Delivery of sustainable supply of non-food biomass to support a “resource-efficient” Bioeconomy in Europe

S2Biom Project Grant Agreement n°608622

Deliverable 5.6:

A brief overview to the GEMIS Model and Database

January 2017




About S2Biom project

The S2Biom project - Delivery of sustainable supply of non-food biomass to support a “resource-efficient” Bioeconomy in Europe - supports the sustainable delivery of non-food biomass feedstock at local, regional and pan European level through developing strategies, and roadmaps that will be informed by a “computerized and easy to use” toolset (and respective databases) with updated harmonized datasets at local, regional, national and pan European level for EU28, Western Balkans, Moldova, Turkey and Ukraine. Further information about the project and the partners involved are available under www.s2biom.eu.

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About this document

This paper is an additional deliverable (D 5.6) which presents a brief introduction to the GEMIS model which was used to determine the life-cycle sustainability indicators for the S2Biom Technology Database.

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List of Acronyms

AOX	adsorbable organic halogen compounds
BOD	biological oxygen demand
C&I	Criteria and Indicators
CED	cumulated energy demand (or primary energy factor)
CEN	European Committee for Standardization
CH_4	Methane
CO_2	Carbon dioxide
COD	chemical oxygen demand
EC	European Commission
EFI	European Forest Institute
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FTE	full time equivalent
GBEP	Global Bioenergy Partnership
GEF	Global Environment Facility
GEMIS	Global Emissions Model for integrated Systems
GHG	greenhouse gas(es)
IINAS	International Institute for Sustainability Analysis and Strategy
ILUC	indirect land use change(s)
ISO	International Standard Organisation
JRC	Joint Research Centre (of the EU)
LCA	life-cycle analysis (or assessment)
LUC	land use change(s)
m^2	square meter
N	nitrogen
N_2O	Nitrous oxide
NO_x	Nitrogen oxides
P	phosphorous
PM_{10}	particulate matter smaller than 10 micrometer
RED	Renewable Energies Directive 2009/28/EC
SO_2	Sulfur dioxide
UNEP	United Nations Environment Programme

1. Introduction and Objectives

The general objective of S2Biom Work Package 5 (WP5) is to provide an improved understanding among decision-makers in policy and industry regarding **sustainability requirements** in biomass value chains addressed in Theme 1. This goes beyond previous discussions on sustainability of liquid biofuels and the ongoing discussions on solid/gaseous bioenergy and biomaterials in aiming to develop comprehensive sustainability requirements for **all non-food biomass** in the broader **bioeconomy**[1]. To achieve this, specific objectives of WP5 are:

- Adaptation of the life-cycle-based EC Environmental Footprint methods in order to develop a complementary methodology specific to non-food biomass value chains[2]
- Identification of sustainability criteria and indicators (C&I) for non-food biomass value chains, gap analysis of respective legislation, regulation and voluntary schemes at international, European and Member State level[3]
- Compilation of consistent sustainability C&I for the short- and medium-term bioeconomy, and an outlook for long-term developments[4].

This paper presents **additional information** on the **quantification** of indicators for the biomass value chains developed in WP3. The results of this work are available in the S2Biom toolset developed in WP4.

This paper is structured as follows:

- Section 2 briefly presents the methodology used for the life-cycle analysis.
- Section 3 introduces the scope of the analysis, and key assumptions.
- Section 4 briefly explains the background data.

The data were all included in the GEMIS 4.95 model and its database which is freely available at www.gemis.de.

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[1] Bioeconomy encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy (EC 2012a, EC 2012b). For a discussion of activities on bioeconomy sustainability requirements, see Fritsche, Iriarte (2014).

[2] See WP5 Task 5.1 (carried out by the JRC) with its deliverable D5.1 http://www.s2biom.eu/images/Publications/ReqNo_JRC90897_s2biom_del5_1_-_env_sust_ass_meth_-_july_2014.pdf.pdf

[3] See WP 5 Task 5.2 (carried out by IINAS) and the respective deliverable D5.2 http://www.s2biom.eu/images/Publications/IINAS_2015_S2Biom_D5_2_Benchmark_and_gap_analysis_Main_report_30_Mar.pdf

[4] See WP 5 Task 5.4 (carried out by IINAS) and the respective deliverable D5.4 http://www.s2biom.eu/images/Publications/IINAS_2015_S2Biom_D5_4_Sustainability_C_I_proposal_Main_report_30_Mar.pdf

2. Methodology

2.1. The life-cycle approach

The S2Biom deliverable D5.4 presented and discussed the criteria and indicators (C&I) for the sustainability analysis and assessment of biomass value chains (Iriarte & Fritsche 2015). The approach to determine most of the **quantitative** indicators is the so-called **life-cycle analysis** (LCA)[5] which is a comprehensive representation of the full value chains of biomass systems. Life-cycles encompass resource extraction (e.g. plantation, forest, waste collection), processing (e.g. palletization) and conversion (e.g. biorefinery, boiler for process heat, CHP plant for electricity and heat), and include transport of biomass feedstocks, and intermediate products. Furthermore, the materials for the construction of the processes are included, as well as waste disposal ("end-of-life"). This "cradle-to-grade" approach was developed over several decades, and is guided by an ISO standard (ISO 2006a+b).

2.2. The GEMIS model

To allow for an easy determination of e.g. resource use of GHG emissions, several models and databases exist which calculate life-cycles, especially for energy systems[6]. Among those, GEMIS (**G**lobal **E**mission **M**odel for **I**ntegrated **S**ystems) is a public domain tool which helps evaluating environmental and cost impacts of energy, material and transport systems, i. e.

- air emissions (SO_2, NO_x, particulates, etc.),
- greenhouse gases (CO_2, CH_4, N_2O etc.),
- water effluents (AOX, BOD, COD, N and P),
- solid wastes (ash, flue-gas treatment residues, production wastes), and
- resource use (primary energy, raw materials, and land).

Furthermore, GEMIS determines economic costs and employment balances.

The GEMIS database is the most relevant part of the model, offering data for more than 10,000 processes, and covering more than 50 countries, including the EU Member States). GEMIS is public domain software (i.e., available free of charge), and updated regularly (see www.gemis.de).

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[5] LCA is originally the acronym for "life cycle assessment", as codified in the ISO Standards 14000ff. In S2Biom, LCA stands for life cycle **analysis**, indicating that not a "full" LCA according to ISO is carried out, but only the **analytical** parts, i.e. scoping, and life cycle inventory

[6] For a brief overview of LCA tools see http://eplca.jrc.ec.europa.eu/ and http://www.lifecycleinitiative.org/

2.3. S2Biom sustainability indicators and GEMIS

The S2Biom sustainability indicators were developed to support assessing bioeconomy value chains. The following table maps these indicators with the respective quantitative results of GEMIS.

Table 1 S2Biom sustainability indicators for the bioeconomy and their quantification with GEMIS

No.	Indicator name	Quantified with GEMIS?
1.1	Land use efficiency	Y
1.2	Secondary resource efficiency	Y
1.3	Energy efficiency	Y
1.4	Functionality (output service quality)	-
2.1	Life cycle GHG emissions (CO_2eq), including direct LUC	Y
2.2	Other GHG emissions	N (possible)
3.1	Protected areas and land with significant biodiversity values	N
3.2	Biodiversity conservation and management	N
4.1	Erosion	N
4.2	Soil Organic C	N
4.3	Soil nutrient balance	N
5.1	Water availability and regional water stress	N
5.2	Water use efficiency	N (possible)
5.3	Water quality	N (possible)
6.1	SO_2 equivalents	Y
6.2	PM_{10}	Y
7.1	Effective participatory processes	-
7.2	Information transparency	-
8.1	Compliance with VGGT to secure land tenure and ownership	-.
9.1	Full direct jobs equivalents along the full value chain	Y
9.2	Full direct jobs equivalent in biomass consuming region (or country)	N (possible)
9.3	Human and Labor Rights	-
9.4	Occupational safety and health for workers	-
10.1	Risks to public health	-
11.1	Risks for negative impacts on price/supply of food basket/fuelwood	-
12.1	Levelized life-cycle cost (excl. subsidies)	N (possible)

Source: own elaboration

As can be seen, 18 of the 27 S2Biom indicators are quantitative, i.e. GEMIS **could**, in principle, calculate those. Yet, GEMIS currently does **not** cover some indicators (e.g. 1.4 Functionality, 4.1 Erosion, 4.2 Soil organic carbon), and some others (e.g. 5.1 and 9.2) are regionalized so that additional data would be needed. Thus, GEMIS can determine a – relevant – **subset** of the S2Biom indicators.

3. Scope and key assumptions

The quantification of (selected) S2Biom sustainability indicators with GEMIS was carried out by IINAS for the biomass value chains given in the S2Biom database, which is available online[7]. The results are available online as well[8], and the value chain data were included in the GEMIS version 4.95 database so that a detailed analysis of results is possible.

As the economic and environmental effects of biomass value chains vary with respect to feedstock, country of origin (e.g. climate and soil conditions), agricultural practice, and regional or country-specific background data such as energy and transport infrastructure, the calculation was carried out with **generic data for the EU28**. The biomass feedstock production data were taken from the BiomassPolicies project[9], and the background data (see Section 4) from GEMIS.

3.1. System boundaries

The life-cycle calculation with GEMIS includes the **full value chain** (i.e. feedstock production and processing, transports within the value chains, conversion to end-uses, materials for construction of processes, auxiliary inputs), but excludes the "end-of-life" (e.g. ash disposal, decommissioning of plants), as there is no data available on that from S2Biom, and the effects are typically very small.

3.2. Allocation

The biomass value chains in S2Biom typically deliver a "key" product as output (e.g., chemical, electricity, heat, transport fuel), but often also other products – so-called **co-products**. To allow for an easy comparison, the various biomass value chains were grouped into clusters, each delivering a similar main output. For the respective main and co-products, the overall burdens (e.g. GHG emissions) were allocated.

Allocation means that each (co-)product is **partially** responsible for the impacts occurring in the supply chain, and the total burdens are allocated to the (co-)products based on a certain denominator. In compliance with the GHG calculation methodology given in the EU Renewable Energies Directive (EU 2009), the **energy** content (heating value) was used for the allocation.

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7 See http://s2biom.alterra.wur.nl/web/guest/conversion

8 See http://s2biom.alterra.wur.nl/data/Conversions%20technologies_sustainability.xlsx

9 See www.biomasspolicies.eu

4. Background data for the LCA

There is multitude of inputs into the life-cycles of biomass value chains, e.g. diesel fuel for agricultural equipment and transport, electricity for auxiliaries, agrochemicals such as fertilizer, and natural gas for process heat.

To allow for a detailed representation of value chains, these inputs require adjustment to national or local circumstances – and tools such as GEMIS help doing so.

Yet, the S2Biom process data reflect new technologies in the EU for the years 2020, and 2030, respectively. Thus, the aggregated EU28 level was assumed for the calculation of the S2Biom indicator subset, i.e. the inputs are modeled to represent the mixes of processes (e.g. electricity mix, refineries, natural gas system etc.) for the EU28 in the respective years (2020 and 2030).

The EU28 data for the average electricity, heat and transport mixes were derived from the EC Reference scenario calculated with the PRIMES model (EC 2016). The respective upstream processes (e.g. coal mining, oil and gas extraction and processing) were taken from the GEMIS database, which reflects the prospective global developments based on the IEA Global Energy Outlook (IEA 2016), and country level assumptions for e.g. GHG emissions from fossil energy production (especially CH_4 emissions).

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