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Scenario framework for SYMOBIO 2.0

Summary of relevant scenarios, strategies and policy targets with a focus on Germany and the EU

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1   BACKGROUND

To determine footprints of the German bioeconomy, a scenario framework is needed in which consistent assumptions are made for framework data. This is particularly important for ex-ante considerations. In SYMOBIO 1.0, the respective procedure, which is described in more detail in Bringezu et al. (2021), was as follows: For the projection, overall trends with regard to economic (Wiebe et al. 2013) and emission development (BMU 2020) are in line with SSP2 (Dellink et al. 2017) developments on global level and a national reference scenario. Structural developments not available from the above sources mainly prolong historical trends as quantified in the models PANTA RHEI (Lutz et al. 2019) and GINFORS (Ahlert et al. 2018) until 2030. They have been translated into EXIOBASE compatible observations and classifications (Stadler et al. 2018).

The approach in SYMOBIO 1.0 builds on earlier work that has projected the EXIOBASE database into the future. Wiebe et al. (2016) developed a general approach for projecting a full MRIO system. The approach is expanded to a global circular economy scenario until 2030 with a focus on energy, material and waste sectors (Wiebe et al. 2019). Other recent MRIO approaches are retrospective using today's structures, which look into e. g. more detailed policy options (Moran et al. 2020) or the role of trade for footprint calculations (Widmann, Lenzen 2018).

For the continuation and improvement of the footprint calculations of the German bioeconomy in SYMOBIO 2.0, the question of the socio-economic framework arises again. In initial internal project discussions, consideration was given to developing not only a business-as-usual scenario but also an expected trends and/or a target scenario in which various political goals in the bioeconomy, agriculture and climate protection are achieved. It was decided to take a decision based on the scenario framework. This report serves the corresponding decision-making.

The internal discussion brought up a broad range of dynamics that could be considered (e.g. nature based carbon dioxide removal, CDR) as well as political targets in different areas (e.g. the share of organic farming, dietary changes) and the possibility to relate the FP outcomes to science-based targets for footprints. Stefan Bringezu had two suggestions: 1) instead of an integrated sustainability scenario he recommends a "wedges approach"– modelling parameter ranges to show to which extent a certain measure or field (e.g. doubling rate of diet change) could contribute to a more sustainable BE, and 2) target orientation values for each FP are published in his book "The World Budget" (Bringezu 2022).

The following additional aspects and questions were also discussed, which should be considered in the further course of the project:

- If nature protection goals are taken seriously, biomass potentials will go down. Such interactions between natural sinks and biomass production and consumption are currently not accounted for in SYMOBIO, but should be considered, either as scenarios or as some degree of disruptions in the trends. One option is to assume additional expectations on soil/land which will influence biomass availability and quality (e.g. protection of peatlands). How this could be done is an open question as targets are likely to disrupt current trends to some degree.

- The degree to which current political targets are reflected requires further discussion – e.g. is the focus on a) changes in behaviours and how they could impact reaching goals (distance to targets) or b) is the focus on targets and showing the degree of change needed to reach them?
- It is not the role and is beyond the capacity of SYMOBIO to model and assess the effectiveness of policy instruments to reach all policy targets, but the modelling work should tie into the current political discussion to provide relevant inputs.

This report is structured as follows: Section 2 briefly describes some background information such as current status, expected developments and future challenges of the bioeconomy, policy initiatives, and recent research regarding footprints of the bioeconomy. In section 3, a concept for the framework scenario is briefly presented and, as far as possible, quantified. Section 4 briefly discusses the principle of the intended implementation. A brief outlook closes the paper in section 5.

2 BIOECONOMY PARTLY OVERSTEPS PLANETARY BOUNDARIES

The United Nations Conference Biodiversity (COP15) ended in Montreal on 19 December 2022 with a landmark agreement on biodiversity to guide global action to protect nature by 2030. The plan includes concrete measures to stop nature loss, including putting 30% of global land and sea under protection by 2030 (UNEP 2022). The urgency to protect biodiversity is proven by many scientific studies. With today's structures, a good life for all, including the protection of biodiversity, is not possible. O'Neill et al. (2018) estimate that resource use would be 2 to 6 times higher than sustainable. Analyses by the International Resource Panel (Oberle et al. 2019) show that biomass use is responsible for around 80% of water stress and land-use related biodiversity loss. Policymakers have recognized the need for a comprehensive change in biomass use. According to Beck-O'Brian et al. (2022) around 23% of total net greenhouse gas emissions are related to land-use. They will have to be drastically reduced to reach the 1.5° or even 2° climate targets, which call for global net zero greenhouse gas emissions around the middle of the century.

In many cases, the bioeconomy is outlined as one of the central solutions to the problems and targets presented. Many countries such as Germany and regions such as the EU (2018) have developed bioeconomy strategies. However, the EU (2022) Bioeconomy Strategy Progress Report shows several gaps. Land and biomass demand need to be better managed and more sustainable consumption patterns are needed. An impact assessment of the EU BE and Biodiversity strategy also shows reducing impacts on the production level in the EU and additional necessary imports, which contradict some policy goals (Wageningen, Bremmer et al. 2021). The authors see the need for more technological progress to close part of these gaps.

The footprints for agriculture biomass, roundwood, agricultural land and GHG emissions are each significantly above the global average and are not sustainable in the long term (Bringezu et al. 2021, Egenolf et al. 2022). According to the results, adequate monitoring of

the BE must consider not only the production perspective but also the consumption per-spective in the form of global footprints of national activity. Similar findings apply to other countries and regions. The bioeconomy is increasingly exceeding planetary boundaries in terms of land, GHG emissions, biodiversity and water footprints in many parts of the world.

At the same time, the bioeconomy is confronted with various growing demands. To achieve the ambitious GHG reduction targets with climate neutrality in Germany by 2045 and in the EU by 2050, the increased use of biomass for energy production is often demanded or assumed. In scenarios of the IEA (2022) in the World Energy Outlook 2022 energy supply from biomass use doubles to triples by 2050 compared to 2021. While projections see an expansion in cropland needed for food, biofuel and biomaterial supply, it might not be enough to feed all the global population. Reforestation is also important to offset unavoida-ble emissions in agriculture or in certain industrial processes. In the future, climate change will increase the variability of biomass production. Risks and uncertainties might increase. From a biodiversity perspective, at least 30% of the land should be protected. At the same time, biomass should increasingly replace other products, for example wood should be used instead of cement or steel in the construction sector, or biomass should increasingly replace fossil raw materials in the chemical industry. Finally, biomass-based products should con-tribute to new technological applications and high added value in industry. Overall, this means that the available biomass will have to be used much more efficiently in the future than today and that clear priorities must be set for biomass use if the ambitious environ-mental targets are to be achieved and hunger is to be defeated.

3   SCENARIO FRAMEWORK

At the SYMOBIO project meeting in November 2022 it was noted to base the decision on scenarios on a short paper, which is presented in the following. According to the current status, the scenario approach in SYMOBIO focuses on the development and modelling of 2 scenarios, a reference scenario and a bioeconomy scenario, where the BE scenario is not a consistent scenario, but rather contains a bundle of possible deviations from the ref-erence.

Scenarios differ from forecasts. While forecasts describe the most probable future develop-ment from today's perspective, scenarios represent various possible development paths under certain conditions. A distinction can be made between trend scenarios, target sce-narios, policy scenarios and counterfactual scenarios. A trend scenario describes the future development under the assumption of stable framework developments. This means that framework data such as international crude oil prices are extrapolated into the future at the current level. Target scenarios show what changes are necessary to achieve a certain goal, such as greenhouse gas neutrality in the EU in 2050. Policy scenarios describe what will happen if certain measures or policies are implemented in comparison to a reference sce-nario without these measures/policies. In the regularly conducted policy scenarios on cli-mate protection in Germany, for example, a with-measures scenario is calculated that con-tains all policy measures that have been adopted by a certain deadline (Repenning et al. 2021). Political targets are missed in this scenario. It thus shows the action gap on the basis of current knowledge. Alternatively, scenarios with additional measures are often developed

that quantify the extent to which the action gap can be closed. In the best case, the policy scenarios are designed in such a way that the policy goals are achieved. However, all scenarios depend on certain assumptions about exogenous variables, so that the uncertainty about the occurrence of the scenario assumptions and thus the scenario results increases over time. The framework data for the 2023 projection report make this process very transparent and reveal the associated uncertainties (UBA 2022).

3.1 GLORIA DATABASE

The GLORIA model (Global Resource Input-Output Assessment) is a multi-regional input-output database that was built by the University of Sydney using the IELab infrastructure for the UN International Resource Panel (UN IRP). GLORIA has 164 regions, 120 sectors each, supply-use transactions T, final demand y, value added v in 5 valuations (basic prices, trade margins, transport margins, taxes on products, subsidies on products) and a continuous time series for 1990-2027. Accompanying satellite accounts (extensions), cover GHG emissions, materials, energy, air pollution, land use, water use, biodiversity, skills and employment. Footprint trends have been calculated for all satellites from 1990-2027. The database is described in detail in Lenzen et al. (2017, 2022). Related data for 1990 until 2027 from the GLORIA database will be used as default if no other specific data information is available. Data from other projections will be aligned to smoothly fit to the GLORIA database.

3.2 REFERENCE SCENARIO

The **reference scenario** describes a largely continuous development with regard to the influencing variables important for the development of the bioeconomy in Germany, Europe and the world. Societal trends are continued (e.g. regarding diets). Major bioeconomy-specific goals are missed. For the framework data, the scenario is predominantly oriented towards trend and/or expected developments. Only if significant deviations from trend developments are anchored in law, as is the case for the energy transition in Germany and the EU with the Climate Protection Act and the Green Deal, is this considered in the reference. General socio-economic framework data such as population development, economic growth, energy prices and developments of new technologies are derived from matching scenarios, which are briefly listed below.

For the global level:

- GLORIA outlook until 2027 (Lenzen et al. 2022)
- OECD-FAO Agricultural outlook (2022)
- IRP Global resources outlook (Oberle et al. 2019)
- IEA: World energy outlook (2022) for energy use of biomass (STEPS or APS scenario)
- Shared socioeconomic pathways (SSP2, middle or the road, version 2.0, mainly population and GDP)

For the EU:

- EU Reference scenario (European Commission et al. 2021c) and EU aging reports (for GDP and population)

- EU Green Deal (Impact assessments) to reach GHG targets reached in 2030 and 2050 (European Commission et al. 2021d)
- Foresight scenarios for the EU BE in 2050 (European Commission et al. 2021b)
- Impact assessment from Wageningen university (Bremmer et al. 2021)
- EU Bioeconomy progress report (2022)

For central framework assumptions for Germany on population, GDP development and energy and CO_2 prices, the assumptions for the projection report 2023 (Table 1) are used.

Table 1: Assumptions for the projection report 2023

	in	2020	2021	2022	2025	2030	2040	2050
Population	Mio.		83,2	83,2	83,5	83,5	83,2	82,7
GDP	AAGR		2,6	1,4	0,8	0,8	1,4	1,3
Import price Crude oil	€2019/GJ	6,4			10,5	8	7,8	7,5
Import price coal	€2019/GJ	2			6	3,2	2,8	2,6
Import price gas	€2019/GJ	3,7			14,6	6,7	6	5,3
Price EU-ETS	€2019/t CO_2	47,7			91,3	108,8	141,3	161,1
CO2 price BEGH	€2019/t CO_2		24	27	38	95	171	216

Source: UBA (2022)

3.3 BIOECONOMY SCENARIO

The bioeconomy scenario is not a consistent scenario that reaches all BR related targets. We are following the idea of Stefan Bringezu. Instead of an integrated sustainability scenario he recommends a "wedges approach"– modelling parameter ranges to show to which extent a certain measure or field (e.g. doubling rate of diet change) could contribute to a more sustainable BE. Within the framework of the BE scenario, important drivers and parameters identified and quantified in work package 1 of SYMOBIO 2.0 are adjusted within the framework of plausible ranges (see section 4 on scenario implementation). The extent to which this changes the model results is then checked in each case. Target orientation values for each FP have been published by Stefan Bringezu (2022) in his book "The World Budget". As it would be very extensive to go into each parameter, different parameter variations will be bundled in the documentation. They still need to be discussed and agreed within the consortium.

At EU level, the design of the EU Green Deal, the Common Agricultural Policy (CAP), the farm to fork strategy and the monitoring of the bioeconomy strategy are of particular interest. The EU's Farm to Fork Strategy is a visible sign that fundamental changes are needed in the way food is produced and land (and water) is used (EU 2020). The strategy includes targets for 2030 to reduce pesticides use and nutrition losses by 50%, fertilizers by 20%, to halve food waste, to increase organic farming to at least 25% of farmland, to increase agricultural land with high-diversity features to at least 10%, to shift towards healthy and plant-based diets, and to a support of a global transition to sustainable agri-food systems.

Key national strategies and laws to be considered in this context include:

- Cornerstones for a National Biomass Strategy (NABIS), (BMUV 2022),
- National Bioeconomy Strategy (BMBF 2020),

- the German government's food strategy (BMEL 2022), which is to be developed by 2023, and

- the Climate Change Act, which envisages a reduction in emissions from the agricultural sector to 56 Mt by 2030, compared to 70 Mt in 2020. For the LULUCF sector, and here in particular for the sink function forests, uncertainty about current and future net emissions is high (Expert Council on Climate Protection 2022).

4 SCENARIO IMPLEMENTATION

Scenarios are implemented directly in the GLORIA MRIO using the approach developed in Wiebe et al. (2018) and applied to among others future material footprints in circular economy scenarios (Wiebe et al., 2019) or future environmental and social footprints of decarbonization strategies in Latin America and the Caribbean (IDB & ILO, 2019). In a recent project for World bank, the model was refined such that the structure of energy consumption of firms and households as well as bilateral trade shares respond to carbon pricing scenarios. The approach will be adjusted to be able to map the footprints of the bioeconomy well and also to be aligned with the approach in Bringezu et al. (2021).

The approach in its initial form is based on two different types of exogenous scenario inputs, which are summarized in Figure 1.

Figure 1: Structure of the MRIO projection model
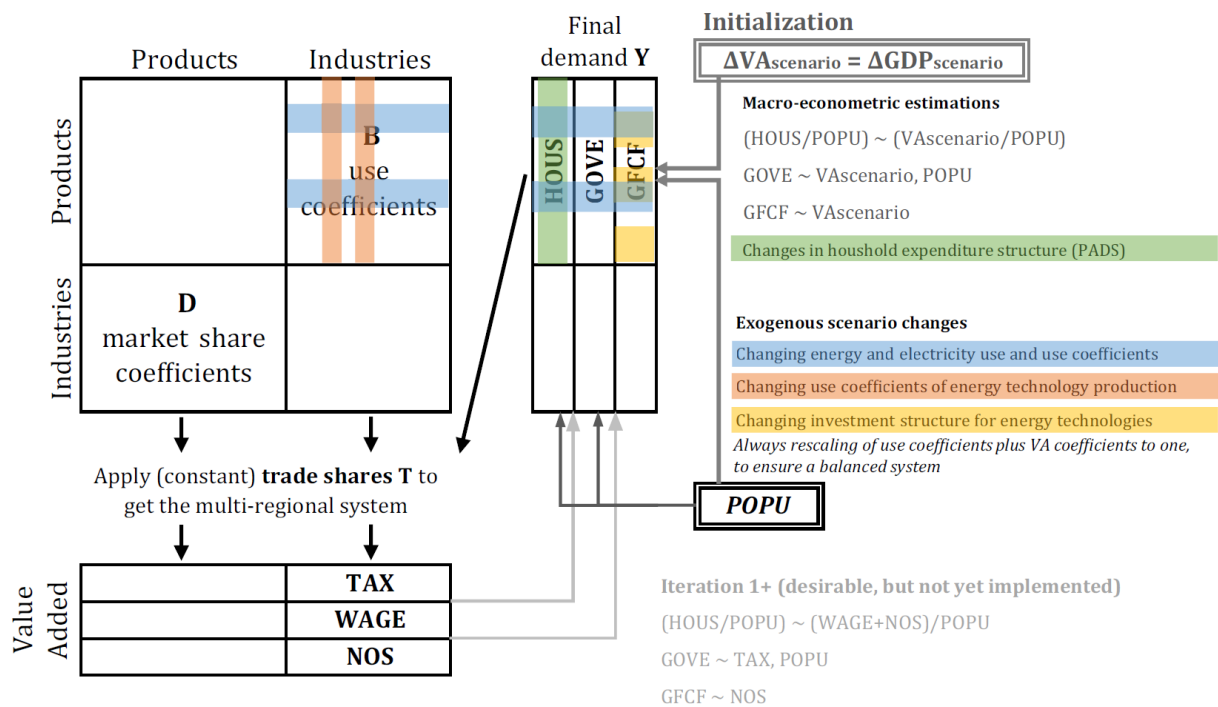
Notation:
HOUS = Houshold final consumption expenditures, GOVE = Government final consumption expenditures, GFCF = Gross fixed capital formation, VA=Value added, GDP = Gross domestic product, POPU = Population, TAX = Taxes and subsidies, WAGE = Compensation of employees, NOS = Net operating surplus

Source: Wiebe et al. (2018)

Firstly, the MRIO projection model is demand driven. The scale of absolute production required is determined by the development of final demand comprising private household consumption, government spending and gross fixed capital formation in each country. The sum of these components constitutes the domestic component of GDP (with exports and imports being the remainder) and their growth rate are exogenously specified scenario parameters, which can either be taken from existing scenarios or specified by econometric models based on demographic and other explanatory variables (as shown in Figure 1). Here we propose to exogenously specified growth trajectories by domestic final demand categories from external sources.

Secondly, the changes in the product structure of final demand are scenario dependent and can be specified using external scenarios to reflect, e.g., changes in dietary pattern of household consumption, substitution of fossil energy consumption by bioenergy or shifts in investment from fossil-based production plants into bio-based ones. On the other hand, structural changes can be modelled using econometric models (e.g. of household consumption) or income and price elasticities, or a mix of all of these approaches.

Thirdly, the changes in production technology, for example substitution from fossil- to bio-based chemicals or shifts from conventional to organic farming, are modelled via changing technology coefficients of the intermediate use matrix of the respective sectors. Additionally, the different intensities derived from the satellite accounts measuring in various units the amount of social, economic or environmental impact in physical per $ or production need to be adjusted accordingly. For example, changes in farming practices are also reflected in changes of yields or substitution of fossil by bioenergy affect carbon intensities of sectors. These changes in the technological coefficients and the intensities can be either specified exogenously for target scenarios or modelled econometrically via elasticities reflecting responses to policy interventions, such as taxes or subsidies.

Finally, bilateral import shares are either fixed in the default case or else can be adjusted exogenously reflecting shifts in international competitiveness induced by changing cost of production across countries and sectors countries either using substitution elasticities from the literature (e.g., Sager, 2021) or econometric models. Changes in cost of production can either be due to exogenous policies or other shocks (e.g. climate change impacts on yields or technological change).

5 OUTLOOK

The scenario framework described above provides an initial overview of the scenarios envisaged in SYMOBIO 2.0 and their implementation. Some aspects still have to be concretized and coordinated with project partners and externally. For the development in Germany, the parallel project of the Thünen Institute has to be emphasized and considered. At the EU level, it should at least be briefly coordinated whether current scenarios are largely met. For important drivers of the bioeconomy, detailed information should be exchanged with the corresponding project partners in SYMOBIO. This will be done in the coming months, especially in the context of work package 1.

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