D5.4 | Most prominent drivers of emissions in LCA for biomethane production

Deliverable:	Description of the most prominent drivers of emissions in LCA for biomethane
production	
Author(s):	Stefan Majer, Katja Oehmichen (DBFZ)
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Coordinator: Stefano PROIETTI, ISIS
Tel: 0039 063 212 655
Fax: 0039 063 213 049
E-mail: sproietti@isis-it.com

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Abbrevations

Eq./Equi.	Equivalent
EU	European Union
EU RED	Renewable Energy Directive 2009/28/EC
GHG	Green House Gases
MJ	Megajoule

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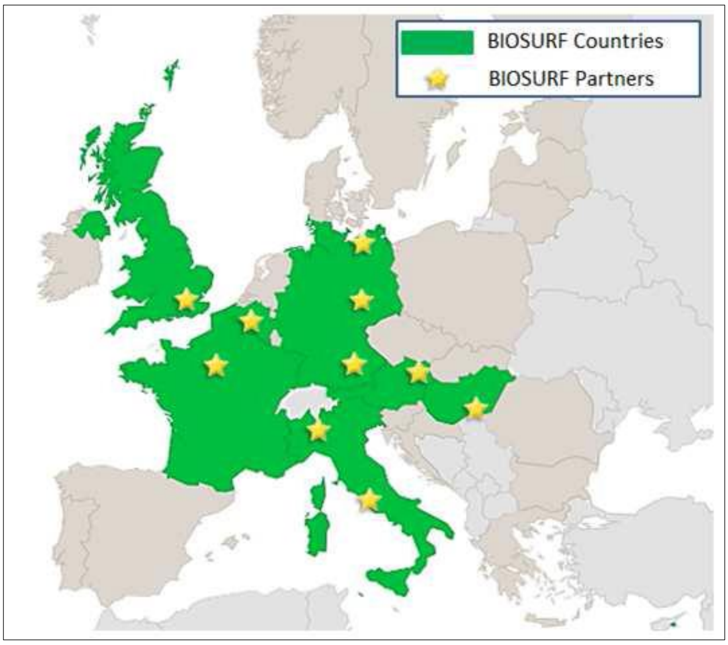
1 Biosurf in a Nutshell

BIOSURF is an EU-funded project under the Horizon 2020 programme for research, technological development and demonstration.

The objective of BIOSURF (BIOmethane as SUstainable and Renewable Fuel) is to increase the production and use of biomethane (from animal waste, other waste materials and sustainable biomass), for grid injection and as transport fuel, by removing non-technical barriers and by paving the way towards a European biomethane market.



The BIOSURF consortium consists of 11 partners from 7 countries (Austria, Belgium, France, Germany, Hungary, Italy and United Kingdom), covering a large geographical area, as indicated in the figure on the left.

The intention of the project is:

- To analyse the value chain from production to use, based on territorial, physical and economic features (specified for different areas, i.e., biofuel for transport, electricity generation, heating & cooling);
- To analyse, compare and promote biomethane registering, labelling, certification and trade practices in Europe, in order to favour cooperation among the different countries and cross border markets on the basis of the partner countries involved;
- To address traceability, environmental criteria and quality standards to reduce GHG emissions and indirect land-use change (ILUC), as well as to preserve biodiversity and to assess the energy and CO2 balance;
- To identify the most prominent drivers for CO2-emissions along the value chain as an input for future optimization approaches and to exchange information and best practices all across Europe with regard to biomethane policy, regulations, support schemes and technical standards.

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2 Introduction and scope of this deliverable

BIOSURF work package 5 is dedicated to the issue of GHG emissions and GHG emission saving from biomethane production and utilisation. So far, three deliverables have been published, covering i) methodological aspects of GHG emission calculations for biomethane (D5.1), ii) data issues (D5.2) and iii) exemplary GHG emission calculations (D5.3).

These previously released documents aim to support biomethane producers or market actors during the process of calculating the carbon footprint of their product, either as single task or part of a sustainability certification process. While the last BIOSURF WP5 deliverable (D5.3) has focussed on a number of GHG calculations for exemplary biomethane value chains, this deliverable will summarise the main findings of D5.3 regarding the foremost influencing factors or drivers for GHG emissions along the biomethane value chain. For this purpose, the main process steps for the production of biomethane will be discussed in separate subchapters.

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3 Main drivers for GHG emissions along biomethane value chains

This chapter represents a short summary of the main findings regarding drivers for GHG emissions from BIOSURF deliverable 5.3. The structure will describe the main process steps from the cultivation of biomass, the transport of biomass up to biogas production and upgrading. Figure 3-1 shows the results of an exemplary GHG calculation for Biomethane from maize silage/catch crops taken from D5.3. The results indicate clearly the importance of the process steps biomass cultivation (substrate production) and the biomass conversion to biogas as well as biogas upgrading to biomethane.

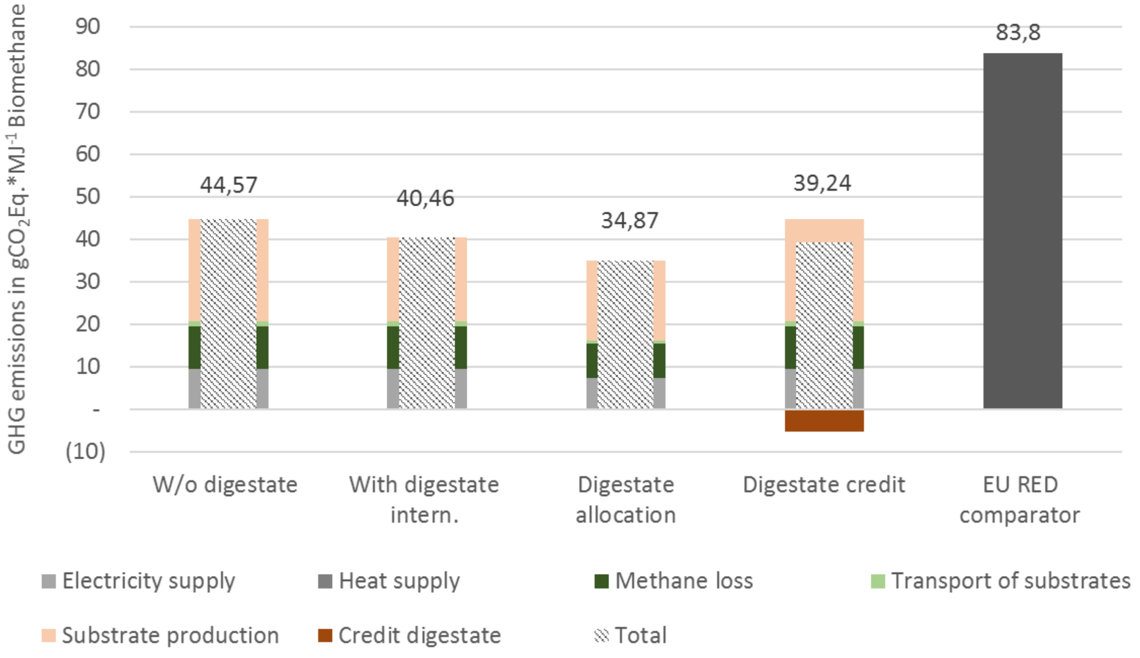

Figure 3-1 GHG emissions from Biomethane production based on maize silage/catch crops (taken from BIOSURF D5.3)

3.1 Cultivation of biomass

In BIOSURF we follow the guidelines for GHG assessment under the EU RED framework [EU RED]. According to Annex V of the directive, it is important to classify the feedstock used for biomethane production as product/co-product or waste/residue. Contrarily to the use of wastes and residues, where the calculation of GHG emissions starts with the collection and treatment, all inputs for the production have to be considered when energy crops are used for biomethane production.

During the process of agricultural production, fertilisers (N, P, K) and other inputs (e.g. plant protective agents, Diesel for agricultural machinery, etc.) are applied/used. Fertiliser supply can be either organic (e.g. digestate, slurry) or based on synthetic fertilisers. The application of nitrogen fertilisers is typically the biggest source of emissions. For the calculation of GHG emissions from

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nitrogen fertiliser application two different aspects have to be considered. The first area covers emissions from the production of synthetic fertilizers. It should be noted here that the different industrial nitrogen fertilizers differ significantly in their specific GHG balance (per kg of N). This means that the choice of nitrogen fertilizer used in the agricultural process makes it possible to reduce the GHG emissions of biogas production [Majer et al. 2010]. Another obvious option to reduce this part of upstream emissions is the use of organic fertiliser (e.g. digestate).

The second important aspect from the application of nitrogen fertiliser relates to the formation of nitrous oxide from the soil as a result of microbiological activity. This quantity, often referred to as field emissions in the literature, is influenced by a number of factors. The climatic and general location-specific factors as well as parameters such as the type of fertilizer application (e.g. for organic fertilizers) are important for the amount of nitrous oxide emissions released. Due to the complexity and the interplay of the numerous influencing parameters, the amount of nitrous oxide produced during the agricultural production process can only be determined based on a detailed knowledge of the site. As a result, simplified calculation approaches are often found in the available literature. Due to the amount of nitrous oxide emissions generated and the enormous environmental impact of nitrous oxide, these emissions are one of the decisive factors in the greenhouse gas balance of biogas substrate production [Müller-Langer et al. 2009, Vetter et al. 2010].

Besides the emissions from fertiliser production and application, the use of diesel for cultivation and harvesting is the third important driver. However, compared to the emissions from the use of nitrogen fertiliser, this part is of less importance.

Considering the emissions from the agricultural cultivation process itself, wastes and residues generally show the potential for lower GHG emissions. The calculations for these substrates usually begin with their collection accounting for the environmental costs of all processes necessary for their provision to the biogas plant [Müller-Langer et al. 2009, Majer et al. 2010].

3.2 Biomethane production

In the next step, the substrate is transported to the biogas plant. Usually, emissions from this process are significantly lower compared to the emissions from substrate cultivation or substrate conversion (compare Figure 3-1). In order to sustain a long-term operation of the biogas plant, quantities of feedstock are stored depending on the plant size. In addition, the covered storage of substrates serves as a biochemical preservation [Soukup et al. 2008].

From the silo, the substrate enters the actual process of biogas production, the fermentation.

GHG calculations for biomethane production processes usually identify the supply of process energy (both electricity and heat) as well as the direct methane emissions as relevant parameters. For the operation of the biogas fermenter, thermal (e.g. for setting the ideal temperature conditions) and electrical energy are required. Depending on the actual configuration of the plant, both demands can be meet using internal solutions for energy provision (e.g. combustion of raw biogas in a boiler or CHP unit) or based on sourcing of energy from external sources (e.g. electricity from the public electricity grid). In addition to the emissions from the supply of the biogas plant with process energy, the consideration of direct methane emissions is particularly relevant at the biogas plant. Since the greenhouse gas methane has a much higher climate efficiency than, for example, CO_2, the

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magnitude of these emissions can decisively influence the overall result. In fermenter operation, leakages and disturbances can lead to methane leaks. Since such leakages are caused by a multiplicity of influencing factors, there are no exact or generalizable results. The available scientific literature sources typically indicate diffuse methane emissions of ~1% for the process of biogas production. (e.g. [Müller-Langer et al. 2009], [Bachmaier et al. 2007]) GHG emissions from the process of biogas upgrading to biomethane are also driven by both process energy supply and methane emissions (methane slip or leakage). It has to be noted that significant differences can occur between the different types/processes of biogas upgrading.

Another important factor for the GHG balance of the overall process is the residence time of the biogas substrates in the fermenter. If the dwell times are too low, the organic substance is only partly decomposed. As a result, residual methane emissions can be generated by fermentation processes in the digestate storage system. In modern biogas plants, this digestate storage is gas-tight covered. Available literature values show the importance of this fermentation residue storage. In the case of an uncovered fermenter storage, additional methane emissions in the amount of more than 44 g CO_2 equivalent per kWhel [Bachmaier et al. 2007] can be assumed in the GHG balance sheet. This effect is illustrated in Figure 3-2. In addition to the storage of the fermentation residues, their application is also a source of relevant environmental emissions. In particular, nitrous oxide and ammonia emissions can affect both the GHG emission and the acidification potential. The level of these emissions is primarily dependent on the way in which the digestate is used and how it is applied on the field. Similar to the already described nitrous oxide emissions from the nitrogen fertilization, general site-specific and climatic factors influence the formation of emissions. The quantification and possible reduction of the formation of nitrous oxide and methane emissions from the digestate is the subject of various research projects. Further research is needed, for example, in the determination of the specific fertilizing effect of various digestate residues and their possible substitution effect on industrial fertilizers. These effects can have an impact on the greenhouse gas balance of biogas production and use [Vetter et al. 2010].

3.3 Sensitivity analysis

To support the discussion of the main drivers for emissions, a sensitivity analysis has been conducted to show the impact of a parameter variation on the overall GHG performance of a biomethane pathway. We have used the 100% slurry pathway (scenario allocation of digestate & slurry credit min) from BIOSURF D5.3 as a base case and have conducted 4 parameter variations. These parameters are:

- Open digestate storage:
  We changed the assumption from a closed storage system for the digestate to an open storage system. This results in significantly higher CH_4 and N_2O emissions. (Emission factor from (Biograce, 2014))

- Electricity sourced from renewable sources:
  We changed the emission factor for the electricity consumption of biogas production and

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upgrading from the average European electricity mix to a mix based on 100% renewables (emission factor EU mix: 751.79 gCO_2-eq.*kWh^{-1} (own assumptions); 100% renewables: 52.8 gCO_2-eq.*kWh^{-1} (own assumptions)

- Reduction of methane losses: Assumptions regarding methane leakage are associated with high uncertainties. In this deliverable, we have followed current scientific literature. However, state of the art biomethane plants might be able to reduce methane leakage. In order to show the impact of potential efforts to reduce these effects, we changed the factor for methane losses from 1.2% (base case) to 0.1%.

- Variation of substrate transport distance from 5km to 50km

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The results of the parameter variation are shown in Table 3-1.

Table 3-1 Results of the sensitivity analysis for the pathway biomethane from slurry. Base case = scenario "Digestate allocation & slurry cred. min" in gCO$_2$-eq.*MJ^{-1} biomethane

	Base case	Open digestate Storage	Renewable electricity consumption	Reduced methane losses	Transport distance variation
Electricity demand	9.04	9.04	0.51	9.04	9.04
Heat demand	0.04	0.04	0.04	0.04	0.04
Methane losses	4.74	76.55	4.74	0.65	4.74
Transport of substrates	0.52	0.52	0.52	0.52	5.20
Avoided emissions from untreated slurry storage	-38.15	-38.15	-38.15	-38.15	-38.15
Total emissions	-20.95	51.44	-29.48	-27.89	-19.12

The parameter variation shows the big impact and the importance of avoiding methane emissions during biomethane production. In the scenario with an open storage of the digestate, the pathways will not meet the mandatory GHG mitigation thresholds set by the EU RED.

Furthermore, the results show that, compared to other parameters, the impact of transport is rather low.

Upstream emissions from the provision of process energy can be an important factor. These emissions can be reduced by the choice of the energy carriers used for the production of process energy (e.g. raw biogas, renewable sources, etc.). However, it is important to note that the activation of this reduction potential might be linked to higher overall costs for biomethane production.

The results of the sensitivity analysis are summarised in Figure 3-2.

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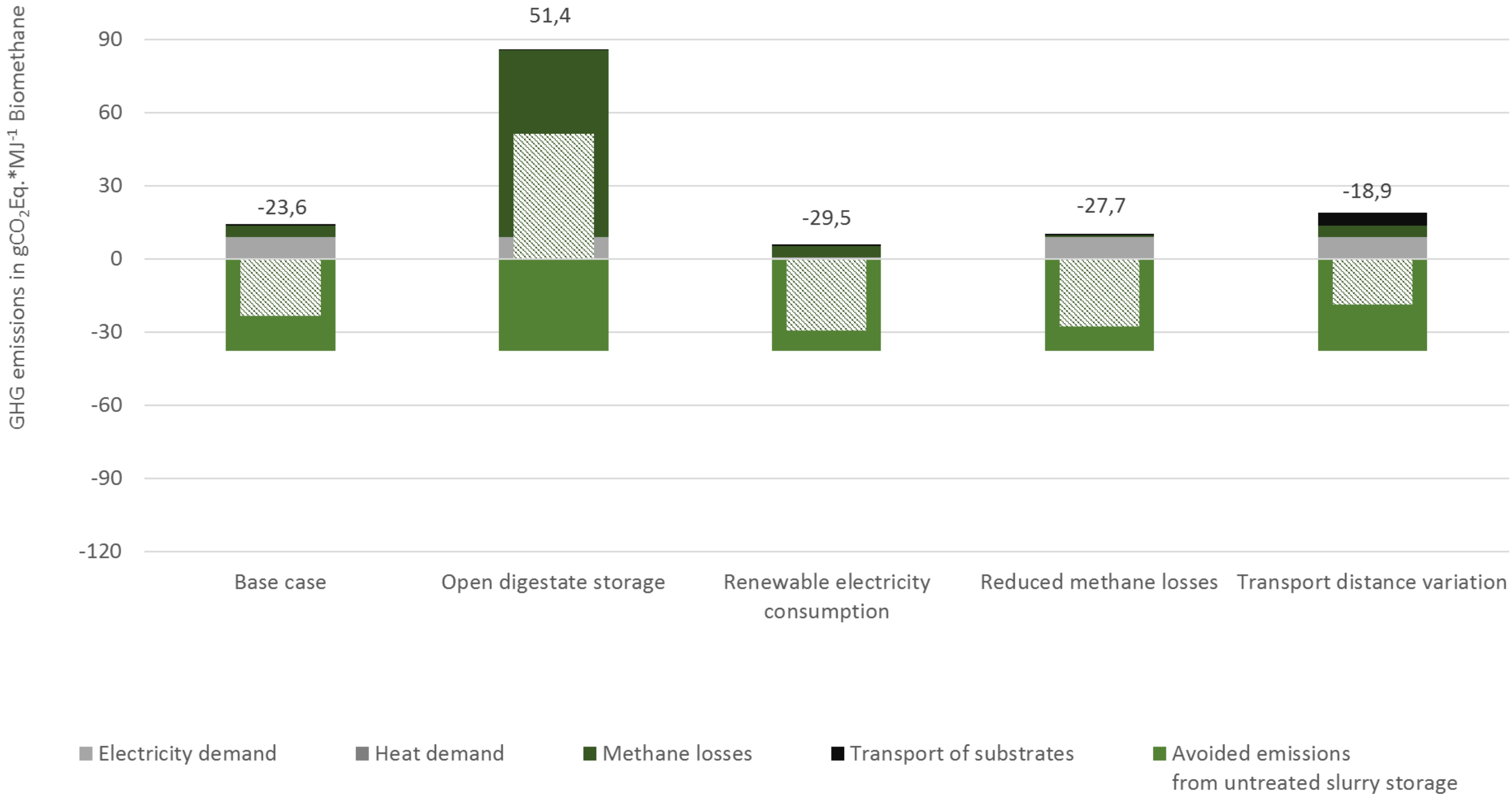

Figure 3-2 Results of the sensitivity analysis for the pathway biomethane from slurry. Base case = scenario “Digestate allocation & slurry cred. min” in gCO$_2$-eq.*MJ^{-1} biomethane

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