Impacts of demo case biogas projects

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Executive Summary of D6.3

DiBiCoos Market Uptake Program has the goal to prepare markets of developing and emerging countries for European Biogas Technology. The focus countries for DiBiCoos Market Uptake Program are Argentina, Ethiopia, Ghana, Indonesia and South Africa. Many different project activities were supporting the project development in these countries, such as market reports, capacity buildings, study tours and matchmaking events. Additionally, in each of the five countries one promising demo project was selected by DiBiCoo. These five demo projects were supported by DiBiCoo with the collaborative preparation of pre-feasibility studies. Another goal of DiBiCoo is to show the impacts of these projects based on the prepared pre-feasibility studies.

Biogas has a variety of products and services to offer. The main product is the generation of sustainable, locally accessible energy. This energy can either replace currently used fossil fuels, or give people their first access to modern energy services.

Furthermore, the use of biogas can have positive impacts on the environment, economy and society. DiBiCoo was only promoting the utilization of wastes and residues, to avoid a conflict of use with primary food or feed production. When residues or wastes are used in a biogas plant, the emissions caused by less sustainable or appropriate disposal can be significantly reduced. A special case is the demo project in Ethiopia, which will utilize invasive water hyacinth in Lake Tana. The current pervasive growth of this water plant is slowly destroying the aqueous ecosystem in Lake Tana. The utilization of the water hyacinth in a biogas process could give a crucial incentive to harvest the water hyacinth and clear the lake. Therefore, in this case the biogas plant also offers a valuable ecosystem service, which significantly improves the health, biodiversity and resilience of the native ecosystem.

Economically, the investment in a biogas plant benefits the local economy, especially since certain parts of the investment and operation use domestic or local inputs. The planning and commissioning, construction, and especially the operation of a biogas plant brings new jobs to a region, which of course benefit the local community and promotes the development of expertise. Furthermore, especially when utilizing municipal wastes, the health hazards for people can be significantly reduced.

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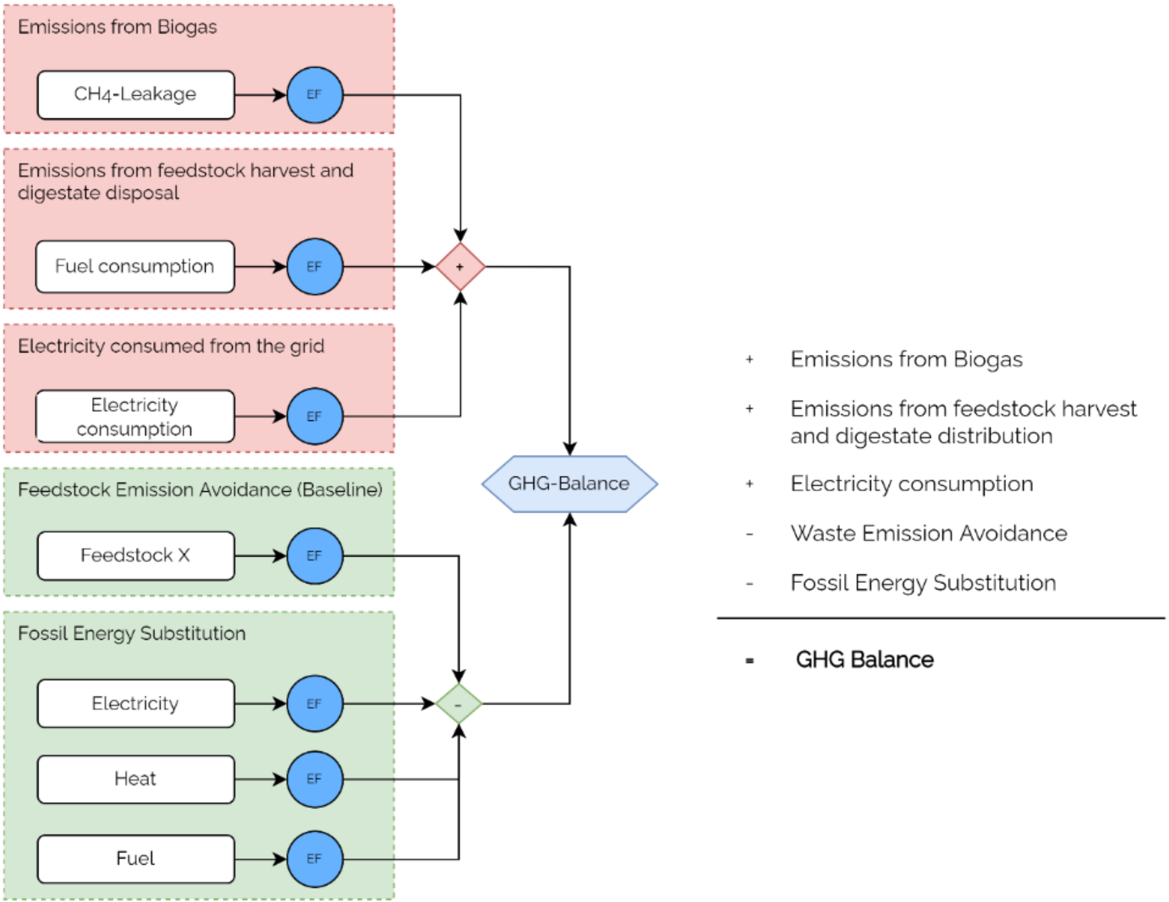
To quantify the impacts of the demo projects, a model for biogas plants from the Austrian Energy Agency was used. This model is able to analyse the produced energy, the invest volumes, the greenhouse gas (GHG) balance, as well as the jobs created or retained. The following table gives an overview about the impacts of the five demo projects based on the conducted analysis:

Country	**Total invest** [EUR]	**Domestic invest** [EUR]	**Foreign invest** [EUR]	**Gross energy production** [MWh/a]	**Unskilled Workers** [FTE]	**Skilled Workers** [FTE]	**Highly Skilled Workers** [FTE]
Argentina	7 700 000	4 580 000	3 120 000	31 000	-	8,3	-
Ethiopia	3 500 000	1 940 000	1 560 000	11 000	5,2	2,1	1,0
Ghana	5 400 000	3 970 000	1 430 000	24 000	2,1	4,2	2,1
Indonesia	10 200 000	6 900 000	3 300 000	39 000	1,0	8,4	1,0
South Africa	3 600 000	1 520 000	2 080 000	18 000	-	0,2	0,1
Sum	**30 500 000**	**18 910 000**	**11 590 000**	**122 000**	**8**	**23**	**4**

*FTE … Full Time Equivalent

For the demo projects, among others, the GHG balance was analysed. The scope of the analysis included the operation of the biogas plants in comparison to a baseline scenario, i.e. the impacts of the actual energy generation and waste disposal. The following figure illustrates the applied methodology for the GHG-balance calculation:



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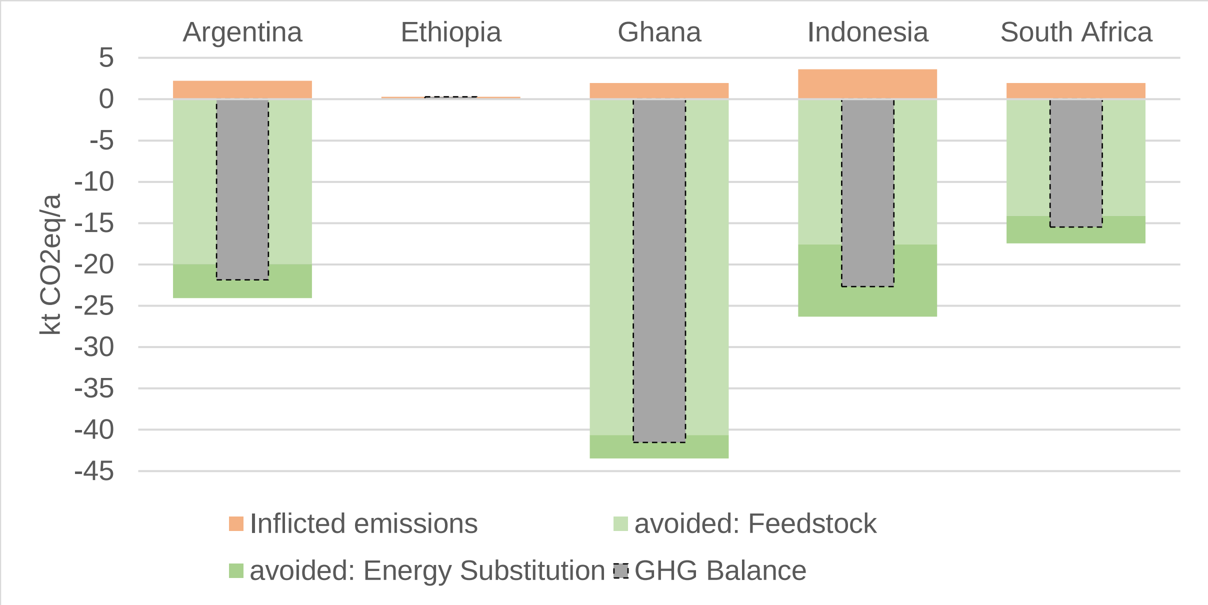
The results of the GHG-balance analysis for the five demo projects are shown in the following figure:



The graph above shows, that four out of five demo projects can cause a significant decrease of CO_{2eq}-emissions. Ethiopia poses a special case, as the analysis depicts only a slightly positive CO_{2eq}-emission. This is due to the fact, that on the one hand, the emission factor of the substituted electricity is very low (because of high hydro power usage), and on the other hand that the water hyacinth is considered to be carbon neutral as native biomass. However,, the Ethiopian case provides an essential ecosystem service. Thus, the impact analysis for biogas plants should consider more than emission reductions and consider the bigger picture.

Biogas plants can have negative impacts under certain circumstances, first and foremost methane leakage and organic leachate due to poor technical construction, operation or maintenance. A major goal of the DiBiCoo Market Uptake Program was to promote solutions, which maintain a safe, reliable and sustainable construction and operation of biogas plants. In Europe and other advanced biogas markets, negative environmental impacts of biogas plants are minimized through the implementation of certain standards, such as the ISO 24252. It is crucial, that standards are implemented and executed via national law and are refined with national and local regulations to manifest the positive effects of biogas production and utilization. In case no relevant national legislation exists funding agencies should prescribe minimum international standards to be followed.

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Summary of the DiBiCoo Project

The **Digital Global Biogas Cooperation (DiBiCoo)** project is part of the EU's Horizon 2020 Societal Challenge 'Secure, clean and efficient energy', under the call 'Market Uptake Support'.

The target importing emerging and developing countries are Argentina, Ethiopia, Ghana, South Africa and Indonesia. Additionally, the project involves partners from Germany, Austria, Belgium and Latvia. The project started in October 2019 with a 33 months-timeline and a budget of 3 Million Euros. It is implemented by the consortium and coordinated by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

The overall objective of the project is to prepare markets in developing and emerging countries for the import of sustainable biogas/biomethane technologies from Europe. DiBiCoo aims to mutually benefit importing and exporting countries through facilitating dialogue between European biogas industries and biogas stakeholders or developers from emerging and developing markets. The consortium works to advance knowledge transfer and experience sharing to improve local policies that allow increased market uptake by target countries. This will be facilitated through a digital matchmaking platform and classical capacity development mechanisms for improved networking, information sharing, and technical/financial competences. Furthermore, DiBiCoo will identify five demo cases up to investment stages in the 5 importing countries. Thus, the project will help mitigate GHG emissions and increase the share of global renewable energy generation. The project also contributes to the UN Sustainable Development Goals (SDG 7) for 'Affordable and clean energy", among others.

Further information can be found on the DiBiCoo website: www.dibicoo.org.

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List of Abbreviations

CAPEX	Capital Expenditures
CHP	Combined Heat and Power
CH_4	Methane
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalent
D	Deliverable
DiBiCoo	Digital Global Biogas Cooperation
DM	Dry matter
GHG	Greenhouse gas
OPEX	Operational Expenditures
T	Task
SC	Steering Committee
VS	Volatile solids (organic dry matter)

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1 Introduction

Climate change is one of the most pressing challenges of our and future generations. Above all, the use of fossil fuels and the related release of additional CO_2 and CH_4 to the atmosphere drives global warming. This leads to severe impacts on our climate system including sea level rise, the increase of extreme weather events and loss in biodiversity. As a result, the living conditions of people, especially in developing countries, will deteriorate.

The energy sector is one of the largest emitters of greenhouse gases and thus a major driver of climate change. The recently published report of the Intergovernmental Panel on Climate Change (IPCC) stated that the energy sector is responsible for 34% (20 Gt CO_2-eq) of total net anthropogenic GHG emissions in 2019[1]. The reduction of emissions in the energy sector is therefore inevitable to reach the Paris climate goal to limit the increase of global average temperature below 1.5°C compared to pre-industrial levels. As the demand for energy rises with the expected growth in population in the upcoming decades, increasing energy efficiency and the decarbonization of energy production are particularly important strategies for a sustainable energy sector.

Renewable energy generation from biomass has grown in recent years and is nowadays a commonly used energy source. Biogas is produced by anaerobic digestion of various raw materials like organic household waste or animal industry waste products, like manure. It can be used for electricity and heat generation, as fuel or as replacement of natural gas or other fossil fuels. It can also be used at any time in a controlled way (it is dispatchable), and can thus ensure grid stability and energy security.

Biogas has proved its potential as a versatile energy carrier, to meet the growing demand for energy, while substituting greenhouse gas intensive fossil fuels. In order to facilitate the expansion of biogas, the EU initiated the Digital Global Biogas Cooperation project. It is an international project funded by the Horizon 2020 program of the European Commission and implemented by GIZ in cooperation with 12 organizations across four continents. The overall objective is to establish a closer cooperation between European technology suppliers and biogas stakeholders in the partner countries Argentina, Ethiopia, Ghana, Indonesia, and South Africa. In each partner country, one project idea was selected as demo case to be a show case about development in the biogas sector the respective country[2].

The goals of these biogas projects are to lead to increased energy security, increased local added value, enhanced job creation and increased share of renewable energy at local level while reducing greenhouse gas emissions[3]. In order to analyse some of the most relevant influences of the demo project on the environment, this report presents the impact analysis for each country. The scope of the analysis includes the three dimensions of sustainability: ecological, economic, and social.

In the first chapter an overview of the used methodology and approach for the assessment of the three dimensions is given. After that, the impacts of the demo projects are presented separately for every country. These chapters also include an overview of the demo projects in general. Then, technical standards to support the overall development, safety, reliability and

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[1] IPCC, Sixth Assessment Report, Climate Change 2022: Mitigation of Climate Change, Working Group II

[2] Factsheet DiBiCoo

[3] https://dibicoo.org/dibicoo-project-4/

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sustainability of the plants are described. Finally, a conclusion to the conducted impact analysis is provided.

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2 Background and Methodology

The impact analysis considers the ecological, economic and social dimensions of the DiBiCoo demo projects. Environmental impacts include the potential for substitution of fossil fuels, or the reduction of untreated waste on landfills. The economic impacts covers the potential investments in the area of the biogas plant. Social impacts address the potential for increased employment in the area, but also noise and odors, or residents' complaints.

The information and the parameters of the impact analysis are based on outputs of the biogas-modelling tool (below). The tool aggregates relevant information for every demo project, such as the technical and financial details of the plant or the data of the feedstock used. Further, a mass and energy balance illustrates the inputs and outputs of the biogas plant, which is the foundation for the environmental analysis.

In this chapter, the general approach of the impact analysis is explained. After that, the results for every of the five demo projects are presented.

2.1 Data Source: Modelling Tool

The basis for all calculations is a modelling tool developed by the Austrian Energy Agency. With information about necessary components, general technical parameters, such as Organic Loading Rate of the digesters, storage time of the gas, etc., the feedstock amounts and its attributes, the model estimates the sizing of the different components, the energy production, as well as CAPEX and OPEX of the plant (see Figure 1). The modelling is based on different literature sources, which give technical and financial data derived from practical studies and technology providers.

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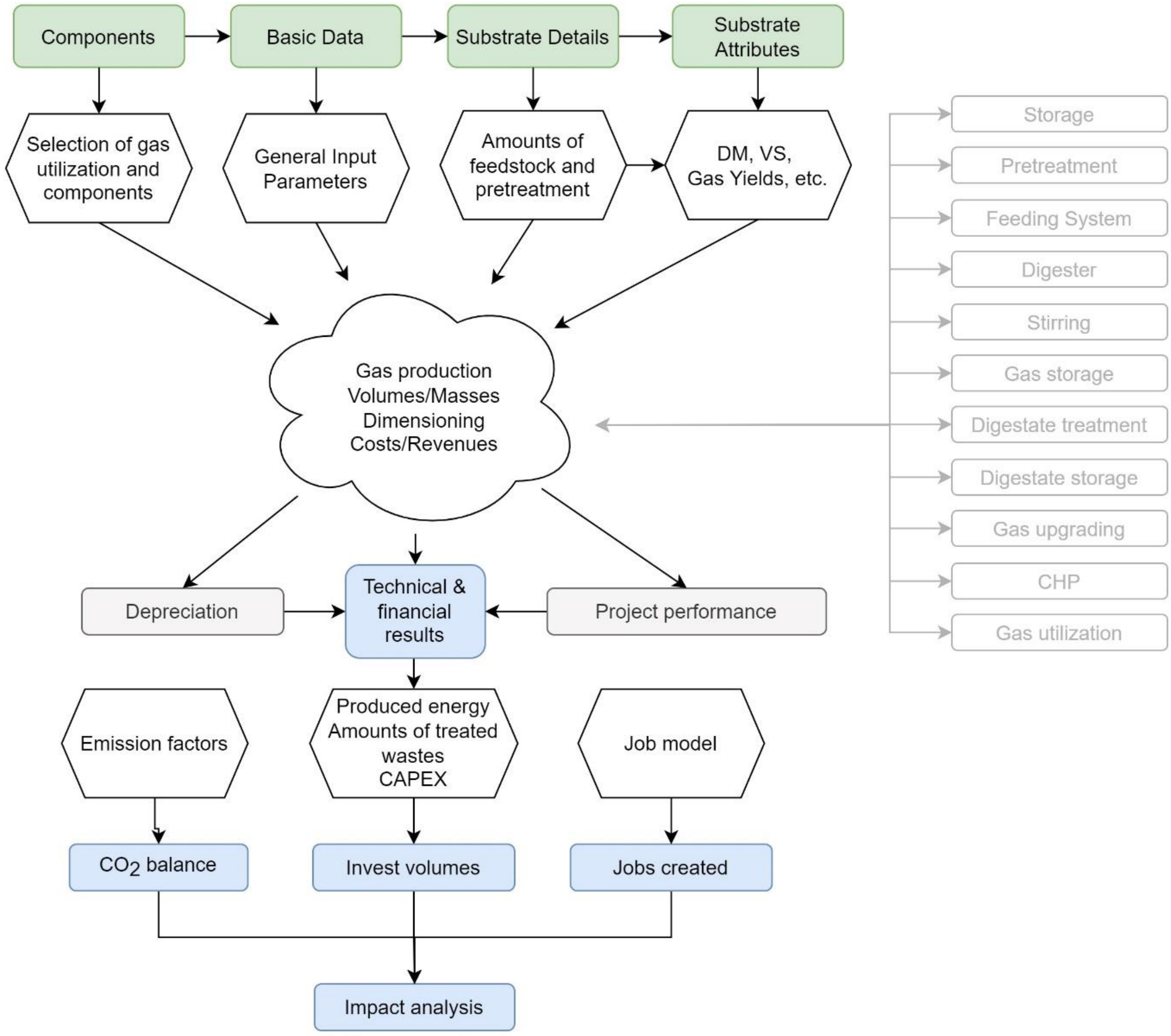

Figure 1: Modelling-Tool, Source: Own representation

The substrate attributes (e.g. dry matter (DM), volatile solids (VS), specific biogas-/methane-yields) together with the feedstock quantity are relevant for the energy production of the system. The selected components are sized according to mass-/volume-flows together with given process parameters. For all components, cost curves were modelled based on industry data to implement a scaling effect in the model to calculate the component costs. Additional costs such as civil work or contingencies, as well as additional costs for waste sorting and extraction of organic fractions are added as share of component costs to sum up to the total investment. The project developers assessed shares of domestic investments and invests going to foreign countries. Deriving from a South African study[4] a job model was created to assess the potential jobs created/sustained during planning and authorization, and construction. The project developers assessed the necessary personnel for the plant operation. In the case that additional waste collection systems are installed, additional jobs

[4] GIZ 2016: Biogas Industry in South Africa: An Assessment of the Skills Need and Estimation of the Job Potential. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, South African-German Energy Programme (SAGEN) and Southern African Biogas Industry Association (SABIA). Online: https://www.crses.sun.ac.za/files/research/publications/SAGEN%20Job%20Pot%20-%20Digital%20(low-res).pdf.

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can be created, yet at this point, the waste is collected by another company. Emission factors were used for the assessment of the CO_2-balance. The methodology is described in more detail in the respective chapters.

2.2 Mass- and Energy-Balance

An important factor for sustainable energy production is the energy balance of the process. To ensure an energy surplus of the project, it is necessary to analyse the Input- and Output-Energy. In addition, the mass balance is important to base management concepts on it and to show the masses that need to be handled.

The mass balance in metric tons has feedstock as its main input. Depending on the DM of the feedstock and the target DM for the digester content, additional water for feedstock dilution may be taken into account. The outputs of the process are biogas and digestate. The biogas consists (to the largest extend) of methane, carbon dioxide and water. The digestate is the mass of feedstock minus the mass of gas. If needed, the liquid fraction of the digestate after solid/liquid separation can be recirculated to prevent the additional use of water (Figure 2).

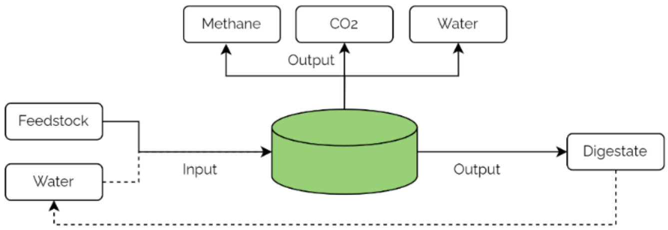

Figure 2: Mass balance, Source: Own representation

The energy balance has electricity and heat as inputs. In all demo projects, the electricity for the biogas operation comes from the national grid, since the feed-in tariffs for renewable energy are higher than the standard electricity price. The heat demand (for heating of digester and sanitation) comes from the combined heat and power plant (CHP plant). If no CHP plant is in place the heat demand can be covered through the utilization of the produced biogas. The energy output of this process step is biogas, which can be utilized in different ways. Four of five demo projects produce electricity and heat with CHP plants, one utilizes the biogas directly in a local gas micro grid after desulfurization (Figure 3).

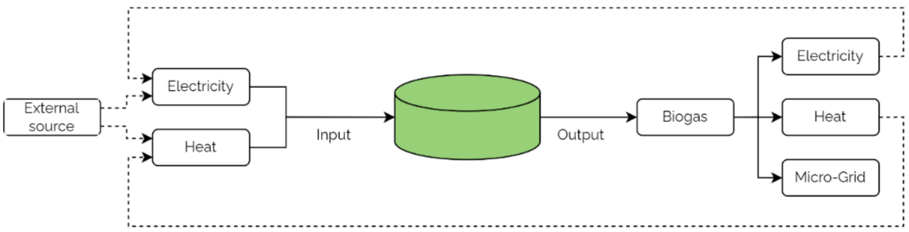

Figure 3: Energy balance, Source: Own representation

2.3 Environmental Impact

The environmental impact of the biogas plants is separated in quantitative and qualitative impacts. The calculation of the quantitative impacts focuses on greenhouse gas emissions. The system boundary for the calculation covers the operation phase of the biogas plant with its input and output flows. For comparison, the emissions are based on the deviation from the

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baseline scenario to the operation scenario. The baseline scenario represents the initial situation of the area without the biogas plant. In the operation scenario the biogas plant is already built and in use. Parameters that remain the same in both scenarios are neglected in this analysis.

For example: The relevant household waste is transported to a landfill in the baseline scenario. In the operation scenario, the waste is transported to the biogas plant. The distance to the landfill and the plant is similar, meaning no (or minor) deviation from the baseline scenario, resulting in no (additional) impact from the biogas plant.

The general approach of the quantitative assessment is to define the parameters for the baseline scenario and the operation scenario in a first step. Then, the parameters, like type and amount of the feedstock or (avoided) waste on landfills is multiplied by specific emission factors for each country obtained from literature. The emission factors represent CO_2 equivalents, meaning that the full greenhouse gas potential of an activity is considered. Nonetheless, the CO_2 emissions from native organic matter, such as biomass, are considered to have a neutral climate impact, as the carbon that is released during the processes has been previously sequestered from the atmosphere and will be sequestered again as the plants regrow. If organic material degrades under uncontrolled, anaerobic conditions, it generates CH_4, which has a higher GHG-potential as CO_2. Therefore, if such uncontrolled conditions would be considered, the positive environmental impact of the biogas operation on GHG-balance would be greater. Table 1 gives and overview of the emission factors used.

Table 1: Emission factors, Source: Own representation

Name	Used for:	Factor	Unit	Short Description	Source
Electricity mix per country	Argentina	0,303	t CO_2eq/ MWh	Toolkit to simplify and standardize the data collection process for urban energy balances and greenhouse gas emissions inventories.	World Bank (2013)[5]
Electricity mix per country	Ethiopia	0,003	t CO_2eq/ MWh	Toolkit to simplify and standardize the data collection process for urban energy balances and greenhouse gas emissions inventories.	World Bank (2013)[5]
Electricity mix per country	Ghana	0,276	t CO_2eq/ MWh	Toolkit to simplify and standardize the data collection process for urban energy balances and greenhouse gas emissions inventories.	World Bank (2013)[5]
Electricity mix per country	Indonesia	0,677	t CO_2eq/ MWh	Toolkit to simplify and standardize the data collection process for urban energy balances and greenhouse gas emissions inventories.	World Bank (2013)[5]
Electricity mix per country	South Africa	0,869	t CO_2eq/ MWh	Toolkit to simplify and standardize the data collection process for urban energy balances and greenhouse gas emissions inventories.	World Bank (2013)[5]

[5] World Bank (2013). Ostojic, D. R., Bose, R. K., Krambeck, H., Lim, J., & Zhang, Y. Sustainable Urban Energy and Emissions Planning Toolkits. Energy Balance and GHG Inventory Spreadsheet. World Bank Publications.

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Waste dumping site	Argentina, Ghana, South Africa	0,74	t CO_2eq/ t waste	Calculation of generalized waste disposal scenarios for developing countries	Barton et al. (2008)[6]
Raw sludge disposal on landfill	South Africa	4,875	t CO_2eq/ t RDS	Emissions of methane from wastewater treatment	Hobsen (2000)[7]
Emissions from septic tank	Ghana	2,55	t CO_2eq/ t feces	Methane estimate per capita per day and human excreta per day	IPCC (2007)[8] and Andriani et al. (2015)[9]
Chicken manure	South Africa	0,43	t CO_2eq/ t manure	Emissions from chicken waste	Kreidenweis et al. (2021)[10]
Diesel	Ethiopia	3,14	t CO_2eq/ Liter	Calculation of GHG emission values along the supply chain	ISCC (2021)[11]
Pome treatment in open lagoons	Indonesia	0,16	t CO_2eq/ t pome	Calculation of GHG emission values along the supply chain	ISCC (2021)[12]

The method for the analysis of environmental impacts is illustrated in Figure 4. Positive factors (inflicted emissions) of the GHG balance are methane leakages from the biogas plant, emissions from feedstock harvest and digestate disposal, and the electricity consumed. The consumption of electricity also includes the sorting and pre-treatment of the feedstock (e.g. municipal solid waste). However, as already mentioned, if the disposal of the feedstock is the same or very similar to the baseline scenario (e.g. same distance to landfill and plant) the transport is not part of the balance. In contrast, waste emission avoidance and the fossil fuel substitution reduces emissions and therefore the GHG balance. If the GHG balance is

[6] Barton, J. R., Issaias, I., & Stentiford, E. I. (2008). Carbon–making the right choice for waste management in developing countries. Waste management, 28(4), 690-698.

[7] Hobson, J. (2000). CH4 and N2O emissions from waste water handling. Good practice guidance and uncertainty management in National Greenhouse Gas Inventories. Geneve, Switzerland: Intergovernmental Panel on Climate Change (IPCC) Publications.

[8] Intergovernmental Panel on Climate Change (2007). Climate change 2007. Synthesis report. Contribution of Working Groups I, II and III to the fourth assessment report. Switzerland: Intergovernmental Panel on Climate Change (IPCC)

[9] Andriani, D., Wresta, A., Saepudin, A., & Prawara, B. (2015). A review of recycling of human excreta to energy through biogas generation: Indonesia case. Energy Procedia, 68, 219-225.

[10] Kreidenweis, U., Breier, J., Herrmann, C., Libra, J., Prochnow, A. (2021). Greenhouse gas emissions from broiler manure treatment options are lowest in well-managed biogas production. Journal of Cleaner Production. Volume 280, Part 2

[11] International Sustainability and Carbon Certification (2021). ISCC EU 205 Greenhouse Gas Emissions, Version 4.0, ISCC System GmbH

[12] International Sustainability and Carbon Certification (2021). ISCC EU 205 Greenhouse Gas Emissions, Version 4.0, ISCC System GmbH

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negative, the demo project leads to the avoidance of emissions, and therefore to a positive impact on the climate.

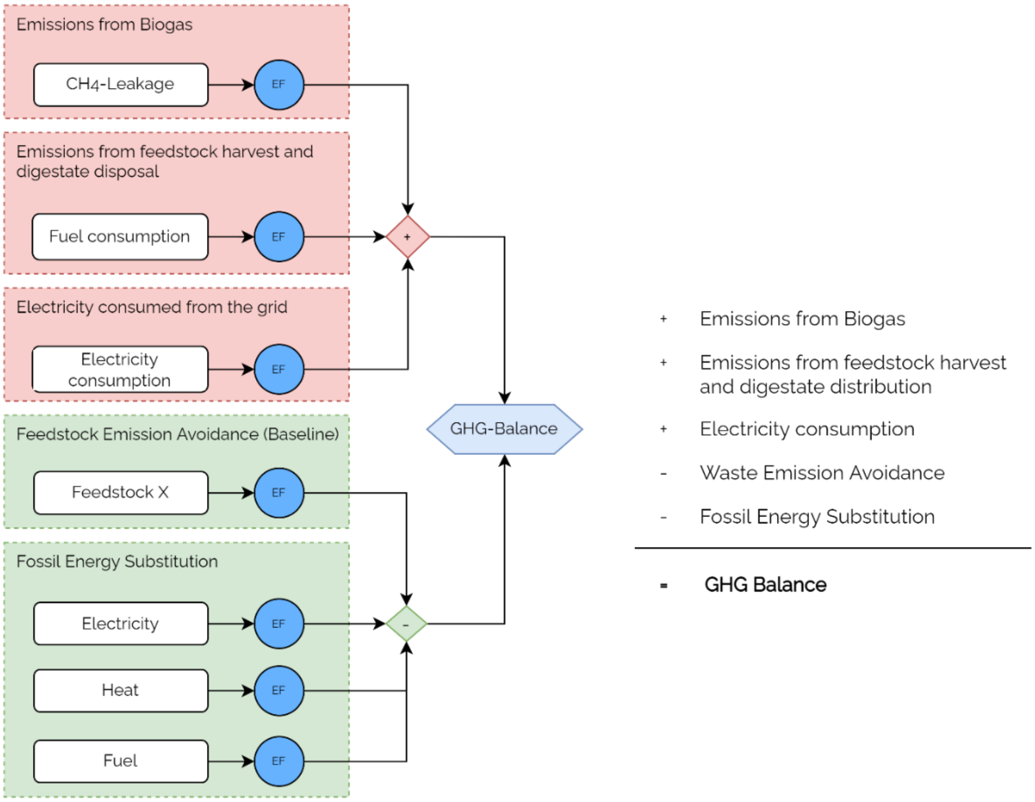

Figure 4: Analysis of environmental impacts, Source: Own representation

Because of limited data availability, additional environmental impacts are described qualitatively: The digestate of the biogas plant can be used to substitute fossil fertilizers. However, the quality of the digestate depends on the quality and purity of the feedstock (the biomass fed into the process in the beginning). In addition, the reduction of waste in landfills or on dumping sites leads to reduced eutrophication, groundwater contamination and soil erosion.

A negative environmental impact is the water usage for the operation of the plant. Particularly affected are countries that suffer from water scarcity. Moreover, the construction of the plant also has an impact on its direct surroundings. It could lead to habitat destruction or interference with the local ecosystem in general. Specific impacts are described in the sections of the demo projects.

2.4 Economic Impact

In addition to the environmental impacts, biogas plants also have an impact on the economic development of a region. In regions without or only with limited access to energy, the energy from the biogas can lead to the use of modern energy services and thus to further economic advancement in general. In addition, the construction and operation of the plant creates jobs in the area, influencing the economic stability of the region. Moreover, the production of electricity, fuel and fertilizer generates income for the people involved.

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Therefore, the production of biogas is a driver for economic growth leading to more employment, local value creation and increased energy security. It is important to mention, that the financing- and ownership structure, as well as the inclusion of the local community strongly affects the potential positive impacts, so it is crucial that biogas plants are implemented with inclusion of the local community and stays accessible for them.

In addition, biogas projects create investments in the region, like the expansion of the grid and road infrastructure. The investment of the plant is calculated in the model described. After assessing the sizes/capacities of the necessary plant components, cost curves deriving from literature gave investment costs for the different components. Where possible, the figures were adapted to actual data from specific technology suppliers. In all other cases, average industry standard values were considered. On top of the component costs, depending on the size of the plant, additional investments such as civil works, waste treatment, or contingencies were added as percentage on the component costs to get the total invest, which is shown in the economic chapters below.

2.5 Social Impact

The main social impacts of the biogas projects are the jobs created. The job assessment was based on a model derived from an in-depth study for South Africa[13]. Based on primary data, the study proposes specific employment factors for different development stages of biogas projects for different sizes (Table 2, Figure 5). For the five demo projects, just the large- and medium scales are applicable. Following the estimated size of the plants the jobs are calculated according the formula with the FTE hours per year equal 2080 working hours per year:

$$Number\ of\ Jobs\ [FTE] = \frac{Employment\ factor\ [Jobs/MW] \times Total\ installed\ power[MW]}{\boldsymbol{FTE\ hours\ per\ year}\ [h]}$$

Table 2: Specific employment factors

Project size and phase	Employment Factor (Jobs / MW)			
	Large	*Medium*	*Small*	*Rural*
Feasibility & Development	6,56	11.68	5.06	5.06
Construction	31.17	192.67	2.29	2.29
Operation & Maintenance	3.89	36.16	9.33	9.33
Total Project	41.62	153.92	16.69	16.69

[13] GIZ 2016: Biogas Industry in South Africa: An Assessment of the Skills Need and Estimation of the Job Potential. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, South African-German Energy Programme (SAGEN) and Southern African Biogas Industry Association (SABIA). Online: https://www.crses.sun.ac.za/files/research/publications/SAGEN%20Job%20Pot%20-%20Digital%20(low-res).pdf.

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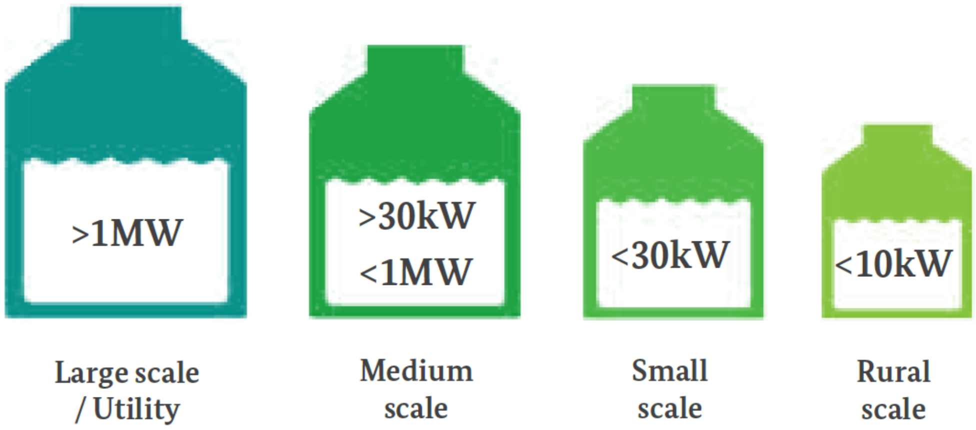

Figure 5: Considered scales of biogas plants

This methodology was used to estimate the jobs necessary for the stage of feasibility & development and construction. For the jobs necessary to operate the plant, the project developers conducted an expert assessment.

Deriving from the total job demand, Figure 6 shares the skill levels for different project stages that were considered for the demo projects.

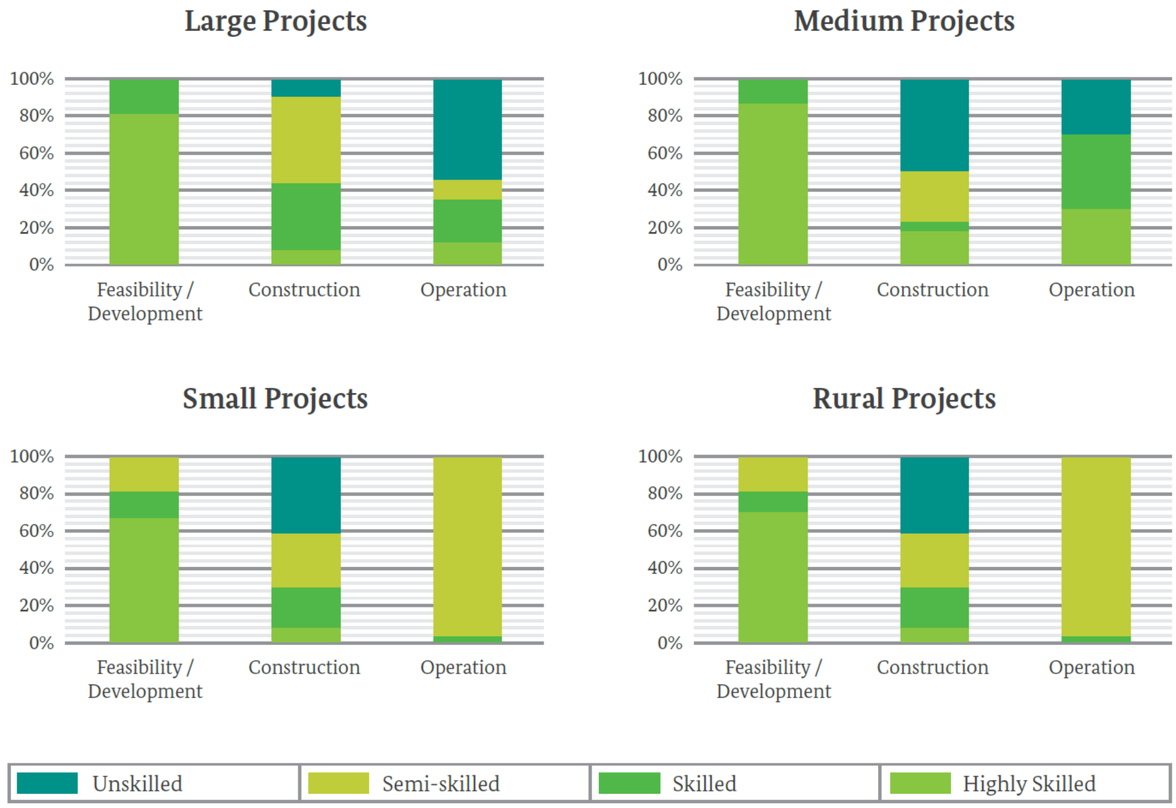

Figure 6: Shares of skill levels needed for different project development stages and biogas plant scales.

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It is important to mention, that the jobs for feasibility & development and construction are temporal jobs and are various, mainly technical and administrational jobs for the duration of the project development and construction phase. Therefore, they are normally not created but maintained. However, the jobs for the operation of the plant are new jobs created.

Additional social impacts are assessed qualitatively. In general, the use of waste as input material for the plant can improve the hygienic standard of the area. Also, household waste is often dumped in unmanaged landfills, resulting in negative impacts such as the formation of gases or the leakage into groundwater leading to negative health effects. Waste from animals, like manure, can also lead to the formation of bacteria and pathogenic organisms if not stored properly. Therefore, the appropriate processing of the organic matter improves the health condition of the population.

Negative social impacts of the biogas plant are the formation of odors and the increase in noise pollution. Odors are generated by the storage and processing of biomass, as well as in the anaerobic fermentation process of the plant. An increase in noise results mostly from the operation of the biogas plant equipment, such as fans or generators.

These negative influences can lead to complaints from the residents. In general, it is recommended to involve the residents of the surrounding area in the planning process of the biogas plant in order to increase the acceptance for the project. For this purpose, information campaigns and stakeholder meetings can be organized.

A further social impact is the potential mutual cooperation of different stakeholders in the project, that increases the knowledge and experience of the stakeholders.

Negative social impacts might derive from unequal shareholding agreements between different stakeholders and local communities. Contractual agreements can be biased and favourable for specific groups while repress others. Corruption might stall implementation or detoriate trust in biogas technologies at all.

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3 Impact Analysis of the Demo Projects

In this chapter, the results for the impact analysis of every demo project (DP) is provided. First, the demo project of the specific country is described in general and the current situation (baseline scenario) is explained. The mass- and energy balance give an overview of the input and output flows of each demo project. Then, the environmental, economic and social impacts per project and country are presented.

3.1 Argentina

Feedstock: Organic fraction of municipal solid waste

Energy output: 25 GWh/a

The city of Rio Cuarto in Cordoba, Argentina has problems with the disposal of municipal solid waste (MSW). Now, the waste is disposed in a landfill resulting in hygiene and social problems, as well as in emissions of greenhouse gases. The project foresees to utilize the organic fraction of MSW as feedstock for a biogas plant to produce green electricity, which will be injected into a public electricity grid.

According to 2021 studies the landfill located on the property of the "Paraje Los Espinillos" sector, is on the verge of collapse. The Secretary of Public Services acknowledged in the annual report, that the remaining capacity of the property was shortened to less than 12 months.

Currently, the city generates about 200 tons of garbage daily. A situation that further complicates the situation is added: the family that owns the lands that surround the property filed a legal appeal against the municipality to prevent the expropriation of new hectares to expand the excavation. This is justified by the poor location, meters from the river (which is also declared a natural reserve). Additionally, an extension of the landfill would generate further pollution that impacts the families that live in close proximity.

The sanitary excavation currently has six cells. These are long trenches, basin-style, which are covered with a membrane so that there are no leaks of the leached liquids generated by the garbage. These liquids leave the cells through escape channels, which are constructed so that the liquids flow into a sealed pool where they end up evaporating. Open-air sanitary excavations produce greenhouse gases such as methane or carbon dioxide, therefore, they lead to global warming and climate change.

The waste on the landfills is neither separated nor treated or recycled. Therefore, a waste treatment facility is necessary to separate the organic fraction from the MSW, which is estimated to be 50%. The transport distance from the waste collection sites to the landfill or the biogas plant are considered to be similar. Therefore, transport is not part of the analysis.

3.1.1 Mass- and Energy-Balance

The project's mass balance comprises the organic fraction of municipal solid waste (27,000 t/a) and water as input. Outputs of the biogas plant are methane (2,254 t/a), CO_2 (4.060 t/a), water (230 t/a) and digestate (20,456 t/a). 23% of the liquid digestate are recirculated as input (Figure 7).

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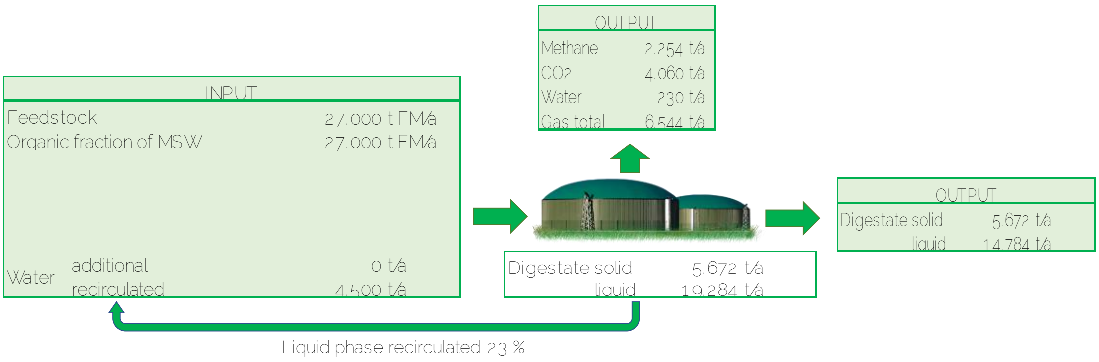

Figure 7: Mass Balance, DP Argentina, Source: Own representation

The energy balance of the demo project in Argentina includes electricity from the grid and heat as input. 21% of the heat are recirculated from the plant. The total energy output is 24,736 MWh per year (Figure 8).

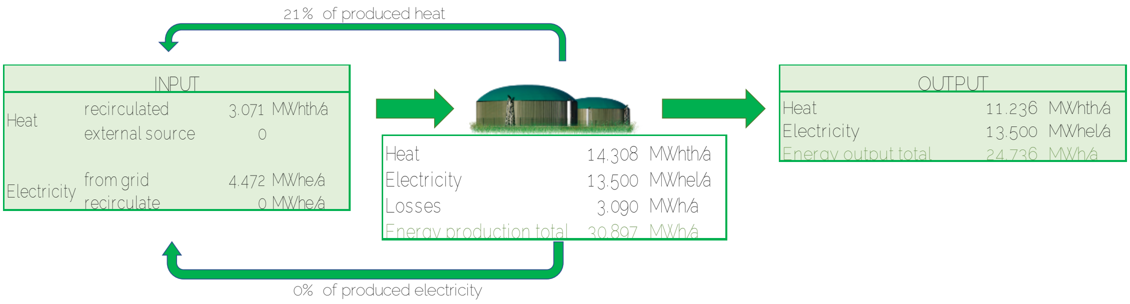

Figure 8: Energy Balance, DP Argentina, Source: Own representation

3.1.2 Environmental Impact

In the Argentinian demo project 4.1 kt CO_2eq are avoided due to the substitution of electricity (electricity-mix Argentina). Also, 20 kt CO2eq are avoided as the fraction of municipal solid waste is not dumped on the landfill. Emissions due to the operation of the plant include the CH_4 leakage resulting in 0.9 kt CO_2eq and the electricity used (1.4 kt CO_2eq). In total, the GHG balance results in -21.9 kt CO_2eq. This means, that more emissions are avoided than inflicted, resulting in a positive impact on the climate (Figure 9, Table 3)

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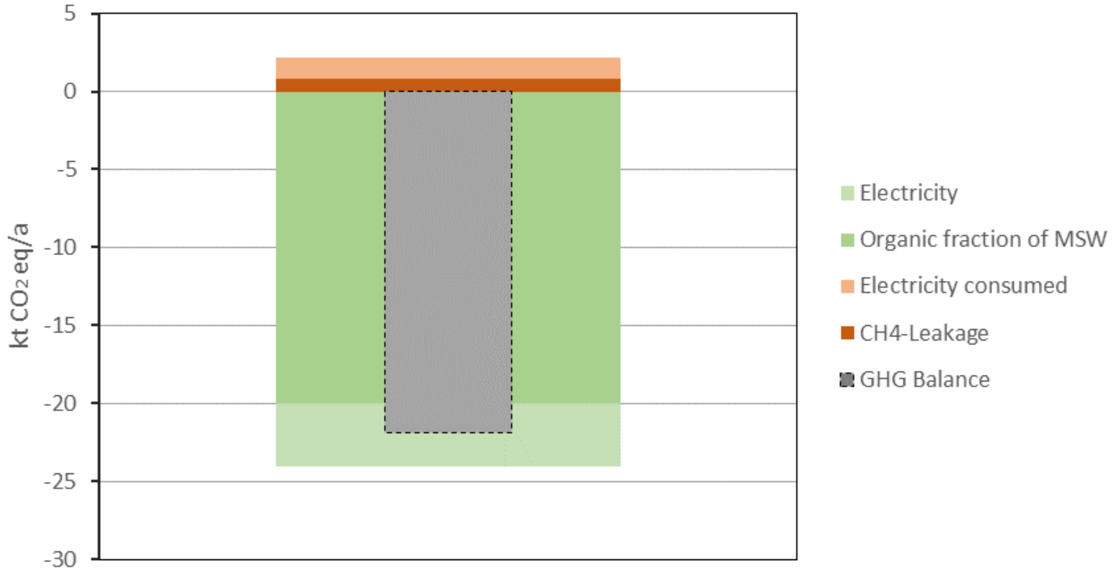

Figure 9: Environmental impact, DP Argentina, Source: Own representation

Table 3: Environmental impact, DP Argentina, Source: Own representation

Inflicted Emissions	[t CO_2e/a]	Avoided Emissions	[t CO_2e/a]
CH4-Leakage	850	Organic fraction of MSW	-19,980
Electricity consumed	1,357	Electricity	-4,096
Sum inflicted emissions	2,207	Sum avoided emissions	-24,076
GHG Balance	**21,869**		

3.1.3 Economic Impacts

Table 4 shows the potential investments with its domestic and foreign shares.

Table 4: Potential investment volumes for the Argentinean demo project

Cost Item	CAPEX [EUR]	Domestic [%]	Domestic [EUR]	Foreign [EUR]
Storage	10 000	100%	10 000	-
Pre-treatment	40 000	50%	20 000	20 000
Feeding system	70 000	40%	28 000	42 000
Digester	1 220 000	100%	1 220 000	-
Stirring	90 000	30%	27 000	63 000
Gas storage	70 000	0%	-	70 000
Digestate treatment	10 000	20%	2 000	8 000
Digestate storage	100 000	100%	100 000	-
Gas cleaning	503 000	30%	150 900	352 100
Gas upgrading	-	0%	-	-
CHP	920 000	0%	-	920 000

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Cost Item	CAPEX [EUR]	Domestic [%]	Domestic [EUR]	Foreign [EUR]
Gas utilization	-	100%	-	-
Transport and installation on site	303 000	70%	212 100	90 900
Civil Works	455 000	100%	455 000	-
Electrical Works	455 000	100%	455 000	-
Gas Grid Connection Costs	-	100%	-	-
Electrical grid connection costs	-	100%	-	-
Waste Treatment	3 033 000	50%	1 516 500	1 516 500
Planning, authorization and commissioning	152 000	50%	76 000	76 000
Land preparation	-	100%	-	-
Land Payment	-	100%	-	-
Miscellaneous and Contingencies	303 000	100%	303 000	-
Sum	**7 734 000**		**4 575 500**	**3 158 500**

3.1.4 Social Impacts

The project has a diverse impacts for the local population.

The implementation of a differentiated collection of waste has mainly an important impact in the poorest sectors of the Rio Cuarto society. There are already different groups organized in small cooperatives that have begun working in this type of jobs. There are also raising concern in the way the final collection and use of residues will be implemented in the city.

According to local studies in the city 369 families collected municipal solid waste for selling components for subsistence. These families were living in poverty as they had no social coverage or retirement program. Sanitary and security measures were inadequate and micro dumps were generated.

There is another impact related to jobs being created/sustained regarding the feasibility, construction, implementation and operation phase of the treatment and post treatment plants to be constructed. The educational level of young people is divided between those who reached a university level (46.6%) and those who finished the secondary level (43.8%). Currently, 66.7% of young people are looking for a new job, while 63.5% have a labor income less than or equal to E 400 per month. Around, 39.1% of young people need financial help from their families. The third dimension of analysis performed during 2021 by the Rio Cuarto foundation in relation to young people lies in the interests they have in relation to the city of Rio Cuarto. At this point it can be said that the majority of young people plan to stay and live in the city of Río Cuarto (64.8%) and the reasons of those who do not want to stay to live mainly is due to lack of job opportunities (51.4%). The main areas of interest of young people are environmental issues (65.3%), education (52.8%), social assistance (48.6%) and cultural activities (36.1%)[14].

Both domestically and internationally, it has been shown that the biogas sector can act as a generator of added value in the communities and regions where the projects are located. The experience with biogas plants in Argentina is, that they provide skilled and high-income jobs

[14] Source https://www.fundacionriocuarto2030.org/anuario-2021/

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for young professionals. These, young professionals thus have a way to stay in their communities without migrating to large cities.

In Argentina, the experience and knowledge gained through the construction and operation of biogas plants allow different local companies to grow and hire additional personal, e.g. in the metalworking, construction, and process sectors. In this way, it can also increase the quantity of equipment and components, which are provided by the national industry complementing and / or competing with the international providers.

Differentiated collection of waste is an activity that has been developed informally. It precedes the work of adding value through classifying, , recycle or reuse. This type of work is usually done by the *Cooperatives Urban Recuperators of Rio Cuarto*, and the cooperative *Todo Sirve Limitada*. Additionally hundreds of families, who without necessarily being organized or enrolled in the Urban Recuperators Program of the municipality, work and live from the collectionand sale of MSW in the city. This work is not remunerated or recognized in municipal budgets, although it significantly reduces the volumes of MSW that eventually end up in municipal landfill sites.

In the year 2021, Municipality of Río Cuarto signed an agreement with the cooperatives, with the aim of bringing together urban recyclers to create the Waste Transfer Center to promote the development of recycling in the city. The initiative aims to improve the conditions of commercialization of recyclable waste (such as cardboard and PET plastic) and simplify the task of urban recyclers, and thus promoting the circular economy of garbage treatment. The Social Foundation will remove the processed material (cardboard and PET plastics) from the Transfer Center of the Oncativo neighborhood for final disposal in the Treatment Plant located south of the city. For its part, the Cooperative "Reciclarte" undertakes to process the material under the conditions and prices established by the agreed upon clauses.

Waste and waste not properly channeled produce a negative impact, generating:

- proliferation of rodents, flies and various insects, pathogenic bacteria, and animals, producing foci of infection of potentially high danger to humans
- dangerous pollutants such as heavy metals, batteries, drugs and hazardous chemical substances; pathological residues, etc.
- Leachate that is generated from the decomposition of the organic matter deposited in the garbage dumps and that due to the rains percolate the different groundwater tables and contaminating them
- accidents and infections caused in the improper handling of the garbage
- clandestine overturning of hazardous pathological waste[15]

Table 5 shows the number of jobs created/sustained to implement the project. Table 6 describes the number of newly created jobs for the operation of the plant according to the skill level (excluding waste collection and transportation).

[15] https://latinta.com.ar/2019/11/municipio-rio-cuarto-cotreco-socios-mega-planta-reciclado-fantasma/)-

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Table 5: Jobs for the demo project implementation of the Argentinean demo project for different implementation stages

Development stage	[h]	[FTE]
Feasibility & Development	50000	24,0
Construction	233000	112,0
Operation & Maintenance	17200	8,3

Table 6: Jobs by skill level for the operation of the Argentinean plant

Skill level	[h]	[FTE]
Unskilled worker	0	0,0
Skilled worker	17200	8,3
Highly skilled worker	0	0,0

3.2 Ethiopia

Feedstock: Water hyacinth

Energy output: 8 GWh/a

At Lake Tana, the biogas production will be combined with environmental protection measures by using water hyacinth (a plant growing in the lake) and organic wastes for the generation of electric power. The plant material will be collected and together with agricultural residues utilized to generate electricity and produce digestate. This will enhance the water quality, biodiversity and ecosystem services of the lake.

Currently, the water hyacinth is collected with three harvesting boats, transported with wheel loaders to the shore and piled up. As the biogas plant would operate at the site, transport is considered to stay similar in the operation scenario and is therefore not part of the impact analysis. The water hyacinth is considered to be carbon neutral.

3.2.1 Mass- and Energy-Balance

The project's mass balance comprises the water hyacinth as input (50,261 t/a). Outputs of the biogas plant are methane (769 t/a), CO_2 (1,478 t/a), water (81 t/a) and digestate (47,933 t/a). There is no recirculation foreseen in the process (Figure 10).

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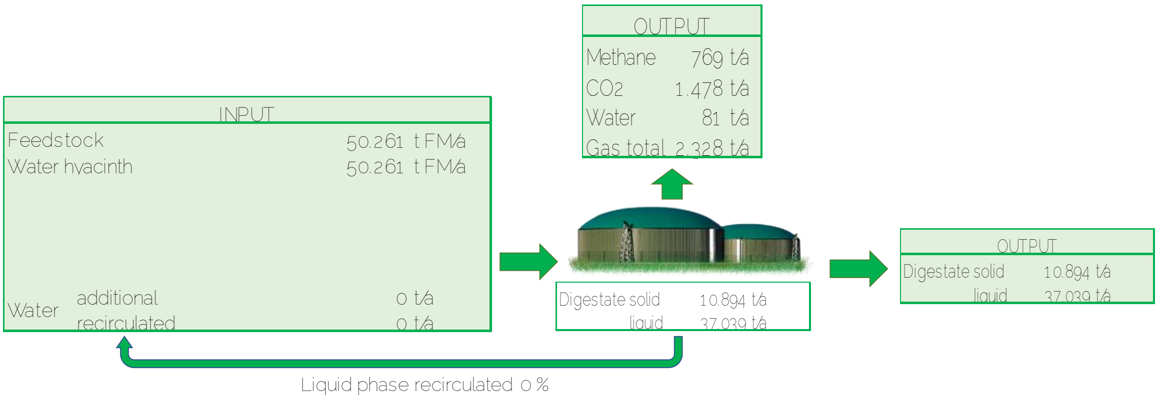

Figure 10: Mass balance, DP Ethiopia, Source: Own representation

The energy balance of the demo project in Ethiopia includes electricity from the grid and heat as input. 28% of the heat are recirculated from the plant. The total energy output is 8.025 MWh per year (Figure 11).

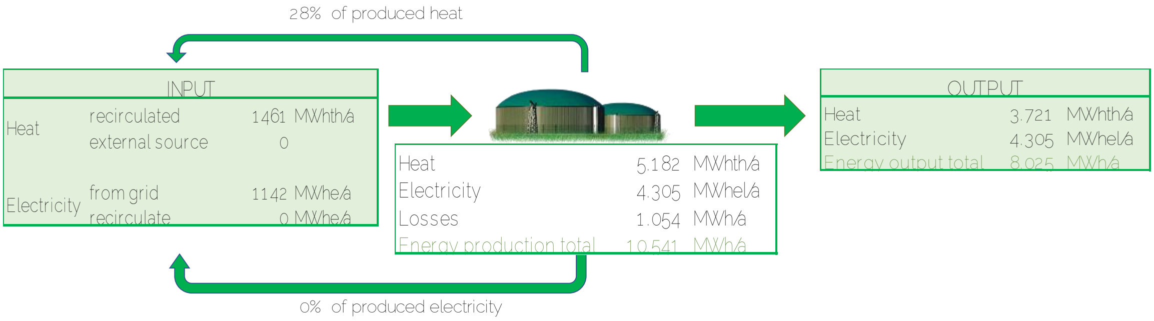

Figure 11: Energy balance, DP Ethiopia, Source: Own representation

3.2.2 Environmental Impact

In the Ethiopian demo project 12 t CO_2eq are avoided due to the substitution of electricity (electricity-mix Ethiopia). Emissions due to the operation of the plant include the CH_4 leakage resulting in 290 t CO_2eq and the electricity used (3 t CO_2eq). In total, the GHG balance results in 281 t CO_2eq additional. This means, that more emissions are inflicted than avoided (Figure 12, Table 7) based on the analysis conducted. However, the analysis does not consider any CH4 emissions released currently in the piles of hyacinth through anaerobic digestions. It is recommended to include this emission reduction potential in more detailed environmental impact assessments.

The harvest of water hyacinth also leads to many positive impacts, as the improvement of water quality, enhanced biodiversity and the provision of ecosystem services, described below. Also, the electricity mix in Ethiopia consists to a large extent of renewable sources from hydro power, thus limiting the potential for GHG-emission reductions through electricity substitution.

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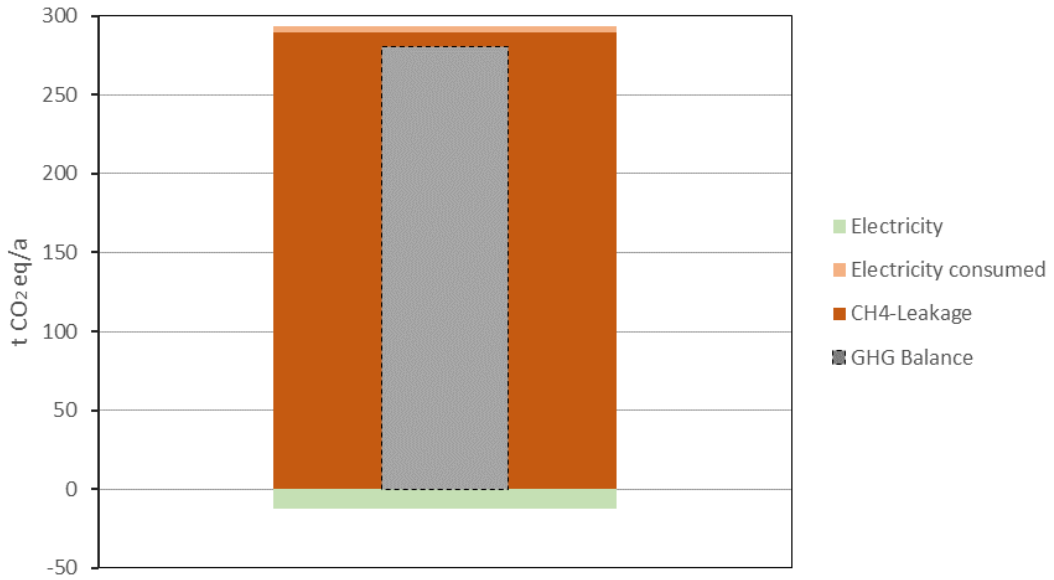

Figure 12: Environmental impact, DP Ethiopia, Source: Own representation

Table 7: Environmental impact, DP Ethiopia, Source: Own representation

Inflicted Emissions	[t CO_2e/a]	Avoided Emissions	[t CO_2e/a]
CH4-Leakage	290	Water hyacinth	-
Electricity consumed	3	Electricity	-12
Sum inflicted emissions	293	Sum avoided emissions	-12
GHG Balance	**281**		

Currently harvested water hyacinth is not used. Instead, it greatly affects the ecosystem of the lake while still expanding day by day. The water hyacinth creates anoxic environmental conditions in the lake, increases the level of toxicity and disease in water bodies, increases mosquito populations, damages ecosystems, affects the function and biodiversity of aquatic ecosystems and fisheries, increases sedimentation and causes increased water loss through evapotranspiration, disrupts irrigation systems[16]. Removing this invasive species has proved futile since they regrow almost immediately. Every year the regional government of Ethiopia spends a huge amount of money and effort to collect the water hyacinth without using it for any other purpose.

Thus, generating biogas has a huge benefit in reducing waste, improving sanitation, reducing the odor effects and above all, it protects the ecosystem of the lake.

Additionally, the substitution of mineral fertilizers with digestate has several benefits; improvement of crop yield, environmentally friendly fertilizer, physically stabilized soil and improved soil through humification, and increase of bacterial and fungal activity in the soil.

[16] Prasetiawan, H., et al. "Study of the water hyacinth extract concentration to the characteristics of gel hand sanitizer." IOP Conference Series: Earth and Environmental Science. Vol. 700. No. 1. IOP Publishing, 2021.

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3.2.3 Economic Impacts

Table 8 shows the potential investments with its domestic and foreign shares.

Table 8: Potential investment volumes for the Ethiopian demo project

Cost item	CAPEX Cost incl. Transport	Domestic	Domestic	Foreign
	[EUR]	[%]	[EUR]	[EUR]
Storage	40 000	100%	40 000	-
Pre-treatment	160 000	50%	80 000	80 000
Feeding system	530 000	10%	53 000	477 000
Digester	770 000	95%	731 500	38 500
Stirring	180 000	0%	-	180 000
Gas storage	50 000	5%	2 500	47 500
Digestate treatment	10 000	50%	5 000	5 000
Digestate storage	230 000	100%	230 000	-
Gas cleaning	503 000	5%	25 150	477 850
Gas upgrading	-	5%	-	-
CHP	300 000	0%	-	300 000
Gas utilization	-	30%	-	-
Transport and installation on site	139 000	100%	139 000	-
Civil Works	194 000	100%	194 000	-
Electrical Works	194 000	100%	194 000	-
Gas Grid Connection Costs	-	100%	-	-
Electrical grid connection costs	10 000	100%	10 000	-
Waste Treatment	-	100%	-	-
Planning, authorization and commissioning	69 500	100%	69 500	-
Land preparation	-	100%	-	-
Land Payment	27 500	100%	27 500	-
Miscellaneous and Contingencies	139 000	100%	139 000	-
Sum	**3 546 000**		**1 940 150**	**1 605 850**

3.2.4 Social Impacts

The reduction of the invasive water hyacinth, affects agricultural production as it smothers aquatic life by deoxygenating the water. This has dramatic implications for the approximately two to three million people who depend on the ecosystem services provided by Lake Tana for their livelihoods, directly or indirectly.

Moreover, the generated energy can be used for several applications: cooking, electric power, or heat generation. The current price increment in the month of June 2022 is 20% compared to the previous month. The price of diesel is 35.43 Ethiopian Birr per liter and the price of octane-95 gasoline is 36.87 Ethiopian Birr per liter.

In general, continuous awareness buildings should be done to include the farmers, the community, the municipality of Bahirdar city and the Ministry of Water and Energy. Without

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creating awareness for the benefits of the project, it will be very difficult to bring a sustainable and long-term change by reducing the water hyacinth coverage in the lake. Through awareness creation, money can be effectively used in collecting the feedstock and in transporting the feedstock to the biogas sites. Those who are living in the surroundings of the lake can also benefit by working in the biogas plant.

More than 95% of the rural population of Ethiopia's is living without access to electricity. The same is true in the rural parts of Bahirdar. Thus, producing biogas from water hyacinth and using the biogas to generate electricity could also benefit the rural community of Bahirdar immensely. Not only the electric power but also the heat can be used for seed drying. At the moment many farmers are facing challenges in drying their seed. Currently, they are using an open drying system. This causes some disadvantages: the drying takes longer, it requires a large surface area, it is uncontrolled and there is the possibility to loose the crops by birds, hens or other animals.

There are many farmers in the proximity of Lake Tana. Most of the farmers are using fertilizer coming from abroad, as Ethiopia does not have large-scale fertilizer producers. In 2015, Ethiopia's fertilizer imports were at its peak in December with 331,000 million tons (about 35% of all 2015 imports). Official reports show that in 2016 Ethiopia has invested $545.23 million. Biogas digestate from water hyacinth can be a high-quality fertilizer and reduce the usage of mineral fertilizers[17]. It is worth mentioning that producing nitrogenous mineral fertilizers is very energy-intensive. Phosphorus and potassium are mined and contain increasingly higher amounts of cadmium and uranium. Thus, the digestate generated from the Biogas system that uses water hyacinth as a feedstock will benefit the farmers immensely. Currently the majority of Ethiopian farmers are suffering due to the shortage of fertilizer due the Russian invasion of Ukraine.

As the selected site for biogas production is near to a farming area, it will reduce the transporting cost of the digestate. Agreements between farmers and the biogas plant operator should be made for long-term win-win solutions of feedstock supply and energy supply. The farmers could supply their agricultural waste and cow dung free of charge for the biogas project operator and in return, they could receive a corresponding quantity of digestate free of charge. It is also highly recommended to separate the digestate in solid and liquid form, as the liquid digestate can be easily pumped. Currently, the digestate spreading process is done manually in Ethiopia. However, as farmers have large areas to cover, it requires a digestate spreading system. Associations could also be established as a business model to receive the digestate from the project owner and sell it to the farmers. Awareness campaigns and capacity building should be done frequently among the farmers to explain, how to use effectively, as well as the benefits of using digestate.

Table 9 shows the number of jobs created/sustained to implement the Ethiopian demo project. Table 10 describes the number of newly created jobs for the operation of the plant according to the skill level (excluding hyacinth collection and transportation).

Table 9: Jobs for the demo project implementation of the Ethiopian demo project for different implementation stages

Development stage	[h]	[FTE]
Feasibility & Development	16640	8,0

[17] https://newbusinessethiopia.com/agribusiness/ethiopia-purchases-1-3-million-metric-tons-fertilizer/

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Construction	79040	38,0
Operation & Maintenance	17140	8,2

Table 10: Jobs by skill level for the operation of the Ethiopian plant

Skill level	[h]	[FTE]
Unskilled worker	10760	5,2
Skilled worker	4300	2,1
Highly skilled worker	2080	1,0

3.3 Ghana

Feedstock: Organic fraction of municipal solid waste

Energy output: 17 GWh/a

The biogas plant will utilize the organic fraction of municipal solid waste together with municipal sludge. Therefore, it will help to sustainably dispose of municipal residues and generate renewable electricity at the same time.

Currently, the mixed municipal waste and the sludge are dumped at a local waste dumping site, which causes greenhouse gases and negative social impacts such as hygiene problems.

Generally, the waste generated in Ghana is disposed in non-sanitary/non-engineered landfill sites without any form of treatment. Unfortunately, the organic fraction of the waste is neither disposed properly nor treated. The organic components, when untreated, often decompose under anaerobic or quasi-anaerobic conditions leading to the emission of greenhouse gases. This is mainly CH_4, and for N-rich mass-flows under semi- or changing anoxic conditions also N_2O. Emissions from the waste sector were estimated to be about 4.5 Mt CO_2 eq in 2012 rising from 1.31 Mt CO_2 eq in 1990. The emissions from the waste sector are a major contributor of GHG emissions, as they contributed about 24% of Ghana's total greenhouse gas emissions excluding emissions from the Agriculture Forestry and Land Use (AFOLU) sector (GoG, 2015). Due to population increase, changing lifestyles and consumption patterns, emissions from waste is expected to double to about 7.2 MtCO_2 eq. by 2040 with business as usual.

In the operation scenario, the organic fraction of the waste is separated, pretreated and utilized in the biogas plant, which produces electricity for the injection in the national grid. The transport distance of the waste to the landfill or the biogas plant are considered to be similar. Therefore, transport is not part of the analysis.

3.3.1 Mass- and Energy Balance

The project's mass balance comprises the organic fraction of municipal solid waste (32,302 t/a), sludge from septic tanks (6,570 t/a) and water as input. Outputs of the biogas plant are methane (1,731 t/a), CO2 (3,117 t/a), water (177 t/a) and digestate (33,847 t/a). 17% of the liquid digestate are recirculated as input (Figure 13).

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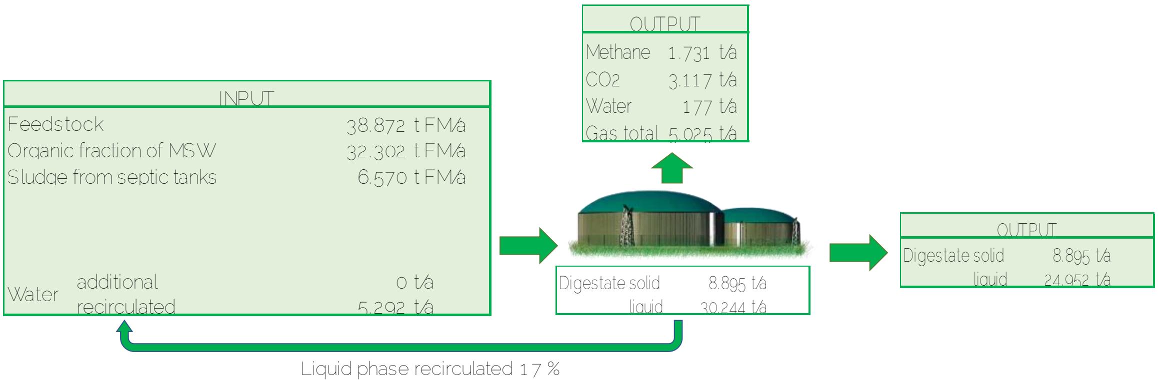

Figure 13: Mass balance, DP Ghana, Source: Own representation

The energy balance of the demo project in Ghana includes electricity from the grid and heat as input. 40% of the heat are recirculated from the plant. The total energy output is 16,914 MWh per year (Figure 14).

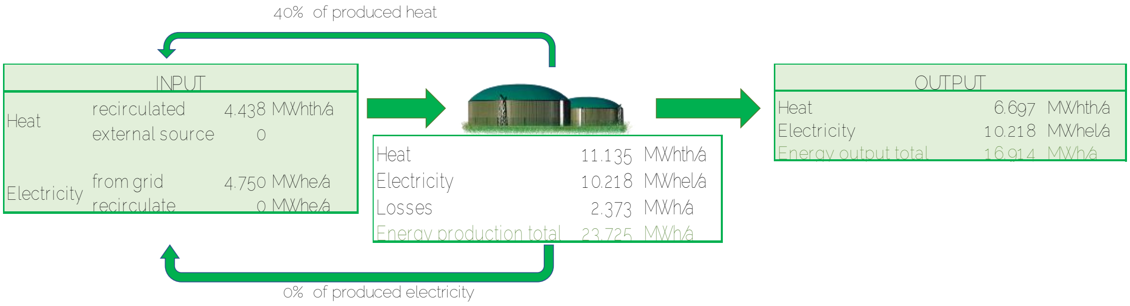

Figure 14: Energy balance, DP Ghana, Source: Own representation

3.3.2 Environmental Impact

In the Ghanian demo project 2.8 kt CO_2eq are avoided due to the substitution of electricity (electricity-mix Ghana). Also, 23.9 kt CO_2eq from waste and 16.8 kt CO_2eq from sludge are avoided as the waste fractions are not dumped on the landfill. Emissions due to the operation of the plant include the CH_4 leakage resulting in 0.7 kt CO_2eq and the electricity used (1.3 kt CO_2eq). In total, the GHG balance results in – 43.5 kt CO_2eq of emission reduction. This means, that more emissions are avoided than inflicted, resulting in a positive impact on the climate (Figure 15, Table 11).

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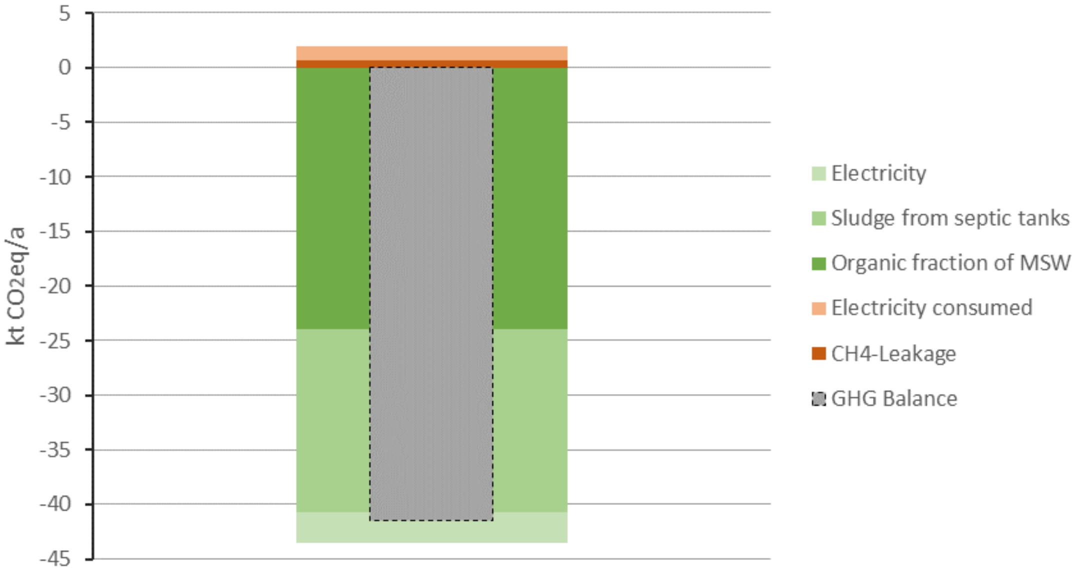

Figure 15: Environmental impact, DP Ghana, Source: Own representation

Table 11: Environmental impact, DP Ghana, Source: Own representation

Inflicted Emissions	[t CO_2e/a]	Avoided Emissions	[t CO_2e/a]
CH4-Leakage	652	Organic fraction of MSW	- 23,903
Electricity consumed	1,309	Sludge from septic tanks	-16,754
		Electricity	-2,816
Sum inflicted emissions	1,961	Sum avoided emissions	-43,473
GHG Balance	**41,512**		

3.3.3 Economic Impacts

Table 12 shows the inflicted potential investments with its domestic and foreign shares.

Table 12: Potential investment volumes for the Ghanean demo project

Cost Item	**CAPEX Cost incl. Transport**	**Domestic**	**Domestic**	**Foreign**
	[EUR]	**[%]**	**[EUR]**	**[EUR]**
Storage	30 000	100%	30 000	-
Pre-treatment	40 000	50%	20 000	20 000
Feeding system	70 000	10%	7 000	63 000
Digester	890 000	95%	845 500	44 500
Stirring	60 000	0%	-	60 000
Gas storage	40 000	5%	2 000	38 000
Digestate treatment	10 000	50%	5 000	5 000
Digestate storage	180 000	100%	180 000	-
Gas cleaning	503 000	5%	25 150	477 850

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Cost Item	CAPEX Cost incl. Transport	Domestic	Domestic	Foreign
	[EUR]	[%]	[EUR]	[EUR]
Gas upgrading	-	5%	-	-
CHP	710 000	0%	-	710 000
Gas utilization	-	30%	-	-
Transport and installation on site	253 000	100%	253 000	-
Civil Works	380 000	100%	380 000	-
Electrical Works	380 000	100%	380 000	-
Gas Grid Connection Costs	-	100%	-	-
Electrical grid connection costs	20 000	100%	20 000	-
Waste Treatment	1 267 000	100%	1 267 000	-
Planning, authorization and commissioning	127 000	100%	127 000	-
Land preparation	101 000	100%	101 000	-
Land Payment	76 000	100%	76 000	-
Miscellaneous and Contingencies	253 000	100%	253 000	-
Sum	**5 390 000**		**3 971 650**	**1 418 350**

3.3.4 Social Impacts

The uncollected waste and waste dumped in open fields and drains pose a huge environmental and health risk. Several flooding incidences in the national capital and other big cities including the proposed project location (Cape Coast) have been attributed to the blockage of storm drains by waste. Additionally, cholera outbreaks in the cities have also been attributed to the lack of proper waste management with diseases linked to poor environmental sanitation responsible for about 70% of out-patient-department (OPD) cases.

On the national scale, the project will initiate to increase Ghana's installed electricity generation capacity, to contribute to the greenhouse gas emission reduction and also to contribute to the achievement of Ghana's renewable energy master plan target.

The proposed project is expected to provide the impetus for accelerated development through the creation of sustainable jobs along the whole value chain especially for indigenes people in the community.

Beside the energy generation, the proposed project will also explore the possibility of dehydrating the digestate from the biogas plant to obtain dry compost, which can be sold as fertilizer to the farming community nearby. Other value additions that will be explored will include biogas upgrading and bottling to be used as a domestic fuel. These will further enhance the efficiency of the plant and make it more economically viable.

Table 13 shows the number of human resources required to implement the project. Table 14 describes the newly created job positions required for the operation of the plant.

Table 13: Jobs for the demo project implementation of the Ghanean demo project for different implementation stages

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Development stage	[h]	[FTE]
Feasibility & Development	40000	19,2
Construction	179000	86,1
Operation & Maintenance	17520	8,4

Table 14: Jobs by skill level for the operation of the Ghanean plant

Skill level		
Unskilled worker	4380	2,1
Skilled worker	8760	4,2
Highly skilled worker	4380	2,1

3.4 Indonesia

Feedstock: Palm oil mill residues

Energy output: 36 GWh/a

The demo-project biogas plant in Indonesia will utilize palm oil production residues to substitute fossil fuel for the production of renewable energy, while reducing the environmental impact from the residues. The feedstock consists of pome, the liquid effluent of the palm oil mill, together with empty fruit bunches, the fibrous residues after the oil extraction.

At the moment, the pome is treated in open lagoons, resulting in significant amounts of methane emissions. The empty fruit bunches are considered as carbon neutral, they are now composted close to the mill. As the plant is located at the mill premises, no additional transport is necessary. This is the reason for transport emissions and jobs not being part of the impact analysis.

3.4.1 Mass- and Energy Balance

The project's mass balance comprises palm oil mill effluent (POME)(109,710 t/a) and empty fruit punches (EFB) (54,855 t/a) as input. Outputs of the biogas plant are methane (2,813 t/a), CO_2 (5,067 t/a), water (287 t/a) and digestate (156,398 t/a). There is no recirculation currently foreseen in the process (Figure 16).

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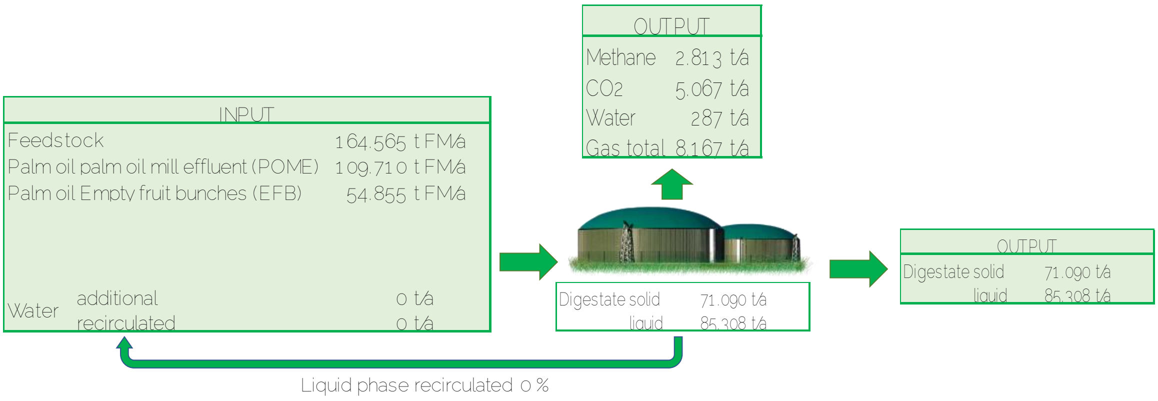

Figure 16: Mass balance, DP Indonesia, Source: Own representation

The energy balance of the demo project in Indonesia includes electricity from the grid and heat as input. 27% of the heat are recirculated from the plant. The total energy output is 29.922 MWh per year (Figure 17).

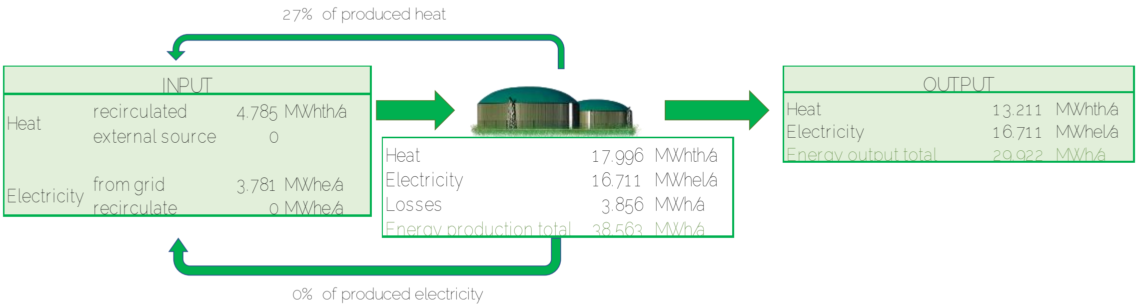

Figure 17: Energy balance, DP Indonesia, Source: Own representation

3.4.2 Environmental Impact

In the Indonesian demo project 11.3 kt CO_2eq are avoided due to the substitution of electricity (electricity-mix Indonesia). Also, 17.6 kt CO_2eq are avoided as the POME is not stored in open lagoons anymore. Emissions due to the operation of the plant include the CH_4 leakage resulting in 1.1 kt CO_2eq and the electricity used (2.6 kt CO_2eq). In total, the GHG balance results in – 25.2 kt CO_2eq. This means, that more emissions are avoided than inflicted, resulting in emission reductions and a positive impact on the climate (Figure 18, Table 15).

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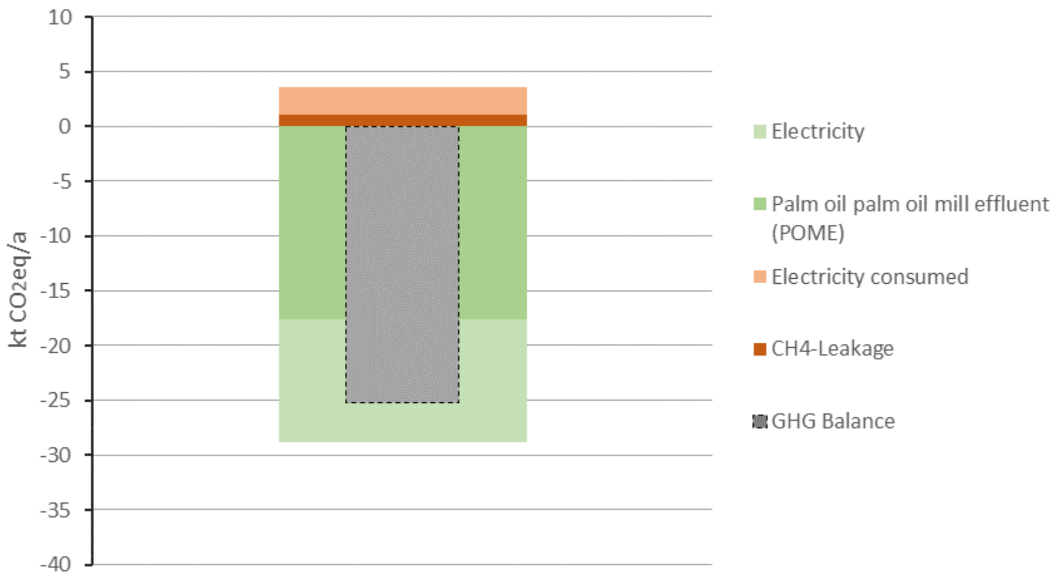

Figure 18: Environmental impact, DP Indonesia, Source: Own representation

Table 15: Environmental impact, DP Indonesia, Source: Own representation

Inflicted Emissions	[t CO_2e/a]	Avoided Emissions	[t CO_2e/a]
CH4-Leakage	1,060	Palm oil palm oil mill effluent (POME)	-17,554
Electricity consumed	2,558	Palm oil Empty fruit bunches (EFB)	-
		Electricity	-11,308
Sum inflicted emissions	3,619	Sum avoided emissions	-28,862
GHG Balance	**-25,243**		

Indonesia is one of the largest producer of palm oil in the world. The palm oil is processed into cooking oil and sometimes into biodiesel. The processing of palm oil produces a lot of waste and by-products and could cause serious damage to the environment. One of these wastes are called Palm Oil Mill Effluent (POME) which is a by-product of oil extraction in palm oil mills and gas a high Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) that can cause serious environmental damage if released directly into waterstreams without treatment[18] (Chin et al., 2013). Fortunately, because of the high organic content of POME, it can be used as a biogas source in the form of methane gas by treating it with a method called anaerobic digestion[19] [20]. Production of biogas from POME can have many benefits, a research

[18] Chin, M. J., Poh, P. E., Tey, B. T., Chan, E. S., & Chin, K. L. (2013). Biogas from palm oil mill effluent (POME): Opportunities and challenges from Malaysia's perspective. Renewable and Sustainable Energy Reviews, 26, 717–726.

[19] Chin, M. J., Poh, P. E., Tey, B. T., Chan, E. S., & Chin, K. L. (2013). Biogas from palm oil mill effluent (POME): Opportunities and challenges from Malaysia's perspective. Renewable and Sustainable Energy Reviews, 26, 717–726.

[20] Harsono, S. S., Grundmann, P., & Siahaan, D. (2015). Role of Biogas and Biochar Palm Oil Residues for Reduction of Greenhouse Gas Emissions in the Biodiesel Production. Energy Procedia, 65, 344–351.

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conducted by Harsono et al.[21] on the effect of biogas production using POME on greenhouse gas (GHG) emission, found that the GHG emitted by POME is reduced from 74.22% of total GHG emission to 33.74% and increases the GHG emissions reduction savings by 63% without including land use change.

Another benefit of the treatment of POME into biogas is that the COD and BOD level of the POME is reduced significantly, Lam & Lee[22] reported that the COD removal efficiency from POME treatment using anaerobic digestion range from 70-97%. Most POME treatment in Indonesia implement the open lagoon technology because of its ease and inexpensive processing and low energy requirements but this method is deemed inefficient and less environmentally friendly[23] [24] than alternatives. Various alternative methods have been proposed to work in tandem with the open lagoon technology in Indonesia using the Life Cycle Assessment (LCA) method. The most promising prosed alternative method for POME treatment in Indonesia involves combining open lagoon technology (COLT) with composting and biogas production. This method is favourable because of its CO_2 emission reduction potential of up to 77.65%, zero eutrophication potential and the production of both electricity and fertilizer[25].

Biogas plants are prone to leakage of the methane gas and CO_2. Moreover, because methane gas is a stronger GHG gas than CO_2, this can cause worse environmental damage than CO_2 emission. Additionally, methane gas is a flammable gas and prone to explosion in enclosed space adding to the risk factor to the biogas plant. This, therefore, increases the requirements regarding safety and causes additionally cost[26] [27].

The land use changes for palm oil plantations and the POME treatment facilities can also impart severe negative consequences to the environment and biodiversity. One of the land use change that is very prominent in Indonesia is clearing or burning of rainforest and peat

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[21] Harsono, S. S., Grundmann, P., & Siahaan, D. (2015). Role of Biogas and Biochar Palm Oil Residues for Reduction of Greenhouse Gas Emissions in the Biodiesel Production. Energy Procedia, 65, 344–351.

[22] Lam, M. K., & Lee, K. T. (2011). Renewable and sustainable bioenergies production from palm oil mill effluent (POME): Win-win strategies toward better environmental protection. Biotechnology Advances, 29(1), 124–141.

[23] Leela, D., & Nur, S. M. (2019). Processing technology POME-pond in Indonesia: A mini review. IOP Conference Series: Earth and Environmental Science, 365(1).

[24] Nasution, M. A., Wibawa, D. S., Ahamed, T., & Noguchi, R. (2018). Comparative environmental impact evaluation of palm oil mill effluent treatment using a life cycle assessment approach: A case study based on composting and a combination for biogas technologies in North Sumatera of Indonesia. Journal of Cleaner Production, 184, 1028–1040.

[25] Nasution, M. A., Wibawa, D. S., Ahamed, T., & Noguchi, R. (2018). Comparative environmental impact evaluation of palm oil mill effluent treatment using a life cycle assessment approach: A case study based on composting and a combination for biogas technologies in North Sumatera of Indonesia. Journal of Cleaner Production, 184, 1028–1040.

[26] Gozan, M., Aulawy, N., Rahman, S. F., & Budiarto, R. (2018). Techno-Economic Analysis of Biogas Power Plant from POME (Palm Oil Mill Effluent) Oil Recovery from Oil Sludge View project Beeswax View project Techno-Economic Analysis of Biogas Power Plant from POME (Palm Oil Mill Effluent). International Journal of Applied Engineering Research, 13(8), 6151–6157.

[27] Obaideen, K., Abdelkareem, M. A., Wilberforce, T., Elsaid, K., Sayed, E. T., Maghrabie, H. M., & Olabi, A. G. (2022). Biogas role in achievement of the sustainable development goals: Evaluation, Challenges, and Guidelines. Journal of the Taiwan Institute of Chemical Engineers, 131, 104207.

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lands for the palm oil plantation[28]. The practice of clearing and burning of the forest causes the release of CO_2 into the atmosphere. Degradation of peat lands can also affect the environment in a negative way because peat lands acts as a carbon sink, and by degrading the peat lands, all the trapped carbon releases into the atmosphere. Furthermore, the rainforest degradation can cause diminishing of wildlife habitat, thus endangering endemic species in the country[29].

3.4.3 Economic Impact

The biogas based palm oil plant is not only beneficial in the environmental sector, but it can also be beneficial for the economy. For example by using biogas conventional cooking gas can be reduced and lighting for residents can be provided, thus potentially saving money. Also, the by-product of biogas production, which is a bio-slurry, can be used as a fertilizer for crops, reducing the need to buy conventional fertilizer. Building a palm oil-based biogas plant can also create job opportunities like plant design, construction workers , operators, and bio-slurry fertilizer producer, which do not require a specific set of skills[30] [31].

A study conducted by Hakim and Valentino[33] on the technical and economical feasibility of POME based biogas for electricity generation, boiler fuel and bio-CNG. The study indicated that POME based biogas is the most profitable scenario with a positive NPV value of IDR 11,474,070,468.00 , IRR percentage of 14.22% and a break-even period of 9 years and 2 month making it the most feasible and profitable out of the three scenario followed by bio-CNG scenario with a positive NPV value of IDR 4,516,065,774.00 , IRR percentage of 11.07% and break even period of 17 years and 5 months and boiler scenario with a positive NPV value of IDR 949,268,291.00 , IRR percentage of 10.60% and break-even period of 11 years and 5 months.

Unfortunately, not all the impact of biogas usage is positive, some impacts can also be negative. Because of the novel nature of palm oil-based biogas plants it can cost a lot of money to operate and often takes a long time to break-even (as mentioned previously), making it a relatively risky investment[34]. The biogas produced by anaerobic digestion also contains impurities. These impurities come for example in the form of CO_2 mixed with the methane gas, thus decreasing its energy density and needs to be purified which can increase cost and effort for some use casesmaking it less feasible to implement[35].

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[28] Wicke, B., Sikkema, R., Dornburg, V., & Faaij, A. (2011). Exploring land use changes and the role of palm oil production in Indonesia and Malaysia. Land Use Policy, 28(1), 193–206.

[29] Mukherjee, I., & Sovacool, B. K. (2014). Palm oil-based biofuels and sustainability in southeast Asia: A review of Indonesia, Malaysia, and Thailand. Renewable and Sustainable Energy Reviews, 37, 1–12.

[30] Harahap, F. I. N. (2018). Dampak pemberdayaan masyarakat melalui program biogas dalam mewujudkan kemandirian energi. JPPM (Jurnal Pendidikan Dan Pemberdayaan Masyarakat).

[31] Hartono, D., & Maharani, J. (2021). The Impact of Biogas Utilization on Poverty in Indonesia. Jurnal Perencanaan Pembangunan: The Indonesian Journal of Development Planning, 5(2), 230–249.

[33] Listrik, P., Boiler, B. B., Hakim, D. L., & Valentino, N. (2019). Tekno Ekonomi Pemanfaatan Biogas Berbasis POME untuk. 18(September), 73–81

[34] Chin, M. J., Poh, P. E., Tey, B. T., Chan, E. S., & Chin, K. L. (2013). Biogas from palm oil mill effluent (POME): Opportunities and challenges from Malaysia's perspective. Renewable and Sustainable Energy Reviews, 26, 717–726.

[35] Obaideen, K., Abdelkareem, M. A., Wilberforce, T., Elsaid, K., Sayed, E. T., Maghrabie, H. M., & Olabi, A. G. (2022). Biogas role in achievement of the sustainable development goals: Evaluation, Challenges, and Guidelines. Journal of the Taiwan Institute of Chemical Engineers, 131, 104207.

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Table 16 shows the estimated, potential investments with its domestic and foreign shares.

Table 16: Potential investment volumes for the Indonesian demo project

	CAPEX Cost incl. Transport	Domestic	Domestic	Foreign
	[EUR]	[%]	[EUR]	[EUR]
Storage	70 000	100%	70 000	-
Pre-treatment	250 000	50%	125 000	125 000
Feeding system	480 000	10%	48 000	432 000
Digester	2 380 000	95%	2 261 000	119 000
Stirring	450 000	0%	-	450 000
Gas storage	150 000	5%	7 500	142 500
Digestate treatment	10 000	50%	5 000	5 000
Digestate storage	230 000	100%	230 000	-
Gas cleaning	503 000	5%	25 150	477 850
Gas upgrading	-	5%	-	-
CHP	1 580 000	0%	-	1 580 000
Gas utilization	-	30%	-	-
Transport and installation on site	610 000	100%	610 000	-
Civil Works	915 000	100%	915 000	-
Electrical Works	915 000	100%	915 000	-
Gas Grid Connection Costs	-	100%	-	-
Electrical grid connection costs	350 000	100%	350 000	-
Waste Treatment	-	100%	-	-
Planning, authorization and commissioning	305 000	100%	305 000	-
Land preparation	244 000	100%	244 000	-
Land Payment	183 000	100%	183 000	-
Miscellaneous and Contingencies	610 000	100%	610 000	-
Sum	**10 235 000**		**6 903 650**	**3 331 350**

In Indonesia, it is mandatory to invest 70% of the total investment in domestic products and services. The investment estimation shows a domestic invest of 67%, so it needs at least 3% more domestic invest to conform with local content rules in Indonesia.

3.4.4 Social Impacts

The biogas based palm oil plant can also impact the social sector. One example is the reduction of poverty by improving the economic sectors. The use of biogas energy for cooking in communal level also provides more time for the women in rural areas that still rely on firewood since they don't have to collect firewood for cooking[36]. The use of the biogas plants

[36] Hartono, D., & Maharani, J. (2021). The Impact of Biogas Utilization on Poverty in Indonesia. Jurnal Perencanaan Pembangunan: The Indonesian Journal of Development Planning, 5(2), 230–249.

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is also believed to improve the local social facilities in the rural area[37]. The usage of biogas can also impact the social sector on a personal level. The people of Kampung Areng, West Java, for example, can benefit from a transfer of knowledge. This transfer of knowledge in turn can educate the people. The use of biogas and biogas products can also increase comfort and security to the people of the village[38].

Table 17 shows the number of jobs required/sustained to implement the project. Table 18 the describes the newly created jobs for the operation of the plant.

Table 17: Jobs for the demo project implementation of the Indonesian demo project for different implementation stages

Jobs	[h]	[FTE]
Feasibility & Development	60000	28,8
Construction	290000	139,4
Operation & Maintenance	21680	10,4

Table 18: Jobs by skill level for the operation of the Indonesian plant

Skill level	[h]	[FTE]
Unskilled worker	2080	1,0
Skilled worker	17520	8,4
Highly skilled worker	2080	1,0

3.5 South Africa

Feedstock: Organic residual waste and wastewater

Energy output: GWh/a

The biogas plant utilizes organic municipal waste, wastewater and crop residues in order to produce bio methane. It will be injected into the local micro gas grid supplying green gas to the surrounding areas.

Currently, the mixed municipal waste and the sewage sludge are dumped at a waste dumping site, which causes greenhouse gases and negative social impacts such as hygiene problems. The crop residues are considered as climate neutral. The transport distance of the waste to the landfill or the biogas plant are considered to be similar. Therefore, transport is not part of the analysis.

South Africa is facing a number of service delivery challenges that are resulting in negative environmental impacts. Much of South Africa's core service delivery infrastructure is ageing,

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[37] Papilo, P., Marimin, Hambali, E., & Sitanggang, I. S. (2018). Sustainability index assessment of palm oil-based bioenergy in Indonesia. Journal of Cleaner Production, 196, 808–820.

[38] Harahap, F. I. N. (2018). Dampak pemberdayaan masyarakat melalui program biogas dalam mewujudkan kemandirian energi. JPPM (Jurnal Pendidikan Dan Pemberdayaan Masyarakat), 5(1), 41–50.

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in some state of disrepair, and functional infrastructure and equipment is often overutilised as a result. In summary:

- Most of South Africa's landfills are poorly managed, often built with no lining, and no gas capture equipment;
- More than half of South Africa's wastewater treatment works (WWTW) are in poor or critical condition, with 75% of municipal wastewater treatment works achieving less than 50% compliance to minimum effluent standards in 2020[39]
- In addition to the poor state of WWTWs, it is not uncommon to find raw sewage flowing through the streets, particularly in informal and low income settlements;
- Approximately 80% of South Africa's power is generated from coal, often using low(er) grade coal;
- The poor management of the power generation stock is well documented and illustrated by the continuous load shedding the country has experienced since 2008, with additional problems often caused by ageing transmission and distribution equipment.

3.5.1 Mass- and Energy Balance

The project's mass balance comprises the organic fraction of municipal solid waste (MSW; 7,300 t/a), concentrated sewage sludge (14,600 t/a), crop residues (7,300 t/a) and chicken manure (7,300) as input. Outputs of the biogas plant are methane (1,287 t/a), CO_2 (2,825 t/a), water (143 t/a), solid digestate (6,499 t/a) and liquid digestate (22,096). There is no recirculation foreseen in the process (Figure 19).

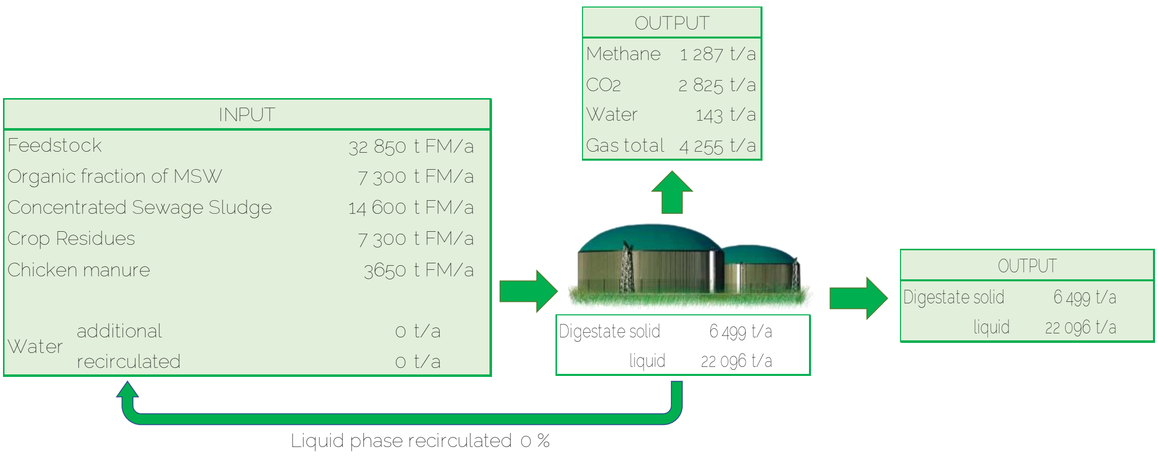

Figure 19: Mass balance, DP South Africa, Source: Own representation

The energy balance of the demo project in South Africa includes electricity from the grid and heat as input. 20% of the biogas are recirculated from the plant. The total energy output is 14,669 MWh per year (Figure 20).

[39] Daily Maverick. (26. April 2021). South Africa's rivers of sewage: More than half of SA's treatment works are failing. Von Daily Maverick: https://www.dailymaverick.co.za/article/2021-04-26-south-africas-rivers-of-sewage-more-than-half-of-sas-treatment-works-are-failing/ abgerufen

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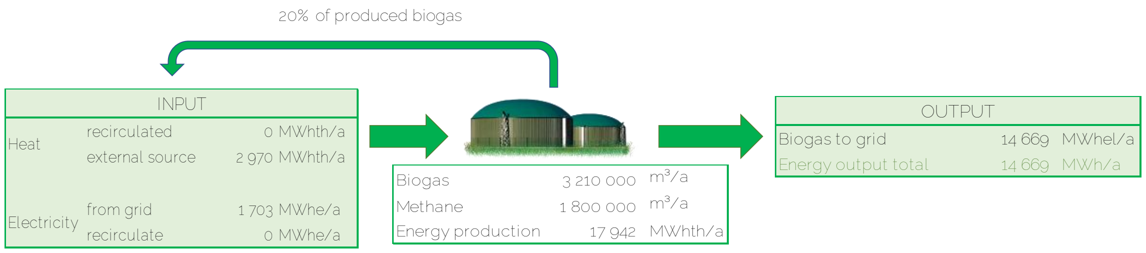

Figure 20: Energy balance, DP South Africa, Source: Own representation

3.5.2 Environmental Impact

In the South African demo project 3.3 kt CO_2eq are avoided due to the substitution of fuel. In addition, 5.4 kt CO_2eq from waste, 7.2 kt CO_2eq from sewage sludge and 1.6 kt CO_2eq from chicken manure are avoided as the fractions are not dumped on the landfill. Emissions due to the operation of the plant include the CH_4 leakage resulting in 0.5 kt CO_2eq and the electricity used 1.5 kt CO_2eq. In total, the GHG balance results in – 17.5 kt CO_2eq. This means, that more emissions are avoided than inflicted, resulting in emission reductions and a positive impact on the climate (Figure 21,).

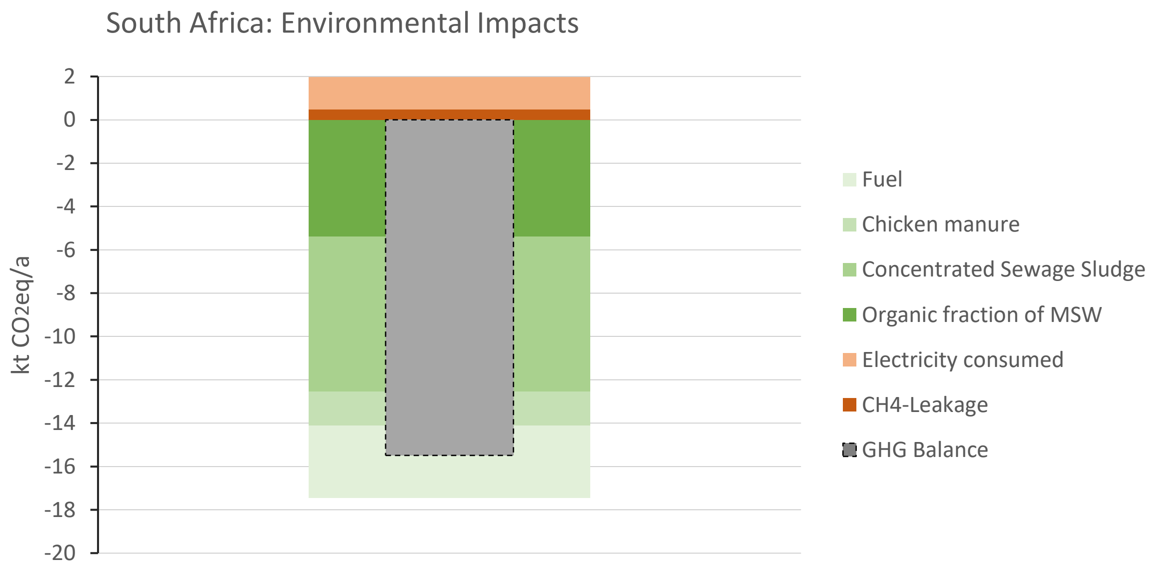

Figure 21: Environmental impact, DP South Africa, Source: Own representation

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Table 19: Environmental impact, DP South Africa, Source: Own representation

Inflicted Emissions	[t CO2e/a]	Avoided Emissions	[t CO2e/a]
CH4-Leakage	485	Organic fraction of MSW	- 5,402
Electricity consumed	1,480	Concentrated Sewage Sludge	- 7,154
		Chicken manure	- 1,570
		Fuel	- 3,330
Sum inflicted	1,965	Sum avoided	- 17,455
GHG Balance	**15,491**		

The Lanseria Biogas Project can provide positive environmental benefits, as well as allevate some of the socio-economic challenges that have become commonplace in South Africa. The positive outputs include the following:

- By substituting fossil fuels for energy generation, as well as avoiding emissions from disposal of organic waste, the project will result in a reduction of GHG emissions of 17,455 t CO_2eq per annum.
- A reduction in environmental emissions and degradation due to diversion of both solid waste and sewage sludge from landfill;
- A shift away from grid energy/electricity, which is still heavily biased towards coal and gas as energy sources (with Eskom – the power generation utility – contributing 38% of the country's GHG emissions in 2017[40])
- Provision of a more reliable and regular solution for waste and sewerage management, as many developments in South Africa still depend on the use of ageing infrastructure (in terms of landfill, wastewater treatment plants as well as energy/power generation plants);
- Although the development is targeted at middle income households, the area is in close proximity to low-middle income areas, where service delivery is often challenging and protests against poor service delivery are not uncommon;
- The project provides a solution for the treatment of organic waste, which will reduce the level (and impact) of illegal dumping in the area, and associated vermin (rats etc).

3.5.3 Economic Impact

With the high unemployment rate in South Africa (34.5% in the 1st quarter of 2022), the Lanseria Biogas Project will provide at least 4 permanent (direct) jobs, and 20 development/construction jobs. In addition, the sludge from the biogas project can be further used to support the development of urban farming within the new housing development, further contributing positively to job creation and economic growth, at the same time reducing reliance on fossil fuel based fertilizers.

Table 20 shows the potential investments with its domestic and foreign shares.

[40] Department of Forestry, Fisheries and the Environment. (2017). National GHG Inventory Report: South Africa.

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Table 20: Potential investment volumes for the South African demo project

Cost Item	CAPEX Cost Incl Transport	Domestic	Domestic	Foreign
	[EUR]	[%]	[EUR]	[EUR]
Storage	30 000	0%	-	30 000
Pre-treatment	90 000	0%	-	90 000
Feeding system	110 000	0%	-	110 000
Digester	770 000	0%	-	770 000
Stirring	60 000	0%	-	60 000
Gas storage	90 000	0%	-	90 000
Digestate treatment	10 000	0%	-	10 000
Digestate storage	130 000	0%	-	130 000
Gas cleaning	503 000	0%	-	503 000
Gas upgrading	-	0%	-	-
CHP	-	0%	-	-
Gas utilization	220 000	0%	-	220 000
Transport and installation on site	201 000	100%	201 000	-
Civil Works	302 000	100%	302 000	-
Electrical Works	302 000	100%	302 000	-
Gas Grid Connection Costs	-	100%	-	-
Electrical grid connection costs	-	100%	-	-
Waste Treatment	342 000	80%	273 600	68 400
Planning, authorization and commissioning	101 000	100%	101 000	-
Land preparation	81 000	100%	81 000	-
Land Payment	60 000	100%	60 000	-
Miscelleaneous and Contingencies	201 000	100%	201 000	-
Sum	**3 603 000**		**1 521 600**	**2 081 400**

3.5.4 Social Impact

Being a new project of its type and scale, the success of this project can lead to a possible template for future residential (and possibly even industrial and commercial) developments. The planning phase will include looking at more sustainable operations, including local solutions such as the wastewater treatment model that form the basis for the Lanseria Biogas project and local energy and waste management solutions. This can reducethe reliance on increasingly under pressure, and inconsistent municipal systems. In addition to reducing negative environmental impacts, such projects have great potential for local economic development and job creation, including supporting secondary/ancilliary value chains such as urban agriculture.

Table 21 shows the number of jobs required to implement the project. Table 22 describes the number of newly created jobs for the operation of the plant.

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Table 21: Jobs for the demo project implementation of the South African demo project for different implementation stag-es

Development stage	[h]	[FTE]
Feasibility & Development	29000	13,9
Construction	133000	63,9
Operation & Maintenance	700	0,3

Table 22: Jobs by skill level for the operation of the South African plant

Skill level	[h]	[FTE]
Unskilled worker	0	0,0
Skilled worker	500	0,2
Highly skilled worker	200	0,1

The biogas plant will be attached to a wastewater treatment plant and the major work force can cover these activities additionally, so the additional jobs created by the biogas plant plant are low.

3.6 Comparison of the demo projects

Figure 22 provides an overview of the GHG balances of all demo projects. Four of five projects lead to negative GHG balances and therefore avoid emissions (compared to current baseline scenario). Also, the Ethiopian demo project leads to overall positive environmental impacts, as the invasive water hyacinth is reduced, although the project can cause minor GHG emissions according to the preliminary analysis conducted.

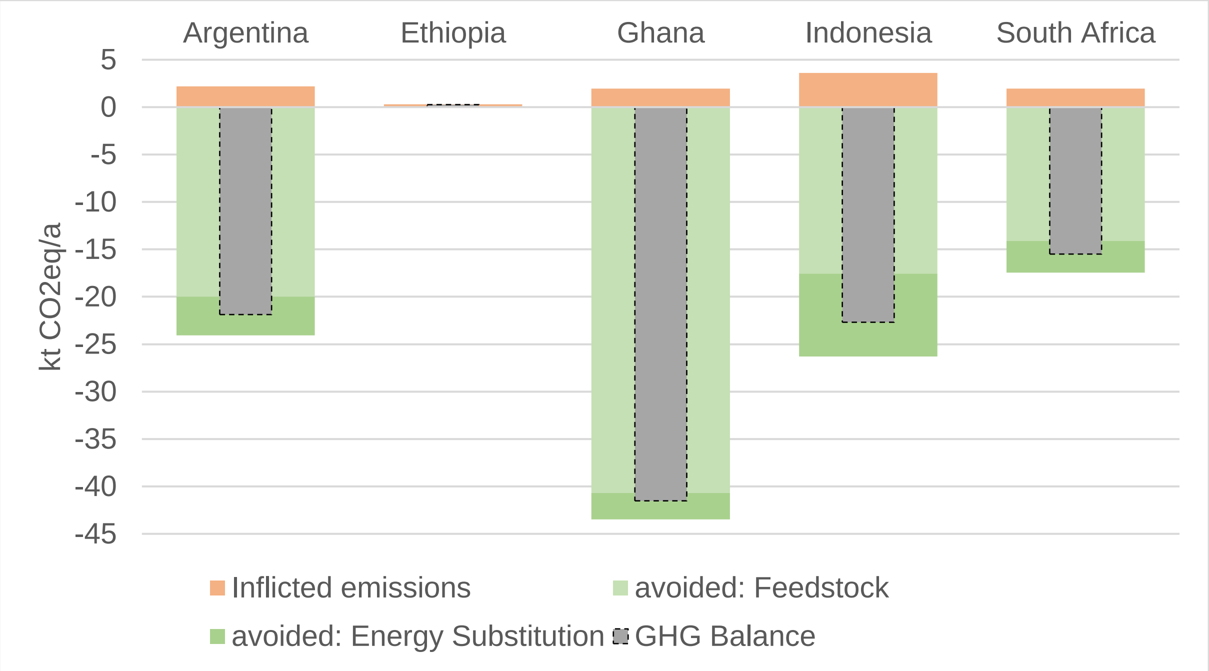

Figure 22: Environmental impact of the demo projects, Source: Own representation

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4 Technical Standards

The biogas sector is growing worldwide. With the development of biogas plants, it becomes increasingly important to establish technical standards to support the overall development, safety, reliability and sustainability.

During a country's early stage of developing biogas structures, there may be regulations for industrial standards (e.g. for approval, electricity connection, pipes for liquids or gas, membranes, valves, concrete, labour regulations and many more) but often no specific regulations adapted for biogas plants.

Usually, those general laws do not cover specifications for the safe construction and operation of biogas plants, but are for other technologies, e.g. gas or electrical installations. For biogas plants, though, this does not really suffice. The adaption of an existing legal framework to biogas plants specific circumstances is one important aspect to enable the development of a healthy biogas sector and safe operation.

Another reason for establishing standards is to ensure the quality of an installation. For a potential biogas plant customer it is usually extremely difficult to judge the quality of offers submitted by biogas plant providers. Standards can help to ensure that offers maintain a certain quality level. The avoidance of hazards and environmental damage is another aspect of quality.

For the biogas sector, social acceptance is crucial. Acceptance takes effect in governmental support systems (e.g. for renewable energy) and the neighbourhood (local people support or prevent an installation), but also in the overall image of biogas: each plant out of order, having technical problems, or each hazard is problematic.

Standards can help to ensure technically reliable, safe and environmentally friendly biogas installations.

4.1 What are standards?

The internationally most acknowledged organisation, working on standards is the International Organization for Standardization, ISO[41].

ISO is defining standards as following:

“ISO standards are internationally agreed by experts.” Think of them as a formula that describes the best way of doing something. It could be about making a product, managing a process, delivering a service or supplying materials – standards cover a huge range of activities. Standards are the distilled wisdom of people with expertise in their subject matter and who know the needs of the organizations they represent – people such as manufacturers, sellers, buyers, customers, trade associations, users or regulators.”

The naming of standards is sometimes used in different ways. Sometimes similar documents are called code of practice. Additionally, there are many other forms of regulations, laws, directive, etc., which supplement standards.

One important aspect is that a biogas stakeholder (manufacturer, constructer, operator etc.) must follow local legislation, which might be laws, ordinances or directives.

Keeping to regulations, technical rules and some standards is often not obligatory but recommendable.

[41] https://www.iso.org/home.html

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However, some legislation demand to apply technical rules or standards. In that case the stakeholder must keep to them because they become legislative binding.

4.2 Importance of standards for biogas industry

It is typical for an emerging sector, that at the beginning, some mistakes are made and the biogas stakeholders learn from practice. Currently we have the situation that several countries gained experiences for several decades, while in other countries biogas plants are relatively new and the experiences in practice is low. These countries can learn from the experienced ones and should avoid making similar mistakes, to maintain biogas plants that must be safe, environmentally friendly and offer long-term reliability of operation.

4.2.1 Reliable operation

Biogas plants can be operated for decades. However, many experiences worldwide show that the installed quality of biogas plants varies a lot. Some installations work for many years if professional maintenance is done. Other installations are of bad quality, the components do not work properly together or components break after some months or years of operation. In a biogas plant, many parts must constrain heavy mechanical stress, like stirrers, feedstock preparation or pumps. If those components are not made in a very robust way and are well adapted to the technical purpose, the operator will face severe problems.

For a customer, e.g. a farmer with a high feedstock potential for a biogas plant, it is very difficult but extremely important to judge the different qualities of offered biogas plants. Standards are an important tool to ensure at least some evidence for the quality of biogas plants.

4.2.2 Safety

There are several potential sources of hazards in biogas plant operation. Methane for example, a flammable and potential explosive gas, is produced. Unfortunately, there have been several accidents with many injured or even deceased persons. This has to be avoided at any cost and it is well known how biogas plants can be operated safely. The key factors here are knowledge and awareness. Often biogas plants can be operated much safer with relatively low effort. More detailed information can be seen in this brochure[42].

Standards can help to ensure that a biogas plant operates safe.

4.2.3 Environment

Biogas plants must be environmentally friendly. In many countries the development of the biogas sector is supported, because of its environmental advantage. The biogas sector must ensure that the biogas plants are environmentally friendly, or otherwise they might cause an environmental damage and lose the support.

There are at least two main aspects of potential environmental damage of biogas plants:

- Methane emissions have a huge greenhouse gas (GHG) potential, which is much more effective compared to carbon dioxide - depending on the considered period about 25 times higher than CO_2[43]. Methane emissions must be limited as good as possible!

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[42] https://www.biogas.org/edcom/webfvb.nsf/id/DE-biogas-safety_eng

[43] IPCC 4th Report (2007)

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- Liquids, e.g. content of the digester and storages, leaching out and getting into the environment may cause at least two problems:
    - Nutrient rich material flows into water bodies and leads to heavy eutrophication. The effect might be the growth of algae or water plants, which leads to oxygen deficit and dying water fauna like dead fish.
    - Leakage into the ground might have a negative influence on the groundwater. Nitrogen in the leachate for example can lead to higher nitrate and nitrite charges in the ground water.

Standards can help to ensure that a biogas plant can be operated environmentally friendly.

4.3 International biogas standards

Over the past decades, the biogas sector has developed significantly worldwide. Depending on the region and the legal framework, the dissemination of biogas plants is very different. Particularly in countries with ambitious expansion rates like Germany, France, UK, China, etc., extensive standardization was an effect. These developments raised the necessity of applicable standards. This led to activities in the International Organization for Standardization (ISO) and the foundation of ISO TC 255 in 2010. In addition, within the European Union (EU), biogas technology is discussed thoroughly and the number of directives and regulations on the subject is increasing.

4.3.1 ISO Standards

At the international level, there are various activities in the field of standardization of biogas technology. The most important organization for international standardization, except for the electrical/electronics sector, is ISO with over 162 member countries and national standardization organizations.

Currently, ISO has published over 22,677 standards, which can be obtained on the ISO website. The topics of the standards range from standards in the field of textile production to pipe connections, data formats, tools, medical products and now, also biogas technique.

In 2010, the Technical Committee TC 255 was established with the aim to develop standards for the field of biogas produced by anaerobic digestion, gasification from biomass and power to gas from biomass sources.

In recent years, various working groups and standards have been set up. Below is an overview of the standards that have been published or are currently being developed:

- ISO 20675: 2018 (Biogas -- Biogas production, conditioning, upgrading, and utilization -- Terms, definitions, and classification scheme) – published
- ISO 24252 (Biogas systems — Non-household and non-gasification) – published
- ISO/DIS 22580 (Flares for combustion of biogas) - published
- ISO/AWI TR 23585 (Safety and Environment Guidelines for Biogas) - under development
- ISO/AWI 23590 (Household Biogas System Requirements) – published

For the biogas sector ISO 24252, Biogas systems, is the most important standard. It was finally published 2021.

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Other Technical Committees also deal with biogas, such as ISO TC 147, where standards on water quality are developed:

- ISO 11734: Water quality - Evaluation of the "ultimate" anaerobic biodegradability of organic compounds in digested sludge - Method by measurement of the biogas production

Further information on the ISO TC 255 can be found here

4.4 European biogas standards

4.4.1 European legislation

Due to the strong development of the biogas sector in Europe, legal frameworks were developed and are briefly described as guidance for legislative frameworks for other countries/regions. The European Commission is still increasingly regulating more details regarding the planning, construction and operation of biogas plants (e.g. MCP Directive) and providing guidelines for the future development of biogas plants in the context of the European energy transition (e.g. Renewable Energy Directive, RED II Directive). General principles for work and plant safety, hygiene, fertilization, electricity and biogas feed-in, emission reduction and energy policy are regulated in other EU directives and must then be implemented promptly in national laws, ordinances and standards. The following is a selection of some important key directives:

- Directive on explosive atmospheres, ATEX 2014/34
- Best available techniques 2018/1147
- EU directive on hazards 2012/18
- Regulation Nr. 1069/2009 on hygiene
- EU Fertilizers Regulation Reg. (EC) No2019/1009: regulates the classification, registration, and labelling of fertilizers (new version in 2022)
- REACH regulation (2006/1907) about Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)
- CLP regulation /2008/1272) on classification, labelling and packaging of substances and mixtures
- Nitrates Directive (91/676/EEC): concerns the protection of waters against pollution caused by nitrates from agricultural sources, mainly from fertilization
- Water framework directive (2000/60/EC): Establishes a water policy within the European Union for a more consistent orientation on sustainable and environmentally compatible use of water
- Directive 2004/8/EC: on the promotion of cogeneration
- MCP directive 2015/2193 on the limitation of emissions of certain pollutants into the air from medium combustion plants
- Regulation (EU) 2019/288 establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy

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- EMIR: European Market Infrastructure Regulation: establishes requirements on OTC derivatives
- REMIT (EU) 1227/2011): Regulation on Whole-sale Energy Market Integrity and Transparency

4.4.2 European Norms

There are many norms in Europe, which touch the biogas sector. Several norms are accepted in or transferred to some countries but not necessarily in all. However, there is such a huge number of norms, describing them would exceed the scope of this document.

4.5 National standards, example Germany

In this chapter, the standards on country level are described. Germany was chosen as example, because the biogas sector developed very much in the last decades accompanied by the development of standards. Currently about 9,500 large sized biogas plants are in operation, several hundred since more than 20 years.

The strong growth in new biogas plants brought also numerous hazards and damaging events as well as increasingly more complex technical status of the plants. These factors were the trigger for further activities in the development of standards in the field of biogas.

Biogas plants were regularly part of extensive laws and regulations, but not the focus. The first real biogas standard was the “Safety Rules for Biogas Plants”. At the same time, the associations in the wastewater sector had already developed further requirements for wastewater treatment plants in their own regulations (ATV regulations).

From the very beginning, the German Biogas Association “Fachverband Biogas e.V.”, has intensively observed and technically accompanied all developments of regulations, regardless of their origin. Volunteer members organize themselves in the association and are supported by the professional support of full-time employees. In other words, working groups are developed within the association to deal with special topics and discussions. New standards are reviewed, commented on and practical solutions provided in hearings and discussions. This information is then made available partly exclusively to the members of the association, partly public available.

Whereas at the beginning of the biogas development mainly national standards were relevant, activities at European and international level (ISO-TC 255) are increasingly gaining importance and must be afterward concretized in national law.

Due to the different jurisdictions of federal and state ministries in Germany, there is a multitude of laws, ordinances, technical regulations, and standards related to biogas, but not exclusively. Additionally, various associations concerned with the subject of biogas also draw up standards (DIN; VDI; DWA, DVGW; VDE, etc.[44]). The result is a hardly manageable abundance of national standards that urgently need to be integrated.

[44] DIN, Deutsches Institut für Normung (German Institute for Standardisation)

VDI, Verein Deutscher Ingenieure (German Society of Engineers)

DWA, Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V. (DWA, German Association for Water, Wastewater and Waste)

DVGW, Deutsche Verein des Gas- und Wasserfaches (German Association of the Gas and Water Industry)

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The increasing complexity also leads to numerous application issues in the practice. In addition, to the recurring question as to which standard or requirement applies to the respective plants, the enforcement authorities lack the necessary resources to implement the complex framework of standards on the plants. Due to many existing biogas plants, the experience gained in their operation, and the occurrence of some unfortunate accidents, more and more complex regulations are implemented.

Based on this experience, it is recommendable for countries with an emerging biogas sector to integrate all standards into a collection in order to avoid overlaps, contradictory definitions, and responsibility problems as well as application issues in the practice.

In Germany, standards and requirements for biogas plants can be developed at different hierarchical levels and published with very different binding force and complexity. Figure 23 is a legal pyramid showing the corresponding hierarchies:

Figure 23: Law pyramid in Germany

A special feature of the law pyramid is that the details and complexity increase from top to bottom, as does the possibility of adapting the requirements to new findings. For the biogas sector, this means that biogas plants are often not explicitly subject to standards and requirements at EU and federal level, but these must be transferred to the particularities of biogas at a lower level of the pyramid. At the national level, this is partly done by means of ordinances that specify higher-level laws for specific sectors. The ordinances can be made even more concrete by means of special technical regulations. In recent years, this has been the case for biogas plants in particular, with the creation of the following technical rules:

- TRwS 793: Technical rule for substances hazardous to waters (TRwS) - Biogas plants - Part 1: Construction and operation with fermentation substrates of agricultural origin - Draft (August 2017)
- TRGS 529: Technical rule for hazardous substances - Activities in the production of biogas - (2015)

These technical regulations have the so-called "presumption effect". This means that if the requirements specified therein are complied with, the general requirements of the relevant ordinance or law are also complied with.

VDE, Verband der Elektrotechnik Elektronik Informationstechnik e.V. (Association for Electrical Engeneering, Electronics, Information Technology)

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As explained before, in addition to these standards and rules from the legislator, several other associations also publish technical rules. These standards rarely have a presumption of conformity. However, the requirements of these standards must be explicitly regulated in the corresponding law, ordinance, etc. For example, the Energy Industry Act (EnWG) states that the DVGW regulations explicitly apply to the generation and operation of biomethane plants in Germany.

Technical regulations and standards from associations and other interest groups are then added at a further hierarchical level. In many cases, these standards are drawn up with precisely specified work processes or public involvement in order to obtain the status of "state of the art" or "generally recognized state of the art". These types of standards can but do not have to, be complied with in every case.

Depending on the size and legal classification of the biogas plants, certain standards and the state of the art must be adhered to automatically or these plants would have to be regularly adapted to the changing requirements. This is reviewed by the responsible enforcement authority and required for the corresponding permit. In the case of technical regulations requirements, it can be deviated from them, if at least an equivalent solution is used within the framework of expert opinion (expert in accordance with §29b of the Federal Emission Control Act - BImSchG).

Due to the numerous connections biogas plants have to other areas like agriculture, waste, emissions, safety, plant construction, electricity and gas production, occupational safety, water protection, among others; they are allocated to different jurisdiction at the federal, state and district level. This results in numerous and sometimes overlapping requirements and standards.

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5 Conclusion

Biogas can have a variety of technical, economic, social and environmental impacts. It can provide access to modern energy services in communities that do not have this access at the moment, or it can substitute fossil fuels. It causes investments benefitting the national and local economy. It creates additional jobs and can give communities new opportunities for stable incomes. With proper capacity building efforts, the local communities can gain experience and expertise in the handling of biogas products (e.g. electricity, digestate as fertilizer), and thus strengthen resilience. Biogas plants can have huge positive impacts on the environment due to the collection and proper treatment of wastes, as well as through reducing significant emissions from improper disposal. This may also reduce the health hazards for the local communities. For all of these potential positive impacts to manifest, proper implementation and operation of biogas plants is necessary. To prevent negative impacts such as methane leakage, explosion hazards, leachate of organic liquids, proper technical systems are necessary. For reliable operation, suitable technologies are crucial. Cooperation of European technology provider with local project developer can transfer existing expertise and help to ensure high quality implementation of biogas projects with reliable, long-term operation and minimized hazards to the human health and the environment. With this, biogas can help to tackle the huge challenges like sustainable energy production and proper waste management.

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6 DiBiCoo Consortium Partners

Coordinator

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Partners from exporting countries

WIP RENEWABLE ENERGIES

AUSTRIAN ENERGY AGENCY

EBA European Biogas Association

kompost & biogas verband

Fachverband BIOGAS German Biogas Association

Latvia University of Life Sciences and Technologies

Partners from importing countries

INTA Instituto Nacional de Tecnologia Agropecuaria

SELECTRA WASTE • WATER • BIOENERGY

iceaddis innovation . collaboration . entrepreneurship

GreenCape

rdi Resilience Development Initiative

SEES INSTITUTE FOR SUSTAINABLE ENERGY AND ENVIRONMENTAL SOLUTIONS

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Digital global Biogas Cooperation

Digital global Biogas Cooperation

Project website: www.dibicoo.org

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