Environmental Product Declaration

Löntsch high head storage power plant | Update 2018

EPD®
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Summary

Company

Axpo is a leading Swiss electricity producer and guarantees a reliable supply of electricity. Hydroelectric and nuclear power plants cover the base load. Fluctuating demand and peak loads are balanced using storage and pumped storage plants.

Product and declared unit

The high head storage power plant on the Löntsch is wholly owned by Axpo. Utilising head of 370 m and its 60 Megawatt (MW) installed capacity to produce valuable peak load energy, Löntsch Power Station makes an important contribution to the electricity production requirements in North-East Switzerland.

The declared product is 1 kilowatt hour (kWh) net electricity generated by Löntsch power plant and thereafter distributed to a customer connected to the Axpo network during the reference year 2016/17 (1 October to 30 September).

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 results presented

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

Environmental impact of electricity generation in the Löntsch power plant

The life cycle assessment methodology has been applied to quantify the environmental impact. It comprises the full electricity generation process and all associated processes from "cradle to grave".
The main results of the life cycle assessment are summarized in the table below. Further results including resource depletion and land usage as well as information on biodiversity or hydrology are given in the EPD.

Environmental impact	Unit	1 kWh net electricity at Löntsch power plant	1 kWh net electricity at Axpo customer
Greenhouse gases	g CO_2-equivalents	5.59 (4.47 to 6.98)	5.80 (4.59 to 7.45)
Ozone-depleting gases	g CFC-11-equivalents	$1.13 \cdot 10^{-6}$ ($5.78 \cdot 10^{-7}$ to $1.78 \cdot 10^{-6}$)	$1.16 \cdot 10^{-6}$ ($5.97 \cdot 10^{-7}$ to $1.69 \cdot 10^{-6}$)
Formation of ground-level ozone	g ethylene-equivalents	$5.53 \cdot 10^{-3}$ ($3.86 \cdot 10^{-3}$ to $7.67 \cdot 10^{-3}$)	$5.77 \cdot 10^{-3}$ ($3.87 \cdot 10^{-3}$ to $8.15 \cdot 10^{-3}$)
Acidifying substances	g SO_2-equivalents	$4.20 \cdot 10^{-2}$ ($3.21 \cdot 10^{-2}$ to $5.18 \cdot 10^{-2}$)	$4.55 \cdot 10^{-2}$ ($3.53 \cdot 10^{-2}$ to $5.53 \cdot 10^{-2}$)
Eutrophying substances	g PO_4^{3-}-equivalents	$8.73 \cdot 10^{-3}$ ($1.17 \cdot 10^{-3}$ to $4.33 \cdot 10^{-2}$)	$9.60 \cdot 10^{-3}$ ($1.26 \cdot 10^{-3}$ to $5.32 \cdot 10^{-2}$)
Depletion of fossil resources	MJ-equivalents	$6.77 \cdot 10^{-2}$ ($5.10 \cdot 10^{-2}$ to $8.56 \cdot 10^{-2}$)	$6.93 \cdot 10^{-2}$ ($5.15 \cdot 10^{-2}$ to $8.71 \cdot 10^{-2}$)

All results are rounded.

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1 Introduction

1.1 The declared product

This document constitutes the certified Environmental Product Declaration (EPD®) of electricity from the high head storage power plant on the Löntsch. The Löntsch power plant is wholly owned by Axpo.

The declared product is 1 kWh net electricity generated at the Löntsch high head storage power plant and thereafter distributed to a customer connected to the Axpo grid network during the reference year 2016/2017 (1 October to 30 September).

The Löntsch power plant was built between 1905 and 1908. Operating in conjunction with the Beznau run-of-river power plant in the lower Aare valley, the Löntsch power plant was, in the early twentieth century, the first significant example in Switzerland of the coordinated operation of a high head storage plant and a low head run-of-river plant. The Löntsch power plant utilises a 370 m head to provide up to 60 MW of valuable peak load power, thus making an important contribution to a secure supply of electricity in North-East Switzerland.

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. To this end it:

- offers a complete Type III environmental declaration programme for any interested organisation in any country to develop and communicate EPDs according to ISO 14025;
- supports other EPD programmes (i.e. national, sectorial, etc.) in seeking cooperation and harmonization 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. EPD® 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 principal 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 14 025 on Type III environmental declarations.
- ISO 14 040 and ISO 14 044 on Life Cycle Assessment (LCA).

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

- Information on land transformation based on a categorisation according to CORINE[1] Land Cover Classes.
- Information on biodiversity.
- Information on hydrology, hydrogeology and river morphology.
- Information on environmental risks.
- Information on electromagnetic fields.
- Information on noise.

1.3 Axpo, LCA and EPD®

There are many reasons to declare the environmental impact of electricity production. For Axpo, the decisive reasons are:

- 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, as the largest electricity producer in Switzerland, Axpo wants to take the initiative in communicating clearly and reliably.
- 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 emissions throughout the entire life cycle. An EPD® environmental declaration is a reliable foundation for the quantitative description of the environmental impact using a number of environmental indicators and taking into account the total production cycle.

For questions concerning this EPD® contact Axpo sustainability management, 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

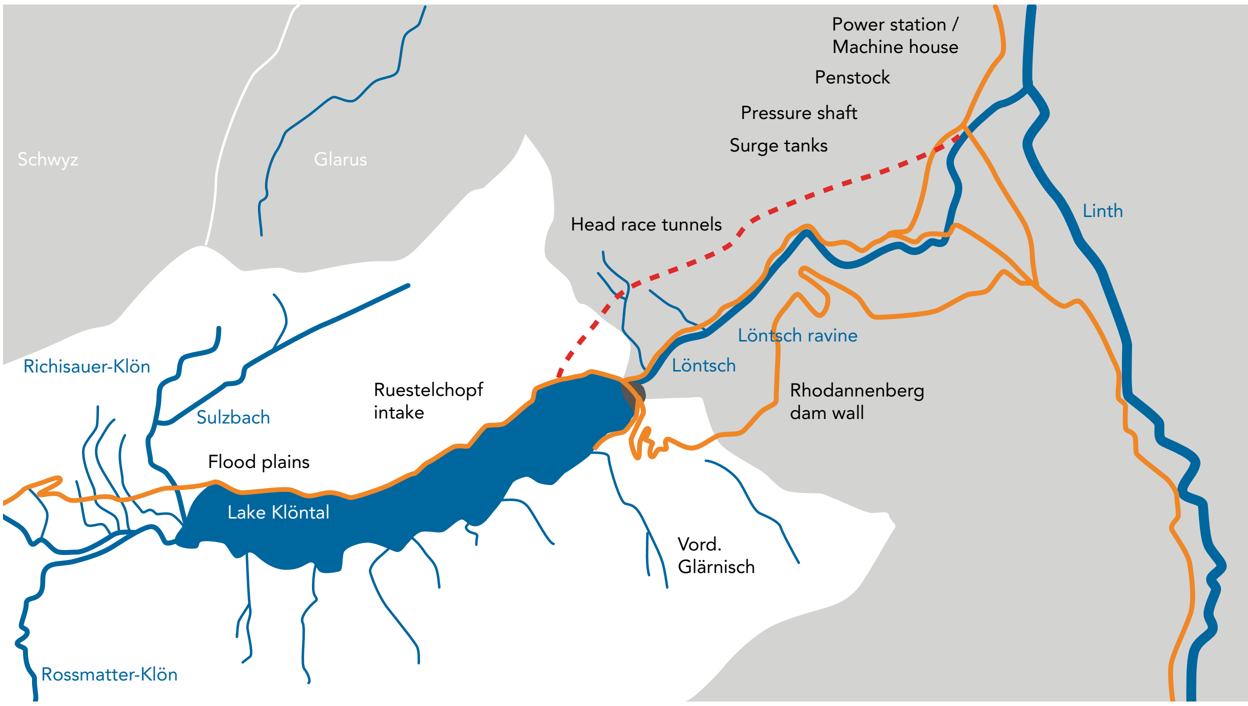
Axpo is a leading Swiss energy company supplying electricity to about three million people. Axpo uses run-of-river power plants and nuclear power plants to cover the base load. Fluctuating demand and peak loads are balanced through storage and pumped storage systems. Key figures of the electricity production of Axpo are summarized in the table below.

Electricity production 2016/17	Axpo [GWh]
Nuclear power plants	16 395
Hydroelectric plants	7846
New renewable energies	1096
Conventional thermal power plants	7567

2.2 Product system description

2.2.1 The Löntsch power plant

The power plant on the Löntsch was built during the period from 1905 to 1908. It was the first high head storage power plant built in Switzerland. After 60 years of operation, the plant was fully overhauled between 1971 and 1975. At that time, the relevant communes agreed to prolong the original 100-year concession by 30 years – to 2038. The Löntsch power plant utilizes the run off from a catchment area of 83 km^2 with an annual average run-off volume of 143 million m^3, a gross head of 370 m and a discharge rate of 20 m^3/s.



Overview of the systems and installations at the Löntsch power plant.

The dam installation

The original Klöntal Lake was formed as the result of a huge prehistoric landslide from the Wiggis massif in the area where the Klöntal valley narrows between Rhodannenberg and Sackberg. The reservoir capacity of the natural lake was increased by the construction of an earth dam wall with an impermeable clay core. The dam wall lies on landslide debris compacted by natural mud deposits. The dam is up to 110 m thick and up to 21.5 m high, while the crown of the dam is 6 m thick and 220 m wide. The utilizable reservoir capacity is 39.8 million m^3. For energy production only the additional reservoir capacity that was created by the dam construction is used. The residual water channel of the Löntsch leads from the Rhodannenberg dam about 5.1 km down to Netstal, where it meets the water discharged from the power plant. One kilometre further downstream, the Löntsch flows into the Linth. A trumpet spillway in Lake Klöntal discharges flood waters into the dam's bottom outlet tunnels with a maximum capacity of 47 m^3/s. This prevents the dam from overflowing in the event of excessive inflows when the lake is already full. The water intakes for the Löntsch power plant are located around 740 m west of the Rhodannenberg dam well in the Ruestelchopf area. From the intakes, the utilized water flows along the 4 km long head race to the surge tank. From here, the water flows through steel-lined pressure shaft and penstock into the distribution pipes in the power station. After passing through the turbine, the water either flows through a short tail race then into the Löntsch or is transferred directly to the lower-lying Dorfbach power plant.

The power station

The machine house contains two vertical-axis Francis turbines, each rated at a maximum of 40 MW. An horizontal-axis 8 MW Pelton turbine utilizes the concessionary minimum discharge and produces electricity for the plant's own requirements. The capacity of the head race tunnels limits the maximum water discharge rate to 20 m^3/s. If both main turbines are operated the maximum power available is 60 MW. On average, 120 million kWh are produced per year. The annual operation at maximum generator performance is 2000 hours. The electricity generated is distributed via Axpo's 50-kV and 16-kV networks.

Maintenance and service

The Löntsch power plant operator together with the cantonal authorities are responsible for the maintainance of the road along Lake Köntal. The power plant staff are also responsible for keeping the shores of the lake and the various picnic sites clean. To preserve trees growing around picnic sites, firewood is provided for tourists and hikers in the summer months. The power plant operator is also responsible for the maintenance of the hiking trails in the lake area. Access for maintenance and operation is either by means of the road to Lake Klöntal or the aerial cableway up to the surge tank.

2.2.2 Electricity production life cycle in the Löntsch power plant

Core processes: construction, operation and dismantling of the power plant

The core processes involve the operation and the construction and dismantling of the power station and all associated installations. The construction includes all the works associated with the reservoir and the production of the required materials: the building of the dam wall, the intakes, the penstock, the power station, the surge tanks and the transport cableway, as well as the excavation of the head race tunnels. The energy required for the construction, mainly diesel fuel, is also included in the core process. The power plant was built between 1905 and 1908. In 1975, some parts were refurbished: the power station, the surge tanks and the pressure tunnels were rebuilt. Parts installed after the construction were also taken into consideration. This includes the turbines, cranes, generators, transformers, emergency power supply and all the general electrical equipment. Operational inputs in the reference year include the fuel used by vehicles and emergency generators, the oil required for heating the buildings and the chemicals required during operations – mainly lubricating oil.

Additionally, methane emissions are considered in the core processes. Methane is formed mainly in lake sediments and may diffuse through the water column to the lake surface or it is released as consequence of water turbining. Regarding the situation of lake Klöntal, methane emissions via the lake surface can only be partly attributed of the anthropogenic use of hydropower as the lake had already been formed earlier by a natural landslide.

Upstream processes: preparation of the operating materials

For the purposes of this study the upstream processes refer to the production of electricity and lubricating oil used as inputs to the core process.

Downstream processes: distribution of electricity

The Löntsch power plant produces electricity, which is fed into the Axpo interregional grid that supplies electricity to consumers. This distribution network consists of a total of about 2000 km of high voltage (110/50 kV) and approx. 100 km of medium voltage (16 kV) power lines. Axpo customers are usually publicly-owned electric utilities in Switzerland that transform and distribute electricity to end customers. Total losses due to the distribution within the Axpo network amounted to approximately 0.6%.

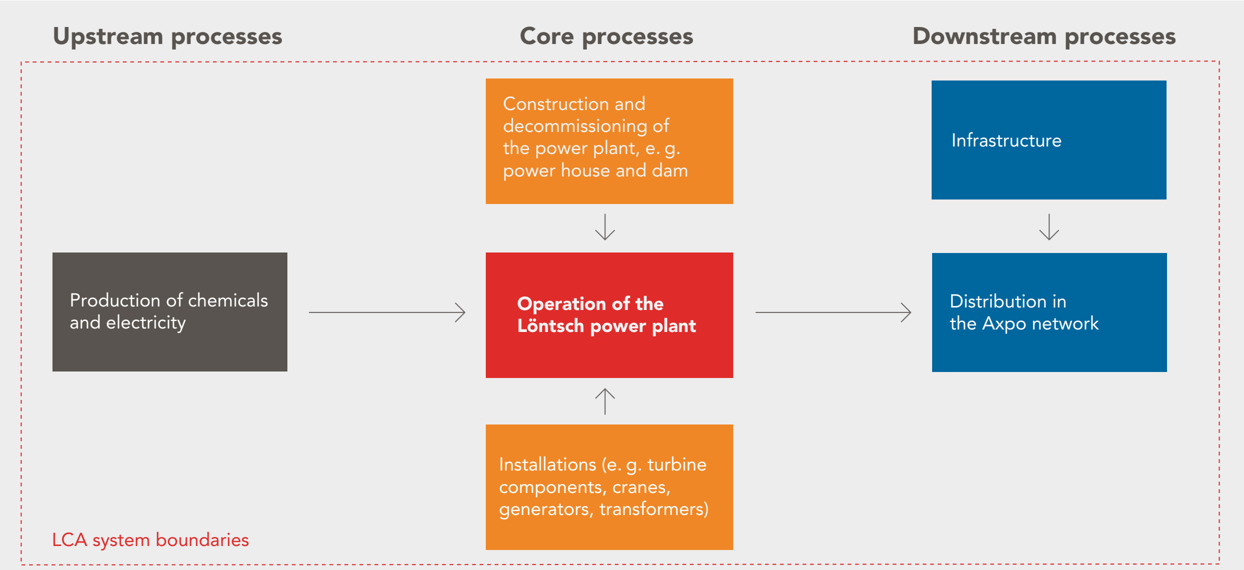
3 Environmental impact declaration

3.1 The Life cycle assessment methodology

According to the ISO 14025 standard, the LCA methodology was applied to quantify the global environmental impact. LCA is a clearly structured framework based on international standards[2] that facilitates the quantification and assessment of emissions to the environment and resource usage along the entire electricity production chain. The LCA findings include comprehensive assessments of the overall energy, mass and emission flows and the proportionate contributions of each of the key processes involved. Furthermore, it also provides quantification of significant environmental indicators, such as greenhouse gas emissions. However, despite these advantages, there are some issues beyond the scope of an LCA. For example, the LCA study only takes into account the normal operating conditions and processes. Unusual process conditions such as accidents are excluded. Additionally, while attempting to consider the "big picture" or total process chain, one can easily loose sight of the local environmental effects e.g. the impact on flora and fauna in the immediate vicinity of the power plant. Finally, an LCA study only quantifies environmental impacts; no economic, social or ethical aspects are considered.

3.2 System boundaries, allocations, and data sources

The LCA comprises the full plant life cycle and associated processes from "cradle to grave", starting with the construction of the plant and the installation of the equipment, followed by the operation of the plant and ending with the dismantling and restoration of the original conditions. The reference period is the 2016/17 year. The period chosen covers one business year of the Löntsch power plant. The figure below is a simplified process chain with system boundaries for the LCA of electricity from the Löntsch power plant.



Simplified process chain of electricity generation and distribution from Löntsch power plant.

[2] ISO 14040 and ISO 14044 as well as Product Category Rules

Data for all processes in the process chain presented above were gathered from the original construction plans or provided directly by the operating personnel of the Löntsch power plant. These data provide a reliable basis for an LCA study. For the calculation of the LCA results, all available data were used without a cut-off for supposedly unimportant data. Relevant data on material and energy supply (power mix, heat and process steam), building material supply (e.g. steel and concrete production), transport services and waste treatment processes were taken from the ecoinvent database[3]. The ecoinvent database is a joint initiative of institutes and departments of the Swiss Federal Institute of Technology and provides consistent, transparent and quality-assured Life cycle inventory (LCI) data.

3.2.1 Core processes

All the materials used for the construction of the Löntsch Power Plant (stone and clay) as well as the energy used for digging the head race tunnels were recorded in detail and published in a special edition of the Schweizerische Bauzeitung[4] (Swiss Construction Newspaper) as early as 1910. The volumes of materials used for the new power plant constructions undertaken in 1975 were estimated by experts. The life span of the plant was assumed to be 80 years. The assessment of the type and quantities of materials required for the installations (turbines, generators and electrotechnology etc.) was made by the operating personnel. A specific, technical life span was estimated for each installation. The amounts of fuel and consumption of auxiliary materials were taken from internal records.

Methane emissions were measured in 2011 applying various methods. The measuring program was performed by the Swiss Federal Institute of Aquatic Science and Technology EAWAG[5]. The specific methane emission factors vary between 0.3 to 3.1 mg CH_4 m^{-2} d^{-1} depending on the applied measuring method. According to EAWAG this result corresponds to typical emission factors found in alpine lakes.

3.2.2 Upstream processes

Data on the impact of the production of heating oil, fuel and auxiliary materials as well as the assumptions about the electric power mix for the operational needs of the power station were taken from the ecoinvent database.

[3] ecoinvent database 2007, Swiss Centre for Life-Cycle Inventories, http://www.ecoinvent.org
[4] "Elektrizitätswerk am Löntsch, Baden", in Schweizerische Bauzeitung, Band LV and LVI, 1910
[5] Report "Methane emissions from lake Klöntal,,, EAWAG, January 2012

3.2.3 Downstream processes

Comprehensive data on the operation of the Axpo distribution grid, such as distribution losses or Sulphurhexafluoride SF_6 emissions was available. Swiss-specific data on the construction and decommissioning of the high voltage and medium voltage transmission grid was taken from the ecoinvent database. Generic transport distances for the consumption of auxiliary materials were used likewise based on ecoinvent data.

3.3 Ecoprofile of electricity generation

Results of the LCA are presented in the ecoprofile tables below and then discussed in greater depth thereafter. More detailed LCA results were available to the certifying body. Quantities are expressed per declared unit 1 kWh generated electricity (net) at Löntsch power plant during the reference year 2016/17. The annual electricity production in the Löntsch reservoir power station varies greatly depending on the meteorological conditions which determine the water collection in the catchment area of Lake Klöntal. Therefore, this report also declares an annual operational average kWh i.e. the annual average net production of 1 kWh of electricity over the past ten years of operation.

The ecoprofile consist of various types of LCA results that can be summarized in three categories:

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

- **Life cycle impact assessment (LCIA) results:**
  In the impact assessment, inventory results that contribute to the same environmental impact (e.g. climate change due to increasing greenhouse gas concentrations in the atmosphere) are grouped and their importance in relation to a specific basic substance is characterized with a factor (e.g. global warming potential of greenhouse gases in relation to CO_2).

- **Material flows:**
  This category includes waste material and material recycling processes and flows.

Ecoprofile – Resource use	Unit	Upstream processes	Core processes operation	Core processes infrastructure	Per kWh at power plant	Per kWh at customer
Non-renewable material resources						
Gravel and sand	g	$2.72 \cdot 10^{-1}$	$3.73 \cdot 10^{-3}$	$3.01 \cdot 10^{1}$	$3.03 \cdot 10^{1}$	$3.05 \cdot 10^{1}$
Calcite	g	$5.55 \cdot 10^{-2}$	$8.17 \cdot 10^{-4}$	1.89	1.94	1.96
Iron	g	$1.08 \cdot 10^{-2}$	$3.17 \cdot 10^{-4}$	$4.68 \cdot 10^{-1}$	$4.79 \cdot 10^{-1}$	$5.11 \cdot 10^{-1}$
Clay	g	$1.68 \cdot 10^{-2}$	$2.62 \cdot 10^{-4}$	6.98	6.99	7.04
Nickel	g	$5.54 \cdot 10^{-4}$	$1.08 \cdot 10^{-5}$	$3.18 \cdot 10^{-2}$	$3.24 \cdot 10^{-2}$	$3.27 \cdot 10^{-2}$
Chromium	g	$2.61 \cdot 10^{-4}$	$3.32 \cdot 10^{-6}$	$1.19 \cdot 10^{-2}$	$1.22 \cdot 10^{-2}$	$1.24 \cdot 10^{-2}$
Barite	g	$5.34 \cdot 10^{-4}$	$1.64 \cdot 10^{-4}$	$1.01 \cdot 10^{-3}$	$1.71 \cdot 10^{-3}$	$1.74 \cdot 10^{-3}$
Aluminium	g	$9.00 \cdot 10^{-4}$	$5.54 \cdot 10^{-6}$	$4.51 \cdot 10^{-3}$	$5.41 \cdot 10^{-3}$	$7.93 \cdot 10^{-3}$
Fluorite	g	$2.55 \cdot 10^{-4}$	$3.65 \cdot 10^{-6}$	$2.86 \cdot 10^{-4}$	$5.45 \cdot 10^{-4}$	$6.21 \cdot 10^{-4}$
Copper	g	$1.18 \cdot 10^{-3}$	$4.20 \cdot 10^{-6}$	$4.58 \cdot 10^{-2}$	$4.70 \cdot 10^{-2}$	$5.45 \cdot 10^{-2}$
Magnesite	g	$4.89 \cdot 10^{-4}$	$2.25 \cdot 10^{-6}$	$6.67 \cdot 10^{-3}$	$7.16 \cdot 10^{-3}$	$7.21 \cdot 10^{-3}$
Zinc	g	$3.19 \cdot 10^{-5}$	$1.64 \cdot 10^{-6}$	$2.95 \cdot 10^{-4}$	$3.29 \cdot 10^{-4}$	$3.41 \cdot 10^{-4}$
Kaolinite	g	$3.37 \cdot 10^{-4}$	$2.16 \cdot 10^{-7}$	$1.14 \cdot 10^{-4}$	$4.51 \cdot 10^{-4}$	$4.60 \cdot 10^{-4}$
Uranium	g	$1.40 \cdot 10^{-4}$	$5.07 \cdot 10^{-8}$	$4.75 \cdot 10^{-6}$	$1.45 \cdot 10^{-4}$	$1.46 \cdot 10^{-4}$
Zirconium	g	$6.32 \cdot 10^{-6}$	$2.40 \cdot 10^{-7}$	$2.04 \cdot 10^{-5}$	$2.69 \cdot 10^{-5}$	$2.90 \cdot 10^{-5}$
Renewable material resources						
Wood	m^3	$4.01 \cdot 10^{-8}$	$3.13 \cdot 10^{-10}$	$3.29 \cdot 10^{-8}$	$7.33 \cdot 10^{-8}$	$8.38 \cdot 10^{-8}$
Non-renewable fossil energy resources						
Hard coal	MJ-equivalents	$8.77 \cdot 10^{-3}$	$5.24 \cdot 10^{-5}$	$8.67 \cdot 10^{-3}$	$1.75 \cdot 10^{-2}$	$1.81 \cdot 10^{-2}$
Crude oil	MJ-equivalents	$2.81 \cdot 10^{-3}$	$3.02 \cdot 10^{-3}$	$1.78 \cdot 10^{-2}$	$2.37 \cdot 10^{-2}$	$2.41 \cdot 10^{-2}$
Natural gas	MJ-equivalents	$9.33 \cdot 10^{-3}$	$1.32 \cdot 10^{-3}$	$1.05 \cdot 10^{-2}$	$2.12 \cdot 10^{-2}$	$2.16 \cdot 10^{-2}$
Lignite	MJ-equivalents	$3.60 \cdot 10^{-3}$	$5.40 \cdot 10^{-6}$	$4.69 \cdot 10^{-4}$	$4.08 \cdot 10^{-3}$	$4.15 \cdot 10^{-3}$
Renewable energy resources						
Converted potential energy in hydropower	kWh	0.00	1.05	0.00	1.05	1.06
Electricity consumption in Löntsch PP	kWh	–	$2.62 \cdot 10^{-2}$	–	$2.62 \cdot 10^{-2}$	$2.71 \cdot 10^{-2}$
Use of recycled material						
Iron scrap	g	$9.14 \cdot 10^{-3}$	$2.59 \cdot 10^{-4}$	1.54	1.55	1.56
Water consumption						
Freshwater	g	$5.35 \cdot 10^{2}$	$8.38 \cdot 10^{-1}$	$1.22 \cdot 10^{2}$	$6.58 \cdot 10^{2}$	$6.65 \cdot 10^{2}$
Saltwater	g	5.36	$9.66 \cdot 10^{-2}$	$7.37 \cdot 10^{-1}$	6.19	6.26
Water for turbining	m^3	$1.14 \cdot 10^{-1}$	1.20	$1.43 \cdot 10^{-2}$	1.32	1.33

Ecoprofile – Pollutant emissions	Unit	Upstream processes	Core processes operation	Core processes infrastructure	Per kWh at power plant	Per kWh at customer
Airborne emissions – impact assessment results						
Greenhouse gases	g CO_2-equivalents	1.61	$5.27 \cdot 10^{-1}$	3.45	5.59	5.80
Ozone-depleting gases	g CFC-11-equivalents	$8.64 \cdot 10^{-7}$	$2.56 \cdot 10^{-8}$	$2.44 \cdot 10^{-7}$	$1.13 \cdot 10^{-6}$	$1.16 \cdot 10^{-6}$
Formation of ground-level ozone	g ethylene-equivalents	$8.15 \cdot 10^{-4}$	$3.85 \cdot 10^{-4}$	$4.33 \cdot 10^{-3}$	$5.53 \cdot 10^{-3}$	$5.77 \cdot 10^{-3}$
Acidifying substances	g SO_2-equivalents	$4.99 \cdot 10^{-3}$	$8.17 \cdot 10^{-4}$	$3.62 \cdot 10^{-2}$	$4.20 \cdot 10^{-2}$	$4.55 \cdot 10^{-2}$
Airborne emissions contributing to given impact assessment results						
Ammonia	g	$8.38 \cdot 10^{-5}$	$7.21 \cdot 10^{-7}$	$3.25 \cdot 10^{-4}$	$4.10 \cdot 10^{-4}$	$4.46 \cdot 10^{-4}$
Carbon dioxide, fossil	g	1.42	$3.54 \cdot 10^{-1}$	3.26	5.04	5.15
Carbon monoxide, biogenic	g	$1.17 \cdot 10^{-4}$	$7.11 \cdot 10^{-7}$	$8.09 \cdot 10^{-5}$	$1.98 \cdot 10^{-4}$	$2.12 \cdot 10^{-4}$
Carbon monoxide, fossil	g	$1.50 \cdot 10^{-3}$	$5.14 \cdot 10^{-5}$	$7.74 \cdot 10^{-3}$	$9.29 \cdot 10^{-3}$	$9.77 \cdot 10^{-3}$
Dinitrogen monoxide	g	$1.49 \cdot 10^{-4}$	$6.81 \cdot 10^{-7}$	$1.47 \cdot 10^{-4}$	$2.97 \cdot 10^{-4}$	$3.05 \cdot 10^{-4}$
Methane, bromochlorodifluoro-, Halon 1211	g	$1.22 \cdot 10^{-8}$	$4.92 \cdot 10^{-11}$	$1.86 \cdot 10^{-9}$	$1.41 \cdot 10^{-8}$	$1.43 \cdot 10^{-8}$
Methane, bromotrifluoro-, Halon 1301	g	$1.30 \cdot 10^{-9}$	$1.55 \cdot 10^{-9}$	$8.73 \cdot 10^{-9}$	$1.16 \cdot 10^{-8}$	$1.17 \cdot 10^{-8}$
Methane, biogenic	g	$2.30 \cdot 10^{-4}$	$6.96 \cdot 10^{-3}$	$8.53 \cdot 10^{-5}$	$7.27 \cdot 10^{-3}$	$7.32 \cdot 10^{-3}$
Methane, fossil	g	$4.41 \cdot 10^{-3}$	$2.91 \cdot 10^{-4}$	$4.81 \cdot 10^{-3}$	$9.52 \cdot 10^{-3}$	$9.77 \cdot 10^{-3}$
Nitrogen oxides	g	$2.20 \cdot 10^{-3}$	$1.28 \cdot 10^{-4}$	$1.90 \cdot 10^{-2}$	$2.14 \cdot 10^{-2}$	$2.19 \cdot 10^{-2}$
NMVOC, non-methane volatile organic compounds	g	$5.57 \cdot 10^{-4}$	$1.78 \cdot 10^{-4}$	$3.09 \cdot 10^{-3}$	$3.83 \cdot 10^{-3}$	$3.93 \cdot 10^{-3}$
Sulphur dioxide	g	$3.09 \cdot 10^{-3}$	$1.59 \cdot 10^{-4}$	$1.79 \cdot 10^{-2}$	$2.12 \cdot 10^{-2}$	$2.35 \cdot 10^{-2}$
Other relevant non-radioactive airborne emissions						
Carbon dioxide, biogen	g	$6.25 \cdot 10^{-2}$	$3.35 \cdot 10^{-4}$	$5.64 \cdot 10^{-2}$	$1.19 \cdot 10^{-1}$	$1.29 \cdot 10^{-1}$
Particles <10 µm	g	$2.02 \cdot 10^{-4}$	$3.56 \cdot 10^{-6}$	$1.16 \cdot 10^{-3}$	$1.37 \cdot 10^{-3}$	$1.49 \cdot 10^{-3}$
Particles < 2.5 µm	g	$3.18 \cdot 10^{-4}$	$1.05 \cdot 10^{-5}$	$2.71 \cdot 10^{-3}$	$3.04 \cdot 10^{-3}$	$3.21 \cdot 10^{-3}$
Particles > 10 µm	g	$9.00 \cdot 10^{-4}$	$1.00 \cdot 10^{-5}$	$3.77 \cdot 10^{-3}$	$4.68 \cdot 10^{-3}$	$4.82 \cdot 10^{-3}$
Arsenic	g	$5.89 \cdot 10^{-7}$	$3.49 \cdot 10^{-9}$	$2.18 \cdot 10^{-5}$	$2.24 \cdot 10^{-5}$	$2.60 \cdot 10^{-5}$
Cadmium	g	$2.03 \cdot 10^{-7}$	$3.38 \cdot 10^{-9}$	$7.55 \cdot 10^{-6}$	$7.76 \cdot 10^{-6}$	$9.03 \cdot 10^{-6}$
Dioxins	g	$5.33 \cdot 10^{-13}$	$1.28 \cdot 10^{-14}$	$2.99 \cdot 10^{-12}$	$3.54 \cdot 10^{-12}$	$3.72 \cdot 10^{-12}$
PAH, polycyclic aromatic hydrocarbons	g	$1.65 \cdot 10^{-7}$	$2.41 \cdot 10^{-9}$	$1.12 \cdot 10^{-6}$	$1.28 \cdot 10^{-6}$	$1.42 \cdot 10^{-6}$
Radioactive airborne emissions						
Carbon 14	kBq	$1.68 \cdot 10^{-4}$	$1.52 \cdot 10^{-6}$	$1.37 \cdot 10^{-5}$	$1.83 \cdot 10^{-4}$	$1.85 \cdot 10^{-4}$
Krypton (all isotopes)	kBq	$9.99 \cdot 10^{-5}$	$3.88 \cdot 10^{-8}$	$3.45 \cdot 10^{-6}$	$1.03 \cdot 10^{-4}$	$1.04 \cdot 10^{-4}$
Radon (all isotopes)	kBq	$1.24 \cdot 10^{-1}$	$4.73 \cdot 10^{-5}$	$4.06 \cdot 10^{-3}$	$1.28 \cdot 10^{-1}$	$1.29 \cdot 10^{-1}$
Waterborne emissions – impact assessment results						
Eutrophying substances	g PO_4^{3-}-equivalents	$8.90 \cdot 10^{-4}$	$9.26 \cdot 10^{-5}$	$7.74 \cdot 10^{-3}$	$8.73 \cdot 10^{-3}$	$9.60 \cdot 10^{-3}$
Waterborne emissions contributing to given impact assessment results						
Phosphate	g	$4.45 \cdot 10^{-4}$	$1.69 \cdot 10^{-6}$	$5.00 \cdot 10^{-3}$	$5.45 \cdot 10^{-3}$	$6.23 \cdot 10^{-3}$
COD, Chemical Oxygen Demand	g	$4.77 \cdot 10^{-4}$	$2.58 \cdot 10^{-4}$	$1.74 \cdot 10^{-3}$	$2.47 \cdot 10^{-3}$	$2.52 \cdot 10^{-3}$

Ecoprofile – Pollutant emissions	Unit	Upstream processes	Core processes operation	Core processes infrastructure	Per kWh at power plant	Per kWh at customer
Other relevant non-radioactive waterborne emissions						
Ammonium, ion	g	$2.82 \cdot 10^{-5}$	$4.39 \cdot 10^{-7}$	$1.54 \cdot 10^{-5}$	$4.40 \cdot 10^{-5}$	$4.58 \cdot 10^{-5}$
Nitrate	g	$5.60 \cdot 10^{-4}$	$1.37 \cdot 10^{-6}$	$6.35 \cdot 10^{-4}$	$1.20 \cdot 10^{-3}$	$1.30 \cdot 10^{-3}$
Sulphate	g	$6.71 \cdot 10^{-3}$	$2.50 \cdot 10^{-4}$	$5.72 \cdot 10^{-2}$	$6.42 \cdot 10^{-2}$	$7.29 \cdot 10^{-2}$
Oil	g	$6.80 \cdot 10^{-5}$	$7.71 \cdot 10^{-5}$	$4.42 \cdot 10^{-4}$	$5.87 \cdot 10^{-4}$	$5.98 \cdot 10^{-4}$
Radioactive waterborne emissions						
Tritium H3	kBq	$2.97 \cdot 10^{-2}$	$1.09 \cdot 10^{-5}$	$9.64 \cdot 10^{-4}$	$3.07 \cdot 10^{-2}$	$3.09 \cdot 10^{-2}$
Other relevant non-radioactive emissions soil						
Oil	g	$4.37 \cdot 10^{-5}$	$4.57 \cdot 10^{-5}$	$2.59 \cdot 10^{-4}$	$3.49 \cdot 10^{-4}$	$3.54 \cdot 10^{-4}$

Ecoprofile – Waste and material subject to recycling	Unit	Upstream processes	Core processes operation	Core processes infrastructure	Per kWh at power plant	Per kWh at customer
Hazardous waste – radioactive						
SF/HLW/ILW in final repository	m^3	$4.60 \cdot 10^{-11}$	$1.65 \cdot 10^{-14}$	$1.47 \cdot 10^{-12}$	$4.75 \cdot 10^{-11}$	$4.78 \cdot 10^{-11}$
LLW in final repository	m^3	$4.01 \cdot 10^{-10}$	$9.81 \cdot 10^{-12}$	$6.76 \cdot 10^{-11}$	$4.78 \cdot 10^{-10}$	$4.81 \cdot 10^{-10}$
Hazardous waste – non-radioactive						
Hazardous waste to incineration	g	$9.39 \cdot 10^{-4}$	$1.21 \cdot 10^{-5}$	$5.74 \cdot 10^{-3}$	$6.69 \cdot 10^{-3}$	$7.74 \cdot 10^{-3}$
Other waste						
Non-hazardous waste to landfill	g	$6.28 \cdot 10^{-3}$	$5.43 \cdot 10^{-4}$	$1.15 \cdot 10^{-1}$	$1.22 \cdot 10^{-1}$	$8.90 \cdot 10^{-1}$
Non-hazardous waste for recycling	g	$5.99 \cdot 10^{-2}$	$1.85 \cdot 10^{-4}$	$1.45 \cdot 10^{1}$	$1.45 \cdot 10^{1}$	$1.46 \cdot 10^{1}$
Non-hazardous waste for incineration	g	$9.39 \cdot 10^{-4}$	$1.21 \cdot 10^{-5}$	$5.74 \cdot 10^{-3}$	$6.69 \cdot 10^{-3}$	$7.74 \cdot 10^{-3}$

3.4 Uncertainty analysis

The purpose of the uncertainty analysis is to quantify the variability of the calculated life cycle assessment results. The variability results from the fact that the input and output parameters for the entire process chain (e.g. annual electricity production, methane emissions) are not precise values, but can fluctuate instead. To this end, probability distributions are assigned to the values of input and output parameters. Probability distributions were taken from the ETH ecoinvent database for all background processes[6]. Additional probability distributions were defined for the most important processes modeled in the present study. For example, the annual electricity production of the Löntsch power plant and methane emissions from lake Klöntal are dominant with regard to most of the life cycle impact assessment categories. To define the variability of these parameters, data of annual electricity production over the past ten years were used as a basis. Regarding methane emissions, emission factors of the different measuring methods were used as well as assumptions regarding the influence of the anthropogenic use of lake Klöntal are considered. The methane emission factor strongly depends on water temperature in the lake, the amount of organic matter as well as the operation scheme of the power plant and varies therefore. The table below summarizes the main assumptions used for the scenarios in the uncertainty analysis.

	Reference scenario for the operating year 16/17	**Scenario minimal environmental impact**	**Scenario maximum environmental impact**
Methane emission factor	3 mg m^{-2} d^{-1}	0.2 mg m^{-2} d^{-1}	3 mg m^{-2} d^{-1}
Surface of lake Klöntal which is affected by the electricity production	Changes in surface area due to power plant operation (1.9 km^2)	Changes in surface area due to power plant operation (1.9 km^2)	Total surface area of lake Klöntal (3.3 km^2)
Annual methane emissions	0.69 Tons	0.14 Tons	3.61 Tons
Electricity production	109.8 GWh (10a average)	123.8 GWh (2012/13)	85.8 GWh (2010/11)

In order to calculate the variability of the life cycle impact assessment results, repeated random sampling using a Monte Carlo algorithm was performed. The uncertainty range is defined in this study as the 95% interval of the sampled distribution. Hence, the minimum value is determined as the 2.5th percentile and the maximum value as the 97.5th percentile. Results of the Monte Carlo analysis are given in the tables below.

1 kWh net electricity at Löntsch power plant					
Environmental impact	**Unit**	**Value calculated without uncertainty**	**Median (50th percentile)**	**Minimum value (2.5th percentile)**	**Maximum value (97.5th percentile)**
Greenhouse gases	g CO_2-equivalents	5.59	5.66	4.47	6.98
Ozone-depleting gases	g CFC-11-equivalents	$1.13 \cdot 10^{-6}$	$1.08 \cdot 10^{-6}$	$5.78 \cdot 10^{-7}$	$1.78 \cdot 10^{-6}$
Formation of ground-level ozone	g ethylene-equivalents	$5.53 \cdot 10^{-3}$	$5.33 \cdot 10^{-3}$	$3.86 \cdot 10^{-3}$	$7.67 \cdot 10^{-3}$
Acidifying substances	g SO_2-equivalents	$4.20 \cdot 10^{-2}$	$4.04 \cdot 10^{-2}$	$3.21 \cdot 10^{-2}$	$5.18 \cdot 10^{-2}$
Eutrophying substances	g PO_4^{3-}-equivalents	$8.73 \cdot 10^{-3}$	$1.78 \cdot 10^{-2}$	$1.17 \cdot 10^{-2}$	$4.33 \cdot 10^{-2}$
Depletion of fossil resources	MJ-equivalents	$6.77 \cdot 10^{-2}$	$6.60 \cdot 10^{-2}$	$5.10 \cdot 10^{-2}$	$8.56 \cdot 10^{-2}$

All results are rounded.

[6] Ecoinvent report No 1, Overview and Methodology, published by the Swiss Centre for Life Cycle Inventories 2007

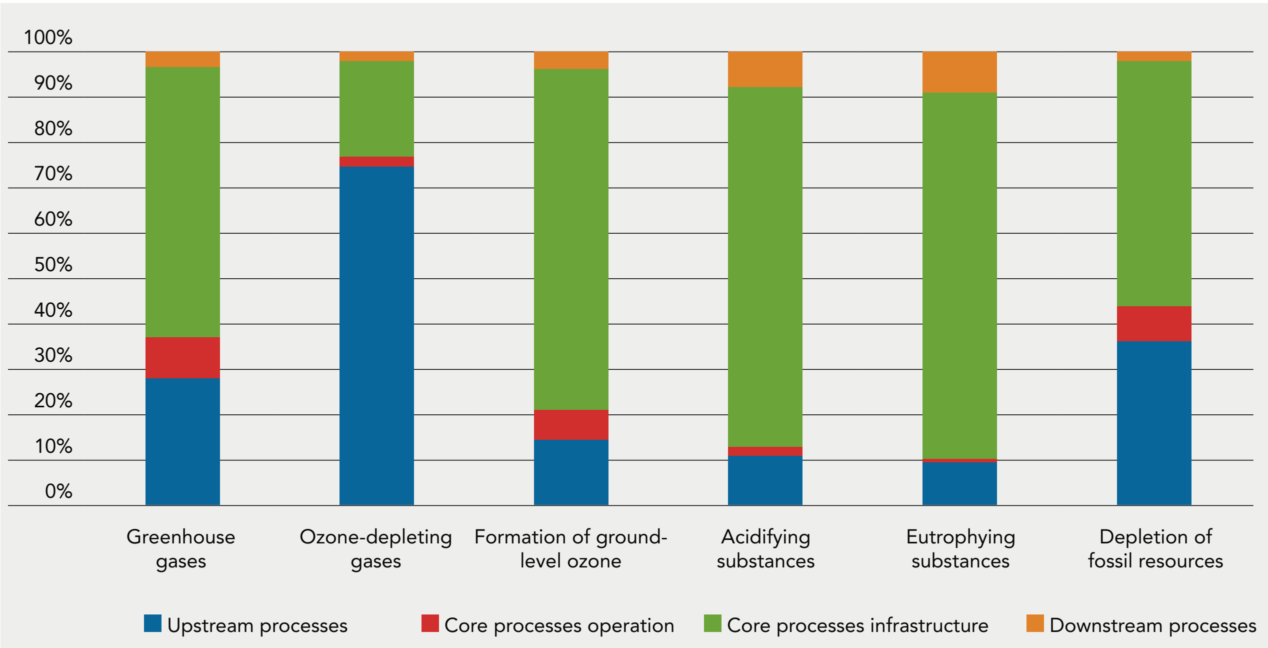
1 kWh net electricity at Axpo customer					
Environmental impact	**Unit**	**Value calculated without uncertainty**	**Median (50th percentile)**	**Minimum value (2.5th percentile)**	**Maximum value (97.5th percentile)**
Greenhouse gases	g CO_2-equivalents	5.80	5.92	4.59	7.45
Ozone-depleting gases	g CFC-11-equivalents	$1.16 \cdot 10^{-6}$	$1.11 \cdot 10^{-6}$	$5.97 \cdot 10^{-7}$	$1.69 \cdot 10^{-6}$
Formation of ground-level ozone	g ethylene-equivalents	$5.77 \cdot 10^{-3}$	$5.64 \cdot 10^{-3}$	$3.87 \cdot 10^{-3}$	$8.15 \cdot 10^{-3}$
Acidifying substances	g SO_2-equivalents	$4.55 \cdot 10^{-2}$	$4.45 \cdot 10^{-2}$	$3.53 \cdot 10^{-2}$	$5.53 \cdot 10^{-2}$
Eutrophying substances	g PO_4^{3-}-equivalents	$9.60 \cdot 10^{-3}$	$1.97 \cdot 10^{-2}$	$1.26 \cdot 10^{-2}$	$5.32 \cdot 10^{-2}$
Depletion of fossil resources	MJ-equivalents	$6.93 \cdot 10^{-2}$	$6.67 \cdot 10^{-2}$	$5.15 \cdot 10^{-2}$	$8.71 \cdot 10^{-2}$

All results are rounded.

3.5 Dominance analysis and conclusions

The contribution of the different life cycle stages to the overall results are shown in the figure below for all life cycle impact categories. The life cycle stages comprise:

- **Upstream processes:** Production of electricity from grid and lubricants.
- **Core processes operation:** Use of heating oil and diesel as well as methane emissions from lake Klöntal and from turbined water.
- **Core processes infrastructure:** Materials and energy used for construction and dismantling of the power station (dam, power house etc.) and the installation of components in the power station (turbines, generators etc.).
- **Downstream processes:** Distribution of electricity within the Axpo grid.



The overall comparison of the life cycle stages shows that upstream processes as well as infrastructure and installations of the power plant contribute most to the total environmental impact.

Regarding the upstream process, the production of electricity from grid used for operational purposes is dominant. The storage power plant Löntsch operates at full power for roughly 2000 hours per year. During this time the internal operational power requirements are covered. At other times the plant's own needs are drawn from the grid. With respect to ozone depleting gas emissions, the upstream contributions arise from the use of cooling agents in fire extinguish systems within the elctricity production chain.

For the infrastructure, the most important process is the production of cement. For the installations, the decisive factors are the production of copper for the generators and steel for the turbines and the penstock.

The life cycle stages operation as well as distribution are of minor importance. The operation also includes methane emission from lake Klöntal and from turbining. In the impact category greenhouse gases fossil carbon dioxide dominates with a 90%-share. Biogenic methane contributes with 3% to the overall result only.

3.6 Differences versus the earlier version of this EPD®

Updated material and energy flows

In the presented EPD® material and energy flows related to the new reference year 2016/2017 are considered. In particular, the annual net electricity production is relevant. As the net electricity in the reference year decreased from 108.8 to 99.2 GWh, relative environmental impacts arising from infrastructure generally increased compared to earlier version of the EPD®.

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 operation activities related to the Löntsch Power Plant changed the original land use. So, in accordance with the PCR instructions, the difference in land use before and after exploitation is systematically classified and quantified using the land classes (CLC) of the EU CORINE programme[7]. Part of the CORINE programme, launched by the European Commission in 1985, is the recording of land cover across Europe using a common nomenclature. The system has 44 classes and three hierarchical levels (e.g. use for industry, mining or forestry). Land transformation for the Löntsch Power Plant is presented in the table below.

In this study, the time of occupation is assumed to be 80 years, which refers to technical lifetime of the power plant. The main activity on the occupied area is the use of the artificially enlarged lake as reservoir for the production of electricity. Occupied industrial area consists of the dam surface as well as the surface of the power house and other buildings used for the operation of the power plant.

CORINE land cover class	Situation before exploitation	Situation after exploitation
Pasture and meadow	1.92 km^2	0 km^2
Natural water bodies	1.4 km^2	1.4 km^2
Artificial water bodies	0 km^2	1.9 km^2
Industrial area	0 km^2	0.02 km^2

All results are rounded.

4.2 Hydrology, river morphology and hydrogeology

4.2.1 Hydrology

Lake Klöntal is a seasonal reservoir which is filled afresh three to four times during the year. The lake level varies between 829 m above sea level (asl) and 847 m asl. However, the lake surface is only lowered to the minimum level during maintenance work. A minimum level of 844.50 m asl is always maintained between the 1 July and 31 October. The pictures below allow a comparison of the natural Lake Klöntal prior to 1905 and the lake today at maximum reservoir capacity. The pre-1905 picture also shows the entrance to the corporation tunnels of the Stream Associates (an association of the water-powered factories in Netstal) who used the water of Lake Klöntal prior to 1900 to power their spinning mills and other factories in Netstal.

Comparison of the natural Lake Klöntal around 1900 (left) with the modern lake at highest water levels in July 2010 (right). In the picture on the left, you can see the entrance to the corporation tunnels at the bottom right.

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

The higher reservoir level that was created by the construction of the dam wall, submerged some land – mainly on the south-eastern and the north-eastern banks. In total 1.9 km^2 of terrestrial habitat was lost. There were also areas around the confluences of the Richisauer- and Rossmaterklön, and the Sulzbach on the south-western end of the lake that were also flooded.

Originally, the Löntsch only flowed out of the lake (over the natural dam that was created by a huge prehistoric rock slide) when there was enough water inflowing via the river Klön (the confluence of the Richisauer- and Rossmatterklön) and the Sulzbach stream. Winter freezing means that Lake Klöntal often has no inflows at all – both in its original and present condition. Therefore there was no year-round water flow in the Löntsch in the natural state either. Today, only the extra storage capacity created by raising the reservoir height is used for electricity production. Consequently, the topographical relationships (i. e. the natural dam created by a rock slide) and the water level in the residual channel in winter months has not changed.

From the bottom outlet tunnels, 10 l/s are permanently released to irrigate the amphibian biotope, which is directly below the dam. The Löntsch itself is fed by the Schletterbach which lies 180 m below the dam and from other springs. The Schletterbach flows mainly after heavy precipitation and when snow is melting. Along the flowing section of the Löntsch in the Löntschtobel ravine, there are some 20 springs which flow into the Löntsch increasing its flow rate. It is highly likely that these springs are fed by underground seepage from Lake Klöntal. Further small streams and rivulets flow into the Löntsch as far as the Löntschtobel ravine: most of them only flow after heavy precipitation.

The water is returned to the river after use at the power station in Netstal. The water users downstream of the Löntsch power station take their water directly from the outlet channel (tailrace) so that not all the water that passes through the turbines is returned to the Löntsch. Between the water outlet and the confluence with the river Linth, over a distance of about 1 km, the water flow rates vary with the operation of the power plant. With the implementation of current draft laws such sudden changes in waterflows will be reduced in future based on requirements and possibilities. The short section between the water outlet and the confluence with the Linth runs through the village of Netstal. In this section, the river bed and banks are extensively reinforced for flood protection. From the confluence onwards the variations in the Löntsch are absorbed by the much larger flows of the Linth.

4.2.2 River morphology

In the river bed of the Klön (above the lake) as far as Lake Klöntal various hydraulic engineering works were carried out in harmony with nature. The river morphology of the Löntsch has been slightly modified for a roughly 800 m section starting at the dam. In this river section, bank protection measures and bridge foundations affect the river morphology. The following section, as far as the exit of the gorge at Riedern is in a more or less natural state. There are pronounced changes in the river width and the bed is in a natural condition, with the exception of one fishery barrage. Bed load enters the stream via the many gullies and scree slopes that transport large quantities of gravel into the Löntsch during heavy precipitation. In the gorge, the river banks are almost completely free of vegetation. Otherwise there is typical native riverside vegetation with softwoods and mixed deciduous forests. From Riedern to the confluence with the Linth, there are mainly man-made river banks to protect against flooding.

4.2.3 Ground water and springs

Along the residual channel of the Löntsch, groundwater protection measures were decreed[8]. The water management of the Löntsch does not affect the springs, as most of them are fed by underground seepage from Lake Klöntal. After the reservoir level was increased, the flow rates in the springs probably increased. The quality of the water in the tapped springs is good.

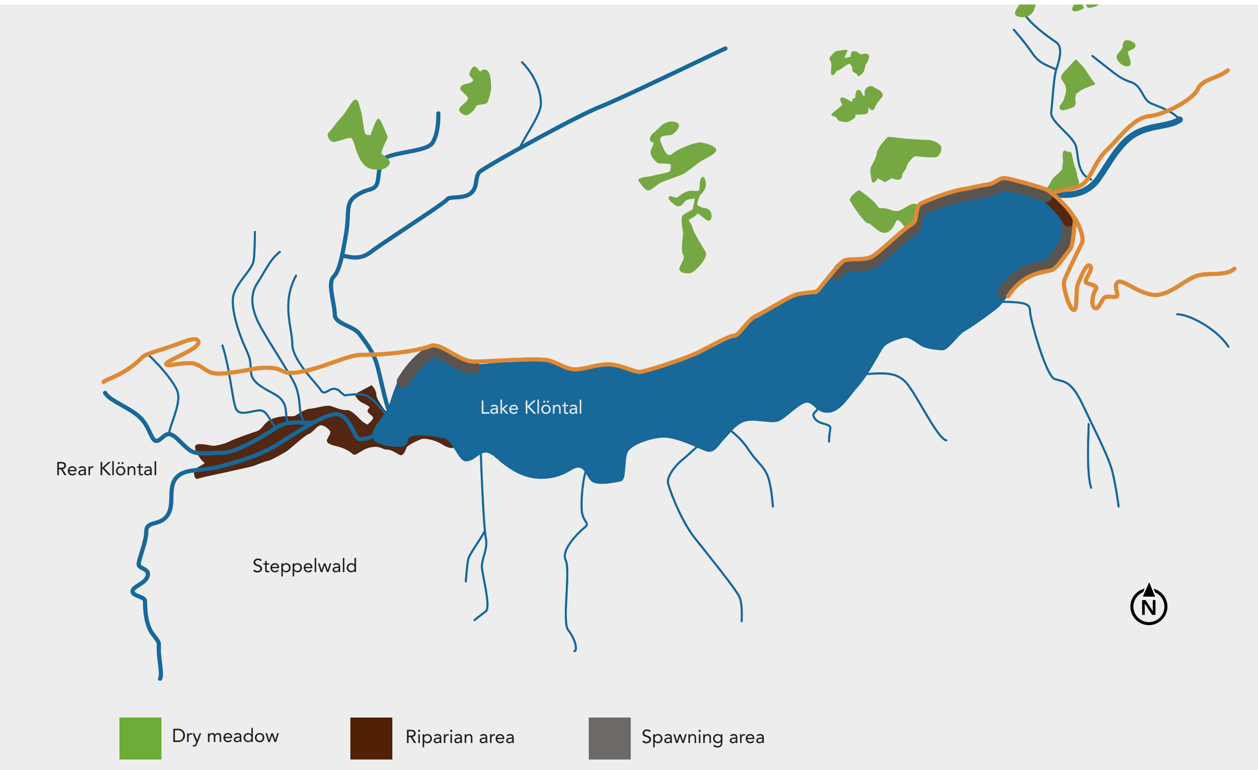
[8] Ecogis, www.ecogis.admin.ch of 6 October 2010

4.3 Biodiversity

4.3.1 Federal inventory of national significance in Klöntal

The Klöntal valley provides a habitat for many different animal and plant species. Rear Klöntal consists of a riparian forest of about 18 hectares, which is of national significance[9]. The formation of a riparian forest was enhanced by the increased reservoir height which raised the ground water levels. This riparian area includes the streams that flow into Lake Klöntal, namely the Richisauerklön and the Rossmatterklön (core zone) and the Sulzbach (buffer zone) as well as the group of springs called the Blue springs (core zone). The vegetation is characterized by the grey alders and ash trees amongst pioneer herb fields. There are also some swampy areas. The embankments of the streams have not been trained – they have been left in their natural condition and so provide the riparian plains with the periodic flooding that is necessary for the preservation of the riparian character. The size of the riparian forest prior to the raising of the dam height is unknown. It is likely that the Richisauerklön and Rossmatterklön, and the Sulzbach inundated the entire valley floor during floods. One can assume the levels of the mouths of both the Richisauerklön and the Rossmatterklön were significantly lower than they are today and that the two rivers only began to create a shared delta after the level of the lake was raised. The newly created delta areas were rapidly colonized by riparian vegetation. As the area around the riparian forest is used anthropogenically (camp site and sewage treatment), the streams cannot meander or expand at will. Periodically it has been necessary to remove gravel from the stream beds to protect the camp site from the risk of flooding. The bed load that enters the lake (of between 4000 to 5000 m^3 per year), is negligible in comparison to the total reservoir capacity of almost 40 million m^3.

Several dry meadow and pasture areas in the Klöntal valley have been included in the Federal Inventory of Nationally Significant Biotopes. These dry meadows and pastures are not affected by the operation of the power plant.



Federal inventories of national significance.

[9] "Aueninventar Kanton Glarus" (Flood plain inventory canton Glarus) status July 2007

4.3.2 Impact of the power plant on its environment

Flora

In the area around the power plant around 900 species of plants can be found[10]. Based on a red list[11], several of them are classified as "vulnerable", "at critical risk" or "endangered". They are listed below. Three of these species were only found in Klöntal prior to 1982. This loss of biodiversity is due to the general increase in anthropogenic activity in the area.

- **Near Threatened (NT):** Canary Grass, Broomrape, Ivy Broomrape, Ghost Orchid (found before 1982), Pyramidal Orchid (found before 1982), French Wild Onions, Marsh Cudweed
- **Vulnerable (VU):** Yellow Coris (found before 1982), Lady's Slipper Orchids, Fire/Tiger Lily, White Adder's Mouth, Dyer's Rocket, Birdeye Pearlwort, Summer Lady's Tresses
- **Endangered (EN):** Milk thistle
- **Critical Risk (CR):** Caley pea

Fauna

Prior to 1994, there were numerous spottings of Papilionoidea butterflies in the Klöntal[12]. At that time, 18 species were positively identified in the riparian area or in its immediate surroundings. The presence of 14 further species was highly likely. A further eight species are present today in the immediate surroundings of the riparian areas. Two of these are critically endangered in Northern Switzerland and one of them is even critically endangered across Europe. Both species are found in several areas around Lake Klöntal, making the area nationally and internationally significant for their protection. The habitat of these species is not affected by the operation of the power plant.

Amphibians such as frogs, newts and salamanders are among the oldest vertebrates. Globally, their numbers have declined massively in recent decades. In the canton of Glarus, only nine species of amphibians remain. Every year in spring, amphibians migrate from their wintering grounds to their breeding waters. In the canton of Glarus the European Common Frog, the Common Toad and the slightly rarer Alpine Newt are present[13]. These amphibians usually spend the winter in sheltered areas of the forest floor or hedgerows. To reproduce they require a standing water body such as Lake Klöntal where they spawn. In late spring, the adult amphibians leave the waters again and spend the summer in pastures, hedgerows, gardens or forests.

There are nationally significant amphibian breeding grounds on the north-eastern shores of Lake Klöntal, as well as in the riparian forest areas. Extensive shore stretches of Lake Klöntal are inhabited by amphibians, these probably having the highest amphibian density in the canton. To get from their spawning grounds on Lake Klöntal back to the forests, amphibians need to cross the Rhodannenberg-Vorauen road. In the past many frogs were run over and killed, due to the relatively high traffic flow to the two camp sites. To prevent this, the Löntsch power plant pro-vided by order of the cantonal environmental agency six amphibian underpasses between 2007 and 2010.

Fish and aquatic ecology

Lake Klöntal is a popular destination for anglers. In the past, the lake was heavily stocked with native and exotic fish species. Today, only Brown Trout and European Lake Trout are released into the lake. Frequent catchings of Pike, European Perch and White Fish suggest successful colonization of the waters by the exotic fish previously released. Further fish species found in Lake Klöntal are Bullheads, Roaches, Minnows, Chubs and Bleaks (all reproducing naturally) and the Canadian Lake Trout (natural reproduction not proven). The fish fauna of the Löntsch consists mainly of Brown Trout and some Rainbow Trout (es-capees from fish farms). Fishing is practiced in the Löntsch. Most of the fish are present due to stocking measures, but it is possible that some natural reproduction is taking place. Originally, fish could only migrate as far as the entrance to the Löntschtobel ravine. Here a number of natural water falls, with heights of several metres, prevent natural fish migration. Today upstream fish migration is stopped short before the ravine by concrete weirs constructed for bed stability reasons. Before the construction of the artificial dam wall, the Löntsch flowed minimal or no discharge during the winter months. This fact is documented in the reports of the Stream Cooperative and is evident by the construction of the corporation tunnels by the Stream Cooperative (in 1856–1859 and 1895–1898) which were required to ensure water supply to power the Netstal factories in winter. Consequently, the flow characteristics of the Löntsch and its aquatic habitat

[10] Swiss Web Flora, www.wsl.ch, retrieved 6 October 2010
[11] Source: Rote Liste der gefährdeten Farn- und Blütenpflanzen der Schweiz, BUWAL, Bern 2002
[12] Source: Schutzplanung Auenprojekt Hinter Klöntal, Forstdirektion des Kanton Glarus, 1995
[13] Source: Press release No 37101 of Canton Glarus, 16 March 2007

were hardly affected in winter by the increase in the dam height and the current use of water for hydro power. In summer, the discharge in the Löntsch is reduced by use of water for power production. However, just 500 m below the dam wall, there is sufficient water flow for an intact aquatic ecosystem, due to the inflow from lateral tributaries.

4.4 Environmental risks

Potential environmental risks are posed by unexpected incidents or accidents which could lead to damaging emissions from the power plant that would negatively impact the environment. Emissions from most foreseeable accidents would be minimal to insignificant because harmful substances (e.g. oil) would be contained within the power plant by safety precautions in place. One imaginable risk would be the sudden breach of the dam wall. To prevent such an event the dam is continually monitored by Axpo as well as external specialists. Increased seepage through the dam would be noticed and appropriate measures immediately undertaken.

4.5 Electromagnetic fields

The term "electromagnetic field" (EMF) refers to the lower frequency range of the electromagnetic spectrum (0 to 300 GHz). EMFs are omnipresent in our environment – whether from natural or man-made sources; intended as in the case of radio signals or unintended as a by-product of electrical power transmission or electrical appliances. Technically, magnetic fields are induced by the motion of electric charges. The strength of the magnetic field is measured in amperes per meter (A/m). In electromagnetic field research, scientists usually specify a related quantity, the flux density (in microtesla, µT). The higher the current, the greater the strength of the magnetic field. One of the main characteristics of an EMF is its frequency or corresponding wavelength. Fields of different frequencies interact with the human body in different ways.

For the protection of people working in power plants, Suva[14] has issued emission limits in accordance with ICNIRP[15]-directive 1998 stipulating a maximum of 500 µT. This limit is not exceeded anywhere in the Löntsch power plant except in the cable tunnel that runs from the switchyard to the powerhouse. However, the field strength falls to below the threshold value within 20 cm from the cables, which means that there is no EMF risk to workers or visitors. Outside the power plant, there are no electromagnetic fields caused by the Löntsch power plant[16].

4.6 Noise and vibrations

The Swiss Federal Noise Protection Act (LSV) limits environmental noise emissions in industrial and commercial areas to 70 dB(A) during the day-time and 60 dB(A) during the night. For residential and trade areas, the limits are 65 dB(A) and 55 dB(A), respectively. The machine house of the Löntsch power plant is in an industrial and trade zone[17], while the water outlet is in a residential and trade zone. The plant does not exceed the Swiss LSV (environmental) or Suva (interior rooms, work safety) limits during any phase of operation including start-up and shut-down and operation at maximum capacity[18]. Vibration caused by the operation of the turbines is not perceptible outside the power plant.

[14] Suva: The Swiss Accident Insurance Institution
[15] ICNIRP: International Commission on Non-Ionizing Radiation Protection
[16] NOK technical report EU 1876 25 April 2003
[17] Source: Zone map Canton Glarus
[18] Suva measurement report 519-647/01.04, 13 January 2004

5 Certification body and mandatory statements

5.1 Information from the certification body

The certification of the Environmental Product Declaration, EPD®, of electricity from the Löntsch high pressure reservoir power plant has been carried out by Bureau Veritas Certification. 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-00332.

5.2 Mandatory statements

5.2.1 General statements

Note that EPDs from different EPD programmes may not be directly comparable.

5.2.2 Omissions of life cycle stages

In accordance with the PCR, the use stage of produced electricity has been omitted since the use of electricity 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 at 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 3.0.

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 and 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

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 Rule

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