D6.1: Report on description of baseline scenario for EU bioeconomy and of scenarios for EU's bioeconomy future

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Monitoring the Bioeconomy

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[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
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Summary

Bioeconomy is very important for the European transition to circular and low carbon societies. The multiple and interrelated economic sectors involved increase the complexity of metrics and constraint the comparability of the various sectors and product options. With the new Green Deal, announced in the end of 2019 as Europe's response to climate and environmental-related challenges, the need for improved knowledge and foresight capacities to guide policy and decision making is now more prominent than ever.

One of the research topics in the BioMonitor project, is to quantify the bioeconomy's environmental, economic, and social impacts in the EU and its Member States and perform scenario based quantitative and qualitative assessment to inform future policy making in this domain.

This report presents the baseline, the storylines and the respective narratives that will be used to analyse the development of the bioeconomy in Europe and give model-based evidence on the potential impacts of policy and technological changes.

Scenario results will be quantified (using policy relevant bioeconomy indicators from the ones developed in WP1) in WP3 (ex-post) and WP5 (ex-ante) and will be disseminated by infographics in WP9. In this report a review of indicators that have been used in relevant models (including the ones that will be employed in the Biomonitor toolbox) is also presented. This is prepared as a link between the scenarios and the foreseen policy analysis work in Tasks 6.3 and 6.4. It aims to improve clarity on: a) which indicators have been used by the existing modelling capacities to inform the current policies, b) what drivers they can interpret, c) scenario examples that show how each model has been used in the past, and d) how these indicators can be refined and combined with the ones selected in Biomonitor (WP1) to further translate the scenario narratives in meaningful and policy relevant information.

The deliverable will be updated on Month 24 (May 2020) to reflect the findings of the stakeholder workshop, relevant updates from WPs 1-5 and any changes or updates of relevant policy. This will not cause any delay to other project activities.

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1 Introduction

1.1 Strategy context

The updated EU Bioeconomy Strategy (European Commission, 2018) adopted in October 2018 aims to develop a sustainable bioeconomy for Europe, strengthening the connection between economy, society and the environment. The update revalidates the five objectives of the 2012 Bioeconomy Strategy:

1. Ensuring food and nutrition security;
2. Managing natural resources sustainably;
3. Reducing dependence on non-renewable, unsustainable resources whether sourced domestically or from abroad;
4. Mitigating and adapting to climate change;
5. Strengthening European competitiveness and creating jobs.

While the objectives remain the same, they are accompanied by three new main action areas:

1. Strengthen and scale-up the bio-based sectors, unlock investments and markets;
2. Deploy local bioeconomies rapidly across Europe;
3. Understand the ecological boundaries of the bioeconomy

To guide policy making, knowledge and foresight capacities are needed, as highlighted in the Staff Working Document linked to the updated EU Bioeconomy Strategy, which states the need to "improve the knowledge base (data, information and tacit knowledge) on all areas of the bioeconomy and a forward-looking capacity (modelling, foresight exercises, scenarios), as essential elements for providing the evidence needed to support policy makers and for underpinning policy coherence" (Commission SWD/2018/431).

In this context, the overall objective of the BioMonitor project is to establish a robust and effective framework to develop statistics and modelling tools for the bioeconomy. This framework will enable the quantification of the bioeconomy and its economic, environmental and social impacts in the EU.

1.2 BioMonitor and WP6

WP6 is the work package that will bring together the respective analysis based on the BioMonitor Data Platform and the BioMonitor Model Toolbox developed in WPs 1 to 5. This will be done by developing storylines and narratives and use the models in the BioMonitor Model Toolbox, (AGMEMOD and BioMat, EFI-GTM and EFI-Scen, MAGNET) to analyse their impacts to the development of the bioeconomy in Europe till 2050 (with intermediate timeline 2030). The analysis will use a set of indicators, selected for their policy relevance from literature and the ones

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reported in Deliverable D1.1[1]. The aim of this report is to present the baseline, the storylines and the respective narratives that will be used to analyse the development of the bioeconomy in Europe.

The project team decided to take the EU reference scenario from the Global Energy and Climate Outlook[2] (GECO) *status quo* reference scenario as inspiration for the Baseline scenario. This is considered as best suited to the work in the project since the EU Reference scenario is used by multiple Commission services and therefore ensures relevance of the scenarios to policy makers. For example, the transition pathways included in GECO are expected to be consistent with the EU's Green Deal[3] for mitigation options and low carbon futures, which is regarded as one of the guiding policies for the development of bioeconomy within the timeline of the Biomonitor project. The EU Reference scenario is updated periodically, which should help ensure the timeliness of the current project with respect to expected market developments.

Chapter 2 presents the baseline, the storylines and the respective narratives and describes policy relevant questions that will be answered by the scenarios in the Biomonitor impact assessment. Chapter 3 provides an overview of the drivers and indicators for the future development of bioeconomy and outlines their use in modelled scenarios and policies informed so far. Finally, Chapter 4 concludes the deliverable with the foreseen work that will link to the impact assessment.

Appendix I outlines the current policy framework.

Appendix II presents the Biomonitor drivers grouped by their use in current EU policies and value chain stages.

Appendix III presents the type (qualitative, quantitative) and the definition of indicators.

[1] http://biomonitor.eu/wp-content/uploads/2019/10/BioMonitor_Deliverable_1.1_Update_1.pdf

[2] https://ec.europa.eu/jrc/en/publication/baseline-global-energy-and-climate-outlook

[3] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

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2 BioMonitor baseline, storylines and narratives

2.1 BioMonitor baseline

As a basis of comparison for the subsequent alternate transition pathways to 2050 (see below), we choose a single representative "business as usual" or status quo BioMonitor Reference Scenario (BRS) to 2050. The time frame represents a mix of scientific rigour and pragmatic thinking. Within the policy arena in Europe (especially within energy and climate policy), 2030 serves as a point of reference that has also been adopted within the BioMonitor project. It has been decided, however, that an extension of the time horizon to 2050 would be scientifically justifiable, where as in climate science, the ripple effects of profound decisions taken today echo ever more strongly on the transition path of human development the further into the future one explores.

Based on expert advice within the project consortium, the existing tools within the BioMonitor modelling platform are well adapted to examine longer time horizons, whilst the additional labour cost of extending time horizon to 2050, is not prohibitive. Moreover, in terms of anticipated woody biomass availability, the expectation of, and repercussions behind the development of forestry systems, only play a more decisive role when considering time horizons which go further afield.

The guiding criterion behind the BRS is to characterise within the BioMonitor modelling platform, a continuity of existing trends and social attitudes in the absence of any drastic course change by society (i.e., in terms of expected macroeconomic growth trends, population, technology change, consumption patterns). Moreover, the BRS should encapsulate a series of reasonable biomass-related public policy instruments (i.e., agricultural policy, bioenergy policy, trade policy), whose evolution and design, as far as feasibly possible, reflects current and anticipated developments. At the current time, a greater degree of certainty on public policy design is available to 2030. Beyond this point (i.e., 2050), some degree of critical thought will be required to decide on 'reasonable assumptions' (i.e., budget limits for policy, reasonable blending rates for biobased energy inputs etc.).

A key source for the design and implementation of the BRS is the European Commission's Global Energy and Climate Outlook (GECO) to 2050 (Keramidas *et al.*, 2018; Weitzel *et al.*, 2019).[4] Based on decade time intervals to 2050, the GECO combines economic drivers with energy market balances and greenhouse gas emissions trends for three world visions. In the spirit of the above discussion, the macroeconomic, energy and emissions assumptions for the BRS are taken from the GECO 'reference' or status quo scenario (henceforth GECOREF).

[4] A more detailed discussion is available online from Keramidas et al., (2018).

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In the energy markets, the GECOREF scenario assumes that any progress (i.e., decarbonisation, decoupling of energy usage from energy consumption, shifting of energy carriers toward electrification) is purely driven and justified by the dynamics of market force pressures (i.e., depletion of fossil resources) and anticipated technology change, with no additional climate agreements beyond 2017, nor investment strategies that promote a more responsible and sustainable model of growth.

The macroeconomic, population, fossil energy prices and emissions trends, therefore also follow 'middle-of-the-road' projections in the absence of any unanticipated economic shocks, or radical (inter-)governmental policy prescriptions.

The assumptions embedded within the transition pathways are presented in Table 1. This series of drivers may be further refined after discussion with the stakeholders.

2.2 Policy relevant questions that will be answered by the scenarios

The scenarios in BioMonitor will be specifically designed to inform the ongoing policy relevant discussions for bioeconomy and its sustainable development. The aim of the work will be to illustrate how different levels of policy ambition can impact economic, environmental and social sustainability and can improve performance in different bioeconomy 'futures'. The integrated assessment is expected to provide answers for the transition pathways and storylines on the following issues:

What are the economic (turnover, value added, etc.), environmental (GHG, carbon use, land and water use, etc.) and socio-economic (employment, etc) impacts from:

a. specific policy changes e.g. ban on use of fossil inputs for chemical products or new instruments in CAP to support the environment

b. degree of technological development

c. low/high oil price,

d. degree of consumer awareness to commit to the bioeconomy

What will be the impacts of trade instruments for the development of:

a. Small number of centralized biorefineries strategically located within Europe (Industry centralised- Strengthen and scale-up the bio-based sectors, unlock investments and markets)

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b. local/ regional decentralized units (Industry decentralised- Deploy local bioeconomies rapidly across Europe),

The structure of the impact assessment will be tailored to respond to the three new main action areas from the 2018 Update of the EU bioeconomy strategy:

1. Strengthen and scale-up the bio-based sectors, unlock investments and markets;
2. Deploy local bioeconomies rapidly across Europe;
3. Understand the ecological boundaries of the bioeconomy

Intra-trade options will be explored.

2.3 Alternative scenarios

The BioMonitor reference scenario serves as a basis for assessing impacts of two alternative storylines, each subdivided into two narratives which diverge gradually from the baseline starting from 2020.

Table 1 Biomonitor storylines and narratives

Storyline	Narrative	Models to be used
1. Pursuing the Green Deal	1.1 Go it alone	MAGNET; AGMEMOD; BioMat; EFISCEN; EFI-GTM;
	1.2 Hand-in-hand	MAGNET; AGMEMOD; BioMat; EFI- GTM;
2. A different world order	2.1 Eco-warrior	MAGNET;
	2.2 Drill baby drill	MAGNET;

The descriptors for each of these narratives is provided below. In Table 2, a series of drivers are listed (may be further revised) that serve as an illustration of the mechanisms at the modellers disposal to characterise each narrative.

Storyline 1: Pursuing the Green deal

Within the updated European Union (EU) Bioeconomy Strategy (European Commission, 2018), there is a stronger emphasis on circularity criteria, which is purposely designed to complement and reinforce the EU's Circular Economy Action Plan (European Commission, 2019). In this context, the ethos behind the first storyline is to test the responsible limits of 'bio-centric dependence' in terms of its contribution to a more sustainable circular model of production and consumption. To examine this thesis, we take a layered approach to the alternate narratives. In the first instance,

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we examine the EU unilaterally pursuing its greener vision (from a bio economy perspective) – henceforth dubbed "Go it alone". In the narrative, "Hand-in-hand", the notion of an active bioeconomy plan is implemented beyond the boundaries of the EU, with the more developed nations taking the lead. A further description of each is provided below.

Narrative 1.1: Go it alone

In this narrative, the EU pursues the Green Deal vision, without waiting for international commitments. The EU will introduce aggressive domestic support policies which encourage significant increases to the demand and supply of biomass for industrial and energy applications. This may take the form of domestic procurement policies, favourable subsidy schemes on biomass inputs, or agricultural policy adjustments to ensure reliable sources of biomass use in existing and new bio-based value chains. In the trade arena, it could also encompass a more open EU trade policy to guarantee access to, and availability of raw (or semi-processed) biomass materials from third countries - which admittedly could have sustainability implications that can be assessed. Furthermore, a sustained financed effort to encourage secure and sustainable forestry supplies would provide increasing availability of woody biomass, particularly toward the end of the simulation period. Significant R&D investment efforts are charged into increasing biomass production and availability and developing nascent bio-industrial sectors in an attempt to reduce cost disadvantage ratios with conventional fossil technologies, as well as fiscal incentives (i.e., subsidies) to enhance biomass availability from agriculture, forestry and fisheries within the EU.

Investments and fiscal incentives (i.e., labour subsidies, biomass subsidies) to these sectors and technologies would have to be met by the public purse, possibly financed by tax hikes on inputs of fossil fuels, or other environmentally harmful processes (the effect could be fiscal neutral overall). Employing trade policy, the EU, to protect its green biobased vision, would impose higher tariffs on fossil-based equivalents from foreign competitors. Through education programmes and advertising awareness campaigns, there is a shift toward more responsible average consumption patterns (i.e., reductions in food waste, reduced (red) meat consumption within the boundaries of a "healthy diet", increase of wood in construction, etc.).

Narrative 1.2: Hand-in-hand

In this narrative, the EU is not acting alone but instead many of the initiatives in 'Go-it-alone' are implemented globally. Thus, the reduction/elimination of tariffs on global trade links for biobased products ensures a more open market to ease the global transition to a more biobased economy and help all regions to pursue domestic bio-industry and bioenergy policies. Again, this policy would have a sustainability implication (i.e., indirect land use), which could be assessed by the models. For less developed countries to be further implicated in this transition pathway, greater social responsibility on the part of developed regions must be assumed. The costs of technology innovation in nascent biobased activities would be shouldered by the rich countries, whilst the availability of the resulting biobased products to poorer countries could be enhanced through the implementation of developed country export subsidies to less developed country markets. Similarly, in tackling food security concerns, competitive less developed and developing countries are provided with much greater market access to developed country agricultural markets, whilst wealthier member states provide export subsidies to those less developed regions where self-sufficiency is considered low.

Moreover, as part of a globally more responsible model of biomass consumption, there would be global initiatives to reduce food waste and establish healthier diets (particularly in more

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developed regions), where reduced demand pressures in developed regions may encourage greater global food affordability through the relieving agricultural market tensions. On the other hand, this may also result in a degree of reduced food production in competitive less developed or developing countries, which brings positive (lower emissions, reduced indirect land usage) and negative (income, employment) trade-offs. These outcomes will be assessed by the models.

Sensitivity Analysis for (i) and (ii): On available residue supplies or land availability for conversion. Maybe also change the assumptions on fossil fuel prices and examine the impacts on the necessary costs to the EU (i.e., lower cost disadvantage facilitates biobased market uptake).

Storyline 2: A different world order

In the two narratives of the first storyline, the focus is on the bioeconomy as an active agent for social, economic and environmental change. This is explored through policies designed to promote this collective of activities. In the two narratives explored here, the bioeconomy is a passive actor which is adapting to the changing world orders. That is, these storylines explore the opportunities afforded to, or resilience of, the bioeconomy under two polarised visions of human development.

Narrative 2.1: BioEco-Resilience

The energy-environment nexus forms a cornerstone of any long run foresight study. In the narratives explored above in storyline 1, the energy-emissions assumptions remain unchanged, when we know that for mankind to overcome the challenge of climate change and the associated negative non-market effects (i.e., collapse of ecosystems, biodiversity degradation, rising water levels, volatile weather patterns etc.), a fundamental shift in decarbonisation of energy markets and cleaner industrial processes and residential habits, is essential. Thus, storyline examines the resilience of, and opportunities afforded to, the bioeconomy to a greener world order, in the absence of any additional direct investment or fiscal support mechanisms to biobased sectors. The main drivers for the energy markets would follow the three pillars in the GECO study, namely (i) increases in energy efficiency to decouple economic growth from energy consumption, (ii) shifting energy carriers toward electrification and (iii) decarbonisation of energy through the adoption of (bio)renewables. These changing energy market trends could be taken from the GECO 'two degree' pathway.[5] The costs of these investments should somehow be internalised within the model mechanism based on an understanding of rate of return expectations from energy investments. In the same vein, emissions reductions accompanied by carbon tax and/or fossil tax increases would also be implemented which are consistent with the GECO two degree scenario. In the case of the relevant biobased sectors (i.e., primary agriculture), some consideration of the expected adaptation costs would be required. This narrative would preserve the vision of an environmentally conscious society (as in the first storyline) through the preservation and enhancement of our forests, reduction of food waste and food losses along the supply chain.

It is expected that fossil-based industries will be hit and renewables will flourish. On the other hand, agriculture which is highly intensive in non-CO2 emissions, is expected to be affected, as will those biobased processing industries that rely on agricultural biomass feedstock (first generation

[5] A pathway which limits temperature rises to 2 degrees above pre-industrial levels by 2100. This target is still considered as potentially achievable.

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biofuels), although more land-sustainable advanced generation technologies which employ lignocellulosic feedstocks may be expected to perform better. The expected benefits (e.g., rising bio-industry competitiveness through the closing of the cost-disadvantage gap with fossil technologies; environmental indicators) and costs (food security, macroeconomic growth, employment) will be assessed by the models.

Narrative 2.2: Drill baby drill

This world order is a polarised version of narrative 2.1. More specifically, this transition pathway examines a fossil centric world order, where all types of public policy support mechanisms inherent within the BRS are removed. In addition, an active pursuit, on the part of developed regions, to encourage greater extraction of fossil-based resources is underway in the pursuit of regionalised self-interest (to the detriment of the planet). This would take the form of a subsidisation of fossil-based industries in developed and developing countries with available energy reserves, resulting in greater extraction rates/availability of fossil resources (subject to realistic expectations).

Inequalities are exacerbated as international institutional strength fades (e.g., in the areas of climate, trade) and regional rivalries emerge (fuelled by populism). On the one hand, developed countries allow emissions to rise even above the BRS through greater exploitation of fossil reserves, whilst the notion of a carbon tax is abandoned. With the absence of co-responsibility, the developing and less developed countries also abandon targeted emissions reductions. In the sphere of trade policy, developed countries pursue insular and retaliatory trade policies through protective rises in tariffs. Moreover, strategic partnerships with energy-rich countries are enhanced as developed country net-importers of fossil energy seek to optimize access to supplies, at the expense of the poorer nations. This transfer of fossil supplies could be represented through developed country subsidies on fossil imports from energy-rich partners. This will in turn have implications on fossil prices. Food continues to be wasted, and even at an increasing rate in the fast growing, middle income countries, as they adopt 'westernised' food consumption habits exhibited by wealthier nation states.

Sensitivity Analysis: Available fossil reserves, or extraction rates. Fossil fuel prices.

3 Drivers and indicators for modelling bioeconomy futures

3.1 Driving forces in scenarios

The bioeconomy is driven by a number of forces and includes multiple sectors. Deliverable 1.1 of the Biomonitor project (Framework for measuring size and development of bioeconomy with a list and detailed description of bioeconomy indicators, measures, and data requirements) sets the

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background for the scope and definitions of bioeconomy as well as the driving factors behind its development. These are especially relevant for the BioMonitor Model Toolbox and Scenario analysis in WP6 as well as the indicators to be considered for monitoring the bioeconomy.
The scenarios to be developed in WP6 will ensure that the driving forces reported in D1.1 are captured in the respective narratives both for the baseline (D6.1) and the other scenarios (D6.2). The ones that WP6 deems have high relevance across sectors and individual value chain stages are describe below.
To summarise, Table 2 below provides an overview of the key model drivers and the possibilities therein for characterising the BRS and the alternate story lines.

*Table 2: **Exogenous drivers that shape the BRS and possibilities for the storylines.***

Driver category	Exogenous model driver	Details:
Land/ biomass stock	**Land productivity***	Exogenous BRS land productivity shocks. In the storylines, it might be possible to examine deviations in direct emissions changes (through lower temperature rises) impact on expected yield changes.
	Woody biomass availability	For the BRS, arising from the relevant model drivers and possible linkages between models within the BioMonitor platform, expected projections in forestry supplies to support wood based products and residues would be harmonised across the relevant models. To reflect the spirit of the alternate storylines, plausible projections of the availability of woody biomass (especially toward the end of the periods) might be revised upward (i.e., Go-it-alone, hand-in-hand, eco-resilinece), based on realistic expectations. The rise in available forestry resources could be accompanied and targeted by rising subsidy support.
Economic growth & technology change	**Real macroeconomic growth/technology change**	Country specific productivity growth is calculated to target assumed real macroeconomic (GDP) rates of growth. In the alternate storylines, at the margin, real growth can deviate with the implementation of additional policies/investments which carry additional social and economic benefits and costs.
	Agricultural production trends*	Anticipated outlook for agricultural production trends within the EU based on official forecasts. In the BRS, these production trends are targeted by technology change shifters that remain unchanged in the alternate storylines.
	Nascent bio-technologies*	In the BRS, reasonable technology change developments in nascent bio-industrial processes may be available from bottoms-up specialist technology models, expert opinion, or even through model assumptions calibrated to the GECO baseline. Again, to factor in the cost of said R&D investments to economic development, a reasonable understanding of the rates of return is key. Alternate storylines can explore higher technology change assumptions (and associated R&D costs), although again, these anticipated changes will either require specialist model input, expert opinion, or model assumptions and calibration.
Energy	**Energy input to industry**	Calibrated input-output technology shifters to mimic energy balance trends by energy type and usage. To factor in the cost of energy investments to economic development, some generalizable

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		understanding of the rates of return on energy efficiency investments would be desirable.
	Energy in final demand	Final energy demand shifters to mimic anticipated changes in energy consumption with (if deemed important) the accompaniment of final energy demand tax structure changes. Alternate storylines may explore more responsible energy demand (possibly with accompanying tax changes).
	Global fossil fuel prices	Changes in world average fossil fuel prices for oil, coal and gas. A sensitivity analysis of fossil fuel price expectations is possible.
Conversion capacity	**Fossil industry***	In the BRS, the development of the fossil based industries is an outcome of the model solution, based on changes in market prices, substitution effects in production and relative rates of real income growth. In the alternate storylines, it is possible to explore different market incentives (taxes/subsidies on inputs/output) on this collective to fit different narratives.
	Feed efficiency*	Exogenous BRS anticipated changes for biomass in animal feed efficiency (through technology change or farm management efficiencies) could be included to improve an understanding of biomass availability across competing uses. In the alternate storylines (subject to data availability), one could examine alternate feed efficiency rates.
Policy mechanisms and reforms	**Carbon Tax**	Global increase in the carbon tax on relevant economic activities by time period. Possible exploration of alternate increases in carbon prices under more ambitious green policies can be considered in alternate scenarios.
	Biofuel mandates*	Exogenous mandates on first-generation and advanced-generation biofuels by region. In the storylines, these mandated blending requirements may be adjusted upward for (more sustainable) advanced generation biofuels.
	Bio-based materials support*	Policy interventions could promote or shut down the production of specific fossil-based or bio-based products. In baseline scenario (BRS?) no specific policy intervention is foreseen. For scenarios they are imaginable and could entail ban on use of specific products or targets on their production/use.
	EU Agricultural Policy*	A plausible EU agricultural policy baseline with detailed information and model implementation on budget limits for first (decoupled/coupled) and second pillar policy instruments. When exploring alternate storylines, a deviation in budget allocations could be contemplated.
	Bilateral and regional trade agreements*	With an emphasis on the EU, ratified and expected trade agreements will be implemented. In addition, the BRS might include third-country trade agreements between large country players on biomass markets. In the alternate storylines, further manipulation of applied tariff rates can capture greater trade openness/closedness.
	Capital stock*	On a country basis, changes in the total available stock of capital, either by assumption of a fixed capital-output ratio, or if possible, through a more complex mechanism related to relative rates of return. In the alternate storylines, at the margin, capital stock growth can deviate with the implementation of additional policies/investments.
	Labour force*	Changes in the total labour force for the regions/countries under consideration. Possible exploration of changing labour force rates in function of the skill type, or, as consistent with economic theory, an assumption of a fixed long-run employment rate. In the alternate

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		storylines, at the margin, labour force changes can deviate with the implementation of additional policies/investments.
Consumers	**Population**	Exogenous rates of population change. With no clear link between bioeconomy developments and population change, at the current stage, it is not envisaged that the alternate storylines will include different rates of population change. If deemed important, it may be possible to include variation through sensitivity analysis.
	Attitudes to food consumption*	In the BRS, the model outcomes determine status quo attitudes to food consumption, based on the prices and income patterns arising from the model baseline. In the alternate storylines, exogenous demand shifts favouring more responsible food consumption can be implemented and, if deemed appropriate, linked to tax/subsidy incentives.
	Attitudes to other bio-based products*	In the BRS, the model outcomes determine status quo attitudes to consumption of other bio-based products such as biobased materials, based on the prices and income patterns arising from the model baseline. In the alternate storylines, exogenous demand shifts favouring the consumption of bio-based materials (reflecting for example awareness about negative external effects of fossil-based materials) can be implemented and, if deemed appropriate, linked to tax/subsidy incentives or other policy interventions (e.g. bans on use of some fossil-based products).

* Not taken from the GECO baseline, but borrowed from a suitable alternative data source or calculated through modelling assumptions.

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3.2 Examples of scenario applications and models used

Table 3 below provides an initial outline of the modelling capacities within BioMonitor, scenario examples that show how each model has been used in the past and respective policies informed.

Table 3: Drivers and policies applied in previous scenarios, and models used

Drivers	Model	Scenario examples that show how each model has been used in the past	Policies informed
Economic growth in GDP	MAGNET	long term projections describing changes in the economy and patterns of investment consistent with changes in capital stock over time	NER300 programme, Horizon 2020, Sustainable Process Industry through Resource and Energy Efficiency (SPIRE), BRIDGE 2020
(Technology & innovation; markets)	AGMEMOD/Biomat (new to be developed)	impact of accelerated technological development from payments on agricultural production growth (Chantreuil, F. 2013)	CAP Pillar I - Direct Payments, NER300 programme, Horizon 2020, Sustainable Process Industry through Resource and Energy Efficiency (SPIRE), BRIDGE 2020
Trade (Market organisation)	MAGNET/	The effect of agricultural trade liberalisation on emissions from land-use and food security (Rutten, M. et al 2013; Verburg, R. et al 2009)	iLUC Directive (EU) 2015/1513, LULUCF-Land use land-use change and Forestry (Dec. 529/2013/EU)
	CAPRI	Impact of set aside and intervention prices on sector-based domestic demand and net exports (Heckelei & Britz, 2001); impact of trade liberalisation (tariffs, export subsidies and tariff quotas) on farm production value (Mittenzwei et al, 2007)	Habitat Directive 92/43/EEC, Natura 2000, Bird Directive 2009/147/EC, CAP Pillar I - Direct Payments, CAP Pillar II – Rural Development
	EFI-GTM	Impact of LULUCF forest reference levels on forestry production and trade (Kallio et al. 2018) Impacts of policy measures to prevent import of illegal wood and wood products (Moiseyev et al. 2011).	EU Forest Strategy, REDD+, FLEGT, LULUCF Regulation (2018)
Agricultural productivity (Technology & innovation; Markets)	MAGNET	The role of technological progress based on human capital investments, labour augmenting and natural resource expansion (Woltjer, G. et al 2014) in labor market impacts on land use (Helming, J. & Tabeau, A. 2018)	NER300 programme, Horizon 2020, Sustainable Process Industry through Resource and Energy Efficiency (SPIRE), BRIDGE 2020
	AGMEMOD/BioMat	Impact of accelerated technological development from payments on agricultural production growth (Chantreuil, F. 2013)	CAP Pillar I - Direct Payments, NER300 programme, Horizon 2020, Sustainable Process Industry through Resource and Energy Efficiency (SPIRE), BRIDGE 2020
	CAPRI	Income distributional impact of different direct payment systems (Gocht et al, 2011); impact of research and development on productivity (Jansson, T. et al 2008)	CAP Pillar I - Direct Payments, NER300 programme, Horizon 2020, Sustainable Process Industry through Resource and Energy Efficiency (SPIRE), BRIDGE 2020
Food demand	MAGNET	Calculating average nutrition indicators through flow of primary agri-food commodities of the global economy	Nitrates Directive, Directive for sustainable use of pesticides
(Markets; consumer preferences)	CAPRI	Integrating complex interrelations between population growth and technological change, policies and competing markets to assess climate change impacts on agriculture, including effects on demand for agricultural products (Frank, S. et al 2014)	iLUC Directive (EU) 2015/1513, EU Bioeconomy strategy (COM(2018) 673)
Raw material demand	MAGNET	Long term projections of consumption by households, including dietary patterns through the adjustment of income elasticities as GDP per capita changes over time	iLUC Directive (EU) 2015/1513
(Markets; consumer preferences)	CAPRI	Increasing feedstock demand on land use, land demand and prices (Britz, W. & Delzeit, R. 2013)	iLUC Directive (EU) 2015/1513, LULUCF-Land use land-use change and Forestry (Dec. 529/2013/EU)

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Drivers	Model	Scenario examples that show how each model has been used in the past	Policies informed
	EFI-GTM	Impact of forest stock set-aside and intensifying use of wood for bioenergy on demand and harvests of local wood (Kallio et al 2019)	EU Forest Strategy, Forest based sector technology platform (FTP), Joint technology initiative for bio-based industries (BBI-JTI), SET plan: Action 8: Renewable Fuels and Bioenergy
Raw material supply	EFI-GTM	Potential availability of primary and secondary forest biomass (Moiseyev et al. 2014)	Habitat Directive 92/43/EEC), Natura 2000, Bird Directive 2009/147/EC, EU Forest Strategy
	EFISCEN	Potential availability of primary forest biomass (Verkerk et al. 2007- 2015; 2019)	
	EFISCEN	Net annual increment changes of European forests from climate change (temperature and precipitation changes) (Nabuurs et al, 2002)	
Climate & environmental change	CAPRI/MAGNET	impact of removing biofuel targets on agricultural area (Adenauer & Britz, 2012)	
	AGMEMOD/ BioMAT (new to be developed)	projection of biofuel crops based on yield changes and area allocation with scenario drivers such as population growth, world prices, innovation, trade agreements…etc. (Salamon et al, 2017)	
Bioenergy (Policy, Markets)	CAPRI	simulate the impacts of biofuel policies (consumer tax exemptions, quota obligations, import tariffs) on food production and prices, use of by-products, pressure on marginal land and share of imported biofuels (Blanco et al, 2012; Adenauer & Britz, 2012)	Renewable energy directive (Dir, 2009/EC/28), iLUC Directive (EU) 2015/1513, EU Bioeconomy strategy (COM(2018) 673)
	MAGNET	land use change and emissions of biofuels use in the EU (Smeets, E. et al, 2014; Kavallari, K. & Tabeau, A. 2014)	Renewable energy directive (Dir, 2009/EC/28), EU Bioeconomy strategy (COM(2018) 673)
	EFI-GTM	Impact of increased globalization or economic growth on energy wood prices, imports and reallocation of wood from competing uses (Moiseyev et al, 2011)	European Technology and Innovation Platform on Bioenergy (ETIP Bioenergy),
	EFISCEN	Potential availability of primary forest biomass (Verkerk et al. 2011; 2019)	Renewable energy directive (Dir, 2009/EC/28), Sustainability requirements (COM(2010)11)
	MAGNET	long term and short term effects of different timings of reforms and policies on farm income and employment	European Technology and Innovation Platform on Bioenergy (ETIP Bioenergy), REDD+
	CAPRI	impact of set aside, premiums and intervention prices on sector-secific production, including NPK balances, feeding requirements, and trade (Heckelei & Britz, 2001, Was et al, 2014); effects of decoupling and liberalisation on resource mobility and available agricultural land (Mittenzwei, K. et al, 2007)	European Standards EN16214 CEN/TC 383 Sustainably produced biomass for energy applications
	AGMEMOD	Impact of equalizing direct payments in EU (Erjavec et al, 2011); reaction of agri-food markets to combining policy-led budgetary support with effects of market prices, taking into account different effects from payments (Chantreuil et al, 2013)	CAP Pillar I - Direct Payments, CAP Pillar II – Rural Development, EU Forest Strategy, European Regional Development Fund, European Regions Research and Innovation Network, Green public procurement (COM(2008)400)
CAP (Policy, Markets)	CAPRI	effects of policy reforms on agricultural provision of food security (Mittenzwei, K. et al 2007); effects of labour and capital on farmers' decisions	CAP Pillar I - Direct Payments, CAP Pillar II – Rural Development, EU Forest Strategy, European Regional Development Fund, European Regions Research and Innovation Network, Green public procurement (COM(2008)400)
Producer behaviour and food supply (consumer preferences)	AGMEMOD	Effects of policy on agricultural supply and demand of food (DG-Agri outlook, 2019(; impact of grow in vegetarians on demand for meat (Jongeneel, et al, 2019)	CAP Pillar I - Direct Payments, CAP Pillar II – Rural Development
	CAPRI	effects of policy reforms on agricultural provision of food security (Mittenzwei, K. et al 2007); effects of labour and capital on farmers' decisions	CAP Pillar I - Direct Payments, CAP Pillar II – Rural Development

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Drivers	Model	Scenario examples that show how each model has been used in the past	Policies informed
	AGMEMOD	Impact of population growth on self-sufficiently rate in EU.	CAP Pillar I - Direct Payments, CAP Pillar II – Rural Development
Demography (Population)	CAPRI	integrating complex interrelations between population growth and technological change, policies and competing markets to asses climate change impacts on agriculture, including effects on demand for agricultural products (Frank, S. et al 2014)	Green public procurement (COM(2008)400)
			European Standards EN16214 CEN/TC 383 Sustainably produced biomass for energy applications

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4 Conclusions

This report describes the baseline (Baseline Reference Scenario) and the alternative scenarios that Biomonitor will employ to perform quantitative and qualitative assessment for the development of bioeconomy to 2030 and 2050. It presents the baseline, the storylines and the respective narratives and describes policy relevant questions that will be answered by the scenarios in the Biomonitor impact assessment. Furthermore, it provides an overview of the drivers and indicators for the future development of bioeconomy and outlines their use in modelled scenarios and policies informed so far.

The report also outlines how and which (group of) models would be able to capture the key policy mechanisms for bioeconomy in EU. The complementary appendices provide insight to possibilities to concretize the scenario narratives towards model inputs and outputs, and how to change/shock the models per scenario.

Work will continue during Months 20-24 and the deliverable will be updated on M24 (May 2020) to reflect the findings of the stakeholder workshop (Marseille- April 2020), relevant updates from WPs 1-5 and any changes or updates of relevant policy.

This will ensure the validity and added value of the scenarios in terms of relevance with the Biomonitor indicators (WP1/ D1.1; D1.2), foreseen datasets like the Biomonitor Data Platform (WP3/ D3.1) and compatibility with the models that will be included in the project (WP4, D4.1) and the input output structure of the Biomonitor Model Toolbox (WP5).

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Appendix 1: Policy mechanisms in EU

On December 2019 the European Commission announced the European Green Deal[6] which resets the Commission's commitment to tackling climate and environmental-related challenges that is this generation's defining task. The Green Deal is an integral part of the Commission's strategy to implement the United Nation's 2030 Agenda and the sustainable development goals[7], and the other priorities[8]. As part of the Green Deal, the Commission will refocus the European Semester process of macroeconomic coordination to integrate the United Nations' sustainable development goals, to put sustainability and the well-being of citizens at the centre of economic policy, and the sustainable development goals at the heart of the EU's policymaking and action. Bioeconomy is expected to have a very important role.

However, bioeconomy is multi-sectoral and includes several complex value chains that are subject to respective policies across different economic domains that impact the development of different value chain stages (e.g. land use, biomass production, etc.). The policy related work in Biomonitor (Tasks 6.3 and 6.4) aims to:

- assess policy impacts across the biobased economy value chains
- understand the implications of existing policies in each value chain stage, and
- provide recommendations for the most appropriate policies, across the various value chain components.

This Annex provides an overview of the current policy landscape for EU bioeconomy by distinct value chain stages (i.e. land use, biomass production, conversion, distribution, end use). The information will be used as the basis to understand which policies per value chain stage need to be included in the Biomonitor scenarios, which drivers represent their challenges best and which indicators are the most appropriate to interpret policy relevant information.

The European biomass policies are presented here according to the stages of the value chain they impact. If policies impact more than just one stage of the value chain, they are listed under the most relevant stage under and other relevant value chain stages are mentioned. The description of these policies is based on the Biomass Policies and S2BIOM databases.

LAND USE

LULUCF Regulation 2018/841 – Land Use, Land-Use Change and Forestry

666 https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf

7 https://sustainabledevelopment.un.org/post2015/transformingourworld

8 See Political Guidelines of President elect Ursula von der Leyen: Political guidelines for the next Commission (2019-2024) – 'A Union that strives for more: My agenda for Europe':

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The Regulation on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry (LULUCF) into the 2030 climate and energy framework was in 2018.
The Regulation implements the agreement that all sectors should contribute to the EU's 2030 emission reduction target, including the land use sector. The Regulation sets a binding commitment for each Member State to ensure that accounted emissions from land use are entirely compensated by an equivalent removal of CO_2 from the atmosphere through action in the sector.

iLUC Directive (EU) 2015/1513

With the growing demand of biofuels in EU, iLUC or "Indirect land use change" Directive was introduced to limit the global land conversion used for biofuel production. Due to the limited cropland used in existing agriculture production, biofuel suppliers have been converting grasslands and forest into cropland for their own crops production. Consequently, instead of reducing greenhouse gas by using biofuels, this action may raise the atmospheric CO2 level since these non-croplands typically absorb a high CO2 level. Hence, this directive encourages and introduce the transition towards the use of Advance biofuels.

Birds Directive (Directive 2009/147/EC)

This Directive relates to the conservation of all species of naturally occurring birds in the wild state in the European territory of the Member States to which the Treaty applies. It covers the protection, management and control of these species and lays down rules for their exploitation, especially through the establishment of a coherent network of Special Protection Areas (SPAs) comprising all the most suitable territories for these species. Since 1994 all SPAs form an integral part of the NATURA 2000 ecological network.

Habitat directive (Dir. 92/43/EEC)

The aim of this Directive is to contribute towards ensuring bio-diversity through the conservation of natural habitats and of wild fauna and flora in the European territory of the Member States to which the Treaty applies. It is built around two pillars: the Natura 2000 network of protected sites (Special Areas of Conservation) and the strict system of species protection. All in all the directive protects over 1.000 animals and plant species and over 200 so called "habitat types" (e.g. special types of forests, meadows, wetlands, etc.), which are of European importance.

Natura2000

Natura 2000 is the centrepiece of EU nature & biodiversity policy. It is an EU-wide network of nature protection areas established under the 1992 Habitats Directive. The aim of the network is to assure the long-term survival of Europe's most valuable and threatened species and habitats. It is comprised of Special Areas of Conservation (SAC) designated by Member States under the Habitats Directive, and also incorporates Special Protection Areas (SPAs) which they designate under the 1979 Birds Directive.

European Standards EN16214 CEN/TC 383 Sustainably produced biomass for energy applications

This EU standard was a further elaboration of the sustainability criteria that was introduced in the revised RED by setting out technical specifications, principles, indicators, verification and auditing schemes to avoid any reconcile diverse interpretations between member states. EU will only accept biofuel to be “sustainably” produced if it follows these criteria:

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- The biofuels must achieve at least 50% of GHG savings when compared to fossil fuels by 2017 and 60% by 2018 (only if the production plants are new)
- Crops that are used for Biofuels are not allowed to be grown in land areas that are converted from high carbon stock, e.g. wetlands and forests
- Raw materials extracted from land with high biodiversity, e.g. primary forest cannot be used in the biofuels production.

PRIMARY BIOMASS PRODUCTION

Sustainability requirements (COM(2010)11) [9]

The Renewable Energy Directive (RED II) defines a series of sustainability and GHG emission criteria that bioliquids used in transport must comply with to be counted towards the overall 14% target and to be eligible for financial support by public authorities. Some of these criteria are the same as in the original RED, while others are new or reformulated. In particular, the RED II introduces sustainability for forestry feedstocks as well as GHG criteria for solid and gaseous biomass fuels.

Default GHG emission values and calculation rules are provided in Annex V (for liquid biofuels) and Annex VI (for solid and gaseous biomass for power and heat production) of the RED II.

Soil protection (COM(2006)231)

The Thematic Strategy for Soil Protection of 2006 consists of a Communication from the Commission to the other European Institutions, a proposal for a framework Directive, and an Impact Assessment. COM(2006)231 sets the frame. It established a ten-year work program for the European Commission. The proposal for a framework Directive (COM(2006) 232) sets out common principles for protecting soils across the EU. Within this common framework, the EU Member States will be in a position to decide how best to protect soil and how use it in a sustainable way on their own territory. Meanwhile this proposal was blocked by Member States in 2010. The Strategy itself is still ongoing.

Agriculture

The policy mechanism that is used in this sector is a combination of financial and regulatory measures. All the policies in this sector only impacted the upstream of its value chain, which are from Land use stage until the conversion stage.

CAP, pillar 1 – Direct payments

Framework for financial support to farmers, with (environmental) requirements on agricultural practices (cross-compliance rules). Since 2015 part of the budget goes to 'Green Direct Payments', including obligatory practices on maintenance of permanent grassland, ecological focus areas and crop diversification.

CAP, pillar 2 – Rural development

Framework (incl. budget) for national and/or regional rural development programmes, defining common EU priorities, including ecosystem enhancement in agriculture and forestry, and shift to a

[9] https://ec.europa.eu/jrc/en/jec/renewable-energy-recast-2030-red-ii

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low-carbon economy (including on-farm renewable energy production). New CAP 2014-2020 in force since 2014.

Nitrates Directive (91/676/EEC)
Restrictions on fertilisation in agriculture (focus on nitrogen) to protect water quality, to be included in Member States' programmes. All of them include a limit of 170 kg/ha/year of livestock manure.

Animal by-products regulation
Rules for movement, processing and disposal of animal by-products not intended for human consumption.

Standards for soil improvers (CEN-TC223)
Standardization of two types of material used in agriculture, horticulture, gardening and landscaping. 1) Soil improvers, that is materials, which may have been composted or otherwise processed, added to soil mainly to improve its physical condition without causing harmful effects. 2) Growing media, that is materials in which plants are grown. Lime products and materials used solely as plant nutrients are excluded.

Standards for fertilizers and liming materials (CEN-TC260)
Harmonization of denominations, specifications, marking, methods of test (physical and/or chemical) and safety conditions, related to fertilizers and Liming materials. Work on items covered by EEC directives currently existing should only be undertaken at the invitation of the Commission.

Forestry
Forestry is a national competence and there is therefore no common EU forest policy. EU instruments for forestry are mainly soft measures, i.e. strategies, voluntary agreements and accounting rules, but there are also other sectoral policies that directly affect forestry.

EU Forest Strategy
Strategy document (2013) defining key principles for sustainable forest management. The cascading principle for forest products (prioritise higher added value) is also mentioned.

EU Timber Regulation
Obligations of operators who place timber and timber products on the market to counter the trade in illegally harvested timber. In force since 2013.

REDD+
"Reducing Emissions from Deforestation and forest Degradation, conservation of forest carbon stocks, sustainable management of forests, and enhancement of forest carbon stocks."
Developed countries provide financial support to developing countries which demonstrate reduced emissions from forests at a national level, as measured against a business as usual scenario (or reference level). Guide to implementation of phytosanitary standards in forestry.

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EU FLEGT Action Plan[10]

The EU published the Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan in 2003. The Action Plan sets out a range of measures available to the EU and its member states to tackle illegal logging in the world's forests. A key element of the FLEGT Action Plan is a voluntary scheme to ensure that only legally harvested timber is imported into the EU from countries agreeing to take part in this scheme. The internal EU legal framework for this scheme is the FLEGT Regulation adopted in December 2005, and a 2008 Implementing Regulation, allowing for the control of the entry of timber to the EU from countries entering into bilateral FLEGT Voluntary Partnership Agreements (VPA) with the EU. Once agreed, the VPAs include commitments and action from both parties to halt trade in illegal timber, notably with a license scheme at the partner country and the issuance of FLEGT licences that certify the legality of timber exported to the EU. An updated Customs and FLEGT Implementation Guidance is available from January 2020[11], to support Customs and FLEGT Competent Authorities in effectively carrying out their tasks in accordance with the FLEGT legislation.

CONVERSION

Sustainable Process Industry through Resource and Energy Efficiency (SPIRE)

SPIRE is an international non-profit association formed to represent the private sector as a partner in the Sustainable Process Industry through Resource and Energy Efficiency (SPIRE) Public-Private Partnership (PPP) launched as part of the Horizon2020 framework programme. The mission of a SPIRE is to ensure the development of enabling technologies and best practices along all the stages of large scale existing value chain productions that will contribute to a resource efficient process industry.

SET Plan Action 8 Communication (2015)6317: Renewable Fuels and Bioenergy

In May 2016, the public consultation process was dedicated to the 4th Energy Union Research, Innovation and Competitiveness common priority for 'more sustainable transport systems that develop and deploy at large scale innovative technologies and services to increase energy efficiency and reduce greenhouse gas emissions'. Action 8 strengthen market take-up of renewable fuels needed for sustainable transport solutions and bioenergy cost reductions aspects.

European Technology Platform on Bioenergy (ETIP Bioenergy)

The European Technology Platform on Renewable Heating & Cooling (RHC Platform) became the European Technology and Innovation Platform (ETIP) in 2016. It aims to bring together stakeholders from the EU energy industry, biomass producer, private organization in the research and technology field, NGOs and the representative from the European Commission to gather their knowledge and resolve the current challenges for bioenergy. The platform allows stakeholders to develop a common strategy to increase biomass consumption in the EU's heating and cooling sector. These stakeholders include expertise from sectors like biomass, geothermal, solar thermal

[10] https://ec.europa.eu/environment/forests/flegt.htm

[11] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2020.020.01.0001.01.ENG&toc=OJ:C:2020:020:FULL

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as well as related industries such as thermal energy storage or even hybrid systems. *The 2050 vision for 100% renewable heating and cooling in Europe* [12] is a report which highlights the principles, the drivers and the challenges of transition to RE. The report also presents the potential of RHC technologies and multidisciplinary way to achieve carbon free HC sectors by 2050 and it is a vision developed by RHC-ETIP.

European Norm biodiesel-FAME (Fatty acid methyl esters): EN14214

This EU legislation is a binding standard that establishes the requirements and tests methods for commercial and delivered fatty acid methyl esters (FAME), commonly used as the main biodiesel in the market. This standard helps facilitate the EU internal market for FAME biodiesel by eliminating trade barriers and is used to promote safety and common technical understanding amongst the EU stakeholder.

European Norm Biodiesel fuel: EN590

This binding standard sets the requirements and test methods that all diesel fuel being sold within the EU must comply with. This standard is relevant to biofuels since it allows conventional diesel fuels to blend with Fatty Acid Methyl Ester up to 7%, due to technical reasons.

European Norm Petrol: EN228

This standard sets specification and test methods for all unleaded petrol sold within the EU, as well as specifying the maximum ethanol content blended in gasoline up to 5%.

prEN16723 - Natural gas and biomethane

To support and facilitate the market penetration of the use of biogas in the EU, this standard was introduced to provide quality specifications and test methods for the updated biogas and biomethane used in 1) the injection in the natural gas grid and 2) transportation fuel.

NER300 programme

This funding programme is aiming to support innovative low-carbon energy demonstration projects that require investment to convert into commercial-scale within the EU. The sales revenue from the EU emissions trading system (ETS) is used to fund this programme, with currently 39 projects selected that boost technologies towards carbon capture and storage (CCS) and renewable energy (RES). NER300 supports wide range of demonstration projects. CCS technologies like-pre-combustion, post-combustion, oxyfuel and industrial applications. RES technologies like- bioenergy, solar power, concentrated solar power, photovoltaics, geothermal, wind, ocean, hydropower, and smart grids.

EU REACH (Reg. 1907/2006)

REACH is the Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals. The main aims of REACH are to ensure a high level of protection of human health and the environment from the risks that can be posed by chemicals, the promotion of alternative test methods, the free circulation of substances on the internal market and enhancing competitiveness

[12] https://www.rhc-platform.org/content/uploads/2019/10/RHC-VISION-2050-WEB.pdf

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and innovation. REACH provides a comprehensive data generation and assessment system for chemicals manufactured and used in the EU, designed to improve the protection of human health and the environment and positioning the EU as frontrunner in achieving the goal set for 2020 at the World Summit for Sustainable Development.

DISTRIBUTION

Alternative fuels infrastructure (Dir. 2014/94/EU)

This directive aims to reduce the dependency of fossil fuels and mitigate environmental impact in EU transport by stimulating the use of alternative fuels through establishing a standard framework of measures.

EU Council Directive 2015/652

The directive outlines the methods for calculation methods to determine the greenhouse gas intensity of the fuels (petrol and diesel) and energy supplied and reporting requirements by the suppliers. The directive also outlines the calculation method for fuel baseline standard and greenhouse gas intensity reductions achieved by the suppliers from fuels and from electricity.

Standards for solid biofuels (CEN/TC335)

This EU standard is used to established specification and fuel classes of solid wood biofuel by setting out clear classification principles. This act as a tool to allow efficient trading and create a mutual understanding between the EU biofuel stakeholders. The standard covers the whole biofuel's value chain, starting from raw material supply till the end-user consumption.

END PRODUCTS/ CONSUMPTION

Fuel quality directive (Dir. 2009/30/EC)

In 2009, several elements in this Directive had been amended including the petrol and diesel specifications. Other amendment includes establishing Article 7a, which enforce fuel production used in energy supplied for road transport to reduce its greenhouse gas intensity. The Directive also introduces sustainability criteria for biofuels to comply with, to help contribute to the greenhouse gas intensity reduction requirement.

Energy Taxation Directive (Dir. 2003/96/EC)

The Directive was first adopted to avoid competitive distortions and regulate the EU's energy sectors within its internal market. However, with the EU initiative to tackle climate change and energy efficiency, the directive was revised. As a result, the proposed rules promote environmentally-friendly consumption by introducing taxes on products and companies' CO2 emissions and energy content. Hence, this produces incentives for companies to invest in alternative energy sources such as biofuels since there are less CO2 emissions produced.

Standards for biobased products (CEN-TC411)

Development of standards for bio-based products covering horizontal aspects. This includes consistent terminology, sampling, certification tools, bio-based content, application of and correlation towards life cycle analysis, sustainability criteria for biomass used and for final products, and aspects where further harmonization is needed on horizontal level.

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Development of standards for bio-solvents, covering product functionality, biodegradability and, if necessary, product specific aspects not covered under CEN/TS 16640:2014 - Bio-based products. CEN/TC 411 includes these technical standards and specifications:[13]

Standardisation on surface active agents (CEN-TC276)
Standardization of classification, terminology, sampling, physical, chemical or other test methods, specifications, etc., of surface active agents and mixtures containing one or more surface active agents with or without other conventional components of soap and detergent formulations. Bio-surfactants: Development of standards for bio-surfactants products. This includes consistent terminology with CEN/TC 411 "Bio based Products" definitions, sampling, certification tools, biobased content, application of and correlation towards life cycle analysis, sustainability criteria for biomass used and for final products; product functionality and other product specific aspects not covered by the CEN/TC 411. There are no published standards on bio-surfactants.

Standardisation on Gaseous and liquid fuels, lubricants and related products of petroleum, synthetic and biological origin CEN/TC 19
Standardisation of methods of sampling, analysis and resting, terminology and specifications and classifications for petroleum related products, fuels, lubricants and hydraulic fluids that origin from mineral oil and biomass, gaseous and liquid fuels for transport and stationary applications.

EU Emissions Trading System (EU ETS)
The EU emissions trading system (EU ETS) is a cornerstone of the European Union's policy to combat climate change and its key tool for reducing industrial greenhouse gas emissions cost-effectively. The first - and still by far the biggest - international system for trading greenhouse gas emission allowances, the EU ETS covers more than 12,000 power stations and industrial plants in 31 countries, as well as airlines (1400 aircraft operators). Currently being reviewed to address the surplus of emission allowances. The EU ETS is running in its phase 3 (2013-2020) which allocated 300 million allowances to fund the deployment of innovative renewable energy technologies and carbon capture and storage through NER 300 programme. The phase 4 (2021-2030) for EU ETS was revised in 2018 to achieve EU'S 2030 emission reduction targets. Phase 4 will focus on:

- Increasing the annual reduction in allowance to 2.2% as of 2021
- Continue the free allocation of allowances to reflect the technological progress
- Support industry and power sector by low-carbon funding mechanisms.

The EU ETS aims to cut greenhouse emissions 21% by 2020 and 43% by 2030 to meet EU climate targets for 2020 and 2030.

The recent amendment to EU ETS by Directive EU (2018/410) emphasises the need to act on shipping emissions.

Effort sharing legislation for Member States

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This effort sharing legislation support policies on climate change and energy sector and help EU move towards low-carbon economy. The legislation establishes binding annual greenhouse gas emission reduction targets for member states. These targets will mainly concern emissions from sectors which are not included in the EU ETS such as transport, buildings, agriculture and waste. The member states national targets will together reduce 10% of the total EU emissions by 2020 and 30% by 2030 compared to 2005 levels.

Energy Performance of Buildings Directive (Dir. 2010/31/EU)

The EU adopted the Energy Performance of Buildings Directive 2010/31/EU (EPBD) which is the main legislative instrument to reduce the energy consumption of buildings. Under this Directive, Member States must establish and apply minimum energy performance requirements for new and existing buildings, ensure the certification of building energy performance and require the regular inspection of boilers and air conditioning systems in buildings. Moreover, the Directive requires Member States to ensure that by 2021 all new buildings are so-called 'nearly zero-energy buildings'.

BRIDGE 2020

The Biobased Industries Consortium (BIC) is a cross sectorial group of 48 large and small enterprises that cooperates with the European Commission in a public-private partnership. This PPP aims at accelerating the development of biobased products in Europe till 2020.

2030 Framework for climate and energy

This framework establishes targets and measures for the EU to tackle climate change issues by securing the energy sector to be more competitive and sustainable. These targets include long-term aims such as reducing greenhouse gas emissions as well as increasing the use of renewable energy. For these targets to be achieved, the framework suggests a new governance system that includes performance indicators to measure these progresses.

Clean Vehicles Directive (Dir.2009/33/EC)

This directive aims at introducing environmentally-friendly vehicles to the EU market in order to achieve a Clean and Energy efficient in road transport vehicles. This is done through public procurement tenders and public services contract that requires all road transport vehicles purchases to consider the energy and environmental impacts associated with the vehicle's operation. The European Commission has launched several projects that developed tools to calculate the vehicle's lifetime cost according to its impacts, which later on could be used to monetise these impacts for inclusion in the purchasing decision.

Ecodesign Directive (Dir. 2009/125/EC)

This EU directive is designed to improve the environmental performance of energy-related products (ERPs) by setting out the minimum requirements on the energy efficiency of these products. This enables the least performing or under-quality products to be eliminated off the market without creating any trade-barriers within the EU. Furthermore, this measure not only contributes to the EU's target on the 2020 energy efficiency objective, but it also promotes innovation through eco-design and encourages the industrial competitiveness for a better-quality product.

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Emission performance standards for passenger cars Regulation (EU) 2019/631
The EU Regulation (EC) No 443/2009 emission performance for new passenger cars and light commercial vehicles was repealed with this new regulation. This regulation aims to reduce CO2 emissions polluted from light-duty vehicles. This is by establishing emission performance standards for new passengers' cars for car manufacturers to comply. The new regulation will apply from 1 January 2020. The regulation sets an EU wide target of 95 g CO_2/km for average emissions for new passenger cars and 147 g CO_2/km for new light commercial vehicles.

Energy Efficiency Directive (Dir. 2012/27/EU)
This Directive is a binding framework that aims to support all EU member states to achieve its 20% energy efficiency target by 2020 and 30% energy efficiency target by 2030. This is by setting out measures that include legal obligations or policy schemes that will encourage member states to improve their energy efficiency consumption throughout their energy chain, starting from the initial stage of energy production till final consumption. The framework also proposed measures that involved public sector in playing as an exemplary role on this notion as well as increasing consumers awareness on their energy consumption.

Green Public Procurement
Green Public Procurement (GPP) is a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured. The basic concept of GPP relies on having clear, verifiable, justifiable and ambitious environmental criteria for products and services, based on a life-cycle approach and scientific evidence base. In the Communication "Public procurement for a better environment" (COM (2008) 400) the Commission recommended the creation of a process for setting common GPP criteria.

EU Monitoring, reporting and verification (MRV) Regulation 2015/757 (as amended by Delegated Regulation 2016/2071)
The EU MRV Regulation lays down rules for monitoring, reporting and verification of carbon dioxide emissions and other information from ships arriving and leaving the ports in order to reduce carbon dioxide emission from maritime transport. The regulation applied to ships which weights 5000 tonnage loading and unloading cargo or passengers at ports in the European Economic Area. In 2018 October, the International Maritime Organization Marine Environment Protection Committee agreed on reduction measure:
-Short-term measures to be decided between 2020 and 2023
-Mid and long term measures to be considered without timelines in agreement.

Renewable energy directive (Dir, 2009/EC/28 & Directive (EU) 2018/2001]
This directive promotes the use of renewable energy in the EU by establishing a common framework and sets binding targets for all member states to achieve, with the ultimate goal of achieving 20% share of renewable energy in the energy sector by 2020. Furthermore, the directive explicitly specified how the transport sector must achieve at least a 10% share of renewable energy from its final energy consumption by 2020.

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The directive also specifies all member states to establish their national actions plans to demonstrate how they will achieve their 2020 binding target, thus promoting the use of renewable electricity and bioenergy through improving their legal framework and provide cooperation mechanisms.
In June 2018, the directive is recast to RED II by introducing new targets for 2030 as stated below:

- 14% RES transportation energy target
- Sub-target of 3.5% of advanced biofuel
- 7% Cap on conventional food-based biofuels

Solid fuel boilers and solid fuel local space heaters
The scope of the proposed ecodesign requirements include solid fuel boiler space heaters and solid fuel boiler combination heaters ('boilers') = 1000 kW. The scope of the proposed energy labelling requirements includes boilers with a rated output of 70 kW or less. Examples of solid fuel local space heaters are: fireplaces (open or closed), wood stoves, coal stoves, pellets stoves, solid fuel cookers.

Standardisation for plastics (CEN-TC249)
Standardization of terminology, test methods and specifications in the field of plastics and plastics-based materials, semi-finished products and products (thermoplastics, thermosets, cellular plastics, degradable plastics, thermoplastics elastomers, composites and reinforcement products for plastics) as well as plastics recycling. Rubber is excluded. Specific end-product related items are also excluded if they are covered by the scope of an existing product TC. (EN15534 (wood plastics); CEN/TS 16398:2012 (biopolymers); CEN/TS 16295:2012 (biopolymers); CEN/TS 16137:2011 (biopolymers).

Research, Innovation, Development and Deployment Strategies
EU Bioeconomy Strategy 2018 (COM(2018) 673)
The Bioeconomy Strategy and its Action Plan aim to pave the way to a more innovative, resource efficient and competitive society that reconciles food security with the sustainable use of renewable resources for industrial purposes, while ensuring environmental protection. The Action Plan describes the Commission's main actions for the implementation of the Bioeconomy Strategy objectives, building on FP7, Horizon 2020 and other relevant existing policy initiatives, such as the EIPs.
European Structural and Investment Fund (ESIF)
The ESIF is managed by European Commission and EU member states. The ESIF has five focus areas:

- research and innovation
- digital technologies
- supporting the low-carbon economy
- sustainable management of natural resources
- small businesses

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There are various funds under ESIF[14]:

- ***European regional development fund (ERDF)***– *promotes balanced development in the different regions of the EU.*
- ***European social fund (ESF)*** *- supports employment-related projects throughout Europe and invests in Europe's human capital – its workers, its young people and all those seeking a job.*
- ***Cohesion fund (CF)*** *– funds transport and environment projects in countries where the gross national income (GNI) per inhabitant is less than 90% of the EU average. In 2014-20, these are Bulgaria, Croatia, Cyprus, the Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia and Slovenia.*
- ***European agricultural fund for rural development (EAFRD)*** *– focuses on resolving the particular challenges facing EU's rural areas.*
- ***European maritime and fisheries fund (EMFF)*** *– helps fishermen to adopt sustainable fishing practices and coastal communities to diversify their economies, improving quality of life along European coasts.*

EU 2050 Long-term Strategy COM (2018)773[15]

The strategy outlines how EU can invest in technological solutions, empower citizens and align action in key areas such as industrial policy, finance and research. The Commission calls for action for prosperous, modern, competitive and climate-neutral economy by 2050.

S3 Platform

The S3 Platform assists EU countries and regions to develop, implement and review their Research and Innovation Strategies for Smart Specialisation (RIS3). Established in 2011 following the Communication 'Regional Policy contributing to smart growth in Europe 2020', the role of the S3 Platform is to provide information, methodologies, expertise and advice to national and regional policy makers, as well as promote mutual learning, trans-national co-operation and contribute to academic debates around the concept of smart specialisation. Registration on the S3 Platform is open to regional and national administrations of EU, candidate and neighbouring countries. The S3 Platform is hosted by the Institute for Prospective Technological Studies (IPTS) in Seville, part of the European Commission's Joint Research Centre.

SCAR Network[16]

The Standing Committee on Agricultural Research (SCAR) has a working group Bioeconomy Strategic Working Group (BSW) coordinates the agricultural research in Europe and looks into how bio-resources can be sustainably produced for the bioeconomy.

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14 https://ec.europa.eu/info/funding-tenders/funding-opportunities/funding-programmes/overview-funding-programmes/european-structural-and-investment-funds_en

15 A Clean Planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy. Accessed xxx

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773

16 https://www.scar-swg-sbgb.eu/

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BSW addresses are how the implementation of the Bioeconomy strategy impacts upon agriculture, forestry, fisheries and aquacultures. How the Bioeconomy fosters new connections between well-established sectors and how this in turn might change these sectors and their sustainable and profitable operation in the future. The BSW also discusses more technical questions (such as those related to biorefineries) as well as strategic ones with respect to the relationship of the Bioeconomy policy to other policy areas (e.g., climate, water, food, forestry).

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Appendix 2: Drivers impacting policy relevant modelling for biobased value chains

This Appendix attempts to translate the existing set of directives, standards, policies and strategies that (in)directly relate to the EU bioeconomy into 'model' language. To do so it outlines a non-exhaustive list of drivers that impact policy relevant modelling, and presents respective indicators that have been used so far to assess policy impacts in EU policies.

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Table 4 Drivers that impact policy relevant modelling for the current EU policies

BioMonitor Drivers / Policy	Land stock and structure	Technology level/change	Energy need	Conversion capacity	Policy mechanisms and reforms
iLUC Directive (EU) 2015/1513	X				
Renewable energy directive (Dir. 2009/EC/28)			x		x
Alternative fuels infrastructure (Dir. 2014/94/EU)		x		x	x
Clean Vehicles Directive (Dir. 2009/33/EC)		x		x	x
Ecodesign Directive (Dir. 2009/125/EC)		x		x	
Effort sharing targets for member states (binding targets)					x
Emission performance standards for new passenger cars (Reg 443/2009)		x			x
EN ISO 17225 Standards for solid biofuels (CEN/TC335)				x	x
Energy Efficiency Directive (Dir. 2012/27/EU)		x	x	x	
Energy Performance of Buildings Directive (Dir. 2010/31/EU)			x		x
EU emissions trading system (EU ETS)		x			
European Standards EN16214 CEN/TC 383 Sustainably produced biomass for energy applications	X				
Fuel quality directive (Dir. 2009/30/EC)				x	
prEN16723 - Natural gas and biomethane			x		
Renewable energy directive (Dir, 2009/EC/28)					x
Solid fuel boilers and solid fuel local space heaters		x			x
Sustainability requirements (COM(2010)11)					x
2030 Framework for climate and energy	x	x	x	x	x
EU Bioeconomy strategy (COM(2018) 673)	x	x	x		x
EU Timber Regulation					
European Technology and Innovation Platform on Bioenergy (ETIP Bioenergy)			x	x	x
European Technology Platform for Sustainable Chemistry (SusChem)		x			
Forest based sector technology platform (FTP)	x	x			x
LULUCF-Land use land-use change and Forestry (Dec. 529/2013/EU)	x				x
Roadmap to a Resource Efficient Europe	x	x	x	x	x
S3 Platform		x		x	x
SCAR Network					x
Horizon 2020		x			x
Joint technology initiative for bio-based industries (BBI-JTI)		x			x
BRIDGE 2020		x		x	
NER300 programme		x			
SET plan: Action 8: Renewable Fuels and Bioenergy		x	x		
Sustainable Process Industry through Resource and Energy Efficiency (SPIRE)		x	x		

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Table 5 Environmental drivers used to assess policy impacts in EU policies

Biomonitor Drivers / Policy	Land use	Nutrient levels	Life cycle GHG	Carbon stocks	Inputs	Harvest/litter	Pollutants/contaminants	Water use	Ecosystem services/productivity
iLUC Directive (EU) 2015/1513	x			x					
Natura 2000									x
Nitrates Directive		x	x		x	x			
Directive for sustainable use of pesticides					x		x		
Standards for soil improvers (CEN-TC223)				x	x				
Soil Thematic Strategy –soil protection COM(2006) 231				x	x				
EU timber Regulation (Reg 995/2010)						x			
Bird Directive 2009/147/EC									x
Habitat Directive 92/43/EEC)	x								x
European Standards EN16214 CEN/TC 383 Sustainably produced biomass for energy applications	x		x						x
Landfill Directive (1999/31/EC) 2030	x								
Sewage Sludge Directive (86/278/EEC)							x		
Standardisation on surface active agents (CEN-TC276)							x		
Standards for biobased products (CEN-TC411)							x		
Animal by-products regulation	x						x		
Bird Directive 2009/147/EC									x
CAP Pillar I: Direct Payments	x			x					
CAP Pillar II –Rural Development									x
CEN/TC 308 – Characterization of sludges							x		
Clean Vehicles Directive (Dir. 2009/33/EC)			x				x		
Effort sharing targets for member states (binding targets)									
Emission performance standards for new passenger cars (Reg 443/2009)			x				x		
EN ISO 17225 Standards for solid biofuels (CEN/TC335)			x						
Energy Efficiency Directive (Dir. 2012/27/EU)						x		x	
EU Council Directive 2015/652			x						
EU emissions trading system (EU ETS)			x	x					

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EU Monitoring, reporting and verification (MRV) Regulation 2015/757			x						
EU timber Regulation (Reg 995/2010)						x			
European Standards EN16214 CEN/TC 383 Sustainably produced biomass for energy applications	x		x			x			x
Fuel quality directive (Dir. 2009/30/EC)			x						
Green public procurement (COM(2008)400)	x		x			x			
Habitat Directive (Dir. 92/43/EEC)	x								x
Industrial Emissions Directive							x		
REACH (Reg. 1907/2006)							x		
Sewage Sludge Directive (86/278/EEC)							x		
Soil protection (COM(2006)231)		x		x					
Soil Thematic Strategy –soil protection COM(2006) 231		x		x					
Standards for fertilizers and liming materials (CEN-TC260)		x							
Standards for soil improvers (CEN-TC223)		x		x					
EU Forest Strategy									
2030 Framework for climate and energy	x		x	x		x		x	x
EU 2020 Biodiversity Strategy COM(2011)									x
EU Timber Regulation						x			
European Technology and Innovation Platform on Bioenergy (ETIP Bioenergy)	x								
Forest based sector technology platform (FTP)	x			x					
LULUCF-Land use land-use change and Forestry (Dec. 529/2013/EU)	x		x	x					x
Roadmap to a Resource Efficient Europe	x	x	x	x	x	x		x	x
SCAR Network	x	x	x		x	x		x	x
Energy Taxation Directive (Dir. 2003/96/EC)									
NER300 programme			x	x					
SET plan: Action 8: Renewable Fuels and Bioenergy			x						
REDD+	x			x					

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Table 6 Economic drivers used to assess policy impacts in EU policies

Biomonitor Drivers / Policy	Biomass production and availability	Energy supply carriers/production	Trade	GDP
EU timber Regulation (Reg 995/2010)			x	
Standards for biobased products (CEN-TC411)	x			
Alternative fuels infrastructure (Dir. 2014/94/EU)	x	x		
Clean Vehicles Directive (Dir. 2009/33/EC)	x			
EN ISO 17225 Standards for solid biofuels (CEN/TC335)	x	x		
Energy Efficiency Directive (Dir. 2012/27/EU)		x		
EU emissions trading system (EU ETS)				
Renewable energy directive (Dir, 2009/EC/28)	x	x	x	
Sustainability requirements (COM(2010)11)			x	
2030 Framework for climate and energy	x	x	x	x
EU 2020 Biodiversity Strategy COM(2011)				
EU Bioeconomy strategy (COM(2018) 673)	x		x	x
European Technology and Innovation Platform on Bioenergy (ETIP Bioenergy)	x	x		
Forest based sector technology platform (FTP)	x		x	
LULUCF-Land use land-use change and Forestry (Dec. 529/2013/EU)	x			
Roadmap to a Resource Efficient Europe	x	x		
Horizon 2020			x	x
Joint technology initiative for bio-based industries (BBI-JTI)				
BRIDGE 2020			x	
Energy Taxation Directive (Dir. 2003/96/EC)				

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Table 7 Social drives used to assess policy impacts in EU policies

Biomonitor Drivers / Policy	Demand/consumption	Employment	Welfare	Food security
EU timber Regulation (Reg 995/2010)	x			
CAP Pillar II –Rural Development		x		
Sustainability requirements (COM(2010)11)	x			
2030 Framework for climate and energy	x			
EU Bioeconomy strategy (COM(2018) 673)	x	x		X
Forest based sector technology platform (FTP)	x	x		
Roadmap to a Resource Efficient Europe				X
S3 Platform				
SCAR Network				X
Horizon 2020				X
BRIDGE 2020	x			
Energy Taxation Directive (Dir. 2003/96/EC)	x			

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Table 8 Models and Indicators used to assess policies in the land use and biomass production stages

		Land Use		Land use and Biomass Production					
		Currrent and projected forest resource structure and development given natural processes or management actions (EFDM & EFISCEN)	Impact of ecosystem services changes on welfare (InVEST)	How climate, water and soil characteristics can affect the production patterns of a given crop and its spatial suitability (PRISM-ELM)	Competition for land and water and the associated consequences for sustainable development given rising food, energy and material demand (MAgPIE)	Comparison of different land and forest management systems and their effects on the environment (EPIC)	Changes in forest area based on income derived from forests and that from an alternative use of the same land (G4M)	Biophysical climate change mitigation potential of an entire forest sector (CBM-CFS3)	Effects and interactions of agricultural policies on nitrogen and GHG emissions, changes in soil organic carbon stocks and nutrient losses to water (MITERRA)
Technical	Land stock and structure	X					X	X	
	Technology level/change								
	Energy need								
	Conversion capacity								
	Policy mechanisms and reforms								X
Environmental	Land use				X		X	X	
	Nutrient levels					X			X
	Life cycle GHG				X	X	X	X	X
	Carbon stocks	X	X				X	X	X
	Inputs				X	X			
	Harvest/litter	X						X	
	Pollutants/contaminants	X				X			
	Water use					X			X
	Ecosystem services/productivity	X						X	
Economic	Biomass production and availability	X		X	X	X	X	X	
	Energy supply carriers/production						X		
	Built-up area								
	Costs/value added/revenue		X				X		
	Trade								
	GDP								
	Price								
Socio-economic	Demand/consumption								
	Farm income								
	Employment								
	Welfare		X						
	Food security								

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Table 9 Models and Indicators used to assess policies in the land use and biomass production stages

	Conversion and End Use
	Existing and future technologies for energy or emission control based on performance and cost (MARKAL)
Land stock and structure	
Technology level/change	X
Energy need	X
Conversion capacity	
Policy mechanisms and reforms	
Land use	
Nutrient levels	
Life cycle GHG	X
Carbon stocks	
Inputs	
Harvest/litter	
Pollutants/contaminants	
Water use	
Ecosystem services/productivity	
Biomass production and availability	
Energy supply carriers/production	X
Built-up area	
Costs/value added/revenue	X
Trade	
GDP	
Price	
Demand/consumption	X
Farm income	
Employment	
Welfare	
Food security	

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Table 10 Models and Indicators used to assess policies in the land use and biomass production stages

		Full Value Chain								
		Impact of anthropic activities on natural resources including disrupting ecosystem services (IMAGE)	Structure and the revenue flows among the commodities, activities, factors and institutions in the Bioeconomy (BIOSAMs)	Impacts of agricultural and energy trade, land and bioenergy policies on the economy at global scale given demographics and resource availability (MAGNET & MIRAGE & GTAP)	Land use issues stemming from competition between agricultural, bioenergy and forestry sectors and role of policy (GLOBIOM)	Optimisation of energy systems for international communities TIMES)	Environmental and market projections from measures, programmes and policies in agriculture (AGMEMOD)	Simulation of the development of agricultural markets, including production, processing and consumption (ESIM & CAPRI & AgLink-COSIMO)	Projections for consumption, production and international trade of wood-based products and pellets (GFTM & EFI-GTM)	Impacts of climate, water, crop, value chain, nutrition and health on global production, trade, demand and prices of agricultural commodities (IMPACT)
Technical	Land stock and structure	X								
	Technology level/change									
	Energy need	X				X				
	Conversion					X		X	X	
	Policy & reforms						X	X		
Environmental	Land use	X		X	X			X		X
	Nutrient levels	X					X	X		
	Life cycle GHG	X			X	X	X			
	Carbon stocks	X								
	Inputs				X			X		
	Harvest/litter				X				X	X
	Pollutants	X								
	Water use	X			X					
	Ecosystem services	X								
Economic	Biomass	X		X	X			X	X	X
	Energy	X		X	X	X	X	X	X	X
	Built-up area									
	Costs/value added/revenue		X			X		X		
	Trade			X	X		X	X	X	X
	GDP			X				X		
	Price			X	X	X	X	X		X
Socio-economic	Demand			X	X		X	X	X	X
	Farm income							X		
	Employment			X				X		
	Welfare			X				X		
	Food security									X

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Appendix 3: Definitions of indicators used in policy relevant modelling

I] Technical

1) Land stock and structure

Quantitative and descriptive

Land structure is described by crop/tree species, age-classes, annual, perennial or biennial designation for crops, growing stock (**m^3/ha**), and increment (**m^3**). Additionally, the share of land or forests certified for sustainable management (**ha/product unit or % of total forests**) is relevant as a link to policy mechanisms and quality standardisation. Finally, additional sub-indicators can be area density **(% of total land**) as well as ratio of annual increment and fellings/harvesting (**% of net annual increment**) (FAO Report).

2) Technology level/change

Descriptive

One way to measure technology growth is through technology readiness levels, expressed differently per feedstock production and conversion stages, and in 9 levels. This indicator measures the development of advanced biorefinery technologies for producing materials or energy and can be assessed by analysing the sector efforts in investing in new technology development and research and development expenditure (FAO Report). The 9 levels of technology readiness are defined as follows (Horizon 2020: Calls – Overview/BIOMASS POLICIES):

- TRL 0: Idea. Unproven concept, no testing has been performed.
- TRL 1: Basic research. Principles postulated and observed but no experimental proof available.
- TRL 2: Technology formulation. Concept and application have been formulated.
- TRL 3: Applied research. First laboratory tests completed; proof of concept.
- TRL 4: Small scale prototype built in a laboratory environment.
- TRL 5: Large scale prototype tested in intended environment.
- TRL 6: Prototype system tested in intended environment close to expected performance.
- TRL 7: Demonstration system operating in operational environment at pre-commercial scale.
- TRL 8: First of a kind commercial system. Manufacturing issues solved.

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- TRL 9: Full commercial application, technology available for consumers.

3) Energy need

Quantitative and descriptive

This indicator is linked to energy efficiency when analysed jointly with energy supply/carriers produced and highlights the self-sufficiency of a value chain. Energy inputs range from primary energy of fuel inputs (non-renewable and renewable) or energy required to produce heat and electricity. It can be expressed in **GJ input per ha** and per fuel type. This indicator can be disaggregated into energy **(kWh)** or fuel (**l/biomass unit**) consumption for cultivation and drying of biomass, and manufacturing **(l/ manufacture process**) or processing (**kWh/ production process**). On a territorial level, energy use can be measured in **kg of oil equivalent per USD 1 000 GDP** (FAO REPORT).

4) Conversion capacity

Capacity of a plant can be measured either in its processing or production power. The former is expressed as feedstock consumption (**ton dry biomass/day or MW Lower Heating Value (LHV)**) while the latter can be expressed as **ton/day, m3/day, Nm3/h** of product (SGAB Technology Status Report).

5) Policy mechanisms and reforms

Quantitative and descriptive

Policy mechanisms include three categories: **regulatory, financial and soft measures**. The first can be mechanisms such as quotas, product standards, targets or qualifying criteria and green procurement. On a territorial level, it can be ratification and implementation of global legal, policy and institutional frameworks. The second includes grants, premiums, feed in tariffs, tax incentives and funds. For instance, subsidies in the form of **funding under annual payment schemes for a value chain stage** or government spending on product procurement programs **(€ or % of total spending**) to support coherence between supply and demand of food and non-food goods, investment in research and development (**€**), and financial support for ecosystem services represent key financial interventions (FAO REPORT). Finally, the third category includes best practice diffusion and promotion, capacity building and awareness raising, such as cluster governance and management or availability of documentation necessary to inform stakeholders (FAO REPORT).

II] Environmental

1) Land Use

Quantitative and descriptive

Refers to the past, current land use or change in land type from one purpose to another and can be measured in hectares **(ha)**. Agricultural land converted to energy crop can be expressed in **ha/ product unit or % of total agricultural land**, equally so for grassland converted to cropland (**% of total grassland**), and forest converted to cropland **(% of total forests**). Land for biomass production can be expressed in **ha/biomass production unit.** These are major land use changes possibly pertaining to the degradation of land, soil, and forests (FAO Report). Land use change can be direct or indirect and can also involve deforestation, afforestation, and rewilding. Land use change can reveal either an increase or a decrease in carbon stock levels.

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2) Nutrient levels

Quantitative and descriptive

Soil nitrogen or phosphorus can be measured in **tonnes/ha or kg/ha,** soil nutrient balance can be measured in **g of nutrients/kg of soil.** This indicator is linked to input (fertiliser).

3) Life cycle GHG

Quantitative

Emissions of carbon dioxide, methane and nitrous oxide must be considered over the full value chain measured in carbon dioxide equivalents **(gCO_2eq/MJ or tonne of product)**. Emissions must be considered in relation to a baseline or reference situation, typically the fossil alternative, where the same services are produced (electricity, heat, transport fuels, materials). Although the combustion of biomass is usually considered CO_2-neutral since emitted carbon is absorbed during plant growth, a more robust assessment of this indicator can be done in combination with soil carbon stock, land use change and ecosystem service productivity indicators. This indicator is also linked to input levels of fertiliser as well as life cycle GHG since fertilisers can produce both CO_2 and NH_4.

4) Carbon stocks (biomass, soil, atmospheric or oceanic)

Quantitative

Carbon stocks are measured in **CO_2eq tonnes**. Biomass and soil organic carbon is measured in **tonnes/ha** where the latter reflects soil quality and productivity. Harvest levels (and removal rates of litter) directly impact soil organic carbon. A precautionary principle can be applied by allowing for maximum conservative removal rates established by experts.

5) Inputs (fertiliser, pesticides, feed)

Quantitative and descriptive

This indicator is measured by the estimated amount of organic or mineral fertilizers and pesticides used (**kg or tonnes**) or total sale (**kg, tonnes or €**)**.** Fertiliser inputs largely involve of nitrogen use efficiency which is defined as total nitrogen inputs and outputs (**kgN/ha output/kgN/ha input)** and gives an indication of the relative utilisation of nitrogen applied to an agricultural production system. High efficiency does not necessarily indicate a sustainable system as it can indicate risk of soil depletion, thus this indicator should be linked to soil nutrient levels.

Integrated pest management includes mechanical, chemical, natural and biological controls. This is linked to welfare, food security and ecosystem services. Pesticide contamination of water streams and soil can be potentially damaging to endemic species. This aspect of pesticide input can be monitored as **groundwater with pesticide concentrations above Environmental Quality Standards**. Risk to human health and food safety can also arise (for instance using antibiotics to control pests). Pesticides can be persistent, bio-accumulated, bioconcentrated and mobile in the environment.

6) Harvest/litter

Quantitative and descriptive

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Harvest levels are measured as a **% of net annual growth** and are directly linked to the removal or leaving in place of residues. This indicator indirectly links to overall soil nutrient levels as well as both biomass and soil organic carbon stock levels. In a sustainable harvesting situation, long-term harvest levels should remain lower than net growth and forests or arable lands can expand their carbon storage. Litter can be defined as standing or lying dead wood in forests (**m^3/ha and % of the total amount of wood used**) or agricultural residues.

7) Pollutants/contaminants

Quantitative and descriptive

Air pollutants include acidification, which is caused by acid-forming substances, e.g. sulphur dioxide, nitrogen oxides and ammonia, measured in grams of sulphur dioxide equivalents **(g SO2eq/MJ or tonne of product)**. Air pollution also includes particle pollution (also known as "particulate matter") in the air which includes a mixture of solids and liquid droplets in a wide range of sizes, measured in **(g PM10/MJ or tonne of product).** Those less than 10 micrometres (μm) in diameter (PM_{10}) are so small that they can get into the lungs, potentially causing serious health problems. Finally, air pollution can also be measured through ammonia **kt/year**. These levels are often linked with the volatilisation of nitrogenous fertilisers. Air pollution can be caused as upstream in the value chain as small-scale combustion of wood logs to downstream processes associated with larger installations.

8) Water use (irrigation and downstream processes)

Quantitative and descriptive

Water use for biomass production, irrigation and processing is calculated in **m^3/tonne outputs.** Quantified on the one hand by volume of water used for irrigation (sprinkler or drop irrigation). This indicator can be described as water use efficiency and linked to life cycle costs. Trends in water abstraction rates depend on various factors: crop variety, irrigation area, irrigation technology, water prices, water restrictions, pumping costs and climate conditions. The environmental impact of irrigation can range from exacerbating marginality of land to increasing land remediation and redistribution of water resources or aquifer recharge, which is linked to ecosystem services and habitat regeneration.

9) Ecosystem Services/Productivity

Quantitative and descriptive

Ecosystem services can be measured as **provisioning, regulating or cultural/recreation** services. For instance, provisioning services comprise fuelwood, genetic material, medicinal resources, water supply, forest products, fish, animals…etc. Regulating services include carbon storage, coastal flood protection, erosion mitigation, pest and disease regulation, pollination, sediment retention, among others. Finally, cultural or recreational services include cultural heritage, health, mental and physical benefits, education, nature tourism, spiritual values…etc. (Neugarten et al, 2018). Another way of measuring the performance of an ecosystem is through **net ecosystem productivity (NEP)** (DeCicco et al, 2016), representing the portion of NPP that becomes material carbon available for local sequestration or other disposition. NEP can be measured through the following equation (Lovett et al, 2006): **amount of organic carbon fixed by photosynthesis in an ecosystem + import of organic carbon - total ecosystem respiration – export of organic carbon – nonbiological oxidation of carbon (in mass $area^{-1}$ $time^{-1}$).**

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Ecosystem services are directly linked to the species which inhabit a certain ecosystem and land use and management changes have direct effects on species and habitats. For instance, excess fertilisation may have toxic impacts on vegetation as leaching of nitrogen causes eutrophication of surface water and soils affecting wildlife flora and fauna. Toxic substances such as pesticides affecting the reproductive capabilities of species can directly affect flora and fauna (BIOMASS POLICIES). Additionally, crop residues left when simplified tillage techniques are used provide a habitat for arthropods, which in turn attract more frequent visits by birds and a greater diversity. The latter is measured as **farmland bird index.** The invasive species index is relevant as these prey on fragilized ecosystems by rapidly colonising areas and compromising the proper functioning of ecosystems. The choice of crop itself can lead to an invasive species dominating an environment. Finally, environmental indicators of soil and water are also relevant to farmland biodiversity: poor soil structure and reduced water filtration can conjunctly lower abundance of soil biodiversity (BIOMASS POLICIES). Key ecosystem functionalities include biotic production potential (**Capacity of ecosystems to produce biomass in kg**), freshwater regulation potential as capacity of ecosystems to regulate peak flow and base flow of surface water, and to recharge ground (**millimetres of water recharged annually**), and finally erosion regulation potential as capacity of ecosystems to stabilize soil and to prevent sediment accumulation downstream (**mass of soil lost per unit area and time**)(FAO REPORT).

III] Economic

1) **Biomass production and availability**

Quantitative and descriptive

Expressed in terms of available bioenergy carriers and biomaterials per hectare of cultivated area **(tonne per ha or GJ/ha/yr)**. Crop yields and feedstock productivity depend on cultivation system, input levels, bioclimatic conditions, and overall land suitability. Domestic biomass production is a broader measure in **kg/capita**.

2) **Energy supply, Carriers, production**

Quantitative and descriptive

Energy content of outputs of the value chain, including both non-renewable and renewable sources (**GJ output)**. Linked to biomass production, this indicator highlights the processing efficiencies of biomass feedstocks into end products. Linked to energy need along the value chain, this indicator also highlights conversion efficiency. By- and co-products along the full value chain are included in calculation of net productivity. On a territorial level, this is expressed by the **share of renewable energy supply (%), production of biofuels and biogas (toe) or naterial replacing non-renewable resources (m^3, tonnes, toe)**

3) **Built-up area**

Quantitative and descriptive

Built-up areas include all non-vegetative, human-constructed elements, such as roads, buildings, runways, and dominated built-up areas implies coverage greater than 50% of a given landscape unit (Schneider et al, 2009) and are calculated in **km^2**. This indicator relates to how accessible a certain infrastructure is and land use change from a marginal status to a developed or industrial one. Socio-economic limitations have a clear influence on the development opportunities of

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regions, particularly where they occur in combination with biophysical limitations. A sub-indicator can be the designation of either a **peri-urban, rural or deep-rural zone**. Additional sub-indicators include the presence of necessary infrastructure for safe burning of processing waste and by-products, recovering and recycling materials as well as the infrastructure and logistics for distribution of bioproducts (FAO Report).

4) Costs/value added/revenue

Quantitative

Costs are measured as levelised life cycle costs and measured as **(€/tonne outputs)**. The cost per unit energy or tonne output is compared to the reference providing the same services (electricity, heat, transport fuels, products). Several components of the costs are biomass processing, CAPEX (investment costs, for a certain annual capacity) and OPEX (operating costs) in terms of feedstock costs and other costs. The net added value is calculated by the **market price minus production costs**. Alternately, the contribution of a particular product or service to economic progress can be measured through revenue, gain, paid wages, R+D costs in relation to revenue, etc., in **€/product unit** (FAO Report).

5) Trade

Quantitative and descriptive

Trade is expressed on a territorial level by the net trade (**export and import, or € or % of total export/imports**) of raw biomass, processed biomass or biomass-related technologies, either cropland-based or forest-based) (FAO Report). Related to integration with industrial energy supply as trade reveals whether a system relies heavily on imports, whether it can rely on domestic sources, or whether it is self-sustainable.

6) GDP

Quantitative

GDP is the potential market share of the product and measured either as:

- the contribution of bioeconomy sectors to GDP **(%)**
- Gross fixed capital formation in relation to GDP **(%)**
- Annual growth rate of real GDP per employed person **(%)**
- Average income of employees in the bioeconomy sectors **(€)**
- Domestic and foreign investments into bioeconomy sectors **(€)**

7) Price

Quantitative

Price is adjusted for inflation and calculated in **€.** Can be disaggregated into world, consumer, or producer prices. Land, bioenergy and biomaterial price volatility.

IV] Socio-economic

Demand/consumption

Descriptive

Change in demand for cropland-based or forest-based biomass towards products or energy as expressed territorially either by the **domestic material consumption per capita or GDP** or the

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material footprint per capita or GDP (FAO Report). A sub-indicator can be the **change in consumption of fossil resources**, highlighting a reduction in the dependence of these resources. Another measure for this can be the **net energy balance** (ratio of bioenergy compared to other energy sources).

1) **Farm income**

Quantitative

The agriculture income as compared to the national average can be expressed in **€/GJ or tonne of product** and measures the remuneration of all factors of production (land, capital and labour) and represents the net value added at factor costs through the following calculation: agricultural factor income = value of agricultural production – variable input costs – depreciation – total taxes + total subsidies. To compare to a national average, income per annual work unit (AWU) is used to correspond to one person occupying an agricultural holding on a full-time basis, calculated in **€/AWU**. This index is available in: Eurostat Economic Accounts for Agriculture, Indicator A. At territorial level, farm income can also be defined by annual amount paid to smallholders and suppliers of feedstock (**€**).

2) **Employment**

Quantitative and descriptive

This indicator assesses job creation as a result of the deployment of biomass accounting for the full value chain and measured as the number of full-time direct job equivalents per energy content or tonne of biobased product across the value chain **(number of full-time jobs/tonne or GJ of end products).** This indicator can be further disaggregated in skilled versus unskilled sub-indicators, rural employment versus industrial employment (**number of employed persons in rural and urban areas (1 000 persons**), and finally share of employment in each group of bioeconomy subsectors **(% of total employment**) (FAO REPORT).

3) **Welfare**

Quantitative and descriptive

Social welfare, or well-being of citizens, is defined as the function of their individual market consumption bundles and the vector of environmental quality parameters (e.g., water quality, air quality, the area covered with forests, the state of biodiversity). Indeed, welfare can be defined by citizens' access to recreation services and biodiversity interaction in ecosystems (Hetemäki et al, 2017). Thus government can maximize social welfare by acting on the provision of market commodities and the provision of environmental quality (Ahlheim et al, 2017). This can be measure as public financial support for market development and ecosystem services (€).

4) **Food security**

Quantitative and descriptive

As a basic measurement, price and supply of a national food basket (**tonnes; €; and %**) can be employed as a measurement for food security, along with changes and volatility of prices. Though not always directly related to a bio-based value chain, food security is also measured by (FAO REPORT):

- **Availability**: kg of household food production and number of varieties of crop diversity
- **Accessibility**: percentage food expenditure to total household expenditures

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- **Utilisation**: degree of access to services
- **Stability**: food prices and supply determined by change in price (€) and amount (kg)

This indicator is linked to land use since food security requires a certain amount of hectares of land set aside for food growing, as well as water use as blue water footprint (m3 of water consumed and/or polluted to produce a unit of non-agricultural good or service) is indicative of how much water is being re-directed to non-food uses (FAO Report).

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