Environmental Product Declaration

Otelfingen Kompogas Facility | Update 2018

Valid until 12 September 2021
EPD registration number S-P-00176
Date of publication 24 August 2009
Revision number v. 4.0

Summary

Company

Axpo Kompogas AG has become a global player in energy recovery via dry fermentation of organic wastes and biogenous materials. Axpo Kompogas AG is fully consolidated within the Axpo group. The fermentation of biomass with the Kompogas process and subsequent conversion of raw biogas into electricity is an important pillar in the strategy of renewable energy generation of Axpo, which is among the leading producers of renewable energy in Switzerland.

Product and declared unit

In the Otelfingen Kompogas facility, approximately 13 000 tonnes of biowaste are treated annually producing 1.7 GWh electricity – among other products – through anaerobic thermophilic fermentation. The declared products in the reference year 2017 are:

- 1 tonne of biowaste treated
- 1 kWh of net electricity generated and thereafter distributed to a customer connected to the local distribution network
- 1 kWh of heat generated
- 1 tonne of liquid fertilizer (press water) produced and thereafter distributed and applied in agriculture
- 1 tonne of solid fertilizer (residue) produced and thereafter distributed and applied in agriculture

The environmental burdens of the Kompogas process are allocated on the products based to their prices in 2017.

The International EPD® System

The International EPD® System managed by EPD International AB is a Type III environmental declaration programme according to ISO 14025. The relevant governing documents in hierarchical order are Product Category Rules for the product groups electricity, steam and hot/cold water generation (UN-CPC groups 171 and 173), General Programme Instructions for environmental product declaration (EPD), ISO 14025 and ISO 14044.

Verification of the presented results

The complete material presented in this EPD® has been reviewed and certified by the accredited certification body Bureau Veritas Certification, Sweden.

Environmental impact of Otelfingen Kompogas facility

The life cycle assessment methodology has been applied to quantify the environmental impact. It comprises the full life cycle of biomass treatment and associated processes from "cradle to grave". The main results are summarized in the table below. Results for other products and further environmental indicators also covering resource depletion and emissions are shown in the EPD®.

Environmental impact	Unit	1 tonne biowaste treated at Kompogas plant	1 kWh net electricity at Kompogas plant
Greenhouse gases	g CO_2-equivalents	$9.57 \cdot 10^{4}$	$1.01 \cdot 10^{2}$
Ozone-depleting gases	g CFC-11-equivalents	$1.73 \cdot 10^{-3}$	$1.77 \cdot 10^{-6}$
Formation of ground-level ozone	g ethylene-equivalents	$1.56 \cdot 10^{3}$	1.64
Acidifying substances	g SO_2-equivalents	$3.22 \cdot 10^{2}$	1.43
Eutrophying substances	g PO_4^{3-}-equivalents	$6.20 \cdot 10^{1}$	$2.67 \cdot 10^{-1}$
Depletion of fossil resources	MJ-equivalents	$3.03 \cdot 10^{2}$	$3.10 \cdot 10^{-1}$

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1 Introduction

1.1 The declared products

This document constitutes the certified Environmental Product Declaration EPD® of the Otelfingen Kompogas biomass fermentation plant. The plant is operated by Axpo Kompogas AG.

The declared products are (reference year is 2017):

- 1 tonne of biowaste treated.
- 1 kWh of net electricity generated and thereafter distributed to a customer connected to the local distribution network.
- 1 kWh of heat generated.
- 1 tonne of liquid fertilizer (press water) produced and thereafter distributed and applied in agriculture.
- 1 tonne of solid fertilizer (residue) generated and thereafter distributed and applied in agriculture.

Axpo is one of the leading renewable energy producers in Switzerland. The fermentation of biomass in the Kompogas process that produces raw gas used to power a cogenerator unit is an important pillar of the Axpo strategy to develop renewable energy resources.

1.2 The Environmental Product Declaration and the International EPD® System

The primary purpose of the International EPD® System is to support companies in the assessment and publication of the environmental performance of their products and services so that they will be credible and understandable by:

- offering a complete programme for any interested organisation in any country to develop and communicate EPDs according to ISO 14025,
- supporting other EPD programmes (i.e. national, sectorial, etc.) in seeking cooperation and harmonisation and helping organisations to broaden the use of their EPDs advantageously on the international market.

This Environmental Product Declaration conforms to the standards of the International EPD Programme, www.environdec.com. EDP® is a system for the international application of Type III environmental declarations conforming to ISO 14025 standards. The International EPD® System and its applications are described in the general programme instructions. The foundational documents for the EPD® System are in order of hierarchical importance:

- Product Category Rules, UN-CPC 171 and 173 (Product Category Rules for preparing an Environmental Product Declaration for Electricity, Steam, and Hot and Cold Water Generation and Distribution), Version 3.0
- General Programme Instructions for Environmental Product Declarations, EPD, Version 2.5
- ISO 14025 for Type III environmental declarations
- ISO 14040 and ISO 14044 for Life Cycle Assessment (LCA)

This EPD® contains an environmental performance declaration based on life cycle assessment. Additional environmental information is presented in accordance with the PCR:

- Information on land use and transformation based on a categorisation according to CORINE[1] Land Cover Classes
- Information on biodiversity
- Information about odour emissions
- Information about relevant risks
- Information about electromagnetic fields
- Information about noise emissions from the operation of the Kompogas facility in Otelfingen

1.3 Axpo, LCA and EPD®

There are many reasons to declare the environmental impact of biowaste treatment and electricity production.

For Axpo, the decisive reasons are:

- The scientific assessment and rigorous minimisation of environmental impact are core pillars of Axpo's sustainability strategy. Our main goal is to minimize green house gas production throughout the total life cycle. An EPD® environmental declaration is a reliable foundation for the quantitative presentation of the environmental impact using a number of environmental indicators and taking into account the total production cycle.
- Electricity generation is a fundamental component of modern society, as electricity is required for the production of most goods and the delivery of almost all services. Therefore Axpo wants to take the initiative in communicating clearly and reliably.

For questions concerning this EPD® contact Axpo Sustainability, sustainability.ch@axpo.com.
For additional information about Axpo, please visit our website at www.axpo.com.

[1] CORINE: Coordination of information on the environment: www.eea.europa.eu/publications/COR0-landcover

2 Manufacturer and product

2.1 Axpo Kompogas AG and Axpo group

Axpo Kompogas AG has become a global player in energy recovery via dry fermentation of biowaste and biogenous materials. Axpo Kompogas AG is fully consolidated within the Axpo group.

Biogenous waste has been treated in Kompogas installations for over 20 years now. In 2014, 15 facilities operated by Axpo Kompogas AG were successfully processing biogenous waste in Switzerland. These facilities treated 180000 tonnes biogenous waste in 2014. The net electricity production amounted to 25 million kilowatt hours. The total production of fuel-grade biogas was 13 million kilowatt hours.

Axpo ensures the electricity supply of North-Eastern Switzerland with a diverse portfolio of technology. Key figures of the energy production of the Axpo group are summarized in the table below.

Energy production 2013/14	Axpo group (GWh)
Nuclear power plants	22824
Hydroelectric plants	8400
New renewable energies	646
Gas and other conventional thermal power plants	3560

2.2 Product system description

2.2.1 Otelfingen Kompogas biomass fermentation plant

The Otelfingen Kompogas plant was commissioned in 1996. Approximately 13000 tonnes of green and organic waste are treated annually in the plant producing raw biogas through anaerobic thermophilic fermentation. The biomass originates on one hand from municipal biowaste collection in surrounding communities and on the other hand from the food industry. No additional co-substrate is used.

The raw biogas produced is converted into electricity and heat in a combined heat and power (CHP) plant. The heat produced is used for the operation of the plant as well as the nearby green house. Additionally, solid and liquid components of the fermentation residue are returned to the environment in the form of solid and liquid fertilizer. The technical service life of the Kompogas fermenter is assumed to be 20 years. The following mass and energy flows were ascertained in the Otelfingen Kompogas facility in 2017. Note, that the amount of treated biowaste and thus, the amount of energy produced in 2017 is about 20 per cent below the long-term average as there was an unplanned outage of the fermenter.

Input		Output	
Green and organic waste	10000 tonnes	Electricity (net)	1.3 GWh
		Heat (net)*	0.13 GWh
Intermediates		Liquid fertilizer	6200 tonnes
Raw biogas	0.9 Mio. Nm^3	Solid fertilizer	1900 tonnes

* Heat delivered to the green house.

2.2.2 The life cycle of biomass treatment at Otelfingen Kompogas facility

Core processes: the Kompogas process
The core processes comprise pre-treatment of biowaste, fermentation, final composting and use of raw biogas to generate heat and electricity.

The biomass delivered to the facility is first mechanically processed. The biodegradable fraction obtained from screening in the mechanical pre-treatment section is placed in an intermediate storage, which ensures a continuous supply of material to the fermentation process. From intermediate storage, the material is transferred to the feeder, where a homogeneous, pumpable mixture is produced. Via heat exchangers, the substrate is pumped to the horizontal Kompogas fermenter. The fermentation process inside the fermenter is based on anaerobic thermophilic dry fermentation at a temperature of about 55 °C. The retention time in the fermenter is about 14 days. As a result of the anaerobic fermentation, a significant part of the biogenous substances is decomposed.

The dewatered fermentation residues undergo further treatment in a closed final composting container over 3 to 4 weeks. This enables the odour and total organic carbon emissions to be selectively captured and directed to the exhaust air purification system. Prior to final disposal, the material undergoes a further 2 to 3 weeks of anaerobic stabilization. Inorganic impurities and energy rich components are separated and thermally utilised.

The biogas obtained in the fermentation process is transformed into electrical power and thermal energy in a CHP unit, making the whole plant a self-sufficient operation with a considerable energy surplus.

Upstream processes: transport of biowaste to the Otelfingen Kompogas facility
Biowaste treated in the Otelfingen Kompogas facility consists of green, yard and garden waste from communities and market gardens as well as food waste from households or the food industry. No co-substrates (e.g. glycerine) are employed, neither are any renewable raw materials added. Transportation of the biowaste to the Otelfingen Kompogas facility is modelled as upstream process. Additionally, the production of auxiliary substances and electricity are modelled as upstream processes.

Downstream processes: electricity and fertilizer distribution
The net electricity generated in the Otelfingen Kompogas facility is fed into the local distribution network (400 V) operated by the cantonal electric utility EKZ[2]. The distribution network consists of 1400 km overhead lines and 13 000 km of cables. In total 6000 GWh electricity are distributed over the network.

Solid and liquid fertilizers are used for agricultural application. Both these natural fertilizers are certified by the Swiss Research Institute of Organic Agriculture (FIBL) for use in organic farming. Because the substrate has been treated in the fermenter for several weeks at around 55 °C, the end result is a totally hygienic quality product. The transportation of the fertilizers to the customers and the application in agriculture are considered as downstream processes in this study.

[2] Elektrizitätswerke des Kantons Zürich (Utilities of Canton Zurich), www.ekz.ch

3 Environmental impact declaration

3.1 The life cycle assessment methodology

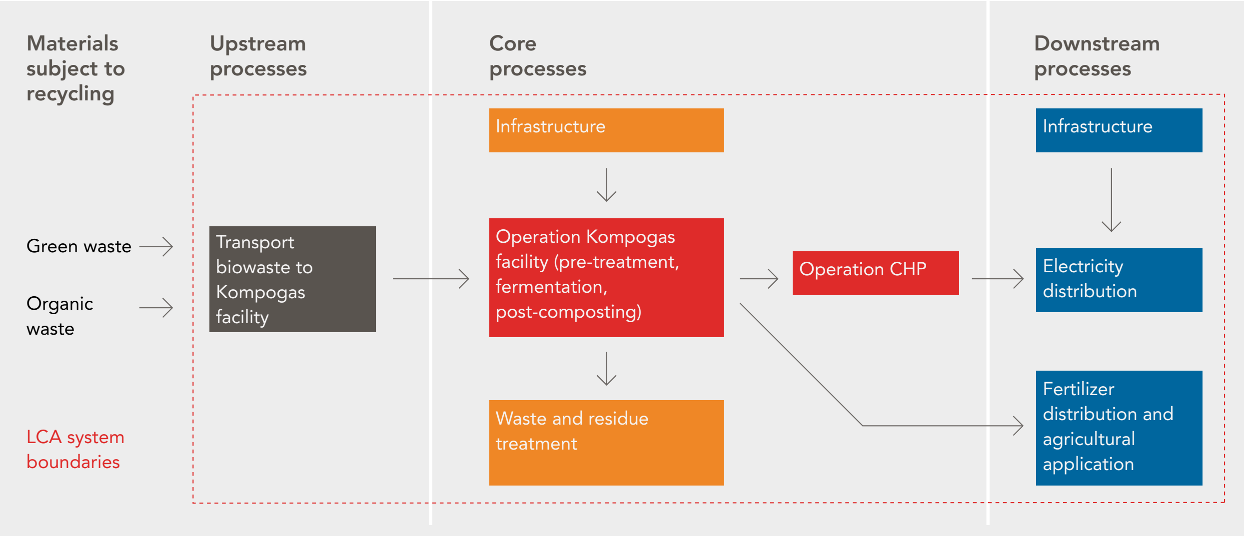
According to the ISO 14025 standard, the life cycle assessment (LCA) methodology was applied to quantify the environmental impact. LCA is a clearly structured framework based on international standards[3] that facilitates the quantification and assessment of emissions to the environment and use of resources along the entire production chain. The LCA delivers comprehensive information about total flows of energy, mass and emissions and assigns them to the most important contributory processes. Furthermore it allows the quantification of critical environmental indicators such as for example, green house gas emissions.

However, despite these advantages, there are also some issues beyond the scope of a LCA. For example, the LCA only studies normal operations. Accidents or other unusual operational circumstances are not taken into consideration in a LCA. Because of the focus on the overall process, there is also a risk of losing sight of localized issues: for example, the air quality directly adjacent to the CHP unit. Finally the LCA only examines the environmental impact and does not take into account economic, social and ethical aspects.

[3] ISO 14040 and ISO 14044 as well as product category rules.

3.2 System boundaries, allocations and data sources

The life cycle assessment comprises the full life cycle and associated processes from "cradle to grave" starting from the transport of biowaste and ending with the distribution and application of products. The figure below is a simplified process chart with system boundaries for the LCA. The process "operation Kompogas facility" comprises the mechanical pre-treatment of the biowaste, fermentation and the final composting. The raw gas produced is used in the CHP unit to produce heat and electricity.



Data for all processes in the process chain presented above were gathered directly from the operating personnel of the Otelfingen Kompogas facility or from measurements and environmental reports. This data set provides a reliable basis for a LCA study. For the calculation of the LCA the distribution of heat to the nearby Kompogas exhibition centre and green house has been omitted as that process contributes less than 1% to the total environmental impact. Data on energy supply (e.g. electricity mix), material supply (e.g. steel and concrete production) and transport services as well as on waste treatment processes (e.g. incineration, wastewater treatment) connected to the investigated process chain was taken from the ecoinvent database[4]. The ecoinvent database is a joint initiative of institutes and departements of the Swiss Federal Institute of Technology and provides consistent, transparent and quality-assured life cycle inventory (LCI) data.

The environmental burdens of the biowaste transport, the infrastructure and the operation of the Kompogas facility are allocated on the products biowaste treatment as well as electricity, fuel-grade biogas, heat, solid and liquid fertilizer production based on their prices at the Otelfingen Kompogas facility in 2017. Heat is used for the operation of the Kompogas process and for the supply of the nearby green house used by Axpo Kompogas AG. In the reference year, no surplus heat was sold. Also, the fertilizer products are offered to local farmers free of charge. Therefore, the allocation factors used in this study for the reference year 2017 are:

Products	Allocation factors
Biowaste treatment	88.7%
Electricity production	11.3%
Heat production	0%
Solid fertilizer production	0%
Liquid fertilizer production	0%

Allocation factors will change in case products of the Otelfingen Kompogas facility will be sold to different prices.

[4] ecoinvent database v3, Swiss Centre for Life Cycle Inventories, http://www.ecoinvent.org

3.2.1 Core processes

Comprehensive environmental data for the operation of the Otelfingen Kompogas facility were available from measurements and data management systems. The product amounts are measured continuously. Information on land use, process water consumed as well as wastewater released was taken from the internal accounting system. Airborne emissions from the fermentation and post treatment (CH_4, NMVOC, NH_3, N_2O) were measured in 2008 and early 2009. The measurements were conducted by an independent engineering firm in accordance with the relevant VDI[5] standards. The amount of waste for treatment in either municipal waste incinerators (inorganic residues) or in the Axpo Tegra[6] biomass incineration plant (organic material with high thermal value) was estimated by the operating personnel of the Otelfingen Kompogas facility. Quantities of auxiliary products (e.g. lubricating oil) as well as diesel consumption were taken from the accounting system. During maintenance, electricity from the local distribution network is used. Infrastructure is considered for the core processes. Data on the infrastructure was approximated with data from the Kompogas facility Oensingen, which is technically comparable. Airborne emissions from the CHP unit (CO, NOx) were measured in 2008. Biogenic CO_2 emissions from the combustion of raw biogas were calculated based on the elemental composition of the biogas. These emissions are allocated on the products heat and electricity only. As allocation factor, the exergy content of the products was used (electricity: 77%, heat: 23%).

3.2.2 Upstream processes

The amount of transported biowaste to the Otelfingen Kompogas facility was taken from the customer register. Transport distances were calculated based on records of customer locations. Inventory data for transport services was taken from the ecoinvent database. Allocation for the recycling of green and organic waste was made according to the "Polluter Pays (PP) allocation method" recommended in the General Programme Instructions of the International EPD® System. According to this principle, when recycling, no environment burden of prior life cycles is taken into account. Therefore, biogenous waste enters this product system free of any environmental burdens.

3.2.3 Downstream processes

Swiss-specific data on the operation, construction and decommissioning of the power distribution network was taken from the ecoinvent database. Generic transport distances for the consumption of auxiliary materials were used.

Regarding the distribution of liquid and solid fertilizer, detailed information on transported quantities and customer locations were available. Emissions to soil from the application of the fertilizers were calculated based on their elemental composition. Airborne emissions (CH_4, NH_3, N_2O) were estimated based on average emission factors from literature. These emissions depend on the application technique, the meteorological conditions and the individual behaviour of the customers.

3.3 Ecoprofile of Otelfingen Kompogas facility

Results of the life cycle assessment are presented in the following ecoprofile tables and commented subsequently. More detailed LCA results have been available for the certifier. Quantities are expressed per operating year 2017 (quantities without allocation) as well as allocated to the declared units "1 tonne biowaste treated" and "1 kWh net electricity generated".

The ecoprofile consist of various types of life cycle assessment results that can be summarized in three categories:

- **Life cycle inventory (LCI) results:**
  Inventory results are direct emissions to and resource consumptions from the environment. Examples for inventory results are CO_2 emissions or the consumption of freshwater.

- **Life cycle impact assessment (LCIA) results:**
  In the impact assessment inventory results that contribute to the same environmental impact (e.g. global warming as a result of an increased concentration of green house gases) are grouped together and weighted by comparison with a reference substance (e.g. potential global warming compared to the effect of CO_2).

- **Material flows:**
  Materials that are subject to waste treatment or recycling are presented in this category.

[5] VDI: Verein Deutscher Ingenieure (Association of German Engineers)
[6] Axpo Tegra AG, www.axpo.com

Ecoprofile – Resource use	Unit	Per operating year 2017 of Kompogas plant	Per tonne of treated biowaste in Kompogas plant	Per kWh net electricity at Kompogas plant
Non-renewable material resources				
Gravel and sand	g	$3.21 \cdot 10^{8}$	$2.80 \cdot 10^{4}$	$2.87 \cdot 10^{1}$
Calcite	g	$5.43 \cdot 10^{7}$	$4.74 \cdot 10^{3}$	4.86
Iron	g	$2.15 \cdot 10^{7}$	$1.88 \cdot 10^{3}$	1.93
Clay	g	$1.78 \cdot 10^{7}$	$1.56 \cdot 10^{3}$	1.59
Nickel	g	$4.20 \cdot 10^{5}$	$3.66 \cdot 10^{1}$	$3.75 \cdot 10^{-2}$
Chromium	g	$1.29 \cdot 10^{5}$	$1.13 \cdot 10^{1}$	$1.16 \cdot 10^{-2}$
Barite	g	$1.03 \cdot 10^{5}$	8.96	$9.18 \cdot 10^{-3}$
Aluminium	g	$7.58 \cdot 10^{4}$	6.62	$6.78 \cdot 10^{-3}$
Fluorite	g	$5.03 \cdot 10^{3}$	$4.39 \cdot 10^{-1}$	$4.50 \cdot 10^{-4}$
Copper	g	$7.39 \cdot 10^{4}$	6.45	$6.60 \cdot 10^{-3}$
Magnesite	g	$3.12 \cdot 10^{5}$	$2.72 \cdot 10^{1}$	$2.79 \cdot 10^{-2}$
Zinc	g	$8.55 \cdot 10^{3}$	$7.46 \cdot 10^{-1}$	$7.64 \cdot 10^{-4}$
Kaolinite	g	$5.16 \cdot 10^{3}$	$4.50 \cdot 10^{-1}$	$4.61 \cdot 10^{-4}$
Uranium	g	$1.12 \cdot 10^{3}$	$9.78 \cdot 10^{-2}$	$1.00 \cdot 10^{-4}$
Zirconium	g	$1.94 \cdot 10^{3}$	$1.69 \cdot 10^{-1}$	$1.73 \cdot 10^{-4}$
Renewable material resources				
Wood	m^3	1.30	$1.14 \cdot 10^{-4}$	$1.16 \cdot 10^{-7}$
Non renewable fossil energy resources[7]				
Hard coal	MJ-equivalents	$7.11 \cdot 10^{5}$	$6.21 \cdot 10^{1}$	$6.36 \cdot 10^{-2}$
Crude oil	MJ-equivalents	$1.77 \cdot 10^{6}$	$1.55 \cdot 10^{2}$	$1.58 \cdot 10^{-1}$
Natural gas	MJ-equivalents	$9.40 \cdot 10^{5}$	$8.21 \cdot 10^{1}$	$8.40 \cdot 10^{-2}$
Lignite	MJ-equivalents	$4.24 \cdot 10^{4}$	3.70	$3.79 \cdot 10^{-3}$
Uranium	MJ-equivalents	$5.05 \cdot 10^{5}$	$4.41 \cdot 10^{1}$	$4.52 \cdot 10^{-2}$
Renewable energy resources				
Energy, in biomass[8]	kWh	$1.07 \cdot 10^{7}$	$9.37 \cdot 10^{2}$	$9.59 \cdot 10^{-1}$
Electricity consumption in Kompogas plant	kWh	$5.52 \cdot 10^{5}$	$4.82 \cdot 10^{1}$	$4.92 \cdot 10^{-2}$
Use of recycled material				
Organic waste treated	g	$1.02 \cdot 10^{10}$	–	–
Iron scrap	g	$8.14 \cdot 10^{6}$	$7.10 \cdot 10^{2}$	$7.27 \cdot 10^{-1}$
Water consumption				
Freshwater	g	$7.83 \cdot 10^{9}$	$6.84 \cdot 10^{5}$	$7.00 \cdot 10^{2}$
Saltwater	g	$9.82 \cdot 10^{7}$	$8.57 \cdot 10^{3}$	8.77

[7] Expressed as Gross Calorific Values
[8] Including the energy of the treated biowaste

Ecoprofile – Pollutant emissions	Unit	Per operating year 2017 of Kompogas plant	Per tonne of treated biowaste in Kompogas plant	Per kWh net electricity at Kompogas plant
Airborne emissions – impact assessment results				
Greenhouse gases	g CO_2-equivalents	$1.10 \cdot 10^{9}$	$9.57 \cdot 10^{4}$	$1.01 \cdot 10^{2}$
Ozone-depleting gases	g CFC-11-equivalents	$1.98 \cdot 10^{1}$	$1.73 \cdot 10^{-3}$	$1.77 \cdot 10^{-6}$
Formation of ground-level ozone	g ethylene-equivalents	$1.79 \cdot 10^{7}$	$1.56 \cdot 10^{3}$	1.64
Acidifying substances	g SO_2-equivalents	$5.08 \cdot 10^{6}$	$3.22 \cdot 10^{2}$	1.43
Airborne emissions contributing to given impact assessment results				
Ammonia	g	$1.19 \cdot 10^{6}$	$1.04 \cdot 10^{2}$	$1.07 \cdot 10^{-1}$
Carbon dioxide, fossil	g	$2.77 \cdot 10^{8}$	$2.41 \cdot 10^{4}$	$2.47 \cdot 10^{1}$
Carbon monoxide, biogenic	g	$2.56 \cdot 10^{6}$	$1.45 \cdot 10^{1}$	1.91
Carbon monoxide, fossil	g	$1.07 \cdot 10^{6}$	$9.34 \cdot 10^{1}$	$9.56 \cdot 10^{-2}$
Dinitrogen monoxide	g	$2.42 \cdot 10^{5}$	$2.12 \cdot 10^{1}$	$2.17 \cdot 10^{-2}$
Methane, bromochlorodifluoro-, Halon 1211	g	$1.92 \cdot 10^{-1}$	$1.68 \cdot 10^{-5}$	$1.72 \cdot 10^{-8}$
Methane, bromotrifluoro-, Halon 1301	g	$9.00 \cdot 10^{-1}$	$7.86 \cdot 10^{-5}$	$8.04 \cdot 10^{-8}$
Methane, biogenic, total	g	$3.20 \cdot 10^{7}$	$2.79 \cdot 10^{3}$	2.86
Methane, fossil	g	$4.09 \cdot 10^{5}$	$3.57 \cdot 10^{1}$	$3.65 \cdot 10^{-2}$
Nitrogen oxides	g	$3.53 \cdot 10^{6}$	$1.36 \cdot 10^{2}$	1.70
NMVOC, non-methane volatile organic compounds	g	$1.76 \cdot 10^{7}$	$1.53 \cdot 10^{3}$	1.57
Sulphur dioxide	g	$3.51 \cdot 10^{5}$	$3.06 \cdot 10^{1}$	$3.14 \cdot 10^{-2}$
Other relevant non-radioactive airborne emissions				
Carbon dioxide, biogen	g	$1.46 \cdot 10^{9}$	$9.27 \cdot 10^{4}$	$4.10 \cdot 10^{2}$
Particles < 10 µm	g	$1.04 \cdot 10^{5}$	9.06	$9.28 \cdot 10^{-3}$
Particles < 2.5 µm	g	$1.43 \cdot 10^{5}$	$1.25 \cdot 10^{1}$	$1.28 \cdot 10^{-2}$
Particles > 10 µm	g	$2.22 \cdot 10^{5}$	$1.94 \cdot 10^{1}$	$1.98 \cdot 10^{-2}$
Arsenic	g	$3.30 \cdot 10^{1}$	$2.88 \cdot 10^{-3}$	$2.95 \cdot 10^{-6}$
Cadmium	g	$1.25 \cdot 10^{1}$	$1.09 \cdot 10^{-3}$	$1.12 \cdot 10^{-6}$
Dioxins	g	$5.93 \cdot 10^{-3}$	$5.18 \cdot 10^{-7}$	$5.30 \cdot 10^{-10}$
PAH, polycyclic aromatic hydrocarbons	g	$5.73 \cdot 10^{1}$	$5.01 \cdot 10^{-3}$	$5.12 \cdot 10^{-6}$
Radioactive airborne emissions				
Carbon 14	kBq	$2.18 \cdot 10^{3}$	$1.90 \cdot 10^{-1}$	$1.94 \cdot 10^{-4}$
Krypton (all isotopes)	kBq	$8.06 \cdot 10^{2}$	$7.04 \cdot 10^{-2}$	$7.20 \cdot 10^{-5}$
Radon (all isotopes)	kBq	$9.91 \cdot 10^{5}$	$8.65 \cdot 10^{1}$	$8.86 \cdot 10^{-2}$
Waterborne emissions – impact assessment results				
Eutrophying substances	g PO_4^{3-}-equivalents	$9.68 \cdot 10^{5}$	$6.20 \cdot 10^{1}$	$2.67 \cdot 10^{-1}$
Waterborne emissions contributing to given impact assessment results				
Phosphate	g	$1.92 \cdot 10^{4}$	1.68	$1.72 \cdot 10^{-3}$
COD, Chemical Oxygen Demand	g	$1.79 \cdot 10^{5}$	$1.57 \cdot 10^{1}$	$1.60 \cdot 10^{-2}$
Ammonium, ion	g	$6.93 \cdot 10^{2}$	$6.05 \cdot 10^{-2}$	$6.20 \cdot 10^{-5}$
Nitrate	g	$1.82 \cdot 10^{4}$	1.59	$1.63 \cdot 10^{-3}$
Other relevant non-radioactive waterborne emissions				
Sulphate	g	$3.00 \cdot 10^{5}$	$2.61 \cdot 10^{1}$	$2.68 \cdot 10^{-2}$
Oil	g	$4.41 \cdot 10^{4}$	3.85	$3.94 \cdot 10^{-3}$
Radioactive waterborne emissions				
Tritium H3	kBq	$2.38 \cdot 10^{5}$	$2.08 \cdot 10^{1}$	$2.13 \cdot 10^{-2}$
Other relevant non-radioactive emissions soil				
Oil	g	$2.66 \cdot 10^{4}$	2.32	$2.37 \cdot 10^{-3}$

Ecoprofile – Waste and material subject to recycling	Unit	Per operating year 2017 of Kompogas plant	Per tonne of treated biowaste in Kompogas plant	Per kWh net electricity at Kompogas plant
Waste related directly to the Kompogas process				
Non-hazardous waste to biomass incineration	g	$6.96 \cdot 10^{8}$	$6.08 \cdot 10^{4}$	$6.22 \cdot 10^{1}$
Non-hazardous waste to municipal incineration	g	$6.00 \cdot 10^{7}$	$5.24 \cdot 10^{3}$	5.36
Waste related to background processes. Hazardous waste – radioactive.				
SF/HLW/ILW[9] in final repository	m^3	$3.67 \cdot 10^{-4}$	$3.21 \cdot 10^{-8}$	$3.28 \cdot 10^{-11}$
LLW[10] in final repository	m^3	$8.77 \cdot 10^{-3}$	$7.66 \cdot 10^{-7}$	$7.84 \cdot 10^{-10}$
Hazardous waste – non-radioactive				
Hazardous waste to incineration	g	$1.96 \cdot 10^{5}$	$1.71 \cdot 10^{1}$	$1.75 \cdot 10^{-2}$
Other waste				
Non-hazardous waste to landfill	g	$5.17 \cdot 10^{6}$	$4.51 \cdot 10^{2}$	$4.62 \cdot 10^{-1}$
Non-hazardous waste to recycling	g	$2.03 \cdot 10^{7}$	$1.77 \cdot 10^{3}$	1.81
Non-hazardous waste to incineration	g	$2.67 \cdot 10^{5}$	$2.33 \cdot 10^{1}$	$2.39 \cdot 10^{-2}$

[9] SF/HLW/ILW: Spent fuel / high-level waste / long-lived intermediate-level waste
[10] LLW: Low and intermediate-level waste

3.4 Dominance analysis and conclusions

3.4.1 Results for the main products

The contribution of the different life cycle stages to the overall results are shown in the figure below for all life cycle impact categories per operating year as well as per product. The life cycle stages comprise:

Upstream processes

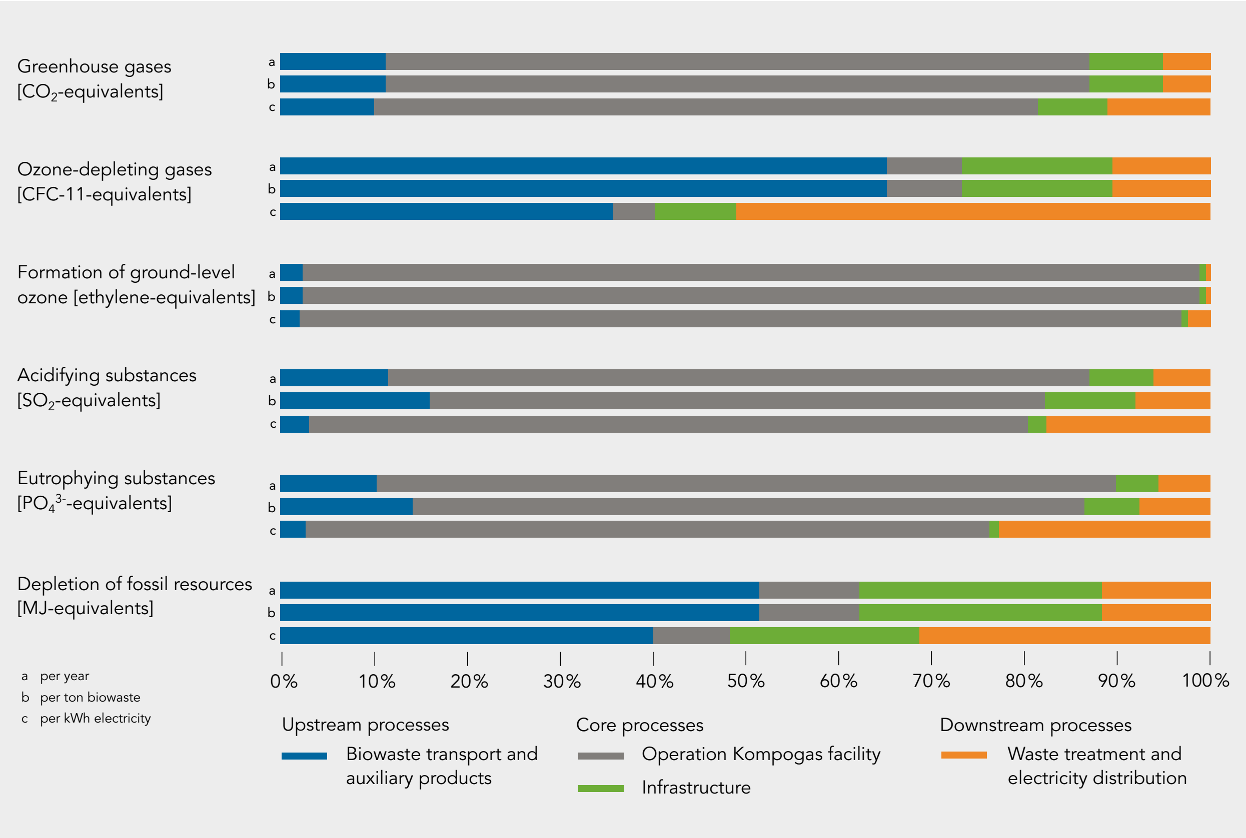
- Transport: collection of biowaste and transport to the Kompogas facility.
- Auxiliary products: production of auxiliaries (e.g. lubricating oil) as well as consumption of electricity from the local power grid.

Core processes

- Operation Kompogas facility: direct emissions from the Kompogas facility (e.g. CH_4, N_2O, NH_3, NMVOC).
- Infrastructure: construction and dismantling of the Kompogas facility.

Downstream processes

- Waste treatment: Transport and thermal treatment of residues in the respective waste incineration facilities (biomass and municipal incineration plants) as well as the wastewater treatment.
- Distribution of electricity in the local power grid.



Emission of greenhouse gases
Biogenous methane is the dominant green house gas contributing 65 to 70 % of the total result. The most significant sources are the fermentation and post-composting processes. The emission factors for biogenous methane emission was measured and calculated by an independent engineering firm according to the relevant VDI standards. The second most important greenhouse gas with 25 % is fossil CO_2 from transport and wheel loader activities.

Emission of ozone-depleting gases
Stratospheric ozone depletion is caused by the catalytic splitting of ozone by chlorine and bromium. The most significant sources of these halogen atoms in the stratosphere is the photodissociation of chlorofluorocarbons (CFCs) and of bromofluorocarbon compounds known as halons. These compounds rise up to the stratosphere after being emitted at the earth's surface.

In this study the main ozone depleting chemical is Halon 1301 an important substance used in fire extinguishers and in petrochemical production plants in the production of petrol, oil or diesel. That is why the fossil fuel requirements of the transport activities and the energy intensive production of building materials such as cement or steel contribute most strongly to the overall impact in this category.

Emission of substances contributing to ground-level ozone formation
The interaction of intensive sunlight, nitric oxide, hydrocarbons and other chemicals in the air leads to the production of photochemical oxidants, the main one being ground-level ozone. The greatest contributing factor (>95 %) is NMVOC emissions that arise during the fermentation and post-composting processes. The emission factors for NMVOCs were based on independent measurements carried out in accordance with the relevant VDI standards.

Emission of acidifying substances
The main contributions results from ammonia emissions from the fermentation process. In the electricity production process, nitrogen oxide is also produced during the combustion of raw gases in the cogeneration unit. Emissions from the cogeneration unit are booked in the "Kompogas Plant Operation" process. The emission factors for ammonia and for nitrogen oxide were determined by independent measurements carried out in accordance with the relevant VDI standards.

Emission of eutrophying substances
The main source of emissions that lead to eutrophication is the fermentation process releasing ammonia and the cogeneration combustion process that releases nitrogen oxide.

Depletion of fossil resources
The fuel consumption for transport and wheel loader activities is the main source of fossil resource consumption. Second most important are energy-intensive processes for the production of building materials (e.g. concrete, steel).

3.4.2 Conclusions for the main products
A comparison of the life cycle stages shows that in most categories, the dominant environmental impact is due to the operation of the Kompogas plant. The reasons are direct airborne emissions from the fermentation process, such as methane, ammonia, dinitrogen monoxide and NMVOC. Exceptions are the impact categories "depletion of ozone" and "depletion of fossil resources" where the production of fossil fuel is dominating. Additionally, the production of energy-intensive construction materials contributes significantly to the depletion of fossil resources. Waste treatment processes are important causes of eutrophication due to emissions during waste incineration as well as of the wastewater treatment processes.

The production of electricity shows similar important sources of environmental impact than the treatment of biowaste. However, the operation of the CHP unit is dominating the impact categories "acidifying substances" and "eutrophying substances" due to direct nitrogen oxides emissions. The distribution of electricity has a minimal environmental impact.

3.4.3 Results for liquid fertilizer

6200 tonnes of liquid fertilizer from the Otelfingen Kompogas facility were distributed to customers and applied in agriculture using drag hose systems to spread the fertilizer. Results of the liquid fertilizer distribution and application are presented for all environmental impact categories in the table below. The fertilizer products are offered to local farmers free of charge. Therefore no environmental burdens are allocated on upstream and core processes (see section 3.2). Emissions related to the agricultural application were estimated based on average emission factors from literature. These emissions depend on the application technique, the meteorological conditions and the individual behaviour of the customers.

Environmental impact	Unit	Upstream processes	Core processes	Downstream processes		Total
		Transport of biowaste	Production of 1 tonne liquid fertilizer	Transport of 1 tonne liquid fertilizer to customer	Agricultural application of 1 tonne liquid fertilizer	1 tonne liquid fertilizer applied in agriculture
Greenhouse gases	g CO_2-eq.	0.00	0.00	$1.84 \cdot 10^{3}$	$1.46 \cdot 10^{4}$	$1.64 \cdot 10^{4}$
Ozone-depleting gases	g CFC-11-equiv.	0.00	0.00	$1.28 \cdot 10^{-4}$	0.00	$1.28 \cdot 10^{-4}$
Formation of ground-level ozone	g ethylene-equiv.	0.00	0.00	$2.46 \cdot 10^{-1}$	$4.82 \cdot 10^{-2}$	$2.94 \cdot 10^{-1}$
Acidifying substances	g SO_2-eq.	0.00	0.00	6.71	$7.92 \cdot 10^{2}$	$7.98 \cdot 10^{2}$
Eutrophying substances	g PO_4^{3-}-eq.	0.00	0.00	$9.76 \cdot 10^{-1}$	$4.04 \cdot 10^{3}$	$4.04 \cdot 10^{3}$
Depletion of fossil resources	MJ-equiv.	0.00	0.00	$2.96 \cdot 10^{1}$	0.00	$2.96 \cdot 10^{1}$

All results are rounded.

3.4.4 Results for solid fertilizer

1900 tonnes of solid fertilizer were distributed to customers and applied in agriculture. Results of the solid fertilizer distribution are presented for all environmental impact categories in the table below. The fertilizer products are offered to local farmers free of charge. Therefore no environmental burdens are allocated on upstream and core processes (see section 3.2). Emissions related to the agricultural application were estimated based on average emission factors from literature. These emissions depend on the application technique, the meteorological conditions and the individual behaviour of the customers.

Environmental impact	Unit	Upstream processes	Core processes	Downstream processes		Total
		Transport of biowaste	Production of 1 tonne solid fertilizer	Transport of 1 tonne solid fertilizer to customer	Agricultural application of 1 tonne solid fertilizer	1 tonne solid fertilizer applied in agriculture
Greenhouse gases	g CO_2-eq.	0.00	0.00	$2.60 \cdot 10^{3}$	$9.40 \cdot 10^{3}$	$1.20 \cdot 10^{4}$
Ozone-depleting gases	g CFC-11-equiv.	0.00	0.00	$1.80 \cdot 10^{-4}$	0.00	$1.80 \cdot 10^{-4}$
Formation of ground-level ozone	g ethylene-equiv.	0.00	0.00	$3.48 \cdot 10^{-1}$	0.00	$3.48 \cdot 10^{-1}$
Acidifying substances	g SO_2-eq.	0.00	0.00	9.48	$6.62 \cdot 10^{2}$	$6.71 \cdot 10^{2}$
Eutrophying substances	g PO_4^{3-}-eq.	0.00	0.00	1.38	$2.86 \cdot 10^{3}$	$2.86 \cdot 10^{3}$
Depletion of fossil resources	MJ-equiv.	0.00	0.00	$4.19 \cdot 10^{1}$	0.00	$4.19 \cdot 10^{1}$

All results are rounded.

3.5 Differences versus the earlier version of the Axpo Kompogas EPD®

Updated material and energy flows
In the presented EPD® material and energy flows related to the new reference year 2017 are considered.

Updated allocation factors
In the presented EPD® the environmental burdens are allocated on the products biowaste treatment as well as electricity production based on their prices at the Otelfingen Kompogas facility in the new reference year 2017. This results in changes of the allocation factors for products.

Database update
A new version of the ETH ecoinvent database was used (version 3) for modelling background processes.

4 Additional environmental information

4.1 Land use

The land use is quantified systematically for the core processes in accordance with the PCR policy pursuant to the CORINE[11] Land Cover classes (CLC). The CORINE program was initiated by the European Commission in 1985 to record land use across Europe according to a uniform nomenclature, among other aspects. The system consists of 44 classes in three hierarchical levels (e.g. use of industrial, mining or forest areas).

As the land was already used as an industrial area before the power plant was constructed, there was no change in the CLC class.

Land used by the power plant	Land use type before construction of the power plant (CLC class)	Land use type after construction of the power plant (CLC class)
5000 m^2	Industrial area, constructed (CLC class 121a)	Industrial area, constructed (CLC class 121a)

4.2 Biodiversity

There is no biotope of national or regional significance on the site or near to the plant so biodiversity is not affected to any significant extent by the operation of the Kompogas plant in Otelfingen.

4.3 Odour emissions

The anaerobic fermentation of organic materials produces unpleasant odours. According to the Swiss Federal Air Protection Act (Luftreinhalteverordnung, SR 814.318.142.1) excessive odours from facilities must be avoided. In general, odours are classed as excessive if they upset more than 25 % of the local population. The exhaust fumes from the fermenter are passed through a purification system consisting of a washer followed by a biofilter. This reduces odours by 95 %. The intensity of odour emissions is under 300 European Odour Units per m^3 (ouE/m^3) – the commonly accepted threshold. Below 300 ouE/m^3 one does not except to cause annoyance due to unpleasant odours. Furthermore, there is no residential area adjacent to the Kompogas plant Otelfingen.

[11] CORINE: Coordination of information on the environment: www.eea.europa.eu/publications/COR0-landcover

4.4 Risk-related issues

Fire and explosion

The anaerobic fermentation process leads to the formation of biogenic methane. Methane is not toxic, however, it is highly flammable and may form explosive mixtures with air. Explosion limits are between 5 and 14 vol. % in air. To minimize the risk of fire and explosions, the Kompogas fermenter has an airtight construction. Furthermore all enclosed spaces or rooms where gas could potentially escape into are served by adequate ventilation systems.

Microbiological hazards

Fermentation is a microbiological process. Therefore, the risk of infections (bacteria, fungi, parasites) has to be minimized. Most effectively, this is achieved by proper handling of the organic material, installation of ventilation systems and personal protective equipment, such as face masks. In addition, important parameters related to microbiological hazards are monitored (e.g. humidity, carbon-nitrogen ratio or the concentration of mould fungus spores in the air).

4.5 Electromagnetic fields

The main source of electromagnetic fields in the Otelfingen Kompogas facility is the conversion of kinetic energy into electricity in the generator. The generator is powered by the lean engine. Various regulatory guidelines and recommendations for magnetic fields at 50-Hz frequency exist. The Swiss Protection Act on Non-Ionizing Radiation (Verordnung über den Schutz vor nichtionisierender Strahlung, SR 814.710) stipulates emission limits for the population of 100 µT. General occupational limits of 400 µT are proposed by SUVA[12]. In the Otelfingen Kompogas facility the magnetic fields are all below 100 µT. Therefore no special precautions need to be taken.

4.6 Noise

The Kompogas Plant Otelfingen is located in an industrial zone. The Swiss Federal Noise Protection Act (Lärmschutzverordnung, SR 814.41) limits noise emissions to 70 dB(A) during the daytime and 60 dB(A) during the night. The operating noise of the Kompogas plant is well below these emission limits because all sources of noise (e.g. cogeneration unit, mechanical compressor, ventilation systems) are located within the building. Noise exposure due to transportation of products is negligible as the industrial zone and access roads are not in immediate vicinity of residential areas.

[12] The Swiss Accident Insurance Fund (SUVA)

5 Certification body and mandatory statements

5.1 Information from the certification body

The certification of the Environmental Product Declaration, EPD®, for the treatment of biowaste as well as the production of electricity, heat, fuel biogas and fertilizer from Otelfingen Kompogas biomass fermentation plant has been carried out by Bureau Veritas Certification, Sweden. Bureau Veritas Certification Sweden has made an independent verification of the declaration and data according to ISO 14025: 2006 EPD verification. The EPD® has been made in accordance with General Programme Instructions for an Environmental Product Declaration, EPD®, published by the International EPD® System and UN-CPC 171 and 173, Product Category Rules (PCR) for preparing an Environmental Product Declaration (EPD®) for Electricity, Steam, and Hot and Cold Water Generation and Distribution. Bureau Veritas Certification Sweden has been accredited by SWEDAC, the Swedish Board for Accreditation and Conformity Assessment, to certify Environmental Product Declarations, EPD®. This certification is valid until 12 September 2021. The registration number is S-P-00176.

5.2 Mandatory statements

5.2.1 General statements

To be noted: EPDs from different EPD programmes may not be comparable.

5.2.2 Omissions of life cycle stages

The use stage of produced electricity and biogas have been omitted in accordance with the PCR since their use fulfils various functions in different contexts.

5.2.3 Means of obtaining explanatory materials

ISO 14025 prescribes that explanatory material must be available if the EPD® is communicated to final consumers. This EPD® is aimed for industrial customers and not meant for B2C (= business-to-consumer) communication.

5.2.4 Information on verification

EPD programme
The International EPD® System, managed by
EPD International AB.
http://www.environdec.com

Product Category Rules
UN-CPC 171 and 173, Product Category Rules (PCR) for preparing an Environmental Product Declaration (EPD®) for Electricity, Steam, and Hot and Cold Water Generation and Distribution, Version 3.

PCR review
The Technical Committee of the International EPD® System. Full list of TC members available on www.environdec.com/TC.

Independent verification
Independent verification of the declaration and data, according to ISO 14025: External, Bureau Veritas Certification, Sweden.
info@se.bureauveritas.com

6 Links and references

Further information on the company:
http://www.axpo.com

International EPD® programme information:
http://www.environdec.com
Information on the International EPD® System, EPD®s,
PCRs and General Programme Instructions, GPI v2.5

Background LCA data:
http://www.ecoinvent.org
The ecoinvent database v3, Swiss Centre for
Life Cycle Inventories

7 Frequently used abbreviations

CHP	Combined Heat and Power Unit
CLC classes	CORINE Land Cover Classes
EPD	Environmental Product Declaration
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
NMVOC	Non-methane volatile organic compounds
PCR	Product Category Rules
VDI	Verein Deutscher Ingenieure (Association of German Engineers)

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