BioMates

Public Summary of Deliverable D4.6:

Report on Social, Health and PolicyAssessment

Grant Agreement number:	727463
Project Acronym:	BioMates
Project title:	Reliable Bio-based Refinery Intermediates — BioMates
Start date of the project:	01.10.2016
Duration of the project:	31.03.2022
Deliverable N°.:	D48
Relative Deliverable No.:	D4.6
Work Package N°. Task N°.:	WP4 (integrated sustainability assessment) Task 4.5
Deliverable title	Report on Social Sustainability Assessment
Scheduled date of submission	31/12/2021
Date of submission of this version:	15/11/2021
Dissemination Level:	Confidential, only for members of the consortium (including the Commission Services) **This summary: Public**
Project website address:	www.BioMates.eu
Deliverable elaborated on the basis of	Amendment AMD-727463-25
Submitting party:	Imperial College London
Responsible author:	Rocio Diaz-Chavez and Yara Evans
Reviewer:	Heiko Keller
Verification:	Report with public summary

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727463.

Contents

List of Figures

List of Tables

Acronyms

CAP	Common Agricultural Policy
CEN	European Committee for Standardisation
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
EAFRD	European Agricultural Fund for Rural Development
EAGF	European Agricultural Guarantee Fund
EC	European Commission
EIA	Environmental Impact Assessment
EIP-AGRI	European Innovation Partnership for Agricultural Productivity and Sustainability
ESIF	European Structural Investment Fund
EU	European Union
EU ETS	European Union Emissions Trading System
FQD	Fuel Quality Directive
GHG	Green House Gas
ICE	Internal Combustion Engine
ICAO	International Civil Aviation Organisation
ILO	International Labour Organisation
LCA	Life Cycle Assessment
Mild-HDT	Mild catalytic hydro-processing
PPS	Purchasing Power Standard
PVPP	Photovoltaic power plant
RDP	EU Rural Development Program
RED	Renewable Energy Directive
RES	Renewable Energy Sources
SAF	Sustainable Aviation Fuel
SHDB	Social Hotspot Database
SIA	Social Impact Assessment
SLCA	Social Life Cycle Assessment
SLCIA	Social Life Cycle Inventories Assessment
TRL	Technology Readiness Level

1. Preface

4.1 Introducing BioMates

The BioMates project combines novel technologies for the cost-effective conversion of residues and second-generation biomass (straw and miscanthus and forestry residues) into high-quality bio-based intermediates (BioMates) that can be co-processed with petroleum streams to produce a hybrid fuel ready for use as transportation fuel (Figure 1). BioMates thus comprise renewable and reliable co-feedstocks. BioMates main conversion processes are AFP and single-stage mild catalytic hydro-processing (mild-HDT). Whist AFP is expected to take place next to feedstock production, the mild-HDT would take place within or next to the refinery to make efficient use of excess energy and energy carriers (such as hydrogen). The BioMates concept will thus allow for minimisation of fossil energy demand, as well as capital and operational costs, since it will partially rely on underlying refinery conversion capacity, to increase the bio-content in final transportation fuels. Broadly, then, the BioMates concept will contribute to the wider agenda for making the transport system sustainable (Holder and Gilpin, 2013; Tsita and Pilavach, 2013; Panoutsou et al., 2021) through use of fuels with biogenic content help reduce GHG emissions, alongside the aims of increasing energy security and promoting economic development in rural areas through enhanced economic activity and job expansion (Gracia et al., 2020).

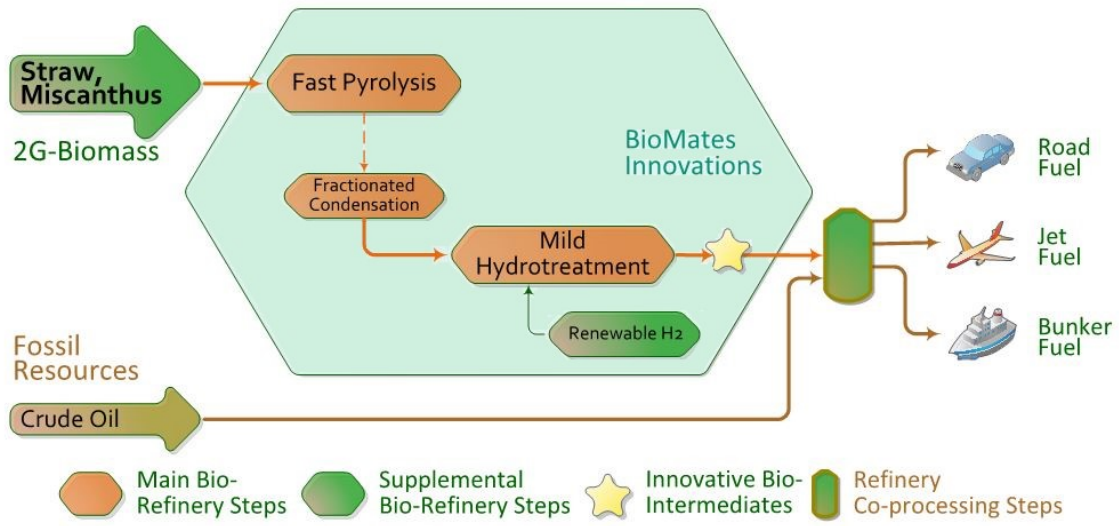


Figure 1: BioMates Concept - Process Flow

4.2 European Commission support

The current framework strategy for a Resilient Energy European Union demands energy security and solidarity, a decarbonized economy and a fully-integrated and competitive pan-European energy market, intending to meet the ambitious 2020 and 2030 energy and climate targets (EC-2014a, EC-2014b). Towards this goal, the European Commission is supporting the BioMates project for validating the proposed innovative technological pathway, in line with the objectives of the LCE-08-2016-2017 call (EC-2015). This project has

received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727463.

4.3 The BioMates team

The BioMates team comprises nine partners from industry, academia and research centres:

- Centre for Research & Technology Hellas / CERTH - Chemical Process & Energy Resources Institute /CPERI, Greece (Project Coordination) - http://www.cperi.certh.gr/
- Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Germany - www.umsicht.fraunhofer.de
- University of Chemistry and Technology Prague UCTP, Czech Republic - http://www.vscht.cz
- Imperial College London ICL, United Kingdom - www.imperial.ac.uk
- Institut für Energie und Umweltforschung Heidelberg gGmbH / ifeu, Germany - www.ifeu.de
- HyET Hydrogen B.V. / HyET, Netherlands - www.hyet.nl
- RANIDO, s.r.o., Czech Republic - http://www.ranido.cz/
- BP Europa SE, Germany - www.bp.com/en/bp-europa-se.html
- RISE Research Institutes of Sweden - www.ri.se

For additional information and contact details, please visit www.biomates.eu.

2. Social sustainability of the BioMates project

2.1 Social Sustainability

The notion of sustainability is implicit in the definition of Sustainable Development put forward by the Brundtland Commission as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987). Since then, reformulations have noted the need to reconcile the environmental, social, and economic dimensions (the 'three pillars' of sustainability). Sustainability assessment that addresses these three dimensions has become established and mandatory for development initiatives, including the establishment of biorefineries (Parajuli et al., 2015). Sustainability is a key factor in the establishment of biorefineries which should be assessed through their entire value chain for environmental, economic, and social sustainability (IEA-BIOENERGY, 2009). Sustainability assessment entails the use of a range of concepts that imply the integration of the three pillars of sustainability into a framework of sustainability principles, indicators, along with methods for assessing initiatives, although further pillars (e.g., policy and institutions) should also be incorporated (Dalal-Clayton and Sadler, 2004; Diaz-Chavez, 2006). Figure 2 provides an illustration of this integration.

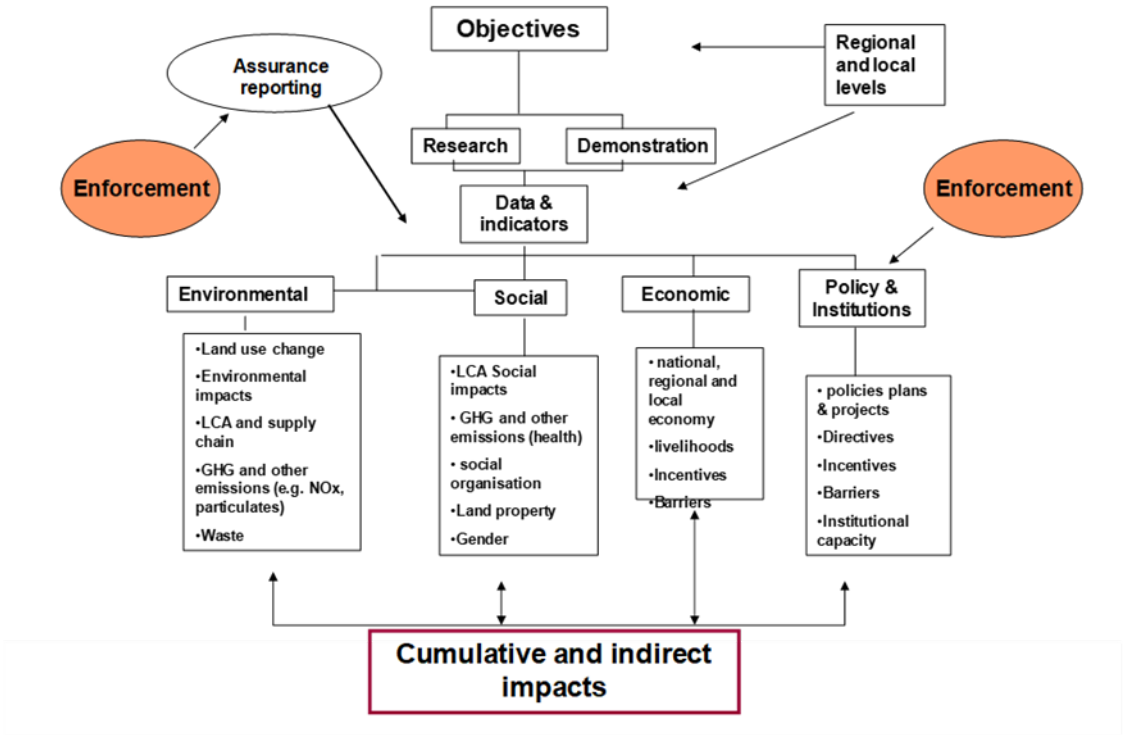


Figure 2: Framework for Sustainability Assessment

There is no universally accepted definition of social sustainability (Colantonio, 2009; Eizenberg and Jabareen, 2017). According to one definition, it refers to "the extent to which social values, social identities, social relationships and social institutions can continue into the future" (Rafianni et al, 2018). The concept of social sustainability has gained greater weight in sustainability assessment, although there are, again, neither universally accepted definitions nor universally accepted methodologies for social sustainability assessment. In broad terms, it entails identifying positive and negative societal impacts of activities, projects, systems, processes, and organizations. Various approaches have been proposed that employ a range of analytical tools derived from EIA, SIA, LCA, policy analysis, and others. SIA, for instance, refers to a systematic, iterative form of assessment that helps understand potential social, cultural or economic impacts of change or proposed change (in Colantonio, 2009).

2.2 SIA and SLCA for Social Sustainability Assessment

Although its initial development dates back to the 1990s (e.g., O'Brien, Doig and Clift, 1996), SLCA has emerged as an important methodology in the last decade and a half, particularly following the incorporation of social criteria into LCA by the UNEP/SETAC Life Cycle group and the publication of their own guidelines for SLCA (Grießhammer et al. 2006; Andrews et al. 2009; UNEP/SETAC 2009, Benoît et al. 2010; UNEP/SETAC, 2013). SLCA guidelines set the context, outline the framework, and identify research needs and further steps (Andrews et al., 2009). Within this framework, SLCA is complementary to LCA and aims to assess the overall sustainability of a product. SLCA is used to assess real and potential negative and positive social impacts of

products and services through their life cycle to help improve social conditions for all stakeholders, broadly defined as those likely to affected by the product system (Andrews et a.l, 2009; Benoît et al. 2013).

The SLCA framework is based on four phases of the LCA ISO standard (ISO, 2006). The Goal and Scope and Interpretation stages correspond to those used in LCA, whilst the inventory stage is based on a stakeholder approach that incorporates impact categories, subcategories, and indicators (Figure 3), where a stakeholder category comprises a cluster of social actors that have shared interests due to their proximate relationship to the product system being assessed (UNEP/SETAC, 2009). The impact categories are related to five stakeholder categories: workers, local community, society, consumers, and value chain actors, which are divided into subcategories to be assessed (Andrews et al. 2009; Benoît et al. 2013). SLCA identifies both positive and negative impacts of the product life cycle which should be used to gauge and encourage compliance with policy instruments (e.g., laws, international agreements, certification standards). They can be assigned to different stakeholders and can also be differentiated according to impact categories.

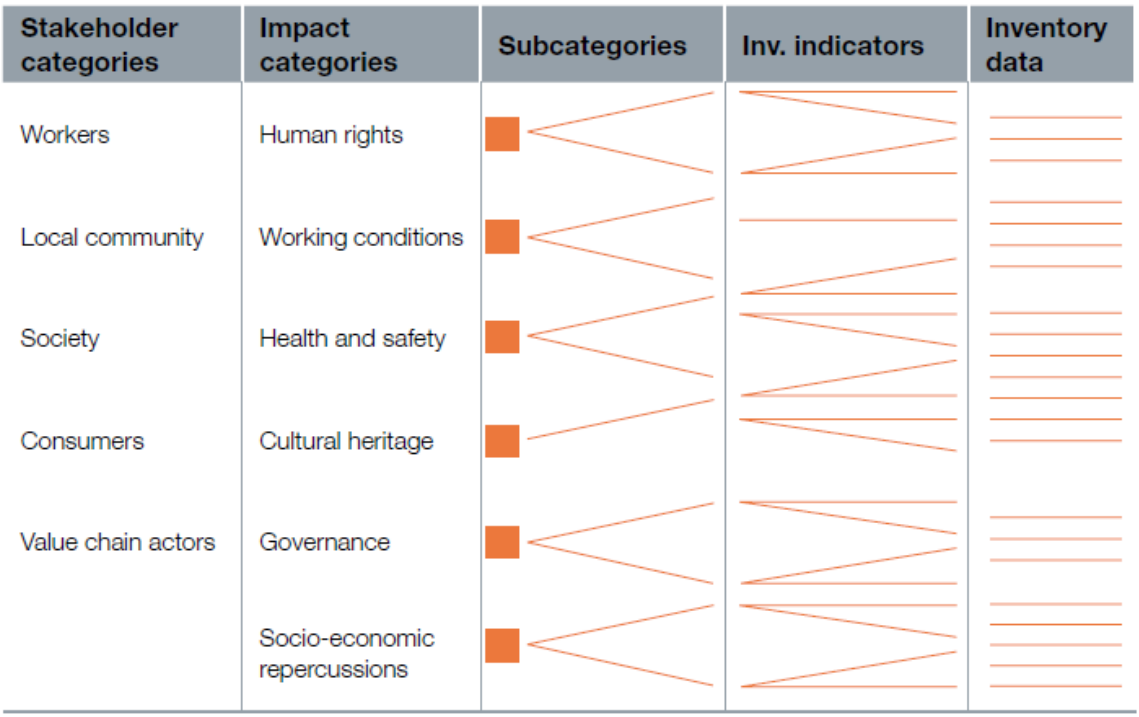


Figure 3: Stakeholders and Impact Categories (UNEP/SETAC, 2009)

The SLCA guidelines (UNEP/SETAC, 2009; Benoît et al., 2013) propose two types of inventories: Type-1 and Type-2 SLCIA. The Type-1 method first gathers data for the subcategories and then assesses the evidence available using performance reference points. These reference points can represent thresholds to which the data can be related to assess the potential impacts. Type-2 SLCIA instead uses impact pathways to convert inventory indicators into midpoints and then endpoints, as in LCA characterization models. The social assessment method is employed to assess potential social impacts using both quantitative, semi-quantitative and qualitative data. While all stakeholder groups and subcategories may be identified in any study, as proposed in the SLCA guidelines (Benoît et al. 2013), only a selection of more relevant categories may need examining.

A variety of methodologies and frameworks have been developed for social sustainability assessment based on SCLA, but none is universally accepted (Reitinger et al., 2011; Benoît et al., 2013; de Luca 2015; Fortier et al., 2019). SLCA is still evolving and can be used on its own or in combination with other techniques (Ciroth et

al. 2011; Klöpffer 2008; Falcone and Imbert, 2018). Given the limitations of current SLCA methodologies, the approach used for the social assessment of BioMates draws from SIA and SLCA, combining elements to provide a more comprehensive and robust analysis, as employed in previous research (Diaz-Chavez, 2013; 2014; Diaz-Chavez et al. 2016). The approach is illustrated in Figure 4.

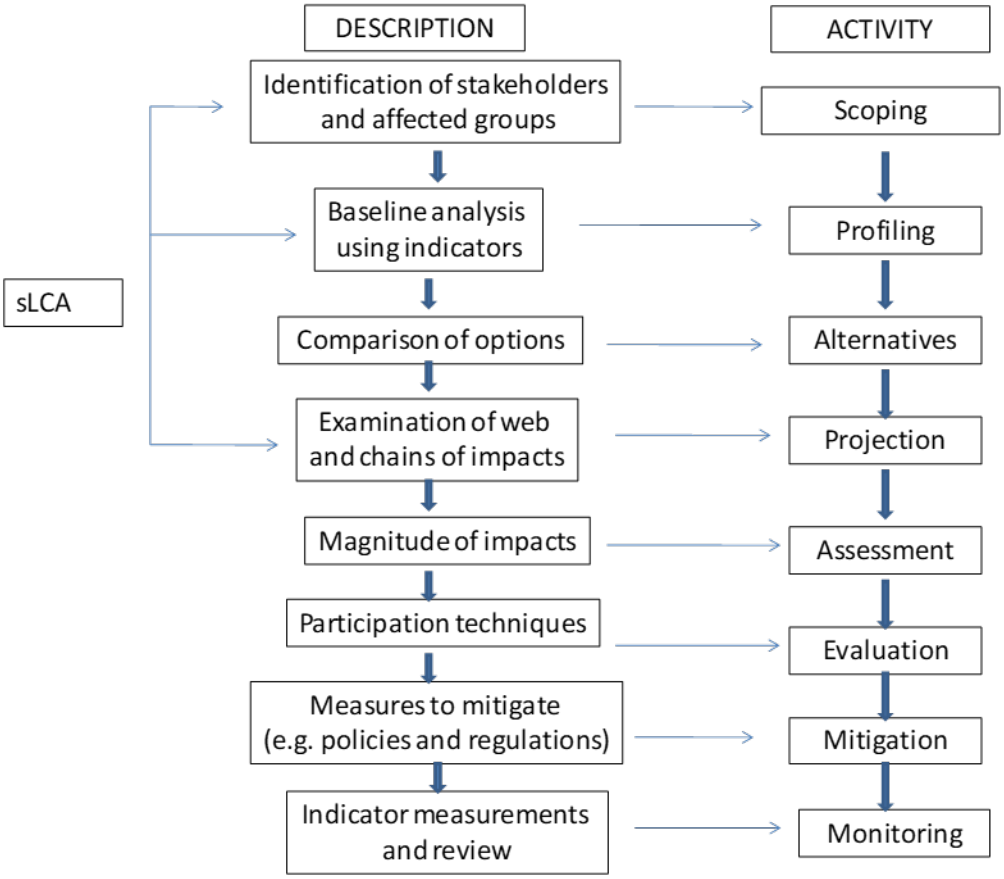


Figure 4: Adapted SCLA and SIA (Diaz-Chavez, 2014; Diaz-Chavez et al., 2016)

From the steps common to SLCA, a direct link can be drawn with different techniques, such as, for instance, mapping stakeholders, creating a baseline (i.e., inventory), and identifying and assessing the impacts. Examples of social, economic and policy issues that can be assessed in the context of BioMates are shown in Figure 5.

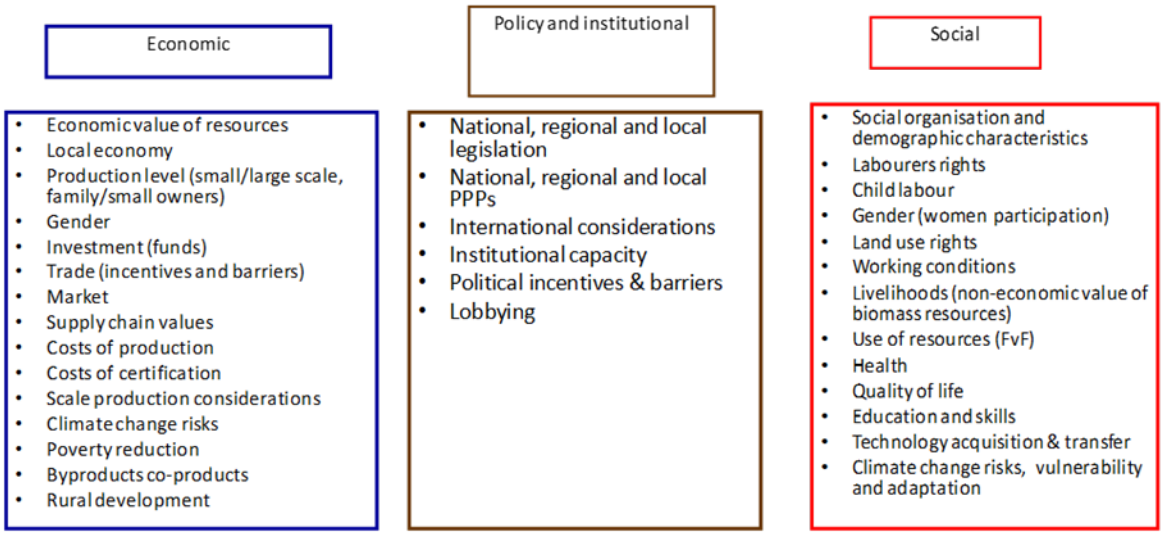


Figure 5: Issues for Assessing Impacts (Diaz-Chavez, 2013)

LCA analyses the effects that a product or process will have on the environment. It provides information about the efficiency of the production and areas for improvement and encompasses all stages in the product's life cycle (e.g., extraction of raw materials, processing, transportation, use, disposal). It requires data about the initial product, as wells data on the full life cycle of all other materials used in making the product (which also applies to green procurement). SLCA, in turn, requires collection of additional data relating to organisational issues along the chain (UNEP-SETAC, 2009). Figure 6 illustrates the specific techniques.

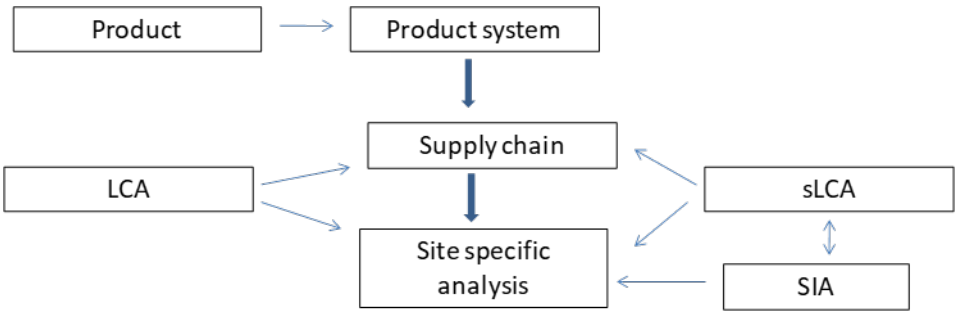


Figure 6: Analysis of a Product System (Diaz-Chavez, 2012)

3 Methodological approach for the social assessment of BioMates

The methodological approach for the social assessment of BioMates encompasses the various steps discussed next. It is worth highlighting that the scope of the assessment of the BioMates concept is limited to potential impacts and risks since BioMates is still at project development stage. For instance, negative impacts that can be anticipated may de increased noise levels, traffic from transportation of bulky biomass to refineries, which are clearly experienced at particular sites of cultivation, transport and refining (Raman et al., 2015) and can only be properly assessed once the biorefinery is in full operation.

Contextual information about the geographical location of process units may be provided in SLCA to enhance the assessment, although not mandatory, however, it is an integral part of SIA. For BioMates, this is provided at country level, both through indicators analysis, and 'hotspot' analysis. Four prototypical regions have been

selected from amongst the project partners' base, as suppliers of the biomass feedstocks (wheat and barley straw, miscanthus, and forest residues) and the location of the pilot process unit. These regions are represented by these following countries: Greece (Southern Europe); the Czech Republic (Central Europe); Germany (Western Europe); Sweden (Northern Europe). These countries are the focus of the assessment which is based on the use of parameters proposed by Diaz-Chavez (2012) that focus on specific stages of the BioMates supply chain, as shown in Table 1.

Table 1: SIA and SLCA Parameters for Assessment of BioMates

No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
1	Trade of feedstock	Incentives and barriers	EU/National	Feedstock	Qualitative Literature Survey Workshop
2	Identification of stakeholders along the supply chain	Producers Regulators Business Traders	National Local	All	Qualitative Desk search Project partners
3	Policies and regulations	International National Regional Local	National International	All	Qualitative Literature Policy documents
4	Potential biorefinery location/logistic	Availability of feedstock	National Local	Feedstock Transport Storage Biorefinery	Qualitative Literature Project partners
5	Land (use/tenure)	• Availability in EU • Ownership and rights	National	Feedstock	Quantitative Indicators FAOSTAT EUROSTAT
6	Community participation	Community acceptance of: • Biorefinery feedstocks, processes, products • Other involvement	National Local	Feedstock Transport Storage Biorefinery	Quantitative Survey Qualitative Workshop
7	Quality of life	Improvement of quality of life Improvement of livelihood Improvement of socio-economic conditions	National Local	N/A (General)	Quantitative EUROSTAT
8	Rural development and Infrastructure	• Roads • Sanitation • Water	National Local	Feedstock Transport Storage Biorefinery	Qualitative SHDB

9	Job creation and wages	• Labour (harvesting; collection of residues) • Jobs created (biorefinery& transportation) • Wages paid according to national/regional regulations (minimum wage)	National Local	Feedstock Transport Storage Biorefinery	Quantitative Indicators EUROSTAT FAOSTAT ILOSTAT SHDB
10	Gender equity	Inclusion of women	National	Feedstock Transport Storage Biorefinery	Quantitative Qualitative EUROSTAT SHDB
11	Labour conditions	ILO conventions and human rights including: • Child labour • Right to organise • Forced labour	National	Feedstock Transport Storage Biorefinery	Quantitative Qualitative ILOSTAT SHDB
12	Health and safety	Compliance with health and safety regulations	National Local	Feedstock Transport Storage Biorefinery	Qualitative Literature SHDB
13	Competition with other sectors	Competition and negative impacts on other industries and sectors	National Local	Feedstock Intermediate and end products	Qualitative Literature

Source: Adapted from Diaz-Chavez (2012)

3.2 The SHDB

The SHDB[1] was used to complement the characterisation of BioMates countries, through a 'hotspot analysis' (parameters 8, 10-12 on Table 1) and to provide a 'combined social hotspot index' for these countries, as explained below. According to the UNEP-SETAC (in Norris and Norris, 2013), 'hotspots are the elementary processes in a region or situation that may seem problematic, where social issues are at risk or, conversely, opportunities exist'. Conceived for use in SLCA, the SHDB is a tool allows to identify hotspots or potential risks in supply chains in specific economic sectors at country level, based on potential social impacts. It is an extended input/output Life Cycle Inventory database providing a solution to enable the modelling of product systems and the assessment of potential social impacts (Norris and Norris, 2015). The potential social impacts of activities in specified economic sectors at country level can be identified through a range of indicators that

[1]Most LCA tools lack the ability to specify the geographical location of production activities—information that is essential for social impact assessments. The SHDB can play a role equal to that of LCA databases in assessing product hotspots, but with the added benefit of geographical accuracy and identification of potential social impacts. The SHDB system's current Global Input-Output model is based on the GTPA7. Quantitative statistics and qualitative information by country and sector are used to develop characterization models. Country-specific sector risk results help provide understanding of the context in which firms operate. The activity variable used in the SHDB is worker-hours. Thus, the SHDB can be used to identify how many worker-hours are involved for each unit process in the supply chain, for a given final product or service output from the system. worker hours are relevant because they represent evidence of the intensity of work required by each country-specific sector directly related to production. Work intensity is one of the criteria proposed to prioritise decision and action (Norris and Norris, 2013). Further information available at: http://socialhotspot.org/.

are used to measure the risk levels associated with social issues, highlight an opportunity to address them (SHDB, 2021).

The SHDB covers social risks in 57 economic sectors in 244 countries. The database is structured around five social categories, with each category subdivided into themes, comprising 23 themes, and over 157 risk indicators. Risks are expressed by country and sector, commodity or production activity (Benoît-Norris et al, 2012; Norris and Norris, 2015). These social categories were defined based on standards, policy frameworks and expert advice. Each indicator is assigned a risk rating (0 = low risk; 1= medium risk; 2= high risk; 3= very high risk) for each country sector according to characterisation rules specific to that indicator (SHDB, 2021). For illustrative purposes, each risk level is assigned a colour equivalent to a traffic light system (green = low risk; orange = medium risk; dark orange = high risk; dark red= very high risk). An example is shown in Figure 7 for the risk that migrant workers in BioMates are not paid enough in the crops sector for making remittances.

Figure 7: Risk to Migrant Workers Income Not Being Enough for Remittances (SHDB, 2021)

The SHDB also allows for obtaining a 'combined social hotspot index' for a particular social category in a particular sector and country. This is obtained through the averaging of all indicators and assigning extra weight to particularly important indicators, yielding a risk rating between 1-4 for each social category. The risk ratings for all social categories are then summed up, divided by the highest sum possible for that sector, and multiplied with 100 to generate a value between 0 and 100 for the index (SHDB, 2021). The index is useful for comparing sectors across countries and visualise the 'hotspot' categories, as in the example shown in Figure 8 for the water sector in the four BioMates countries. However, it is to be noted that the SHDB does not allow for assessing positive impacts, and as the data provided is aggregated by industry sectors, it is not possible to differentiate between specific products or technologies.

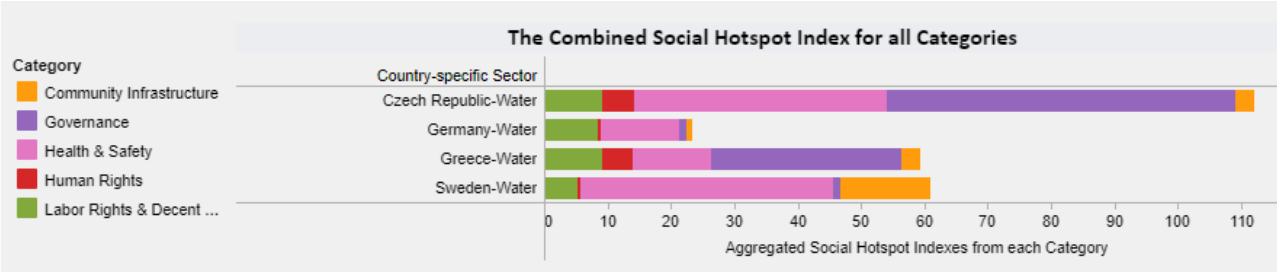


Figure 8: The Combined Social Hotspot Index for BioMates Countries (SHDB, 2021)

3.3 BIOMATES product system and the reference system

A range of process pathways have been developed for BioMates, based on the ligno-cellulosic feedstocks that will be used to obtain the BioMates bio-oil for co-processing with fossil fuels (Annex I). For the purposes of the assessment, inputs to and products from the different process BioMates stages (raw, intermediate, final) were grouped following the sector classification used in the SHDB. To these were added the sectors corresponding to the processes and products that BioMates aims to replace (i.e., the reference system).

Therefore, the main inputs and products assessed in the SIA/SLCA encompass the BioMates product system, that is, all sectors that are part of its value chain (see Annex II for definition):

- Cereals (barley, for straw biomass)
- Crops (miscanthus biomass)
- Wheat (for straw biomass)
- Forestry (biomass residues)
- Chemicals (process/product)
- Electricity (process)
- Gas (process/product)
- Oil (process/product)
- Petroleum and coal (process/product)
- Transport (logistics)

The SHDB was used to assess a range of issues and identify hotspots in the economic sectors relevant to BioMates. In a further step, SHDB indicators for social impact categories were used to compare the risks associated with implementing the BioMates concept according to specific scenarios and the risks associated with the reference product system. This specific element of the assessment is discussed later in the report (section 8.1).

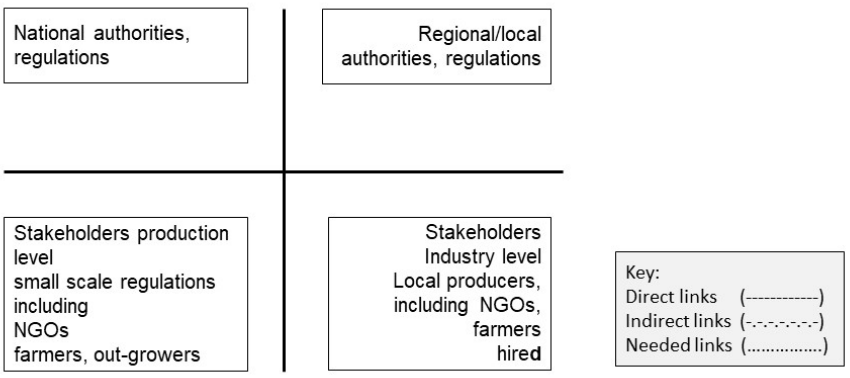
3.4 Mapping of stakeholders

Various methodologies exist for stakeholder mapping (e.g., UNEP/SETAC, 2009). Stakeholder selection should be comprehensive and include those at the production level (NGOs, farmers, other civil organisations), industry, consumers, society at large and any other value chain actors. Stakeholder participation is emphasised in both SIA and SLCA, where inventory data and impact assessment categories are specified for the stakeholders defined. An example of an approach for mapping stakeholders is shown in Figure 9.

The mapping of stakeholders uses a quadrat for sorting the stakeholders.

Stakeholders in crops and agriculture are identified first. Next are stakeholders at the production level, encompassing farmers, NGOs (and other civil organisations), and the industry sector (including also farmers with different forms of participation, such as out-growers).These are followed by stakeholders from local government, national government, NGOs (and other civil organisations) and industry. These last two quadrats may include also farmers, but at different levels of organisation.

The links between these different bodies and stakeholders are expressed depicted through lines, as direct, indirect or needed. The closer they are, the closer the relationship is or should be.



Source: Diaz-Chavez et al. (2010)

Figure 9: Methodology for Mapping Stakeholders

For the social assessment of BioMates, 18 stakeholders based mostly in Europe and representing diverse sectors (academic, research, chemicals, biofuels, and oil) participated in discussions about different aspects of BioMates at a workshop[2] (held in April 2021). A further set of stakeholders along with members of the public also participated in an online questionnaire survey (run between April-May 2021), to give their views on a range of issues relating to the implementation of the BioMates concept (sample N=104). Their contributions were incorporated into the assessment whenever appropriate.

3.5 Assessment, uncertainty, and subjectivity

As with other life cycle assessment methodologies, SLCA seeks to minimize uncertainty and provide clearer and robust analysis to support the decision-making process. While these methods share an orientation towards uncertainty, they differ markedly in how they analyse subjective information, and in understanding the role such analysis play in reducing uncertainty about the results (UNEP/SETAC, 2009). Often, in SLCA subjective data (which tends to be qualitative) is the most appropriate to use (e.g., workers' perception of their degree of control over their work schedules and working environment). Nevertheless, uncertainty in the assessment can be reduced through critical scrutiny of data and sources, acknowledging limitations where they occur.

3.6 System boundaries

System boundaries specify which unit processes are part of the product system and need to be included in the assessment. The sustainability assessment of BioMates encompasses the entire value chain from 'cradle to grave', i.e., from biomass cultivation or collection of residues, respectively, to the distribution and usage of final products. The focus is on the provision of transportation fuels. All further products are considered as 'co-products'. The SLCA of BioMates focuses on stakeholders and impacts along the BioMates chain impacts assessed at the national level and in the sectors specified (Figure 10).

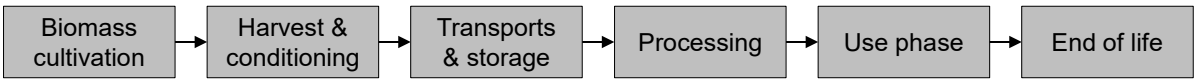


Figure 10: BioMates System Boundaries

3.7 Methodological harmonisation for assessment of BioMates

As discussed earlier, the social sustainability assessment employed here draws on tools and techniques from diverse methodologies. Table 2 illustrates the harmonisation of methodologies for the social assessment of BioMates. The overall social sustainability assessment of BioMates is thus based on the results obtained through this harmonised methodology.

[2] A full description and discussion of the workshop and its results is reported in D39.

Table 2: Harmonisation of Methodologies for Assessing BioMates

Harmonisation of methodologies for assessing BioMates

Countries	Czech Republic, Germany, Greece, Sweden
• SLCA (parameters /indicators)	√
• SIA (parameters/indicators)	√
• SHDB (risks and 'hotspots')	√
• Mapping of stakeholders	√
• Stakeholders' workshop	√
• Stakeholder's and public survey	√
• Health and Safety review	√
• Policy review	√

4 Social assessment of BioMates

Following the SIA/SCLA parameters identified earlier for the social assessment of BioMates, this section introduces, discusses, and synthesises the data results obtained for the BioMates countries. As can be seen in Table 1, the parameters that provide the contextual characterisation were assessed using data from a range of quantitative and qualitative data sources. Thus, for instance, SIA was based on indicators drawn from secondary databases (e.g., EUROSTAT, FAOSTAT, ILOSTAT, OECD; see ANNEX II for definition), whilst SLCA was based on indicators from the SHDB. Data was also drawn from academic sources and grey literature. In addition, where relevant and appropriate, the assessment also drew on primary data, that is, the perspectives of stakeholders obtained through discussions at the workshop as well as the views and opinions of stakeholders and members of the public obtained through the survey.

4.4 Trade of Feedstock

No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
1	Trade of feedstock	Incentives and barriers	EU/National	Feedstock	Qualitative Literature Survey Workshop

The BioMates project envisages the use of two types of advanced or advanced biomass feedstocks (i.e., not used as food or animal feed), comprising straw (from wheat and barley), and the perennial grass miscanthus, although forestry residues may also be used. These will be converted into the BioMates bio-oil for further co-processing with crude oil streams in conventional refineries.

Stakeholders at the workshop noted several issues about incentives and barriers to the trade of BioMates feedstocks. A key issue was the price of feedstocks, both for biomass and for crude oil. This was seen as an important risk and, therefore, a potential barrier, due to likely fluctuation and volatility. For biomass feedstocks, this could be addressed through state provision of incentives (including subsidies), legislation to

help maintain price stability, and by locking farmers and buyers into long-term contracts. Price was also identified as a risk for the co-feedstock crude oil, relating to levels, stability, and volatility.

A further potential barrier to biomass feedstock trade relates to the risk of availability, which links to volume, seasonality (i.e., whether available year-round), and competition with other uses (e.g., straw left on the ground post-harvest as soil cover for replenishment) and processes (e.g., other biorefinery uses). As with price, the provision of state incentives to farmers, and engaging farmers through long-term contracts were proposed as measures proposed to safeguard biomass availability. The origin of the biomass was also seen as an issue, which linked to a concern with whether it would entail importation (i.e., cross-boundary movement) and all associated costs (e.g., financial, environmental, social).

The survey results shows that nearly one half of respondents (46%) thought that the government should subsidise the cultivation of biomass for producing biofuels, although two fiths (41%) were against it, and nearly one tenth (12%) were unsure. Also, most respondents thought it important (44%) or very important (31%) that that crop producers receive state incentives to help expand the production and consumption of biofuels.

Other potential barriers identified by stakeholders and survey respondents to the trade of feedstock were: land use changes associated with crops for bioenergy/biofuels; the potential impacts of rapidly increasing non-food crop production on the production of food crops; lack of government incentives and the need to make them mandatory, particularly in the EU, where member countries are not obliged to provide subsidies to the same extent for farmers to grow non-food crops for biofuels. All these issues have been amply discussed in the literature on biofuels and hybrid fuels (e.g., Diaz-Chavez, 2011; Awudu and Zhang, 2012; Ekener- Petersen, Hoglund, and Finnveden, 2014; Hennig, Brosowski, and Majer, 2016; Goetz, German and Weigelt, 2017; Reboredo, Ramalho, and Pessoa, 2017; Hassan et al, 2018; van Dyk et al., 2019; Brown et al., 2020; Panoutsou et al., 2021).

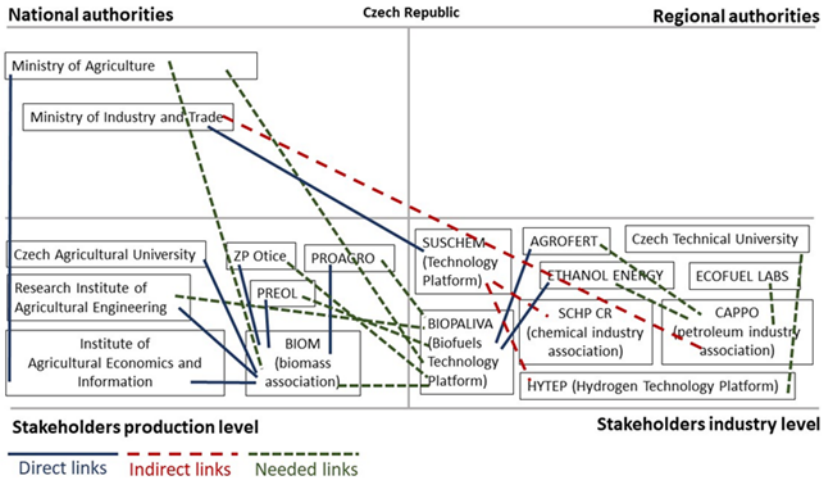
4.5 Identification of Stakeholders

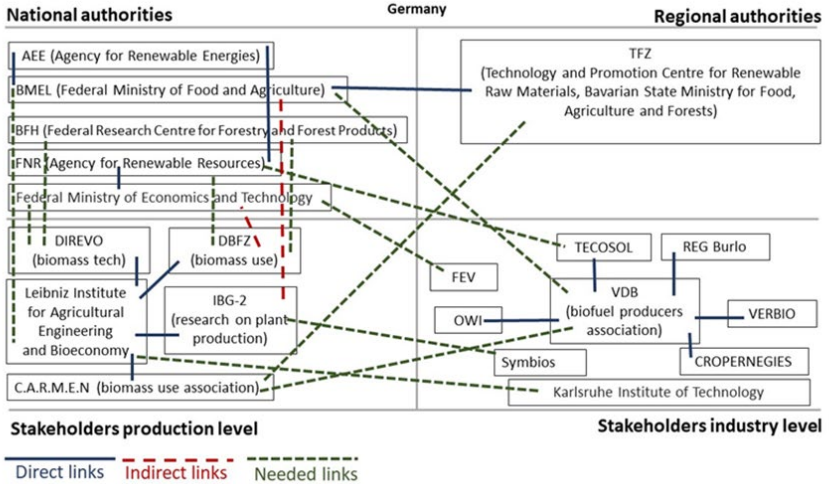
No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
2	Identification of stakeholders along the supply chain	Producers Regulators Business Traders	National Local	All	Qualitative Desk search Project partners

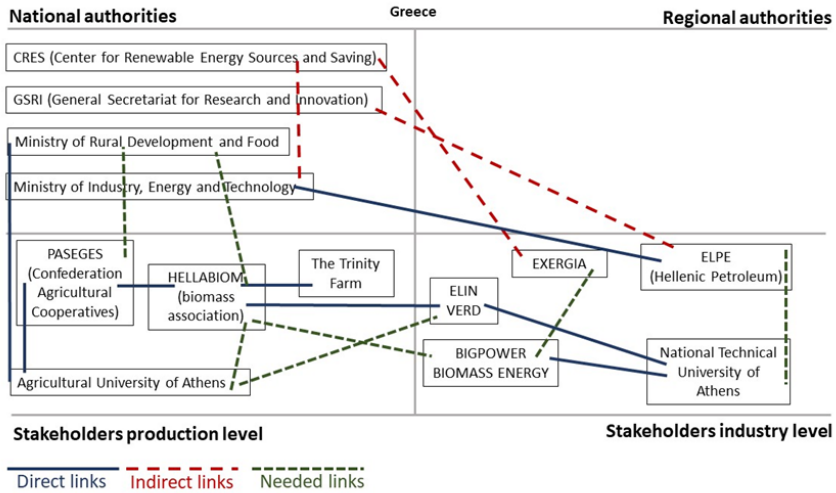
The mapping of stakeholders followed the method discussed previously (section 5.4). The aim was to trace the linkages between the different stakeholder categories. The stakeholders were identified through desk research, project partners, and participants at the workshop, to obtain a comprehensive, rather than exhaustive, selection of key stakeholders. The stakeholders and stakeholder linkages are shown in Table 3 for each of the BioMates countries.

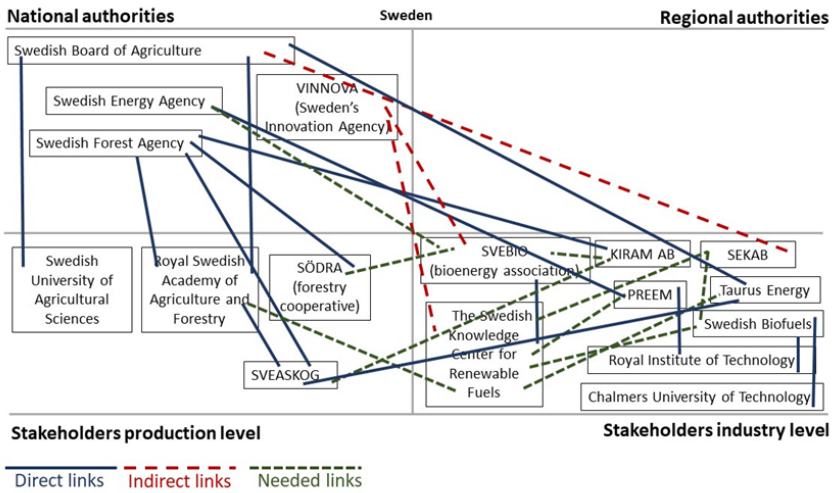
As can be seen, the linkages are traced between different stakeholders as direct, indirect and those perceived as needed, if not yet necessarily extant. The mapping of stakeholders aims to identify the key social actors that should collaborate for the implementation of the BioMates concept. It envisages a 'multi-actor approach', similar to that employed in projects funded by the EIP-AGRI (EC, 2021c). This entails bringing together farmers, farm advisor, scientists and other stakeholders to collaborate throughout a project's

Table 3: Mapping of BioMates Stakeholders









execution to develop novel practical solutions to emergent problems through knowledge exchange and innovation dissemination.

4.6 Policies and Regulations

No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
3	Policies and regulations	International National Regional Local	National International	All	Qualitative Literature Policy documents

A great variety of policy instruments are relevant to the BIOMATES chain at different geographical scales (e.g., the EU, national level, and supra-national), although the interest here is on the EU since it is the geographical remit of the project. As can be seen in Figure 11. BioMates falls within the remit of a very wide range of policy instruments, many of which also intersect.

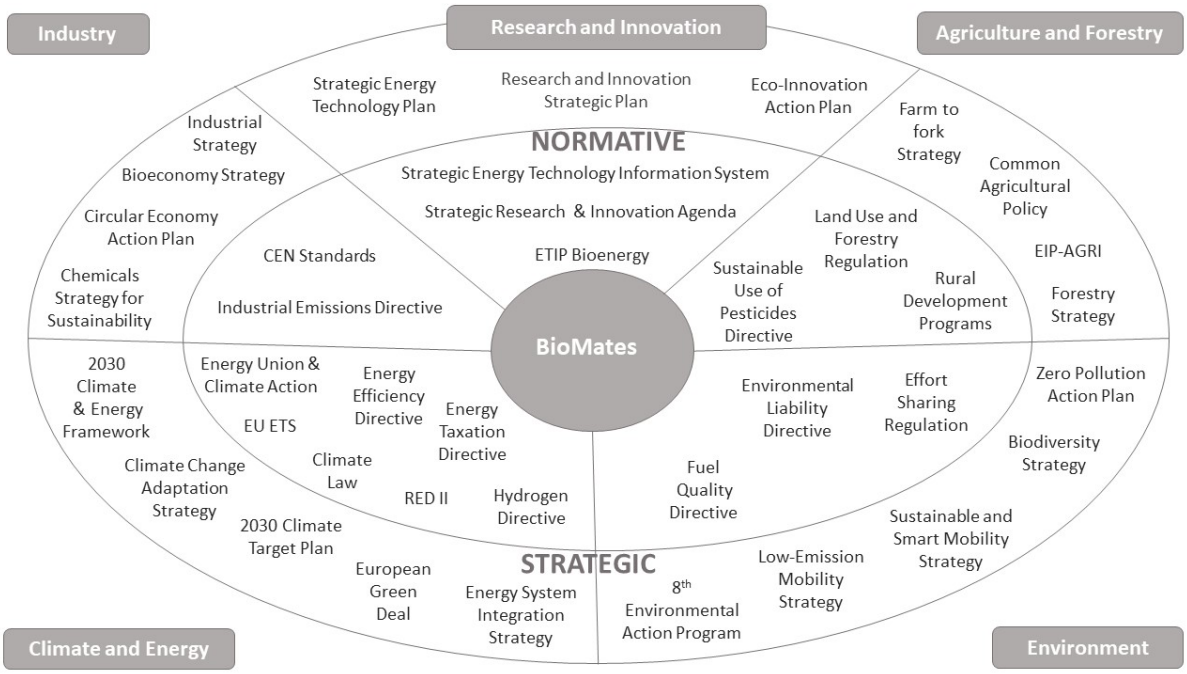


Figure 11: Policy Instruments Relevant to BioMates

The assessment focuses on the most relevant instruments to BioMates to highlight how they may enable, boost or hinder the scaling up of the BioMates concept to full commercial ventures to help reduce dependence on fossil fuels in the context of a recent momentous shift in policy and strategy for energy and climate change (but see ANNEX III for a description of further instruments).

4.6.1 The European Green Deal, Climate Law and the 'Fitfor55' package

In December 2019, the EC put forward the European Green Deal, a new overarching strategy aimed making Europe the first climate-neutral continent by 2050, as part of its commitments to 2015 the Paris Agreement. The European Climate Law, which came into force in July 2021, enshrines in binding legislation the Green Deals' goal to achieve climate neutrality, as well as setting an intermediate target for net GHG emissions by at least 55% by 2030, compared to 1990 levels. Also in July 2021, the EC adopted package of proposals ('Fitfor55') to overhaul the EU's climate, energy, land use, transport and taxation policy instruments to achieve this intermediate target. Key aims and measures are proposed within each of the following instruments (although many intersect). They are described in turn, and the implications for BioMates highlighted and discussed.

4.6.2 Land Use and Forestry Regulation ('LULUCF')

This regulation set a binding commitment for member states to ensure that accounted GHG emissions from land use, land use change or forestry are entirely compensated by at least an equivalent accounted removal of CO_2 from the atmosphere in the period 2021-2030, (the 'no debit rule', where GHG emissions cannot exceed GHG removals within the sector). It sets an overall EU target set for carbon removals from the atmosphere by natural sinks to enable the EU to reach climate neutrality in the land use, forestry and agriculture sectors by 2030. Emissions from biomass used in energy will now be recorded and accounted towards each member state target for 2030, with scope extended from forests to all land uses. Also, member states can buy and sell net accounted removals from and to other member states, to encourage them to increase CO_2 removals beyond their own targets. The regulation is being revised as part of the 'Fitfor55' package, and key changes include: abolishing the 'no-debit' rule; reinforcing member states obligation to submit integrated mitigation plans for the land sector; covering the whole land sector from 2031 by including non-CO2 emissions from the agriculture sector; introducing a carbon removal certification scheme that sets a value on mitigation actions and possible trade-in certificates, simplifying reporting requirements for member states, and integrating land sector synergies into the climate and energy framework (EUR-LEX, 2021b).

The regulation is relevant to BioMates insofar as it applies to the suppliers of the biomass feedstocks (i.e., straw from wheat and barley, miscanthus, forestry residues), with GHG emissions from agriculture and forestry to be accounted for and offset.

4.6.3 EU Forestry Strategy (revised)

This strategy replaces the EU Forest Strategy adopted in 2013 and revised in 2018. It aims to protect, restore and enlarge the EU forests to combat climate change, reverse biodiversity loss, and ensure multifunctionality and resilience of forest ecosystems. This is to be achieved by a host of actions, including: promoting a sustainable forest bioeconomy, ensuring sustainable use of wood-based resources for bioenergy, promoting non-forest based economic activities (e.g., ecotourism), ensuring forest restoration, and forest restoration and reinforced sustainable forest management for climate adaptation; reforestation and afforestation of biodiverse forests, including planting some 3bn trees by 2030, and providing incentives for forest owners and managers to improve the quantity and quality of forests (EUR-LEX, 2021c).

Forestry residues are one of the potential biomass feedstocks to be used in the BioMates concept, so this strategy is relevant, insofar as sets out the wider parameters for use and protection of forestry resources.

4.6.4 The Renewable Energy Directive (revised)

The original Renewable Energy Directive (RED, 2009/28) was the first EU legal instrument created to promote the use of renewable energy, setting binding national targets to be met by member states on the share of renewable energy in energy consumption across all economic sectors, which includes a sub-target for energy used in transport to be produced with renewable sources. Its key aim is to mandate and incentivise renewable energy to replace fossil fuels. The directive limits the share of unsustainable crop based biofuels and promotes certain types of biofuels, those produced from materials listed and defined in Part A of Annex IX. Member states use these materials to determine the levels of support to different types of biofuels under their national framework and the list of materials is to be reviewed every two years to add new materials, although none that are already in it can be removed before 2030. The directive has been amended substantially several times and recast in 2018 (REDII) to cover the period 2021-2030, and for the transport sector, it refocused EU support away from crop-based biofuels towards advanced fuels, such as advanced biofuels. The proposed revision of the directive is now being considered by the Council and the European Parliament, with adoption expected by the end of 2022.

As the EC notes, the proposed review of the REDII is to bring it into line with a host of other energy and climate legislation and policy initiatives that are also being reviewed or introduced in the 'Fit for 55% package'. Key proposed changes for RED II include new targets for energy consumption and GHG emission savings to be met by 2030. The headline target for reduction of GHG emissions is set at 40%, which now also covers indirect land-use change. The proposal is to increase renewable energy in the EU energy mix from 32% (set in 2018) to 40% by 2030. For the transport sector, the new target for GHG intensity reduction for fuels (out of all energy supplied to transport) is 13% compared to a liquid fossil fuel baseline GHG intensity, with an additional sub-target of 2.2% for advanced biofuels for transport energy, which are to be achieved through obligation on fuel suppliers.

The proposed revision removes multipliers towards the target (bar for aviation and maritime transportation), so fuels are now counted only once. The rationale behind this is that expressing the transport target as GHG intensity reduction dispenses with the need to use multipliers to promote renewable energy sources, since different sources save different amounts of GHG emission and contribute differently to a target. Thus, fuels that achieve higher GHG savings make a larger contribution towards the policy target and so are greatly encouraged. It also introduces a new 2.6% energy mandate for renewable fuels of non-biological origin which include renewable electrolysis hydrogen and electrofuels. These mandates exclude food-based biofuels. The provision remains binding only at the EU level, so member states are free to determine their national contributions and must submit their national energy and climate plan reviews by 2023. Indeed, member states have the option to lower their ambition on transport energy targets if they reduce their cap on crop biofuels below the maximum limit of 7%. However, final consumption of energy cannot be lower than the baseline national targets set for 2020, which for BioMates countries are: Czech Republic,13%; Germany, 18%; Greece, 18%; and Sweden, 49%, enforceable from transposition of the directive in June 2021 onwards.

The RED defines a series of sustainability and GHG emission criteria with which liquid biofuels and bioliquids used in transport must comply to be counted towards the overall RES target and to be eligible for financial support by public authorities. The revised proposal incorporates new and adjusted sustainability and GHG emissions saving criteria for biofuels and sustainability criteria for forest biomass (e.g., a ban on the use of biomass from primary and biodiverse forests, stumps and roots), as well as mandating member states to design support schemes based on the biomass cascading principle whereby woody biomass is used according to its highest economic and environmental added-value. Only those that

meet the criteria will be included in the gross final consumption of energy from renewable sources in each member state. Advanced biofuels produced from selected feedstocks can contribute a share of at least 0.2% the final consumption of energy in the transport sector in 2022, raising to minimum of 1 % in 2025, and no less than 3.5% in 2030. For fuels for road transportation their contribution will be twice their energy content, whereas for aviation and shipping, their share is 1.2 times, and for rail, 1.5. times.

The methodology that sets out the rules for the accounting system is yet to be developed but it will determine the share of biofuel for transport, resulting from co-processing with fossil fuels, as is the case of the final hybrid product obtained from the co-processing of the BioMates bio-oil with fossil sources. The directive also specifies the GHG emission saving from the use of biofuels, which for the transport sector will be at least 65% for biofuels consumed in the transport sector from January 2021 onwards. The revised directive also encourages the development of voluntary standards for producing sustainable biofuels, with member states designing support schemes for the cascading use of woody biomass for bioenergy (EUR-LEX, 2021a).

This directive is highly relevant BioMates since it determines what feedstocks can contribute to the share of transport energy intensity reduction. The agricultural residues to be used as feedstocks (wheat and barley straw) are covered in the feedstocks listed in Part A of Annex IX of the directive for conversion into advanced biofuels (item (e): straw) and so can contribute to the sub-target of 2.2% for advanced biofuels in transport sector energy. The crop miscanthus is covered in the same list of feedstocks in Part A of Annex IX (item (p): other non-food cellulosic material, which includes this crop), but as dedicated energy crop for transport fuel, it must not cause ILUC, or cause it only to a very limited extent and that such effect is mitigated appropriately. Forestry residues are also listed in Part A of Annex IX of the directive as appropriate for conversion into advanced biofuels (item (o): biomass fraction of wastes and residues from forestry; item (q) other ligno-cellulosic material except saw logs and veneer logs; EUR-LEX, 2021d). Hence, the choice of biomass feedstocks enables BioMates to make a tangible contribution to increased use of renewable energy in transportation and reduced GHG from the transport sector in the EU (and possibly in other geographical regions too), as intended since the inception of the project. The directive also allows member states flexibility in determining the targets when transposing it to their own national legislation. The deadline for national transposition of RED II was June 2021 (although it is not certain that all member states accomplished it), but it will have to be transposed again once the revised directive comes into force.

A pending issue is the definition of the accounting system that will determine the share of biofuels for transport that result from co-processing with fossil fuels, as is the case of the hybrid fuel that is the end-product in BioMates. The methodology will be specified through delegated acts by the EC by December 2021 (EUR-LEX, 2021d).

4.6.5 Effort Sharing (revised)

This regulation establishes annual binding GHG emission reduction targets from 2020 to 2030 for each member state for sectors not included in the EU ETS (building, agriculture, waste, small industry, transport). The aim is to achieve emission reduction across the EU of 30 % by 2030, compared to the 2005 baseline. The regulation is being revised as part of the 'Fitfor55' package to assign stronger reduction targets for each member state. National targets were previously upgraded in line with an EU-wide reduction of 40% by 2030 compared to 2005 in the sectors covered by regulation, so that they can contribute to the EU's 2030 climate ambition to reach at least 55% net GHG emission reductions by 2030 below 1990 levels. The review contains a legislative proposal to amend the legislation's binding annual GHG emission reductions for member states for 2021-2030 by at least 40 % compared to 2005 levels,

thereby raising it by 11% compared to the existing EU-wide target of a 29% emission reduction. Member states will contribute to the overall EU reduction by 2030 with targets ranging from 10% to 50% below 2005 levels. The targets for BioMates countries are 26% for the Czech Republic; 50% for Germany; 22.7% for Greece, and 50% for Sweden (EUR-LEX, 2021e).

This regulation is relevant to BioMates insofar as the concept is implemented in EU countries covered by it, contributing to the binding targets for reducing GHG emissions from the transportation section.

4.6.6 The Emissions Trading Scheme (revised)

The ETS is a cornerstone of the Union's climate policy and its key tool for reducing GHG emissions in a cost-effective and economically efficient way. It is the world's first major carbon market, and the largest multi-country, multi-sector GHG emissions trading system in the world. It works on the 'cap and trade' principle which limits the total GHG emissions allowed by all participants which then is converted into tradable emission allowances. Participants must monitor and report their emissions annually and surrender enough emission allowances. The directive has been amended several times. Phase 3 (2013-2020) set the cap for the EU as whole. The legislative framework of the EU ETS for phase 4 (2021-2030) was revised in 2018 to ensure it aligns with the EU target for emissions reduction for 2030 (by at least 40% relative to 1990) and contribution to the Paris Agreement, but it is now being revised to lower the overall emissions cap per economic sector, phase out free emission allowances for aviation, and include shipping for the first time. The sectors covered by the ETS must reduce their emissions by 43% compared to 2005 levels to achieve the EU's overall GHG emissions reduction target for 2030. The pace of emission cuts is also being ramped up, with the overall number of emission allowances decreasing at the annual rate of 2.2% (compared to the current rate of 1.74%) from 2021 onwards. Since 2012, aviation operators flying into or from an airport in the EU have been covered by the ETS, but proposed changes include its extension to shipping, revision of the rules for aviation emissions and establishing a separate emission trading system for road transport and buildings. It is also being reviewed in relation to its application to aviation to ensure that sector contributes to the emission reduction target in line with the 2030 Climate Target Plan and the Green Deal, and also as regards CORSIA (EC, 2021d).

As BioMates will lead to the production of hybrid fuels for air, road and water transportation, it falls within the remit of the ETS since the scheme covers emissions from aviation, and will now also be extended to include shipping, whilst a separate scheme will be set up to cover road transportation.

4.6.7 CO_2 emission performance standards (revised)

This regulation is being revised to curb rising GHG emissions in the transport sector, leading to a phase-out of sales of new internal combustion of passenger cars and new light commercial vehicles. Thus, new cars must cut their emissions by 55% from 2030 and 100% from 2035 compared to 2021, and all new cars registered from 2035 onwards are to be zero-emission. It is seen to complement the new ETS for road transport and addresses the supply of more fuel efficient and zero-emission vehicles, by setting requirements on vehicle manufacturers with regard to their new vehicle fleets. A key argument for the changed targets is that if no ambitious action is taken to achieve zero-emission road transport, other sectors of the economy would have to contribute more to the overall EU emission reduction targets. EURO 7 pollution standards, the new emissions standard is likely to be the final one until all cars become zero-emission. The details are expected to be announced late in 2021 (EUR-LEX, 2021f).

The proposal to phase out the sale of new ICE passenger and light commercial vehicles could be seen as a 'ban by stealth' that may more obviously limit the scope of the BioMates concept, since it will confine

the use of the hybrid fuel to ICE passenger and light commercial vehicles whose fleet in the EU will decrease overtime. But since the regulation does not contemplate heavy vehicles (i.e., trucks/lorries), and the hybrid fuel is also envisaged for use in aviation and maritime transport, there is still potential for market expansion of BioMates within those segments.

4.6.8 ReFuelEU Aviation Initiative (new)

The ReFuelEU Aviation Initiative comprises EU-wide harmonised rules for sustainable aviation fuels that will apply to fuel supplier and airline operators to create a level-playing field. It introduces targets for SAF and synthetic aviation fuels from 2025 to 2050. Fuel suppliers must blend increasing levels of SAFs in jet fuel taken on-board at EU airports, including synthetic low carbon fuels (minimum of 2% SAF, 5% in 2030, and 6% in 2050). Fuels must receive sustainability certification in accordance with the RED II (now also being revised) and biofuels from crops are excluded from these targets. Also, the shares of SAF and synthetic aviation fuels are calculated on a volume basis, in contrast to the accounting in RED II, which is on an energy basis. The proposed regulation directly binds obligated parties with non-compliance attracting penalties by member states. This initiative falls within the scope of the Sustainable and Smart Mobility Strategy, which aims to boost the uptake of SAFs and contribute to the EU increased climate targets for 2030 (55% reduction) and 2050 (climate neutrality) (EC, 2021e).

This initiative is highly relevant to BioMates, since its hybrid fuel is expected to be used as a jet fuel, and the biogenic content derived from agricultural residues will help contribute to SAF targets.

4.6.9 FuelEU Maritime Initiative (new)

The FuelEU Maritime initiative puts forward a common regulatory framework across the EU to increase the share of renewable and synthetic low carbon fuels (e-fuels) in the fuel mix of international maritime transport. This is so that the maritime sector can contribute to the EU's new ambition to cut GHG emissions by at least 55% by 2030 and achieve climate neutrality by 2050. It sets a maximum limit on the GHG content of energy used by ships calling at European ports. Being a regulation, it will be directly binding on ship operators, and applies to all energy used on ships at EU ports of call and on shipping between EU ports of call. It also counts as half of the energy used on voyages between an EU port and a third country and includes the additional requirement that ships must use on-shore power for all energy needs when at berth from 2030 onwards (EC, 2021f).

This initiative will also enable the market expansion of BioMates, since its hybrid fuel is expected to be used as a jet fuel, thus contributing to the lowering of GHG emissions in the maritime sector.

4.6.10 Energy Taxation Directive (revised)

The ETD establishes the framework for the taxation of electricity, motor vehicles and aviation fuels, and heating fuels in EU member states. The aim is to ensure to improve functionality in the EU internal energy market and avoid distortions of competition through different tax systems. This instrument is currently being revised as part of the 'Fitfor55' package to align with the taxation of energy products with EU energy and climate policies, promote clean technologies, and remove exemptions and reduced rates that encourage consumption of fossil fuels. The following are the key changes envisaged: the taxation of fuels according to their energy content and environmental performance, instead of volume; simplify the categorisation of products for taxation purposes; phase out exemption for certain products to ensure that fossil fuels can longer be taxed below minimum rates; remove full exemptions for fossil fuels used in air and maritime transportation within the region (EUR-LEX, 2021g).

This directive should benefit the BioMates hybrid fuel as regards energy content and environmental performance, although the fossil fuel content is likely to be subject to higher taxation due to loss of exemptions and increased minimum rates.

4.6.11 Fuel Quality Directive (2009/30)

Although not being currently revised this is a key instrument that aims to reduce GHG emissions and air pollutant emissions, setting carbon intensity reduction targets on fuel suppliers. It enabled the establishment of a single fuel market that ensures that vehicles can move anywhere in the EU using compatible fuels, and it applies to petrol, diesel and biofuels in road transport. It mandates that member states ensure a reduction of GHG emissions, with suppliers obliged to respect the target, by a minimum of 6% in 2020 and beyond. Member states must also monitor and report on GHG emissions intensity. Along with the RED, it regulates the sustainability of biofuels. For biofuels to be certified as sustainable, their GHG emissions must be lower than those from the fossil fuel they replace (between 50%-60%). Also, the feedstocks for biofuels cannot be sourced from land with high biodiversity or high carbon stock (EUR-LEX, 2021h).

This directive means that the hybrid fuel containing the BioMates bio-oil can be made available anywhere within the EU single market and can be certified as sustainable as long as its emissions are lower than conventional fossil fuels and the biomass feedstock sourced from appropriate land.

4.6.12 Biofuel incorporation policies in BioMates countries

As seen previously, in line with the EU legislation for GHG emission reductions, member states have an obligation to incorporate biofuels into their fossil fuels. This may comprise setting targets for overall biofuels incorporation or placing differentiated renewables obligation in petrol or diesel or both, or still both an overall biofuels obligation and distinct incorporation obligations in petrol and /or diesel. Currently, Germany and Sweden, do not have mandatory biofuels incorporation, relying solely on targets for the reduction of the carbon intensity of transport fuels. The ‘double-counting’ mechanism for biofuels is in place in many member states, again, except, again, in Germany and Sweden, but it is in the process of being implemented in the Czech Republic. The GHG reduction targets for transport fuels set out in the FQD requires the reduction of transport fuels’ GHG intensity is implemented in all member states (6% from 2020). Regarding tax incentives for biofuels or blended fuels, there are no distinct fiscal frameworks for biofuels. In Sweden, for instance, there is a tax cut based on CO_2 fuel content, whereas in the Czech Republic a reduced tax applies to the E85 blend. Key national biofuels policies BioMates countries are shown in Table 4. However, the proposed review of key policy instruments being carried out under the ‘Fitfor55’ package will likely entail important changes in biofuel incorporation policies in BioMates countries (e.g., the removal of ‘double counting’).

Table 4: Transposition of EU Biofuel Policies to BioMates Countries

Country	Policy/Legislation	Features
Czech Republic	Act No. 201/2012	regulates pollution and airpollution, lays down the rights and obligations of public administration and fuel producers
	Act No. 201/2012	Minimum volume of biofuels petrol - 4.1%; diesel – 6%; pure biofuels and biofuel content in blended fuels are exempt from tax
	Decree No. 133/2010	lays down the requirements for fuels, the monitoring of their composition and quality
Germany	1974/2013 German Federal Imission Control Act (BImSchG)	In January 2015, the biofuel quota was replaced with a GHG reduction quota, set at 6% from 2020 onwards, which can be achieved through use of discusse or electricity for road vehicles; there are very few incentives for promoting the use of renewable energy in the transport sector, and all tax relief for biofuels were terminated in January 2016.
Greece	Law No. 3054/2002	Since January 2019, transportation fuels must contain 3.3% bioethanol, or bio-ethers from biological origin from 2020 onwards
	FEK B 67/2009	Biodiesel quota of at least 7%
	Law No.4399/2016	Provides support to biofuels through different types of subsidies
Sweden	Act No. 2017:1201	From Jan 2020, the minimum volume of biofuels is 4.2% for petrol and 21% for diesel; there is also a tax exemption for biofuels (energy and CO2 taxes)
	Act No. 2010:598	Sustainability criteria for biofuels and bioliquids; biofuels must be certified

Source: RES-LEGAL (2021).

Although the parameter on policies and regulations generally refers to instruments that fall within the remit of BioMates, there was scope for using the SHDB to assess risks relating to overall governance in a country, namely, risk of corruption and fragility of the legal system. The results relating to risks in sectors relevant to BioMates are shown in Table 5. As can be seen in this table, the risk of corruption and fragility in the legal system is very high in the Czech Republic, high in Greece, but low in Germany and Sweden.

Table 5: Risks Related to Governance in BioMates Countries

Sectors	**Cereals**	**Crops**	**Wheat**	**Forestry**	**Chemicals**	**Electricity**	**Gas**	**Oil**	**Petro/coal**	**Transport**
Overall risk of corruption and fragility in the legal system										
Czech Republic	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH
Germany	L	L	L	L	L	L	L	L	L	L
Greece	H	H	H	H	H	H	H	H	H	H
Sweden	L	L	L	L	L	L	L	L	L	L

Key: the colours and risk levels are based on those used in the SHDB (2021): L = Low (green); Medium (yellow); H= High (red); VH = Very High (dark red); NA= Not Applicable (clear); ND = No Data (grey); NE= No Evidence (pink); NMW = Nationa Minimum Wage.

4.7 Potential Biorefinery location

No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
4	Potential biorefinery location/logistic	Availability of feedstock	National Local	Feedstock Transport Storage Biorefinery	Qualitative Literature Survey Workshop

Availability of feedstock is a key determinant of the viability of a biorefinery, and feedstocks typically account for 40-60% of the operating costs, therefore biorefineries are only likely to attract investment when sustainable provision of affordable feedstock can be assured (Caputo, 2005; Hennig, Brosowski, and Majer, 2016). Biomass production is crucial given that is generates the large share of impacts of whole chain, whilst also helping drive regional development. In particular, agricultural residues are set to play an important role in biomass provision to biorefineries, and even though availability from current farming practices may be regionally and seasonally limited, the supply chain for cereal straw is well established and the cultivation of the main crop component account for most of the costs involved (Star-COLIBRI, 2011).

As with the building of any refinery, the choice of location of a BioMates biorefinery will be based on a number of considerations, chiefly among them, the availability of biomass feedstock. Table 6 shows the production volumes for wheat and barley in BioMates countries for three years, with percent change calculated to show variability. This indicator is useful to point to potential availability of straw, two key feedstocks being piloted in BioMates, although it is not known what proportion of this straw is currently being used (issues related to feedstocks availability are discussed at length in D5.9).

Table 6: Crop Production in BioMates Countries

Crop	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Barley	tonnes			
2009	2003032	12288100	341084	1680900
2015	1991415	11629900	512628	1672300
2019	1718060↓	11591500↓	366580↓	1546500↓
Wheat	tonnes			
2009	4358073	25192350	2139472	2277900
2015	5274272	26549500	1458705	3300400
2019	4812160↓	23062600↓	979220↓	3476800↑

Source: FAOSTAT(2021)

Regarding barley, the data shows a decrease in production volumes between 2015 - 2019 across all countries, being most drastic in Greece (-28.5%), but also marked in the Czech Republic (-13.7%), less so in Sweden (-7.5%) but negligible in Germany (- 0.3%). Wheat production has also decreased in the same period in three countries, being most severe in Greece (-32.9%), marked in Germany (-13%), and significant in the Czech Republic (-8.7%), with Sweden being the only country where production increased (5.3%).

In addition, there is data available on the volumes wheat crop residues that are burned but could also possibly be recovered for use as biomass feedstock for BioMates, whilst at the same time saving on GHG emissions. Table 7 shows the tonnage of wheat residues burned in three different years, with percent difference calculated for tonnage between 2015 and 2019, to show the more recent trend. The most

pronounced change is the substantive decline in Greece (-30%), followed by a more modest reduction in Germany (-5%), whist the levels of wheat residues being burned increased in Sweden (2.6%) and slightly less in the Czech Republic (1.2%).

Table 7: Wheat Residues Burned in BioMates Countries

Crop	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Wheat		tonnes		
2010	333430	1319079	294993	158840
2015	331928	1313080	200856	183020
2019	335780↑	1247240↓	140196↓	187796↑

Source: FAOSTAT(2021)

The availability of feedstock, in turn, is conditioned by various factors, particularly price. Table 8 shows the producer prices for wheat and barley for three years to indicate variability. Prices for wheat have increased in Germany, the most marked (6.5%), but less markedly both in the Czech Republic (1.8%) and Greece (1.9%), whereas in Sweden prices declined (-2.1%). For barley, prices grew very markedly in Germany (19.2%), and they also grew in Sweden (8.5%) and the Czech Republic (6.7%) but declined in Greece (-3.7%).

Table 8: Producer Prices in BioMates Countries

Crop	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Soft Wheat		Euros per 100 kg		
2010	13.42	14.95	16.46	16.99
2015	15.48	16.15	19.40	15.10
2020	15.76↑	17.21↑	19.77↑	14.78↑
Barley		Euros per 100 kg		
2010	12.33	N/A	16.29	14.36
2016	14.91	12.60	16.20	12.43
2020	15.91↑	15.03↑	15.60↓	13.49↑

Source: EUROSTAT (2021; online data code: APRI_AP_CRPOUTA)

A further dimension of interest is that of changes in crop production area which may highlight issues around productivity. Table 9 shows data for the area harvested for barley and wheat in BioMates countries for three years, although changes over the last few years are of greater interest. The size of the harvested area for barley increased in Sweden (9.3%), and in Germany (4.4%), but it declined markedly in Greece (-28%), followed by a sizeable decline in the Czech Republic (-14.5%). For wheat, the area harvested declined drastically in Greece (-30%), but much less so in Germany (-5%), whilst it increased in Sweden (2.6%) and also in the Czech Republic (1.2%).

Table 9: Area Harvested in BioMates Countries

Crop	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Barley		hectares		
2009	454820	1877894	127768	361800
2015	365946	1621800	184289	318830
2019	319580↓	1708800↑	132570↓	291760↑
Wheat		hectares		
2009	831300	3226036	779813	374800
2015	829820	3282700	502141	457550
2019	839450↑	3118100↓	350490↓	469490↑

Source: FAOSTAT (2021)

Thus, the data shows a trend for decreasing production levels of wheat and barley recently in BioMates countries in relation to the middle of last decade (most drastically in Greece), but the picture is rather mixed regarding changes in harvested area size with growth in decline for both crops, although it declined and substantially in Greece, again, for both crops. Regarding production prices, prices for both wheat (bar Sweden) and barley (bar Greece) have tended to increase. Nevertheless, a recent forecast of feedstock potential availability based on rates of growth of cultivated areas in the EU up until 2030 suggests that wheat and barley straw will increase only marginally (Wietschel, Thorenz, and Tuma, 2019).

Regarding miscanthus, although no similarly detailed data is available, it was estimated that only around 20,000 ha of miscanthus were commercially grown in the EU in the mid-2010s (Lewandowski et al., 2016). Miscanthus is also seen as being best suited for cultivation on marginal land, that is, land that is less suitable for conventional crop production. But there is debate about what constitutes marginal land (Raman et al., 2015; Elbersen et al., 2019), since at least two meanings can be identified, one that refers to land that is unsuited for food production, whilst the other refers to land whose economic value is marginal (Shortall, 2013). Studies also show that lack of knowledge, technical equipment and integration into a structured biomass market may discourage farmers from cultivating this perennial bioenergy crop (Fradj et al., 2020).

4.8 Land Use/Tenure

No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
5	Land (use/tenure)	• Availability in EU • Ownership and rights	National	Feedstock	Quantitative (FAOSTAT) (EUROSTAT) Indicators: • Used land • Unused land • Fallow land

A range of indicators are used in this section to show changes in patterns related to land use. Before introducing these, it is useful to consider the geographical distribution of the population in the four BioMates countries. These are shown in Table 10.

Table 10: Population Distribution in BioMates Countries

Population and geographical distribution	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Population (million/2020)	10.7	83.1	10.7	10.3
Population in predominantly rural areas (%)	21.2	15.6	31.3	9.0
Population in intermediate regions (%)	53.5	40.8	23.6	51.3
Population in predominantly urban areas (%)	25.3	43.6	45.2	39.7
Rural areas share of land (2018/%)	84.2	66.6	93.2	64.2
Sources: Human Development Index (2021), EC Statistical Factsheets (2021)				

The share of different types of land use in the four BioMates countries for 2019 are shown in Table 11. As can be seen, three of these have proximate proportions of land area as agricultural land, apart from Sweden, which has the smallest proportion. The shares of land given over to cropland is also proximate

between the Czech Republic and Germany, but just over one quarter in Greece, and again, much smaller in Sweden. Forest land, in turn, land corresponds to over two-thirds of the land area in Sweden, the largest share of land in any of the countries, although it accounts for proximate share in the other countries.

Table 11: Land Use as Share of Land Area in BioMates Countries (%)

2019	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Agricultural land	45.64	47.7	47.35	7.38
Cropland	32.79	34.1	24.99	6.25
Forest land	34.65	32.68	30.27	68.7

Source: FAOSTAT (2021)

Data about the size of agricultural land is shown in Table 12 for BioMates countries in three separate years. It can be seen that there has been an expansion in agricultural land, albeit small, in the Czech Republic (.85%), Germany (0.39%), but a decrease in Greece (-1.55%) and Sweden (-0.70%).

Table 12:Agricultural Land Area in BioMates Countries

Agricultural land (1000 ha)	*Czech Republic*	*Germany*	*Greece*	*Sweden*
2009	3545	16886	7560	3067
2015	3494	16731	6199	3028
2019	3523↑	16666↓	6103↓	3004↓

Source: FAOSTAT (2021)

Regarding the area of arable land, the data in Table 13 shows a general decline in the four countries, although less marked in the Czech Republic (-0.24%), than in relation to Germany (-1.1%), which is also lower than the decline in Greece (-1.6%) and Sweden (-1.4%).

Table 13: Arable Land in BioMates Countries

Arable land (1000 ha)	*Czech Republic*	*Germany*	*Greece*	*Sweden*
2009	2581	11945	2547	2627
2015	2490	11846	2171	2575
2019	2484 ↓	11714↓	2136↓	2540↓

Source: FAOSTAT (2021)

The area of cropland in the four BioMates countries has also declined (Table 14), most markedly in Greece (-1.9%), followed by Sweden (-1.4%), and Germany (-1.15%), being the slightest in the Czech Republic (-0.2%).

Table 14: Cropland in BioMates Countries

Cropland (1000 ha)	*Czech Republic*	*Germany*	*Greece*	*Sweden*
2009	2620	12145	3686	2630
2015	2536	12051	3282	2578
2019	2531↓	11913↓	3221↓	2543↓

Source: FAOSTAT (2021)

In terms of forest land, the only change in area between the last two years shown in Table 15 was an increase in the Czech Republic (0.3%), so forest area in the remainder countries stabilised.

Table 15: Forest Land in BioMates Countries

Forest land (1000 ha)	*Czech Republic*	*Germany*	*Greece*	*Sweden*
2009	2655	11403	3871	28082
2015	2668	11419	3901	27980
2019	2675↑	11419	3901	27980

Source: FAOSTAT (2021)

The area of grassland in BioMates countries is shown in Table 16 for two years for which there is data available. The data shows that the area of permanent grassland increased in Czech Republic (1.6%), Germany (1.54%), and Sweden (0.7%), but that it declined in Greece (-11.6%). Table 16 also shows data for unused permanent grassland that is eligible for subsidies. This are increased the most in the Czech Republic and very markedly (121.4%), and also grew in Greece (4.0%), but declined in Germany (17%), whereas no data is available for Sweden (no subsidies available).

Table 16: Grassland in BioMates Countries

Grassland area	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Permanent	hectares			
2013	960,080	4,620,980	2,102,380	448,650
2016	944, 890↓	4,692,000↓	1,859,250↓	451,940↑
Permanent agricultural grassland not in use (eligible for subsidies)	hectares			
2013	4,350	18,590	7,600	0
2016	9,630	15,440	7,910	0

Source: EUROSTAT (2021; online data code: EF_LUS_PEGRASS)

Although data about the size of unutilised agricultural areas is not available for recent years, the data in Table 17 gives a sense of the potentially available land and agricultural holdings that could be converted for use for cultivation of miscanthus.

Table 17: Unutilised and Fallow Land and Holdings

2016	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Unused agricultural area (ha)	4,830	26,170	128,670	0
Unused agricultural holdings	480	9,030	66,520	0
Fallow land (ha)	18,590	311,960	126,930	172,500
Agricultural holdings with fallow land	2,050	7,3150	82,820	23,080

Source: FAOSTAT (2021; online data codes: EF_LUS_MAIN; EF_LUS_ALLCROPS)

Another two categories of land are of interest, classified as special areas, as shown in Table 18, again with data for only two years. Regarding the size of wooded areas, Germany shows the largest increase (8%), with growth also recorded for Sweden (1.3%), whereas Greece has seen the greatest decline (-16%), followed closely by the Czech Republic (-13%). The area for short-rotation coppices grew in three countries, being the most marked and sizeable in the Czech Republic (99.7%), followed by an also

significant increase in Germany (52.5%), but much less so in Greece (1.63%), whereas Sweden that area shrank (-4.1%).

Table 18: Special Areas in BioMates Countries

Special Areas	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Wooded	hectares			
2013	1,520,460	1,303,200	38,990	3,382,410
2016	1,321,390	1,404,230	32,750	3,336,930
Short-rotation coppice	hectares			
2013	350	3,580	8,200	11,400
2016	1,240	5,460	9,540	10,930

Source: EUROSTAT (2021; online data code: EF_LUS_SPAREA)

Land tenure is also another important indicator of patterns of ownership and tenancy in rural areas in BioMates countries. Table 19 shows tenure data according to gender for 2016. As can be seen, more holdings are owned across the four countries than are held by tenants, and men make up the vast majority of owners and tenants in all countries. Germany has the highest ratio of men's ownership to women's (9.8:1), followed by the Czech Republic (7.3:1) and Sweden (5.3:1), whilst Greece has the lowest ratio (1.9:1), or the least concentration of land ownership by gender. Regarding the ratio of men's tenancy to women's, Germany has the highest ratio (9.9:1), followed by Sweden (8.6:1) and the Czech Republic (7.6:1), whilst Greece, again, has the lowest ratio (1.8:1).

Table 19: Tenure of Agricultural Holdings by Gender in BioMates Countries (2016)

Tenure/Gender	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Owners	*Number of holdings*			
Men	18,860	220,510	424,950	46,250
Women	2,580	22,400	221,370	8,660
Total	23,750	246,780	646,790	58,960
Tenants	*Number of holdings*			
Men	12,190	183,710	99,420	20,260
Women	1,600	18,380	53,540	2,330
Total	16,520	205, 980	153,070	25,510

Source: EUROSTAT (2021; online data code: EF_MP_TENURE)

These changing patterns in land use in the four regions reflect various dynamics (e.g., intensification, abandonment, concentration) that are likely conditioned both by local and wider social, economic, political and cultural processes (e.g., increased investment on land, increased employment in agriculture, purchase of smaller concerns by large agri-business corporations, mechanisation, export-orientation, etc).

Finally, a further indicator relevant use of fertilisers. Table 20 shows the data for consumption of fertiliser in each BioMates country, with percentage change calculated for 2018 in relation to 2015. The data shows a mixed picture, with decreased use of fertilisers in Germany (-18%) and in the Czech Republic (-9.3%), but increased use in Greece (13%), and some increase in Sweden (4%). The reasons for should changes may relate to intensification of production, quality of local soils, crop productivity or use of efficient crop varieties. One of the potential co-products of BioMates is biochar that can be used as a fertiliser to off-set any detrimental soil effects of removal of wheat and barley and their straw and from the harvesting of miscanthus.

Table 20: Fertiliser Consumption in BioMates Countries

Consumption	*Czech Republic*	*Germany*	*Greece*	*Sweden*
	kg per hectare of arable land			
2011	100.6	191.5	159.7	85.1
2015	192.3	202.3	118.3	96.5
2018	174.4↓	166.5↓	133.3↑	100.4↑

Source: FAOSTAT (2021; online data code: AEI_FM_USEFERT).

4.9 Community participation

No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
6	Community participation	Acceptance of biorefinery • Feedstock • Technologies • Products Other involvement	National Local	Feedstock Transport Storage Biorefinery	Quantitative (EUROSTAT) Survey Qualitative SHDB Workshop (stakeholders/public)

This parameter relates to opportunities for community participation in different facets of projects such as BioMates, such as access to rural land, the gender make-up of the rural labour force, the concentration of land holdings, and also includes social acceptance of key features of the project, particularly the use of biomass feedstocks, technologies and products.

Purchase prices for agricultural land may potentially deter newcomers into agricultural production as landowners, and much more so where land values are increasing. Table 21 shows the agricultural prices for both arable land and permanent grassland in three BioMates countries (no data available for Germany), with percentage difference calculated for 2019 in relation to 2015 prices. As can be seen, prices for arable land in the Czech Republic have increased massively (69.5%), representing the largest increase among the countries, although they also in Sweden (16%), but actually declined in Greece (-4.5%). Regarding permanent grassland, broadly the same pattern is observed. Prices jumped up considerably (55%) in the Czech Republic, representing the largest increase, followed at quite some distance by the price increase in Sweden (11.5%), whereas in Greece, prices declined (-7.3%).

Table 21: Agricultural Prices for Arable Land in BioMates Countries

Period	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Arable land		Euros per hectare		
2011	1,836	N/A	15,393	6,811
2015	4,775	N/A	12,633	7,751
2019	8,095↑	N/A	12,064↓	9,019↑
Permanent grassland		Euros per hectare		
2011	2,232	N/A	6,177	2,370
2015	3,495	N/A	4,674	2,897
2019	5,414↑	N/A	4,333↓	3,230↑

Source: EUROSTAT (2021; online data code: APRI_LPRC)

Participation in farm work according to gender is also of interest since it raises issues around income earning opportunities in rural areas. Data for farm workers by gender for two years for BioMates countries are shown in Table 22. The figures for male workers show a decline across all countries, being more marked in Germany (-5.5%) and in Sweden (-2.7%), but slightly less in Greece (-1.7%) and the Czech Republic (-1.3%). Changes in the pattern of employment of women in farm work show a trend towards decline in Germany (-11%), the most marked, followed by Greece (-5.8%), and Czech Republic (-1.6%), although Sweden bucks the trend, showing a slight increase (1.8%). Overall, then, although there is a general decline in farm labour, it is more marked amongst women. However, as with land ownership and tenancy, the ratio of men to women in farm show that men predominate, although they are much lower. Focusing just on the data for 2016, the ratios are proximate for Germany (2.09: 1) and the Czech Republic (2.08:1), and lower still but proximate for Sweden (1.75:1) and Greece (1.69:1),

Table 22: Farm Labour Force According to Gender in BioMates Countries

Gender	*Czech Republic*	*Germany*	*Greece*	*Sweden*
	Directly employed by the farm on a regular basis			
Men				
2013	89,160	468,040	765,820	84,560
2016	88,020↓	442,210↓	753,060↓	82,310↓
Women				
2013	42,970	238,210	472,670	46,150
2016	42,270↓	211,550↓	445,320↓	46, 970↑

Source: EUROSTAT (2018; online data code: EF_LF_MAIN)

Of interest too are two other indicators, drawn from the SHDB for four relevant sectors, relating to levels of commercial labour (i.e., contractual labour) in rural sectors and size of agricultural land holdings, which can point to concentration or dispersion. Table 23 with data shown for the BioMates countries. As can be seen, the presence of commercial labour in rural sectors is very high in Germany and Sweden, and high in the Czech Republic. This translates as more opportunities for income-earning in these sectors in these countries, in contrast to Greece, where prospects may be limited, given the low commercialisation of labour in these sectors. Regarding the presence of large agricultural land holdings, the levels are low in the Czech Republic and in Greece. But they are high in Germany and very high in Sweden, which points to concentration by large businesses, likely at the expense of small farmers, which can be a problematic development, since small farms play a central role in the economic fabric of rural areas (e.g., by preserving cultural heritage, maintaining social life and rural life). Raman et al. (2015) note, for instance, that the lignocellulosic-biorefinery model presupposes greater efficiency from economies of scale which in turn requires large commercial enterprises able to manage globally distributed operations. Yet, ironically, this can lead to the amalgamation of smaller farms and the hollowing-out of rural communities; hence, more attention to issues of ownership of land, resources and operations is required to open up smaller-scale partnerships or social enterprise models (Raman et al., 2015).

Table 23: Characteristics of Agricultural Labour and Holdings in BioMates Countries and Sectors

Sectors	**Cereals**	**Crops**	**Wheat**	**Forestry**
Commercial Labour in Agriculture, Forestry and Fishing				
Czech Republic	H	H	H	H
Germany	VH	VH	VH	VH
Greece	L	L	L	L
Sweden	VH	VH	VH	VH
Large Agricultural Land Holdings				
Czech Republic	L	L	L	L
Germany	H	H	H	H
Greece	L	L	L	L
Sweden	VH	VH	VH	VH

Key: the colours and risk levels are based on those used in the SHDB (2021): L = Low (green); Medium (yellow); H= High (red); VH = Very High (dark red); NA= Not Applicable (clear); ND = No Data (grey); NE= No Evidence (pink); NMW = National Minimum Wage.

The survey of stakeholders and the wider public addressed questions about biofuels and hybrid fuels, including the use of biomass feedstocks and the wider role of biofuels in society and local development to gauge social acceptance. Most respondents agree that biofuels help create jobs in rural areas (86%) and that they can also help increase farmers' income (70%), and that the range of fuel crops should be widened top encourage expansion of the biofuels market (78%). But most (75%) also thought that the state should provide incentives to crop growers, and also tax credits to biofuel producers (83%). But whilst less than half (46%) thought that the government should subsidise the cultivation of biomass, over two thirds (68%) thought that it should subsidise biofuels production. Over one half (55%) thought that biofuels should be made only from non-food crops, but whilst about one third (34%) thought that such crops should be grown in their own country, the same proportion (34%) disagreed. This latter result size may likely awareness of the fact that this kind of exclusion could the principle of the single market in the EU since a majority of respondents (62%) were European residents.

4.10 Quality of life

No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
7	Quality of life	Material living conditions • Income • Consumption • Material conditions	National Local	N/A	Quantitative

This parameter relates to different aspects of quality of life that fall outside the scope of the 'product lifecycle' approach that applies to other parameters. Nevertheless, it is relevant to consider these different aspects since the implementation of the BioMates concept has wider societal implications and aims to contribute to social sustainability. A first indicator relates to elements of life satisfaction. Table 24 shows how adult men and women of various levels of education in BioMates countries rated their life satisfaction in relation to two issues in 2018 on a scale of 0-10 (with 10 being total satisfaction). Firstly, in

relation to financial situation, the ratings for men and women converge in the Czech Republic and Germany and indicate a moderate degree of satisfaction. They are also proximate for men and women in Greece but the rating there is on the mid-scale, and whilst they are also similar for men and women in Sweden, the ratings there are the highest. This pattern is broadly repeated in for the life satisfaction in relation to time use.

Table 24: Average Rating of Life Satisfaction in BioMates Countries

Rating 0-10 Age ≥ 16 All levels of education	*Czech Republic*		*Germany*		*Greece*		*Sweden*	
	Men	*Women*	*Men*	*Women*	*Men*	*Women*	*Men*	*Women*
Financial situation								
2018	6.8	6.6	6.8	6.7	5.3	5.1	7.7	7.6
Time use								
2018	6.9	6.9	6.7	6.7	5.6	5.5	7.3	7.4

Source: EUROSTAT (2021; ILC_PW01)

Another important dimension of quality of life is income since it enables consumption of key goods and services essential to social reproduction. Table 25 shows the mean net income for both men and women in the BioMates countries at three points in time, with percent difference used to report changes between 2010-2019. As can be seen, the levels of net income increased in 2019 relative to 2015, for both men and women in the Czech Republic, in Germany and Greece, but declined in Sweden. But there was variation on the magnitude of change across the countries. Thus, in the Czech Republic, income increased by 36% for men, and 34.5% for women. In Germany, it increased by 12.5% for men, and 11.8% for women. In Greece, the increase was 8.5% for men, and 8.9% for women. The decrease in Sweden was much more marked for women (-3.3%) than for men (-0.85%).

Table 25: Mean Equivalised Net Income in BioMates Countries (% of population)

Mean ncome Euros	*Czech Republic*		*Germany*		*Greece*		*Sweden*	
age (16-64) and gender	*Men*	*Women*	*Men*	*Women*	*Men*	*Women*	*Men*	*Women*
2010	8,540	8,222	22,895	21,932	14,780	14,518	21,078	20,873
2015	8,957	8,649	25,074	23,891	8,855	8,756	28,552	28,604
2019	12,220↑	11,630↑	28,218↑	26,708↑	9,607↑	9,532↑	28,310↓	27,668↓

Source: EUROSTAT (2021; ILC_DI03)

A further indicator that relates to quality of life is the ability to 'make ends meet' (i.e., to earn enough income to provide for basic needs), a subjective non-monetary measure. Table 26 shows the data for households that have experienced some degree of difficulty in making ends meet, at three points in time in BioMates countries. As can be seen, the trend across the countries was for a decline in the proportion of households experiencing any degree of difficulty, with the exception of Sweden, which bucked the trend, and more markedly amongst those experiencing some difficulty, although that category also experienced a slight increase in 2019.

Table 26: Ability to Make Ends Meet in BioMates Countries

Year/Country	*Czech Republic*	*Germany*	*Greece*	*Sweden*
% Households making ends meet with great difficulty				
2010	8.4	2.8	24.2	3.5
2015	7.8	2.6	38.2	3.2
2019	3.3↓	1.4↓	38.2	3.3↑
% Households making ends meet with difficulty				
2010	19.1	6.1	34.2	4.7
2015	18.8	5.0	39.5	3.9
2019	9.8↓	3.7↓	33.3↓	4.3↑
% Households making ends meet with some difficulty				
2010	38.6	12.7	24.0	9.0
2015	37.8	10.2	16.6	7.0
2019	28.4↓	9.0↓	18.8↑	11.6↑

Source: EUROSTAT (2021; online data code: ILC_MDES09)

4.11 Rural development and infrastructure

No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
8	Rural development and Infrastructure	Access to • Sanitation • Water Rural development	National Local	Feedstock Transport Storage Biorefinery	Qualitative SHDB

For this parameter, two key issues related to rural infrastructure are access to sanitation and water. They were assessed using SHDB data BioMates countries, which focuses on the level of risk of lack of access to these infrastructural services within a country. The results are shown in Table 27where it can be seen that the risk was identified as low across all BioMates countries. This is important, given the proportion of the population living predominantly in rural areas in these countries, notably in Greece (31%) and the Czech Republic (21%), being less sizeable in Germany (16%) and Sweden (9%).

Table 27:Risk Related to Access to Water and Sanitation in BioMates Countries

Sectors	Cereals	Crops	Wheat	Forestry	Chem	Electricity	Gas	Oil	Petro/coal	Transport
	Risk of access to an improved source of water and sanitation (rural)									
Czech Republic	L	L	L	L	L	L	L	L	L	L
Germany	L	L	L	L	L	L	L	L	L	L
Greece	L	L	L	L	L	L	L	L	L	L
Sweden	L	L	L	L	L	L	L	L	L	L

Key: the colours and risk levels are based on those used in the SHDB (2021): L = Low (green); Medium (yellow); H= High = Very High (dark red); NA= Not Applicable (clear); ND = No Data (grey); NE= No Evidence (pink); NMW = National Minir Wage.

A further indicator is that about the quality of roads. Although the available data does not distinguish between rural roads and roads elsewhere, there is data about the quality of roads, as shown in Table 28 for the BioMates countries. As can be seen quality is assessed through a ranking system, with average

scores for countries from two different years used to help gauge the quality ranking for any of the countries ranked that year, as illustrated by BioMates countries. The data shows that Germany and Sweden scored the highest in 2010, with ranks sitting well above the average, whilst Greece ranked just above the average, and the Czech Republic, below it. In 2019, Germany and Sweden had the same ranking score which were well above the average score, whilst Greece ranked above the average, and the Czech Republic, again, ranked below the average. In terms of change in individual scores, the Czech Republic improved its position (9.8% increase), and so did Greece (11.4% increase) whilst the ranking lowered for Germany (17.4% decrease) and Sweden (5.7% decrease). Road quality is important as road transportation is an integral aspect of the BioMates chain (i.e., the transportation of feedstocks, the pyrolysis oil, the processed bio-oil), with three different configurations of the biorefinery processes set up envisaged ((see illustrations about logistics in Annex I).

Table 28: Quality of Roads in BioMates Countries

Quality rank: 1(low) - 7(high)	*Czech Republic*	*Germany*	*Greece*	*Sweden*
2010 Average (138 countries)= 4.02 points	3.55	6.42	4.13	5.71
2019 Average (141 countries) = 4.07 points	3.90	5.30	4.60	5.30

Source: The Global Economy (2021)

4.12 Job creation and wages

No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
9	Job creation and wages	• Jobs created (feedstock production/residues collection) • Jobs created (biorefinery) • Jobs created (transportation) • Wages paid according to national/regional regulations (minimum wage)	National Local	Feedstock Transport Storage Biorefinery	Quantitative (EUROSTAT) Indicators • GDP/PPS • Employment • Economic activity • Unemployment • Risk of poverty • Agricultural income • Agricultural GDP • Fertiliser expenditure

This parameter is assessed through a variety of indicators relating to employment, with emphasis on the agricultural sector, given the use of biomass feedstocks and that the conversion technologies are expected to be sited in biorefineries set up in rural areas. The first indicator is the share of agricultural GDP in Biomates countries in 2020, shown in Table 29. It can be seen that the largest contribution of agriculture to GDP is by Greece, followed by the Czech Republic and Sweden, with Germany having the lowest contribution.

Table 29: Agriculture as % of GDP

Year/country (2020)	*Czech Republic*	*Germany*	*Greece*	*Sweden*
GDP (Million Euros)	213,660	3, 332,230	165,830	472,262
Agricultural GDP (Million Euros)	5,243	21,912	8,172	8,670
% of GDP	2.5	0.6	4	1.6

Source: EUROSTAT (2021)

Data on employment in different key sectors of the economy in BioMates countries is shown in Table 30. Two different points in time are shown, with percentage change calculated for employment in agriculture. As can be seen, the number of workers in agriculture are much lower than in other sectors, by several orders of magnitude. In terms of change in agricultural employment, all countries experienced a contraction, which was most marked in Germany (-18.5%); and Greece (-16.5%), but also notable in Sweden (-9.5%) and the Czech Republic (-6.7%).

Table 30: Sectoral Employment in BioMates Countries

Year/country	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Agriculture				
2010 (000)	151	626	544	95
% of total employment	3.1	2.1	12.4	2.1
2019 (000)	141	511	454	86
% of total employment	*2.6↓*	*1.2↓*	*10.0↓*	*1.3↓*
Industry (including construction)				
2010(000)	1 856	10 756	860	898
2019(000)	1 975	11 524	600	940
Manufacturing				
2010(000)	1 236	7 580	468	545
2019(000)	1 455	8 013	377	514
Services				
2010(000)	2 878	26 612	29 86	3 531
2019(000)	3 186	30 361	28 56	4 105

Source: EUROSTAT (2021; online data code: urt_pjanaggr)

A further indicator of relevance is employment rate, as shown in Table 31 which contains both data for the labour force and by gender for three years spanning a decade in BioMates countries. A first issue to note is the greater participation among men than among women in all countries in both years. Secondly, employment increased in all countries bar Greece

Table 31: Employment Rate in BioMates Countries

Employment (20-64) as % of total population	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Total	%	%	%	%
2010	70.9	75.0	63.8	78.1
2015	74.8	76.5	54.9	80.5
2020	79.7↑	80.0↑	61.1↓	80.8↑
Men	%	%	%	%
2010	79.6	80.4	76.0	81.1
2015	83.0	82.3	64.0	82.5
2020	87.2↑	83.1↑	70.7↓	83.2↑
Women	%	%	%	%
2010	60.9	69.7	51.8	75.0
2015	66.4	73.6	46.0	78.3
2020	71.9↑	76.9↑	51.8↑	78.3

Source: ILOSTAT (2021; online data code: T2020_10)

Further disparity between employment rates among men and among women in BioMates countries is shown in Table 32. The data show rates for gender employment gap for two years spanning a decade. As can be seen, the gap has tended to close across all countries. The closing of the gap was substantive both in Germany (-34%) and Sweden (-33%), and although somewhat lower, marked, also important in Greece (-23%) and the Czech Republic (-22%).

Table 32: Gender Employment Gap in BioMates Countries

Year/Country	*Czech Republic* %	*Germany* %	*Greece* %	*Sweden* %
2008	19.5	12.3	27.5	6.3
2018	15.2↓	8.1↓	21.0↓	4.2↓

Source: EUROSTAT (2021)

Turning to pay rates, Table 33 shows the mean annual gross earnings by men and women in 2018 in BioMates countries for three sectors relevant to BioMates for which data were available. As can be seen, men were earning more than women in all sectors across all countries. Within countries, in the Czech Republic, the lowest wage was earned by women in the transportation and storage sector, whereas the highest wage earned by men in the professional, scientific and technical sector. In Germany, men earned the highest wage in the electricity and gas sector, whereas women earned the lowest in transportation and storage. In Greece, the highest wage was earned by men in the professional, scientific and technical sector, whilst women earned the lowest wage in the electricity and gas sector. Finally, in Sweden, the highest wage was earned by men in professional, scientific and technical sector, with women earning the lowest wage in transportation and storage.

Table 33: Mean Annual Gross Earnings in BioMates Countries

2018	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Electricity and gas (Euros)				
Men	23,393	73,015	31,89	54,371
Women	19,267	57,084	23,416	47,892
Transportation and storage (Euros)				
Men	15,829	36,813	30,540	39,647
Women	13,872	34,651	25,938	37,808
Professional, scientific, technical (Euros)				
Men	25,522	68,601	32,779	56,295
Women	18,901	45,503	22,276	47,616

Source: EUROSTAT (2021; online data codes: EARN_SES18_27)

These results translate as a gender pay gap, illustrated in Table 34 The data demonstrates both important differences both between the rates across countries for the three sectors shown and within countries. Across the countries, the highest pay gap in the electricity and sector is in Greece, followed by Germany and the Czech Republic, and the lowest, in Sweden. In transportation and storage, Greece emerges with the highest rate, which is several times that of the other countries. In the professional, scientific and technical, the rates are above a quarter in three countries, being the highest in Germany, with the lowest gap in Sweden. Within countries, the lowest gap is in transportation and storage (except for Greece) and the highest is in the professional, scientific and technical sector.

Table 34: Sectoral Gender Pay Gap in BioMates Countries

2018	*Czech Republic* %	*Germany* %	*Greece* %	*Sweden* %
Electricity and gas	17.5	20.5	22.0	9.5
Transportation and storage	5.3	4.4	22.3	0.5
Professiona, scientific, technical	25.0	29.4	26.8	11.2

Source: EUROSTAT (2021; online data code: EARN_GR_GPGR2)

Turning to GDP, Table 35 shows the real GDP per capita for three years in BioMates countries. It can be seen that GDP has grown in between the years, with the largest growth relative to year 2015 being experienced in the Czech Republic (12%), followed by Germany (5.3%), Sweden (3.7%), whilst in Greece it actually declined, if by a small margin (1%).

Table 35: GDP per Capita in BioMates Countries

GDP per capita (PPS)	*Czech Republic*	*Germany*	*Greece*	*Sweden*
2010	21,000	30,000	21,100	32,000
2015	24,400	34,200	19,200	35,300
2020	27,340↑	36,000↑	19,000↓	36,600↑

Source: EUROSTAT (2021; online data code: SDG_10_10)

A further indicator of interest is disposal income (i.e., net income after taxation). Table 36 show the evolution for real gross disposable per capita income of households using 2008 as the base year. As can be seen, gross disposable income grew across all countries, throughout the period, bar Greece, where it declined in 2015, but began to bounce back in 2019.

Table 36: Real Gross Disposable Income of Households per Capita in BioMates Countries

Index = 2008	*Czech Republic*	*Germany*	*Greece*	*Sweden*
2010	101.69	100.59	91.63	103.01
2015	105.57	105.88	71.58	113.59
2019	121.34↑	113.35↑	75.43↑	119.45↑

Source: EUROSTAT (2021; online data code: TEPSR_WC310)

Another indicator of interest is what can be broadly termed as social cost, encompassing expenditure incurred for social reproduction of households. Table 37 illustrates a cost index based on a world average for 2017, with data shown for various items of social costs BioMates countries, which themselves can be subsumed under an overall cost of living. It can be seen that the least costly item across the countries is healthcare in the Czech Republic, whilst the costliest item is healthcare in Sweden. Within countries, again, health care is the least costly item in the Czech Republic, and transport, the costliest. In Germany, housing and utility is the costliest item, and the least costly, healthcare. In Greece, food is the costliest, as

opposed to housing and utility, the least costly. Finally, in Sweden, as seen, healthcare is the costliest of items, whilst food is the least costly. Regarding the cost of living, it is the highest in Sweden, and lowest in the Czech Republic.

Table 37: Social Cost Index for BioMates Countries

World Average = 100	*Czech Republic*	*Germany*	*Greece*	*Sweden*
2017	*Index*			
Cost of living	83.97	127.47	104.66	155.01
Cost of food	93.18	116.02	121.13	142.43
Housing and utility	89.81	161.34	93.83	165.46
Healthcare	46.54	112.67	95.17	189.48
Transport	97.56	141.33	120.91	160.40

Source: World Bank International Comparison Program (2021)

A final economic indicator relating to paid employment is the proportion of low wage earners as a proportion of all employees. The data for BioMates countries is shown in Table 38 for two years. As can be seen, Germany has the highest proportion of low-wage earners, whilst Sweden has the lowest. In terms of change, the proportion of low-wage earners declined in both Czech Republic (-17%), Germany (-7%), but increased very markedly in Greece (53%) and in Sweden (44%).

Table 38: Low-wage Earners in BioMates Countries

Year/Country	*Czech Republic* *%*	*Germany* *%*	*Greece* *%*	*Sweden* *%*
2010	18.19	22.24	12.82	2.51
2018	15.09↓	20.68↑	19.65↑	3.61↑

Source: EUROSTAT (2021; EARN_SES_PUB1A$DV_352)

Data from the SHDB also illustrate the risk that the average wage in sectors relevant to BioMates may be lower than the Minimum Wage in each of the countries. This is illustrated in Table Table 39. Whilst the risk across the sectors in the countries are mostly low, there are clearly some hotspots. Thus, the risk is very high in Greece in the agricultural and forestry sectors. It is also high in agriculture, chemicals and petroleum and coal sectors in the Czech Republic.

Table 39: Risk of Sector's Average Wage Being Lower than the Country's Minimum Wage

Sectors	Cereals	Crops	Wheat	Forestry	Chemicals	Electricity	Gas	Oil	Petro/coal	Transport
Czech Republic	H	H	H	M	H	L	L	L	H	L
Germany	L	L	L	L	L	L	L	L	L	L
Greece	VH	VH	VH	VH	L	L	L	L	L	L
Sweden	L	L	L	L	L	L	NA	NA	L	L

Key: the colours and risk levels are based on those used in the SHDB (2021): L = Low (green); Medium (yellow); H= High (red); VH = Very High (dark red); NA= Not Applicable (clear); ND = No Data (grey); NE= No Evidence (pink); NMW = National Minimum Wage.

Turning to unemployment, Table 40 shows disaggregated data by gender for adults of employment age in BioMates countries over three years covering a decade. As the data shows, unemployment has been consistently higher among women than among men in the period in the Czech Republic and Germany, where the trend is also for a decline in unemployment rates for both genders. In Greece, there was a sharp increase in unemployment, both for men and women in 2015, but in both cases, it has since

declined. The picture in Sweden is also more mixed, with unemployment declining for both men and women in 2015 but growing back up later.

Table 40: Unemployment in BioMates Countries

Gender/Year Age (15-64)	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Men	%	%	%	%
2010	6.4	7.4	10.1	8.7
2015	4.2	5.0	21.8	7.6
2020	2.2↓	4.2↓	13.6↓	8.3↑
Women	%	%	%	%
2010	8.5	6.5	16.4	8.5
2015	6.1	4.2	28.9	7.3
2020	3.0↓	3.4↓	21.5↓	8.3↑

Source: EUROSTAT (2021; online code: UNE_RT_A)

Again, data from the SHDB illustrate the risk of unemployment in sectors relevant to BioMates in the four countries, showing a mixed picture (Table 41). Whilst for the most part the risk of unemployment is low or medium, the 'hotspot' sectors are chemicals and petroleum and coal, being very high or high across the countries.

Table 41: Risk of Unemployment in BioMates Countries

Sectors	Cereals	Crops	Wheat	Forestry	Chemicals	Electricity	Gas	Oil	Petro/coal	Transport
Czech Republic	M	M	M	M	VG	L	L	L	VH	M
Germany	M	M	M	M	VH	L	L	L	VH	M
Greece	L	L	L	L	H	L	L	L	H	M
Sweden	L	L	L	L	H	L	L	L	H	M

Key: the colours and risk levels are based on those used in the SHDB (2021):L = Low (green); Medium (yellow); H= High (red); V = Very High (dark red); NA= Not Applicable (clear); ND = No Data (grey); NE= No Evidence (pink); NMW = National Minimum Wage.

A further useful indicator is that of people of working age (15-64) who were neither employed nor unemployed during a specified reference period (ILO, 2021). Table 42 shows data for men and women in outside the labour force in BioMates countries for three points in time spanning a decade, with percent change calculated for 2020 in relation to 2015. Overall, the results show a trend towards a decrease among men and women outside the labour force. This is most marked for men in Germany (-15.4%) and the Czech Republic (-14.7%), but less so in Sweden (-4.3%), whereas in Greece it increased (4.2%). For women, the trend was for a pronounced decline in Germany (-21.1%), followed by Czech Republic (-11.4%), with a smaller drop in Greece (-4.6%), whilst in Sweden the share of women outside the labour force increased (3.1%).

Table 42: People Outside the Labour Force in BioMates Countries

Gender/Year Age (15-64)	*Czech Republic* 000	*Germany* 000	*Greece* 000	*Sweden* 000
Men				
2010	343	639	307	361
2015	252	950	190	140
2020	215↓	804↓	198↑	134↓
Women				
2010	586	1023	676	439
2015	429	1420	366	160
2020	380↓	1120↑	349↓	165↑

Source: ILOSTAT (2021)

A final and important measure of vulnerability is further given by the indicator on people at risk of poverty, with data in Table 43 showing the proportion of this group in the four BioMates countries in three separate years encompassing nearly a decade. Over the period, Greece had the highest proportion of people at risk of poverty, whilst Czech Republic had the lowest. In terms of change, the trend in Sweden was for an increase in the population at the risk of poverty, whereas in the Czech Republic, it declined. In Germany and in Greece, the proportion of those at risk of poverty had increased in 2015 but had declined in 2019.

Table 43: Population at Risk of Poverty in BioMates Countries

Year	*Czech Republic* *%*	*Germany* *%*	*Greece* *%*	*Sweden* *%*
2010	14.4	19.7	27.7	17.7
2015	14.0	20.0	35.7	18.6
2019	12.5↓	17.4↓	30.0↑	18.8↑

Source: EUROSTAT (2021; oline data code: ILC_PEPS01)

The biorefinery concept is likely to provide employment throughout the supply chain, in agricultural activities (e.g., cultivation, biomass collection, and transportation) in biorefinery (construction and operation; management and administration), and in research and development (at the biorefinery and in outside organisations). Potential jobs to be created will depend on plant scale, capacity and complexity of processes. In agricultural activities, for instance, the characteristics of the workforce and work patterns related to biomass supply to biorefineries may mirror wider trends (e.g., male dominated, low-skilled, full-time). Nevertheless, expectations about job creation for biomass cultivation may need to be tempered by key characteristics of agriculture in the EU. For instance, an analysis by Star-COLIBRI, (2011) over a decade ago noted that family farms predominated, with over 80% of the workforce comprising farmers' families. Also, permanent workers make up only about 12% of the workforce, whilst one third of farm workers work less shorter hours in agriculture and just over one third of these hold full time jobs; about half of all EU farms require less than one full-time person over the year. Some of the data seems to indicate that these patterns may be changing (i.e., greater presence of commercial labour in agriculture). Recent estimates suggest that local deployment of one biorefinery can create up to 4,000 jobs over four years (EC, 2018f). Other data shows that Europe accounted for some 10% of the estimated 2.5 million employment in biofuels worldwide, one of the smaller shares due to a higher mechanisation of agriculture; cultivation and harvesting of various types of feedstock make up the bulk of these jobs, whilst feedstock processing requires far fewer workers as jobs generally require higher technical skills and offer better pay (IRENA, 2020). Job creation in the context of the recently increased renewable energy targets for 2030 in the transport sector in the EU is expected to be moderate, with estimates indicating up to nearly 50,000 direct jobs created in the production of advanced biofuels (that is, excluding indirect jobs created in the supply chain for feedstock (EUR-LEX, 2021c). Thus, it is difficult to estimate the number of potential jobs that BioMates may help create along the chain.

4.13 Gender equity

No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
10	Gender equity	Inclusion of women	National	Feedstock Transport Storage Biorefinery	Qualitative SHDB

Gender equity relates to fair treatment of men and women alike and enables gender equality, which is one of the 17 Sustainable Development Goals for achieving a better and more sustainable future for humanity. The aim is to eradicate all forms of discrimination against women and ensure their full and effective participation and equal opportunities in all facets of social life. Gender equity and equality therefore are integral to any discussion about sustainability. In addition, the ILO has set out conventions relating to equality of treatment at the workplace which address gender equality issues, two of which are directly relevant to the case of biomass production and biorefineries. The Discrimination (Employment and Occupation) Convention (1958), safeguards against discrimination of the basis of race, colour, sex, religion, political opinion, national extraction or social origin. The Equal Remuneration Convention (1951) prescribes equal remuneration for men and women for work of equal value.

The examination of some parameters has already shown that there is disparity between men and women in BioMates countries. This was seen in relation to access and control of natural resources (parameter 5, 'land tenure'), involvement in agricultural work (parameter 6, 'community participation'), and labour market participation and income earning (parameter 9, 'job creation and wages'), which are all indicators of gender inequality in varying degrees, which link directly to the parameter covered here. A further indicator is provided by the SDBH, which assesses the risk of gender inequality in economic sectors in a country. Table 44 shows the results for the sectors relevant to the BioMates chain in the four BioMates countries. As can be seen, the risk of gender inequality across the sectors is assessed as mostly as low or medium (being totally low in transport), and except in Greece, where it is high in half of all sectors.

Table 44: Risk of Gender Inequality in BioMates Countries

Sectors	**Cereals**	**Crops**	**Wheat**	**Forestry**	**Chemicals**	**Electricity**	**Gas**	**Oil**	**Petro/coal**	**Transport**
Czech Republic	M	M	M	M	M	M	M	M	M	L
Germany	L	L	L	L	L	L	L	L	M	L
Greece	L	L	L	L	H	H	H	H	H	L
Sweden	M	M	M	M	M	M	M	M	M	L

Key: the colours and risk levels are based on those used in the SHDB (2021): L = Low (green); Medium (yellow); H= High (red); VH = Very High (dark red); NA= Not Applicable (clear); ND = No Data (grey); NE= No Evidence (pink); NMW = National Minimum Wage.

A further indicator of interest is that of women's share of low pay earners, that is, the proportion of low-pay workers amongst the low-paid who are women. Table 45 shows the share of low-pay women in BioMates countries in 2014. As can be seen, Germany has the highest share of women as low-pay earners, followed by the Czech Republic, and Greece, whilst Sweden has the smallest share which is also well below that of the other countries.

Table 45: Women's Share of Low-pay Earners in BioMates Countries

Year	*Czech Republic* *%*	*Germany* *%*	*Greece* *%*	*Sweden* *%*
2014	56.6	62.1	41.5	16.5

Source: ILOSTAT (2021)

4.14 Labour conditions

No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
11	Labour conditions	ILO convention and human rights, including • Child labour • Forced Labour • Right to organise	National	Feedstock Transport Storage Biorefinery	Quantitative Qualitative ILOSTAT SHDB

This parameter focuses on issues related to labour conventions and human rights. Labour and working conditions are largely regulated by national legislation that may incorporate elements from the conventions and policies drawn up and overseen by the ILO. The representatives of governments, employers and workers are brought together through the ILO to jointly shape policies, programmes and standards. Moreover, the ILO has also developed mechanisms for overseeing the enforcement of conventions, protocols and recommendations following adoption by the ILO itself and ratification by member states. The most relevant and overarching conventions that cover labour themes relevant to BioMates are shown in Table 46 noting whether and when they were ratified in BioMates countries

Table 46: ILO Conventions Relevant to BioMates

No	Convention and Year Issued	Date of Ratification			
		Czech Republic	Germany	Greece	Sweden
Freedom of Association and Collective Bargaining					
26	Minimum Wage Fixing Machinery (1928)	1993	1929	Not ratified	Not ratified
11	Right of Association (agriculture) (1921)	1993	1925	1952	1923
87	Freedom of Association and Protection of the Right to Organise (1948)	1993	1957	1962	1949
98	Right to Organise and Collective Bargaining (1949)	1993	1956	1962	1950
Forced Labour					
29	Forced Labour (1957)	1993	1956	1952	1931
105	Abolition of Forced Labour Convention (1957)	1996	1959	1962	1958
	Elimination of Child Labour and Protection of Children and Young Persons				
111	Discrimination (Employment and Occupation) (1958)	1933	1961	1984	1962
138	Minimum Age (1921)	2007	1976	1986	1990
182	Worst Forms of Child Labour (1999)	2001	2002	2001	2001

Source: ILO (2021)

The SHDB was used to assess risks of lack enforcement of labour conventions either at country level or in the sectors relevant to the BioMates chain in the four countries, with results shown in Table 47. As can be seen, in relation to the right to strike, Sweden is the only country where the risk is low, whereas in the three other countries it is identified as medium across all sectors. In terms of the risk of lack of enforcement of collective bargaining and freedom of association rights, the risk is low in Greece and Sweden, but medium in Germany and the Czech Republic. But in relation to the risk of non-ratification of ILO conventions by sector, the picture is more mixed. Sweden is the only country where the risk is

identified as low across all sectors, except in transport (for lack of data). In Greece and the Czech Republic, the risk is medium in agriculture and forestry, and low in all other sectors. In Germany, the risk if low in the gas and oil sectors, and medium in all others.

Table 47: Risk of Lack of Enforcement of Labour Rights Conventions

Sectors	Cereals	Crops	Wheat	Forestry	Chemicals	Electricity	Gas	Oil	Petro/coal	Transport
Risk of that a country does not enforce the right to strike										
Czech Republic	M	M	M	M	M	M	M	M	M	M
Germany	M	M	L	M	M	M	M	M	M	M
Greece	M	M	L	M	M	M	M	M	M	M
Sweden	L	L	L	L	L	L	L	L	L	L
Risk that a country does not enforce collective bargaining and freedom of association rights										
Czech Republic	M	M	M	M	M	M	M	M	M	M
Germany	M	M	M	M	M	M	M	M	M	M
Greece	L	L	L	L	L	L	L	L	L	L
Sweden	L	L	L	L	L	L	L	L	L	L
Risk that a country does not ratify ILO conventions by sector										
Czech Republic	M	M	M	M	L	L	L	L	L	ND
Germany	M	M	M	M	M	M	L	L	M	ND
Greece	M	M	M	M	L	L	L	L	L	ND
Sweden	L	L	L	L	L	L	L	L	L	ND

Key: the colours and risk levels are based on those used in the SHDB (2021): L = Low (green); Medium (yellow); H= High (red); VH = Very High (dark red); NA= Not Applicable (clear); ND = No Data (grey); NE= No Evidence (pink); NMW = National Minimum Wage.

The SHDB was also used to assess the risks of both child labour and forced labour in BioMates sectors in the four countries. Table 48 shows the results. Regarding the risk of child labour, as can be seen, for the most part there was no evidence of such risk in any of the sectors and countries, except for Greece, where the risk was identified as low in the agriculture. The risk of forced labour, in turn, was identified as low for most sectors and countries in Greece, where it was assessed as high in agriculture, and medium in the remainder sectors.

Table 48: Risk of Child Labour and Forced Labour in BioMates Countries

Sectors	Cereals	Crops	Wheat	Forestry	Chemicals	Electricity	Gas	Oil	Petro/coal	Transport
Risk of child labour in the sector										
Czech Republic	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Germany	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Greece	L	L	L	NE	NE	NE	NE	NE	NE	NE
Risk of forced labour in the sector										
Sweden	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Czech Republic	L	L	L	L	L	L	L	L	L	L
Germany	L	L	L	L	L	L	L	L	L	L
Greece	H	H	H	H	M	M	M	M	M	M
Sweden	L	L	L	L	L	L	L	L	L	L

Key: the colours and risk levels are based on those used in the SHDB (2021): L = Low (green); Medium (yellow); H= High (red); VH = Very High (dark red); NA= Not Applicable (clear); ND = No Data (grey); NE= No Evidence (pink); NMW = National Minimum Wage.

Two final issues were assessed using the SHDB, as shown in Table 49. Regarding the lack of provision of adequate labour laws, the results show that the risk is high in the Czech Republic, medium in Greece, and low in Germany and Sweden. In turn, the risk of excessive working time across the sectors was shown to be low in the Czech Republic and Sweden, but medium in Germany and Greece.

Table 49: Risk Relating to Labour Laws and Working Time

Sectors	Cereals	Crops	Wheat	Forestry	Chem	Elec	Gas	Oil	Petro/coal	Transport
Risk that the country does not provide adequate labour laws										
Czech Republic	H	H	H	H	H	H	H	H	H	H
Germany	L	L	L	L	L	L	L	L	L	L
Greece	M	M	M	M	M	M	M	M	M	M
Sweden	L	L	L	L	L	L	L	L	L	L
Risk of excessive working time by sector										
Czech Republic	L	L	L	L	L	L	L	L	L	L
Germany	M	M	M	M	M	M	M	M	M	M
Greece	M	M	M	M	M	M	M	M	M	M
Sweden	L	L	L	L	L	L	L	L	L	L

Key: the colours and risk levels are based on those used in the SHDB (2021): L = Low (green); Medium (yellow); H= High (red); VH = Very High (dark red); NA= Not Applicable (clear); ND = No Data (grey); NE= No Evidence (pink); NMW = National Minimum Wage.

The four BioMates countries are also signatories of two further relevant conventions. One is the UN Protocol to Prevent, Suppress and Punish Trafficking in Persons, Especially Women and Children (ratified by Germany, Greece, and Sweden in 2000, and by the Czech Republic in 2002). The other treaty is the Council of Europe Convention on Action against Trafficking in Human Beings that came into force in 2008 and which the four countries ratified by 2017.

4.15 Health and Safety

No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
12	Health and safety	Compliance with health and safety regulations	National Local	Feedstock Transport Storage Biorefinery	Qualitative Literature Partners' data SHDB

This parameter assesses occupational health and safety issues of the BioMates project. Specific conversion technologies that may be integrated into a biorefinery are biochemical (fermentation and enzymatic treatment), and thermochemical (thermochemical pre-treatment, combustion, pyrolysis, gasification, liquefaction). In general, the higher the number of processes involved and the higher the complexity, the higher occupational health and safety risks and hazards. But the environmental and health risks posed by biorefineries are expected to be lower than those posed by traditional chemical/petrochemical plants. For instance, Accardi et al (2013) analysed the unit operations and equipment used in biorefineries in Italy, discussing different processes (i.e., mechanical, thermal, chemical/physical, biochemical) and occupational hazards, finding that main hazard is posed by biological agents. But overall, biorefineries have the potential to significantly reduce the environmental impact of production processes and improve the safety for workers.

Risk assessment is a crucial step in Occupational Safety and Health (OSH) or Health and Safety (H&S) management system that organisations and companies must adopt and develop to implement their policies to address mitigate risks at the workplace (Nunes, 2017). All BioMates project partners whose institutions carry out technical work in laboratories, pilot and demonstration plants described and reviewed their health and safety risk, hazards and procedures fully in a separate document as part of the project's requirements (see D9.1). Their reporting on safety risk, hazards and mitigating procedures covered three key aspects: the transportation of BioMates fractions; the technical execution and performance of project processes at laboratories the workplace; and compliance with local and national guidelines and laws on health and safety of general staff at the workplace. The assessment was carried on the basis of guidelines by the British Standard Institutions management systems for Occupational Health and Safety (BS 8800, 2004), which are in line with guidelines, standards, regulations and legislation set out by supra-national organisations such as WHO and ILO. For instance, the ILO's Convention No. 155 on Occupational Safety and Health Convention (1981) stipulates that each member state in consultation all stakeholders, will formulate, implement and periodically review national policy on occupational safety, occupational health and the working environment, aimed at preventing accidents and injury to health related to work, and minimising the causes of hazards inherent in the working environment, although only two BioMates countries have so far ratified it (the Czech Republic, in 1993; and Sweden, in 1982). In addition, the EU issues its own Occupational and Health (OSH) Strategic Framework, which was recently revised to cover the period 2021-2027, to protect EU workers from work-related accidents and diseases, identifying key challenges and strategic objectives for health and safety at work, which include simplifying OSH legislation, and better enforcement by member states (EC, 2021g).

In terms of the transportation of any of the BioMates fractions (inputs and products), Table 50 shows key international legislation with which project partners and any future business developing BioMates must comply, according to the transportation mode.

Table 50: Transportation of BioMates Fractions

Fractions	**Bio-oil; catalyst; fossil**
Mode	**Legislation**
Land	International Carriage of Dangerous Goods by Road (ADR) Regulation for the International Carriage of Dangerous Goods by Rail (RID)
Inland waterway	International Carriage of Dangerous Goods by Inland Waterways (ADN)
Sea	International Maritime Dangerous Goods (IMDG)
Air	Technical Instructions for the Safe Transport of Dangerous Goods by Air (ICAO-TI) IATA Dangerous Goods Regulations

Source: BioMates- D9.1 (2020)

The overall assessment of H&S risks, procedures and mitigation by BioMates partners at their workplaces and facilities, can be seen in Table 51. As evident, partners have complied with all requisite and mandatory national and international instruments.

Table 51: Assessment of Health and Safety Compliance by BioMates Partners

BioMates project	H&S Assessment		
Partner organisation	Compliance with H&S instruments on handling and transportation of BioMates products/fractions	Compliance with general H&S international laws and regulations for the workplace	Compliance with general H&S national laws and regulations for the workplace
BP	✓	✓	✓
CERTH	✓	✓	✓
FRAUNHOFER	✓	✓	✓
HyET	✓	✓	✓
RANIDO	✓	✓	✓
RISE	✓	✓	✓
UCTP	✓	✓	✓

However, it is important also to draw attention to health and safety hazards associated with the logistics of biomass transportation to the biorefinery, handling and storage until they are fed into the biorefinery processes. As already noted, the biomass feedstocks for the BioMates concept are straw (wheat, barley), miscanthus and forestry residues. The main hazards are self-heating, off-gassing and dust explosions, which present a fire risk, air pollution, moulds and spores, and foul liquids that may pose occupational health risks, requiring careful handling and containment measures according to the requisite international and national regulations (ILO, 2012; IEA-Bioenergy, 2013).

In addition to the H&S assessment of BioMates partner's relating to human and environmental risks and hazards, further assessment of health safety was possible through use of the SHDB, which allows for assessing health risks in specific sectors through the BioMates chain. Table 52 shows the results of the risk assessment for both non-fatal and fatal injuries in the sector. As can be seen, the risks for both fatal and non-fatal injuries is low for Germany and Greece. The risk of non-fatal injury for the agricultural sectors and in electricity are medium for Sweden, but high in the other sectors. For the Czech Republic, the risks are either high or very high, so these sectors are all 'hotspots' for non-fatal workplace injury. Regarding fatal injuries, again, the risks are low for Germany and Greece across all sectors. For Sweden, the risks in the agricultural, forestry and oil sector are all very high, but medium in the remainder sectors. The risks

in the Czech Republic are very high for the agriculture, forestry, gas and oil sectors, high for transprot and medium in the remainder sectors.

Table 52: Risk of Injury in BioMates Countries

Sectors	Cereals	Crops	Wheat	Forestry	Chemicals	Electricity	Gas	Oil	Petro/coal	Transport
Risk of non-fatal injuries in the sector										
Czech Republic	VH	VH	VH	VH	VH	H	H	H	VH	H
Germany	L	L	L	L	L	L	L	L	L	L
Greece	L	L	L	L	L	L	L	L	L	L
Sweden	M	M	M	M	H	M	H	H	H	H
Risk of fatal injuries in the sector										
Czech Republic	VH	VH	VH	VH	M	M	VH	VH	M	H
Germany	L	L	L	L	L	L	L	L	L	L
Greece	L	L	L	L	L	L	L	L	L	L
Sweden	VH	VH	VH	VH	M	M	VH	VH	M	M

Key: the colours and risk levels are based on those used in the SHDB (2021): L = Low (green); Medium (yellow); H= High (red); VH = Very High (dark red); NA= Not Applicable (clear); ND = No Data (grey); NE= No Evidence (pink); NMW = National Minimum Wage

On the issue of non-fatal accidents, data on Table 53 shows numbers for the four BioMates countries on two different years for some of the key sectors (although some of the data it is in aggregate with other sectors). The data illustrates a rather mixed picture regarding trends, with numbers declining in some sectors in relation to 2011, but others increasing. The most notable increase has been in the number of accidents in agriculture, forestry and fishing in the Czech Republic, which was very steep (1272%), followed by also a pronounced increase in Germany in the chemicals sector (352%). In terms of decline, the highest share was in transportation and storage in the Czech Republic (-89%). The figures for Greece are generally very low compared to the countries and have tended to decline (except for the electricity sector), and similarly, in Sweden, apart from transportation and storage (increase of 23%), the figures are also generally lower than most other countries.

Table 53: Non-fatal Accidents at Work in BioMates Countries

Non-fatal (N)	*Czech Republic*	*Germany*	*Greece*	*Sweden*
	Agriculture, Forestry, Fishing			
2011	2,696	66, 28	218	588
2019	36,991↓	44,502↑	86↓	612↑
	Electricity, gas, steam and air conditioning supply			
2011	138	2,108	57	110
2019	13↓	9,532↑	83↑	65↓
	Manufacture of chemicals and chemical products			
2011	333	6,662	117	74
2019	66↓	4,705↑	32↓	121
	Manufacture of coke and refined petroleum products			
2011	11	10	66	16
2019	0↓	119↑	14↓	8↓
	Transportation and storage			
2011	4,058	74,777	984	3,225
2019	449↓	86,789↑	508↓	3,968↑

Source: EUROSTAT (2021; online data code HSW_N2_01)

The SHDB was also used to assess health risks for many conditions as well as risk of death across the BioMates sectors in the four countries. Table 54 shows only the results for those that were identified as medium or above across the sectors. As can be seen, the risk of death due to occupation was assessed as high for three issues, and medium for mesothelioma (from inhaling asbestos). Similarly, the risks of loss of life years due to occupation were high for many conditions, but medium for airborne particulates and, again, for mesothelioma.

Table 54: Occupational Hazards in BioMates Countries

All four countries across all sectors	Risk level
Risk of death due to occupation	
By exposure to carcinogens	H
By leukemia	H
By lung cancer	H
By mesothelioma	M
Risk of loss of life years due to occupation	
By airborne particulates	M
By asthma due to airborne particulates	H
By chronic obstructive pulmonary disease due to airborne particulates	H
By exposure to carcinogens	H
By leukemia	H
By lung cancer	H
By mesothelioma	M
Sectors: cereals; crops; wheat; forestry; chemical, electricity; gas; oil; petroleum and coal, transport.	

Source: SHDB (2021)

Moving on to focus on health from a macro perspective, Table 55 shows data for per capita health spending and health spending as a percentage of GDP in the BioMates countries, based on average of over 180 countries in 2018. As can be seen, Germany had spent the most as a percentage of GDP, followed closely by Sweden, whereas Greece and the Czech Republic trailed somewhat behind, although all shares are higher than the average for all countries measured.

Table 55: Health Expenditure in BioMates Countries

2018	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Health spending per capita average (184 countries) =US$ 998.86	1, 765.59	5, 472.20	1, 566.90	5, 981.71
Health spending as % of GDP average (182 countries)= 6.53 %	7.65	11.43	7.72	10.90

Source: EUROSTAT (2021;online data code: ILC_PEPS01)

On health service delivery, Table 56 shows figures for hospital bed availability and practising doctors in BioMates countries for two years spanning a decade. Regarding the number of hospital beds per 10,000 people, it can be seen the trend has been for a decline across the four countries, being most pronounced in Sweden (-22.7%), quite marked in Greece (-3.7%), also significant in the Czech Republic (-9.5%), and lowest in Germany (-2.9%). By contrast, the data for practising doctors (unavailable for Greece) shows a trend towards increased numbers in relation to 2008, being more pronounced in Germany (21.8%), followed by Sweden (17.2%), and the Czech Republic (13.6%).

Table 56: Health Service Delivery in BioMates Countries

Health Personnel	*Czech Republic*	*Germany*	*Greece*	*Sweden*
Hospital beds (per 10,000)				
2007	73.3	82.4	48.8	28.6
2017	66.3↓	80.0↓	42.1↓	22.1↓
Practising Physicians (per 1,000 pop)				
2008	355,54	354,06	N/A	368,24
2018	403,76↑	431,09↑	N/A	431,74↑

Source: WHO (2021); EUROSTAT (2021; online data code: TPS00044).

Finally, the SHDB was used to assess the risk that not enough beds are available to support the population, which is assessed in relation to BioMates countries, thereby covering all economic sectors. As can be seen in Table 57 the risks are low in Czech Republic and in Germany, medium in Greece, and high in Sweden.

Table 57: Risk to Access to Hospital Bed (per 1000 population)

Sectors	**Cereals**	**Crops**	**Wheat**	**Forestry**	**Chem**	**Elec**	**Gas**	**Oil**	**Petro/coal**	**Transport**
Risk that there are too few hospital beds to support the population in the country										
Czech Republic	L	L	L	L	L	L	L	L	L	L
Germany	L	L	L	L	L	L	L	L	L	L
Greece	M	M	M	M	M	M	M	M	M	M
Sweden	H	H	H	H	H	H	H	H	H	H

Key: the colours and risk levels are based on those used in the SHDB (2021): L = Low (green); Medium (yellow); H= High (red); VH = Very High (dark red); NA= Not Applicable (clear); ND = No Data (grey); NE= No Evidence (pink); NMW = National Minimum Wage

4.16 Competition with other sectors

No	Parameter	Characteristics/ criteria	Assessment Level	Supply chain stage	Data type and source
13	Competition with other sectors	Competition and negative impacts on other industries and sectors	Local	Feedstock Intermediate and end products	Qualitative Literature Survey Workshop

The BioMates concept may face different levels of competition with established uses for biomass feedstocks, other biorefinery inputs, and with fossil fuels themselves.

Current main uses for straw are animal bedding and fodder, heat and power, horticulture, mushroom production, frost protection and natural fertilizer, although alternative forestry residues may be extracted sustainably (e.g., wood chips, saw dust and shavings, paper crumb). Forestry residues are mostly left on site following forest management operations but can be collected for many uses (e.g., heat and power, wood pulp, panel board production, mulch, animal bedding, and landscaping), with large potential for extracting them without having negative impacts (GOVUK, 2016). As a general rule, feedstocks that are left uncollected can be collected sustainably within limits. Hence, whilst straw and wood that are diverted from animal bedding may entail depending on replenishment from other sustainable sources, diversion of animal feed may mean more need for roughage or carbohydrate crops, with potential ILUC risk (Arup-Urs, 2014). Dedicated feedstocks for biofuels currently face little competing uses, such as miscanthus, which is used only in small volumes for animal bedding, and biomaterials, but if miscanthus is grown as a

dedicated biofuel crop on arable land without mitigating measures it will likely cause ILUC (GOVUK, 2016; Arup-Urs, 2014).

In terms of other inputs, BioMates proposes to produce its own 'green hydrogen' (i.e., zero-emission) from a PVPP for use in the mild-HDT stage. Hydrogen is needed for upgrading high-oxygen content biomass feedstocks into 'drop-in' biofuels for co-processing in petroleum refineries. A key challenge remains finding cheap and renewable sources of hydrogen, with global hydrogen demand expected to increase, adding pressure on existing refinery capacity for hydrogen (van Dyk et al, 2019). Hence, by supplying its own renewable hydrogen, BioMates will avoid competition for this input with other sectors.

The BioMates bio-oil obtained from the AFP may, in turn, compete to some extent with the gamut of bio-oils that have been used for producing chemicals for several years now, as well as applications as fuels in boilers, engines, and turbines for heat and power generation, or still bio-oils upgraded to high-quality hydrocarbon fuels (Czernik and Bridgwater, 2004).

In the context of transportation fuels, the upgraded hybrid fuel obtained from co-processing of the BioMates bio-oil with crude petroleum streams may also face some competition from other transport renewable fuels, namely biodiesel and bioethanol which can be also used without engine modification, and a range of advanced biofuels under development (e.g., lignocellulosic ethanol, fuel from algae, biohydrogen, biomethanol, Fischer-Tropsch diesel, biohydrogen diesel), and biomethane (REA, 2021). There is also likely to be competition with biodiesel production for aviation and maritime transportation (Panoutsou et al., 2021).

The BioMates bio-oil may also compete unfavourably with oil prices, especially in the context of low oil prices that prevailed since the mid-2010's up until recently in the context of the Covid pandemic, although oil prices have begun to rise again in the last few months. The competition between biofuels and fossil fuels as a perennial challenge to the development of the biofuels sector has been extensively documented. For instance, Reboredo, Ramalho and Pessoa (2017) argued that no effort to reduce biofuels production costs through technological breakthrough can compete with cheap oil, calling for the abolition of fossil fuels subsides, and scrutiny of subsidies for advanced biofuels to prevent distortions by unfair competition in the energy market.

BioMates potential competition with feedstocks, inputs and petrol prices were all discussed by stakeholders at the workshop, who noted competition for biomass uses (e.g., straw left on the ground post-harvest as soil cover for replenishment) and competition with other processes (e.g., other biorefinery uses) as posing a risk to the development of the BioMates chain. Similarly, about one fifth (19%) of survey respondents thought that competition from other renewable fuels is a potential barrier to the development of hybrid fuels from BioMates.

4.17 'Hotspots' in the BioMates product system in BioMates countries

This section introduces two further assessments that draw on the SHDB to identify the hotspots in the BioMates product system in BioMates countries. The first assessment entailed selecting the issues that are categorised as very high risk and high risk in the product system in each country within the five social impact categories that structure the SHDB (after Ekener- Petersen, Hoglund, and Finnveden, 2014). The results are shown in Table 58. Under each social impact category are listed themes and issues whose risks are assessed through indicators represented in number within brackets. As can be seen, there are social hotspots in BioMates sectors in all countries across all categories. In terms of individual countries, the

Czech Republic leads with the highest number of high or very risks (299), followed far behind by Germany (221) and Greece (220), whereas Sweden has the lowest number of such risks (150).

Table 58: Hotspots in the BioMates Product System

Risk Level	Labour	Health and Safety	Human rights	Governance	Community infrastructure
Czech Republic					
Very high risk	• Unemployment (2)	• Injuries/deaths (22)	• Health (20)	• Corruption (20)	
High risk	• Labour laws (23) • Migrant workers (60) • Wage assessment (5)	• Injuries/deaths (5) • Toxics/ hazards (80)	• Gender equity (10) • Health (20)	• Corruption (10) • Legal system (20)	• Small holders v commercial farms (4)
Germany					
Very high risk	• Migrant workers (10) • Unemployment (1)				• Small holders v commercial farms (4)
High risk	• Labour laws (1) • Migrant workers (60) • Unemployment (10)	• Toxics/hazards (80)	• Health (40)	• Legal system (10)	• Small holders v commercial farms (4)
Greece					
Very high risk	• Wage assessment (4)			• Corruption (10	• Small holders v commercial farms (4)
High risk	• Forced labour (4) • Labour laws (3) • Migrant workers (80) • Unemployment (2) • Wage assessment (4)	• Toxics/hazards (40)	• Gender equity (5) • Health (38)	• Corruption (10) • Legal system (10)	
Sweden					
Very high risk		• Injuries/ deaths (2)			• Small holders v commercial farms (8)
High risk	• Labour laws (5) • Migrant workers (60) • Unemployment (6)	• Injuries/deaths (5) • Toxics/ hazards (80)	• Health (10) • Indigenous rights (4)	• Corruption (9)	• Access to hospital beds (8)

Source: SHDB (2021)

The second assessment entailed the use of the Combined Social Hotspot Index, which integrates the results of analysis of all risks levels within the BioMates product system in the four countries, providing an overall index of the risks that enables for easy visualisation of the hotspots. Tables 59-62 shows the combined social hotspot index for BioMates countries and sectors. As can be seen, some commonalities are evident. For instance, the prime hotspot across the sectors in the Czech Republic, Germany and Sweden is health and safety. Governance (relating to fragility of legal systems and corruption) is a hotspot in the Czech Republic and in Greece. Labour rights are a hotspot in Germany and Greece, whereas community infrastructure is more of an issue in Sweden.

Table 59: The Combined Social Hotspot Index for the Czech Republic

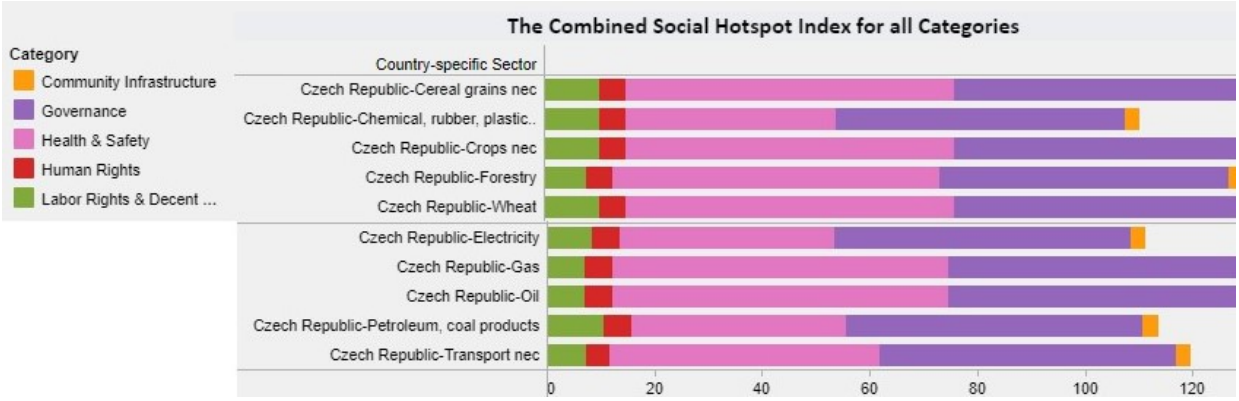


Table 60: The Combined Social Hotspot Index for Germany

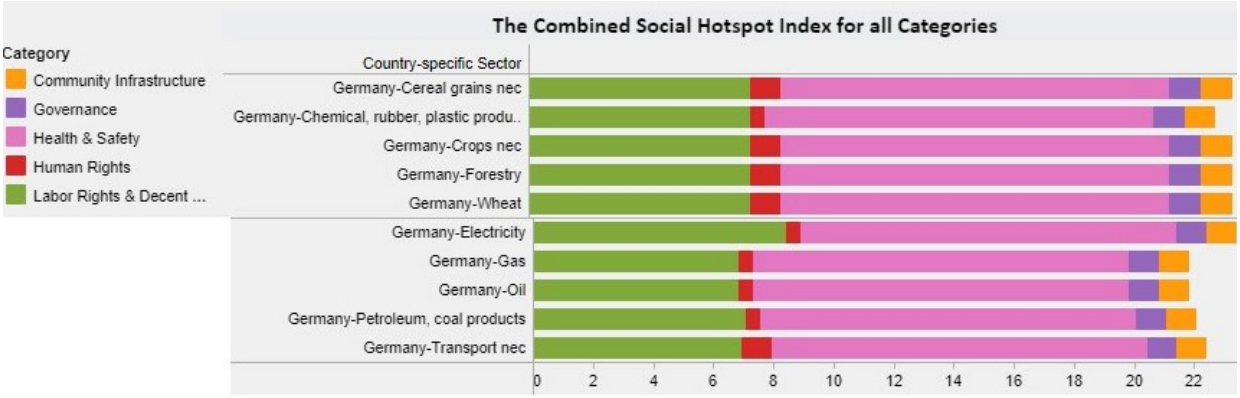


Table 61: The Combined Social Hotspot Index for Greece

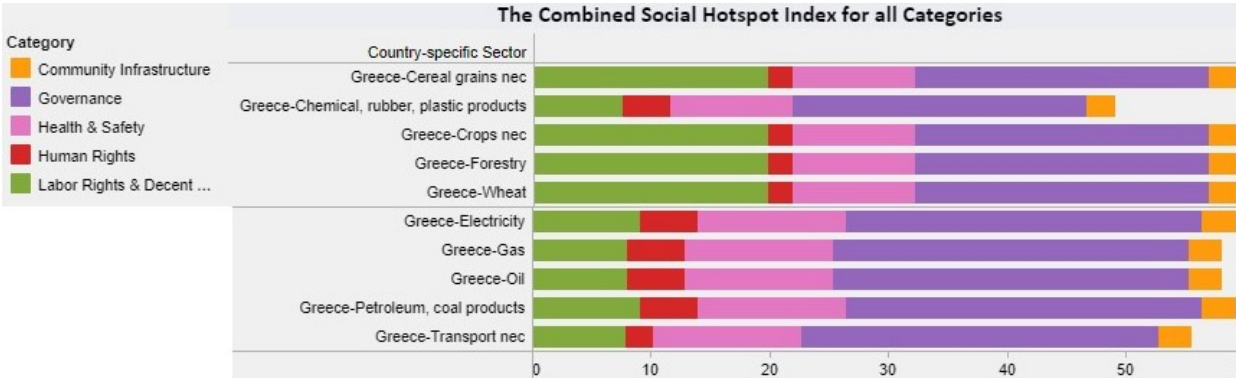
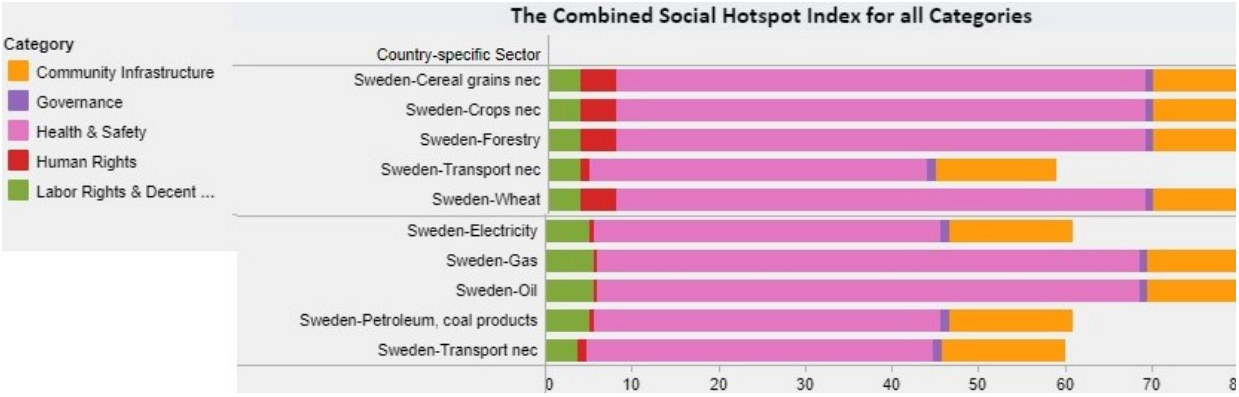


Table 62: The Combined Social Hotspot for Sweden



5 Social sustainability assessment of BioMates

This section introduces the assessment of the social sustainability of BioMates. The assessment focuses on the potential impacts, risks or benefits associated with developing the BioMates chain in four countries in the EU, from the conversion of agricultural and forestry residues and the energy grass miscanthus, through to the processes to obtain the BioMates bio-oil and the end-product, the hybrid fuel. The assessment has two elements, which are introduced in turn. The assessment of the different BioMates scenarios and pathways that are possible to implement is introduced first. This is then followed by the overall assessment of BioMates that incorporates the results of the SIA and SLCA parameters.

5.1 Social Assessment of BioMates scenarios

As seen previously, the SHDB was used to identify hotspots in the economic sectors in BioMates countries (Table 58). In a further step, SHDB indicators were used for assessing scenarios and pathways that are possible to implement through the BioMates concept, and ascertain which are socially sustainable. The assessment entailed a comparison of risk levels and potential impacts relating to the various BioMates pathways and scenarios against the levels of risks and impacts associated with the current product reference system. Thus, the risks in sectors in BioMates countries were compared against the risks in sectors in the reference countries.The comparison helped ascertain in which system the levels of risk were lowest (either BioMates or reference), and which BioMates pathways and scenarios are socially sustainable. The resulting assessment is shown in Table 63, along with a description of each scenario and the evaluation system used.

The results show that the risks associated with the implementation of BioMates are lower in ten scenarios regarding the indicator in four social impact categories. In other words, BioMates has a net positive effect in terms of these social impact categories. Thus, the risk that the country does not provide adequate labour laws by sector was lower in most scenarios (namely 1, and 4-14). The same holds for overall risk of gender inequality, overall risk of corruption, and the risk that children that will not attend school, which are all lower in the same scenarios (1, 6-14). However, the risks associated with the implementation of two BioMates scenarios (number 2 and 3) are the same as for the reference system, namely, the risk that the country does not provide adequate laws by sector.

Therefore, most scenarios are socially sustainable (i.e., due to BioMates' net positive effect) except for those using miscanthus and forestry residues as biomass feedstocks, since they pose the same or higher risks as the reference system.

Nevertheless, it is worth reiterating that the results from this assessment were based on analysis of data drawn from the SHDB relating to levels of risk by sector and country level. However, the SHDB does not distinguish between products and technologies and this precludes any further differentiation among the various scenarios envisaged for BioMates regarding social impacts.

Table 63: Social Assessment of BioMates Scenarios

Scenario	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Labour rights and decent work (risk of lack adequate labour laws)	+	0	0	+	+	+	+	+	+	+	+	+	+	+
Health and Safety (risk of occupational hazards)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Human Rights (overall risk of gender inequality)	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Governance (overall risk of corruption)	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Community Infrastructure (risk that children are out of school)	+	+	+	+	+	+	+	+	+	+	+	+	+	+

BioMates scenarios	
1	Base case (wheat and barley straw)
2	Miscanthus
3	Forest residues
4	HDT and Pyrolysis Separate from Refinery
5	All Pyrolysis Units Separate from Refinery and HDT
6	Disposal of aqueous phase
7	Pyrolysis char replaces coal/coke
8	H_2 from natural gas
9	H_2 electrolysis using grid power mix
10	Mechanical H_2 compression
11	Mechanical H_2 recovery
12	O_2 use
13	Entry point for Light Vacuum Gas Oil
14	Entry point for Light Gas Oil

Evaluation system		
Risk	**Symbol**	**Impact**
High	--	Negative (significant)
Medium	-	Negative (moderate)
Low	+	Positive
The same in either system	0	Cancel out

5.2 Overall Social Sustainability Assessment of BioMates

The overall assessment of the BioMates value chain that incorporates the results of the SIA and SLCA parameters was carried out using the more comprehensive evaluation system, show in Table 64. The results of the overall assessment are shown in Table 65, in a matrix that provides a synoptic view of the key issues, actions and further comments.

Table 64: Evaluation System for the Overall Social Assessment of BioMates

Impact	*Type*	*Evaluation*
Direct	D	Where the project itself produces the impact
Background	B	Where local conditions influence implementation of the project
Positive	+	Project likely to produce a benefit
Negative	-	Project likely to produce impact that will not be of social benefit to country/local community
Neutral	N	Project produces no impact at all

Risk	*Benefit*	*Type*	*Evaluation*
L	**L**	Low	According to the data and indicators examined, and the likelihood of a problem emerging in the future even where the impact was assessed as positive
M	**M**	Medium	
H	**H**	High	
VH	**VH**	Very High	

The colours assigned to risks are based on a 'traffic light' system: green means it is viable ('proceed'); yellow is for warning ('caution'); red is for not viable ('stop'). The same colours are used for the benefits, but in reverse. Mitigating measures are suggested for potentially negative impacts

Table 65: Overall Social Sustainability Assessment of BioMates

No	Parameter	Characteristics/Criteria	Type	Impact	Risk	Benefit	Actions/Mitigation	Observations
1	Production of biomass feedstock	Incentives	B	+	M	H	Provision of state incentives/subsidies; locking farmers and buyers into long-term contracts	Subsidies and incentives to help encourage investment in the BioMates concept.
		Barriers	B	-	M	L	Some assurance about availability of biomass, and a degree of price and policy stability	Overall sound 'business case' needed to attract investment for implementing BioMates.
2	Identification of stakeholders along the supply chain	Producers Regulators Business Traders Researchers	D	+	L	H	All stakeholders (local, regional, national) to be mapped and involved in the set-up of BioMates biorefineries in specific areas	Identification of local level stakeholders alongside promotion of joint work (unions; cooperatives; associations) to help establish the chain (market penetration and expansion).
3	Policies and regulations	International National	B	- +	M	H	Ensure stable, coherent, and interconnected policies for energy and transport to encourage investment in the BioMates concept	Extensive policy framework in the EU for energy and transport needs to be transposed properly/timely to enable the scaling up of BioMates into a commercial venture
		Enforcement	D	+	M	H	Full and timely national transposition of EU policies	Risk to governance: high in Greece and very high in the Czech Republic (all sectors).
5	Land	Use and ownership	B	N	M	M	Mostly men are landowners/ tenants so opportunities for women required; risk of concentration of landownership if biorefinery model oriented to economies of scale	Area of agricultural land declining (bar in the Czech Republic); area of arable land and cropland declining in all countries; area of grassland generally declining (except in Sweden).
6	Community participation	Acceptance of biorefinery • Feedstock • Technologies	D	-+	H	M	Risk that 'economies of scale' model may lead to concentration of land/holdings, squeezing	Increasing prices for arable land and permanent grassland (Czech Republic and Sweden); commercial labour in agriculture and large

No	Parameter	Characteristics/Criteria	Type	Impact	Risk	Benefit	Actions/Mitigation	Observations
		• Products Other involvement					out small farms; need to foster small-scale partnerships and social enterprise; miscanthus to be grown in 'marginal land' to avoid land use change	agricultural land holdings very high in Sweden and Germany and high in the Czech Republic; no issues regarding acceptance of the BioMates concept, but miscanthus as a dedicated crop has potential to cause land use change
7	Quality of life	Material living conditions • Income • Consumption • Material conditions	B	+	L	M	BioMates can contribute to this dimension by creating local income earning opportunities	Life satisfaction highest in Sweden, lowest in Greece; mean equivalised incomes growing for men and women (except in Sweden).
8	Rural development and Infrastructure	Roads	B	+	M	H	Transportation of inputs and products is integral to the BioMates chain, thus road quality and safety are important considerations	Quality of roads (including in rural areas) improving in the Czech Republic and Greece but declining in Germany and Sweden; BioMates may contribute to expansion of road network.
		Water (availability and quality) for the local population	D	+	M	H	Need to ensure that cultivation of miscanthus does not disrupt local biomass supply patterns	Low risk of no access to water and sanitation (including rural areas); concern about miscanthus requiring large volumes of water to grow and process.
9	Job creation and wages	Labour involved on feedstock production/residues collection; biorefinery; transportation	D	-&+	M	H	Job opportunities to prioritise local labour pool whenever possible	BioMates will create local jobs (both low and high skilled) but likely to be limited in number/scope (seasonal); employment in agriculture declining in all countries.
		Wages paid according to national/regional regulation (minimum wage)	D	+	M	H	Monitoring of enforcement of legislation needed for labour remuneration in countries/sectors where there is high/very high risk of breach	Disposable income increasing in all countries; very high risk of average wage being lower than NMW in Greece (agro-forestry) and Czech Republic (in half of all sectors); population at risk of poverty increasing in Greece and Sweden.

No	Parameter	Characteristics/Criteria	Type	Impact	Risk	Benefit	Actions/Mitigation	Observations
10	Gender equity	Inclusion of women	D	+	M	H	Men predominate as landowners and tenants; women to be offered greater opportunity to access resources and participate in different stages of the BioMates chain	Indicators of economic activity by gender shows that men are more economically active in women in all countries; gender employment gap declining across all countries; women outside the labour force increasing in Germany and Sweden; risk of gender inequality high in Greece (in half of all sectors); women's share of low-pay earners highest in Germany.
11	Labour conditions	Conventions on • child labour • forced labour • right to organise	D	-&+	M	H	Monitoring of enforcement of legislation needed for child and forced labour in countries/sectors where there is high/very high risk of breach	All BioMates countries are signatories of ILO conventions that are transposed into national legislation; risks of child labour and forced labour high in Greece (agro-forestry sectors).
12	Health and safety	Compliance with health and safety regulations at the different stages of the chain	D	+	H	H	Monitoring of enforcement of legislation needed for health and safety at the workplace in there is high/very high risk of injuries and occupational hazards;	All BioMates countries have legislation in place for Health and Safety at the workplace and for transportation of hazardous substances; risk of fatal and non-fatal injuries high or very high in the Czech Republic (all sectors) and Sweden (most sectors); occupational hazards mostly high in all countries and sectors; number of hospital beds declining in all countries.
13	Competition with other sectors	Competition and negative impacts on other industries and sectors	D	-	M	L	Ensure little or no disruption to established uses of biomass or mitigate against it	BioMates may face only low competition for its required inputs (straw, miscanthus, forest residues; hydrogen) and its products (bio-oils, hybrid fuels); unfavourable competition with fossil fuels (subsidies and prices).

6. Overall Policy Assessment

As seen previously, the EU policy arena contains several instruments that are relevant to BioMates concept and can play an enabling role in its scaling up into a commercial venture and, that way, contribute to the diverse goals of various policy agendas for energy, climate, rural development, and environmental conservation. Of the instruments discussed in section 8, the most pressing regarding the prospects for BioMates are the RED and the regulation on CO_2 emission standards that abolishes some type of ICE vehicles.

The RED II defines the regulatory framework for the period 2021-2030 and so the parameters set by it and any ensuing reviews apply to the implementation of BioMates in the EU. The ongoing review of REDII, with the increased targets for GHG intensity reduction along with the sub-target for advanced biofuels in transport energy, should help create opportunities for the market expansion of BioMates, increasing demand for its hybrid fuel for road transportation, particularly long-distance heavy-duty vehicles, as well as maritime transport and aviation, the other segments of the transportation sector that are notoriously difficult to decarbonise. The fact that multipliers have been kept for the accounting of the energetic contribution of advanced biofuels in these segments further enhances the potential for the take up of BioMates, and they are expected to become even more important in these segments beyond 2030 as the use of fossil fuels would clash with carbon neutrality aims (EUR-LEX, 2021c). Moreover, in an assessment of future scenarios for RES growth, advanced biofuels are expected to contribute the highest share (8-9%), and along with electrification, showing the most marked growth trends (EUR-LEX 2021a). But technological challenges and volume availability may also hold back advanced biofuels from meeting the 2030 targets, especially if competition for feedstocks make it difficult to control costs and price volatility (EUR-LEX, 2021c). Yet, advanced drop-in fuels derived from biomass feedstocks are expected to provide the volumes needed for achieving carbon emission reduction and climate mitigation goals, even though they have been slow to reach commercial maturity (van Dyk et al., 2019; Brown et al, 2020). This is due to significant technical challenges, high capital costs, and low oil prices, so their co-processing with petroleum streams in conventional refineries will help reduce costs (van Dyk et al., 2019).

Nevertheless, the market expansion of BioMates will also hinge on how the energetic content of the biogenic component of co-processed, hybrid fuels is determined, which will only be known by the end of 2021. This will bear on the cost of the renewable component, where quota fulfilment is an important factor, and will largely determine the price fuel suppliers are willing to pay. In addition, the BioMates bio-oil will compete with other renewable products that EU member states can use to comply with legal mandates, by obligating fuel suppliers to help achieve the binding targets. The supply may count in three ways. It may count in energy terms as fuel suppliers are required to incorporate a minimum share of renewable energy in the fuels they supply to the market, including minimum shares for advanced biofuels. It may also count in in terms of emission savings, as fuel suppliers are required to reduce the emission intensity of fuels placed on the market with no sub-targets for advanced biofuels. The supply may also count both as energy and as emission savings (EUR-LEX, 2021a). However, the regulatory framework varies across the EU, according to the ways they are transposed into national policies, with commercial value generally expressed either as value per energy unit (in EUROS/GJ) or value per GHG saving (in EUROS ton CO_2 reduced). Focusing on value per energy unit, recent analysis of the costs of biofuels showed that they were higher than those of fossil fuels, lying in the range of 17-44 EUR/GJ, whereas fossil fuel prices lie in the 8–14 EUR/GJ range (Brown et al., 2020).

Regarding the revision of the regulation on CO_2 emission standards, the proposal to abolish new passenger and light commercial ICE vehicles from 2030 onwards and that all such all new vehicles registered from 2035 are to be zero-emission will certainly limit the scope of BioMates in road transportation beyond 2030. BioMates is being developed at a time when ICE vehicles in the EU are set to remain the main technology in road transport into the next decade, comprising around some 75% of the total light vehicle fleet, hence biofuels remain the most realistic renewable option for most transport vehicles up to 2030, and thus a key component in technology mix to address raised targets for reducing GHG emissions from the transportation sector (Panoutsou et al., 2021). Indeed, despite ambitious electrification targets in the EU, ICE vehicles will still predominate by far over zero and low-emission vehicles, which are expected to comprise only 10% of vehicles in this segment by 2025, whilst by 2035, some 85% of the vehicle stock will still be powered by ICE vehicles, although by 2050, this would be reversed, with electric vehicles dominating the stock, and ICE comprising only 20% (Michalopoulos, 2019). Clearly, there is a role for BioMates in this segment since the hybrid fuel can be supplied to existing ICE vehicles, and it can also still be supplied to long-distance heavy duty vehicles (i.e., trucks), since they are not covered by the proposal. But this proposal could be reconsidered to enable sustainable renewable fuels and hybrid fuels to play a more prominent role in the defossilisation of road transport in the short-term by pushing back the deadlines for introducing a ban on ICE vehicles. As it stands, the proposal has the potential to seriously deter investment on the BioMates concept, given the tight schedule for setting up and running a BioMates biorefinery before the ban of new ICE vehicles comes into force in 2030.

Indeed, as has been extensively documented, lack of stability in policy frameworks affecting biofuels, as clearly exemplified by shifts such as the ban on new ICE vehicles, tend to discourage new investment and financial commitment in the sectors affected, thereby jeopardising efforts at market expansion within them. The very increased impetus for decarbonising the transport sector in the EU through the slew of amended or new policies that set targets for GHG reductions may thwart investment in new fuel technologies, thus paradoxically impacting on the ability of member states to meet their legal mandates for reducing GHG emissions. The feedback on the EC's adoption of the new proposals for the RED (open to the public between July-November 2021; EC, 2021h) reveals various concerns regarding policy change. This includes comments about the fact that the current review of the REDII is the second in just three years and that constantly changing the legal framework undermines investor confidence in the biofuel sector that may lead businesses to pause investment decisions thus putting the future supply of biofuels in EU at risk. There were also calls for suspending the introduction of the proposed changes until RED II is fully enforced by member states, which for the most part has yet to happen, although the deadline for it lapsed in June 2021, with the transposition market by policy disarray and quagmire (see Vierhout, 2016). Failure to meet the deadline for transposition is further compounded by the obligation to implement the new changes without first having clarification from delegated acts and specific legislative detail which may take months or years to be disclosed. Some also thought that the obligation on suppliers to decrease the GHG intensity of fuels should be raised, and gradually, from an initial 6% in 2021 as set in the current FQD, to 11% in 2025, and 16% by 2030 ensure continuous defossilisation efforts by member states. Others also thought that the directive places a burden on the biofuel sector through the application of its sustainability criteria which, in turn, sets the biofuel sector at a disadvantage to the fossil sector. Similarly, the proposed minimum taxation level for biofuels, which for advanced biofuels would be equivalent to the 98.6% of the fossil fuel taxation base, disproportionately penalises biofuels, which on average save a much higher proportion of GHG than fossil fuels, which is all the more problematic, given the relatively small share of advanced biofuels in overall transport energy (EC, 2021h).

Moreover, the policy arena in the EU is highly fragmented due to the significant variations in the ways member states transpose and implement the RED and FQD and compliance mechanisms, which in turn derive from their own interpretations of policy and legislation that may be marked by ambiguity or lack of clarity. There is a patent lack of harmonisation in the enforcement of control mechanisms, verification and documentation for feedstocks and biofuels (Arup-Urs, 2014; Brown et al., 2020), which jeopardises the effective operation of a single market for biofuels (Vierhout, 2016). Thus, fragmentation, lack of harmonisation, coherence, transparency, and stability of policies and strategies all operate to constrain or stifle investment in biofuel ventures and novel biorefinery technologies, therefore, hindering the development of the biofuels sector, with obvious implications for BioMates. These and other important policy challenges have been extensively documented in the literature on biofuels and hybrid fuels and most remain intractable (e.g., Diaz-Chavez, 2011; Awudu and Zhang, 2012; Ekener- Petersen, Hoglund, and Finnveden, 2014; Hennig, Brosowski, and Majer, 2016; Goetz, German and Weigelt, 2017; Reboredo, Ramalho, and Pessoa, 2017; Hassan et al, 2018; van Dyk et al., 2019; Brown et al., 2020; Panoutsou et al., 2021).

5 Conclusions and recommendations

Ultimately, it is a complex combination of factors, conditions and dynamics operating at different scales that will determine whether and where a BioMates biorefinery or biorefinery process are set up and to what extent they can operate sustainably. Addressing this complexity requires the use of methodologies that address specificities attaching to contextual location of the biorefinery and its wider socio-economic and policy environment (e.g., a full feasibility study, SEIA of the whole supply chain, application of Equator Principles [3], etc), which the sustainability assessment conducted here is not meant to ever replace. Nevertheless, the overall social sustainability assessment of BioMates has highlighted the potential positive and negative impacts, the risks and benefits of implementing BioMates in different socio-economic, policy and cultural contexts within the EU (summed up in Table 65). BioMates can contribute to socially sustainable rural development, by creating local jobs and income earning opportunities through the chain, so long as it addresses or mitigates 'hotspot' issues relating to land use and ownership, gender equity, health and safety, labour conditions, and competition (for inputs and products). But such positive contributions will also be conditioned by the degree of integration achieved by the BioMates value chain, and the impacts of policy frameworks that regulate the wider context within which it must operate, relating to access to biomass feedstocks and prices, their role in meeting targets for the defossilisation of transportation, and their standing against fossil fuels. These considerations inform the recommendations put forward next.

A critical factor for the success of biorefineries is bringing together key stakeholders who usually operate in different market sectors (particularly agriculture and forestry, chemicals, energy, and transportation) to cooperate in multi-disciplinary partnerships for discussions and knowledge exchange on biorefinery issues, to develop synergies, to foster research, development and innovation, and to speed up the deployment of new technologies (EIA-BIOENERGY, 2009; Leibensperger et. al, 2021). As seen previously (section 7.3), a range of stakeholders were identified in the four BioMates countries that should come together to drive the implementation of the BioMates in those countries. Similarly, the social sustainability of BioMates, wherever it is implemented in future, will necessarily require engaging stakeholders (e.g., workshops, interviews, surveys, focus groups) to help identify and address the gamut

[3] http://equator-principles.com/

of important issues related to biorefinery supply/value chains, particularly about local dynamics (e.g., community involvement, gender equity, health and safety and working conditions, and adequate remuneration).

On the supply side, producers interested in cultivating miscanthus for BioMates should seek to grow them on marginal land to avoid displacing cultivation of food crops, or else, take action to mitigate for such displacement. Suppliers of biomass feedstocks for BioMates should be required to adopt the same sustainable principles relating to land use, workforce, working conditions and wages, equality of opportunity, and health and safety incumbent on businesses running BioMates biorefineries. Indeed, commitment to social reporting (e.g., provision of producer-specific indicators) should be a key stipulation for selecting suppliers, or where not feasible, the auditing of suppliers could be carried out, ensuring that any 'hotspot' issues are addressed.

Producers and investors involved in the development of the BioMates chain should prioritise recruitment of labour from local labour pools as much as possible, particularly for low-skilled/unskilled functions, since highly-skilled positions may be more difficult to source locally. They should also provide appropriate working conditions and enforce all requisite regulations to ensure the health and safety of the workforce, paying particular attention to 'hotspot' issues and ensure to avoid or mitigate for them. To address issues of gender equity, they should ensure that men and women are given equality of opportunity to access, progress and upskill on jobs and income-generating activities as well as paying statutory wages or wages that bridge any gender pay gaps. The BioMates concept may also provide an opportunity for producers and businesses to foster gender equity through capacity-building initiatives (e.g., summer schools, internships, apprenticeships).

Stakeholders at the BioMates workshop generally agreed that synthetic fuels have a role to play in the defossilisation of the transportation sector in the immediate future, and that use of hybrid fuels may become a standard practice in the sector. The prospects for the BioMates concept are promising since it offers an effective interim solution to the seemingly intractable challenge of achieving zero carbon emissions through the phasing out of fossil fuels from the transportation sector. BioMates hybrid fuels can also be used directly in the conventional engines, without modification, and be supplied through existing fuelling stations (Chin et al, 2014). They will add to the portfolio of fuels that incorporate biofuels being developed for shipping (Bach et al, 2020) and aviation (Filimonau, Miroslaw and Pawlusińsky, 2018; Kim, Lee and Jaemyung, 2019). Indeed, as Panoutsou et al (2021) note, advanced biofuels can make a substantive contribution to efforts to decarbonise road, air and water transportation in the short to medium term, so long as the challenges besetting their value chain are addressed to help speed up production and market uptake. Thus, BioMates novel technologies have an important role to play in helping the EU meet its commitments to reducing carbon emissions from transport through increased use of renewable fuels and hybrid fuels with biogenic content.

However, the success and sustainability of BioMates hinge on addressing challenges specific to its concept (i.e., due to the combination of types of feedstocks used, the conversion processes, and the intermediate and final products obtained) as well as the long-standing challenges contingent on the evolving landscape for sustainable transportation fuels. For instance, stakeholders at the BioMates workshop noted that current policies in the EU to offer no real incentives for the market take-up of either bio-oils or hybrid fuels. Policies that ban the use of particular types of crops or biomass, policy focus on quotas (rather than on quality) and the enforcement of quality regulations and standards were all seen as barriers to market expansion. In particular, the uneven implementation of regulations for renewable energy across the EU

region was seen as major barrier. Stakeholders called for a variety of measures to address the challenges confronting the development of biofuels or hybrid fuels chains, including:

- regulation of prices of biomass feedstocks
- provision of subsidies to help policy targets
- parity in the provision of incentives to different renewable fuels
- accounting for bio-content in all energy products
- making hybrid fuels eligible for discounting
- policies to encourage the demand for hybrid fuels
- greater support to investment in production and commercialisation of hybrid fuels
- more investment to help overcome technological 'bottlenecks' and "the valley of death" (i.e., the non-realisation of the potential of novel technologies through lack of scaling-up)

In the context of current policy review in EU, the following recommendations merit attention:

- increase yet further the obligation on suppliers to decrease the GHG intensity of fuels by 2030 to encourage greater use of renewable liquid fuels
- ensure that minimum taxation rates of the different renewable fuels reflect their GHG savings potential compared to fossil fuels
- simplify and stabilise the regulatory frameworks in the EU to avoid undermining investor confidence and jeopardising investment in the biofuels sector
- encourage development of knowledge-sharing platforms to link up investors (who may lack knowledge of the biofuels sector) with bioindustry project promoters (who may lack knowledge about public funding and financial mechanisms) for the leveraging private funding for scaling up biorefinery concepts such as BioMates

The policy arena is diversified enough to help drive the development of the BioMates concept and help enable the mainstreaming its hybrid fuels for the transportation sector. But success will require action on several fronts. It will require much greater articulation, stability and coherence of policy frameworks and instruments. It will require concerted action among biofuel producers and different segments of the biofuels industry, along with their greater connectedness with oil companies and the different segments in the transportation sector. It will require greater commitment to decarbonistion by the transport sector, by businesses and government. The undertaking of these actions will certainly help achieve integration of the proposed BioMates chain, widen the market for its products, and ensure its sustainability.

6 Disclaimer

This report reflects only the authors' view. Neither the European Commission nor its executive agency, CINEA, are responsible for any use made of the information it contains.

7 References

5.3 General

Andrews, E, Lesage, P., Benoît, C, Parent, J, Norris, G, Revéret, J (2009) Life cycle attribute assessment: Case study of Quebec greenhouse tomatoes, *Journal of Industrial Ecology*, 13 (4): 565-578.

Arup-URS (2014) *Advanced Biofuel Feedstocks – An Assessment of Sustainability*, Arup-URS Consortium, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277436/feedstock-sustainability.pdf

Awudu, I and Zhang, J (2012) 'Uncertainties and sustainability concepts on in biofuel supply management chain', *Renewable and Sustainable Energy Reviews*, 16: 1359 -1368, https://doi.org/10.1016/j.rser.2011.10.016.

Benoît, C N, Norris, G, Valdivia, S, Ciroth, A, Moberg, A, Bos, U, Prakash, S, Ugaya, C and Beck, T (2010) The guidelines for social life cycle assessment of products: just in time! The International *Journal of Life Cycle Assessment*, 15(2), pp.156–163 (http://link.springer.com/10.1007/s11367-009-0147-8).

Benoît-Norris, C, Cavan, DA, Norris, G (2012) 'Identifying social impacts in product supply chains: overview and application of the social hotspot database', *Sustainability*, 4: 1946–1965.

Benoît, C, Traverso, M, Valdivia, S, Vickery-Niederman, G, Franze, J, Azuero, L, Aulision, D (2013): *The methodological sheets for sub-categories in social life cycle assessment sLCA,* UNEP-SETAC.

Brown, A, Waldheim, L, Landalv, I, Sadler, E, Ebadian, M, McMillan, JD, Bonomi, A and Klein, B (2020) Advanced Biofuels – potential for cost reduction IEA BIOENERGY Summary Series, Task 41, https://www.ieabioenergy.com/wp-content/uploads/2020/02/T41_CostReductionBiofuels-11_02_19-final.pdf

Caputo, AC, Palumbo, M, Pelagagge, PM, and Scacchia, F (2005) 'Economics of biomass energy utilization in combustion and gasification plants: effects of logistic variables', *Biomass Bioenergy*, 28: 35-51.

Chin, H, Choong, W, Alwi, SRW, and Mohammed, AH (2014) 'Issues of social acceptance on biofuel development', *Journal of Cleaner Production*, 71 (2014) 30- 39; https://doi.org/10.1016/j.jclepro.2013.12.060.

Ciroth, A, Finkbeier, M, Hildenbrand, J, Klöpffer, W, Mazijn, B, Prakash, S, and Sonnemann, G, (2011) *Towards a Life Cycle Sustainability Assessment: Making informed choices on products*, United Nations Environmental Programme (UNEP): Paris.

Colantonio, A (2009) *Social Sustainability: A review and critique of traditional versus emerging themes and assessment methods*, https://www.researchgate.net/publication/267818292_Social_Sustainability_A_review_and_critique_of_traditional_versus_emerging_themes_and_assessment_methods

Czernik, S and Bridgwater, AV (2004) Overview of Applications of Biomass Fast Pyrolysis Oil, *Energy and Fuels,* 18(2): 590-598, DOI: 10.1021/ef034067u.

Dalal-Clayton, B, and Sadler, B (2004) *Sustainability Appraisal*, A Review of International Experience and Practice, Institute for Environment and Development: London.

de Luca, AI de, Iofrida, N, Strano, A, Falcone, G, Gulisano (2015) 'Social life cycle assessment and participatory approaches: a methodological proposal applied to citrus farming in Southern Italy', Integrated Environmental Assessment Management, 11 (3): 383-396.

Diaz-Chavez, R (2006) 'Measuring Sustainabiltiy in Peri-urban Areas: case study of Mexico City', in Simon, D and Thompson, D (eds) *The Peri-Urban Interface*: approaches to Sustainable Natural and Human Resource Use, Earthscan: London; 246 – 261.

Diaz-Chavez R, Mutimba S, Watson H, Rodriguez-Sanchez, S and Nguer M (2010)*Mapping food and bioenergy in Africa: A report prepared for FARA*. Accra, Ghana. 60 pp. ISBN 978-9988-1-1060-x. Web site: www.fara-africa.org.

Diaz-Chavez, R (2011) 'Assessing Biofuels: Aiming for Sustainable Development or Complying with the Market? *Energy Policy*, 39: 5763-5769; https://doi.org/10.1016/j.enpol.2011.03.054.

Diaz-Chavez, R (2012) *Socio-Economic Assessment of Biorefinery projects: a methodological review.* 20th European Biomass Conference and Exhibition, Milan 18 - 22 June 2012.

Diaz-Chaves, R (2013) *Final Report on Social Assessment of the BIOCORE project:* www.biocore-europe.org/file/D7_4%20Final%20assessment%20of%20the%20economic%2c%20sociallegalpolitical%20sustainability%20of%20the%20BIOCORE%20biorefining%20system.pdf.

Diaz-Chavez, R (2014) 'Indicators for Socio-Economic Sustainability Assessment', in Rutz, D and R Janseen, (eds) *Socio-economic impacts of Bioernergy Production*, Springer: Switzerland: 17-37.

Diaz-Chavez, R, Stichnothe, H, Johnson, K (2016) 'Sustainability Considerations for the Future Bioeconomy', in Lamers,P, Searcy, E, Hess, J R, Stichnothe, H (eds) *Developing the Global Bioeconomy:Technical, Market, and Environmental Lessons from Bioenergy*, Academic Press.

EC (2014a) European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - A policy framework for climate and energy in the period from 2020 to 2030, COM(2014) 15 final, Brussels, 22.01.2014, http://www.europarl.europa.eu/meetdocs/2009_2014/documents/nest/dv/depa_20140212_06/depa_20140212_06en.pdf; *http://bit.ly/1LUcJKL*

EC (2014b) European Commission, Energy Union Package - Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions and the European Investment Bank - A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, COM(2015) 80 final, Brussels, 22.01.2014, http://eur-lex.europa.eu/resource.html?uri=cellar:1bd46c90-bdd4-11e4-bbe1-01aa75ed71a1.0001.03/DOC_1&format=PDF, *http://bit.ly/198SAUf*

EC (2015) European Commission, LCE-08-2016-2017 "Development of next generation biofuel technologies", Publication date: 14 October 2015, https://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/lce-08-2016-2017.html, *http://bit.ly/2ndtvPc*

EC (2021a) *Statistical Factsheets*, https://ec.europa.eu/info/food-farming-fisheries/farming/facts-and-figures/farms-farming-and-innovation/structures-and-economics/economics/statistical-factsheets_en.

EC (2021b) *EU Agricultural fact sheets*,https://ec.europa.eu/info/food-farming-fisheries/farming/facts-and-figures/performance-agricultural-policy/agriculture-country/eu-country-factsheets-0_en

EC (2021c) *The Agricultural European Innovation Partnership,* https://ec.europa.eu/eip/agriculture/en/node.

EC (2021d) *The EU Emissions Trading System*, https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets_en,

EC (2021e) ReFuelEU Aviation Initiative,

https://ec.europa.eu/info/sites/default/files/refueleu_aviation_-_sustainable_aviation_fuels.pdf

EC (2021f) *FuelEU Maritime Initiative*, https://ec.europa.eu/info/sites/default/files/fueleu_maritime_-_green_european_maritime_space.pdf

EC (2021g) EU Strategic Framework on Health and Safety at Work 2021 – 2027, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0323&qid=1633353800221

EC (2021h) *EU renewable energy rules – review, Commission adoption, Feedback Period*, https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12553-EU-renewable-energy-rules-review_en.

Eizenberg, E and Jabareen, Y (2017) Social Sustainability: a new conceptual framework, *Sustainability*, 9: 68, https://doi.org/10.3390/su9010068.

Ekener- Petersen, E, Hoglund, J, and Finnveden, G (2014) Screening Potential Social Impacts of Fossil Fuels and Biofuels for Vehicles, Energy Policy, 73: 416–426, http://dx.doi.org/10.1016/j.enpol.2014.05.034.

Elbersen, B, Eupen, VE, Mantel, S, Verzandvoort, S, Boogaard,H, Mucher, S, Cicarreli, T, Elberson, W, Baiz, Z, Iqbal, Y, Cossel, M, McCallum, I, Carrasco, J, Ramos, C, Monti, A, Scordi, D, and Eleftheriadis, I (2019) Deliverable 2.1 Definition and classification of marginal lands suitable for industrial crops in Europe, Wageningen University and Research, EU Horizon 2020; MAGIC; GA-No.: 727698 Ref. Ares(2019)92399, https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c07b5180&appId=PPGMS.

EUR-LEX (2021a) Proposal to amend RED II,

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0557&qid=1634756423960

EUR-LEX (2021b) *Land Use and Forestry Regulation*, https://eur-lex.europa.eu/search.html?scope=EURLEX&text=Regulation++2018%2F841&lang=en&type=quick&qid=1634130339542

EUR-LEX (2021c) *EU Forestry Strategy*, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0572

EUR-LEX (2021d) *RED (recast)*, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018L2001-20181221&qid=1631902960612

EUR-LEX (2021e) *Effort Sharing*, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0555&qid=1634129813856

EUR-LEX (2021f) Regulation for CO2 emissions performance for cars and vans, https://ec.europa.eu/info/sites/default/files/amendment-regulation-co2-emission-standards-cars-vans-with-annexes_en.pdf

EUR-LEX (2021g) *Energy Taxation Directive* (review), https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52021PC0563

EUR-LEX (2021h) *Fuel Quality Directive*, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0030

EUROSTAT (2018) *Database,* https://ec.europa.eu/eurostat/data/database

FAOSTAT (2018) *Data,* http://www.fao.org/faostat/en/#data

Falcone, M and 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), 1031; https://doi.org/10.3390/su10041031.

Filimonau, V, Mirosław, M and Pawlusiński, R (2018) 'Public attitudes to biofuel use in aviation: Evidence from an emerging tourist market', *Journal of Cleaner Production*, 172: 3102-3110; https://doi.org/10.1016/j.jclepro.2017.11.101.

Fortier, MP, Teron, L, Reames, TG, Munardy, DT (2019) 'Introduction to evaluating energy justice across the life cycle: A social life cycle assessment approach', *Applied Energy*, 236: 211-219.

Gracia, A, Barreiro-Hurlé, J, Pérez, LP (2020) 'Assessing the benefits of sustainability certification of biofuels: how much are consumers willing to pay', *New Medit 2*; https://doi.org/10.30682/nm2002a.

Goedkoop, M.J.; de Beer, I.M; Harmens, R.; Saling; P, Morris, D; Florea, A; Hettinger, AL; Indrane; D, Visser; Morao, A; Musoke-Flores, E; Alvarado, C; Rawat, I; Schenker, U; Head, M; Collotta, M; Andro, T; Viot, J; Whatelet, A (2020) *Product Social Impact Assessment Handbook*, Amersfoort, https://product-social-impact-assessment.com/wp-content/uploads/2021/04/20-01-Handbook2020.pdf.

Goetz, A, German, L and Weigelt, J (2017) 'Scaling up biofuels? A critical look at expectations, performance and governance', *Energy Policy*, 110: 719-723; https://doi.org/10.1016/j.enpol.2017.05.004

GOVUK (2016) RED *Annex IX factsheets*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277600/annexIX-factsheets.pdf

Grießhammer, R, Benoît, C, Dreyer, LC, Flysjö, A, Manhart, A, Mazijn, B, Méthot, AL, Weidma, B (2006) *Feasibility study: integration of social impacts into LCA*, https://lca-net.com/publications/show/feasibility-study-integration-social-aspects-lca/

Hassan, S, Williams, G A, Jaiswal, AK (2018) 'Lignocellulosic Biorefineries in Europe: current state and prospects', *Trends in Biotechnology*, 37(3):231-234; doi: 10.1016/j.tibtech.2018.07.002. .

Hassan, SS, Williams, GA, Jaiswal, AK (2019) 'Moving towards the second generation of lignocellulosic biorefineries in the EU: Drivers, challenges, and opportunities', *Renewable and Sustainable Energy Reviews*, 101: 590–599; https://doi.org/10.1016/j.rser.2018.11.041.

Hennig, C., Brosowski, A., and Majer, S. (2016) 'Sustainable feedstock potential: a limitation for the bio-based economy?' *Journal of Clean Energy Production*, 123:200-202; https://doi.org/10.1016/j.jclepro.2015.06.130.

HDI (2021) *Human Development Index*: Data; http://hdr.undp.org/en/data.

Holden, E and Gilpin, G (2013) 'Sustainable Transport and Biofuels: a conceptual discussion', *Sustainability*, 5: (7), 3129-3149; https://doi.org/10.3390/su5073129.

Hodgson, E. Ruiz-Molina, M, Marazza, D, Pogrebnyakova, E, Burn, C, Higson, A, Rehberger, M, Gyalai-Korpos, M, di Lucia, L, Noël, Y, Woods, J, Gallagher, J (2016) Horizon scanning the European bio-based economy: a novel approach to the identification of barriers and key policy interventions from stakeholders in multiple sectors and regions', *Biofuels, Bioproducts and Biorefining*, 10: 508–522; https://doi.org/10.1002/bbb.1665.

IEA-BIOENEGY (2009) *Biorefineries: adding value to the sustainable utilisation of biomass*, IEA-BIOENERGY,https://www.ieabioenergy.com/blog/publications/biorefineries-adding-value-to-the-sustainable-utilisation-of-biomass/

IEA-BIOENERGY (2013) Health and Safety Aspects of Solid Biomass Storage, Transportation and Feeding, https://www.ieabioenergy.com/blog/publications/health-and-safety-aspects-of-solid-biomass-storage-transportation-and-feeding/

IRENA (2020) Renewable Energy and Jobs – Annual Review 2020, International Renewable

Energy Agency, Abu Dhabi, https://www.irena.org/publications/2020/Sep/Renewable-Energy-and-Jobs-Annual-Review-2020.

ILO (2012) Promoting Safety and Health in a Green Economy; ILO, http://www.ilo.org/safework/info/WCMS_175600/lang--en/index.htm

ILO (2021) *Conventions*, ILO: https://www.ilo.org/dyn/normlex/en/f?p=1000:12000:::NO:::

InterregEU (2021) *Commission launches the Fit for 55% Package*, https://www.interregeurope.eu/policylearning/news/12610/commission-launches-the-fit-for-55-package/?no_cache=1&cHash=a371af17736f1f2f09030ee45e7dd6f2

ISO (2006) *ISO 14040, Environmental management, Life cycle assessment, Principles and framework*, International Organization for Standardization, https://www.iso.org/standard/37456.html.

Klöpffer (2008) 'Life-cycle based sustainability assessment of products', *International Journal of*

Life Cycle Assessment, 13 (2), 89–94.

Lewandowski, I; Clifton-Brown, J; Trindade, LM; van der Linden; C, Schwarz; K, Mullher-Samann, K; Anisimov, A; Chen, C; Dolstra, O; Donnision, I; Farrar, K; Fonteyne, S; Harding, G; Hastings, A; Huxley, LM; Iqbal, Y; Khokhlov, N; Kiesel; A, Lootens, P; Meyer, H; Mos, M; Muyelle, H; Nunn, C; Ozguven, M; Roldan-Ruiz, I; Schule, H; Tarakanov, I; van der Weijde, T; Wagner, M; Xi, Q; and Kalinina, O (2016) Progress on Optimizing Miscanthus Biomass Production for the European Bioeconomy: Results of the EU FP7 Project OPTIMISC, Frontiers in Plant Science,18, https://doi.org/10.3389/fpls.2016.01620.

Kim, Y, Lee, J, and Jaemyung, A (2019) 'Innovation towards sustainable technologies: A socio-technical perspective on accelerating transition to aviation biofuel', *Technological Forecasting and Social Change*, 145: 317-329; https://doi.org/10.1016/j.techfore.2019.04.002.

Leibensperger, C, Yang, P, Zhao, Q, Wei, S and Cai, X (2021) The synergy between stakeholders for cellulosic biofuel development: perspectives, opportunities, and barriers, *Renewable and Sustainable Energy Reviews*, 13: 110613; https://doi.org/10.1016/j.rser.2020.110613.

McCormick, K, and Kautto, N (2013) 'The Bioeconomy in Europe: An overview', Sustainability, 5: 2589–2608; https://doi.org/10.3390/su5062589.

Michalopoulos, S (2019) *Biofuel expert calls on EU to revisit RED II to avoid 'impetus of oil'*, https://www.euractiv.com/section/agriculture-food/news/biofuel-expert-calls-on-eu-to-revisit-red-ii-to-avoid-impetus-of-oil.

Norris, C and Norris, G (2015) 'The Social Hotspots Database Context of the SHDB', in Murray, J, McBain, D, and Wiedmann, T (eds) *The Sustainability Practitioner's Guide to Social Analysis and Assessment*, Common Ground; https://www.researchgate.net/publication/287215286_Chapter_8_The_Social_Hotspots_Database_Context_of_the_SHDB

Nunes, I (2017): *Occupational safety and health risk assessment methodologies*, https://oshwiki.eu/wiki/Occupational_safety_and_health_risk_assessment_methodologies#cite_note-BSI.2C_2007-1.

O'Brien, M, Doig, A, Clift, R (1996) Social and environmental Life Cycle Assessment (SELCA) 'Approach and methodological development', International Journal Life Cycle Assessment, 1(4):231-237.

Panoutsou, C, Germer, S, Karka, P, Papadokostantakis, S, Kroyan, Y, Wojcieszyk, K, Marchand, P, and Landalv, I (2021) 'Advanced biofuels to decarbonise European transport by 2030: Markets, challenges, and policies that impact their successful market uptake', *Energy Strategy Reviews*, 34: 100633; https://doi.org/10.1016/j.esr.2021.100633.

Parajouli, R, Dalgaard, T, Jørgensen, U, Adamsen, A, Knudsen, M, Birkved, Gylling, M and Schjørring, J (2015) Biorefining in the prevailing energy and material crisis: a review of sustainable pathways for biorefinery value chains and sustainability assessment methodologies, Renewable and Sustainable Energy Reviews, 43: 244 – 263.

Rafiaani, P, Kuppens, T, Van Dael, M, Azadi, H, Lebailly, P, Van Passel, S, Social sustainability assessments in the biobased economy: towards a systemic approach, Renew. Sust. Energy. Rev. 82 (2018) Part 2, 1839-1853.

Reitinger, C, Dumke, M, Barosevcic, M, and Hillerbrand, A (2011) 'A conceptual framework for impact assessment within SLCA', International Journal of Life Cycle Assessment, 16 (4):380–388.

Reboredo, FH, Ramalho, JC, Pessoa, MF (2017) 'The forgotten implications of low oil prices on biofuels', *Biofuels, Bioproduction and Biorefineries*, 11:625–632, DOI: 10.1002/bbb.1769.

RES-LEGAL (2021) *Legal sources on renewable energy*, http://www.res-legal.eu/

SHDB (2021) *Social Hotspot Database*: http://www.socialhotspot.org/.

Shortall, OK (2013) "Marginal land" for energy crops: exploring definitions and embedded assumptions, *Energy Policy*, 62: 19-27.

Star-coliBRI (2011) *Join European Biorefinery Vision for 2030*; Star-coliBRI: https://setis.ec.europa.eu/energy-research/sites/default/files/project/docs/Star-COLIBRI%20Final%20Publishable%20Executive%20Summary.pdf

TE (2020) RED II and advanced biofuels: recommendations about Annex IX of the Renewable Energy Directive and its implementation at national level, Transport and Environment, https://www.transportenvironment.org/sites/te/files/publications/2020_05_REDII_and_advanced_biofuels_briefing.pdf

TGE (2021) *Roads quality - Country rankings*, https://www.theglobaleconomy.com/rankings/roads_quality/

Tsita, KG and Pilavachi, PA (2013) 'Evaluation of next generation biomass derived fuels for the transport sector', *Energy Policy*, 62: 443-455; https://doi.org/10.1016/j.enpol.2013.07.114.

UNEP/SETAC (2009) *Guidelines for Social Life Cycle Assessment of Products*, UNEP-Paris; http://www.unep.fr/shared/publications/pdf/dtix1164xpa-guidelines_slca.pdf.

UNEP/SETAC, The Methodological Sheets for Subcategories in Social Life Cycle Assessment (S-LCA), Paris, 2013.

UPEI (2021) *Position Paper: Solving the Fuels Policy Conundrum: recommendations for a holistic and ambitious 'FitFor55'framework*, Europe's Independent Fuels Suppliers, https://www.upei.org/download/1302/978/17?method=view.

van Dyk, S, Jianping, S, McMillan, J, Saddler, J (2019) 'Potential synergies of drop-in biofuel production with further co-processing at oil refineries', Biofuels, Bioproducts, Biorefining, 13:760–775; https://doi.org/10.1002/bbb.1974.

Vierhout, R (2016) Obstacles to achieve an internal market for transportation fuels *with bio-components*, https://www.upei.org/images/160804_Obstacles_to_an_internal_market_for_biofuels_DEF.pdf.

WECD (1987) *Report of the World Commission on Environment and Development: Our Common future,* Brundtland Report, United Nations, https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf.

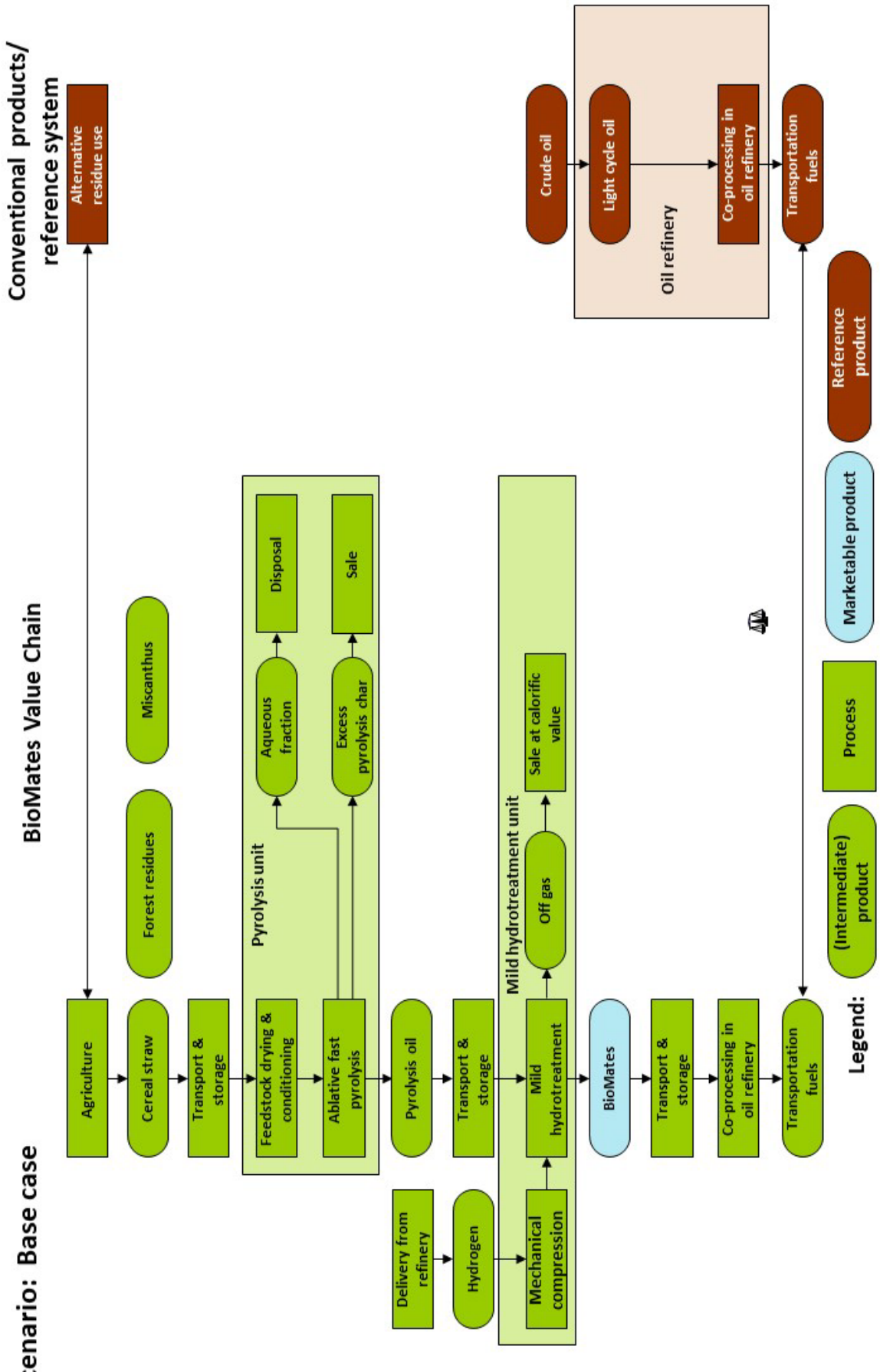
Wietschel, L, Thorenz, A and Tuma, A (2019) Spatially explicit forecast of feedstock potentials for second generation bioconversion industry from the EU agricultural sector until the year 2030, Journal of Cleaner Production 209: 1533-1544; https://doi.org/10.1016/j.jclepro.2018.11.072

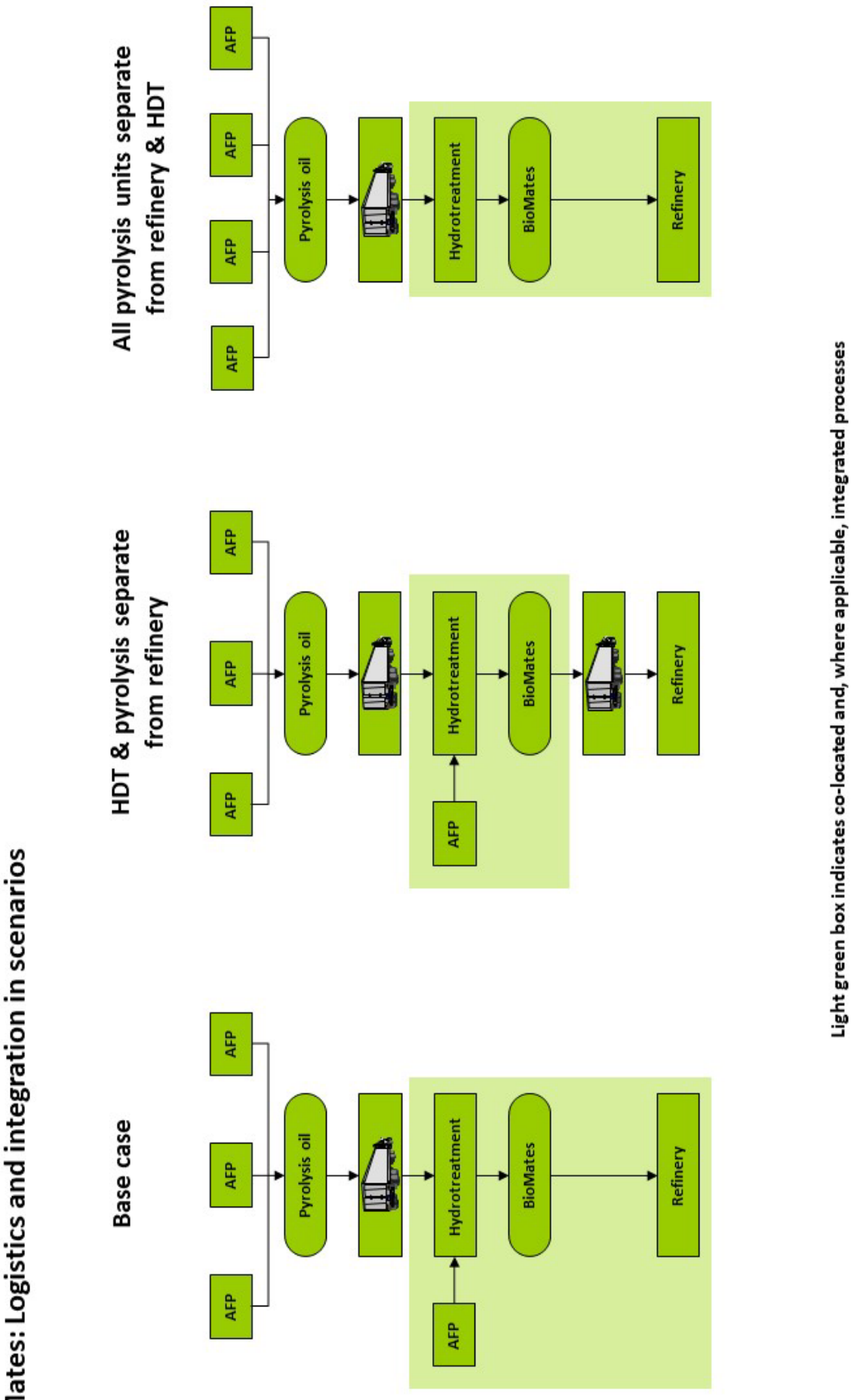
5.4 BioMates Deliverables

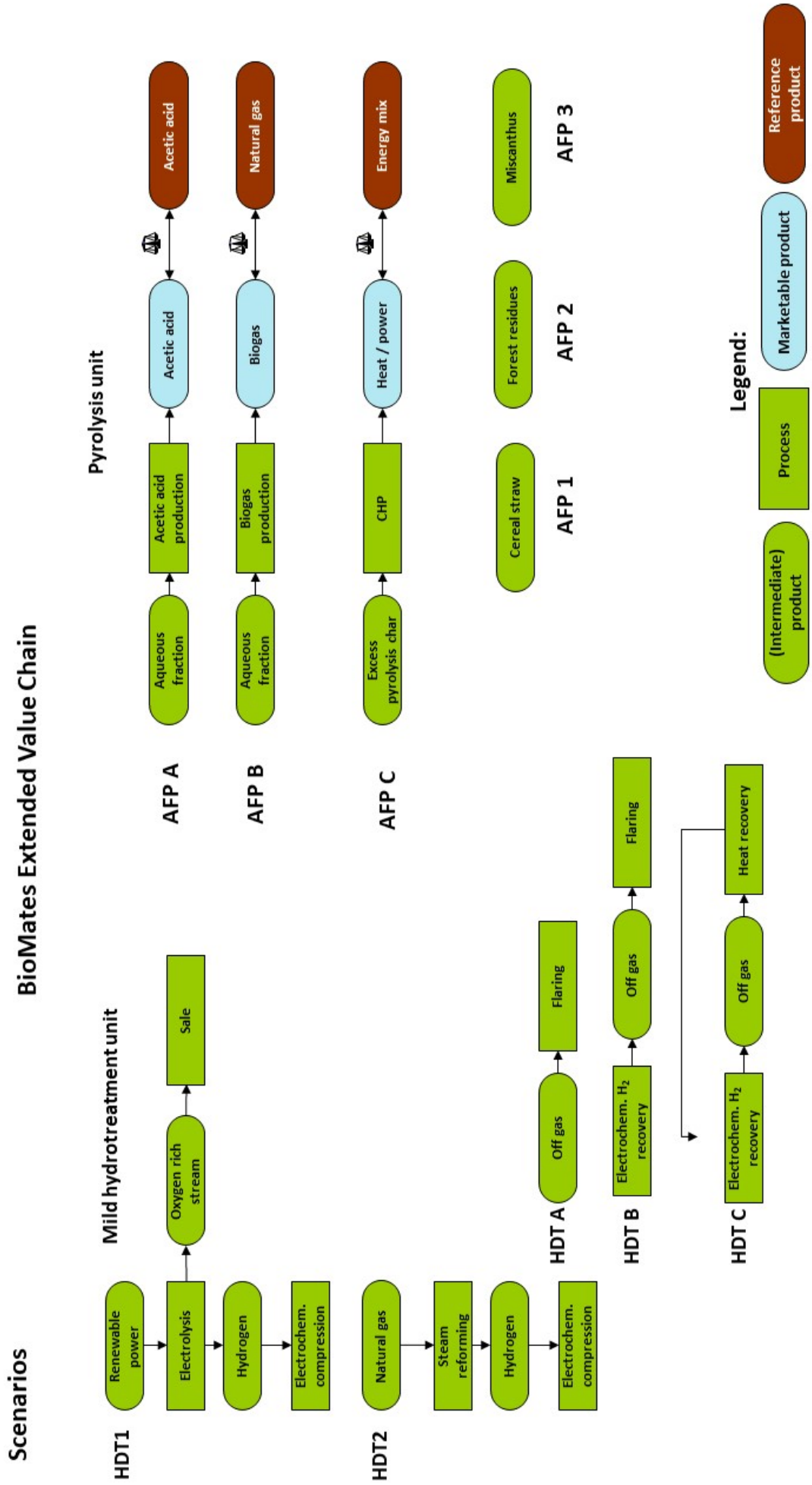
For public deliverables and public summaries of confidential deliverables, please see http://www.biomates.eu/results/approved-deliverables, https://s.fhg.de/openaire-biomates or https://s.fhg.de/Cordis-BioMates

D5.1/D11	Technical risk management report – confidential report with public summary
D5.9/D51	Feedstock-risks management report – confidential report with public summary
D4.2/D39	Report on Workshop conducted with stakeholders – public report

ANNEX I – BioMates Scenarios and Pathways




BioMates: Logistics and integration in scenarios
Base case
HDT & pyrolysis separate from refinery
All pyrolysis units separate from refinery & HDT
AFP
Pyrolysis oil
Hydrotreatment
BioMates
Refinery
Light green box indicates co-located and, where applicable, integrated processes


BioMates Extended Value Chain
Scenarios
HDT1
Renewable power
Electrolysis
Oxygen rich stream
Sale
Hydrogen
Electrochem. compression
HDT2
Natural gas
Steam reforming
Hydrogen
Electrochem. compression
Mild hydrotreatment unit
HDT A
Off gas
Flaring
HDT B
Electrochem. H2 recovery
Off gas
Flaring
HDT C
Electrochem. H2 recovery
Off gas
Heat recovery
Pyrolysis unit
AFP A
Aqueous fraction
Acetic acid production
Acetic acid
Acetic acid
AFP B
Aqueous fraction
Biogas production
Biogas
Natural gas
AFP C
Excess pyrolysis char
CHP
Heat / power
Energy mix
AFP 1
Cereal straw
AFP 2
Forest residues
AFP 3
Miscanthus
Legend:
(Intermediate) product
Process
Marketable product
Reference product

ANNEX II – Definition of Socio-Economic Indicators

Indicator	Measurement Unit	Explanation	Data Source
Agricultural/Forestry Indicators			
Agricultural hodling	Unit	An agricultural holding, or holding or farm is a single unit, both technically and economically, operating under a single management and which undertakes economic activities in agriculture within the economic territory of the EU, either as its primary or secondary activity. The holding may also provide other supplementary (non-agricultural) products and services.	EUROSTAT
Arable land	Thousand hectares	Land worked (ploughed or tilled) regularly, generally under a system of crop rotation.	EUROSTAT
Cropland	Thousand hectares	Land on which agricultural crops are grown; it includes arable, land tillage land, and agro-forestry systems where vegetation falls below the thresholds used for the forest land category; it fallow land	EUROSTAT
Fallow land	Thousands of hectares	All arable land, whether worked or not, but which will not be harvested for the duration of a crop year; its essential is that it is left to recover, normally for the whole of a crop year; bare land with no crops at all; land with spontaneous natural growth which may be used as feed or ploughed in; land sown exclusively for the production of green manure (green fallow); it includes arable land lying fallow for less than 5 years or for 5 years or more if for the purpose of fulfilling the ecological focus area	EUROSTAT
Farm labour (AWU)	Thousands of persons	One annual work unit corresponds to the work performed by one person who is occupied on an agricultural holding on a full-time basis (i.e. the minimumhours required by the relevant natiional provisions governing contracts of employment; if these are not available, then 1800 annual working hours are taken as the minimum, equivalent to 225 working days of eight hours.	EUROSTAT
Fertiliser Expenditure	Millions of Euros	The amount spent on fertilisers and soil improvers annually; this is the estimation of purchases by regional areas. Purchases by agriculture are based on the data relating to sales by branches which supply these intermediate goods (after inclusion of external trade). Obtained from farm structure surveys.	EUROSTAT
Grassland	Thousand hectares	Areas of land predominantly covered by communities of grassland, grass-like plants and forbs; may include sparsely occurring trees within a limit of a canopy of < 10 % and shrubs within a total limit of cover (including trees) of 20 %.	EUROSTAT
GDP of agricultural Sector	Billions of Euro	GDP of the agricultural sector reflects the total value of all goods and services produced less the value of goods and services used for intermediate consumption in their production in Agriculture.	EUROSTAT
Unutilised agricultural area	Thousand hectares	Land previously used for an agricultural purpose but which is no longer worked and which is not used in the crop rotation system. It could be brought back into cultivation. It is not considered by the farmer as part of the rotation.	EUROSTAT
Utilised Land Area	Thousand hectares	Land area and its utilisation: size and distribution of the land area of the holding, in particular, the utilised agricultural area (UAA) which comprises arable land, permanent grassland, permanent crops and kitchen gardens; an utilised area of 5ha or more	EUROSTAT
Wooded area	Thousand hectares	Land covered with trees or forest shrubs, including plantations of poplar and other similar trees inside or outside woods and forest-tree nurseries grown in woodland for the holding's own requirements, as well as forest facilities (forest roads, storage depots for timber, etc.).	EUROSTAT

Indicator	Measurement Unit	Guidance	Data Source
Socio-economic and health service indicators			
At risk of poverty	Percentage of total population	The at-risk-of-poverty rate is the share of people with an equivalised disposable income (after social transfer) below the at-risk-of-poverty threshold, which is set at 60 % of the national median equivalised disposable income after social	EUROSTAT

		transfers. This indicator does not measure wealth or poverty, but low income in comparison to other residents in that country or regional comparisons, which does not necessarily imply a low standard of living.	
Disposable income	Currency value	All income from work (employee wages and earnings from self-employment); private income from investment and property; transfers between households; all social transfers received in cash including old-age pensions.	EUROSTAT
Economically Active population	Thousands of persons	The statistical unit is a person aged 15 and over, living in private households; people living in collective households, i.e. residential homes, boarding houses, hospitals, religious institutions, workers' hostels, etc. are not included; it comprises employed and unemployed persons.	EUROSTAT
Employment rate	Percentage	The percentage of employed persons in relation to the comparable total population. For the overall employment rate, the comparison is made with the population of working-age	EUROSTAT
Equivalised disposable income		The total income of a household, after tax and other deductions, that is available for spending or saving, divided by the number of household members converted into equalised adults.	EUROSTAT
Gender gap	Percentage	It refers to any statistical disparities between men and women. Usually, however, it refers to differences in labour market statistics, such as the gender pay gap, employment and unemployment.	EUROSTAT
Gender pay gap	Percentage	The difference in average wages between men and women. The unadjusted gender pay gap is calculated as the difference between the average gross hourly earnings of male and female paid employees as a percentage of average gross hourly earnings of male paid employees.	EUROSTAT
Gross Domestic Product (GDP) - Purchasing power standard per inhabitant	Billion Euros	GDP is an indicator of the output of a country or a region. It reflects the total value of all goods and services produced less the value of goods and services used for intermediate consumption in their production. Expressing GDP in PPS (purchasing power standard) eliminates differences in price levels between countries.	EUROSTAT
Health personnel	Number of medical doctors	This refers to human resources available for providing health care services in the country, irrespective of the sector of employment (i.e. e independent, employed by a hospital or any other health care provider).	EUROSTAT
Human Development Index	Social measurement adopted from UN	Ranking of countries' levels of social and economic development based on four criteria: life expectancy at birth, mean years of schooling, expected years of schooling and gross national income per capita.	United Nations Development Programme
People outside the labour force	Thousands of persons or Percentage	People who are neither employed nor unemployed; it can include pre-school children, school children, students, pensioners and housewives or -men; include working-age.	EUROSTAT
Sectoral Employment	Thousands of persons or Percentage	Represents the sector of the economy that the economically active populations work in	EUROSTAT
Unemployment (Age and Gender)	Thousands of persons	Unemployed persons comprise persons aged 15-74 who were 1. without work during the reference week; 2. currently available for work; 3. actively seeking work or who had found a job to start within a period of at most three months; all three conditions must be fulfilled simultaneously	EUROSTAT
Unemployment rate	Percentage	The number of people unemployed as a percentage of the labour force	EUROSTAT

ANNEX III – Sector Definition According to the SHDB

Sector	Description
Cereals	Other Grains: maize (corn), barley, rye, oats, other cereals
Crops	Other Crops: live plants; cut flowers and flower buds; flower seeds and fruit seeds; vegetable seeds, beverage and spice crops, unmanufactured tobacco, cereal straw and husks, unprepared, whether or not chopped, ground, pressed or in the form of pellets; swedes, mangolds, fodder roots, hay, lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether or not in the form of pellets, plants and parts of plants used primarily in perfumery, in pharmacy, or for insecticidal, fungicidal or similar purposes, sugar beet seed and seeds of forage plants, other raw vegetable materials
Wheat	Wheat: wheat and meslin
Forestry	Forestry: forestry, logging and related service activities
Chemicals	Basic chemicals, other chemical products, rubber and plastics products
Electricity	Production, collection and distribution
Gas	Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction
Oil	Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction
Petroleum & Coke	Coke oven products, refined petroleum products, processing of nuclear fuel
Transport	Road, rail; pipelines, auxiliary transport activities; travel agencies

Source: SHDB (2021)

ANNEX IV – Further Policy Instruments Relevant to BioMates

Overarching instruments are introduced first, followed by the instruments relevant to specific stages of the BioMates concept to which they mostly apply (i.e., feedstocks, processing, and end-product).

OVERARCHING INSTRUMENTS

2030 Climate and Energy Framework (COM/2014/ 0015)

This framework was revised in 2018 to include increased EU-wide targets and policy objectives for 2021 – 2030. It sets key binding targets for 2030: GHG emission reduction targets of 40% relative 1990 levels, implementable through various other EU instruments (EU ETS, the Effort Sharing Regulation, and the Land Use and Forestry Regulation). The share of renewable energy is set at 32% and an improvement in energy efficiency of at least 32.5% is required (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2014:15:FIN).

EU Strategy for Low-Emission Mobility (COM/2016/501 final)

This is a key component of the broader shift to the low-carbon, circular economy in the EU. It sets three priority action areas for action: increasing the efficiency of the transport system through digital technologies, smart pricing and encouraging the shift to lower emission transport modes; speeding up the deployment of low-emission alternative energy for transport (i.e., advanced biofuels, electricity, hydrogen and renewable synthetic fuels); moving towards zero-emission vehicles. It is also being revised as part of the 'Fitfor55 (https://ec.europa.eu/transport/sites/default/files/themes/strategies/news/doc/2016-07-20-defossilisation/com%282016%29501_en.pdf.)

A Clean Planet for All (COM/2018/ 773 final)

This is a strategy to anchor the EU's commitment to achieving net-zero greenhouse gas emissions by 2050, although it launches no new policies nor revises its 2030 targets. It is an aspirational document to guide EU climate and energy policies and frame its long-term contributions to achieving the Paris Agreement objectives and the UN Sustainable Development Goals, through a set of pathways and scenarios. It outlines a vision of the economic and societal transformations required and calls for joint action on seven main strategic building blocks, including scope for defossilisation of the transport sector, with heavy emphasis on electric power, including the proposed electrification of short-distance sea shipping and inland waterways. But advance biofuels are seen to have a role in aviation, long distance shipping and heavy-duty vehicles, so long as they are carbon-free throughout their production chain. The strategy also highlights the important role of sustainable biomass in helping achieve a net-zero emissions economy, although it also notes the need for increasing amounts of biomass, with projected increases in bio-energy consumption by around 80% by 2050 compared to current levels. It also notes the potential for new demand for woody biomass to help diversity farming businesses (up to 10% of EU's agricultural land), enabling the cultivation of abandoned land and conversion of land currently used for food-based biofuels, all of which will help improve farm productivity and income, as well as potentially increasing the value of arable land. The Green Deal is expected to create jobs in some sectors (e.g., farming and forestry and renewable energy sectors) but it will require strategies for addressing a declining and ageing labour force as well as displacement due to technological change. The agriculture and forestry sectors, for instance, will require a sufficiently skilled workforce to meet their demands and challenges, although in a

context of decreasing rural population (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018DC0773)

Regulation on Governance of Energy Union and Climate Action (2018/1999)

This instrument establishes a governance mechanism for implementing the strategies and measures for meeting all EU climate-related policy instruments and long-term commitments in line with the Paris Agreement. Member states are required to submit an Integrated National Energy and Climate Plan for 2021-2030 and subsequent ten-year plans thereafter (https://eur-lex.europa.eu/legal-content/EN/TXT/?toc=OJ:L:2018:328:TOC&uri=uriserv:OJ.L_.2018.328.01.0001.01.ENG)

The European Green Deal (COM/2019/640)

This comprises a set of proposals to help the EU transform its economies and societies to enable a reduction of its net GHG emissions by at least 55% by 2030 in relation to 1990 levels and become the first climate neutral continent by 2050. It is the foremost overarching EU framework. It sets out an initial roadmap of the key policies and measures, encompassing wide ranging plans and actions for various sectors, including climate, energy, transport and taxation changes. For road transport, for instance, it aims to reduce emissions from vans by 50% by 2030, and to reach 0 emissions from new cars by 2035. Road transport will be covered by emissions trading (through the ETS), putting a price on pollution, boosting the use of cleaner fuels and higher investment on clean technologies. It also envisages carbon pricing for aviation and promoting SAFs through imposing an obligation for planes to be powered by sustainable blended fuels for all departures from EU airports. It includes seven actions for the agricultural sector, including a reform of CAP (see section). It also commits to stepping up efforts to ensure legislation and policies relevant to the Green Deal are enforced and implemented effectively (https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en).

Biodiversity Conservation Strategy (COM/2020/380)

This strategy entails comprehensive long-term plan to protect nature and reverse the degradation of ecosystems by 2030 and is a core part of the Green Deal. It aims to build resilience to the impacts of climate change, forest fires, food insecurity, and disease outbreaks (including by protecting wildlife and fighting illegal wildlife trade). It contains specific commitments and actions, such as a nature restoration plan for degraded ecosystems and binding nature restoration targets will be proposed by the end of 2021, based on the results of a series of actions that include, for instance, assessment of the EU and global biomass supply and demand and related sustainability, and data review for biofuels with high ILUC risk and set a path for their gradual phase out by 2030 (https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590574123338&uri=CELEX:52020DC0380).

2030 Climate Target Plan (COM/2020/ 562 final)

This instrument commits the EU to cut greenhouse gas emissions by at least 55% by 2030, to help achieve climate neutrality by 2050, stimulate the creation of 'green' jobs, and encourage international partners to increase their ambition to limit the rise in global temperature to 1.5°C. It confirms that policies and measures implemented and envisaged by the member states in relation to their current obligations to such reduction will remain effective after 2020. It set the target for renewable energy of at least 27% of total energy consumed in the EU, but member states set their own national targets. It increases the cap on the maximum permitted GHG emissions 2.2% after 2020 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0562).

Sustainable and Smart Mobility Strategy (COM/2020/ 789)

The Strategy lays the foundation for making the EU transport system sustainable, smart and resilient. It includes an action plan (with over 82 initiative to orient policy over four years) for achieving a 90% reduction in transport-related GHG emissions by 2050 to help the EU achieve climate neutrality as envisaged in the Green Deal (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789&qid=1634128845205).

Strategy for Energy System Integration (COM/2020/299)

This instrument aims at creating a climate neutral integrated energy system that improves energy production and consumption, by establishing a comprehensive terminology for all renewable and low-carbon fuels along with an EU system for their certification based on lifecycle GHG emission savings and sustainability criteria. The system is anchored on three key goals: achieving circularity in the energy system; use of cleaner electricity; promotion of renewable and low-carbon fuels, including hydrogen, where there is no other alternative. Actions to achieve these include a more integrated energy infrastructure, making energy markets fit for defossilisation, a digitalised energy system and a supportive innovation framework (https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2020:299:FIN).

EU Strategy on Adaptation to Climate Change (COM/2021/82)

This strategy builds on the original 2013 strategy (COM/2013/216). It aims to step up action across the economy and society to achieve for climate resilience in 2050. It is to be implemented in concert with other European Green Deal components. It will promote sub-national, national and regional approaches to adaptation, requiring that the private and public sectors work closely together, and providing tools to support the private sector to identify risks and steer investment towards action on adaptation and resilience. Financial support is to be made available through a range of sources (e.g., ESIFs, the CAP, LIFE, etc). It highlights the urgent need for devising solutions to help farmers and land managers address climate risks (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021AE1138&qid=1634129435880).

Energy Efficiency Directive (COM/2021/558)

This directive first came into force in 2014 to mandate energy efficiency improvements within the EU. It was amended in 2018 as part of the 'Clean Energy for All Europeans package', to include a new headline 2030 Union energy efficiency target of at least 32,5% (compared to projected energy use in 2030), to extend and strengthen the energy savings obligation beyond 2020. It is being revised again to set a more ambitious binding annual target at EU level, raised to 45% to help the EU achieve the Paris Agreement goal (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0558).

European Climate Law (Regulation 2021/1119)

This legislation provides the foundation for increased ambition and policy coherence on climate adaptation, committing the EU to make continuous progress to boost adaptive capacity, strengthen resilience and reduce vulnerability to climate change. It introduces a framework for gradual reduction of anthropogenic of GHG emissions, highlighting the threat by climate change and the need for measures to reduce it to 1,5 °C and deliver on the implementation of the Paris Agreement. It calls for all sectors of the economy in the EU to help in the effort and to achieve climate neutrality by 2050 and

for them to draw up indicative voluntary roadmaps to this end. It sets a binding target for reducing GHG emissions in the EU by at least 55% by 2030 compared to 1990 levels (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32021R1119).

EU INSTRUMENTS FOR FEEDSTOCKS

Common Agricultural Policy

The cornerstone of agricultural policy in the EU since launched in 1962, the CAP is policy for all EU member states, whose key aims are to support farmers and improve agricultural productivity; safeguard EU farmers to ensure a decent living; help tackle climate change and the sustainable management of natural resources; maintain rural areas and landscapes across the EU; and keep the rural economy alive by promoting jobs in farming, agri-food industries and associated sectors. Key measures are the provision of income support to farmers; regulation of and support to the marketing of agricultural products; and rural development. A new, reformed CAP was recently agreed by the EU institutions and is scheduled to come into force in January 2023, pending further agreements. Meanwhile, a transitional regulation is in force that extends most of the CAP rules that were in place during the 2014-20 period. The policy is financed through the EAGF (for rural income support and market measures) and the EAFRD, (rural development; (see below). The new CAP is aligned with Green Deal's objectives so that it can contribute to the EU's environmental, climate, and biodiversity protection commitments, through the strategies Farm to Fork and Biodiversity. A key change is the implementation of CAP through national CAP Strategic Plans which define the key parameters for the implementation of all CAP instruments by each member state (direct payments, rural development and sectorial interventions). This strategic approach applies to both "pillars" of the CAP together: to support for wider rural development (CAP Pillar II), and to direct income support payments to farmers and sectoral interventions (the bulk of CAP Pillar I). The legislative proposals for CAP envisage an agricultural policy that will deliver on three general objectives: to foster a smart, resilient and diversified agricultural sector ensuring food security; to bolster environmental care and climate action and to contribute to the environmental and climate-related objectives of the EU; to strengthen the socio-economic fabric of rural areas. These are operationalised into further nine specific objectives covering the economic, environmental, and social dimensions of sustainability: to ensure a fair income to farmers; to increase competitiveness; to rebalance the power in the food chain; climate change action; environmental care; to preserve landscapes and biodiversity; to support generational renewal; vibrant rural areas; to protect food and health quality (https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en).

Rural Development Programs

RDPs aim to strengthen the social, environmental and economic sustainability of rural areas in the EU. Member states implement national and regional RDPs, which are co-financed by EAFRD and national budgets. Under the CAP transitional regulation (due to a recent, major review of the CAP), RDPs have been extended to 2022, and as a result, during this period, many of the projects and schemes included in RDPs will continue to run until the end of 2025. From 2023 onwards, all new rural development actions will be incorporated into national CAP strategic plans which will be built around key social, environmental and economic objectives for EU agriculture, forestry, and rural areas. Each RDP must work towards at least four of the six priorities of the EAFRD, which are: fostering knowledge transfer and innovation in agriculture, forestry and rural areas; enhancing the viability and competitiveness of all types of agriculture, and promoting innovative farm technologies and sustainable forest management; promoting food chain organisation, animal welfare and risk

management in agriculture; promoting resource efficiency and supporting the shift toward a low-carbon and climate resilient economy in the agriculture, food and forestry sectors; restoring, preserving and enhancing ecosystems related to agriculture and forestry; promoting social inclusion, poverty reduction and economic development in rural areas. Table 66 illustrates the level of funding provided by the EAFRD for BioMates countries for the transitional period, as well as the key priorities in their RDPs, some of which directly align with BioMates aims for rural development, including development of renewable energy, diversification of agricultural activities, and more efficient use of natural resources (https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/rural-development_en#ruraldevelopmentprogrammes).

Table 66: RDPs and EAFRD for BioMates countries 2021-2022

Country	***Czech Republic***	***Germany***	***Greece***	***Sweden***
Total 2021-2022 (bn Euros)*	4.75	3.14	5.6	3.9
Key priorities relevant to BioMates	• Modernisation of farms to improve performance, competitiveness and reduce soil erosion risk • Food chain organisation to increase added value of agricultural production and and improve animal welfare • Restoring, preserving and enhancing agriculture and forestry ecosystems • Support afforestation of agricultural land • Development of local rural areas through non-agricultural activities	• Investment in physical assets and infrastructure agriculture and forestry development • Diversification of economic activities in rural areas • Basic services and village renewal in rural areas • Improvement of resilience of the forestry sector • Organic farming	• Development of supply chain partnerships in the agri-food sector • Restructuring and modernisation of farms • Support to farmers to participate in quality schemes, local markets, and development of short supply chains and producer groups/organisations • Preserve biodiversity, improve water and soil management and support agro-forestry and afforestation • More efficient use of natural resources, and development of renewable energy • Improve services and infrastructure, and investments in non-agricultural activities in rural areas	• Knowledge transfer and innovation in agriculture, forestry and rural areas • Modernization of farms to increase market participation to diversify agricultural activities • Food chain organisation to increase the value of agricultural products and improve animal welfare • Restoring, preserving and enhancing agriculture and forestry ecosystems • More efficient services and infrastructures in rural areas

Source: https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/rural-development_en#ruraldevelopmentprogrammes. *Includes both EU and national contributions; Total EU-27 budget Euros 34.7bn (2021-22)

The Hydrogen Strategy (2020/301)

This strategy was adopted to accelerate the development of clean hydrogen and help decarbonise the energy sector in the EU. Hydrogen is suitable can address the limits and challenges of renewable electricity, especially in storage, heavy-duty transport and energy-intensive industries. As the cost of clean or low-carbon hydrogen remains uncompetitive, most hydrogen produced currently is fossil-based. The strategy outlines a number of key actions and presents three strategic phases in the timeline up to 2050, and key areas for action include an investment agenda, boosting demand and scale-up, regulatory framework, and research and innovation. The EC launched the European Clean Hydrogen Alliance, made up of stakeholders from industry, public authorities and civil society to help scale up production and demand for clean hydrogen in Europe. The Alliance is tasked with setting up the investment agenda and facilitate the implementation of actions (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0301).

Sustainability standards

Various sustainability standards exist that relate to production and use of biomass in transport, heat and power, and eligibility for EU incentive schemes (such as those in the RED and the FQD). Also, the Roundtable for Sustainable Biomaterials has also issued several international sustainability standards to certify biomass, biofuels and biomaterials (RSB, 2016). This includes, for instance, the CORSIA Certification, for use by feedstock producers, refineries and traders globally to certify eligible SAFs, and the EU RED Fuel Certification for fuel producers, traders, processors and transporters working within, or trading with, the EU. It is recognised by the EC to prove compliance with the requirements of the EU RED as well as with the RSB's sustainability principles, and it is the process of being recognised under the requirements of REDII (https://rsb.org/about/what-we-do/the-rsb-principles/).

EU INSTRUMENTS RELATED TO PROCESSES

Sustainable Use of Pesticides Directive (2009/128)

The aim of this instrument is to achieve a sustainable use of pesticides in the EU through reduction of risks and impacts of pesticide use on human health and the environment and by promoting the use of the Integrated Pest Management, along with alternatives approaches (e.g., non-chemical alternatives). Actions implemented by member states (national action plans) under this directive relate to other key strategies (i.e., Biodiversity, Farm to Fork), that have adopted targets for reducing the use of pesticides. The directive currently being revised to focus on achieving pesticide use and risk reduction targets by 2030 (https://ec.europa.eu/food/plants/pesticides/sustainable-use-pesticides_en).

REACH (1907/2006)

This chemicals directive tracks information on the hazards to human health and environment by various chemical substances and regulates exemption from the obligation to register. It places responsibility on industry to assess and manage the risks posed by chemicals and provide appropriate safety information for users. But has been revised in the new chemicals' strategy for sustainability, as part of the EU's zero pollution ambition, a key commitment of the Green Deal. The strategy bans the use of the most harmful chemicals in consumer products and aims to ensure that all chemicals are used more safely and sustainably (https://ec.europa.eu/growth/sectors/chemicals/reach/review_en)

The Industrial Emissions Directive (2010/75)

The IED is the main instrument that commits EU member states to minimise pollution from industrial sources. It covers highly polluting industrial activities and lays down the obligations to be met by all industrial installations. It lists an array of measures for the prevention of water, air and soil pollution, and provides a basis for drawing up operating licences or permits for industrial installations. The directive is based on the 'polluter pays principle' and 'best available technology' to help reach its goals of lowering emissions. Businesses can apply for exemptions if the cost of the best available technology is greater than the benefit (https://ec.europa.eu/environment/industry/stationary/ied/legislation.htm)

Standards

The production, storage, transportation and use of biofuels is governed by various voluntary international standards, which have been issued by CEN, and are seen as essential for market development. These include, for CEN/TC19 (Gaseous and liquid fuels, lubricants and related products of petroleum, synthetic and biological origin); CEN/TC 383 (sustainably produced biomass for energy applications), CEN/TC 441 (fuel labelling) (https://www.cencenelec.eu/)

FUNDING

European Regional Development Fund

The ERDF aims to strengthen economic and social cohesion within the EU by addressing regional imbalances through funding of projects. Funding for 2021-2017 aims to make EU regions more competitive and smarter, through innovation, and support to small and medium-sized businesses; greener (low-carbon and resilient); more connected (enhanced mobility), and more social, supporting effective and inclusive employment, education, and skills, which are aims to which BioMates can contribute (https://ec.europa.eu/regional_policy/en/funding/erdf/).

European Agricultural Guarantee Fund

The EAGF is the first pillar of the CAP, provides income support to farmers and support to agricultural markets. Its allocation for the period 2021-2027 is €291.1 billion, of which €270 bn are earmarked for income support, and the remainder, for market support (https://ec.europa.eu/info/funding-tenders/find-funding/eu-funding-programmes/european-agricultural-guarantee-fund-eagf_en).

European Agricultural Fund for Rural Development

The EAFRD, the second pillar of the CAP, finances the EU's rural development programmes. Total allocation for 2021-2027 is nearly €100 bn to invest on the priority programs that include, for instance, restoring, preserving and enhancing agriculture and forestry ecosystems; modernisation of farms to improve performance, competitiveness and reduce soil erosion risk; and support to farmers to participate in quality schemes, local markets, and development of short supply chains and producer groups/organisations

(https://ec.europa.eu/regional_policy/en/policy/what/glossary/e/european-agricultural-fund-for-rural-development)

Global context: supranational organisations within BioMates policy scope

The policies issued by various supranational institutions may also directly or indirectly have a bearing on different aspect of the BioMates concept, although no policies are assessed here, but it is appropriate to note their remit in BioMates, as shown in Table 67.

Table 67: Supranational organisations

Organisation	*Remit*	*BIOMATES relevance*
FAO	Agriculture and agri-foods systems	Land use, feedstock production
ICAO	Civil Aviation	Regulations for aviation safety, security, efficiency and regularity and environmental protection
ILO	Labour	Workplace and working conditions, wages, collective bargaining
IMO	Civil Maritime Transportation	Safety and security of shipping and the prevention of marine and atmospheric pollution by ships
OECD	Governance	The four BioMates countries are members; social, economic and environmental arenas
WHO	Health	Occupational health and hazards
WTO	International trade	The four BioMates countries are members; import/export/ tariffs for agricultural goods, industrial products, services and intellectual property