms of users, we considered e.g., the Norwegian Truck Owners Association (NLF[19]), and the Norwegian Logistics and Freight Association[20] as good representatives. The stakeholder category “consultancy” included only one actor from the region that could be relevant to interview. The same applies to the categories “workers” and “local community”.

An early meeting with the Biovalley initiative confirmed interest in the EBIO project. Several stakeholders from the region were identified as relevant for data collection in the final SIA. Consultation with local stakeholders is crucial (Falcone et al., 2019; UNEP, 2020), to ensure that different perspectives are considered and make the assessment more relevant for decision-makers at the local level. However, due to lack of formal links to the project, only some of the identified stakeholders were available in this case. In the following chapter, we present the assessment framework that will be applied in this study.

[5] https://www.arbaflame.no/
[6] https://www.obio.no/home
[7] https://glocalgreen.com/en/
[8] https://www.silvagreenfuel.no/
[9] https://biovalley.no/
[10] https://sirkularesolor.no/
[11] https://www.enova.no/about-enova/
[12] https://en.innovasjonnorge.no/
[13] https://siva.no/english/
[14] https://www.nmbu.no/en
[15] https://www.nibio.no/en
[16] https://investinor.no/en/
[17] https://bellona.org/
[18] https://zero.no/
[19] https://lastebil.no/
[20] https://www.nholt.no/

# 4. Assessment framework and methodology

## 4.1 Assessment framework

To assess the potential social impacts of implementing a value chain for production of advanced biofuels using EBIO technology in Innlandet, we developed a framework that addresses all the five stakeholder categories identified in S-LCA and takes an impact pathway approach.

An impact pathway approach assesses potential or actual social impacts by considering causal or directional relationships between the product system activities and the resulting potential social impacts, to identify and track the consequences to longer-term implications along an impact pathway (UNEP-SETAC, 2009; UNEP, 2020). In terms of pathways, we are concerned with sustainability transition pathways for energy and transport, to explore the social acceptance and long-term social impacts of the EBIO technology in terms of socio-technical system change. Table 1 provides an overview of the main impact categories, subcategories, and indicators selected for each stakeholder category.

*Table 1: Overview of the developed assessment framework.*

| | Impact Category | Subcategories | Indicators |
|---|---|---|---|
| Value chain | Competence | Skill mix | Job requirements by qualification |
| | Competitive-ness | Potential adopters | The number of existing enterprises that may adopt the process technology |
| | | Substitution of non-sustainable products | The types and volume of non-sustainable products on the market that the end-product can replace |
| | | Incentives for early providers (production side) | The extent to which biofuel production is incentivised |
| | Governance | Transparency | The extent to which strategic plans, annual reports, sustainability reporting, etc. from the involved enterprises are publicly available |
| | | Traceability | The extent to which the origin of the input factors can be traced and managed |
| Workers | Health and safety | Health and safety of workers | The percentage of workers that are exposed to dust, gas or steam most of the time<br>The percentage of workers that are exposed to skin-irritating substances most of the time<br>The percentage of workers that have an elevated risk of accidents |
| | Human rights | Gender equality at work | The male/female wage ratio<br>The male/female employment ratio |

| | | | |
|---|---|---|---|
| | Labour rights and decent work | Fair wages | Wages for each part of the value chain compared to minimum wage |
| | | Unionisation | The share of workers organised in trade unions |
| | | Meaningful work | The percentage of workers that are required to work at a high pace often or always.<br>The percentage of workers that will often or always be required to acquire new knowledge and skills. |
| Users | Social acceptability | Fulfilment of formal sustainability criteria | The extent to which the end-product meets sustainability criteria laid down in relevant regulations |
| | | Willingness to pay | The maximum price consumers are willing to pay for one unit of the end-product |
| | Usability | Ease of use | The extent to which the end-user needs to modify user equipment or practices |
| | Availability | Incentives for users | The extent to which the use of the end-product is incentivised |
| Local community | Contribution to local economy | Value creation | The expected gross product of the economic activity related to implementation of the solution |
| | Quality of life | Employment | The expected number of new employees resulting from implementation of the solution |
| | | Bequest value | The level of satisfaction from preserving the natural environment for future generations |
| | Innovation capacity | Contribution to innovation clusters | The number of existing clusters expected to benefit from the initiative |
| | | R&D activities | The number of R&D activities initiated in connection with the solution |
| | Regional attractiveness | Contribution towards realisation of regional development strategies | The extent to which implementation of the solution can contribute towards realisation of regional development strategies |
| | | Regional economic attractiveness | The extent to which implementation of the solution can influence the economic attractiveness of the region |
| Wider society | Energy security | Renewable share of energy mix | The extent to which implementation of the solution will increase the renewable share of the energy consumption |
| | | Secure energy supply for transport | The extent to which implementation of the solution can contribute to securing supply of biofuel |
| | Food security | Use of arable land | The territory of arable land needed to produce the annual need for feedstock |
| | Sustainability transition | Alignment with national decarbonisation policies | The extent to which implementation of the solution is aligned with national policies for decarbonising the transport sector<br>The amount of GHG emission the implementation of the solution can contribute to reduce |

| | | | |
|---|---|---|---|
| | | Contribution towards circularity | The amount of waste the implementation of the solution can contribute to reduce |

The impact categories and subcategories are described in more detail in Annex 1, and the indicators defined in Annex 2.

## 4.2 Selection of impact categories

To arrive at the assessment framework presented above was a process involving extensive desk study and dialogue with stakeholders internal to the project. First, an initial set of social impact categories and sub-categories was selected, based on the UNEP-SETAC guidelines (2009, 2020) and the mentioned literature review (reported in M1.3).

The relevance of the selected categories was subsequently discussed and ranked by the project partners. In May 2023, we had a face-to-face workshop session, where both research partners and industry partners initially sat together in groups, and thereafter ranked the relevance of each sub-category individually, using a 1-5 Likert scale.

In August 2023, the feedback from the first session was summarised and presented at an online meeting, for another round of feedback. As a result of this process, some of the initial sub-categories were discarded, and those exhibited in Table 2 were validated.

Each impact category is justified and described in detail in Annex 1.

## 4.3 Selection of indicators

The indicator set was developed in parallel with the selection of subcategories, through an iterative process which involved review of existing indicators, used in the reviewed literature and/or other relevant indexes, standards and statistics for Norway and the EU; categorisation of the indicators, in terms of stakeholder and impact categories; assessing their quality; and selecting a set of high-quality indicators that covers all important impact categories and subcategories.

The indicators were collected in a matrix, categorised by stakeholder categories, impact categories and sub-categories. The matrix also contains the relevant measurement units, for some indicators this can be a specific number, in monetary terms (euro or NOK), for others it is more relevant to provide a percentage, and for yet others we only apply an ordinal ranking. Furthermore, the matrix presents the level of measurement for each of the indicators. The levels range from enterprise and sector to region (county) and national level. From public statistics we can find values related to industry codes or the municipal level.

If the indicator is measured over time, there is a field indicating direction, that is, if the indicator value is expected to increase or decrease over time. There is also a field for sources and alternative sources. The source or calculation method is where the indicator value is retrieved from. This can be calculated quantitatively through input-output modelling, or qualitatively through desk studies or stakeholder consultation. Public statistics can be an alternative source, for comparing or as proxy if the indicator value at the preferred level cannot be found. There is also a field for links to available data sources or sources explaining the indicator more thoroughly. Additionally, each indicator has a comment field, if there is a need to specify, for instance limitations in the available data sources or in which time perspective this indicator will be relevant for.

Inspired by previous work with indicators for climate change adaptation, the collected indicators were evaluated based on the following seven quality criteria:

1. Interpretability – the indicator should be unambiguously interpretable (Collotta et al., 2019)
2. Reliability (on-target) – the indicator should measure what it is supposed to measure (Snep et al., 2020)
3. Sensitivity – It should be possible to influence the indicator value (Harley et al., 2008)
4. Data availability – There should be data available to quantify the indicator value (Collotta et al., 2019)
5. Efficiency – It should not take long to quantify the indicator value (Snep et al., 2020)
6. Generalisability – The indicator should be relevant for other regions and companies (Standard Norway, 2019; Standard Norway, 2021; the German Federal Government, 2019)
7. Relevance – The indicator should be relevant for SIA (Snep et al., 2020).

Each indicator was given a score from 1 (poor) – 5 (very good) for each of the quality criteria. Finally, an overall score of 1-5 was awarded to identify possible key indicators. The final scoring was done qualitatively, based on a combination of assessments mentioned in the original sources. The quality assessment generated an initial indicator set that was evaluated by the project partners in one physical and one online workshop. The partners' feedback was incorporated in two revised indicator sets, one for assessment of potential social impacts, and one for measuring impacts following the actual implementation of the solution. In the next, online workshop interaction, the project partners were presented with the indicator set for potential impacts, which also are those presented and applied in this report.

The indicator set is presented in Annex 2. The annex consists of 32 factsheets, one for each indicator. Table 2 shows the template applied for the factsheets and explains the logic behind each of the aspects included in the form.

*Table 2: Template fact sheet for characterisation of each of the selected indicators.*

| | |
|---|---|
| Indicator ID | *Each indicator is given an ID for easy reference in the final assessment. This consists of an initial letter, referring to the relevant stakeholder category, and a number, depending on the number and order of indicators for each stakeholder category.* |
| Title | *This line provides the exact formulation of the indicator.* |
| Value | *This line will eventually provide the final value identified for the indicator. We have indicated values at a five-level scale -2 to 2.* |
| Impact category | *Links the indicator to a specific main impact category.* |
| Sub-category | *Links the indicator to a specific sub-category.* |

| | |
|---|---|
| Scale/unit | *The scale/unit varies across the indicators, and is in some cases quantitative (e.g., currency, tons, or hectares), and in others qualitative, e.g., ordinal ranking (low-medium-high).* |
| Level | *Shows at what level the indicator can be assessed, e.g., enterprise, sector, regional or national level.* |
| Direction | *For some indicators, we want the impact to increase positively (P), for others (e.g., exposure to accidents at work) we would like to see a limited impact as possible (N).* |
| Stakeholder category | *Specifies the relevant stakeholder category.* |
| Source/ Calculation method | *Defines the valuation method.* |
| Alternative source | *Provides information about other valuation methods that may be suited, depending on the time, resources, and data available for assessment.* |
| Description | *Brief explanation of the rationale behind the selection of the respective indicator.* |
| References | *Points to sources that can be used in making the assessment.* |
| Comment | *Any additional comments.* |

## 4.4 Assessment methods

In this assessment mixed methods were applied, to provide a broad perspective on the potential social impacts of implementing an EBIO biofuel plant in Innlandet.

A key method was the application of a dynamic input-output model developed by SINTEF. This model expands on the static input-output model by combining it with macroeconomic forecasting. Input-output analysis is a common approach to evaluate effects on employment and on economic activity (value-added in sectors) (Brinkman et al., 2019). Such analysis is based on input-output tables, which display a snapshot of a national economy for a given year in terms of how economic sectors trade and how final products are consumed by different end consumers. The comprehensive description of sectoral economic linkages makes it possible to study the effects of a new economic activity through entire value chains. The modelling is presented in more detail in chapter 6.

Besides the modelling, available national statistics and databases were used to provide quantitative assessment for some indicators. Generic data were applied, both to enable assessment of parts of the life cycle that are not within the activity sphere of the project partners, and since the focal solution still is at a low technology readiness level (TRL3-4), implying that limited data are available. The generic data included data for related sectors, and similar kinds of products. Thus, it is data with a lower resolution than case- or site-specific data (UNEP-SETAC, 2020, p. 67).

The combination of quantitative and qualitative assessment is crucial, as social sustainability analysis should combine different perspectives and integrate criteria of different quality and origin (Omann & Spangenberg 2002, Littig & Griessler 2005). While qualitative indicators may not be measured according to a fixed ratio, they may be ranked according to an ordinal scale, such as "high-medium-low" impact. Such ranking will be subjective and add limited explanatory value unless accompanied by full-text qualitative assessment. It has, however, been noted that that such methods can be useful to consider the subjectivities of sustainability, particularly through the inclusion of stakeholder perspectives (Mattioda et al. 2019).

Qualitative assessments can be based on different data collection methods. In this case, as the focal solution is complex and early-stage, desk study and semi-structured stakeholder interviews were applied. All interviews were carried out online (in Teams) in the first half of 2024. Each interview lasted approximately one hour and covered the background and relevant activities of the respective stakeholder, as well as barriers, drivers, and potential impacts of producing biofuel via the EBIO technology in Innlandet, considering the identified categories and sub-categories of impacts. Table 3 provides an overview of the stakeholders interviewed, sorted by category.

*Table 3: Stakeholders interviewed.*

| Stakeholder category | Number of interviews |
|---|---|
| **Industry actors** | 5 |
| **Forest owners (cooperative)** | 1 |
| **Education, research and development** | 1 |
| **Public initiatives and decision-makers** | 3 |
| **Users** | 1 |
| **Total** | 11 |

Relevant NGOs and financing institutions were also contacted, but unfortunately not available for interviews. As the focal solution has not been implemented, there were no workers to address. Instead, potential impacts for this stakeholder category were assessed via generic data, and the interviewed stakeholders were asked to reflect on potential impacts for workers, based on their experience or impressions of other bioenergy activities.

The qualitative and quantitative assessments relate to both short-term impacts (impacts if an EBIO biofuel plant was established now, or in the next two years) and potential longer-term impacts, towards 2040.

For the assessment we use a reference scale to supplement the descriptive assessments and figures, to distinguish between different directions and degrees of impact. The scale is as follows:

+2: Strong positive impact, ideal or close to ideal performance

+1: Modest positive impact, e.g., some progress beyond compliance

0: Neutral, no significant positive or negative impact, e.g., compliance with local laws

-1: Modest risk of negative impact or non-compliant situation

-2: High risk of negative impact, or documented negative performance, e.g., wages paid are below the legal minimum wage

Such a scale is recommended as an example reference scale in the guidelines for S-LCA of products and organisations (UNEP, 2020). More specific values can be added as the technology advances and more specific data become available. The advantage of the five-level scale valuation approach is that the indicators become more comparable.

# 5. Input-output analysis

## 5.1 Modelling framework

To assess employment and value-added we deployed an economic input-output (IO) model with socio-economic extensions. These types of models have the advantage of both estimating the direct effects of changes in the economy and the indirect, or value chain effects of the changes, making them a preferred tool for understanding the full effects of changes in the economy, such as changes in consumption, production structures or the establishment of a new industry in the economy.

The specific model applied has been developed at SINTEF with the working title MEIONorway. The model has previously been applied to study the potential of an offshore wind sector in Norway (Aponte et al., 2021), the potential for circular economy interventions in different sectors in Norway (Nørstebø et al., 2020; Wiebe et al., 2023) and circular economy strategies for the plastics sector in Estonia (Young et al., 2023) among others.

In its most basic form, a one-region input-output model consist of various economic data and socioeconomic extensions (Figure 4).

| Input output Table | Using sectors | Final demand | Total use |
|---|---|---|---|
| Supplying sectors | Z (L) | Y | x |
| Value added (labour, taxes, etc.) | VA | | |
| Output | x' | | |

| | |
|---|---|
| Employment, waste intensities | S |

*Figure 4: The components of an input-output model (Young et al., 2023).*

The monetary flows between economic sectors are covered in the Z-matrix and final demand of households, governments, and exports (among others) in the Y-matrix. Summing Z and Y across columns gives the total output of economic sectors (x). In addition to this, economic sectors need factor inputs such as employment and capital and they need to pay taxes. These components together make up the value-added (VA) in the economy. When summing across the rows, these sum up to total input (x'), which is equivalent to output (x) on a sectoral level, hence input equals output. Socio-economic extensions can be tagged on to these models in the form of impacts per monetary unit of output (the S-matrix in Figure 4). These models can also be multiregional and have global coverage, but as we are primarily concerned with the Norwegian context here, a single-region model for Norway was deemed sufficient.

The model is based on the official IO tables for Norway published by Statistics Norway (2022). The sector classification follows the standardised NACE classification (ShowVoc, 2023), which is used for IO tables for most European countries and several other countries outside Europe, which allows for easy comparison of analysis across countries.

## 5.2 New sector setup

When investigating the economic impacts of an industry or sector that is yet to be established, many unknown variables are involved. In IO analysis a way to tackle this challenge is to use an existing and known sector as a starting point and make assumptions or adjustments from that sector. The task is to set up the new building blocks of the new sector in a state where nothing is produced, and then introduce the production and possibly let it replace other products on the market to study its effect on the economy.

For setting up the new sector, the "Coke and refined petroleum product" sector (NACE code 19) was used as a starting point. The most important reason for choosing this sector is that it is assumed to produce similar products to the EBIO industry (mainly fuel and oil). With this assumption in place, the key adjustment to resemble the EBIO industry is to change the input structure. The goal here is to make the input structure as similar as possible to the inputs needed to produce the EBIO product(s).

For confidentiality reasons Statistics Norway aggregate NACE sector codes 19 (Coke and refined petroleum products), 20 (Chemicals and chemical products), and 21 (Basic pharmaceutical products and pharmaceutical preparations) into one sector. Hence, numbers are only available for NACE code 21. This sector has the following most important inputs from other industries per the most recent Norwegian IO table from 2020 (Table 4).

*Table 4: Top 20 inputs (in Million NOK) to NACE code 21: Basic pharmaceutical products and pharmaceutical preparations*

| Rank | Top inputs | Top input values | % |
|---|---|---|---|
| 1 | Mining and quarrying | 28783 | 54.9 % |
| 2 | Wholesale trade services, except of motor vehicles and motorcycles | 2649 | 5.1 % |
| 3 | Land transport services and transport services via pipelines | 2624 | 5.0 % |
| 4 | Electricity, gas, steam and air-conditioning | 2401 | 4.6 % |
| 5 | Basic pharmaceutical products and pharmaceutical preparations | 2142 | 4.1 % |
| 6 | Retail trade services, except of motor vehicles and motorcycles | 2113 | 4.0 % |
| 7 | Warehousing and support services for transportation | 1411 | 2.7 % |
| 8 | Repair and installation services of machinery and equipment | 1007 | 1.9 % |
| 9 | Public administration and defence services; compulsory social security services | 957 | 1.8 % |
| 10 | Financial services, except insurance and pension funding | 732 | 1.4 % |
| 11 | Legal and accounting services; services of head offices; management consulting services | 720 | 1.4 % |
| 12 | Security and investigation services; services to buildings and landscape; office administrative | 700 | 1.3 % |
| 13 | Water transport services | 495 | 0.9 % |
| 14 | Computer programming, consultancy and related services; information services | 486 | 0.9 % |
| 15 | Services auxiliary to financial services and insurance services | 358 | 0.7 % |
| 16 | Real estate services (excluding imputed rents) | 350 | 0.7 % |
| 17 | Rental and leasing services | 309 | 0.6 % |
| 18 | Sewerage; waste collection, treatment and disposal activities; materials recovery; remediatio | 308 | 0.6 % |
| 19 | Telecommunications services | 274 | 0.5 % |
| 20 | Services furnished by membership organisations | 260 | 0.5 % |
| **Sum** | | **49078** | **93.6 %** |

The top inputs list is largely dominated by "Mining and quarrying". While the top 20 inputs make up 93.6% of the total inputs, there are six sectors that make up 77.7% of the total inputs. What this tells us is that these sectors are key to focus on when changing the input structure.

Similarly, the top outputs from the "Basic pharmaceutical products and pharmaceutical preparation" sector to other sectors can be found (Table 5).

*Table 5: Top 20 outputs (in Million NOK) from NACE code 21: Basic pharmaceutical products and pharmaceutical preparations.*

| Rank | Top outputs | Top output values | % |
|---|---|---|---|
| 1 | Constructions and construction works | 4292 | 12.6 % |
| 2 | Human health services | 3376 | 9.9 % |
| 3 | Mining and quarrying | 2623 | 7.7 % |
| 4 | Land transport services and transport services via pipelines | 2439 | 7.2 % |
| 5 | Basic pharmaceutical products and pharmaceutical preparations | 2142 | 6.3 % |
| 6 | Products of agriculture, hunting and related services | 1569 | 4.6 % |
| 7 | Fish and other fishing products; aquaculture products; support services to fishing | 1534 | 4.5 % |
| 8 | Water transport services | 1157 | 3.4 % |
| 9 | Air transport services | 1144 | 3.4 % |
| 10 | Retail trade services, except of motor vehicles and motorcycles | 1007 | 3.0 % |
| 11 | Wholesale trade services, except of motor vehicles and motorcycles | 968 | 2.8 % |
| 12 | Warehousing and support services for transportation | 905 | 2.7 % |
| 13 | Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services | 671 | 2.0 % |
| 14 | Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services | 579 | 1.7 % |
| 15 | Public administration and defence services; compulsory social security services | 561 | 1.6 % |
| 16 | Wholesale and retail trade and repair services of motor vehicles and motorcycles | 537 | 1.6 % |
| 17 | Food products, beverages and tobacco products | 537 | 1.6 % |
| 18 | Accommodation and food services | 524 | 1.5 % |
| 19 | Repair and installation services of machinery and equipment | 509 | 1.5 % |
| 20 | Social work services | 466 | 1.4 % |
| **Sum** | | **27538** | **81 %** |

While the outputs, or intermediate demand from other sectors, are of less interest in this case, it is of interest to see which sectors rely on output from the "Basic pharmaceutical products and pharmaceutical preparation" to produce their own goods. The top twenty outputs make up about 81% of total outputs, showing again a relatively high concentration of a few sectors, as was the case for the input structure (Table 4). Particularly "Construction and construction work" (12.6%), which is also the sector with the largest production value in Norway, and "Human Health Service" (9.9%) stand out in this context. Relevant to note is that "Mining and quarrying" (7.7%), which is the dominating sector that "Basic pharmaceutical products and pharmaceutical preparation" requires input from, also is an important demanding industry.

## 5.3 Adjustments to production structure to resemble EBIO

Here we relied on literature and the results from the technoeconomic assessment in the EBIO project (Deliverable D1.5) to make the proper adjustments to the sector structure, as well as socio-economic extensions. The following adjustments were made:

- Input structure (Using results from D1.5)
- Value-added adjustments per unit of output
- Labour requirements per unit of output
- Imports adjustments
- Demand adjustments (intermediate and final)

In the following sub-sections, we discuss these adjustments one by one.

**Input structure adjustments**

The techno-economic assessment (D1.5) explored both the CAPEX and OPEX of the EBIO technology, but due to the challenges of determining the investments and building phases' effects on the whole economy in a specific year (where in the economy is the investment coming from), we focused on the operational phase including maintenance and the capital investments costs distributed over the lifetime of the components. As such, the analysis here represents a future state where the EBIO process is fully operational.

Specifically, we based our new analysis on the provided Net Present Value (NPV) (Deliverable D1.5, Table 11). The averaged yearly costs of both the operational and capital investment phases are given in the NPV. To utilize this information in the input-output analysis, we assigned these cost components to economic sectors following the NACE classification (Table 6).

*Table 6: Inputs from the NPV estimates in D1.5 and allocations to the sectors in the IO tables.*

| Input | Annualized costs (k€/year) | Allocation to IO sector | Share of input in the NPV in D1.5 | Share of total input new sector |
|---|---|---|---|---|
| **Pyrolytic oil** | 1016 | R02 | 52.4 % | 16.9% |
| **Water** | 6.47 | R36 | 0.3% | 0.1% |
| **Electricity** | 834 | RD | 43.0% | 13.8% |

| | | | | |
|---|---|---|---|---|
| **Heating (steam)** | 43.8 | RD | 2.3% | 0.7% |
| **Cooling (water)** | 0.12 | R36 | 0.0% | 0.0% |
| **Mixing tank** | 9.4 | R25 | 0.5% | 0.2% |
| **Membrane column** | 4.9 | R25 | 0.3% | 0.1% |
| **Electrochemical reactor 1** | 3.6 | R27 | 0.2% | 0.1% |
| **Electrochemical reactor 2** | 22.4 | R27 | 1.2% | 0.4% |

The allocation of the products in Table 6 to IO sectors was not straightforward as the NACE sector codes are not at the individual product level detail. The allocations above are resultingly best estimates based on a search of NACE product and HS product codes. Note here that although pyrolytic oil most likely will be placed in the Chemicals and chemical products (R20) sector, this sector is coupled with Basic pharmaceutical products and pharmaceutical preparations (R21) in the Norwegian IO tables for confidentiality reasons. As placing pyrolytic oil in R21 will be like conventional oil/ production (this sector is dominated by oil production), we place pyrolytic oil in the Products of forestry, logging, and related services (R02) sector. This is not to say that R02 necessarily will produce pyrolytic oil, but rather to distinguish pyrolytic oil from conventional oil production.

Factors related to structural funding opportunities, tax regimes, and incentives were considered to fall outside the scope (as per Deliverable D1.5), so here we assumed the same structure as for the parent sector in the IO table.

All input coefficients sum up to 100% (or 1 in the A-matrix) in an input-output system which is the starting point for adjusting the input coefficients to resemble the inputs needed for production in the EBIO sector.

In IO tables, a specific sector needs input from most other sectors of the economy (see Table 7). This usually entails input that are not physical products but rather services not included in the NPV analysis in D1.5, such as transport services, wholesale and retail, and financial services. These inputs usually make up a smaller share of the total inputs needed. The inputs that we assumed are replaced by the inputs in Table 6, on the other hand, make up the remaining 30.7% when subtracting imports totalling 31.2% (which is not analysed here) (Table 7):

*Table 7: Inputs replaced in the parent sector.*

| Sector | Share in parent sector |
|---|---|
| **Mining and quarrying (RB)** | 25.5% |
| **Electricity, gas, steam, and air-conditioning (RD)** | 2.1% |
| **Basic pharmaceutical products and pharmaceutical preparations (R21)** | 1.9% |
| **Rubber and plastics products (R22)** | 0.2% |
| **Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials (R16)** | 0.2% |

| | |
|---|---|
| **Constructions and construction work (RF)** | 0.2% |
| **Basic metals (R24)** | 0.2% |
| **Machinery and equipment n.e.c. (R28)** | 0.1% |
| **Fabricated metal products, except machinery and equipment (R25)** | 0.1% |
| **Products of forestry, logging, and related services (R02)** | 0.1% |
| **Electrical equipment (R27)** | 0.1% |
| **SUM** | **30.7%** |
| | |

Given the current low production surplus of the final product from the estimates in D1.5 at approximately 4.7%, combined with the discussion above that inputs from particularly service sectors are omitted in the NPV, we reduced the net operation surplus in the IO table that in the parent sector is 3.5% to 2% as an estimate. The remaining 1.5% was added to the 30.7% making the total 32.2% and these are distributed according to the shares in Table 6. The resulting shares are shown in the second column from the right (Table 6) and represent the new input shares in the EBIO sector.

## Value-added adjustments

The components that make up value-added in the "Basic pharmaceutical products and pharmaceutical preparations" sector are quite different from the economy-wide value-added components (Table 8).

*Table 8: Components of value-added (VA) as share of total output for the "Basic pharmaceutical products and pharmaceutical preparations" sector (left) versus the Norwegian economy as a whole (right)*

| Value added components | VA share of total inputs ind | VA share of total inputs economy-wide |
|---|---|---|
| Compensation of employees | 11.1 % | 35.1 % |
| Wages and salaries | 0 % | 0.0 % |
| Other net taxes on production | 0 % | -0.1 % |
| Consumption of fixed capital | 8 % | 5.0 % |
| Operating surplus, net | 3 % | 27.0 % |

Most notable is the low overall value-added share out of total inputs (22.0%) compared to the economy-wide share (67.1%). In fact, the "Basic pharmaceutical products and pharmaceutical preparations" ranks 58 out of 65 in value-added of all sectors. This could be an indication of costly input from Mining and Quarrying making the sector less profitable.

The "Consumption of fixed capita" value was adjusted above, but beyond this we assumed that the EBIO sector will have a similar structure as its parent sector, so the other value-added coefficients were kept the same as for the "Basic pharmaceutical products and pharmaceutical preparations" sector.

## Employment adjustments

Similarly, to value added and intermediate inputs, we took the "Basic pharmaceutical products and pharmaceutical preparations" sector as a starting point. This sector employs approximately 0.02 employees per MNOK output, making it the fourth lowest sector when ranked by employees per unit of output. The economy-wide average is 0.5 employees per MNOK of output. Findings in the EBIO project suggests that 10-15 persons will be employed at the factory, while the production value once the factory is operating at full load capacity is in the range of 232-408 MNOK (based on calculations in the scenario section further down) in basic pricing depending on the market price of biofuel. This gives an employment coefficient of 0.025-0.065. We set this value to 0.035, which is between the economy-wide coefficient and the "Basic pharmaceutical products and pharmaceutical preparations" sector's coefficient.

The relatively low direct employment effects compared to the rest of the economy in the EBIO sector indicates that indirect value chain employment effects can be expected to dominate the employment generated in the value chain of EBIO.

**Imports adjustment**

Again, we used the "Basic pharmaceutical products and pharmaceutical preparation" sector's import share (31.2%), which is significantly larger than the economy-wide import share (11.8%). This indicates that a large portion of the value chain effects due to activity in this sector can be seen in other countries. We did the same adjustments to the import coefficients as for the domestic coefficients above (see bullet point lists).

**Demand adjustments**

Final demand was set to have the equivalent structure of the "Basic pharmaceutical products and pharmaceutical preparations" sector, where the underlying assumption is that the final product produced by the EXIO sector is the same as the "Basic pharmaceutical products and pharmaceutical preparations" sector and can replace this product (i.e., mainly fuel).

**Final sector setup**

As a last step, we assumed that the share of input needed from EBIO's own sector is approximately 3.9%. This entails scaling down all the other inputs to the EBIO sector (sectoral and value-added components) by 3.9%. With the assumptions above in place, we arrived at the following setup for the EBIO sector (Figure 5):

| sector code | sector name | type | row domestic | column domestic | row imports | column imports | Color codes |
|---|---|---|---|---|---|---|---|
| CPA_A01 | Products of agriculture, hunting and related services | sector | 0.014 | 0.000 | 0.018 | 0.000 | New sector |
| CPA_A02 | Products of forestry, logging and related services | sector | 0.001 | 0.169 | 0.001 | 0.000 | column-specific entries |
| CPA_A03 | Fish and other fishing products; aquaculture products; support services to fishing | sector | 0.014 | 0.000 | 0.022 | 0.000 | row-specific entries |
| CPA_B | Mining and quarrying | sector | 0.003 | 0.000 | 0.046 | 0.000 | parent sector |
| CPA_C10-C12 | Food products, beverages and tobacco products | sector | 0.005 | 0.001 | 0.008 | 0.000 | extensions |
| CPA_C13-C15 | Textiles, wearing apparel and leather products | sector | 0.000 | 0.000 | 0.002 | 0.001 | |
| CPA_C16 | Wood and of products of wood and cork, except furniture; articles of straw and plaiting mater | sector | 0.004 | 0.000 | 0.004 | 0.001 | |
| CPA_C17 | Paper and paper products | sector | 0.001 | 0.000 | 0.003 | 0.001 | |
| CPA_C18 | Printing and recording services | sector | 0.001 | 0.000 | 0.000 | 0.000 | |
| CPA_C19 | Coke and refined petroleum products | sector | 0.000 | 0.000 | 0.000 | 0.000 | |
| CPA_C20 | Chemicals and chemical products | sector | 0.000 | 0.000 | 0.000 | 0.000 | |
| CPA_C21 | Basic pharmaceutical products and pharmaceutical preparations | sector | 0.000 | 0.000 | 0.106 | 0.147 | |
| CPA_C22 | Rubber and plastics products | sector | 0.002 | 0.000 | 0.024 | 0.004 | |
| CPA_C23 | Other non-metallic mineral products | sector | 0.004 | 0.000 | 0.014 | 0.001 | |
| CPA_C24 | Basic metals | sector | 0.002 | 0.000 | 0.016 | 0.000 | |
| CPA_C25 | Fabricated metal products, except machinery and equipment | sector | 0.003 | 0.002 | 0.003 | 0.002 | |
| CPA_C26 | Computer, electronic and optical products | sector | 0.001 | 0.000 | 0.000 | 0.001 | |
| CPA_C27 | Electrical equipment | sector | 0.000 | 0.004 | 0.000 | 0.002 | |
| CPA_C28 | Machinery and equipment n.e.c. | sector | 0.001 | 0.000 | 0.000 | 0.000 | |
| CPA_C29 | Motor vehicles, trailers and semi-trailers | sector | 0.001 | 0.000 | 0.004 | 0.000 | |
| CPA_C30 | Other transport equipment | sector | 0.003 | 0.000 | 0.001 | 0.000 | |
| CPA_C31_C32 | Furniture; other manufactured goods | sector | 0.001 | 0.000 | 0.001 | 0.000 | |
| CPA_C33 | Repair and installation services of machinery and equipment | sector | 0.005 | 0.008 | 0.003 | 0.004 | |
| CPA_D35 | Electricity, gas, steam and air-conditioning | sector | 0.003 | 0.146 | 0.002 | 0.127 | |
| CPA_E36 | Natural water; water treatment and supply services | sector | 0.000 | 0.001 | 0.001 | 0.000 | |
| CPA_E37-E39 | Sewerage; waste collection, treatment and disposal activities; materials recovery; remediatio | sector | 0.005 | 0.003 | 0.006 | 0.009 | |
| CPA_F | Constructions and construction works | sector | 0.038 | 0.000 | 0.046 | 0.000 | |
| CPA_G45 | Wholesale and retail trade and repair services of motor vehicles and motorcycles | sector | 0.005 | 0.000 | 0.004 | 0.000 | |
| CPA_G46 | Wholesale trade services, except of motor vehicles and motorcycles | sector | 0.009 | 0.022 | 0.006 | 0.000 | |
| CPA_G47 | Retail trade services, except of motor vehicles and motorcycles | sector | 0.009 | 0.018 | 0.008 | 0.000 | |
| CPA_H49 | Land transport services and transport services via pipelines | sector | 0.022 | 0.022 | 0.018 | 0.000 | |
| CPA_H50 | Water transport services | sector | 0.010 | 0.004 | 0.130 | 0.000 | |
| CPA_H51 | Air transport services | sector | 0.010 | 0.000 | 0.020 | 0.000 | |
| CPA_H52 | Warehousing and support services for transportation | sector | 0.008 | 0.012 | 0.006 | 0.002 | |
| CPA_H53 | Postal and courier services | sector | 0.001 | 0.002 | 0.001 | 0.000 | |
| CPA_I | Accommodation and food services | sector | 0.005 | 0.000 | 0.006 | 0.000 | |
| CPA_J58 | Publishing services | sector | 0.001 | 0.001 | 0.001 | 0.001 | |
| CPA_J59_J60 | Motion picture, video and television programme production services, sound recording and mu | sector | 0.001 | 0.001 | 0.002 | 0.000 | |
| CPA_J61 | Telecommunications services | sector | 0.001 | 0.002 | 0.000 | 0.000 | |
| CPA_J62_J63 | Computer programming, consultancy and related services; information services | sector | 0.002 | 0.004 | 0.002 | 0.002 | |
| CPA_K64 | Financial services, except insurance and pension funding | sector | 0.002 | 0.006 | 0.000 | 0.001 | |
| CPA_K65 | Insurance, reinsurance and pension funding services, except compulsory social security | sector | 0.000 | 0.001 | 0.000 | 0.000 | |
| CPA_K66 | Services auxiliary to financial services and insurance services | sector | 0.001 | 0.003 | 0.000 | 0.001 | |
| CPA_L68B | Real estate activities without imputed rents | sector | 0.002 | 0.003 | 0.001 | 0.000 | |
| CPA_L68A | Imputed rents | sector | 0.004 | 0.000 | 0.004 | 0.000 | |
| CPA_M69_M70 | Legal and accounting services; services of head offices; management consulting services | sector | 0.001 | 0.006 | 0.001 | 0.003 | |
| CPA_M71 | Architectural and engineering services; technical testing and analysis services | sector | 0.002 | 0.001 | 0.001 | 0.000 | |
| CPA_M72 | Scientific research and development services | sector | 0.000 | 0.001 | 0.000 | 0.000 | |
| CPA_M73 | Advertising and market research services | sector | 0.003 | 0.001 | 0.001 | 0.000 | |
| CPA_M74_M75 | Other professional, scientific and technical services; veterinary services | sector | 0.002 | 0.001 | 0.002 | 0.001 | |
| CPA_N77 | Rental and leasing services | sector | 0.001 | 0.003 | 0.002 | 0.002 | |
| CPA_N78 | Employment services | sector | 0.000 | 0.002 | 0.000 | 0.000 | |
| CPA_N79 | Travel agency, tour operator and other reservation services and related services | sector | 0.000 | 0.000 | 0.000 | 0.000 | |
| CPA_N80-N82 | Security and investigation services; services to buildings and landscape; office administrative | sector | 0.006 | 0.006 | 0.009 | 0.001 | |
| CPA_O84 | Public administration and defence services; compulsory social security services | sector | 0.005 | 0.008 | 0.005 | 0.000 | |
| CPA_P85 | Education services | sector | 0.002 | 0.001 | 0.004 | 0.000 | |
| CPA_Q86 | Human health services | sector | 0.030 | 0.000 | 0.104 | 0.000 | |
| CPA_Q87_Q88 | Social work services | sector | 0.004 | 0.000 | 0.010 | 0.000 | |
| CPA_R90-R92 | Creative, arts and entertainment services; library, archive, museum and other cultural service | sector | 0.002 | 0.000 | 0.002 | 0.000 | |
| CPA_R93 | Sporting services and amusement and recreation services | sector | 0.001 | 0.000 | 0.001 | 0.000 | |
| CPA_S94 | Services furnished by membership organisations | sector | 0.001 | 0.002 | 0.001 | 0.000 | |
| CPA_S95 | Repair services of computers and personal and household goods | sector | 0.000 | 0.000 | 0.000 | 0.000 | |
| CPA_S96 | Other personal services | sector | 0.000 | 0.000 | 0.002 | 0.000 | |
| CPA_T | Services of households as employers; undifferentiated goods and services produced by hous | sector | 0.000 | 0.000 | 0.000 | 0.000 | |
| CPA_U | Services provided by extraterritorial organisations and bodies | sector | 0.000 | 0.000 | 0.000 | 0.000 | |
| R_EBIO_new | EBIO_new | sector | 0.039 | 0.039 | 0.000 | 0.0955 | |
| RNAM | Use of imported products, cif | imports | #N/A | 0.294 | #N/A | #N/A | |
| RNTS | Taxes less subsidies on products | tls | #N/A | 0.003 | #N/A | #N/A | |
| RADJ | Total intermediate consumption adjusted / final use at purchasers' prices | sum | #N/A | 0.81 | #N/A | #N/A | |
| VA1 | Compensation of employees | va | #N/A | 0.10 | #N/A | #N/A | |
| VA2 | Wages and salaries | va | #N/A | 0.00 | #N/A | #N/A | |
| VA3 | Other net taxes on production | va | #N/A | 0.00 | #N/A | #N/A | |
| VA4 | Consumption of fixed capital | va | #N/A | 0.07 | #N/A | #N/A | |
| VA5 | Operating surplus, net | va | #N/A | 0.0196 | #N/A | #N/A | |
| RZ | Output at basic prices | output | #N/A | 1.0000 | #N/A | #N/A | |
| FD1 | HHE | fd | 0.08 | #N/A | 0.17 | #N/A | |
| FD2 | NPISH | fd | 0.00 | #N/A | 0.00 | #N/A | |
| FD3 | GOV | fd | 0.00 | #N/A | 0.03 | #N/A | |
| FD4 | GFCF | fd | 0.02 | #N/A | 0.00 | #N/A | |
| FD5 | CIES | fd | 0.01 | #N/A | 0.03 | #N/A | |
| FD6 | EXP | fd | 0.59 | #N/A | 0.03 | #N/A | |
| S | Total use | use | 1.00000 | #N/A | 0.95 | #N/A | |
| CO2 | Carbon dioxide (kg) | extension | #N/A | 43365.55 | #N/A | #N/A | |
| CH4 | Methane (kg) | extension | #N/A | 12.24 | #N/A | #N/A | |
| N2O | Nitrous oxide (kg) | extension | #N/A | 6.48 | #N/A | #N/A | |
| HFK | Hydrofluorocarbons (kg) | extension | #N/A | 0.00 | #N/A | #N/A | |
| PFK | Perfluorocarbons (kg) | extension | #N/A | 0.00 | #N/A | #N/A | |
| nEmp L | number of employees low skilled | extension | #N/A | 0.01 | #N/A | #N/A | |
| nEmp M | number of employees medium skilled | extension | #N/A | 0.00 | #N/A | #N/A | |
| nEmp H | number of employees high skilled | extension | #N/A | 0.00 | #N/A | #N/A | |

*Figure 5: Sector setup for the EBIO sector implemented in the IO table. Top three ranked values per excel sheet column marked in green.*

The figure (Figure 5) sums up all the main adjustments as sketched out with the "Basic pharmaceutical products and pharmaceutical preparations" sector as a starting point.

## 5.4 Scenarios

In its current state (Figure 5), the EBIO sector produces a total of 1 MNOK of output and is not yet implemented in the economy. The sector is implemented into the economy when demand from the sector is introduced in the scenario section of the model. Here we explore two scenarios, scenario 0 (the baseline scenario) where the EBIO sector never is introduced, and scenario 1 (the alternative scenario) where the EBIO sector is gradually introduced and demand from the sector replaces demand of the original product (e.g., biofuel replaces gasoline). The share of biofuels versus conventional fuels does not change in the projected years in scenario 0, while in scenario 1, the share increases, but only due to introduction of the EBIO technology.

In scenario 0, the economy is projected up until 2040 based on projections of GDP and population increases in Norway, but there are no technological improvements and preferences for goods and services stays unchanged.

In scenario 1, there is a gradual increase in production in the EBIO sector. From the findings in the NPV in D1.5 we see that the total yearly expected product market value when production is at full capacity is 2036 k€/year. Input output tables come in basic prices, which means that trade and transport margins and taxes less subsidies are excluded from the price. As a simplification we assume this to amount to 20% of the market price. The future exchange rate between EUR and NOK is difficult to predict but using the five past years exchange rates as the basis, we set this to 11 NOK/€. In total this means that the factory produces 17.9 MNOK of output yearly.

This output is distributed between final demand and intermediate demand (demand from other sectors). We assume here that other sectors start demanding from the EBIO sector instead of conventional fuel, meaning that a certain amount is subtracted from the "Basic pharmaceutical products and pharmaceutical preparations" sector and added to the EBIO sector.

The non-intermediate demand is set for final demand. The size of these two demand components and the distribution between them is determined in the model. Since the Leontief model, which is the basis for input-output analysis, is a demand-driven model it is the demand that decides the output value. Resultingly, the demand is set in several iterations of the model to ensure the resulting output value of 17.9 MNOK in the first year of production (set to 2025 in the model). The results of these iterations give the scenario1 input to the model (Table 9) composed of adjustments to intermediate and final demand:

*Table 9: Changes to intermediate and final demand in scenario1.*

| Component | Sector to | Sector from | Value | Period |
|---|---|---|---|---|
| **Technical coefficient (A)** | EBIO | Basic pharmaceutical products and pharmaceutical preparations | 0.028% | 2025 |
| **Final demand** | EBIO | Basic pharmaceutical products and pharmaceutical preparations | 9.8 MNOK | 2025 |

## 5.5 Uncertainty analysis

We acknowledge the uncertainty in our analysis, particularly due to the assumptions made in the sector setup which can be attributed to the other components of the projects still being under development at the time of authoring this report. To account for this uncertainty, we performed an uncertainty analysis using Monte Carlo Simulations where we included a set of chosen variables considered to be important for the value-added and employment results (Table 10).

*Table 10: Variables included in Monte Carlo Simulation.*

| Array | Sector supply | Sector demand | Final demand category | Extension category |
|---|---|---|---|---|
| **A** | Products of forestry, logging and related services | EBIO_new | N/A | N/A |
| **A** | Electricity, gas, steam and air-conditioning | EBIO_new | N/A | N/A |
| **S** | N/A | EBIO_new | N/A | Employment low-skilled |
| **S** | N/A | EBIO_new | N/A | Employment medium-skilled |
| **S** | N/A | EBIO_new | N/A | Employment high-skilled |
| **S** | N/A | EBIO_new | N/A | $CO_2$ |
| **A** | EBIO_new | EBIO_new | N/A | N/A |
| **VA** | N/A | N/A | N/A | Compensation of employees |
| **Y** | N/A | N/A | Exports | N/A |

We let these variables vary according to a mean, a standard deviation, and a probability distribution. We took a simplified approach letting the mean be the value in the IO system, the standard deviation is set equal to 1.25 and we use a lognormal distribution for all the chosen variables. The Monte Carlo simulations run 1 000 iterations per year.

It is important to note that this is not a comprehensive list of all factors affecting uncertainty of results, and including more variables would create a larger uncertainty range than what is shown later in the following chapter, on results.

# 6. Results

The presentation of assessment results is structured according to the identified stakeholder categories, and the subcategories and indicators selected for each stakeholder category. The level of detail is variable, depending on the availability of data, as well as the assessment methods. E.g., for generic indicators linked to national statistics and model-based assessment the results are more concrete than for the indicators where the assessment largely depends on stakeholder consultation.

We use a reference scale to supplement the descriptive assessments and figures, to distinguish between different directions and degrees of impact, as described above (chapter 4).

## 6.1. Impacts on the value chain

### Skill mix

The Confederation of Norwegian Enterprise (NHO) is Norway's largest organisation for employers. They provide annual statistics on business enterprise, market and future perspectives, and the competence needs of business companies. According to their figures for 2022, 62% of the member companies in Innlandet reported an uncovered need for competence (NHO, 2023). This is in the lower range, compared to the figures for other counties.

The competence most sought after in Innlandet was artisanry at vocational level (52%), and engineering and technical expertise (41%) (ibid.). Importantly, as many as 50% of the companies with unmet competence needs in 2022 reported that their recruitment efforts failed, while 41% reported that they hired staff with lower competence than desired (ibid.). This reflects the relatively low educational level in the region.

As noted in chapter 3, the industry partners in EBIO estimate that a fast pyrolysis plant with electrochemical upgrading will require around 10-15 employees, including two managers and technical staff. Considering the above-mentioned observations, this will be a small, but highly significant contribution to the regional skill mix, given the specific conditions in Innlandet. The latter observation was strengthened through the interviews. Several interviewees thought limited competence in chemistry and biochemistry would be a challenge in the initial phase of an establishment, while anticipating positive impacts on the regional skill mix in a medium and longer-term perspective. Whereas one interviewee reflected that the plant could drain out manpower and competence from other actors, others foresaw a certain sharing and flow of competence across industries, which they thought would be positive for the region.

On these grounds, our assessment is that a positive impact (+2) can be anticipated.

**Potential adopters**

According to Statistics for Innlandet (2023), the county had 10,792 enterprises in Agriculture, forestry and fishery, 1,875 enterprises in Industry, and 102 enterprises in Mining and quarrying in 2023. However, 69% of all the enterprises in Innlandet are small, individual enterprises. Less than 1% are large companies with more than one hundred employees, and most of these are in the settlements Hamar, Gjøvik, Lillehammer and Ringsaker. An assessment to identify the most promising green innovation projects in Innlandet county, carried out under the Biovalley partnership, identified fourteen local clusters as promising for a circular bio-hub strategy, and altogether associated with an increased value creation potential of 15.5 billion NOK (EY, 2023). The main report, Innlandsporteføljen, found that Innlandet has the value chains and ecosystems required for scaling the bioeconomy. Among the aspiring bio-hubs, around half involve forestry and wood material streams and actor networks for whom future biofuel production potentially could be relevant:

- "7 Sterke"[21], Kongsvinger area, with focus on building products and other, plus new freight terminal planned. 3 000 acres reserved for new industry.
- Skjerven Biopark[22] – including among others Hunton[23], and Eidsiva[24], who will utilize excess heat from Hunton for heating energy.
- Begna Bruk[25], has large sawmill. Planning a high-tech automated plant for processing of timber. Unlike others, good availability of electrical power (around 1.600 GWh anually).
- Granli Kongsvinger: intermodal transport and logistics hub serving freight transport across borders.
- Sørli – multi-purpose terminal, timber transport, plywood production, biogas, biochar.
- Sirkulære Solør – Moelven[26], Forestia[27] and more, biochar and biogas.
- Sirkula[28] og trehjørningen – energy and soil improvement from waste.

Thus, the interviewed stakeholders identified several potential adopters of the EBIO technology. Some of the bio-hubs are already discussing advanced biofuel production. One actor noted that the EBIO concept seems interesting but possibly may compete with solutions under development in the bio-hubs.

According to some, there is currently no surplus of biomass in the region. Producers of bioenergy are in a challenging situation right now due to increasing prices and limited availability of biomass. Thus, existing actors with access to the needed biomass, (e.g., Forestia) could be in a better position to adopt the technology. For these, an EBIO biofuel plant could have a positive effect on corporate sustainability, replacing export with local higher value production from waste wood chips and sawdust, which may substitute for fossil fuels. On the other hand, several stakeholders noted that availability of

[21] https://www.7sterke.no/
[22] https://www.skjervenbiopark.no/
[23] https://huntonfiber.co.uk/
[24] https://www.eidsiva.no/
[25] https://begnabruk.no/english/
[26] https://www.moelven.com/about-moelven/
[27] https://forestia.com/
[28] https://www.sirkula.no/

electricity can be a limiting factor. According to some, Begna Bruk is the only hub where this would not be a challenge. On the other hand, the 2023 strategy for green bioeconomy growth in Innlandet (Innlandsporteføljen), anticipates that the limited power grid capacity is a challenge that will be resolved, 5-7 years from now (EY, 2023).

Against this background, the score provided for this indicator is +1.

**Substitution of non-sustainable products**

Based on statistics for energy consumption it is possible to estimate how much of the fossil fuel consumption biofuels from electrochemical processing can replace. Based on the KPIs for EBIO and the assumed capacity of the case plant, like the existing facility in Gävle (section 3.2., Figure 2), we anticipate a positive impact, which is important in a sustainability transition perspective, however limited in volume by the size of the plant.

This resonates with the interview results, where most of the consulted stakeholders foresaw a positive impact in terms of substitution. One actor doubted that biofuels will be deployed for all transport segments and saw heavy-duty road transport as the segment with the biggest potential. Another industry actor also stressed the potential, while pointing to logistical challenges, including access to biomass and eventual costs. He stressed that if the price is competitive, biofuel from an EBIO plant in Innlandet may be used by several actors. According to the regional bioeconomy strategy, the interface between energy, sustainability and innovative technology is the area of greatest opportunity for Innlandet, and the planned bio hubs may help reduce the costs.

Another point noted was that the impact in terms of replacing unsustainable products will depend on what alternatives the fuel is compared with (e.g., in terms of environmental product declarations (EPD)). Although various criteria and requirements exist, it is sometimes unclear which products are considered most sustainable and why.

Further, it was stated that the biomass used for biofuel production also may have other uses, potentially including other products generating higher value and gains in sustainability. Here, it should be noted that the electrochemical upgrading of cellulosic sugars also brings opportunities in form of by-products (e.g., phenolic acids), creating further potential for substitution of non-sustainable products. Phenolic acids may for instance be used in polymers, for chemical industry, such as Jotun, and give price that is twice the price of biofuel. The EBIO process can also provide other compounds that may serve as platform chemicals to produce various other higher value-added products.

Against this background, we rate this indicator +2.

**Incentives for early providers**

In Norway, support for biofuel initiatives may be sought from Enova, a state enterprise for the promotion of environment-friendly energy solutions, which has large programs for technology development of sustainable energy carriers, including biofuels, as well as stimulation of broad collaboration and value chain development for such innovations (Pilot-E and Green Platform). Further, a broad funding program called Bionova[29] (coordinated support from the Research Council of Norway, Innovation Norway, and Siva, a state enterprise for industrial enterprise development) was established in 2023.

At the same time, the national Strategy for green industry (Grønt Industriløft) emphasizes innovation in the forestry and wood processing sector, and specifically that efficient utilisation of residues can contribute to increased value creation (Norwegian Ministry of Trade, Industry, and Fisheries, 2023). As development and upgrading of production technology and access to financial capital are critical, the statal investment company Investinor has earmarked 300 MNOK for investment in forestry and wood industries, if desired in a joint fund with private actors.[30] The national authorities are also considering regulatory measures to ensure efficient and profitable use of the bioresources, e.g., making it illegal or unfavourable to let part of the resources go to waste. The national biofuel mandates for road transport, non-road vehicles, aviation and maritime transport may also be considered as incentives.

The interviews with stakeholders revealed their awareness of existing incentives, however, some interviewees pointed out that these incentives do not always match the scope of new initiatives (or the other way round). Some of the public stakeholders noted that the total amount of funding available has increased greatly; from 60 million NOK two years ago to currently 340 million NOK. Moreover, there is not a fixed set of grant/application types, flexibility is rather emphasized, with a focus on reducing risk for investors, triggering the capital needed to develop a product or value chain. How much support that is needed varies, depending both on risk and capabilities of the applicant companies. While cost-benefit assessment is the main criterion, sustainability is also important. Here, the EU Taxonomy for sustainable finance is used as basis, however this framework is not complete yet, so enterprises must document the sustainability of their projects.

Further, stakeholders emphasized a broader picture of factors that might influence producers' willingness to engage in advanced biofuel initiatives. While there are relevant funding schemes, it is necessary to consider long-term economic viability and what the price of the final product eventually will be. Further, the interviewees pointed out that whereas pilot facilities can get support, broader technology-neutral national policies make it difficult to trigger investments. Overall, the interviewed actors felt that existing incentives should be complemented by further ones and supported through the broader mix of policies and policy instruments to create a favourable and predictable investment environment. One interviewee called specifically for an innovation fund, from industry, as he felt there has been too much focus on research in Norway, and too little '& innovation'. Another noted that contracts of difference are applied to trigger other value chains, and in principle could be applied also for advanced biofuels, if one wants larger volumes. For individual actors, investment in this range would be a major effort, and as the resources are not unused or un-priced today, actors must weigh the risk and potential returns against what the Swedish industry is willing to pay. Against this background, one stakeholder commented that the potential for implementation may be bigger in parts

[29] https://www.innovasjonnorge.no/artikkel/bionova-tilskudd-til-biookonomi-og-klimatiltak
[30] https://investinor.no/skal-investere-300-mill-kr-i-norske-skog-selskaper/

of Norway where the source material is more available/less utilised today, such as in some parts of Western Norway.

Notwithstanding this complexity, we observe that there are increasing incentives, which may be conducive for value chain development, thus the score provided for this indicator is +1.

**Transparency**

According to the Norwegian Accounting Act (Ministry of Finance, 1998, updated 2023), all medium-sized and large companies are required to provide publicly available annual reports. Besides the annual accounts and explanation thereof, the annual report shall provide information about other conditions in the organisation, such as working environment, annual absence due to disease and injuries, gender equality, environmental aspects, research activity, etc. Since 2018, small companies, e.g., fulfilling two of three criteria; sales less than 70 MNOK, assets less than 35 MNOK, and/or less than 50 employees, are exempted from this rule.

Norway ranks fourth on the global Corruption Perceptions Index (CPI), which covers 180 countries (Transparency International, 2023). Since 2022, a national Transparency Act requires enterprises to conduct due diligence assessments, for both their own business, their supply chain, and their business partners, to find out where the biggest risks are in terms of human rights and decent working conditions. This applies to large Norwegian companies, as well as larger foreign enterprises that offer goods or services and are liable to tax to Norway. The assessments must be carried out in accordance with the OECD Guidelines for Multinational Enterprises (however, these guidelines include more than the Transparency Act). Listed companies are also subject to the Norwegian Code of Practice for Corporate Governance, and to the Euronext Guidance to Issuers for Environmental, Social, and corporate Governance (ESG) reporting, which is voluntary and based on the standards developed by the Global Reporting Initiative (GRI). Moreover, they will be subject to the new EU regulations on Sustainable Finance and Corporate Sustainability Reporting (European Parliament and Council of the European Union, 2022).

A recent review (Simonnæs et al., 2023) suggests that companies are moving away from "blind" disclosure and "tick the box" exercises, towards more adapted, relevant and business-specific disclosures. In line with this, the interviewed stakeholders reported that transparency has not been very high in the forestry industry, although some improvements have been achieved recently.

Bigger actors, who would be at the beginning of the value chain as suppliers of biomass, have sustainability reports and comply with the laws. While compliance is required and anticipated, transparency is seen to entail more, and the stakeholders pointed out that due to stricter standards, high transparency is expected to "become the new normal" as it is associated with competitive advantage. The key standard in question is the Norwegian PEFC Forest Standard (PEFC N 02:2022), which is commonly applied in forest industry in Innlandet (and Norway more broadly) and provides a basis for high transparency.

We therefore set the score for this indicator to +2.

**Traceability**

The Norwegian PEFC Forest Standard (PEFC N 02:2022) is widely adopted and increasingly required throughout the whole value chain (PEFC, 2023). This standard cover three main topics (manager responsibility and planning, logging and forestry measures, and special environmental values), each associated with several requirements. Related to manager responsibility and planning, future harvesting production, outdoors recreation, water resources, biodiversity and important areas for herding reindeer are aspects that must be considered. The requirements related to logging and forestry measures ensure traceability, in terms of how the biomass is produced, how waste is handled, what kind of trees are cut, how reforestation is taken care of, etc. Harvesting activities shall take into consideration economy, outdoor recreation, biodiversity, etc., pointing, therefore, at the coherence with planning activities. In addition, special environmental issues, e.g., consideration for birds of prey and owls, biologically critical areas, etc., shall be considered (PEFC N 02:2022).

At the same time, further information could be required when it comes to the production itself. For example, the PEFC Standard does not outline any specific requirements on the types of equipment used, although it suggests that waste and emissions from the production should be kept as low as possible and that best available technology shall be preferred. In addition, it also outlines how to deal with discharges of fuel (PEFC N 02:2022).

The interviewed stakeholders mostly related traceability to the origin of biomass and suggest that biomass stemming from the Norwegian forestry would have higher traceability than many other types of biomasses, contributing to high traceability of the end-product. Some also pointed out that traceability would be even higher if processing of the biomass would take place locally.

As we relate traceability to input factors necessary to produce the final product (biofuel), the assessment of this subcategory is set as medium. Assessed score: +1.

## 6.2 Impacts on workers

### Health and safety of workers

While we asked the interviewees about potential impacts on workers, they had limited basis for assessing this kind of impacts, and few opinions were voiced. Potential impacts on workers are therefore assessed mainly in terms of aggregated results for the relevant sectors. When it comes to health and safety, Statistics Norway provides information on the share (percentage) of the total stock of workers per industry that is exposed to various health and safety risks. Table 11 provides an overview of the percentages provided for the indicators selected as most relevant for this case-study.

*Table 11. Sector-wide results for selected physical work environment indicators (exposure to gas, dust, and fumes; skin-irritating substances; and high risk of accidents), drawn from Statistics Norway, Table 07783: https://www.ssb.no/statbank/table/07783/tableViewLayout1/ (last accessed 13th December, 2023).*

| Sector | Workers exposed to gas, dust, and fumes most of the time | Workers exposed to skin-irritating substances most of the time | Workers exposed to elevated risk of work-related accidents |
|---|---|---|---|
| **Agriculture, forestry, and fishery** | 11% | 5% | 10% |

| | | | |
|---|---|---|---|
| **Mining and quarrying** | 7% | 6% | 4% |
| **Electricity, water, and renovation** | 8% | 9% | 6% |
| **Technical services, facility management** | 1% | 2% | 1% |
| **Industry** | 10% | 7% | 2% |
| **Average across all sectors of the economy** | 3% | 8% | 3% |

On this basis, we can say that when considering statistics for the sectors where we are likely to see the strongest employment effects, there are no marked social hotspots related to workers' health and safety. The sector with the highest levels of exposure for the selected indicators is Agriculture, forestry, and fishery. It should be noted, however, that this is a broad category. At the same time, looking at the percentages for the most relevant sectors in comparison with the averages for the whole economy gives an indication that there will not be any gains in terms of physical working environment either.

Considering the workers directly employed at the potential EBIO biofuel plant, literature suggests that for pyrolysis of biomass generally, fire and explosion (including dust explosion on hot surfaces, combustion during storage), particulate and gaseous emissions, gas leakage (particularly CO), and noise pollution are risks for operators and the public that should be considered (Lynch and Joseph, 2010). It has also been noted that exposure to the bio-oils could be associated with hazards to human health, e.g., acute toxic effects in the case of loss of containment, and a marginal carcinogenic potential, due to the presence of carcinogenic compounds (e.g. catechol and PAHs) (Cordella et al., 2012). Most importantly, a safety data sheet (SDS) for fast pyrolysis oil from lignocellulosic biomass, provided by BTG Biofuels (IEA Bioenergy, 2023, Annex A), states the following hazards:

H304: May be fatal if swallowed and enter airways.

H315: Causes Skin Irritation.

H317: May cause an allergic skin reaction.

H319: Causes serious eye irritation.

H412: Harmful to aquatic life with long lasting effects.

These hazards are quite common in chemical industry, and usually minimized through careful precautionary measures (as described in the above-mentioned SDS). However, without further information, e.g., about the incidence of risk events, it is difficult to make a proper assessment for this indicator.

Our assessed reference scale score for this indicator is therefore 0.

**Gender equality at work**

At a general level, Norway is not doing bad in terms of **gender balance**. E.g., the share of women on the corporate boards is 20.0%, and the share of CEOs in the same category of enterprises is 17.3%. For larger limited liability companies (with a capital of more than 1 MNOK), the share of female board membership is much higher (43.1%), while the share of female CEOs is lower (11.4%, Statistics Norway, 2023o). However, when we look at the ratio of male/female employees in different industry sectors, there are considerable differences. Table 12 provides an overview of the shares of men and women in the sectors deemed most relevant for our study.

*Table 12: Number of male and female employees in selected industries in Norway. Source: Statistics Norway, annual employment statistics, 2023. https://www.ssb.no/arbeid-og-lonn/sysselsetting/statistikk/arbeidskraftundersokelsen.*

| Sector | Male employees | Female employees |
|---|---|---|
| **Agriculture, forestry, and fishery** | 50 000 | 12 000 |
| **Mining and quarrying** | 55 000 | 14 000 |
| **Electricity, water, and sanitation** | 29 000 | 7 000 |
| **Technical services, facility management** | 117 000 | 88 000 |
| **Industry** | 153 000 | 54 000 |

This shows that the involved sectors still are quite male dominated in terms of employment. Some of the interviewed stakeholders did, however, anticipate a slight, positive effect on gender balance, as they expected an EBIO biofuel plant would require employees with competence in chemistry, which is a popular subject for women in higher education in Norway, as well as at high school level, where the ratio of female students doing chemistry is 59%, compared to 41% for males, as opposed to e.g., ICT, where the majority (77%) are male (Statistics Norway, 2024). Thus, several interviewees reasoned, the establishment of an EBIO biofuel plant could attract more females to the industry (in Innlandet) compared to the current status. This was seen as highly desirable impact.

We therefore assess the impact for this indicator to +1.

When we look at **gender balance in monthly salaries**, a significant imbalance between women and men remains. Table 13 provides an overview of salaries for men and women in some of the most relevant employee categories for this assessment.

*Table 13: Average monthly salaries for men and women, for some of the most relevant job categories considered in Statistics Norway, Table 11418. https://www.ssb.no/arbeid-og-lonn/lonn-og-arbeidskraftkostnader/statistikk/lonn Last accessed 13. December 2023.*

| Employee category | Average monthly salary (2022) | Average monthly salary for men (2022) | Average monthly salary for women (2022) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| **Managers in forestry, horticulture, etc-** | 65 570 | 68 620 | 60 020 |
| **Managers in oil and gas** | 119 490 | 119 420 | 119 760 |
| **Managers, industrial production** | 79 710 | 79 830 | 78 890 |
| **Managers, logistics and transport** | 74 200 | 74 470 | 72 840 |
| **Foresters** | 38 830 | 38 830 | -- |
| **Assistants in forestry** | -- | -- | -- |
| **Assistants in mining and quarrying** | -- | -- | -- |
| **Assistant workers in construction** | 41 910 | 42 140 | 36 990 |
| **Operators in wood processing** | 41 460 | 42 000 | 38 230 |
| **Operators in lumber production** | 39 510 | 39 700 | 37 740 |
| **Process controllers in chemical industry** | 57 810 | 57 990 | -- |
| **Electricians** | 46 210 | 46 460 | 38 750 |
| **Automation workers** | 52 090 | 52 660 | 41 680 |
| **Carpenters** | 41 430 | 41 520 | 35 090 |

Since the gender imbalance in salaries is present across all the sectors we consider,[31] it is not likely that the establishment of a pyrolysis plant with EBIO technology in Innlandet would exert any significant impact when this indicator is concerned. However, if biofuel from the EBIO biofuel plant is compared to biofuels produced elsewhere in the world, we may find a positive impact, considering that the gender imbalance in Norwegian working life is less than in many other countries.

For the case in focus, we consider the impact for this indicator as neutral and thus give it the score 0.

**Fair wages**

While no general, minimum wage has been defined for Norway, minimum wages are defined for nine sectors, with the aim to hinder exploitation of foreign migrant workers. One of these sectors is agriculture, where the minimum wage for permanently hired unskilled workers in 2023 was 164,80 NOK per hour, and for skilled workers 178, 80 NOK. The latter pay amounts to a monthly salary of 26 820 NOK (Norwegian Labour Inspection Authority, 2023).

As shown in Table 14, there is no figure for assistant workers in forestry, but the average monthly salary for the sectors we consider most relevant in this SIA are way above the minimum wage for agriculture.

[31] To a lesser extent for managers than for workers, except in forestry and horticulture, where there is a big difference between salaries for men and women, also at the managerial level.

*Table 14: Average monthly salary (NOK) for the most relevant categories of workers. Source: Statistics Norway, Salaries. https://www.ssb.no/arbeid-og-lonn/lonn-og-arbeidskraftkostnader/statistikk/lonn. Last accessed 11. December 2023.*

| Categories of workers | Average monthly salary (NOK) (2019) |
|---|---|
| **Assistant workers in forestry** | - |
| **Entrepreneurs in forestry (and agriculture)** | 40 760 |
| **Operators in wood processing industry** | 41 470 |
| **Operators in lumber industry** | 39 520 |
| **Operators in chemical industry** | 50 530 |
| **Process controllers in chemical industry** | 57 810 |

According to Statistics Norway, the average monthly salary in Norway in 2023 was 50.790 NOK, while the median monthly salary was the same. However, this includes all categories of managers as well as all levels of employees. If we consider that most people in Innlandet currently are employed in forestry and agriculture, the establishment of a fast pyrolysis plant with EBIO technology could lead to an improvement of wages at the local level, to the extent that those hired need chemical industry competence and are paid according to the averages found in national statistics (Table 12).

Based on the above, our finding for this indicator is that there will be a positive impact in terms of fair wages (+2), e.g., the direct and indirect employment resulting from the implementation of a fast pyrolysis plant with EBIO technology in Innlandet will be linked to sectors and job categories with significantly higher incomes than the minimum wages for other sectors in Norway. While most did not voice any opinion, one of the interviewed actors made statements supporting this point.

**Unionisation**

According to the OECD and AIAS (2021), Norway has one of the highest rates of trade union membership in the world. The trade union density (% of employees) is around 50% (50.4% in 2019), and the adjusted bargaining (or union) coverage rate (% of employees with the right to bargain) is 69% (2017).

Unfortunately, Statistics Norway does not provide figures for trade union membership by sector. However, this is another area where we can expect to see positive impact, if comparing with biofuel produced in other countries, especially in the developing world.

Thus, we do not ascribe any impact to this indicator here (score 0). We still include the indicator in the assessment, to highlight its relevance for future and/or comparative assessments.

**Meaningful work**

As regards the indicators for job requirements, e.g., The percentage of workers that are required to often or always work at a high pace and opportunities, and The percentage of workers that are required to acquire new knowledge and skills most of the time, we also only have aggregated data for the time being. For the latter indicator, the most recent data for the selected sectors are from 2016. For the former, figures from 2022 are available. The most relevant statistics for both indicators are presented below (Table 15).

*Table 15. Number of workers required to acquire new knowledge or skills most of the time. Source: Statistics Norway: Job requirements. https://www.ssb.no/statbank/table/07913/tableViewLayout1/ Last accessed 11. December 2023.*

| Sector | Number of workers required to acquire new knowledge or skills most of the time (2016) | Number of workers that are required to often or always work at a high pace (2022) |
|---|---|---|
| **Agriculture, forestry and fishery** | 26% | 42.4% |
| **Mining and quarrying** | 36% | 40.0% |
| **Electricity, water and renovation** | 33% | 41.9% |
| **Technical services, facility management** | 52% | 49.7% |
| **Industry** | 32% | 42.7% |
| **All sectors/employees** | 40% | 49.9% |

It is difficult to say much about potential social impacts of the studied solution based on these statistics (Table 15). The values for each sector suggest that a fair share of the workers is required to develop their knowledge and skills most of the time, which can be associated with enhanced ability to cope and meaningfulness in their everyday work tasks. At the same time, they are slightly lower than the value for all sectors/employees (40%). One of the interviewed stakeholders commented that an EBIO biofuel plant most likely will be associated with a positive impact in relation to this indicator, as well as in terms of attractiveness of the workplace.

We anticipate that the job requirements in terms of acquiring new knowledge and skills will be high for those directly employed at the new plant, but rather low for the indirect employment associated with the establishment of an EBIO biofuel plant. We therefore rate the impact as 0.

The percentages of workers reporting that they often or always are required to work at a high pace are generally high. However, for the sectors where we expect the highest employment effects (see section 7.4), here falling in the categories Agriculture, forestry and fishery, Mining and Quarrying, and Electricity, water and renovation, these percentages are markedly lower than the average for all sectors/employees.

Thus, we do not find any potential social hotspot or risk area associated with this indicator, and we give this one too a score of 0.

## 6.3 Impacts on users

### Fulfilment of formal sustainability criteria

The revised Renewable Energy Directive (EU/2023/2413) defines the sustainability criteria of bioenergy through various provisions. Firstly, the reduction of GHG emissions over the entire value chain, from raw material production to final use, must be at least 70%, compared to fossil fuels. Annex 3 further specifies limits for the energy content of fuels for different uses, e.g., 43 MJ/kg and 36 MJ/l for co-processed oil of biomass or pyrolyzed biomass origin to be used for replacement of diesel, and 44 MJ/kg and 34 MJ/l for hydrotreated (thermochemically treated with hydrogen) oil of biomass origin, for the same use.

The main text also includes provisions addressing the negative direct impact some forms of biofuel production may have in terms of indirect land use change (ILUC). To this end, limits are set on high ILUC-risk biofuels, in terms of the volumes of these fuels that EU countries can count towards their national targets for renewables in transport. The limits impose a freeze equivalent to 2019 levels for the period 2021-2023, which will gradually decrease from the end of 2023 to zero by 2030. The directive also introduces an exemption to these limits, for biofuels certified as low ILUC-risk.

Furthermore, RED III provides specific rules for biofuels produced from forest biomass, requiring the sustainability of harvesting operations and the accounting of land-use change emissions. It emphasizes the need to enhance the protection of especially biodiverse and carbon-rich habitats, such as primary and old-growth forests, highly biodiverse forests, grasslands, peat lands and heathlands. Thus, it also states that exclusions and limitations to the sourcing of forest biomass from such areas should be introduced. Moreover, the principle of the cascading use of biomass is upheld, and it is stated that harvesting shall be carried out considering maintenance of soil quality and biodiversity in accordance with sustainable forest management principles, at the same time as sustainability criteria concerning forest biomass harvesting should be further specified.

To prove that these requirements are met, a biofuel producer must be certified by an independent third party. The documentation must include sourcing details and carbon footprint data, as well as an internal record of accurately mass balanced input and output materials.

The degree of fulfilment of these criteria will depend on the next steps of development of the EBIO technology. At the current stage, the estimated overall carbon yield of combined electrochemical conversion, catalytic upgrading and co-refining is 70-75% for co-hydrotreatment and 60-65% for co-FCC based on small pilot experiments.

As the Norwegian PEFC Forest Standard (PEFC N 02:2022) is widely applied in Innlandet, and the regional authorities keep good track of the forest resources in Innlandet and have ensured that 4.8% of the total land used for forestry already is protected, we assume that the considered EBIO biofuel plant will fulfil the current sustainability criteria.

While acknowledging a level of uncertainty, considering the low technology readiness level (TRL) of the EBIO technology, we estimate that the sustainability criteria defined for advanced biofuels will be fulfilled, and rate the impact as +2 for this indicator.

**Willingness to pay**

Jåstad et al. (2020) refer to three studies that indicate a higher WtP for bio-based fuel compared to fossil fuels in the Nordic countries. A higher WtP for biofuels may reflect an increasing awareness of sustainability, where bio-based fuel is seen as one of the solutions for decarbonisation of transport.

Over time, when the focus on sustainability is even greater, consumers will also be able to demand biofuel that is based on biomass that i.e., is not imported or edible. Information is crucial for making such a choice (Andersson et al., 2020).

The WtP may also vary between consumer groups, such as businesses and air passengers. Goding et al. (2018) found that Swedish business customers' willingness to pay for sustainable biofuel cannot cover a 50 % blend-in, and Xu et al. (2022) could not find evidence of a higher WtP for sustainable aviation fuel. Seetaram et al. (2018) found highest willingness to pay for sustainable fuels for longer flights, while Rice et al. (2020) found higher willingness to pay for shorter flights. Frequent flyers may have a lower focus on sustainability, compared with the average population, and this can vary with age and profession.

At the same time, the interviewees highlighted that WtP will largely depend on what the actual price of the final product would be, and whether the final product will be viable without support in the long term. In future, increasing cost of biomass may lead to higher prices for the final products. One stated that whereas actors are interested in sustainability, they are not interested in paying more for more sustainable solutions. Another noted that his own company uses some biobased energy in their processes and chooses it also when it is slightly more expensive than conventional fuel but would find it hard to accept a big price difference. A similar view was voiced by the users' representative, who stated that actors may be willing to pay more, «but not much more». According to one of the public stakeholders, the WtP for «green premium» is uncertain, costs are increasing, the technical solutions for biofuels currently on the market are not good enough, and the infrastructure is not well suited. In effect, it is difficult to pass the «Valley of Death», and one needs to strengthen the business case by focusing on holistic value chain and circular economy principles to succeed.

Against this background, we and assume an increasing and positive correlation between awareness of sustainability and WtP, but also acknowledge the uncertainty emphasized by local stakeholders, leading to a score of +1.

## Ease of use

The usability of the final product is hard to assess, as the technology is under development. However, if the EBIO technology is upscaled as foreseen, the final product (advanced biofuel in this assessment) would be compatible with the existing equipment and practices in the transport sector, indicating high usability of the final product. At the same time, if the final product does not have the qualities required by its potential final user (transport sector), the usability will be low and potential use by other actors would require mapping their needs and interest in using this product.

While ease of use is crucial, stakeholders wonder whether the existing infrastructure allows for its further and broader uptake in road transport. In addition to the vehicles themselves, it is necessary to consider main transport routes and whether the needed infrastructure and volumes of biofuel will be available there. However, they also pointed at competition between different sustainable options, e.g., biogas competing against biodiesel for the same segments, suggesting that ease of use can be higher for biodiesel.

The social impact in this category, therefore, could preliminarily be assessed as positive (+2), as use of the final product would allow the users to increase the use of non-fossil-based alternative without additional costs or organisational changes.

**Incentives for use of the end-product**

The revised Renewable Energy Directive (RED III) (EU/2023/2413) establishes binding targets for the share of renewable energy in the transport sector (including maritime and aviation). By 2030, EU countries are required to either achieve a share of 29% of renewable energy in transport or to reduce the emissions intensity of transport fuels by 14.5%, as well as a combined sub-target for renewable fuel of non-biological origin (RFNBOs) and advanced biofuels of 5.5% (with a minimum share of RFNBOs, such as green hydrogen, of 1%). There is also an indicative goal, of at least 1.2 % of energy used in maritime transport to come from RFNBOs in 2030.

Moreover, the RED III defines that use of biofuels and biogas from used cooking oil (UCO) and animal fats is limited to 1.7% in final consumption for all energy used in transport, there will still be a x2 multiplier (possibility to count two times the real energy content) for advanced biofuels, and by 2030, the share of conventional biofuels consumed in 2020 in the transport sector (all modalities, not just road and rail) in Member States shall be +1%, and a maximum of 7%. Overall, these targets increase the scope for advanced biofuels substantially.

At the national level, the biofuel mandate for road transport was increased from 2024, from 17% to 19%, with a requirement that 12.5% should be advanced biofuels. The biofuel mandates for other applications remained, i.e. 0.5% for aviation, 6% for maritime transport, and 10% for other applications (non-road). The Norwegian Government aims to increase the biofuel mandates further for all transport modalities towards 2030. However, they also warn that they will introduce breakpoints for assessing future use of biofuels every other year from 2025, to ensure that all sustainability criteria are met. Moreover, the possibility of merging the requirements for maritime transport and non-road machinery will be considered.[32] These considerations are creating some uncertainty regarding future framework conditions.

Meanwhile, the planned expansion of the EU Emission Trading System (ETS) and revision of the EU Energy Taxation Directive (ETD) (European Parliament, 2022) will have implications, also for Norwegian users. The new structure of tax rates will be based on the real energy content and environmental performances of fuel and electricity, and not on the volume itself. Energy products will be grouped into five categories, and a specific minimum tax rate will apply to each energy product within the same category.

Conventional fossil fuels, such as gas oil and petrol, and non-sustainable biofuels will be subject to the highest minimum rate of €10.75/GJ when used as a motor fuel and €0.9/GJ when used for heating. This rate also serves as a reference rate for the other categories. The next category of rates applies to fuels such as natural gas, LPG, and non-renewable fuels of non-biological origin. Two thirds of the reference rate will apply to this category for a transitional period of 10 years – i.e., a minimum rate of €7.17/GJ when used for motor fuel and €0.6/GJ when used for heating - before being taxed at the same rate as conventional fossil fuels. The next category is sustainable biofuels. To reflect these products' potential in supporting decarbonisation, half of the reference rate applies – i.e., a minimum

[32]Presentation of the state budget for 2024, website of Norwegian Government : https://www.regjeringen.no/no/statsbudsjett/2024/a-til-aa/id2994694/?expand=2996705

of €5.38/GJ when used as motor fuel and €0.45/GJ when used for heating. The lowest minimum rate of €0.15/GJ applies to electricity, advanced sustainable biofuels and biogas, and renewable fuels of non-biological origin such as renewable hydrogen. The rates will be revised annually.

In Norway, biodiesel is exempted from the $CO_2$-tax on mineral products, as well as sulphur excise tax duty (The Norwegian Tax Administration, 2023a). Considering road transport differentiated rates for the road tax on fuels are present. The rates for 2024 are shown below (Table 16):

*Table 16: Road tax rates for different fuels (The Norwegian Tax Administration, 2024).*

| Fuel | Road tax rate |
|---|---|
| **Petrol** | 4.62 NOK per litre |
| **Bioethanol** | 2.16 NOK per litre |
| **Diesel (for vehicle propulsion)** | 2.71 NOK per litre |
| **Biodiesel** | 3.02 NOK per litre |
| **Natural gas** | 2.96 NOK per Sm3 |
| **LPG** | 3.86 NOK per kg |

Overall, bioethanol enjoys the lowest road tax rate of 2024. However, the road tax rates for diesel and natural gas are currently lower than that for biodiesel (The Norwegian Tax Administration, 2024).

Thus, there are incentives for users in place. However, at the national level, this landscape has been changing over time, e.g., there have been different signals in terms of procurement of public tendered transport and policy statements regarding the potential of different alternative fuels.

Stakeholder interviews support that changing political landscape might hinder use of the end-product. They also point out that creation of incentives would influence other actors indirectly and point out the need for fair competition and question the economic viability of the end-product without these incentives. Therefore, we give this indicator a score of +1.

## 6.4 Impacts on the local community/region

### Employment

This section presents results from the input-output modelling, for domestic effects in Norway only. Import effects (i.e., effects in other countries) will also take place, but this requires a multiregional IO database, while MEIONorway is a single-region IO model. The economy-wide results show a decline in value-added and an increase in employment (Figure 6).

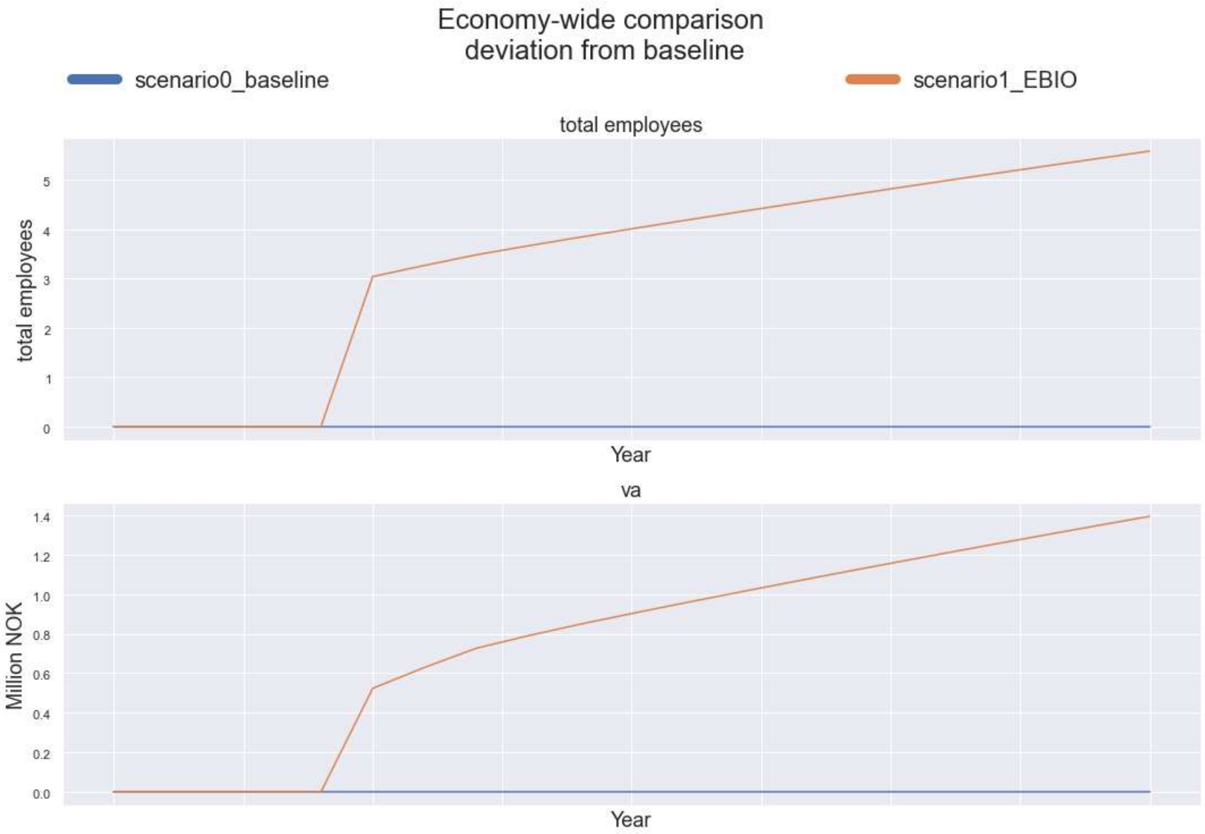


*Figure 6: Results for employment, and value-added as deviation from scenario 0*

According to the modelling, employment increases by 5.6 in 2040, compared to scenario0. However, value-added remains practically unchanged with an increase of 1.4 MNOK.

As seen in Figure 6, there is a slight increase in total employment in the economy in 2040. This is the result of negative and positive effects that partly cancel each other out. Looking at the top four and top bottom sectors (Figure 7), we see that the largest negative employment effect is found in the "Mining and quarrying" sector.

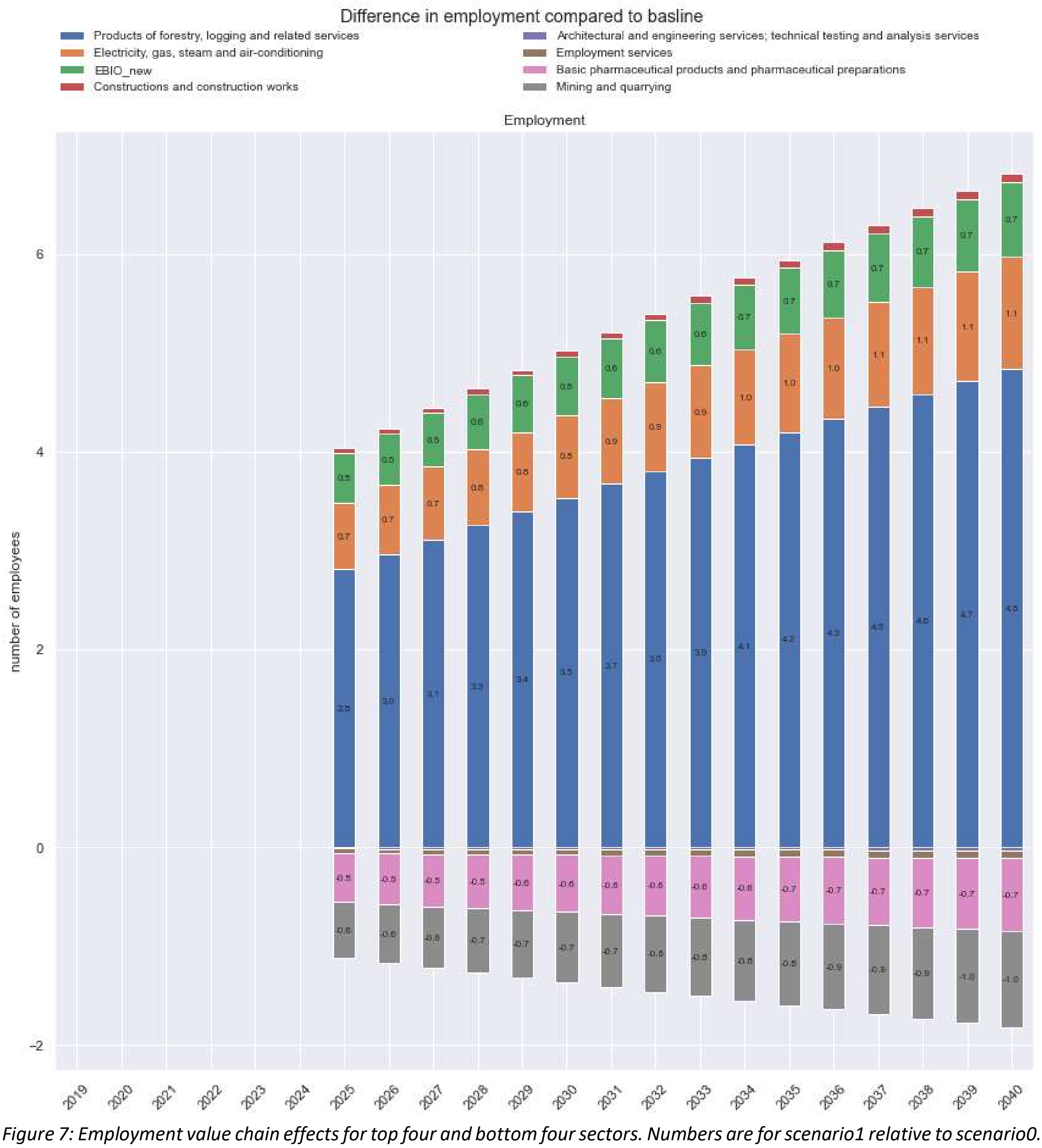


*Figure 7: Employment value chain effects for top four and bottom four sectors. Numbers are for scenario1 relative to scenario0.*

1.0 of the total 2.0 decrease in employees is in the “Mining and quarrying” sector followed by the "Basic pharmaceutical products and pharmaceutical preparations" sector with 0.7. On the increased employment side, the largest component is in the "Products of forestry, logging and related services" EBIO sector with 4.8 out of the total 7.6 increase in employees followed by the "Electricity, gas, steam and air-conditioning" sector with 1.1 and the EBIO sector with 0.7.

"Employment services" ranks third on the negative side with -0.08 employees. The remaining sectors only have marginal effects. In total, 15 sectors have negative employment effects, while 48 have positive effects in the economy.

*Structural Path Analysis*

To understand more of the employment effects in the economy we can perform a so-called Structural Path Analysis (SPA). This type of method investigates the value chains of sector effects and breaks down the consumption-based impacts in a sector into value chain components. We here perform this analysis for employment in the EBIO sector (Table 17).

*Table 13: Structural Path Analysis (SPA) of the top 20 contributing paths for employment due to consumption from the EBIO sector.*

| Number of employees | % | order | sectorCodes |
|---|---|---|---|
| 0.38 | 47.7 | 1 | ['R_EBIO_new'] |
| 0.04 | 4.5 | 2 | ['R86' 'R_EBIO_new'] |
| 0.02 | 3.1 | 2 | ['RB' 'R_EBIO_new'] |
| 0.02 | 2.8 | 2 | ['R21' 'R_EBIO_new'] |
| 0.02 | 1.9 | 2 | ['R49' 'R_EBIO_new'] |
| 0.02 | 1.9 | 2 | ['R_EBIO_new' 'R_EBIO_new'] |
| 0.01 | 1.7 | 3 | ['R10_12' 'R01' 'R_EBIO_new'] |
| 0.01 | 1.3 | 2 | ['R50' 'R_EBIO_new'] |
| 0.01 | 1.3 | 2 | ['R03' 'R_EBIO_new'] |
| 0.01 | 1.2 | 2 | ['R01' 'R_EBIO_new'] |
| 0.01 | 1.0 | 2 | ['RI' 'R_EBIO_new'] |
| 0.01 | 0.9 | 2 | ['R47' 'R_EBIO_new'] |
| 0.01 | 0.8 | 2 | ['R46' 'R_EBIO_new'] |
| 0.01 | 0.8 | 2 | ['R51' 'R_EBIO_new'] |
| 0.01 | 0.7 | 2 | ['R10_12' 'R_EBIO_new'] |
| 0.01 | 0.7 | 3 | ['R10_12' 'R03' 'R_EBIO_new'] |
| 0.01 | 0.6 | 2 | ['RF' 'R_EBIO_new'] |
| 0.00 | 0.6 | 2 | ['R84' 'R_EBIO_new'] |
| 0.00 | 0.6 | 2 | ['R87_88' 'R_EBIO_new'] |
| 0.00 | 0.6 | 2 | ['R52' 'R_EBIO_new'] |

The total number of employees in the EBIO sector is approximately 0.7 in 2040 (see Figure 7). The top twenty value chain sequences cover about 0.59 or (78.8%) of this employment.

The top component is generated in its own sector, i.e., employment in the EBIO sector needed to produce its own output. This generates 0.38 employees or 50.8% of the employment in the sector. Next follows five value chain components with two links (order = 2 in Table 17), where the most important value chain is employment due to EBIO input needed in R86 (Human health services). The top ranking third order component, (other than input to its own sector) which ranks 7$^{th}$ in Table 17, and creates 0.01 employees in EBIO, is the input needed from EBIO for the production in R01 (Products of agriculture, hunting and related services) targeted to produce output in R10_12 (Food products, beverages and tobacco products).

SPA looks at which value chains need input from EBIO to produce the final product of that value chain. This is largely a consequence of letting the EBIO sector replace some of the input to other sectors that originally came from the "Basic pharmaceutical products and pharmaceutical preparations" (Table 9), where we assume that some of the conventional fuel produced by this sector as input to other sector is replaced by biofuel produced by the EBIO sector.

As most of the positive effects will be localised to Innlandet, we categorize them as related to the local community/region, even though the modelling as such relates to sectors, rather than regions. The modest, but positive overall employment effect predicted by the model resonates with statements from the interviews, where the relatively small size of the considered EBIO biofuel plant was associated with positive, but limited employment effects. Notably, the value of these potential impacts was considered high, as attracting people to Innlandet and recruitment of skilled workers have been challenging.

Considering these findings, we ascribe a score of +2 to the employment effects.

**Value creation – value added**

The sectoral picture for value-added (Figure 8) is not very different than that for employment.

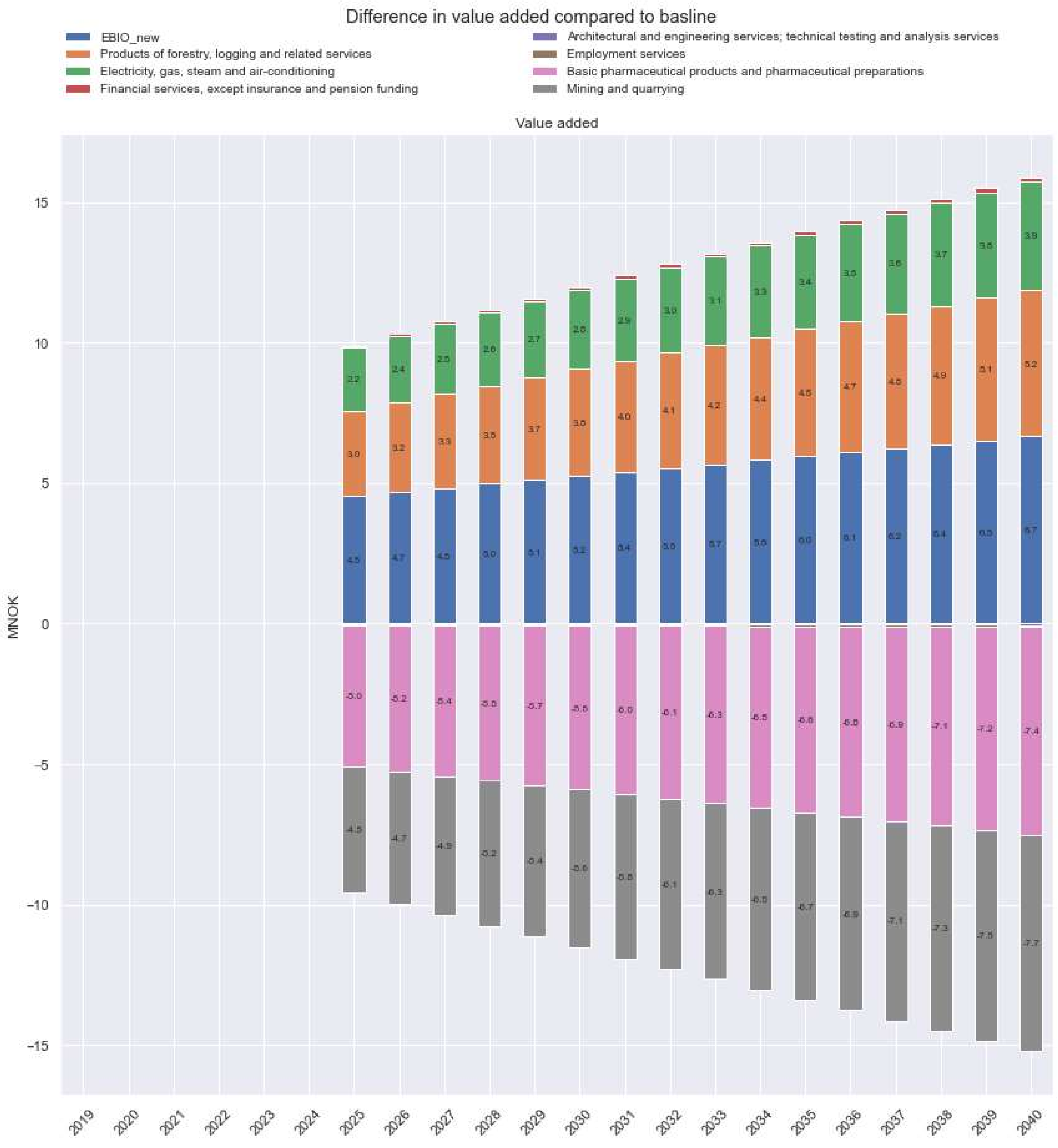


*Figure 8: Value-added value chain effects for top four and bottom four sectors. Numbers are for scenario1 relative to scenario0.*

Of the total increase in 2040 of 16.8 MNOK, 6.7 MNOK takes place in the EBIO sector, followed by "Products of forestry, logging and related services" with 5.2 MNOK and "Electricity, gas, steam and air-conditioning" with 3.9 MNOK.

The total decrease is 15.4 MNOK in 2040. The largest components are “Mining and quarrying” with 7.7 MNOK and "Basic pharmaceutical products and pharmaceutical preparations" with 7.4 MNOK. Third on the list is "Employment Services" with 0.06 MNOK. A total of 14 sectors has negative developments in value added, while 49 sectors see their value-added increase.

*Uncertainty analysis*

The Monte Carlo simulations show a moderately large uncertainty range on a sectoral level, and small uncertainties at an economy-wide level (Figure 9).

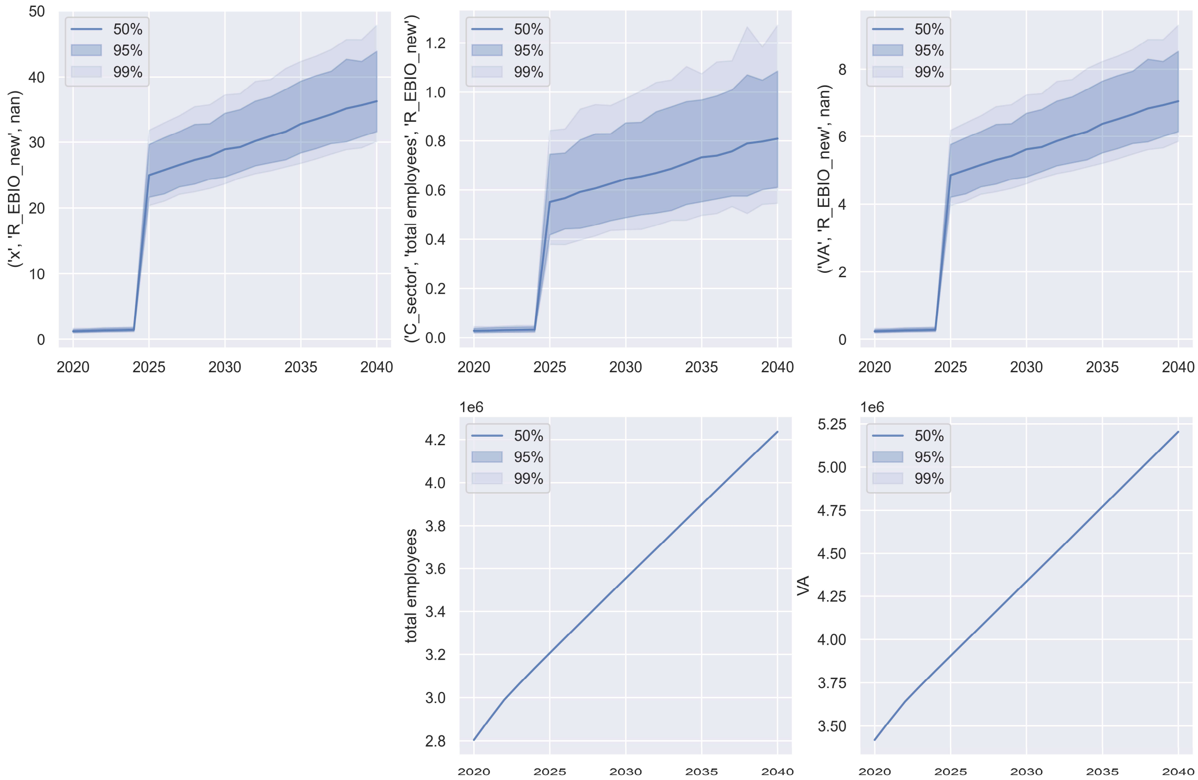


*Figure 9: Monte Carlo simulations for scenario1. Plots show production output value in the EBIO sector (top left), number of employees in the EBIO sector (top middle), economy-wide employment (bottom middle), as well as value-added in the EBIO sector (top right) and economy-wide value-added (bottom right). The blue line is the 50% percentile (given as the original value), while the lighter blue bands are the 5-95% and 1-99% percentiles.*

For economy-wide results, the uncertainty range is small. This is mainly due to the small size of the EBIO sector in a nation-wide context.

On an indicator-specific and sector-specific level these values vary much more. The 1-percentile is about 63% of the value in the 99-percentile for production value, 64% for value added and 47% for employment in the EBIO sector. This indicates a moderate uncertainty range for these indicators in the EBIO sector under the assumption that the chosen variables in Table 10 are the most important sources of uncertainty.

The interviewees from Innlandet saw value creation as one of the most crucial indicators - more important than employment, since the relative size of the workforce is declining, and sectors without high value creation will become less able to employ people in future.

The interviews also drew attention to several challenges that may be noted here. First, the availability of feedstock could be a challenge. While several actors have proposed biofuel initiatives before, these did not materialise. According to some of the interviewees, this is due to structural conditions, complex interactions between buyers and sellers, and their perceptions of uncertainty, price, etc., resulting in a situation where wood-based feedstock is not necessarily available, even if the resources are there. Moreover, wood cannot be stored for long, and forest that is left too long without harvesting loses value. As noted above, power grid capacity is a challenge for many of the biohubs that potentially could adopt the EBIO technology.

Considering the positive results for the EBIO sector and related sectors, but also minding the noted decreases and challenges, this indicator is scored as +1.

**Bequest value**

Potential impacts on the level of satisfaction from preserving the natural environment for future generations must be assessed in consultation with local stakeholders. Stakeholders internal to the project consider this as a highly relevant indicator. Moreover, the population in Innlandet is known for a high level of environmental awareness and engagement, starting from a movement to reduce pollution and improve the ecological state of Lake Mjøsa (1073-1982) (Throne-Holst, 1999).

We initially anticipated that an EBIO biofuel plant in Innlandet would be associated with bequest value, as a contribution towards climate neutrality and enhanced resource efficiency. However, we did not rule out that some voices might be critical, given the broader sustainability debates surrounding biofuel production and the possible association with more intensive forestry and potential loss of biodiversity in a longer-term perspective. A study carried out in Norway in 2021 argues that whereas e.g., firewood and chips can be produced locally and small-scale, biofuels must be produced at industrial scale - also implying more industrial logging practices (Torvanger, 2021). According to the author, local logging and firewood production is easier to combine with nature protection and outdoor activities, and may therefore be associated with more social benefits, in terms of ecosystem services. At the same time, the study suggests that conflicts with other societal interests are reduced if more forest areas are protected, especially in the vicinity of cities, whereas other areas are open for logging – as is the case in Innlandet.

The interviewed stakeholders had a slightly different perspective, seeing the existing forestry industry in Innlandet as already sustainable, since most parts of the harvested trees eventually are used. While they recognised the potential positive impact of an EBIO biofuel plant in terms of decarbonisation and addressing the climate crisis, they also weighed the production of biofuels against other possible uses of these resources. On this point, one interviewee noted that one must consider how much value and employment is created, who are the final users, and what is the price and usability. Thus, he emphasized the importance of considering social impacts in a holistic perspective. Another noted that while local citizens will value local impacts, there is also the need to consider the impacts in a global context, making sure the raw material is used in the most sustainable way.

Thus, this indicator is given the moderately positive score of +1.

**Contribution to innovation clusters**

Several clusters and member associations that can be influenced by the activities related to the EBIO technology have been identified in the Innlandet region, be it through collaboration and knowledge transfer or competition for the resources. These organisations can increase the innovation capacity related to the technology and contribute to the uptake of the technology, given that they manage to exploit existing resources (Pavão et al., 2019). These possible clusters and innovation networks in Innlandet include Norskog[33], Norwegian Wood Cluster[34], NCE Heidner bio cluster[35] and TotAl Gruppen[36].

Norskog is a member organisation for forest owners in Norway, covering the whole country. Its members stand behind 15% of total harvesting of the forest resources in Norway (Norskog, 2023a). The organisation participates in R&D projects both in Norway and abroad (Norskog, 2023b).

Norwegian Wood Cluster is a cooperative enterprise working to «to provide the world with innovative and sustainable building solutions in wood" and is a member of the Norwegian Innovation Clusters (Norwegian Wood Cluster, 2024).

NCE Heidner bio cluster is Norwegian national cluster for green bioeconomy and sustainable food production with around fifty members that work with research and innovation related to, among other, biotechnology (NCE Heidner Biocluster, 2020).

TotAl Gruppen is an independent network working to promote value creation and innovation in manufacturing companies in Innlandet with approximately 50 members and has strong competence within material technology and products, processes and structures related to aluminium (TotAl Gruppen, 2023).

The presence of these four clusters and members organisations can on one side indicate potential for high innovation capacity in the region and the ability of the technology at stake to increase it, thus we give it a score of +2. However, to assess the social impact in the whole category, this subcategory must be considered in relation to the subcategory R&D activities.

**R&D activities**

Statistics Norway provides statistics on public support for R&D that covers public grants, loans, advisory services and other services aimed at promoting R&D and innovation in businesses. The information is divided per type of aid, policy agency, and can be retrieved at the county level. Figure 10 shows the number of enterprises and the total amount of support per county in 2023.

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[33] https://norskog.no/?lang=en
[34] https://www.nwcluster.no/
[35] https://heidner.no/nce-heidner-biocluster/
[36] https://total-gruppen.no/

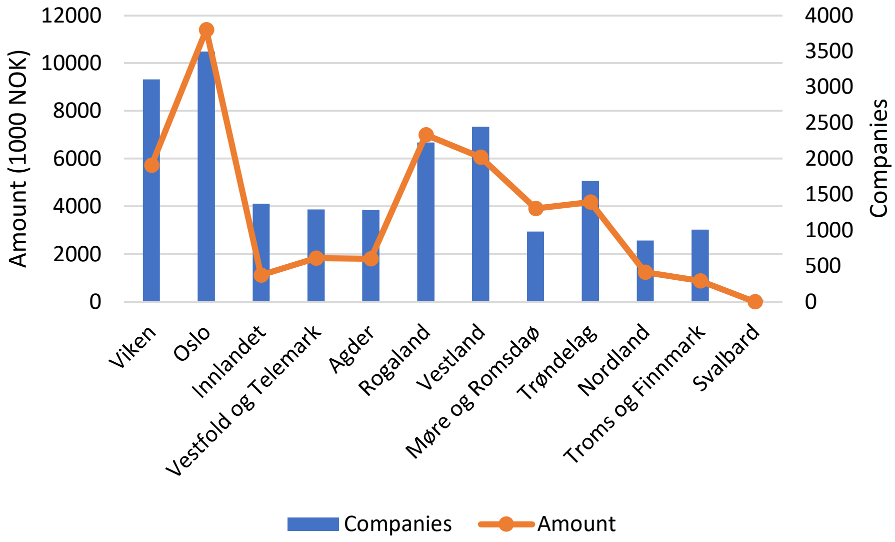


*Figure 10: Total amounts of R&D support and number of enterprises benefiting from such support per county (source: Statistics Norway).*

Innlandet received the lowest amount of support after Troms and Finnmark and Svalbard (Statistics Norway, 2023p). Innlandet is also the third lowest in terms of costs for in-house R&D, costs for purchased SFO, R&D personnel, R&D person-years and the share of business working with R&D (Statistics Norway, 2023q).

According to the county administration, Innlandet collected only 3% of the grant funding available from public innovation funders in 2022, and the enterprises at stake receive only 1/3, compared with the average business enterprise in Norway (EY, 2023). Thus, there is a substantial potential for local actors to draw more public grant support for research, development, and innovation than they do today (p. 52)

Innlandet had around 25 patent applications in 2021, whereas Rogaland County, which is at the top end, had more than 250 (EY, 2023, p. 51). It must be noted, however, that Innlandet also has an industry structure suggesting a lower need for patenting.

Inland Norway University of Applied Sciences (INN), which is a key competence institution in the region, has a faculty of applied ecology, agrisciences and biotechnology, but no programs in chemistry or biochemistry.

The interviewed stakeholders emphasised the county administration's active work to establish more impactful R&D activities and initiatives in Innlandet. The region already has several existing cluster initiatives that engage in various activities regarding use of natural resources and industrial development in the region. The actors in these clusters see further potential to explore possibilities within, for example, Horizon Europe to address research and innovation challenges where collaboration with international partners could be beneficial.

At the same time, the interviewees noted that, even where there are projects and initiatives related to circular economy and bio-based solutions, upscaling usually is the problem. While the establishment of an EBIO biofuel plant could result in increased R&D activity, yielding positive impacts for the local economy, several stakeholders claimed that in the past, upscaling has been hindered by an unpredictable political environment. One noted that the benefits in terms of R&D may be big, but difficult to estimate in advance. There is substantial variation, e.g., between enterprises that are part of large companies with headquarters in Oslo, and more local ones, in terms of what they can and want to do of research locally.

Our findings indicate that there is considerable potential for increasing research and innovation efforts in Innlandet. Still, a pyrolysis plant with EBIO technology will not be a huge initiative and it is difficult to assess its potential R&D impacts. Thus, we give it the score +1.

**Contribution towards regional development strategies**

The establishment of an EBIO biofuel plant, utilizing lower grade side streams of the wood industry, would help fulfil key strategies in the Bioeconomy strategy for Innlandet 2017-2024 (Hedmark and Oppland counties, 2017), such as strategy 9 "Develop the region further within residual resources and the exploitation of return streams" and strategy 6 "Work to increase market opportunities for bio-based products".

For the former, the document calls on a variety of different actors and stakeholders to support initiatives to increase the utilization of biological side streams. In relation to the latter, it is stated that the region will start using biofuels in public transportation, as well as encourage its use in construction, agriculture, and other transport. The following strategy, Innlandsporteføljen, aims to realise the vision of «the circular, green growth county» by 2030, through multiple green biohubs, as noted above (EY, 2023). The strategy document sees a strong momentum for development of new renewable energy, including bioenergy as well as PV. While the above-mentioned limitation in terms of power grid capacity is acknowledged, realisation of certain "green diamonds" is considered in a short-term perspective, and within 5-7 years improved grid capacity and value propositions for green power-intensive industry are foreseen (ibid., p.13).

Previous research with key stakeholders in Innlandet has identified high-value utilization of residual biomass products as a business area with an especially large potential for market growth in Innlandet (Sandberg et al., 2020). The land-based bioeconomy is also a priority area in the regional plan for research and development, which includes establishment of a national competence centre for bioeconomy in Innlandet.

Accordingly, the interviewed stakeholders saw a potentially strong positive impact for this indicator. They also pointed out that connecting the establishment of an EBIO biofuel plant to one of the ongoing biohub initiatives potentially would be beneficial. On the downside, one interviewee noted that a biofuel plant may be associated with increase in local emissions in several areas, including other emissions/leaching to the soil, water, and air, in addition to $CO_2$ emissions, and stressed the need to consider the link between local and national emissions.

Thus, we score the potential impact for this indicator as +2.

**Regional economic attractiveness**

Enhanced economic attractiveness is a stated aim in Innlandsporteføljen, together with increased export intensity and productivity (EY 2023, p. 5). However, regional economic attractiveness is not measured systematically in Innlandet today, and the key stakeholders considered it difficult to estimate.

We expect that the establishment of a new EBIO biofuel plant will establish new connections with enterprise external to the region, e.g., in terms of digital infrastructure, and that new products will be patented in Norway. A successful new investment could also generate increased interest from foreign investors. The same view was voiced by most of the consulted stakeholders. However, one noted that whereas the potential establishment of advanced biofuel production could have a positive influence, other factors, such as challenges in terms of transport and logistics could be more important.

As these impacts are associated with some uncertainty, and the size of the considered establishment is modest, we assign a score of +1 to this indicator.

## 7.6 Impacts on wider society

### Renewable share of the energy mix

With the assumptions outlined in chapter 3, e.g., a production of 3.5 tons bio-oil per hour and 7 000 operating hours per year, the plant will provide 24 500 tons of bio-oil per year.

This is the same capacity as an existing fast pyrolysis plant that BTG Bioliquids recently provided for Pyrocell in Gävle, Sweden, which also converts roughly 35 000 – 40 000 tons of dry wood residues into oil each year (without the electrochemical upgrading under development in EBIO). According to BTG Bioliquids (2020), the pyrolysis petrol produced at the plant in Gävle can power an equivalent of 15 000 family cars per year, thus making a considerable contribution to the reduction of climate gas emissions from transport.

When we consider the total energy use in Norway and convert the expected amount of bio-oil to energy using relevant rates and calculators that are available on the internet, the volume of renewable energy produced from our case plant in Innlandet will be rather modest.

If we consider an energy content of 24 MJ/kg (Pyrotech Energy, 2020), and 24 000 MJ/ton and have 24 500 tons of bio-oil per year, we get 588 000 000 MJ, or roughly 0.163 TWh per year. According to the most recent national assessment (Statistics Norway, 2022), the total energy use in Norway, including the continental shelf, was 326 TWh (2021). Of this, 138 TWh was electricity, 165 TWh fossil energy, 16 TWh bioenergy and around 7 TWh district heating (largely by use of bioenergy). The annual use of energy for transport in Norway is 53-58 TWh, of which around 90% still is based on fossil fuels (The Ministries' security and service organisation, 2023).

The potential positive impact on the renewable share of the energy mix was clearly recognised by the interviewed stakeholders. As noted in the most recent bioeconomy strategy (Innlandsporteføljen), Innlandet currently produces only 7% of the renewable energy generated in Norway (EY, 2023), thus the foreseen volume will make a significant contribution, however modest in a national and wider societal perspective. At the same time, one interviewee emphasized the need to take uncertainty into consideration. The price of the end product, and the final energy demand of a fullscale EBIO biofuel plant, will be crucial for the final impact related to this indicator.

Against this background, it may be argued that the potential EBIO biofuel plant in Innlandet will make a small, but still valuable contribution to the renewable share of the national energy mix (+1).

**Secure energy supply for transport**

In 2022, 483 million litres of biofuel were reported used on Norwegian roads. This constituted 13% of all the fuel used on Norwegian roads that year (Norwegian Environment Agency, 2023). Currently, 98.5% of the biofuel used on Norwegian roads is based on imported feedstock, mostly (83.9%) based on used cooking oil and waste from butcheries (UCO), and mostly from countries beyond Europe (e.g., China and the USA) (ibid.). Such feedstock is classified as B-feedstock, while more sustainable feedstock in form of residues from forestry, agriculture and industrial processes, classified as A-feedstock, rarely is used for transport fuel (ibid.)

In all, 3.2 million litres of advanced biofuel was used in aviation in Norway in 2022, all based on UCO from European countries. While the EU is trying to limit the use of B-feedstock, its use has been increasing in Norway. Moreover, a recent report suggests that there is not enough waste in form of UCO within the EU to reach the EUs target of tripling the use of biofuel by 2030 (Transport and Environment, 2023b), and there is a considerable room for fraud associated with the production and sale of class B feedstock. The Norwegian Environment Agency, therefore, recommends that the Norwegian requirements should be tilted towards class A feedstock, both for environmental reasons and to stimulate the production of sustainable biofuel in Norway (ibid.).

Although the volume that can be produced from the potential EBIO biofuel plant is limited, the modular design makes expansion and upscaling relatively easy, and considering the above-mentioned factors even limited volumes can make important contributions to reduce import dependency and secure a sustainable supply of transport energy.

The interviewed stakeholders anticipated a positive impact on security of supply of advanced biofuels from the potential establishment of an EBIO biofuel plant in Innlandet. One interviewee, representing the user side, stressed that local production would be positive, since the countries biofuels currently are imported from eventually may decide to limit their export and rather use the biofuel to achieve their own. Another, from the industry, thought it would be especially positive if local actors could produce the biofuel for their own use. However, he also noted that this would depend on the local suppliers of transport services, as the industry actors usually do not possess vehicles themselves.

Our assessment is that there will be a highly positive impact for this indicator (+2), as secure supply of biofuels can contribute to reduced dependence on imported fossil fuels, as well as imported biofuels.

**Use of arable land**

An ambitious bioenergy policy may lead to the use of arable land for biofuel production (Dias et al., 2021), and in Norway arable land is a very scarce resource (NIBIO, 2023). Implementation of the EBIO solution, however, does not require use of arable land, as production will be based on residues from forestry and the wood processing industry. This result emerged from the workshop and follow-up meeting with the project partners.

A wider model-based study of the role of forest-based biofuels in future transition scenarios for the Nordic countries (Jåstad et al., 2021) found that the potential for increased use of biomass for energy in the Nordic countries is significant. Forest biomass constitutes the main feedstock potential for biofuel in the Nordic region, and the model-based scenarios suggest that, from a resource viewpoint, a 100% fossil-free Nordic transportation sector based on electrification and biofuels is feasible. It will, however, require increased utilization of wood resources, and a massive buildout of renewable electricity capacity in the coming decades (ibid.).

A report carried out by NIBIO for the county administration in Innlandet shows that the forest resources of Innlandet consist of nearly 230 million $m^3$, with a growth of 5.8 mill. $m^3$ forest timber on forestry land (NIBIO, 2021). The standing volume continues to grow, but the annual growth is slightly reduced, as substantial areas are taken out of production due to building of roads, leisure homes, and cultivation. Model-based prognoses indicate that in a long-term perspective the forestry production in Innlandet may be increased considerably through increased investments in forest cultivation and proper management of overgrown areas and forest in areas of high altitude (ibid.).

The assessment, therefore, indicates no negative impact for the use of arable land. If the solution is compared to first generation biofuel, this would be an advantage. The score is thus +2.

**Alignment with national decarbonisation policies**

The Norwegian Government's Climate Status and Plan, of October 2024, states that a speedier phasing in of higher shares of biofuels, towards the stated 2030 targets, is planned (Norwegian Ministry of Climate and Environment, 2024, p. 7). At the same time, the Government will take steps to increase the production of biofuels in Norway. To this end, the Ministry of Agriculture and Food shall evaluate different instruments, including the existing Bionova.

When decarbonisation of transport is concerned, some of the most concrete prioritised measures are to gradually increase the biofuel mandate for road traffic to 33% by 2030, gradually increase the biofuel mandate for other applications (non-road machinery) to 28% by 2030, to gradually increase the biofuel mandate for maritime transport to 18% by 2030, and to increase the biofuel mandate in aviation to the same levels as in the EU Refuel Aviation (however noting that before the biofuel mandate here is increased, the airlines must be credited for use of biofuel in the EU ETS system). Moreover, there are aims to speed up the phasing in of low and zero emission fuels in aviation, and to establish a system for use and further increase that ensures stability, control, and predictability in the market for biofuels (Norwegian Ministry of Climate and Environment, 2024, p. 36). At the same time, zero emission solutions, such as battery-electric propulsion, hydrogen, and ammonia, are promoted strongly, e.g., via public procurement and support for research, development, and implementation of value chains.

Furthermore, the national Climate status and plan states that while the current domestic production of advanced biofuel is less than 50 million litres, and the Silva Green Fuel and Biozin initiatives potentially can produce a total of 100–200 million litres, the technology is immature and expensive. Therefore, domestically produced biofuel will only constitute a small share of the energy used in transport by 2050 (ibid., p. 55). At the same time, the rapid phase in is expected to give a considerable, but gradual and steady increase in the price of biofuels, which will make it easier for the end users to adjust. According to the Climate status and plan, the total use of biofuel will depend on the extent to which other climate measures are implemented, but the total use of biofuels according to the accelerated phase-in plan will be around 1.1 litres of biofuel by 2030, excluding aviation (ibid., p. 57).

On the other hand, the Government's presentation of the 2024 state budget warns that advanced biofuel is a limited resource, hence it is necessary to balance the need for more biofuel to reduce transport emissions against the costs, global availability, and sustainability characteristics of the biofuel. Against this background, the Government has proposed a control mechanism for the national biofuel policy, where the government regularly (starting from 2025) will assess the impact of the prevailing policy before increasing the biofuel mandates further, as noted in section 6.3 (p. 48).

The interviewed stakeholders perceived the signals from the national government regarding the need to switch from fossil to alternative fuels in transport as quite clear. However, several of them stated that the signals regarding which alternative fuels that will be promoted for different transport applications are unclear. They felt that the price of the final product and availability of needed infrastructure will be decisive for the choices users in the market eventually will make, and that these two factors remain challenging when it comes to biofuels. Furthermore, they noted that the policies and framework conditions for biofuels have been unpredictable and changing in the past.

Our assessment is that there will be a medium score for this indicator (+1), considering the mixed signals from the national authorities.

**Contribution towards circularity**

Operating at full capacity, the plant will use 40 000 tons of sawdust per year. This will be added to the current use in Innlandet, of 2 316 000 $fm^3$ (all for sawmills) and reduce the currently increasing export of lumber. Thus, in terms of circularity, an EBIO biofuel plant will help create more local resource loops as well as create increased value from wood residues, in medium term through production of biofuel, in longer term with potential also for platform chemicals.

While recognising this potential, several of the interviewed stakeholders considered the forest and forest-based industry as already circular, since all the resources are used for some purposes. One of them emphasized that new forest is planted, when the old one is logged, and all the resources are used for different purposes for now. The industry is also working on take-bake and recycling of wood products form construction industry.

Another stated that, "the less you process wood chips, the more value you can create". In his view, the product is already circular, so advanced biofuel production will represent a competing activity. While seeing local value creation as positive, he noted that for business actors, local activity must be weighed against other factors, least, economic attractiveness. One of the actors in the wood processing industry pointed out that the industry utilizes as much as possible of the residues and waste materials but see further possibilities for reuse and recycling of existing products. This would reduce their dependency on virgin raw materials, where they experience decreasing access due to increasing prices and decreasing availability of necessary volumes.

One of the public stakeholders asked whether other sources of biomass, such as return chips or logging waste, can be used with the EBIO technology. In his view this would be more aligned with the principles of circular economy, as sawdust may be used for other products before being utilised for biofuel production. Using the resources where as little processing as possible is required for value creation made more sense to him. Another concern voiced, also by the stakeholder representing education and research, was about the lifetime of the plant – that the estimate of this must be realistic and has a significant influence on the social impacts generated. In relation to this, the risk of lock-in was noted, as there may be/come more sustainable ways to utilise the resources.

Our assessment is that there will be a significant positive impact for this indicator, however limited by the capacity of the plant. Thus, the score provided is +1.

# 7. Discussion and conclusion

## 7.1 Summary discussion of results

The table below (Table 18) provides a summary overview of the assessment made for the different main impact categories and impact subcategories included in this study.

*Table 14: Summary overview of assessment results. In the Indicators column, dark green represents a strong, positive impact (+2); light green a significant, but modest positive impact (+1); yellow, no significant impact (0); light red, risk of a small, but significant negative impact (-1), and dark red (not applied) the risk of a strong negative impact.*

| | Impact category | Subcategories | Indicators | Justification |
|---|---|---|---|---|
| Value chain | Compe-tence | Skill mix | Job requirements by qualification | • Added competence in bio-based chemistry in Innlandet will be of high value, given the needs previously identified |
| | Compe-titive-ness | Potential adopters | The number of enterprises that may adopt the process technology | • Several relevant bio-hubs are developing in Innlandet<br>• Limited availability of electricity is a challenge, therefore few, and perhaps only one, of the present hubs are relevant |
| | | Substitution of non-sustainable products | The types and volume of non-sustainable products on the market that the end-product can replace | • With the targets for EBIO being met, the biofuel may substitute fossil fuels in aviation, maritime, and/or heavy truck transport<br>• In a long-term perspective, the by-products may substitute fossils as platform chemicals<br>• With the considered plant capacity, volumes will be limited |
| | | Incentives for early providers | The extent to which biofuel production is incentivised | • Various types of public grant funding for production and value chain development are available |
| | Gover-nance | Transparency | The extent to which strategic plans, annual | • High for larger companies<br>• Low for smaller companies |

| | | | | |
|---|---|---|---|---|
| | | | reports, sustainability reporting, etc. from the involved enterprises are publicly available | • Indications that it is improving |
| | | Traceability | The extent to which the origin of the input factors can be traced and managed | • Relatively high for the biomass, lower for other input factors |
| Workers | Health and safety | Health and safety of workers | The percentage of workers that are exposed to dust, gas or steam most of the time | • High for Agriculture, forestry, and fishery (11%) and Industry (10%)<br>• Lower for the other implicated sectors<br>• Average for the economy is 3% |
| | | | The percentage of workers that are exposed to skin-irritating substances most of the time | • Highest for Electricity, water and sanitation (9%)<br>• Otherwise, lower than average for the economy<br>• Average for the economy is 8% |
| | | | The percentage of workers that have a high risk of accidents | • Relatively high for Agriculture, forestry, and fishery (10%)<br>• Lowest for Electricity, water, and sanitation (1%)<br>• Average for the economy is 3% |
| | Human rights | Gender equality at work | The male/female wage ratio | • Not balanced, average salary for women 87% of men in Norway<br>• Roughly same as in the EU (12.7% difference, Statista, 2023) |
| | | | The male/female employment ratio | • Most of the new jobs created will be in sectors that are male dominated in terms of male/female employment<br>• Interviewees suggested jobs requiring chemistry competence my attract female employees, as a highly desirable impact |
| | Labour rights and decent work | Fair wages | Wages at each process step compared to minimum wage | • Well above minimum wages for agriculture in Norway |
| | | Unionisation | The share of workers organised in trade unions | • Average trade unionship around 50%<br>• Much higher than average for the EU (23%)<br>• Decreasing (as in the EU) |
| | | Meaningful work | The percentage of workers that are required to often or always work at a high pace | • Ranges from 42.4 to 49.7%<br>• Slightly lower than average for all sectors<br>• Highest for Technical services/facilities management |

| | | | | |
|---|---|---|---|---|
| | | | The percentage of workers that will often or always be required to acquire new knowledge and skills | • Assumed to be high for those directly employed at the plant<br>• Low for Forestry, Agriculture and Fishery<br>• Below average for most parts of the value chain |
| Users | Social accept-ability | Fulfilment of formal sustain-ability criteria | The extent to which the end-product meets sustainability criteria laid down in relevant regulations | • To the extent that EBIO has met the targets specified for its technical KPIs, the solution will meet the sustainability criteria laid down in RED III |
| | | Willingness to pay | The maximum price consumers are willing to pay for one unit of the end-product | • Relevant literature suggests consumers are willing to pay more for sustainable fuels |
| | Usability | Fit with existing systems and practices | The extent to which the end-user needs to modify user equipment or practices | • When the targets of EBIO are met, the fuel can be used as drop-in fuel without engine modifications or blending with their petroleum counterparts |
| | Availa-bility | Incentives for users | The extent to which the use of the end-product is incentivised | • Incentives in place<br>• However, incentives for other alternative fuel/propulsion solutions tend to be higher |
| Local community | Contri-bution to local economy | Value creation | The expected gross product of the economic activity related to implementation of the solution | • Increase in value-added in the new value chain, sectors strongly present in Innlandet<br>• Decrease in petroleum-related sectors |
| | Quality of life | Employment | The expected number of new employees resulting from implementation of the solution | • Direct employment: 0.7 employees<br>• Indirect employment: 6.9 employees (70% in Forestry, logging, and related services)<br>• Decrease in mainly petroleum-related sectors (2.0 employees) |
| | | Bequest value | The level of satisfaction from preserving the natural environment for future generations | • Positive impact expected, linked to previous and generally high engagement for the environment in the region |
| | Inno-vation capacity | Contribution to innovation clusters | The number of existing clusters expected to benefit from the initiative | • Four relevant clusters |
| | | R&D activities | The number of R&D activities initiated in connection with the solution | • New R&D activity can be anticipated<br>• Specific numbers not available at present |

| | | | | |
|---|---|---|---|---|
| | Regional attrac-tiveness | Contribution towards realisation of regional development strategies | The extent to which implementation of the solution can contribute to realisation of regional development strategies | • Strong degree of alignment |
| | | Regional economic attractiveness | The extent to which implementation of the solution can influence the economic attractiveness of the region | • Anticipating modest, positive impact<br>• To be assessed in consultation with stakeholders |
| Wider society | Energy security | Renewable share of energy mix | The extent to which implementation of the technology will increase the renewable share of the energy consumption | • Small, but important contribution to the national mix of sustainable, renewable energy |
| | | Secure energy supply for transport | The extent to which implementation of the solution can contribute to securing supply of biofuel | • Modest, but significant contribution towards reducing current import dependency when it comes to advanced biofuels |
| | Food security | Use of arable land | The territory of arable land needed to produce the annual need for feedstock | • Non ILUC-risk feedstock<br>• No conflict with food production<br>• Positive impact if compared with first generation biofuels, in terms of saving land for food production in developing countries |
| | Sustaina bility tran-sition | Alignment with national decarbon-isation policies | The extent to which implementation of the technology is aligned with national policies for decarbonising the transport sector | • Biofuel is recognised as having an important role in Norway's energy transition<br>• Strong focus on R&D&I of other alternative fuels, e.g., hydrogen and ammonia |
| | | | The amount of GHG emission reductions associated with implementation of the solution | • Significant positive impact anticipated (linked to KPIs for EBIO)<br>• Limited by the capacity of the plant |
| | | Contribution towards circularity | The amount of waste the implementation of the technology can contribute to reduce | • Significant, but limited by the capacity of the plant<br>• Most of the lumber is already being utilized, but the EBIO biofuel plant would result in higher value products and more localised loops |

As the table shows, a wide range of positive potential impacts are identified. However, the extent of some of these are limited, as they are related to the relatively small plant defined in the scope for this case-study, and the volumes of feedstock, biofuels and by-products it can be associated with.

With a larger facility, consisting of more pyrolysis units, we may anticipate stronger positive impacts for several of the indicators. However, we have also noted that increasing competition over residues from forestry and wood industry is anticipated, and that there is some uncertainty regarding the future direction and framework conditions for different alternative fuels in Norway.

In line with previous studies, we find positive impacts at the regional level, in terms of employment and value creation, but also in form of strengthened innovation capacity, regional attractiveness, and other factors influencing the quality of life for citizens.

However, the input-output analysis also highlights that the positive impacts in terms of value creation and employment will be accompanied by decreases in other sectors. This underscores the need to look beyond specific regions and consider multiple scales in SIA.

At the value chain level, we also note that there are many potential positive impacts, linked to the interaction between the focal technology and the industrial context in the region under study.

When impacts on workers are concerned, our assessment suggests that the potential implementation of an EBIO biofuel plant will have limited impact on health and safety aspects, or on the male/female wage ratio. There is a modest risk associated with the rate of male/female employment, as most of the potential new jobs are in male-dominated sectors. However, the consulted stakeholders pointed out that the required competence might attract women with higher education in chemistry and bio sciences, which they saw as highly desirable, considering the current demographic trends in Innlandet. This indicator is therefore given a moderately positive score.

When it comes to labour rights and decent work, we do not see that the studied case will have any significant impact on the degree of unionisation. We do, however, anticipate a positive result for the subcategory Fair wages. As to Meaningful work, the generic data collected suggest no impact on job demands in terms of work at a high pace. One might see a modest risk in terms of workers' opportunities to acquire new knowledge and skills, in the sense that most of the potential new employment falls in sectors scoring lower on this indicator than the average for all sectors in Norway. However, we consider that those directly employed at a new EBIO biofuel plant would often be required to acquire new knowledge and skills and therefore rate the impact for this indicator as neutral.

The results for impacts related to users are largely positive. As regards the wider society, we anticipate a modest, positive impact on the renewable share of the energy mix, as our focus is on a relatively small facility and Norway has a rather large share of renewable energy already.

The level of alignment with national decarbonisation policies is positive. The contribution towards energy security for transport is also rated as highly significant, considering the Norway's current import dependency and the limited availability of bioresources in an increasingly unstable global political context. Furthermore, potential global impacts, in terms of providing low ILUC risk and thus potentially replacing biofuels produced from land better used for food production, and contributing towards a circular economy, are highlighted.

Lastly, this assessment shows that social sustainability depends on the focal technology and the local context. In the studied case, potential positive impacts in terms of contributing to the regional bioeconomy strategy, enhancing local competence and skill mix, and increasing regional economic attractiveness will be particularly valuable, considering the shortcomings and challenges previously identified for Innlandet in these areas. At the same time, the limited power grid capacity constitutes a barrier to implementation in some parts of the county, however not in all, and there are indications that structural conditions (e.g., linked to ownership) are complicating the interaction between buyers and sellers and security of supply of biomass from forestry. As noted by the consulted stakeholders, as well as in previous research (Jåstad et al., 2021), the availability of forest residues for advanced biofuel production in Innlandet may be influenced by the demand for biomass for other uses, e.g, local chipboard production and paper and pulp industry. However, cascading and the possible utilisation of by-products, such as phenols, may also influence the value-added positively in future.

## 7.2 Limitations

This assessment has a few limitations. We have limited information about what the final EBIO concept will be. Hence the assessment is mainly based on assumptions, related to existing fast pyrolysis plants and preliminary findings from the project.

Furthermore, it should be noted that the input-output results above are for Norway as a whole and exclude import effects. As the EBIO sector is set up to also rely on import supplies, positive effects in form of increased value-added may be generated in other countries. The exact location of such effects will depend on the location of the trade partners. The model employed here based on the Norwegian IO table does not provide information on the regions of imports, only total imports per sector are given. To identify the regions of such effects, a multiregional IO database with global coverage could be used as an extension of this study.

Similarly, we cannot identify the exact effects in Innlandet versus effects in the rest of Norway, due to lack of county-level detail in the model. Still, given the importance of input from the forestry sector, and the substantial forestry sector in Innlandet county, we can expect considerable indirect effects in Innlandet, particularly for employment. However, given the increasing interconnectedness between sectors and regions, we can expect effects for these indicators in most regions in Norway.

We have here assumed that the final product is a type of biofuel that can largely replace conventional fuel in the market. However, there is a chance that the final product will not reach this stage. In that case, the EBIO sector might deliver a product that has a reduced final demand and increased intermediate demand in the sector setup and scenario. Then, results might change. The degree and direction of this change is highly dependent on the market readiness of the product and which sectors will further process the product for it to become a product ready for final demand.

In addition, sales of e.g., platform chemicals may generate more positive effects (compared to our results) in terms of value-added. However, the total economy-wide effects on value-added and employment will depend on the products they replace in the market. The total effect can become negative if the by-products replace existing products with high value-added and employment multipliers in the economy, and vice versa if it replaces a product with low multipliers.

In section 6.4 we investigated the uncertainty of IO variables and the effects these have on the employment and value-added results. Another source of uncertainty are the parameters we set to arrive at the monetary output from the EBIO sector. The physical quantity produced in the EBIO sector set to 3 650 tons of biofuel is of course highly relevant, but also the conversion factors involved, i.e. the price of biofuel and the exchange rate from € to NOK could be part of an uncertainty analysis. Future work should investigate the impact these uncertainties will have on the results.

At a broader level, it has been noted that social data are not subject to mass balances like environmental data and are often qualitative and difficult to compile or even locate. Social indicators should measure the social impacts, but often lack a clear consensus (Valente et al., 2018). Hence, the choice of indicators and assessment might be subjective.

Against this background, we took a systematic approach, combining desk-study of existing literature on social sustainability assessment of biobased products with assessment using established criteria for selection of social impact indicators and discussion with the project partners, which represent different research disciplines and segments of the biofuel value chain. We also included criteria and indicators of different quality, e.g., quantitative and qualitative, generic and site-specific.

While some local stakeholders generously provided of their time, the access to relevant stakeholders was limited by lack of formal links (they did not participate in the project). It was challenging to communicate the focal solution to them, and for them to have informed opinions. Still, the conducted interviews added nuance to the assessment, and underscore the importance of including different perspectives, as noted by e.g., Falcone et al. (2019).

## 7.3 Conclusion

In this work we have provided a framework for SIA of implementing electrochemical conversion of fast pyrolysis liquid into green fuels and biochemicals (the EBIO technology) and applied it in a case-study focused on a potential pyrolysis plant in Innlandet county, Norway. We have looked at potential social impacts for different stakeholder categories, including the potential value chain actors, workers, users, local community or region, and the wider society.

Our findings for employment suggest a positive overall effect in the economy, with the most significant value chain effects found in the forestry and wood sector and expected to benefit Innlandet county. Value added is slightly increased, where the positive effects of increased value-added in the EBIO sector and forestry sector are by a small margin larger than the negative effects on value-added the petroleum-related sectors. However, both effects on value added and employment are small.

Furthermore, we find positive potential impacts on innovation capacity and regional attractiveness, as well as social acceptability, linked to the fulfilment of formal sustainability criteria, usability, WtP, and the existence of incentives for users.

The potential social impacts related to workers are less pronounced. Assessment of generic data suggests that the impact on most indicators will be limited. However, there is a potential positive impact in terms of fair wages. In terms of gender equality, most of the employment generated will be in sectors where most employees are male, however the consulted stakeholders highlighted the potential benefit of attracting educated women with expertise the region needs, as chemistry and biochemistry in Norway have a high ratio of female students.

Considering impacts on the wider society, our assessment highlights the alignment with national decarbonisation strategies and potential to reduce Norway's current import dependency as regards biofuel. A pyrolysis plant with EBIO technology in Innlandet may also enhance circular bioeconomy. Finally, the risk of indirect land use change is limited, and no negative impacts on food security are foreseen.

As the focal technology is at an early stage of development and the availability of data has been limited, the results of this assessment are uncertain and must be followed by more detailed investigation when the technology reaches a higher level of maturity.

# References

(References marked with asterix are used in Annex 1 and Annex 2).

Ahmad, S., Ouenniche, J., Kolosz, B. W., Greening, P., Andresen, J. M., Maroto-Valer, M. M., & Xu, B. (2021). A stakeholders' participatory approach to multi-criteria assessment of sustainable aviation fuels production pathways. *International Journal of Production Economics.*, *238*. https://doi.org/https://doi.org/10.1016/j.ijpe.2021.108156

Allain, S., Ruault, J. F., Moraine, M., & Madelrieux, S. (2022). The «bioeconomics vs bioeconomy» debate: Beyond criticism, advancing research fronts. *Environmental Innovation and Societal Transitions*, *42*, 58-73. https://doi.org/10.1016/j.eist.2021.11.004

Andersson, L., Ek, K., Kastensson, Å. & Wårell, L. (2020). Transition towards sustainable transportation - What determines fuel choice ? *Transport Policy, 90,* 31-38. https://doi.org/10.1016/j.tranpol.2020.02.008

*Anjos, T.P., Matias, M. & Gontijo, L.A. (2012). *Work, 41 (1)*, 2117-2121. DOI: 10.3233/WOR-2012-0440-2117

Aponte, F. R., Andersen, T., Norstebo, V. S., Uggen, K. T., Bjelle, E. L., & Wiebe, K. S. (2021, Jan 13-15). Offshore Wind: Employment and value creation of EPCI exports in Norway.*Journal of Physics Conference Series* [Eera deepwind'2021]. European-Energy-Research-Alliance (EERA) 18th Deep Sea Offshore Wind R and D Digital Conference (EERA DeepWind), Sintef, Electr Network.

*Bathelt, H., Malmberg, A., & Maskell, P. (2004). Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography*, *28*(1), 31-56. https://doi.org/10.1191/0309132504ph469oa

*Baudry, G., Delrue, F., Legrand, J., Pruvost, J., & Vallée, T. (2017). The challenge of measuring biofuel sustainability: A stakeholder-driven approach applied to the French case. *Renewable & Sustainable Energy Reviews*, *69*, 933-947. https://doi.org/10.1016/j.rser.2016.11.022

Becker, H.A, 2001. Social Impact Assessment. European Journal of Operational Research, 128: 311-321.

*Bilan, Y., Samusevych, Y., Lyeonov, S., Strzelec, M., & Tenytska, I. (2022). The Keys to Clean Energy Technology: Impact of Environmental Taxes on Biofuel Production and Consumption. *Energies*, *15*(24), Article 9470. https://doi.org/10.3390/en15249470

Biovalley. (2022). *Om Biovalley*. Biovalley. Retrieved 07.12.2023 from https://biovalley.no/#ombiovalley

*Bosona, T., Gebresenbet, G., & Olsson, S. O. (2018). Traceability System for Improved Utilisation of Solid Biofuel from Agricultural Prunings. *Sustainability*, *10*(2), Article 258. https://doi.org/10.3390/su10020258

Bringezu, S., Distelkamp, M., Lutz, C., Wimmer, F., Schaldach, R., Hennenberg, K. J., Böttcher, H., & Egenolf, V. (2021). Environmental and socioeconomic footprints of the German bioeconomy. *Nature Sustainability*, *4*(9), 775-783. https://doi.org/10.1038/s41893-021-00725-3

Brinkman, M. L. J., Wicke, B., Faaij, A. P. C., & van der Hilst, F. (2019). Projecting socio-economic impacts of bioenergy: Current status and limitations of <i>ex-ante</i> quantification methods. *Renewable & Sustainable Energy Reviews*, *115*, Article 109352. https://doi.org/10.1016/j.rser.2019.109352

BTG Bioliquids. (2020). From sawdust to tank. Retrieved 22.12.2023 from https://www.btg-bioliquids.com/plant/pyrocell-gavle-sweden/

Bueno, N. (2017). From the Right to Work to Freedom from Work: Introduction to the Human Economy. International Journal of Comparative Labour Law and Industrial Relations 4, 463-487. ttps://kluwerlawonline.com/journalarticle/International+Journal+of+Comparative+Labour+Law+and+Industrial+Relations/33.4/IJCL2017020

Burdge, R.J. (2003). The practice of social impact assessment background. *Impact Assessment and Project Appraisal*, 21:2, 84-88, DOI: 10.3152/147154603781766356

*Cabrera-Jiménez, R., Mateo-Sanz, J. M., Gavaldà, J., Jiménez, L., & Pozo, C. (2022). Comparing biofuels through the lens of sustainability: A data envelopment analysis approach. *Applied Energy*, *307*. https://doi.org/https://doi.org/10.1016/j.apenergy.2021.118201

*Cambridge Dictionary. (2023). *Usability.* Retrieved 11.12.2023 from https://dictionary.cambridge.org/dictionary/english/usability

*CEN. (2016). EN16751:2016. Bio-based products - Sustainability criteria. In: European Committee for Standardisation.

Colantonio, A. (2009). Social sustainability: a review and critique of traditional versus emerging themes and assessment methods. IIn Horner, M., Price, A., Bebbington, J. and Emmanuel, R., (eds.) SUE-Mot Conference 2009: Second International Conference on Whole Life Urban Sustainability and its Assessment: conference proceedings. Loughborough : Loughborough University, 2009, pp. 865-885. https://eprints.lse.ac.uk/35867/1/Colantonio_Social_sustainability_review_2009.pdf

Collotta, M., Champagne, P., Tomasoni, G., Alberti, G., Busi, L. & Mabee, W. (2019). Critical indicators of sustainability for biofuels: an analysis through a life cycle sustainability assessment perspective. *Renewable and Sustainable Energy Reviews, 115*, 109358. https://doi.org/10.1016/j.rser.2019.109358Get rights and contentCorradini, C., Morris, D., & Vanino, E. (2023). Towards a regional approach for skills policy. *Regional Studies*, *57*(6), 1043-1054. https://doi.org/10.1080/00343404.2022.2031950

Cordella, M., Torri, C., Adamiano, A., Fabbri, D., Barontini, F., Cozzani, V. (2012). Bio-oils from biomass slow pyrolysis: A chemical and toxicological screening. Journal of Hazardous Materials, Vol. 231–232, p. 26-35, https://doi.org/10.1016/j.jhazmat.2012.06.030.

*Correa, D.F., Beyer, H.L., Fargione, J.E., Hill, J.D., Possingham, H.P., Thomas-Hall, S.R., Schenk, P.M. (2019). Towards the implementation of sustainable biofuel production systems, Renewable and Sustainable Energy Reviews 107, 250-263. https://doi.org/10.1016/j.rser.2019.03.005.

*Council of Europe (2023). 12 Principles of Good Governance. Retrieved 20.12.2023 from https://www.coe.int/en/web/good-governance/12-principles

County Governor of Innlandet. (2023). Fakta og statistikk - landbruk. Retrieved 06.12.2023, from https://www.statsforvalteren.no/nb/innlandet/landbruk-og-mat/fakta-og-statistikk2/Dayasindhu, N. (2002). Embeddedness, knowledge transfer, industry clusters and global competitiveness: a case study of the Indian software industry. *Technovation*, *22*(9), 551-560, Article Pii s0166-4972(01)00098-0. https://doi.org/10.1016/s0166-4972(01)00098-0

Dias, T.A.C., Lora, E.E.S., Maya, D.M.Y., del Olmo, O.A. (2021). Global potential assessment of available land for bioenergy projects in 2050 within food security limits. Land Use Policy 105, 105346, https://doi.org/10.1016/j.landusepol.2021.105346.

*Dreyer, L., Hauschild, M., & Schierbeck, J. (2006). A Framework for Social Life Cycle Impact Assessment. *Int J Life Cycle Assessment*, *11*, 88-97. https://doi.org/https://doi.org/10.1065/lca2005.08.223

*Dreyer, L. C., Hauschild, M. Z., & Schierbeck, J. (2010). Characterisation of social impacts in LCA. *International Journal of Life Cycle Assessment*, *15*(3), 247-259. https://doi.org/10.1007/s11367-009-0148-7

Ekener, E., Hansson, J., & Gustavsson, M. (2018). Addressing positive impacts in social LCA-discussing current and new approaches exemplified by the case of vehicle fuels. *International Journal of Life Cycle Assessment*, *23*(3), 556-568. https://doi.org/10.1007/s11367-016-1058-0

*Energy Norway. (2021). Fornybarbarometeret 2021. Status for norsk fornybarnæring. Retrieved 20.12.2023 from https://www.fornybarnorge.no/contentassets/14940b60888e47e98af41fab67129f7d/energi_norge_bar21_master_lowres_oppslag.pdf

*EUR-Lex. (2023). *Competitiveness.* Retrieved 11.12.2023 from https://eur-lex.europa.eu/EN/legal-content/glossary/competitiveness.html

European Commission. (2016). *A European Strategy for Low-Emission Mobility*. Retrieved 20.12.2023 from https://eur-lex.europa.eu/resource.html?uri=cellar:e44d3c21-531e-11e6-89bd-01aa75ed71a1.0002.02/DOC_1&format=PDF

European Commission. (2019). *Communication from the Commission. The European Green Deal.* Brussels Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52019DC0640

*European Commission. (2019a*). Employment and Social Developments in Europe 2019*. Retrieved 20.12.2023 from https://ec.europa.eu/social/main.jsp?catId=738&langId=en&pubId=8219

European Commission. (2019b). *Commission Delegated Regulation (EU) 2019/807 of 13 March 2019 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council as regards the determination of high indirect land-use change-risk feedstock for which a significant expansion of the production area into land with high carbon stock is observed and the certification of low indirect land-use change-risk biofuels, bioliquids and biomass fuels.* Retrieved 29.12.2023 from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0807

European Parliament and Council of the European Union. (2003). *Directive on Biofuels for Transport (2003/30/EC)*. Retrieved from https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32003L0030

European Parliament and Council of the European Union. (2018). *Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast).* Retrieved 12.12.2023 from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001

European Parliament and Council of the European Union. (2022). *Directive (EU) 2022/2464 of the european parliament and of the council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting*. Retrieved 12.12.2023 from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022L2464

European Parliament and Council of the European Union. (2023). *Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652*. Retrieved 12.12.2023 from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302413

European Parliament (2022). *DRAFT REPORT on the proposal for a Council directive restructuring the Union framework for the taxation of energy products and electricity (recast) (COM(2021)0563 – C9-0362/2021 – 2021/0213(CNS)).* https://www.europarl.europa.eu/doceo/document/ECON-PR-719624_EN.pdf

Eurostat. (2008). *NACE Rev.2. Statistical classification of economic activities in the European community.* Retrieved 20.12.2023 from https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF

*Eurostat. (2023). *Glossary: Arable land*. Retrieved 15.12.2023 from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Arable_land

EY (2023). *Innlandsporteføljen. Innlandets viktigste innovasjonsprosjekter for å nå visjonen om å bli et grønt sirkulært vekstfylke. Innlandets viktigste innovasjonsprosjekter for å nå visjonen om å bli et grønt sirkulært vekstfylke.* Report by Ernst & Young. https://gp0873.n3cdn1.secureserver.net/wp-content/uploads/2023/12/Innlandsportefoljen-2023.pdf

Falcone, P. M., Garcia, S. G., Imbert, E., Lijo, L., Moreira, M. T., Tani, A., Tartiu, V. E., & Morone, P. (2019). Transitioning towards the bio-economy: Assessing the social dimension through a stakeholder lens. *Corporate Social Responsibility and Environmental Management*, *26*(5), 1135-1153. https://doi.org/10.1002/csr.1791

Falcone, P. M., & Imbert, E. (2018). Social Life Cycle Approach as a Tool for Promoting the Market Uptake of Bio-Based Products from a Consumer Perspective. *Sustainability*, *10*(4), Article 1031. https://doi.org/10.3390/su10041031

*Felce, D., & Perry, J. (1995). Quality of life: Its definition and measurement. *Research in Developmental Disabilities, 16*(1), 51–74. https://doi.org/10.1016/0891-4222(94)00028-8

*Ferreira, V., Pié, L., Mainar-Causapé, A., & Terceño, A. (2023). The bioeconomy in spain as a new economic paradigm: the role of key sectors with different approaches. *Environment Development and Sustainability*. https://doi.org/10.1007/s10668-022-02830-5

*Freiling, J. (2004). A competence-based theory of the firm. *Management Revue*, ISSN 1861-9916, Rainer Hampp Verlag, Mering, Vol. 15, Iss.1, pp.27-52.

*Gegg, P., & Wells, V. (2017). UK Macro-Algae Biofuels: A Strategic Management Review and Future Research Agenda. *Journal of Marine Science and Engineering*, *5*(3), Article 32. https://doi.org/10.3390/jmse5030032

Goding, L., Andersson-Franko, M., Lagerkvist, C.J., 2018. Preferences for bio jet fuel in Sweden: the case of business travel from a city airport. Sustain. Energy Technol. Assess. 29(October 2017), 60–69. DOI: 10.1016/j.seta.2018.06.015

*Groiß-Fürtner, D., Mair-Bauernfeind, C., & Hesser, F. (2023). Proposing a Multi-level Assessment Framework for Social LCA and Its Contribution to the Sustainable Development Goals. In F. Hesser, I. Kral, G. Obersteiner, S. Hörtenhuber, M. Kühmaier, V. Zeller, & L. Schebek (Eds.), *Progress in Life Cycle Assessment 2021. Sustainable Production, Life Cycle Engineering and Management.* . Springer, Cham. https://doi.org/https://doi.org/10.1007/978-3-031-29294-1_7

*Guvenen, F., Kuruscu, B., Tanaka, S., & Wiczer, D. (2020). Multidimensional Skill Mismatch. *American Economic Journal-Macroeconomics*, *12*(1), 210-244. https://doi.org/10.1257/mac.20160241

Harley, M., Horrocks, L. & Hodgson, N. (2008). Climate change vulnerability and adaptation indicators. *ETC/ACC technical paper 9*. https://www.eionet.europa.eu/etcs/etc-cca/products/etc-cca-reports/etcacc_tp_2008_9_ccvuln_adapt_indicators-1/@@download/file/ETCACC_TP_2008_9_CCvuln_adapt_indicators.pdf

Hedmark and Oppland counties (2017). *Bioeconomy strategy for Innlandet 2017-2024.* https://www.regjeringen.no/contentassets/afc36304247d48f0a3546f992e0e0305/biookonomistrategi-for-innlandet_feb18.pdf

*Humphrey, J., & Schmitz, H. (2004). Chain Governance and Upgrading: Taking Stock. In H. Schmitz (Ed.), *Local Enterprises in the Global Economy: Issues of Governance and Upgrading.* (pp. 349-381). UK: Edward Elgar Publishing Limited.

*IBGC (2010). Code of Best Practice of Corporate Governance. Retrieved 20.12.2023 from https://www.ecgi.global/download/file/fid/9872

*IEA. (2022). *Biodiesel and diesel prices, 2019 to April 2022.* IEA. Retrieved 6.12.2023 from https://www.iea.org/data-and-statistics/charts/biodiesel-and-diesel-prices-2019-to-april-2022

*IEA (2023). Policies database. Retrieved 20.12.2023 from https://www.iea.org/policies?sector%5B0%5D=Transport&qs=bio&technology%5B0%5D=Biofuel

IEA Bioenergy (2023). Registration of DTL products and derivatives. March 2023. Report by Bert van de Beld, Hans Heeres – BTG Biomass Technology Group BV, The Netherlands. IEA Bioenergy

Technology Collaboration Programme. https://task34.ieabioenergy.com/wp-content/uploads/sites/3/2023/03/IEA-substance-registration-DTL-products-FINAL.pdf

*Illukpitia, P., de Koff, J.P. (2014). Economics of Small-Scale Biodiesel Production. Bioenergy. Tennessee State University, ANR-B11 2014. https://www.tnstate.edu/extension/documents/BiodieselEconomics.pdf

Innlandsstatistikk (2023). Næringsstruktur (enterprise structure). https://www.innlandsstatistikk.no/naringsliv/naringsstruktur/¨

Innlandsstatistikk (2023). Næringsliv (business life). https://www.innlandsstatistikk.no/naringsliv/

*Jagtap, S.P., Pawar, A.N & Lanane, S. (2020). Improving the usability of biodiesel blend in low heat rejection diesel engine through combustion, performance and emission analysis. *Renewable Energy, 155,* 628-644. https://www.sciencedirect.com/science/article/pii/S096014812030447X?via%3DihubJåstad, E. O., Bolkesjo, T. F., & Rorstad, P. K. (2020). Modelling effects of policies for increased production of forest-based liquid biofuel in the Nordic countries. *Forest Policy and Economics*, *113*, Article 102091. https://doi.org/10.1016/j.forpol.2020.102091

Jåstad, E. O., Bolkesjo, T. F., Rorstad, P. K., Midthun, A., Sandquist, J. &Trømborg, E. (2021). The future role of forest-based biofuels: industrial impacts in the Nordic countries. Energies, 14, 2073. https://doi.org/10.3390/en14082073

*Kabir, F., Gulfraz, M., Raja, G. K., Inam-ul-Haq, M., Batool, I., Awais, M., Habiba, U., and Gul, H. (2019). "Comparative study on the usability of lignocellulosic and algal biomass for production of alcoholic fuels," *BioRes*. 14(4), 8135-8154. https://bioresources.cnr.ncsu.edu/resources/comparative-study-on-the-usability-of-lignocellulosic-and-algal-biomass-for-production-of-alcoholic-fuels/

Kamali, F. P., Borges, J. A. R., Osseweijer, P., & Posada, J. A. (2018). Towards social sustainability: Screening potential social and governance issues for biojet fuel supply chains in Brazil. *Renewable & Sustainable Energy Reviews*, *92*, 50-61. https://doi.org/10.1016/j.rser.2018.04.078

*Lanzini, P., Testa, F., & Iraldo, F. (2016). Factors affecting drivers' willingness to pay for biofuels: the case of Italy. *Journal of Cleaner Production*, *112*, 2684-2692. https://doi.org/10.1016/j.jclepro.2015.10.080

*Lau, A. & Lo, W. (2015). Regional innovation system, absorptive capacity and innovation erformance: An empirical study, Technological Forecasting and Social Change 92: 99-114. https://doi.org/10.1016/j.techfore.2014.11.005.

Littig, B. & Griessler, E. (2005). Social Sustainability: A Catchword Between Political Pragmatism And Social Theory. International Journal Of Sustainable Development 8(1–2): 65–79.

Lynch, J. and Joseph, J. (2010). Guidelines for the Development and Testing of Pyrolysis Plants to Produce Biochar. International Biochar Initiative. https://biochar-international.org/wp-content/uploads/2024/02/IBI_Pyrolysis_Plant_Guidelines.pdf

*Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy*, *41*(6), 955-967. https://doi.org/10.1016/j.respol.2012.02.013

Martin, M., Royne, F., Ekvall, T. & Moberg, A. (2018). Life Cycle Sustainability Evaluations of Bio-based Value Chains: Reviewing the Indicators from a Swedish Perspective. *Sustainability, 10* (2), 547 ; https://doi.org/10.3390/su10020547

*Marting Vidaurre, N. A., Vargas-Carpintero, R., Wagner, M., Lask, J., & Lewandowski, I. (2020). Social Aspects in the Assessment of Biobased Value Chains. *Sustainability*, *12*(23), Article 9843. https://doi.org/10.3390/su12239843

Mattioda, R.A., Tavares, D.R., Casela, J.L., Cansiglieri, O.J. (2019). Social life cycle assessment of biofuel production. In: Ren, J., Scipioni, A., Manzardo, A., Liang, H. (eds.): Biofuels for a More Sustainable Future. Life Cycle Sustainability Assessment and Multi-Criteria Decision-Making. Elsevier. https://doi.org/10.1016/B978-0-12-815581-3.00009-9

Ministry of Finance. (1998 ; 2023). Lov om årsregnskap m.v. (regnskapsloven). Retrieved 20.12.2023 from https://lovdata.no/dokument/NL/lov/1998-07-17-56

*Mizik, T., & Gyarmati, G. (2021). Economic and Sustainability of Biodiesel Production-A Systematic Literature Review. *Clean Technologies*, *3*(1), 19-36. https://doi.org/10.3390/cleantechnol3010002

NCE Heidner Biocluster. (2020). *Næringsklyngen NCE Heidner Biocluster*. https://heidner.no/om-klyngen/

*Neverauskiene, L. O., Danileviciene, I., & Tvaronaviciene, M. (2020). Assessment of the factors influencing competitiveness fostering the country's sustainability. *Economic Research-Ekonomska Istrazivanja*, *33*(1), 1909-1924. https://doi.org/10.1080/1331677x.2020.1763821

NHO (2023). Nøkkeltall for Næringslivet i Innlandet. Statistics from the Norwegian Confederation of Enterprise. https://www.nho.no/regionkontor/nho-innlandet/nokkeltall_naringsliv_innlandet/#Heading%20Kompetansebarometer

NIBIO (2023). Ten facts about soil and farmland preservation in Norway. News article published 03.02.2023. https://www.nibio.no/en/news/ten-facts-about-soil-and-farmland-preservation-in-norway

Norskog. (2023a). *Hvem er Norskog?* Retrieved 21.12.2023 from https://norskog.no/om-oss/

Norskog. (2023b). *FoU-prosjekter*. Retrieved 21.12.2023 from https://norskog.no/prosjekter/#1584113551378-f6e44737-ec01

*Norwegian Environment Agency. (2018). *Kunnskapsgrunnlag for omsetningskrav i skipsfart.* https://www.miljodirektoratet.no/globalassets/publikasjoner/M1125/M1125.pdf

Norwegian Environment Agency. (2020). *Klimakur 2030*. https://www.miljodirektoratet.no/globalassets/publikasjoner/m1625/m1625.pdf

Norwegian Environment Agency. (2023). *Biodrivstoff.* https://www.miljodirektoratet.no/ansvarsomrader/klima/transport/biodrivstoff/

Norwegian Government (2016). *The Government's bioeconomy strategy.* https://www.regjeringen.no/contentassets/32160cf211df4d3c8f3ab794f885d5be/nfd_biookonomi_strategi_uu.pdf

Norwegian Government (2021). *Nasjonal strategi for ein grøn, sirkulær økonomi.* https://www.regjeringen.no/contentassets/f6c799ac7c474e5b8f561d1e72d474da/t-1573n.pdfNorwegian Labour Inspection Authority. (2023). *Minimum wage*. Retrieved 20.12.2023 from https://www.arbeidstilsynet.no/en/working-conditions/pay-and-minimum-rates-of-pay/minimum-wage/

Norwegian Maritime Authority. (2023). *Potensielle sikkerhetsutfordringer ved bruk av drivstoff innblandet FAME.* https://www.sdir.no/sjofart/regelverk/rundskriv/potensielle-sikkerhetsutfordringer-ved-bruk-av-drivstoff-innblandet-fame/

*Norwegian Ministry of Climate and Environment. *Mld. St. 13 (2020-2021). Report to the Storting. Norway's Climate Action Plan for 2021-2030.* https://www.regjeringen.no/contentassets/a78ecf5ad2344fa5ae4a394412ef8975/en-gb/pdfs/stm202020210013000engpdfs.pdf

Norwegian Ministry of Climate and Environment (2024). *Regjeringens klimastatus og -plan [The Government's Climate Status and Plan].* https://www.regjeringen.no/contentassets/1b2fd715fe494bd886a4756a49737670/no/pdfs/regjeringens-klimastatus-og-plan.pdf

Norwegian Ministry of Trade, Industry and Fisheries. (2023). *Veikart 2.0. Grønt Industriløft.* https://www.regjeringen.no/contentassets/b5a51f3220474b3197ea21feb260f5b3/no/pdfs/veikart-2_0-gront-industriloft.pdf

Norwegian Wood Cluster (2024*). About the Norwegian Wood Cluster*. Retrieved 27.08.2024 from https://www.nwcluster.no/om-oss

Nørstebø, V. S., Wiebe, K. S., Andersen, T., Grytli, T., Johansen, U., Aponte, R. F., Perez-Valdes, G. A., & Jahren, S. (2020). *Studie av potensialet for verdiskaping og sysselsetting av sirkulærøkonomiske tiltak.Utvalgte tiltak og case.* SINTEF.

*OECD. (2017). *OECD Guidelines on Measuring the Quality of the Working Environment*. https://doi.org/doi:https://doi.org/10.1787/9789264278240-en

*OECD. (2019). *Regions in Industrial Transition*. https://doi.org/doi:https://doi.org/10.1787/c76ec2a1-en

*OECD (2022a). Main Science and Technology Indicators, Volume 2022 Issue 2. https://doi.org/10.1787/1cdcb031-en

*OECD (2022b). Measuring the attractiveness of regions. OECD Regional Development Papers No. 36. https://www.oecd-ilibrary.org/docserver/fbe44086-en.pdf?expires=1704203496&id=id&accname=guest&checksum=6BB180D30FB520F0E0AE9EF7AE6E2BF7

*OECD. (2023). *Gender equality at work.* https://www.oecd.org/stories/gender/gender-equality-and-work

OECD and AIAS. (2021). Institutional characteristics of trade unions, wage setting, state intervention and social pacts. OECD Publishing, Paris. Retrieved 20.12.2023 from https://www.oecd.org/employment/collective-bargaining-database-norway.pdf

Omann, I., & Spangenberg, J. (2002). Assessing Social Sustainability; the Social Dimension of Sustainability in a Socio-Economic Scenario, Sustainable Europe Research Institute SERI. Proceedings of the 7th Biennial Conference of the International Society for Ecological Economics, Sousse, 6-9 March 2002.

*Overland, I. (2016). Energy: The missing link in globalisation. *Energy Research & Social Science*, *14*, 122-130. https://doi.org/10.1016/j.erss.2016.01.009

*Paddle.com Market Limited. (2023). *Willingness to pay : What is WTP and how to increase it.* Retrieved 20.12.2023 from https://www.paddle.com/resources/willingness-to-pay

Partidario M.R., 2015. A strategic advocacy role in SEA for sustainability. Journal of Environmental Assessment Policy and Management (JEAPM), 17(1):1550015.

Partidario M.R., 2016. Using strategic thinking and critical decision factors to achieve sustainability. In: Gibson R.B. (ed.), chapter 10, Sustainability assessment: applications and opportunities. London (UK): Earthscan: 169–193.

Pavão, P. N. R., Couto, J. P. A., & Natário, M. M. S. (2019). A Tale of Different Realities: Innovation Capacity in the European Union Regions. In *The role of knowledge transfer in open innovation*. https://doi.org/DOI: 10.4018/978-1-5225-5849-1.ch013

PEFC. (2022). Norsk PEFC Skogstandard. Available at: https://cdn.pefc.org/pefc.no/media/2023-04/191010dd-81a3-41ec-9aeb-76a67effda24/b877f9c0-47fa-5a50-b9ab-b82536994907.pdf

PEFC. (2023). *Norsk PEFC Skogstandard*. Retrieved 21.12.2023 from https://pefc.no/vare-standarder/norsk-pefc-skog-standard

Platform on Sustainable Finance. (2022). *Final Report on Social Taxonomy*. Available at: https://finance.ec.europa.eu/system/files/2022-08/220228-sustainable-finance-platform-finance-report-social-taxonomy_en.pdf

Pyrotech energy PTY Ltd. (2020). Mobile Pyrolysis Plant. Retrieved 22.12.2023 from https://pyrotechenergy.com/pyrolysis-oil/

Refsgaard, K., Kull, M., Slätmo, E., & Meijer, M. W. (2021). Bioeconomy - A driver for regional development in the Nordic countries. *New Biotechnology*, *60*, 130-137. https://doi.org/10.1016/j.nbt.2020.10.001

*Reinales, D., Zambrana-Vasquez, D. & Saez-De-Guinoa, A. (2020). Social Life cycle Assessment of Product Value Chains Under a Circular Economy approach : A Case Study in the Plastics Packgaing Sector. Sustainability, 12 (16), 6671. **https://doi.org/10.3390/**su12166671

*Research Council of Norway. (2023a). Samarbeidsprosjekt for å møte samfunnsutfordringer i samfunn og næringsliv. Retrieved 20.12.2023 from https://www.forskningsradet.no/utlysninger/2023/samarbeidsprosjekt-samfunn-naeringsliv/#results

*Research Council of Norway. (2023b). Prosjektbanken. Retrieved 20.12.2023 from https://prosjektbanken.forskningsradet.no/en

Rice, C., Ragbir, N.K., Rice, S., Barcia, G., 2020. Willingness to pay for sustainable aviation depends on ticket price, greenhouse gas reductions and gender. Technol. Soc., 60(December 2019), 101224. DOI: 10.1016/j.techsoc.2019.101224

*Rocca, S., Agostini, A., Giuntoli, J., & Marelli, L. (2015). *Biofuels from algae: technology options, energy balance and GHG emissions*. P. O. o. t. E. Union.

*Rogers, M. (2001). Evolution: Diffusion of Innovations. In N. J. Smelser, Baltes., P.B. (Ed.), *International Encyclopedia of the Social & Behavioral Sciences.*: Pergamon.

Sandberg, E., Hatling, M. & Vik, L.H. (2020). Bioøkonomi i Innlandet – tiltak og virkemidler. https://sintef.brage.unit.no/sintef-xmlui/bitstream/handle/11250/2724318/Bio%25C3%25B8konomi%2bInnlandet%2b%2btiltak%2bog%2bvirkemidler.pdf?sequence=1&isAllowed=y

*Saravanan, A., Karishma, S., Kumar, P. S., & Rangasamy, G. (2023). A review on regeneration of biowaste into bio-products and bioenergy: Life cycle assessment and circular economy. *Fuel*, *338*, Article 127221. https://doi.org/10.1016/j.fuel.2022.127221

Seetaram, N., Song, H., Ye, S., Page, S., 2018. Estimating willingness to pay air passenger duty. Annals of Tourism Research, 72(October 2017), 85–97. DOI: 10.1016/j.annals.2018.07.001.

ShowVoc. (2023). *ESTAT_Statistical_Classification_of_Economic_Activities_in_the_European_Community_Rev._2.1._(NACE_2.1)*. https://doi.org/https://showvoc.op.europa.eu/#/datasets/ESTAT_Statistical_Classification_of_Economic_Activities_in_the_European_Community_Rev._2.1._%28NACE_2.1%29/data

Simonnæs, S.G., Aarbakke, A. & Nygård, L. (2023). Environmental, Social and Governance Law. Norway. Retrieved 20.12.2023 from https://iclg.com/practice-areas/environmental-social-and-governance-law/norway

Snep, R.PH., Voeten, J., Mol, G & Van Hattum, T. (2020). Nature Based Solutions for Urban Resilience: A Distinction Between No-Tech, Low-Tech and High-Tech Solutions. *Frontiers in Environmental Science, 8*. https://doi.org/10.3389/fenvs.2020.599060

Standard Norway. (2019). NS-EN ISO 14090 :2019. Klimatilpasning. Prinsipper, krav og retningslinjer (ISO 14090 :2019).

Standard Norway. (2021). NS-EN ISO 14091:2021. Klimatilpasning - Retningslinjer for sårbarhet, påvirkninger og risikovurdering (ISO 14091:2021).

Statista. (2023). *Gender pay gap of average gross hourly earnings in the European Union from 2010 to 2021*. Retrieved 22.12.2023 from https://www.statista.com/statistics/1203158/gender-pay-gap-in-europe/

Statistics for Innlandet. (2023). Accessed 28.08.2024 at https://www.innlandsstatistikk.no/

Statistics Norway. (2022). *Supply and Use and Input-Output tables. National Accounts*. https://doi.org/https://www.ssb.no/en/nasjonalregnskap-og-konjunkturer/metoder-og-dokumentasjon/supply-and-use-and-input-output-tables

Statistics Norway. (2023a). Agricultural and forestry properties, buildings and inhabitation (C) 2007 - 2022. In: Statistics Norway.

Statistics Norway. (2023b). Dwellings, by type of building and densely/sparsely populated areas (M) 2006 - 2023. In: Statistics Norway.

Statistics Norway. (2023c). Educational attainment, by county, age, sex and field of education. Two-part upper secondary school level (C) 2017 - 2022. In : Statistics Norway.

Statistics Norway. (2023d). Employed persons, by industry division (5 digit level, SIC2007). 4th quarter (M) 2008 - 2022. In: Statistics Norway.

Statistics Norway. (2023e). External trade in goods, by commodity group (three digit SITC) (NOK 1 000) 1988 - 2022. In : Statistics Norway.

Statistics Norway. (2023f). External trade in goods, by commodity number (HS) and country 1988 - 2022. In: Statistics Norway.

Statistics Norway. (2023g). Number of enterprises and amount of support, by county, type of aid and policy agency (C) 2017 - 2022. In: Statistics Norway.

Statistics Norway. (2023h). Research and development in the business enterprise sector. In : Statistics Norway.

*Statistics Norway. (2023i). *Value added.* Retrieved 11.12.2023 from https://www.ssb.no/a/metadata/conceptvariable/vardok/1744/en

*Statistics Norway. (2023j). *Employed persons.* Retrieved 20-.12.2023 from https://www.ssb.no/a/metadata/conceptvariable/vardok/1116/en

*Statistics *Norway*. (2023k). Research and development in the business enterprise sector. Retrieved 20.12.2023 from https://www.ssb.no/en/teknologi-og-innovasjon/forskning-og-innovasjon-i-naeringslivet/statistikk/forskning-og-utvikling-i-naeringslivet

*Statistics Norway. (2023l). Research and development in the higher education sector. Retrieved 20.12.2023 from https://www.ssb.no/en/teknologi-og-innovasjon/forskning-og-innovasjon-i-naeringslivet/statistikk/forskning-og-utvikling-i-universitets-og-hogskolesektoren

*Statistics Norway. (2023m). Research and development in the institute sector. Retrieved 20.12.2023 from https://www.ssb.no/en/teknologi-og-innovasjon/forskning-og-innovasjon-i-naeringslivet/statistikk/forskning-og-utvikling-i-instituttsektoren

*Statistics Norway.(2023n). Research and development in the business enterprise sector. Retrieved 20.12.2023 from https://www.ssb.no/en/statbank/table/11145/

Statistics Norway. (2023o). Fakta om likestilling. Retrieved 20.12.2023 from https://www.ssb.no/befolkning/faktaside/likestilling

Statistics Norway. (2023p). 12643: Number of enterprises and amount of support, by county, type of aid and policy agency (C) 2017 - 2022. Retrieved 22.12.2023 from https://www.ssb.no/en/statbank/table/12643/

Statistics Norway. (2023q). Research and development in the business enterprise sector. Retrieved 22.12.2023 from https://www.ssb.no/en/statbank/table/11145/

Statistics Norway (2024). Kvinner og realfag Gode skoleresultater – liten endring i yrkesvalg. SSB analyse 2020/02 (figures last updated 3. June, 2024). https://www.ssb.no/utdanning/artikler-og-publikasjoner/gode-skoleresultater-liten-endring-i-yrkesvalg

*Stobierski, T. (2020). Willingness to pay : what it is & how to calculate. *Harvard Business School Online.* Retrieved 19.12.2023 from https://online.hbs.edu/blog/post/willingness-to-pay

*Tang, R. and Beer, A. (2022). Regional innovation and the retention of foreign direct investment: a place-based approach. *Regional Studies 56* (10): 1757-1770. https://doi.org/10.1080/00343404.2021.2006173

The German Federal Government. (2019). 2019 Monitoring Report on the German Strategy for Adaptation to Climate Change. Report by Interministerail Working Group on Adaptation to Climate Change. Available at: https://www.umweltbundesamt.de/sites/default/files/medien/421/publikationen/das_2019_monitoring_report_bf.pdf

The Ministries' security and service organisation. (2023). Mer av alt – raskere. Energikommisjonens rapport. Available at: https://www.regjeringen.no/contentassets/5f15fcecae3143d1bf9cade7da6afe6e/no/pdfs/nou202320230003000dddpdfs.pdf

The Norwegian Tax Administration. (2023a). *Mineral product tax.* Retrieved 18.12.2023 from https://www.skatteetaten.no/en/business-and-organisation/vat-and-duties/excise-duties/about-the-excise-duties/mineral-product/

The Norwegian Tax Administration. (2023b). *Road tax on fuel.* Retrieved 18.12.2023 from https://www.skatteetaten.no/en/business-and-organisation/vat-and-duties/excise-duties/about-the-excise-duties/road-tax-on-fuel/

The Patent Board. Søk. Retrieved 22.12.2023 from https://search.patentstyret.no/advanced/#/

Throne-Holst, H. (1999). The role of the consumers in environmental successes. The Norwegian prohibition of phosphates in laundry detergents. The housewives' movement in the lake Mjøsa district. SIFO Work Report 1, 1999. https://oda.oslomet.no/oda-xmlui/bitstream/handle/20.500.12199/5261/file48385_arbeidsrapport_1-1999.pdf?sequence=1&isAllowed=y

TotAl Gruppen. (2023). *En aktiv industriklynge*. Retrieved 21.12.2023 from https://total-gruppen.no/om-total-gruppen-as/

Transparency International. (2023). Corruption perceptions index. Retrieved 20.12.2023 from https://www.transparency.org/en/cpi/2022/index/nor

Transport and Environment. (2023a). *2023 Renewable Energy Directive fact sheet. Biofuels.* https://www.transportenvironment.org/wp-content/uploads/2023/09/RED-III-Fact-sheet-biofuels-FINAL.pdf

Transport and Environment (2023b). The fat of the land. The impact of biofuel demand on the European market for rendered animal fats. https://www.transportenvironment.org/wp-content/uploads/2023/05/Cerulogy_Fat-of-the-land_May_23.pdf

Transport and Environment (2024). *How EU states can tackle unsustainable biofuels and promote cleaner alternatives?* Briefing. September 2, 2024. https://www.transportenvironment.org/articles/how-eu-states-can-tackle-unsustainable-biofuels-and-promote-cleaner-alternatives

UNEP-SETAC. (2009). *Guidelines for social life cycle assessment of products*. Retrieved 21.09.2021 from https://wedocs.unep.org/bitstream/handle/20.500.11822/7912/-Guidelines%20for%20Social%20Life%20Cycle%20Assessment%20of%20Products-20094102.pdf?sequence=3&amp%3BisAllowed=

UNEP. (2020). *Guidelines for Social Life Cycle Assessment of Products and Organisations 2020.*

*UNEP. (2021). *Methodological Sheets for Subcategories in Social Life Cycle Assessment (S-LCA ) 2021.* https://www.lifecycleinitiative.org/wp-content/uploads/2021/12/Methodological-Sheets_2021_final.pdf

Valente, C., Brekke, A., & Modahl, I. S. (2018). Testing environmental and social indicators for biorefineries: bioethanol and biochemical production. *International Journal of Life Cycle Assessment*, *23*(3), 581-596. https://doi.org/10.1007/s11367-017-1331-x

Wang, Z., Kamali, F.P., Osseweijer, P. & Posada, J.A. (2019). Socio-economic effects of aviation biofuel production in Brazil: a scenarios-based input-output analysis. *J. Cleaner Prod., 230*, pp. 1036-1050, 10.1016/j.jclepro.2019.05.145

Wiebe, K. S., Norstebø, V. S., Aponte, F. R., Simas, M. S., Andersen, T., & Perez-Valdes, G. A. (2023). Circular Economy and the triple bottom line in Norway. *Circ.Econ.Sust.*, *3*, 1-33. https://doi.org/https://doi.org/10.1007/s43615-021-00138-6

*World Bank. (2023). *What is food security?* Retrieved 1.12.2023 from https://www.worldbank.org/en/topic/agriculture/brief/food-security-update/what-is-food-security

Xu, B., Ahmad, S., Charles, V. &Xuan, J. (2022). Sustainable commervcial aviation : What determines air trevellers' willingness to pay more for sustainable aviation fuel ? Journal of Cleaner Production, 374, 133990. https://doi.org/10.1016/j.jclepro.2022.133990

*Xu, H., Willink, J., Yue, Z., Zhang, H. & Pang, H. (2021). Multidimensional Scientometric indicators for the detection of emerging research topics. *Technological Forecasting and Social Change, 163.* https://doi.org/10.1016/j.techfore.2020.120490

Young, E. E. C. S. D., Bjelle, E. L., Gaspers, A., Lindberg, H. Ø., Pille, K., Jürmann, P., Kukumägi, K., & Sapelkov, K. (2023). *Impact analysis for a potential circular economy strategy for the plastic sector in Estonia*.

*Zhang, J., Wang, T., Chang, Y. & Liu, B. (2023). A sustainable development pattern integrating data centers and pasture-based agrivoltaic systems for ecologically fragile areas. *Resources, Conservation and Recycling, 188.* https://doi.org/10.1016/j.resconrec.2022.106684

*Zhang, Q., Vonderembse, M.A. & Lim, J.-S. (2010). Value chain flexibility : A dichotomy of competence and capability. International Journal of Production Research, 40 (3), 561-583. DOI: 10.1080/00207540110091695

# Annex 1: Description of impact categories

**Annex 1: Description of impact categories**

In this section, we define each of the main impact categories and the associated criteria/sub-categories related to each stakeholder category, with reference to source literature and the scope of the present assessment. The related indicators are further described in Annex 2: Indicator factsheets.

1. **Impact categories – value chain**

**Main impact category: Competence**

Competence can be defined as the organisational, repeatable, and learning-based ability to sustain the coordinated deployment of assets and resources enabling a firm to reach and defend its competitiveness (Freiling, 2004: 30). The concept encompasses e.g., skills, as learned abilities or talents that enable the effective accomplishment of a specific task; capabilities, as the blends of personal and technical skills, knowledge, and behaviours that allow an individual or organisation to perform effectively; and competency, which refers to the practical application of a person's skills and knowledge in a work setting.

Competence is associated with value chain flexibility (Zhang et al., 2010), and previous research on regional economic development highlights the importance of knowledge capabilities, as they affect the spatial distribution of knowledge development possibilities, qualities, and utilisation. With strengthened knowledge capabilities, a region has a greater opportunity of producing new firms and valuable products and processes, which in turn may improve local conditions for innovation and new employment (Lau and Lo 2015).

Subcategory: Skill mix

Skill mix is the combination or grouping of different categories of workers employed in any field of work. Skills have been regarded as fundamental drivers of productivity and economic growth (Corradini et al., 2023). Still, despite policy efforts supporting ever-higher levels of education, advanced economies remain characterised by significant and persistent skills shortages, gaps and mismatches that hamper productivity and growth (Guvenen et al., 2020). These issues have a marked spatial dimension, and lack of appropriately skilled workers is increasingly identified as a prominent barrier faced by regions in industrial transitions (OECD, 2019). As noted above (section 3.3), the level of education and skills is a matter of concern in Innlandet, hence this subcategory seems particularly relevant.

The subcategory is associated with the indicator ***Job requirements by qualification*** (ID V1, Annex 2, p. 100).

**Main impact category: Competitiveness**

In a competitive market, several companies provide similar goods or services. A competitive economy is an economy whose sustained rate of productivity can drive innovation, growth and, consequently, income and welfare (EUR-Lex., 2023). Competitiveness is closely related to sustainability in that you can compare the production costs of fuels at different levels of sustainability (Neverauskiene et al., 2020). Competitiveness of biofuels means cost effectiveness - the ability of biofuels to compete with the production costs of other fuels (Mizik & Gyarmati, 2021). Baudry et al. (2017) consider competitiveness as an important aspect of the sustainability of biofuels and point out that this aspect was among the highest concerns for most of the stakeholders in their study. While Baudry et al. (2017) defined competitiveness as an economic indicator, we include it as a main impact category for this assessment, as it is crucial for value creation and employment, and associated with further opportunities for further innovation and uptake of sustainable products.

Subcategory: Potential adopters

The number and type of adopters reflects the diffusion of an innovation (Rogers, 2001), hence also for the competitiveness of the EBIO technology in terms of innovation uptake and upscaling. The adopters of an innovation can be classified into five categories, based on innovativeness (the degree to which they are earlier than others in adopting the new solution): innovators (the first to adopt), early adopters, early majority, late majority, and laggards (ibid.). Identifying potential adopters is, therefore, necessary to understand the conditions for the diffusion of the innovative technology at stake.

The indicator selected for this subcategory is ***The number of existing enterprises that may adopt the technology*** (ID V2, Annex 2, p.100)).

Subcategory: Substitution of non-sustainable products

Biofuels are produced mainly to substitute for fossil fuels, as more sustainable and eco-friendly alternatives. However, their sustainability depends on the production methods, low cost-technology implementation, and the substrate used as input (Correa et al., 2019). The end-product from applying the EBIO technology may also substitute biofuels made from biomass resources that have a larger ecological, environmental or climate footprint (Cabrera-Jiménez et al., 2022). Substitution of non-sustainable products is selected as sub-category to indicate the potential for sustainable growth as a result of this substitution.

The indicator selected for this subcategory is ***The types and volume of non-sustainable products on the market that the end-product can replace*** (ID V3, Annex 2, p.101).

Subcategory: Incentives for early providers (production side)

Incentives for early providers indicates the maturity of the market, and potential for future competitiveness. The incentive arrangements such as subsidies or tax deduction for producers (Bilan et al., 2022) will normally be active in a short-term period, until the market appears more mature. IEA provides an overview of current policies for incentivizing biofuel supply in different countries (IEA, 2023).

The indicator selected for this subcategory is ***The extent to which biofuel production is incentivised*** (ID V4, Annex 2, p.102).

**Main impact category: Governance**

Value chain governance refers to the relationships among the producers, buyers, sellers, service providers and regulators that operate within or influence the range of activities required to bring a product or service from inception to its end use (Humphrey & Schmitz, 2004). Value chain governance is one of the main impact categories in the Guidelines for S-LCA (UNEP, 2020), where it is associated with the subcategories fair competition, corporate social responsibility, supplier relationships, respect for intellectual property, and wealth distribution. In the guidelines, transparency is associated with customers as a stakeholder category, rather than with the value chain. However, the Code of Best Practice of Governance (IBGC, 2010) promoted by the OECD emphasises the pillars transparency, accountability, and fairness, which also are among the 12 principles of good governance defined by the Council of Europe (2023). Moreover, transparency is important for other stakeholders, including public decisionmakers and local communities, as well customers, and should be an objective for the value chain actors. We therefore include it as a subcategory here, together with traceability.

Subcategory: Transparency

Transparency denotes the extent to which outsiders can observe the actions of the value chain actors. This is a consequence of business policies concerning corporate decision-making and operations openness to employees, shareholders, and other stakeholders, as well as regulations and local norms. From an outsider perspective, transparency can be defined as the perceived quality of intentionally shared information from the corporation. Thus, sufficient transparency enables an informed choice for the consumer, and concerns information regarding social responsibility, as documented in the form of standards or labels (UNEP, 2021). Groiß-Fürtner et al. (2023) assessed the "existence of public sustainability reporting" and the "availability of public documents on agreements to sustainability issues" to address transparency. Transparency is also considered as an important subcategory for biobased products by Ekener et al. (2018), who relate it to the presence of clear sustainability reports, labels, and certification highlighting the (over)compliance with existing regulations.

In this assessment, we link it with the indicator ***The extent to which strategic plans, annual reports, etc. from the involved enterprises are publicly available*** (ID V5, Annex 2, p.102).

Sub-category: Traceability

Traceability refers to the availability of information about the quality and processing of the biomass, starting from its origin and source, and is considered as a necessary precondition for sustainable production of biomass used for various purposes, including generation of renewable energy (Bosona et al., 2018). Previous studies on the sustainability and acceptability of biofuels for aviation and road transport have looked at the transparency of the production pathway from feedstock to the final product (Ahmad et al., 2021; Lanzini et al., 2016). According to Bosona et al. (2018), designing a good traceability system can guarantee final users that the product complies with the necessary quality requirements. Traceability has been related to different stakeholder groups, e.g., Ahmad et al. (2021)

place it under society, and Falcone et al. (2019) relate it mainly to users. In this assessment we consider traceability in relation to the transparency of the production pathway from the feedstock to the final product, in line with Ahmad et al. (2021). However, in accordance with the Guidelines on S-LCA (UNEP-SETAC, 2009), we place it under the impact categories for the value chain.

The indicator selected for this subcategory is ***The extent to which the origin of the input factors can be traced and managed*** (ID V6, Annex 2, p.102).

2. **Impact categories – workers**

**Main impact category: Health and safety**

Human health is included as an area of protection in both environmental and S-LCA, linked to the intrinsic value of human life, as well as economic value. However, it has been noted that S-LCA should embrace a broader understanding of human life, encompassing the value of a good and decent life. At least three important aspects are identified: 'human health', to live a healthy and naturally long life; 'human dignity', to live a decent life and enjoy respect and social membership; and 'basic needs fulfilment' (Dreyer et al., 2006). As described by Valente et al. (2018), occupational health should aim for the highest degree of physical, mental, and social well-being of workers in all occupations; the prevention of departures from health caused by working conditions, and the protection of workers from risks resulting from factors adverse to health.

Subcategory: Health and safety of workers

This subcategory is recommended in the Guidelines for S-LCA (UNEP-SETAC, 2009) and widely applied. We define this subcategory in line with the Guidelines on Measuring the Quality of the Working Environment (OECD, 2017), which relies mainly on the job demands-resources model, considering the physical and social environments of work to include physical risk factors and physical demands (i.e. job demands) and social support at work (i.e. job resources).

As regards health and safety, ***The percentage of workers that are exposed to gas, dust and steam most of the time*** (ID W1, Annex 2, p.5), ***The percentage of workers that are exposed to skin-irritating substances most of the time*** (ID W2, Annex 2, p.5), and ***The percentage of workers that have a high risk of accidents at work*** (ID W3, Annex 2, p.6 ) are selected as indicators. This is in line with Brinkman et al. (2019), who apply the number of work-related accidents and health issues as an indicator, and with Valente et al. (2018), who include similar indicators with slightly different wording.

**Main impact category: Human rights**

Besides human wellbeing, one of the primary goals of S-LCA is the protection of human rights (Dreyer et al., 2010). Human rights, according to the Universal Declaration of Human Rights (UDHR) are rights we have simply because we exist as human beings, regardless of nationality, sex, national or ethnic origin, religion, language, political conviction, or any other status. They range from the most fundamental - the right to life - to the rights to food, education, work, health, and liberty. Under the impact category human rights, our framework includes gender equality at work as the most relevant subcategory.

Subcategory: Gender equality at work

Article 2 of the UDHR states the right to Freedom from discrimination, that is, that everyone can claim their rights regardless of sex, race, language, religion, social standing, etc. Still, women are at disadvantage in labour markets: Cumulative differences in employment rates, participation in part-time work, compensation and work quality result in substantial gender gaps in earnings and career advancement, in turn leading to lower lifetime earnings and a greater risk of old-age poverty for women (OECD, 2023). The gender wage gap, on average 11.9% across the OECD, is a key issue (ibid.)

Against this background, two indicators are selected for this subcategory: a) ***The male/female wage ratio*** (ID W4, Annex 2, p.6) and b) ***The male/female employment ratio*** *for each part of the value chain, compared to those for the economy (Norway) as a whole* (ID W5, Annex 2, p.105).

**Main impact category: Labour rights and decent work**

The right to work and enjoy just and favourable working conditions, and the right to join trade unions are well-established, e.g., by the United Nations Guiding Principles on Business and Human Rights, and the Organisation for Economic Cooperation and Development Guidelines for Multinational Enterprises (Bueno, 2017). Apart from being central in the guidelines on S-LCA (UNEP, 2020), labour rights is one of the four criteria set for the social sustainability of the bio-based part of bio-based products by the European Committee for Standardisation (CEN, 2016). We therefore include it as a main impact category, linked with fair wages, unionisation, and the notion of decent work, which emphasises the need to respect the physical and mental integrity of workers in their exercise of their employment.

Subcategory: Fair wages

Proper compensation for work is required, as a crucial dimension of job quality and labour rights. "Fair salary" can be taken to refer to the value of a service being reflected in the wage received (UNEP, 2021). Compensating differentials are considered as a key dimension of job quality, e.g., in the EU. Income and wages—but not necessarily if they are fair or not— is a commonly used subcategory in SIA of biobased value chains (Marting Vidaurre et al., 2020). Valente et al. (2018) emphasise that wages paid for a normal working week should meet at least the minimum wage, established either by law, collective bargaining agreement or an industry standard. Ekener et al. (2018) and Kamali et al. (2018) include (non) fair salary as a subcategory, without discussing specific indicators, while Brinkman et al. (2019) applies wage levels at bioenergy company, compared to minimum or median wage, as an indicator under 'employment and income'. For our case study related to Innlandet, comparison to minimum wage is a suitable indicator, which stakeholders easily can relate to. In cases where a comparative assessment is to be made, between solutions and value chains located in or cutting across different countries, it will be important to relate the wage data to purchasing power in the respective countries. This can be done by translating the nominal wages to real wages, i.e. applying the equation real wage = nominal wage x 100/consumer price index.

Selected indicator: ***Wages for each part of the value chain compared to minimum wage*** (ID W6, Annex 2, p.105).

Subcategory: Unionisation

Workers' right to organise in trade unions and participate actively in corporate governance is crucial to ensure good working conditions. It is also important when it comes to social dialogue, e.g., regarding how to understand and balance economic, environmental, and social sustainability objectives (European Commission, 2019). High trade union density and collective bargaining coverage tend to coincide with higher investment in social welfare, and transitions at various levels tend to be managed better if discussed and agreed between business managers, public decision-makers and trade unions, as social partners (ibid.).

Related indicator: ***The share of workers organised in trade unions*** (ID W7, Annex 2, p.106).

Subcategory: Meaningful work

Among the job demands recognised in literature, job content refers to the lack of variety or short work cycles, under-use of skills, fragmented or meaningless work, high uncertainty, and frequent contact with the public. The emotional burdens this imposes on workers constitutes a job demand that may significantly reduce workers' well-being. Job resources, on the other hand, include aspects of the working environment such as skill variety, decision latitude (autonomy), opportunities to learn, and social support, which tend to be associated with rewards and increased well-being at work. Thus, e.g., Brinkman et al. (2019), link training and/or education provided to employees to the impact category Equal opportunities. Opportunities to learn and requirements to acquire new knowledge and skills are included as indicators in OECD's Guidelines on Measuring the Quality of the Working Environment, as well as in national statistics for Norway and many other countries, hence generic data are available.

For this subcategory, two indicators have therefore been selected: ***The percentage of workers that are required to often or always work at a high pace*** (ID W8, Annex 2, p.8), and ***The percentage of workers that will often or always be required to acquire new knowledge and skills*** (ID W9, Annex 2, p.107).

3. **Impact categories – users**

**Main impact category: Social acceptability**

Social acceptability can be defined as the general public's perception of the production and use of the end-product. This subcategory is used by, among others, Ahmad et al. (2021) in their multicriteria assessment of sustainable aviation fuels production pathways, and Gegg and Wells (2017) in their study on macro-algae biofuels. Its relevance is also noted by Falcone et al. (2019), who found that social acceptability was deemed relevant by all respondents and recognised by two out of three as "very important" for the social assessment of bio-based products. While Falcone et al. (2018) linked consumer social acceptability to the indicators feedback mechanisms for consumers, transparency, and end-of-life responsibility, Falcone et al. (2019) linked social acceptability to the perceived benefits of the product, public commitment to sustainability issues, community engagement, and land use. For this assessment, we have selected Fulfilment of formal sustainability criteria as a subcategory linked to socio-political acceptance, and Willingness to pay as a subcategory related to market acceptance and the value end-users ascribe to the product(s).

Subcategory: Fulfilment of formal sustainability criteria

The biofuel as end-product must meet European criteria for sustainability of energy, as laid down in the revised Renewable Energy Directive (RED III). This entails that the reduction of greenhouse gas emissions over the entire chain, from raw material production to final use, must be at least 65%, when compared to fossil fuels, and the feedstock must not be associated with indirect land use change (ILUC). Furthermore, the criteria specified in the Delegated Regulation (EU) 2019/807, for determining high ILUC-risk feedstock, and for certifying low ILUC-risk biofuels, must be considered. As noted in RED III, the bioenergy sustainability criteria will be further strengthened, and woody biomass will have to be used according to its highest economic and environmental added value (so-called cascading use). The performance of the solution in relation to these criteria, e.g., degree of compliance and progress beyond compliance will be crucial for the uptake of the solution and its long-term contribution to society.

The indicator defined for this subcategory is ***The extent to which the end-product meets sustainability criteria laid down in formal regulations*** (ID U1, Annex 2, p.108).

Subcategory: Willingness to pay

Willingness to pay (WtP) is the maximum price that a customer is willing to pay for a product or service. WtP is often influenced by the consumption or non-consumption of others, and varies depending on the context, different demographics, the specific customer in question, and can fluctuate over time. The WtP can also be non-observable (Stobierski, 2020). As a result, WtP is usually represented as a price range, rather than a single currency figure. WtP can reflect market demand and can also drive product development (Paddle.com Market Limited, 2023). WtP has been chosen here, to distinguish between WtP for an environmentally friendly fuel compared to conventional fuels (Jåstad, 2020).

Related indicator: ***The maximum price consumers are willing to pay for one unit of the end-product*** (ID U2, Annex 2, p. 109).

**Main category: Usability**

The Guidelines on S-LCA (UNEP-SETAC, 2009) do not include usability as an impact category; however they suggest that this aspect should be considered in future S-LCA studies, and that the selection of impact subcategories must be tailored to the solution and system being assessed. The reviewed literature on social impact and sustainability assessment of bio-based products has also paid limited attention to the usability. Ekener et al. (2018) propose "user value" as an impact category, but do not define it in precise terms. Still, as usability and sustainability often are closely linked (see e.g., Anjos et al., 2012), usability is included as a main impact category in our assessment. At a general level, usability can be understood as "the fact of something being easy to use, or the degree to which it is easy to use," (Cambridge Dictionary, 2023). In research on technology implementation and use, the term relates to the degree to which a solution may be used by specified consumers to achieve specified objectives with effectiveness, efficiency, and satisfaction in their context of use (ISO 9241-11). This is also how we understand it here.

<u>Subcategory: Ease of use</u>

In research on biofuels, usability is linked very closely with the technical properties of different types of biomass and products, and how these can be enhanced, e.g., through different blending processes (Kabir et al., 2019; Jagtap et al., 2020). Here, we focus on the socio-technical aspects, that is, how the fit with existing systems and practices can enable or limit the uptake of the solution, whether time and resource-demanding modifications are needed, and how the level of convenience for users may decrease or increase. When it comes to advanced biofuels for transport, fit with existing equipment and practices can be an advantage in comparison with other alternative fuels, such as hydrogen and ammonia. At the same time, there are different requirements and limitations for different applications. Examples from shipping show that blending in different types of biofuels up to a certain percentage does not require engine modifications, but higher percentages could lead to technical challenges (Norwegian Environment Agency, 2018).

Selected indicator: ***The extent to which the end-user needs to modify user equipment or practices*** (ID U3, Annex 2, p.109).

**<u>Main category: Availability</u>**

The Guidelines on S-LCA (UNEP-SETAC, 2009) do not include availability as a main impact category. However, in the case of the technologies under development as the technology in the scope of this assessment, availability can, indeed, have positive or negative impact. By availability we mean not only that end-product is existing, but the extent to which it is within reach for the target users, in terms of e.g., proximity or affordability, that is, availability conditioned by the related infrastructure, distribution, prices and incentives.

<u>Subcategory: Incentives for end users</u>

As a subcategory of availability, Incentives for use of the end-product is included in this assessment. Such incentives can exist in form of subsidies for users (e.g., differentiated taxes (Bilan et al., 2022). IEA provides a list of policies for incentivising biofuel consumption in different countries.

Selected indicator: ***The extent to which the use of the end-product is incentivised*** (ID U4, Annex 2, p.109).

4. **Impact categories – local community/region**

**<u>Main impact category: Contribution to local economy</u>**

Actions that can contribute to the local economy can be made by local businesses, their employees, residents and local organisations, or in collaboration between different local stakeholder groups.

Examples of contributions can be provision of new products and services, developed skills, employment, opportunities for volunteering and grant funding. Smaller communities may have greater opportunities to achieve social connectedness across stakeholder groups. Contribution to economy has been pointed out as an important sustainability performance criterion (Ahmad et al., 2021), and connecting sustainability performance to the local level of value creation allows to identify regions suitable for sustainable development (Zhang et al., 2023).

Subcategory: Value creation

Brinkman et al. (2019) use gross value-added as an indicator for their impact category Rural economic development. It can be used for a higher value utilisation of biomass resources (value-added production (Ferreira et al., 2023; Saravanan et al., 2023). Values added and gross income generated from domestic production in an industry or sector (or in total for all industries/sectors), derived and defined as output less intermediate consumption. Value added is published in basic prices, i.e. subsidies on products are included, whereas VAT and other taxes on products are not (Statistics Norway, 2023i).

Indicator: ***The expected gross product of the economic activity related to implementation of the solution*** (ID L1, Annex 2, p.111).

**Main impact category: Quality of life**

Sustainability is related to the quality of life in a population or community – whether the economic, social, and environmental systems that make up the community are providing a healthy, productive, meaningful present and future life for all community residents. In general, quality of life is related to changes in society or a social system from a level of dissatisfaction to a level of satisfaction. Moreover, it has been argued that interaction in personal values, life conditions and life satisfaction will determine quality of life (Felce and Perry, 1995). Key dimensions of quality of life have thus been identified as physical, material, social wellbeing, psychological and religious wellbeing, and development and activity (ibid.).

Subcategory: Employment

A recent review of research on the social aspects of biobased value chains (Marting Vidaurre et al., 2020) found that job creation was the most often assessed aspect, addressed mainly for the cultivation stage of forest biomass and sugarcane, and in conversion plants. The impact on employment may be either direct and/or indirect. New positions may be established in response to the new technology, and implementing the technology may impact the rate of employment with the suppliers (Reinales et al., 2020). Kamali et al. (2018) in their review find that employment and jobs indeed are an important social issue that is necessary to take into consideration. Employed persons are persons performing at least one hour of income-producing work during the week or day referred to, as well as persons who have this sort of work, but who were temporarily absent due to sickness, vacation, paid leave, etc. Persons in the civil service and conscripts are considered employed persons. Involuntary laid off persons, with a continuous duration of up to three months, are defined as employed and temporarily absent (Statistics Norway, 2023j). Previous studies have used unemployment percentage in a country and in a sector (Valente et al., 2018), and number of local jobs created in relation to final product energy unit (Ekener et al., 2018) as indicators.

For the present assessment, we use ***The expected number of new employees resulting from implementation of the solution*** (ID L2, Annex 2, p.111) as indicator for this subcategory.

Subcategory: Bequest value

Bequest value is understood as the value seen in ensuring the availability of biodiversity and ecosystem functioning to future generations. Bequest value is closely linked with existence value, referring to a sense of wellbeing, from simply knowing that ecosystems are conserved (or environmental challenges are reduced). Potential impacts along these lines cannot be measured exactly but may be rated ordinally through stakeholder perceptions of the solution's impact on the local community, linked to the level of awareness and previous engagement with environmental challenges.

Selected indicator: ***The level of satisfaction from preserving the natural environment for future generations*** (ID L3, Annex 2, p.112).

**Main impact category: Innovation capacity**

Innovation capacity relates to the ability of innovation networks to exploit existing resources, and to create a sustainable competitive advantage by driving innovation activities in a constantly changing environment (Pavão et al., 2019). Local development, in terms of measures undertaken to address local development, is one of the four main criteria emphasised by the European Committee for Standardisation (CEN, 2016).

Subcategory: Contribution to innovation clusters

Clusters can contribute to knowledge transfer and exchange among their members (Bathelt et al., 2004; Dayasindhu, 2002), and thus help create enabling conditions and contribute to spreading the knowledge about the innovative technology at stake, increasing the possibilities for its further uptake, and the potential for development of synergies with other sustainable innovation processes, for example leading to local utilisation of the by-products from the biofuel production.

To assess social impact in this subcategory, ***The number of existing clusters expected to benefit from the initiative*** is used as an indicator (ID L4, Annex 2, p.112).

Subcategory: Research and development activities

At an overarching level, innovation and technology can be assessed in terms of gross domestic spending on R&D, defined as the total expenditure (current and capital) on R&D carried out by all resident companies, research institutes, university and government laboratories, etc., in a country or region (OECD, 2022a). To identify recent or ongoing relevant research activities in a specific field, a common method is screening patents and publications (Xu et al., 2021). Some research and development activity are also traceable through the owners of relevant support schemes, such as in our case, Innovation Norway (Research Council of Norway, 2023b) and the national Research Council (Research Council of Norway, 2023a).

Statistics for innovation Norway's support schemes are sorted by county and type of support. Research and development activity per industry type in the private sector (Statistics Norway, 2023k), in the higher education sector (Statistics Norway, 2023l), in the institute sector (Statistics Norway, 2023m) and at county level (Statistics Norway, 2023n) is also available. The project bank of the national Research Council provides information on project owners, but not all project partners.

Selected indicator: ***The number of R&D activities initiated in connection with the solution*** (ID L5, Annex 2, p.113).

**Main impact category: Regional attractiveness**

Regions and sub-national governments are increasingly challenged by globalisation and looking to capitalise on their assets and opportunities through inclusive and sustainable development. Under this lens, it is increasingly recognised that economic development and human and planetary well-being are inextricably linked. The concept of regional attractiveness, accordingly, addresses the assets and potential challenges a region has, in terms of strengthening its attractiveness towards investors, talent and visitors.

Subcategory: Regional attractiveness

OECD (2022b) proposes a multi-dimensional approach for assessment of regional attractiveness: the regional attractiveness compass. The approach considers global engagement beyond international connections and financial drivers alone. In total, the methodology considers multiple indicators across 6 domains (economic attraction, connectedness, visitor appeal, natural environment, resident well-being, land use and housing), where economic attraction seems most relevant for EBIO. This can be assessed in multiple ways, e.g., by intellectual property rights or patent applications per number of inhabitants, given that intellectual property is a key determinant of a region's innovation ecosystem that may both attract and retain foreign investment at the subnational level (Tang and Beer, 2022). When potential and not actual impacts are considered, stakeholder consultation may be a suitable alternative.

Selected indicators: ***The extent to which implementation of the solution can contribute towards realisation of regional development strategies*** (ID L6, Annex1, p.15), and ***The extent to which implementation of the solution can influence the economic attractiveness of the region*** (ID L7, Annex 2, p.114).

5. **Impact categories – society**

**Main impact category: Energy security**

Energy security can be defined as the uninterrupted availability of energy sources at an affordable price (IEA, 2023). It is also related to the association between national security and the availability of natural resources for energy consumption, which is unevenly distributed among countries. Access to energy is crucial in supporting the provision of basic needs – such as food, lighting, water, and essential health care, and at the same time a precondition for economic growth, political stability and prosperity. While international energy relations have contributed to globalisation and increased energy security, it has also created energy vulnerability (Overland, 2016).

Brinkman et al. (2019) include energy independence, related to change in fossil fuel imports, and diversification of the energy mix, as social sustainability indicators. They also consider energy access as an impact category, with bioenergy to expand access to modern energy services, and share of population that has increased access to energy, as indicators. Kamali et al. (2018) propose energy import dependency; final energy consumption per capita; total primary energy supply per capita, as possible indicators for biofuels.

Subcategory: Contribution to the share of primary energy consumption from renewable sources

Renewable energy is expected to play an important role in the further development of Norway (Energy Norway, 2021). In the national Climate Plan (Norwegian Ministry of Climate and Environment, 2021), it is clearly pointed out that use of sustainable biofuels (together with other renewable energy alternatives) is necessary to consider for the reduction of $CO_2$ emissions. Advanced biofuels, therefore, are expected to play a more important role in the future Norwegian energy mix. We therefore include this subcategory, related to the share of primary energy consumption from renewable sources, as a much-used indicator of sustainable energy transition. Energy consumption represents the sum of electricity, transport, and heating.

Selected indicator: ***The extent to which implementation of the solution will contribute to the share of primary energy consumption from renewable sources*** (ID S1, Annex 2, p.115).

Subcategory: Contribution to secure energy supply in the transport sector

Secure energy supply is an inalienable part of the energy security. While the transport sector is a user of the biofuels produced through the implementation of EBIO technology and, therefore, can be considered as relating to users, the broader category relates to the whole society, as disruption of energy supply in one sector will cause consequences for other parts of the society. Under secure energy supply, we understand the ability of the EBIO technology to contribute to meeting the demands of the transport sector and its potential to reduce the dependency on imported biofuels.

Impact in this subcategory is indicated by **The extent to which implementation of the solution can contribute to securing supply of biofuel** (ID S2, Annex 2, p.115).

**Main impact category: Food security**

A widely used definition of food security was adopted in 1996, by the World Food Summit statement that "food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (quoted by World Bank, 2023), where food security comprises four dimensions; physical availability of food, economic and physical access to food, food utilisation, and stability of the previous three dimensions over time (World Bank, 2023). While the Guidelines for S-LCA do not address food security specifically, several studies on sustainability and social impacts of bio-based products present food security as an important impact category or sustainability aspect (Ahmad et al., 2021; Baudry et al., 2017; Ekener et al., 2018; Falcone et al., 2018).

Subcategory: Use of arable land

In this category, use of arable land was identified as a relevant impact subcategory. We follow the definition of "arable land" as "land worked (ploughed or tilled) regularly, generally under a system of crop rotation" (Eurostat, 2023). Previous studies of biobased products have included Impact of feedstock used for SAF production on food security (Ahmad et al., 2021), and loss of natural resources and grazing land as indicators (Brinkman et al., 2019) as a criterion related to food security (Ahmad et al., 2021). The European Committee for Standardisation (CEN) includes land use rights and land use change (including indicators related to food security) as one out of four key dimensions of the social sustainability of bio-based products (Falcone et al., 2018).

The indicator associated with this subcategory is the ***Territory of arable land needed to produce the annual need of feedstock*** (ID S3, Annex 2, p.116).

**Main impact category: Contribution to sustainability transition**

A sustainability transition can be defined as a long-term, multi-dimensional transformation process, through which socio-technical systems shift towards more sustainable production and consumption methods (Markard et al., 2012). As climate change and environmental degradation are an existential threat, countries around the world are developing new growth strategies, to transform into modern, climate-friendly, resource-efficient, and competitive economies, e.g., the EU has established the European Green Deal. The contribution to such transformation (or lack thereof) may thus be considered as a relevant category of social impacts, especially when we consider alternative fuels and their potential role in sustainable energy transition.

As decarbonisation and circular economy are two of the main components in e.g., the Green Deal, we associate the main impact category Contribution to sustainability transition with one subcategory related to each of these transformative processes. Since our focus is on potential contributions to this targeted societal change, we do not aim to address environmental sustainability as such, or include other aspects of environmental sustainability (e.g., toxicity, eutrophication, or other factors influencing biodiversity) in this category. In EBIO, environmental sustainability is assessed in detail as part of another task, on environmental LCA.

Subcategory: Alignment with national decarbonisation policies

By alignment with national decarbonisation policies, we mean the extent to which the solution is included in the suite of measures designed to enable decarbonisation in the case country and will contribute towards realisation of the country’s stated decarbonisation targets.

This subcategory is addressed via the indicator ***The extent to which implementation of the solution is aligned with national policies for decarbonising the transport sector*** (ID S4, Annex 1, p.18), and ***The amount of GHG emissions the implementation of the solution can contribute to reduce*** (ID S5, Annex 2, p.117).

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Subcategory: Contribution towards circularity

This subcategory refers to the contribution towards circular economy. While circular economy can embrace several strategies, the main principles behind are creating value by extending the life cycle of products and reducing waste to a minimum. For the technology at stake, contribution to circular economy in this assessment is mostly associated with waste reduction, as value creation is covered through other impact categories.

Therefore, in this subcategory one, main indicator, namely ***The amount of waste the implementation of the solution can contribute to reduce*** (ID S6, Annex 2, p.117).

# Annex 2: Indicator factsheets

| | |
|---|---|
| ***Indicator ID*** | *V1* |
| ***Title*** | *Job requirements by qualification* |
| ***Value*** | |
| ***Impact category*** | *Competence* |
| ***Sub-category*** | *Skill mix* |
| ***Scale/unit*** | *% per skill* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *P (positive)* |
| ***Stakeholder category*** | *Value chain* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *Education level per region (Statistics Norway)* |
| ***Description*** | *Skills may be a fundamental driver of productivity and economic growth* |
| ***References*** | |
| ***Comment*** | *The categorisation of skills will be made in cooperation with the stakeholders* |

| | |
|---|---|
| ***Indicator ID*** | *V2* |
| ***Title*** | *The number of enterprises that may adopt the process technology* |
| ***Value*** | |
| ***Impact category*** | *Competitiveness* |
| ***Sub-category*** | *Potential adopters* |
| ***Scale/unit*** | *# (number)* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *P* |

| | |
|---|---|
| ***Stakeholder category*** | *Value chain* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *Extract companies from the national Register of Business Enterprises (in Norway; the Brønnøysund register centre) with the relevant industry categorisation code* |
| ***Description*** | *Indicator for the potential of the EBIO technology uptake* |
| ***References*** | *https://forvalt.no and https://www.ssb.no/en/klass/klassifikasjoner/6* |
| ***Comment*** | *Identify the right industry category. Be aware that companies may be registered under the wrong code.* |

| | |
|---|---|
| ***Indicator ID*** | *V3* |
| ***Title*** | *The types and volume of non-sustainable products on the market that the end-product can replace* |
| ***Value*** | |
| ***Impact category*** | *Competitiveness* |
| ***Sub-category*** | *Substitution of non-sustainable products* |
| ***Scale/unit*** | *Volume per product type* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Value chain* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *Energy consumption statistics* |
| ***Description*** | *Biofuel and its by-products can replace fossil-based products on the market and help reduce greenhouse gas emissions* |
| ***References*** | *https://www.ssb.no/en/statbank/table/13615/* |
| ***Comment*** | *Advanced biofuel and byproducts based on wood residues and the EBIO technology (fast pyrolysis with electrochemical upgrading) may also substitute less sustainable biobased products* |

| | |
|---|---|
| ***Indicator ID*** | *V4* |
| ***Title*** | *The extent to which biofuel production is incentivised* |
| ***Value*** | |
| ***Impact category*** | *Competitiveness* |
| ***Sub-category*** | *Incentives for early providers* |
| ***Scale/unit*** | *High-medium-low* |
| ***Level*** | *Region* |
| ***Direction*** | *P (short term), N (Negative - long term)* |
| ***Stakeholder category*** | *Value chain* |
| ***Source/ Calculation method*** | *Stakeholder interviews with public authorities and other experts* |
| ***Additional source*** | *Desk study and market survey* |
| ***Description*** | *Implementation can be fostered through incentives, i.e. subsidies or reduced taxes and levies* |
| ***References*** | *https://www.enova.no/privat/alle-energitiltak/* |
| ***Comment*** | *Advantages are often given in the early market phase, so the measure is unpredictable. The effect is hard to calculate, and one may not be able to identify all arrangements* |

| | |
|---|---|
| ***Indicator ID*** | *V5* |
| ***Title*** | *The extent to which strategic plans, annual reports, sustainability reporting, etc. from the involved enterprises are publicly available* |
| ***Value*** | |
| ***Impact category*** | *Governance* |
| ***Sub-category*** | *Transparency* |
| ***Scale/unit*** | *Low-medium-high* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Value chain* |

| | |
|---|---|
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *Survey, interviews* |
| ***Description*** | *Availability of strategic plans, annual reports, etc. from the involved enterprises covering activities related to the implementation of the technology shows how transparent these enterprises are about the aspects that can influence the social sustainability and social impact of the technology* |
| ***References*** | *The enterprises' homepages* |
| ***Comment*** | *One must be clear about what to look for, to know that it is missing* |

| | |
|---|---|
| ***Indicator ID*** | *V6* |
| ***Title*** | *The extent to which the origin of the input factors can be traced and managed* |
| ***Value*** | |
| ***Impact category*** | *Governance* |
| ***Sub-category*** | *Traceability* |
| ***Scale/unit*** | *Low-medium-high* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Value chain* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *Survey, interviews* |
| ***Description*** | *The indicator shows whether the origin of the input factors necessary for the technology implementation will be traced and managed* |
| ***References*** | *TraceaBILITY: https://unece.org/DAM/trade/Publications/ECE_TRADE_429E_TraceabilityForSustainableTrade.pdf* |
| ***Comment*** | |

| | |
|---|---|
| ***Indicator ID*** | *W1* |
| ***Title*** | *The percentage of workers that are exposed to dust, gas or steam most of the time* |
| ***Value*** | |
| ***Impact category*** | *Health and safety* |
| ***Sub-category*** | *Health and safety of workers* |
| ***Scale/unit*** | *%* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *N* |
| ***Stakeholder category*** | *Workers* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *National statistics* |
| ***Description*** | *Indicator for the work environment and the potential health issues* |
| ***References*** | *https://www.ssb.no/en/statbank/table/07988/*<br><br>*https://www.osha.gov/annotated-pels* |
| ***Comment*** | *The statistics are given per industry category on an aggregated level. OSHA is a common reference in the oil and gas industry, that provides permissible exposure limits (PELS) for a range of substances. Exposure to hazardous chemicals through any route of entry (inhalation, ingestion, skin contact or absorption, etc.), including potential, accidental or possible, exposure, should be as low as possible* |

| | |
|---|---|
| ***Indicator ID*** | *W2* |
| ***Title*** | *The percentage of workers that are exposed to skin-irritating substances most of the time* |
| ***Value*** | |
| ***Impact category*** | *Health and safety* |
| ***Sub-category*** | *Health and safety for workers* |
| ***Scale/unit*** | *%* |

| | |
|---|---|
| ***Level*** | *Enterprise* |
| ***Direction*** | *N* |
| ***Stakeholder category*** | *Workers* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *National statistics on working environment* |
| ***Description*** | *Indicator for the work environment* |
| ***References*** | *https://www.ssb.no/en/statbank/table/07988/*<br><br>*https://www.oecd-ilibrary.org/docserver/9789264278240-en.pdf?expires=1697637104&id=id&accname=oid013346&checksum=6353B1CA0A08DBFEA053231D263BB8B4* |
| ***Comment*** | *The statistics are given per industry category on an aggregated level. OSHA is a common reference in the oil and gas industry, that provides permissible exposure limits (PELS) for a range of substances. Exposure to hazardous chemicals through any route of entry (inhalation, ingestion, skin contact or absorption, etc.), including potential, accidental or possible, exposure, should be as low as possible* |

| | |
|---|---|
| ***Indicator ID*** | *W3* |
| ***Title*** | *The percentage of workers that have a high risk of accidents at work* |
| ***Value*** | |
| ***Impact category*** | *Health and safety* |
| ***Sub-category*** | *Health and safety of workers* |
| ***Scale/unit*** | *%* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *N* |
| ***Stakeholder category*** | *Workers* |

| | |
|---|---|
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *National statistics on working environment* |
| ***Description*** | *Indicator for work-related health issues* |
| ***References*** | *https://www.ssb.no/en/statbank/table/14125*<br><br>*https://www.oecd-ilibrary.org/docserver/9789264278240-en.pdf?expires=1697788791&id=id&accname=oid013346&checksum=8A7B2526559CD6F3816CCAA25113CB25* |
| ***Comment*** | *The statistics are given per industry category on an aggregated level. The job characteristics approach defines the quality of the working environment in terms of a number of specific characteristics that influence workers' well-being. Physical risk factors is one important dimension, addressed in most working environment assessments, e.g., the EU-Labour Force Survey ad hoc Modules includes the following indicator: "Accidents at work resulting in injuries occurred in the 12 months before the reference week"* |

| | |
|---|---|
| ***Indicator ID*** | *W4* |
| ***Title*** | *The male/female wage ratio* |
| ***Value*** | |
| ***Impact category*** | *Human rights* |
| ***Sub-category*** | *Gender equality at work* |
| ***Scale/unit*** | *#* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *N* |
| ***Stakeholder category*** | *Workers* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *Survey, interviews* |
| ***Description*** | *The indicator should indicate wage differences for equal work between men and women* |
| ***References*** | *https://www.ssb.no/en/statbank/table/11656* |

| | |
|---|---|
| ***Comment*** | |

| | |
|---|---|
| ***Indicator ID*** | *W5* |
| ***Title*** | *The male/female employment ratio* |
| ***Value*** | |
| ***Impact category*** | *Human rights* |
| ***Sub-category*** | *Gender equality at work* |
| ***Scale/unit*** | *#* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *N* |
| ***Stakeholder category*** | *Workers* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *Survey, interviews* |
| ***Description*** | *The indicator should indicate the gender distribution in the EBIO-sector* |
| ***References*** | *https://www.ssb.no/en/statbank/table/08536* |
| ***Comment*** | |

| | |
|---|---|
| ***Indicator ID*** | *W6* |
| ***Title*** | *Wages for each part of the value chain compared to minimum wage* |
| ***Value*** | |
| ***Impact category*** | *Labor rights and decent work* |
| ***Sub-category*** | *Fair wages* |
| ***Scale/unit*** | *NOK/Month* |

| | |
|---|---|
| ***Level*** | *Enterprise* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Workers* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *Survey, interviews* |
| ***Description*** | *The indicator indicates whether the salary corresponds to the salary in comparable industries. Proper compensation for work is required, as a crucial dimension of job quality and labour rights. Compensating differentials are considered as a key dimension of job quality, e.g., in the European Union. Anticipated wages paid, as compared with the minimum (or average?) living wage in relevant sectors provides a good indicator of the level of compensation and working conditions faced by employees.* |
| ***References*** | *https://www.arbeidstilsynet.no/en/working-conditions/pay-and-minimum-rates-of-pay/minimum-wage/*<br><br>*https://www.ssb.no/en/statbank/table/13126/*<br><br>*The European Structure of Earnings Survey (ESES) - https://ec.europa.eu/eurostat/web/microdata/structure-of-earnings-survey* |
| ***Comment*** | *When there is no minimum-wage, the wage can be compared to the average wage of a relevant industry category.* |

| | |
|---|---|
| ***Indicator ID*** | *W7* |
| ***Title*** | *The share of workers organised in trade unions* |
| ***Value*** | |
| ***Impact category*** | *Labour rights and decent work* |
| ***Sub-category*** | *Unionisation* |
| ***Scale/unit*** | *%* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Workers* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |

| | |
|---|---|
| ***Additional source*** | *Survey, interviews* |
| ***Description*** | *Trade union organisation indicate the ability to negotiate working conditions* |
| ***References*** | *https://www.ssb.no/en/statbank/table/03546/* |
| ***Comment*** | *The public statistics is aggregated per country. The associations can indicate industry type* |

| | |
|---|---|
| ***Indicator ID*** | *W8* |
| ***Title*** | *The percentage of workers that are required to often or always work at a high pace* |
| ***Value*** | |
| ***Impact category*** | *Labour rights and decent work* |
| ***Sub-category*** | *Meaningful work* |
| ***Scale/unit*** | *%* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *N* |
| ***Stakeholder category*** | *Workers* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *National statistics* |
| ***Description*** | *The indicator reflects the work environment and job demands* |
| ***References*** | *https://www.ssb.no/en/statbank/table/07913/* |
| ***Comment*** | *The statistics are given per industry category on an aggregated level. Job demands are all physical, psychological, social or organisational aspects of a job that require continuous physical and/or psychological (i.e., cognitive or emotional) effort. A job demand may lead to positive as well as negative outcomes. Quantitative job demands, such as very high workload or high time pressure tends to be associated with negative responses, such as stress, depression, anxiety or burnout.* |

| | |
|---|---|
| ***Indicator ID*** | *W9* |
| ***Title*** | *The percentage of workers that will often or always be required to acquire new knowledge and skills* |
| ***Value*** | |
| ***Impact category*** | *Labour rights and decent work* |
| ***Sub-category*** | *Meaningful work* |
| ***Scale/unit*** | *%* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Workers* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *National statistics* |
| ***Description*** | *The indicator reflects whether the workers have varied work tasks and are given the opportunity to learn* |
| ***References*** | *https://www.ssb.no/en/statbank/table/07913/*<br><br>*https://oshwiki.osha.europa.eu/en/themes/job-demands* |
| ***Comment*** | *The statistics are given per industry category on an aggregated level. Among job demands, which may lead to positive as well as negative outcomes, cognitive demands impinge primarily on the brain processes involved in information processing (e.g. the difficulty of the work). While it may be demanding, such job content is mostly associated with meaningful work.* |

| | |
|---|---|
| ***Indicator ID*** | *U1* |
| ***Title*** | *The extent to which the end-product meets sustainability criteria laid down in relevant regulations* |
| ***Value*** | |
| ***Impact category*** | *Social acceptability* |
| ***Sub-category*** | *Fulfilment of formal sustainability criteria* |
| ***Scale/unit*** | *Low-medium-high* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Users* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *Desk study and interviews* |
| ***Description*** | *The end-product must meet European criteria for sustainability of energy, as laid down in the revised Renewable Energy Directive (RED III). The reduction of greenhouse gas emissions over the entire chain, from raw material production to final use, must be at least 65%, when compared to fossil fuels. The biomass used as feedstock must not be associated with indirect land use change (ILUC). The Delegated Regulation (EU) 2019/807 sets out specific criteria both for determining high ILUC-risk feedstock, and for certifying low ILUC-risk biofuels, bioliquids and biomass fuels. As noted in RED III, the bioenergy sustainability criteria will be further strengthened and apply to smaller installations (equal or above 7.5 MW) as well as those larger than 20 MW. Woody biomass will have to be used according to its highest economic and environmental added value (so-called cascading use). Financial support will be banned for energy produced using saw logs, veneer logs, industrial grade roundwood, and stumps and roots.* |
| ***References*** | *Revised Renewable Energy Directive (RED III): https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302413*<br><br>*Delegated Regulation (EU) 2019/807: https://www.fao.org/faolex/results/details/en/c/LEX-FAOC188157/* |
| ***Comment*** | *The indicator can function as a checklist point, where the producer can ensure the highest possible value utilisation of the biomass, and reduction of greenhouse gas emissions.* |

| | |
|---|---|
| ***Indicator ID*** | *U2* |
| ***Title*** | *The maximum price consumers are willing to pay for one unit of the end-product* |

| | |
|---|---|
| ***Value*** | |
| ***Impact category*** | *Social acceptability* |
| ***Sub-category*** | *Willingness to pay* |
| ***Scale/unit*** | *€/l* |
| ***Level*** | *End-product* |
| ***Direction*** | *N* |
| ***Stakeholder category*** | *Users* |
| ***Source/ Calculation method*** | *Literature review* |
| ***Additional source*** | *Survey* |
| ***Description*** | *The value end-users ascribe to the product reflects market acceptance* |
| ***References*** | |
| ***Comment*** | *The willingness to pay may be unobservable and the respondents may have incentives to not reveal their willingness to pay* |

| | |
|---|---|
| ***Indicator ID*** | *U3* |
| ***Title*** | *The extent to which the end-user needs to modify equipment or practices* |
| ***Value*** | |
| ***Impact category*** | *Usability* |
| ***Sub-category*** | *Fit with existing systems and practises* |
| ***Scale/unit*** | *High-medium-low* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *N* |
| ***Stakeholder category*** | *Users* |
| ***Source/ Calculation method*** | *Stakeholder consultation* |
| ***Additional source*** | *Desk study* |

| | |
|---|---|
| ***Description*** | *Indicate whether the product is easy to use and does not require changes in equipment or practices on the user side* |
| ***References*** | |
| ***Comment*** | *The end-product is fuel, but biofuel can be compared to other sustainable alternatives, e.g., hydrogen and electric vehicles* |

| | |
|---|---|
| ***Indicator ID*** | *U4* |
| ***Title*** | *The extent to which the use of the end-product is incentivised* |
| ***Value*** | |
| ***Impact category*** | *Availability* |
| ***Sub-category*** | *Incentives for users* |
| ***Scale/unit*** | *High-medium-low* |
| ***Level*** | *Regional* |
| ***Direction*** | *P (short term), N (long term)* |
| ***Stakeholder category*** | *Users* |
| ***Source/ Calculation method*** | *Desk study and stakeholder consultation* |
| ***Additional source*** | *User surveys* |
| ***Description*** | *Application can for instance be incentivised by subsidies or reduces taxes and levies* |
| ***References*** | *https://www.enova.no/privat/alle-energitiltak/* |
| ***Comment*** | *Advantages are often given in the early market phase* |

| | |
|---|---|
| ***Indicator ID*** | *L1* |
| ***Title*** | *The expected gross product of the economic activity related to implementation of the solution* |
| ***Value*** | |
| ***Impact category*** | *Contribution to the local economy* |
| ***Sub-category*** | *Value creation* |
| ***Scale/unit*** | *MNOK* |
| ***Level*** | *Sector* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Local community* |
| ***Source/ Calculation method*** | *Input-output modelling* |
| ***Additional source*** | *Proff forvalt - A credit and marketing tool where you can access accounting data, such as the number of employees and turnover per company. The tool is searchable by industry category code* |
| ***Description*** | *Indicator on whether implementation of the technology results in economic growth* |
| ***References*** | *https://forvalt.no/* |
| ***Comment*** | *The value added includes economic ripple effects/value chain impacts* |

| | |
|---|---|
| ***Indicator ID*** | *L2* |
| ***Title*** | *The expected number of new employees resulting from implementation of the solution* |
| ***Value*** | |
| ***Impact category*** | *Quality of life* |
| ***Sub-category*** | *Employment* |
| ***Scale/unit*** | *#* |
| ***Level*** | *Regional* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Local community* |

| | |
|---|---|
| ***Source/ Calculation method*** | *Input-output model output* |
| ***Additional source*** | *Interview with local stakeholders and Proff Forvalt* |
| ***Description*** | *Indicator on whether implementation of the technology results in economic growth* |
| ***References*** | *https://forvalt.no/* |
| ***Comment*** | *To be compared with the current number of employees* |

| | |
|---|---|
| ***Indicator ID*** | *L3* |
| ***Title*** | *The level of satisfaction from preserving the natural environment for future generations* |
| ***Value*** | |
| ***Impact category*** | *Quality of life* |
| ***Sub-category*** | *Bequest value* |
| ***Scale/ unit*** | *Low-medium-high* |
| ***Level*** | *Region* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Local community* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional*** | *Willingness to pay surveys* |

| | |
|---|---|
| ***source*** | |
| ***Description*** | *This indicator relates to the non-use values that often are associated with environmental innovations: Existence value, referring to a sense of wellbeing, from simply knowing that ecosystems are conserved (or environmental challenges are reduced), and bequest value, understood as the value seen in ensuring the availability of biodiversity and ecosystem functioning to future generations. Potential impacts along these lines cannot be measured exactly but may be rated ordinally through stakeholder perceptions of the solution's impact on the local community, linked to the level of awareness and previous engagement with environmental challenges.* |
| ***References*** | *https://www.ipbes.net/sites/default/files/webform/impact_tracking_database/62662/20220419%20Novel%20Approach%20to%20Identify%20and%20Prioritize%20Connections%20Between%20Nature%20and%20Well-Being%20NZ.pdf* |
| ***Comment*** | *The valuation will be made in cooperation with the stakeholders* |

| | |
|---|---|
| ***Indicator ID*** | *L4* |
| ***Title*** | *The number of existing clusters expected to benefit from the initiative* |
| ***Value*** | |
| ***Impact category*** | *Innovation capacity* |
| ***Sub-category*** | *Contribution to innovation clusters* |
| ***Scale/unit*** | *#* |
| ***Level*** | *Regional* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Local community* |
| ***Source/ Calculation method*** | *Stakeholder interviews* |
| ***Additional source*** | *Desk study* |
| ***Description*** | *Indicates the possibilities of acquiring and spreading knowledge about the technology and increasing uptake and boost innovation* |
| ***References*** | *https://nic.innovasjonnorge.no/klyngene* |
| ***Comment*** | *Informal clusters may also exist* |

| | |
|---|---|
| ***Indicator ID*** | *L5* |
| ***Title*** | *The number of R&D activities initiated in connection with the solution* |
| ***Value*** | |
| ***Impact category*** | *Innovation capacity* |
| ***Sub-category*** | *R&D activities* |
| ***Scale/unit*** | *#* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *P (short term)* |
| ***Stakeholder category*** | *Local community* |
| ***Source/ Calculation method*** | *Desk study and consultation with regional stakeholders* |
| ***Additional source*** | |
| ***Description*** | *One can find information about ongoing research and innovation initiatives by screening publications, patent applications, grant applications or grants and research project databases* |
| ***References*** | *https://www.ssb.no/en/statbank/list/foun*<br><br>*https://prosjektbanken.forskningsradet.no/en* |
| ***Comment*** | *There are often more R&D activities in the early phase* |

| | |
|---|---|
| ***Indicator ID*** | *L6* |
| ***Title*** | *The extent to which implementation of the solution can contribute towards realisation of regional development strategies* |
| ***Value*** | |
| ***Impact category*** | *Regional attractiveness* |
| ***Sub-category*** | *Contribution towards realisation of regional development strategies* |
| ***Scale/unit*** | *Low-medium-high* |
| ***Level*** | *Region* |
| ***Direction*** | *P* |

| | |
|---|---|
| ***Stakeholder category*** | *Local community* |
| ***Source/ Calculation method*** | *Desk study and consultations with regional stakeholders* |
| ***Additional source*** | *Interviews* |
| ***Description*** | *The indicator shows whether the implementation of the technology can contribute to the realisation of regional development plans and strategies on bioeconomy and circular economy* |
| ***References*** | *https://www.regjeringen.no/contentassets/afc36304247d48f0a3546f992e0e0305/biookonomistrategi-for-innlandet_feb18.pdf*<br><br>*https://biovalley.no/om-biovalley/* |
| ***Comment*** | *The valuation will be made in cooperation with the stakeholders* |

| | |
|---|---|
| ***Indicator ID*** | *L7* |
| ***Title*** | *The extent to which implementation of the solution can influence the economic attractiveness of the region* |
| ***Value*** | |
| ***Impact category*** | *Regional attractiveness* |
| ***Sub-category*** | *Regional economic attractiveness* |
| ***Scale/unit*** | *Low-medium-high* |
| ***Level*** | *Region* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Local community* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *National statistics: Number of entities divided by 1000 inhabitants (DOI: 10.15405/epsbs.2021.12.04.26)* |
| ***Description*** | *OECD proposes a multi-dimensional approach to assessing regional attractiveness: the regional attractiveness compass. The approach considers global engagement beyond international connections and financial drivers alone. In total, the methodology considers multiple indicators across 6 domains (economic attraction, connectedness, visitor appeal, natural environment, resident well-being, land use and housing), where economic attraction seems most relevant for EBIO.* |

| | |
|---|---|
| ***References*** | *https://www.oecd-ilibrary.org/sites/a9448db4-en/1/3/3/index.html?itemId=/content/publication/a9448db4-en&_csp_=57e3f24f16d6ac6808a936fc51accb08&itemIGO=oecd&itemContentType=book*<br><br>*https://search.oecd.org/regional/Regional-Attractiveness-Brochure.pdf* |
| ***Comment*** | |

| | |
|---|---|
| ***Indicator ID*** | *S1* |
| ***Title*** | *The extent to which implementation of the solution will increase the renewable share of the energy consumption* |
| ***Value*** | |
| ***Impact category*** | *Energy security* |
| ***Sub-category*** | *Renewable share of energy mix* |
| ***Scale/unit*** | *Low-medium-high* |
| ***Level*** | *Region* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Wider society* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *Use energy consumption statistics* |
| ***Description*** | *Indicate whether the end-product and residual products from the EBIO solution can contribute to replacing fossil alternatives locally* |
| ***References*** | *https://www.fornybarnorge.no/publikasjoner/rapport/2021/fornybarometeret-host-2021/status-fornybarandelen-i-norge/* |
| ***Comment*** | *The renewable share in consumption depends on the energy mix and the renewable share in electricity and local heat production, in addition to the consumption of fuel.* |

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| ***Indicator ID*** | *S2* |
| ***Title*** | *The extent to which implementation of the solution can contribute to securing supply of biofuel* |
| ***Value*** | |
| ***Impact category*** | *Energy security* |
| ***Sub-category*** | *Secure energy supply for transport* |
| ***Scale/unit*** | *Low-medium-high* |
| ***Level*** | *Regional* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Wider society* |
| ***Source/ Calculation method*** | *Consultation with regional stakeholders* |
| ***Additional source*** | *Calculations based on energy consumption and import statistics* |
| ***Description*** | *The ability of the EBIO solution to contribute to meeting the demands of the transport sector and its potential to reduce the dependence on imported fuels* |
| ***References*** | *https://www.ssb.no/en/statbank/table/13585*<br><br>*https://www.ssb.no/en/energi-og-industri/energi/statistikk/produksjon-og-forbruk-av-energi-energibalanse-og-energiregnskap* |
| ***Comment*** | |

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|---|---|
| ***Indicator ID*** | *S3* |
| ***Title*** | *The territory of arable land needed to produce the annual need for feedstock* |
| ***Value*** | |
| ***Impact category*** | *Food security* |
| ***Sub-category*** | *Use of arable land* |
| ***Scale/unit*** | *Hectares* |
| ***Level*** | *Region* |
| ***Direction*** | *N* |

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| ***Stakeholder category*** | *Wider society* |
| ***Source/ Calculation method*** | *Consultation with stakeholders* |
| ***Additional source*** | *GIS analysis* |
| ***Description*** | *The indicator shows the impact of the technology implementation on food security using arable land for production of annually needed volumes of biomass feedstock. Implementation of the solution should not conflict with food production* |
| ***References*** | *https://kart8.nibio.no/nedlasting/dashboard* |
| ***Comment*** | *Arable land is any land capable of being ploughed and used to grow crops* |

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| ***Indicator ID*** | *S4* |
| ***Title*** | *The extent to which implementation of the solution is aligned with national policies for decarbonising the transport sector* |
| ***Value*** | |
| ***Impact category*** | *Sustainability transition* |
| ***Sub-category*** | *Alignment with national decarbonisation policies* |
| ***Scale/unit*** | *Low-medium-high* |
| ***Level*** | *National* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Wider society* |
| ***Source/ Calculation method*** | *Consultation with stakeholders* |
| ***Additional source*** | *Desk study, calculation method for market share and climate gas reduction per market segment* |
| ***Description*** | *To what extent will the planned production contribute towards the national climate gas reduction targets. That is, the specific targets (percentage of total fuels distributed by each distributor) and rules for the use of advanced biofuels in road, maritime and air transport, as laid down in the national Product Regulation and most recent policies for decarbonation of the transport sector.* |
| ***References*** | *https://www.miljodirektoratet.no/ansvarsomrader/klima/transport/biodrivstoff/*<br><br>*https://www.stortinget.no/no/Saker-og-publikasjoner/Sporsmal/Skriftlige-sporsmal-og-svar/Skriftlig-sporsmal/?qid=93546* |

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| ***Comment*** | *Norwegian legislation - the product regulation (Produktforskriften) includes specific targets (percentage of total fuels distributed by each distributor) and rules for the use of advanced biofuels in road, maritime and air transport. The regulation includes sustainability criteria in terms of total climate gas emissions and land use. Grant support to establish sustainable production is provided, through Enova. However, the framework conditions for the use of biofuels are more uncertain, due to e.g., policy debate about its sustainability as compared with other solutions.* |

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| ***Indicator ID*** | *S5* |
| ***Title*** | *The amount of GHG emissions the implementation of the solution can contribute to reduce* |
| ***Value*** | |
| ***Impact category*** | *Sustainability transition* |
| ***Sub-category*** | *Alignment with national decarbonisation policies* |
| ***Scale/unit*** | *# Ton* $CO_2$ |
| ***Level*** | *National* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Wider society* |
| ***Source/ Calculation method*** | *Input output modelling* |
| ***Additional source*** | *Emission statistics per industry and calculation* |
| ***Description*** | *Substituting fossil fuels with the expected production of the end-product from* |
| ***References*** | *https://www.ssb.no/en/statbank/table/13931* |
| ***Comment*** | *By replacing relevant energy products greenhouse gas emissions can be calculated* |

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| ***Indicator ID*** | *S6* |
| ***Title*** | *The amount of waste the implementation of the solution can contribute to reduce* |
| ***Value*** | |
| ***Impact category*** | *Sustainability transition* |

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| ***Sub-category*** | *Contribution towards circularity* |
| ***Scale/unit*** | *Ton* |
| ***Level*** | *Enterprise* |
| ***Direction*** | *P* |
| ***Stakeholder category*** | *Wider society* |
| ***Source/ Calculation method*** | *Consultation with stakeholders* |
| ***Additional source*** | *Input output modelling* |
| ***Description*** | *The production of biofuel can use residual products from the forest and wood processing industries as input factors* |
| ***References*** | *https://www.ssb.no/en/statbank/table/12818/* |
| ***Comment*** | |