Environmental Product Declaration

Wildegg-Brugg run-of-river Power Plant | Update 2019

EPD®

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Summary

Company

Axpo is a leading Swiss electricity producer. Axpo guarantees a reliable supply of electricity to north-eastern Switzerland. Hydroelectric and nuclear power plants secure the base load. Fluctuating demand and peak loads are balanced using storage and pump storage plants.

Product and declared unit

The Wildegg-Brugg run-of-river power plant, wholly owned by Axpo, uses the head difference over a 9-km stretch of the River Aare to produce a total power output of 50 megawatt (MW). This represents an annual average electricity generation of around 300 gigawatt hours (GWh) – an important contribution to Axpo's baseload production.

The declared product is 1 kilowatt hour (kWh) net electricity generated in Wildegg-Brugg run-of-river power plant and thereafter distributed to a customer connected to the Axpo network during the reference year 2017/2018 (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 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 electricity generated by Wildegg-Brugg run-of-river Power Plant

The life cycle assessment methodology has been applied to quantify the environmental impact. It comprises the complete 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 are shown in the EPD®.

Environmental impact	Unit	1 kWh net electricity at Wildegg-Brugg power plant	1 kWh net electricity at Axpo customer
Greenhouse gases	g CO_2-equiv.	3.2 (2.5 to 5.0)	3.4 (2.7 to 5.4)
Ozone-depleting gases	g CFC-11-equiv.	$2.5 \cdot 10^{-7}$ ($1.7 \cdot 10^{-7}$ to $4.6 \cdot 10^{-7}$)	$2.6 \cdot 10^{-7}$ ($1.7 \cdot 10^{-7}$ to $4.6 \cdot 10^{-6}$)
Formation of ground-level ozone	g ethylene-equiv.	$2.6 \cdot 10^{-3}$ ($1.8 \cdot 10^{-3}$ to $4.8 \cdot 10^{-3}$)	$2.8 \cdot 10^{-3}$ ($2.1 \cdot 10^{-3}$ to $5.2 \cdot 10^{-3}$)
Acidifying substances	g SO_2-equiv.	$1.6 \cdot 10^{-2}$ ($1.2 \cdot 10^{-2}$ to $2.6 \cdot 10^{-2}$)	$1.8 \cdot 10^{-2}$ ($1.4 \cdot 10^{-2}$ to $2.8 \cdot 10^{-2}$)
Eutrophying substances	g PO_4^{3-}-equiv.	$2.8 \cdot 10^{-3}$ ($2.3 \cdot 10^{-3}$ to $1.3 \cdot 10^{-2}$)	$3.1 \cdot 10^{-3}$ ($2.7 \cdot 10^{-3}$ to $1.5 \cdot 10^{-2}$)
Depletion of fossil resources	MJ-equiv.	$3.1 \cdot 10^{-2}$ ($2.3 \cdot 10^{-2}$ to $4.9 \cdot 10^{-2}$)	$3.3 \cdot 10^{-2}$ ($2.6 \cdot 10^{-2}$ to $5.4 \cdot 10^{-2}$)

Table of contents

1 Introduction

1.1 The declared product

This document constitutes the certified Environmental Product Declaration EPD® of electricity generated by the Wildegg-Brugg run-of-river hydroelectric power plant. Wildegg-Brugg power plant is owned and operated by Axpo.

The declared product is 1 kWh net electricity generated in Wildegg-Brugg power plant and thereafter distributed to a customer connected to the Axpo network during the reference year 2017/2018 (1 October to 30 September).

Wildegg-Brugg power plant renders an important contribution to the base load electricity production of Axpo. Provided water levels are sufficient, the plant is operated throughout the year. The Wildegg-Brugg power plant commenced operation in 1952.

1.2 The environmental 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 EPD®s according to ISO 14025,
- supports other EPD® programmes (i.e. national, sectorial, etc.) in seeking cooperation and harmonization as well as helping organisations to advantageously broaden the use of their EPD®s 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 in order of hierarchical importance, are:

- 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 3.1.
- General Programme Instructions for Environmental Product Declarations, EPD, Version 2.5.
- ISO 14025 on Type III environmental declarations
- ISO 14040 and ISO 14044 on 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 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 and vibrations

1.3 Axpo, LCA and EPD®

There are many reasons to declare the environmental impact of 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 minimise greenhouse gas production throughout the total life cycle. An EPD® environmental declaration is a reliable foundation for the quantitative presentation of 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, as the largest electricity producer in Switzerland, Axpo wants to take the initiative in communicating clearly and reliably.

For questions concerning this EPD®, contact Axpo.
E-mail: 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 using storage and pump storage plants. Key figures of the energy procurement of Axpo are summarized in the table below.

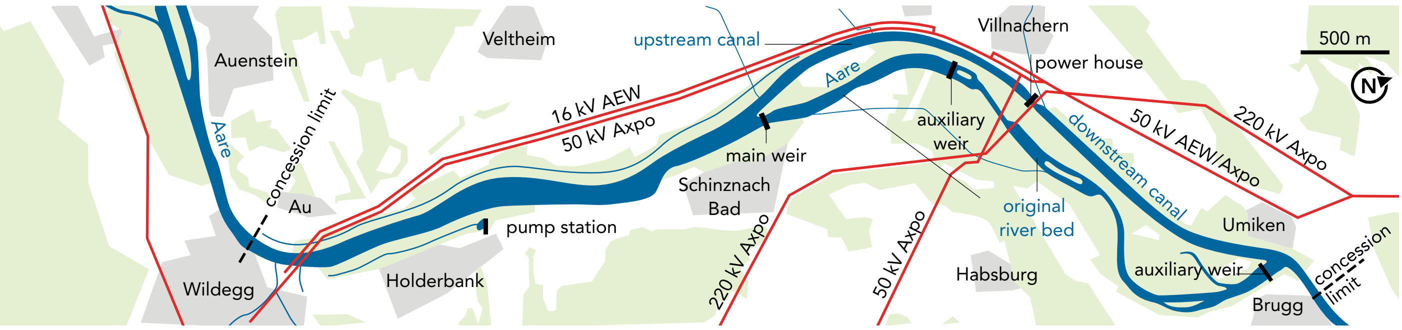
Energy procurement 2017/2018	Axpo (GWh)
Nuclear power plants	18 632
Hydroelectric power plants	9307
New renewable energies	1292
Gas and other conventional thermal power plants	6499

2.2 Product system description

2.2.1 Wildegg-Brugg Power Plant[2]

The river section of Wildegg-Brugg power plant extends from the lower concession limit of the Rupperswil-Auenstein power plant near Wildegg to the railway bridge near Umiken above Brugg, 9.35 km downstream. The catchment area covers 11.7 km^2. The power house is situated roughly halfway along the 4.5-km power station canal. The existing head between the upper water level, which is kept constant, and the lower water level depends on the level of the River Aare. When the flow in the Aare supplies 420 m^3/s – the maximum discharge capacity of the turbines[3] – the net vertical drop, known as the water "head", is 14.10 m.

The concessionary minimum residual flow through the original river bed is 10 m^3/s and can be discharged via a small turbine in the weir. Higher volumes have to be discharged by flows over the weir.



Overview of the Wildegg-Brugg Power Plant installations.

[2] Sources: Plant description Axpo (formerly NOK); transfer of the concession for the Wildegg-Brugg power plant from the Aarewerke AG to NOK AG in Baden; document from the Government of the Canton of Aargau to the Grand assembly, 1947.

[3] The discharge capacity corresponds to the maximum water volume that can pass through the turbines of a hydroelectric plant. This is the amount that can be used to generate electricity. If the flow is greater, then the excess water will be discharged via the weir.

Embankments in the dam area

The wide, flat River Aare valley makes embankments on both sides of the river in the reservoir area necessary. These were established between 1949 and 1953 during the construction of the power plant. There is just one short stretch below Holderbank where the right river bank is able to contain the dammed river naturally. Above the dam, the water level is 4 to 4.5 m above the surroundings. In order to minimize the upstream damming which might affect the flow of the Rupperswil-Auenstein hydroelectric power plant, extensive excavations were carried out in the channel during the dam construction. The crests of the embankments are 4 metres wide and 1.5 m higher than the level of the expected highest water level. They rest on the natural gravel substrate. The river-facing sides of the embankments are sealed with a concrete lining. Any water that leaks through by seepage is collected in drains that channel it along with local groundwater and surface water back into the river at suitable points. The left bank drains seepage water and the contents of the Schinznacher Talbach into the Aare river bed below the dam. Water collected in the right bank's drain is pumped back into the Aare at Holderbank as a continuation of the drain is prevented by the rising terrain at this point.

Upstream canal

The 2.4-km-long upstream canal begins with a 40-m-wide section which narrows to 21.2 m as it approaches Wallbach where the Aare is squeezed between protruding valley slopes. In the upper section, the water depth in the centre of the river is 7 m and in the lower section it is 8.2 m. The discharge current of 420 m^3/s corresponds to an average flow rate of 1.10 m/s in the wider section and 1.30 m/s in the narrower section. The river bed is only slightly lower than the surrounding land, except along the Wallbach cliff outcrop, therefore the embankments are in places up to 7 m higher than immediate vicinities. The embankments, like those in the dam section, were built with compacted fine gravel and sand sealed with concrete slabs. The river bed was also sealed with concrete slabs to prevent subterranean seepage, in particular into the main layer of sedimentary limestone that crosses under the canal and supplies the thermal springs of Schinznach Bad.

Downstream canal

Most of the 2.1-km downstream canal was artificially lowered by excavation of the gravel valley floor. In some places it is 13 m below the surrounding terrain. From the 24-m-wide upper section, the river bed begins to rise towards the canal opening. In so doing it broadens and cuts into the rising surrounding rock terrain that consists of molasse and bog iron ore. When the plant is running at the maximum discharge rate, the average flow rate in this canal is 1.90 m/s. A 2.2 km long road-topped embankment along the canal protects the surrounding land from water overflows. From the end of the canal, the river bed was widened and deepened as far as the railway bridge in Brugg.

Auxiliary weirs

The thermal waters of Bad Schinznach have their source in the northern circular fold of the Jura mountains. The gravel of the Aare valley, which is groundwater-saturated, lies above the spring water-bearing rock. During the reservoir and dam construction, there were concerns that there might be a mixing of groundwater and thermal spring water despite the deep catchment shafts. To reduce this risk, the main weir had to be located more than 750 m upstream of the baths and an auxiliary weir was built 1.5 km downstream the main weir to maintain average groundwater conditions. As a consequence of the 2011 revised Federal Act on the Protection of Waters, there are ongoing investigations if the auxiliary weirs could possibly be opened or dismantled. The second auxiliary weir close to the lower licensed stretch of the river dates back to the time of the former Brugg water mill and was included in the Wildegg-Brugg power plant project for conservation of the natural landscape and environment.

The power house

The power house is equipped with two Kaplan turbines and two electric generators that feed three-phase transformers. The two units have a combined capacity of 50 MW and produce an average of 300 million kWh annually. Wildegg-Brugg power plant is the most powerful run-of-river power plant on the River Aare.

2.2.2 Electricity production life cycle of Wildegg-Brugg Power Plant

Core processes: construction, operation and dismantling of the power plant
The core processes involve the construction, operation, and dismantling of the power plant and all associated installations. The power plant was built between 1949 and 1953. The assessment of the civil works includes all the works associated with the reservoir: the excavation and building of the embankments for the artificial canal, the production of materials for the dam, barrage, and auxiliary weirs as well as for the power house and the pump station at Holderbank. The electrical, diesel and coal[4] energy required for these works is also included in the core processes. Installations are considered to be all the equipment installed after the civil works were completed. They include turbines, cranes, generators, transformers, emergency generators and all the general electrical auxiliary equipment. Operational inputs in the reference year include the fuel used by vehicles and emergency generators, the electricity required by the Holderbank pump station and the chemicals required for operation – mainly lubricating oil.

Upstream processes: external electricity supply
For the purposes of this study the upstream processes refer to the production of electricity for the Holderbank pump station as well as the manufacturing of lubricating oil.

Downstream processes: distribution of electricity
Wildegg-Brugg power plant produces electricity, which is fed into the Axpo network that supplies electricity to consumers throughout the area covered by Axpo. This distribution network consists of approx. 2000 km of high-voltage (110/50 kilovolt [kV]) and approx. 60 km of medium-voltage (16 kV) power lines. Axpo customers are usually publicly owned electric utilities in Switzerland that further transform and distribute electricity.

[4] Coal was used in steam locomotives for material transport.

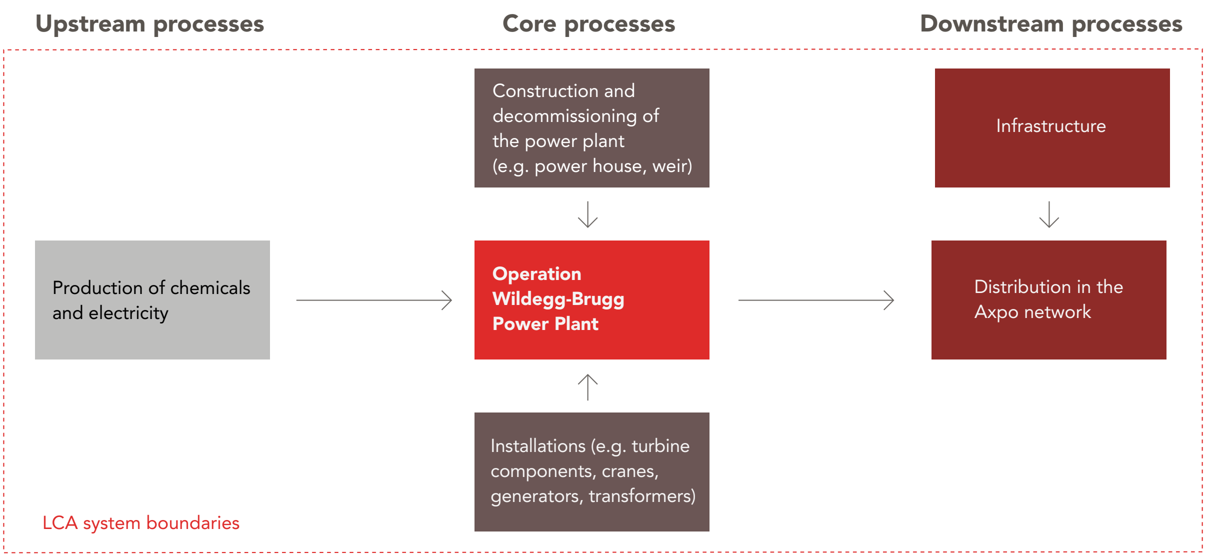
3 Environmental impact declaration

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 of the electricity generation in Wildegg-Brugg power plant and the subsequent distribution. LCA is a clearly structured framework based on international standards[5] that facilitates the quantification and assessment of emissions to the environment and resource use along the entire electricity production chain. The LCA allows for comprehensive findings on overall energy, mass and emission flows, key processes that are involved and the quantification of important environmental impacts, such as greenhouse gas emissions. However, despite these advantages, there are also some issues beyond the scope of an LCA. For example, the LCA study only focuses on the normal operation of processes. Unusual process conditions or even accidents are not included. Additionally, due to the investigation of the full process chain, local effects on the environment may not be considered, such as the impact on flora and fauna in the immediate vicinity of the dams. Finally, a LCA study only quantifies environmental impacts; no economic, social or ethical aspects are included.

3.2 System boundaries, allocation, and data sources

The life cycle assessment comprises the full plant life cycle and associated processes from "cradle to grave". The reference period is from 1 October 2017 to 30 September 2018 – one business year of the Wildegg-Brugg power plant. The figure below is a simplified process chain with system boundaries for the LCA of electricity from Wildegg-Brugg power plant. Data for all processes in the process chain presented above was gathered from the original construction plans or provided directly by the operating personnel of the Wildegg-Brugg 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 using a cut-off for supposedly unimportant data. Data on energy supply (power mix), building material supply (e.g. steel and concrete production) and transport services as well as on waste treatment processes (e.g. incineration, waste water treatment) connected to the investigated process chain was taken from the ecoinvent database. The ecoinvent database[6] 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.



Simplified process chain of electricity generation and distribution from Wildegg-Brugg power plant.

[5] ISO 14040 and ISO 14044 as well as product category rules, UN-CPC 171 and 173.

[6] ecoinvent database, Swiss Centre for Life Cycle Inventories, www.ecoinvent.org

3.2.1 Core processes

All the materials (cement, gravel, steel, etc.) and the energy (electricity, diesel, etc.) used for the construction of the Wildegg-Brugg power plant were recorded in detail and published in a special edition of the "Swiss Construction Magazine" as early as 1956[7]. The lifespan of the plant was assumed to be 80 years, which corresponds to the duration of the concession. The assessment of the type and quantities of materials required for the installations (turbines, generators and electro-technology, etc.) was made by the operating personnel. A specific, technical lifespan was estimated for each installation. The amounts of fuel and consumption of auxiliary materials as well as the electricity requirements of the Holderbank pump station were taken from internal records.

3.2.2 Upstream processes

Data on the impact of the production of auxiliary materials as well as the assumptions about the electric power mix for the Holderbank power station were taken from the ecoinvent database.

3.2.3 Downstream processes

Comprehensive data on the operation of the Axpo distribution grid was available, such as distribution losses or sulphur hexafluoride (SF_6) emissions. 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.

3.3 Ecoprofile of electricity generation

Results of the life cycle assessment are presented in the ecoprofile tables below and then discussed in greater depth thereafter. More detailed LCA results were available for the certifier. Quantities are expressed per declared unit 1 kWh generated electricity (net) at Wildegg-Brugg power plant.

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

- **Life cycle inventory (LCI) results:**
  Inventory results are direct emissions to and resource consumption 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. climate change due to increasing greenhouse gas concentrations in the atmosphere) are grouped and their importance in relation to a specific basic substance is characterised with a factor (e.g. global warming potential of greenhouse gases in relation to CO_2).

- **Material flows:**
  Selected materials that are subject to waste treat ment or recycling are presented in this category.

[7] Wildegg-Brugg Power Plant, Baden, Schweizerische Bauzeitung, Issue 79, 1956

Ecoprofile – Resource use	Unit	Upstream processes	Core processes operation	Core processes infrastructure	Per kWh at power plant	Per kWh at Axpo customer
Non-renewable material resources						
Gravel and sand	g	$2.5 \cdot 10^{-2}$	$3.4 \cdot 10^{-2}$	$1.6 \cdot 10^{1}$	$1.6 \cdot 10^{1}$	$1.6 \cdot 10^{1}$
Calcite	g	$5.2 \cdot 10^{-3}$	$1.9 \cdot 10^{-3}$	2.1	2.1	2.1
Iron	g	$2.5 \cdot 10^{-3}$	$2.6 \cdot 10^{-3}$	$3.0 \cdot 10^{-2}$	$3.5 \cdot 10^{-2}$	$6.0 \cdot 10^{-2}$
Clay	g	$1.6 \cdot 10^{-3}$	$6.8 \cdot 10^{-4}$	$7.5 \cdot 10^{-1}$	$7.5 \cdot 10^{-1}$	$7.6 \cdot 10^{-1}$
Nickel	g	$5.2 \cdot 10^{-5}$	$9.4 \cdot 10^{-5}$	$2.3 \cdot 10^{-2}$	$2.3 \cdot 10^{-2}$	$2.4 \cdot 10^{-2}$
Chromium	g	$2.5 \cdot 10^{-5}$	$3.0 \cdot 10^{-5}$	$8.6 \cdot 10^{-3}$	$8.7 \cdot 10^{-3}$	$8.8 \cdot 10^{-3}$
Barite	g	$5.1 \cdot 10^{-5}$	$4.5 \cdot 10^{-5}$	$6.2 \cdot 10^{-4}$	$7.1 \cdot 10^{-4}$	$7.4 \cdot 10^{-4}$
Aluminium	g	$8.5 \cdot 10^{-5}$	$1.1 \cdot 10^{-4}$	$1.8 \cdot 10^{-3}$	$1.9 \cdot 10^{-3}$	$1.3 \cdot 10^{-2}$
Fluorite	g	$2.4 \cdot 10^{-5}$	$3.4 \cdot 10^{-6}$	$9.0 \cdot 10^{-5}$	$1.2 \cdot 10^{-4}$	$1.4 \cdot 10^{-4}$
Copper	g	$1.1 \cdot 10^{-4}$	$5.3 \cdot 10^{-5}$	$9.2 \cdot 10^{-3}$	$9.3 \cdot 10^{-3}$	$1.0 \cdot 10^{-2}$
Magnesite	g	$4.6 \cdot 10^{-5}$	$1.7 \cdot 10^{-5}$	$4.9 \cdot 10^{-3}$	$5.0 \cdot 10^{-3}$	$5.0 \cdot 10^{-3}$
Zinc	g	$3.4 \cdot 10^{-6}$	$2.4 \cdot 10^{-5}$	$1.5 \cdot 10^{-4}$	$1.7 \cdot 10^{-4}$	$1.8 \cdot 10^{-4}$
Kaolinite	g	$3.2 \cdot 10^{-5}$	$1.6 \cdot 10^{-6}$	$5.3 \cdot 10^{-5}$	$8.7 \cdot 10^{-5}$	$9.0 \cdot 10^{-5}$
Uranium	g	$1.3 \cdot 10^{-5}$	$7.9 \cdot 10^{-8}$	$1.2 \cdot 10^{-5}$	$2.5 \cdot 10^{-5}$	$2.5 \cdot 10^{-5}$
Zirconium	g	$5.9 \cdot 10^{-7}$	$1.2 \cdot 10^{-6}$	$8.7 \cdot 10^{-6}$	$1.0 \cdot 10^{-5}$	$1.1 \cdot 10^{-5}$
Renewable material resources						
Wood	m^3	$3.8 \cdot 10^{-9}$	$7.7 \cdot 10^{-10}$	$2.1 \cdot 10^{-8}$	$2.5 \cdot 10^{-8}$	$2.9 \cdot 10^{-8}$
Non renewable fossil energy resources						
Hard coal	MJ-equiv.	$8.2 \cdot 10^{-4}$	$1.8 \cdot 10^{-4}$	$9.6 \cdot 10^{-3}$	$1.1 \cdot 10^{-2}$	$1.2 \cdot 10^{-2}$
Crude oil	MJ-equiv.	$2.8 \cdot 10^{-4}$	$8.2 \cdot 10^{-4}$	$1.0 \cdot 10^{-2}$	$1.1 \cdot 10^{-2}$	$1.2 \cdot 10^{-2}$
Natural gas	MJ-equiv.	$8.8 \cdot 10^{-4}$	$4.1 \cdot 10^{-4}$	$6.5 \cdot 10^{-3}$	$7.8 \cdot 10^{-3}$	$8.3 \cdot 10^{-3}$
Lignite	MJ-equiv.	$3.4 \cdot 10^{-4}$	$1.1 \cdot 10^{-5}$	$4.9 \cdot 10^{-4}$	$8.4 \cdot 10^{-4}$	$1.0 \cdot 10^{-3}$
Renewable energy resources						
Converted potential energy in hydropower	kWh	0.0	1.1	0.0	1.1	1.1
Use of recycled material						
Iron scrap	g	$8.6 \cdot 10^{-4}$	$2.0 \cdot 10^{-3}$	1.1	1.1	1.1
Water consumption						
Freshwater	g	$5.0 \cdot 10^{1}$	1.0	$1.2 \cdot 10^{2}$	$1.7 \cdot 10^{2}$	$1.7 \cdot 10^{2}$
Saltwater	g	$5.0 \cdot 10^{-1}$	$2.8 \cdot 10^{-2}$	$7.6 \cdot 10^{-1}$	1.3	1.4
Water for turbining	m^3	$1.1 \cdot 10^{-2}$	$3.3 \cdot 10^{1}$	$1.6 \cdot 10^{-2}$	$3.3 \cdot 10^{1}$	$3.3 \cdot 10^{1}$

Ecoprofile – Pollutant emissions	Unit	Upstream processes	Core processes operation	Core processes infrastructure	Per kWh at power plant	Per kWh at Axpo customer
Airborne emissions – impact assessment results						
Greenhouse gases	g CO_2-equiv.	$1.5 \cdot 10^{-1}$	$9.7 \cdot 10^{-2}$	2.9	3.2	3.4
Ozone-depleting gases	g CFC-11-equiv.	$8.1 \cdot 10^{-8}$	$6.7 \cdot 10^{-9}$	$1.6 \cdot 10^{-7}$	$2.5 \cdot 10^{-7}$	$2.6 \cdot 10^{-7}$
Formation of ground-level ozone	g ethylene-equiv.	$8.2 \cdot 10^{-5}$	$1.4 \cdot 10^{-4}$	$2.4 \cdot 10^{-3}$	$2.6 \cdot 10^{-3}$	$2.8 \cdot 10^{-3}$
Acidifying substances	g SO_2-equiv.	$4.7 \cdot 10^{-4}$	$3.3 \cdot 10^{-4}$	$1.6 \cdot 10^{-2}$	$1.6 \cdot 10^{-2}$	$1.8 \cdot 10^{-2}$
Airborne emissions contributing to given impact assessment results						
Ammonia	g	$7.9 \cdot 10^{-6}$	$2.0 \cdot 10^{-6}$	$1.4 \cdot 10^{-4}$	$1.5 \cdot 10^{-4}$	$1.6 \cdot 10^{-4}$
Carbon dioxide, fossil	g	$1.3 \cdot 10^{-1}$	$9.2 \cdot 10^{-2}$	2.8	3.0	3.2
Carbon monoxide, biogenic	g	$1.1 \cdot 10^{-5}$	$1.7 \cdot 10^{-6}$	$4.9 \cdot 10^{-5}$	$6.2 \cdot 10^{-5}$	$6.7 \cdot 10^{-5}$
Carbon monoxide, fossil	g	$1.4 \cdot 10^{-4}$	$2.7 \cdot 10^{-4}$	$6.5 \cdot 10^{-3}$	$6.9 \cdot 10^{-3}$	$8.6 \cdot 10^{-3}$
Dinitrogen monoxide	g	$1.4 \cdot 10^{-5}$	$3.5 \cdot 10^{-6}$	$6.5 \cdot 10^{-5}$	$8.3 \cdot 10^{-5}$	$8.8 \cdot 10^{-5}$
Methane, bromochlorodifluoro-, Halon 1211	g	$1.1 \cdot 10^{-9}$	$3.9 \cdot 10^{-11}$	$1.9 \cdot 10^{-9}$	$3.1 \cdot 10^{-9}$	$3.3 \cdot 10^{-9}$
Methane, bromotrifluoro-, Halon 1301	g	$1.3 \cdot 10^{-10}$	$4.0 \cdot 10^{-10}$	$5.1 \cdot 10^{-9}$	$5.6 \cdot 10^{-9}$	$5.8 \cdot 10^{-9}$
Methane, biogenic	g	$2.2 \cdot 10^{-5}$	$1.3 \cdot 10^{-6}$	$5.2 \cdot 10^{-5}$	$7.5 \cdot 10^{-5}$	$7.8 \cdot 10^{-5}$
Methane, fossil	g	$4.2 \cdot 10^{-4}$	$1.4 \cdot 10^{-4}$	$4.0 \cdot 10^{-3}$	$4.6 \cdot 10^{-3}$	$5.0 \cdot 10^{-3}$
Nitrogen oxides	g	$2.1 \cdot 10^{-4}$	$2.2 \cdot 10^{-4}$	$1.1 \cdot 10^{-2}$	$1.1 \cdot 10^{-2}$	$1.2 \cdot 10^{-2}$
NMVOC, non-methane volatile organic compounds	g	$5.7 \cdot 10^{-5}$	$1.1 \cdot 10^{-4}$	$1.8 \cdot 10^{-3}$	$2.0 \cdot 10^{-3}$	$2.1 \cdot 10^{-3}$
Sulphur dioxide	g	$2.9 \cdot 10^{-4}$	$1.6 \cdot 10^{-4}$	$6.8 \cdot 10^{-3}$	$7.3 \cdot 10^{-3}$	$8.5 \cdot 10^{-3}$
Other relevant non-radioactive airborne emissions						
Carbon dioxide, biogen	g	$5.9 \cdot 10^{-3}$	$6.5 \cdot 10^{-4}$	$4.8 \cdot 10^{-2}$	$5.4 \cdot 10^{-2}$	$5.7 \cdot 10^{-2}$
Particles, <10 μm	g	$1.9 \cdot 10^{-5}$	$2.1 \cdot 10^{-5}$	$7.6 \cdot 10^{-4}$	$8.0 \cdot 10^{-4}$	$9.4 \cdot 10^{-4}$
Particles, < 2.5 μm	g	$3.0 \cdot 10^{-5}$	$3.6 \cdot 10^{-5}$	$1.4 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$	$1.7 \cdot 10^{-3}$
Particles, > 10 μm	g	$8.4 \cdot 10^{-5}$	$1.9 \cdot 10^{-3}$	$3.0 \cdot 10^{-3}$	$5.0 \cdot 10^{-3}$	$5.3 \cdot 10^{-3}$
Arsenic	g	$5.5 \cdot 10^{-8}$	$2.4 \cdot 10^{-8}$	$4.1 \cdot 10^{-6}$	$4.2 \cdot 10^{-6}$	$4.8 \cdot 10^{-6}$
Cadmium	g	$1.9 \cdot 10^{-8}$	$9.5 \cdot 10^{-9}$	$1.4 \cdot 10^{-6}$	$1.4 \cdot 10^{-6}$	$1.6 \cdot 10^{-6}$
Dioxins	g	$5.0 \cdot 10^{-14}$	$3.9 \cdot 10^{-14}$	$2.8 \cdot 10^{-12}$	$2.9 \cdot 10^{-12}$	$3.1 \cdot 10^{-12}$
PAH, polycyclic aromatic hydrocarbons	g	$1.5 \cdot 10^{-8}$	$1.1 \cdot 10^{-8}$	$5.9 \cdot 10^{-7}$	$6.1 \cdot 10^{-7}$	$1.2 \cdot 10^{-6}$
Radioactive airborne emissions						
Carbon 14	kBq	$1.6 \cdot 10^{-5}$	$4.6 \cdot 10^{-7}$	$1.9 \cdot 10^{-5}$	$3.5 \cdot 10^{-5}$	$5.6 \cdot 10^{-5}$
Krypton (all isotopes)	kBq	$9.4 \cdot 10^{-6}$	$5.8 \cdot 10^{-8}$	$8.6 \cdot 10^{-6}$	$1.8 \cdot 10^{-5}$	$1.8 \cdot 10^{-5}$
Radon (all isotopes)	kBq	$1.2 \cdot 10^{-2}$	$6.4 \cdot 10^{-5}$	$1.0 \cdot 10^{-2}$	$2.2 \cdot 10^{-2}$	$2.2 \cdot 10^{-2}$
Waterborne emissions – impact assessment results						
Eutrophying substances	g PO_4^{3-}-equiv.	$8.4 \cdot 10^{-5}$	$4.5 \cdot 10^{-5}$	$2.7 \cdot 10^{-3}$	$2.8 \cdot 10^{-3}$	$3.1 \cdot 10^{-3}$
Waterborne emissions contributing to given impact assessment results						
Phosphate	g	$4.2 \cdot 10^{-5}$	$1.2 \cdot 10^{-5}$	$1.2 \cdot 10^{-3}$	$1.2 \cdot 10^{-3}$	$1.4 \cdot 10^{-3}$
COD, Chemical Oxygen Demand	g	$4.6 \cdot 10^{-5}$	$1.1 \cdot 10^{-4}$	$1.0 \cdot 10^{-3}$	$1.2 \cdot 10^{-3}$	$1.2 \cdot 10^{-3}$
Other relevant non-radioactive waterborne emissions						
Ammonium, ion	g	$2.6 \cdot 10^{-6}$	$2.6 \cdot 10^{-7}$	$6.7 \cdot 10^{-6}$	$9.7 \cdot 10^{-6}$	$1.0 \cdot 10^{-5}$
Nitrate	g	$5.2 \cdot 10^{-5}$	$2.6 \cdot 10^{-6}$	$1.8 \cdot 10^{-4}$	$2.3 \cdot 10^{-4}$	$2.5 \cdot 10^{-4}$
Sulphate	g	$6.3 \cdot 10^{-4}$	$1.9 \cdot 10^{-4}$	$1.4 \cdot 10^{-2}$	$1.4 \cdot 10^{-2}$	$1.6 \cdot 10^{-2}$
Oil	g	$6.9 \cdot 10^{-6}$	$1.9 \cdot 10^{-5}$	$2.6 \cdot 10^{-4}$	$2.9 \cdot 10^{-4}$	$3.1 \cdot 10^{-4}$
Radioactive waterborne emissions						
Tritium H_3	kBq	$2.8 \cdot 10^{-3}$	$1.5 \cdot 10^{-5}$	$2.5 \cdot 10^{-3}$	$5.3 \cdot 10^{-3}$	$5.4 \cdot 10^{-3}$
Other relevant non-radioactive emissions soil						
Oil	g	$4.4 \cdot 10^{-6}$	$1.2 \cdot 10^{-5}$	$1.5 \cdot 10^{-4}$	$1.7 \cdot 10^{-4}$	$1.7 \cdot 10^{-4}$

Ecoprofile – Waste and material subject to recycling	Unit	Upstream processes	Core processes operation	Core processes infrastructure	Per kWh at power plant	Per kWh at Axpo customer
Hazardous waste – radioactive						
SF/HLW/ILW[8] in final repository	m^3	$4.3 \cdot 10^{-12}$	$2.3 \cdot 10^{-14}$	$3.9 \cdot 10^{-12}$	$8.2 \cdot 10^{-12}$	$8.3 \cdot 10^{-12}$
LLW[9] in final repository	m^3	$3.8 \cdot 10^{-11}$	$2.7 \cdot 10^{-12}$	$6.5 \cdot 10^{-11}$	$1.1 \cdot 10^{-10}$	$1.1 \cdot 10^{-10}$
Hazardous waste – non-radioactive						
Hazardous waste to incineration	g	$8.8 \cdot 10^{-5}$	$9.5 \cdot 10^{-5}$	$2.7 \cdot 10^{-3}$	$2.9 \cdot 10^{-3}$	$3.1 \cdot 10^{-3}$
Other waste						
Non-hazardous waste to landfill	g	$5.9 \cdot 10^{-4}$	$5.9 \cdot 10^{-4}$	$1.8 \cdot 10^{-2}$	$1.9 \cdot 10^{-2}$	$2.1 \cdot 10^{-2}$
Non-hazardous waste for recycling	g	$5.6 \cdot 10^{-3}$	$4.9 \cdot 10^{-4}$	$2.3 \cdot 10^{-2}$	$2.9 \cdot 10^{-2}$	$3.4 \cdot 10^{-2}$
Non-hazardous waste for incineration	g	$8.8 \cdot 10^{-5}$	$9.5 \cdot 10^{-5}$	$2.7 \cdot 10^{-3}$	$2.9 \cdot 10^{-3}$	$3.1 \cdot 10^{-3}$

3.4 Uncertainty analysis

The purpose of the uncertainty analysis is to quantify the variability of the calculated lifecycle assessment results. The variability results from the fact that the input and output parameters for the entire process chain (e.g. annual electricity production) 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. Additional probability distributions were defined for the most important processes modeled in the present study. For example, the annual electricity production of the Wildegg-Brugg power plant are dominant with regard to most of the life cycle impact assessment categories. The annual electricity production in run-of-river power plants is strongly dependant on the meteorological conditions which determine the river flow rates. To define the variability of that parameter, data of annual electricity production over the past ten years were used as a basis. Over the last 10 years, the annual net electricity production has varied from 190 GWh to 370 GWh, with an average of 288 GWh. In the reference year, the annual net electricity production amounted to 290 GWh, which is slightly above the long-term average.

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 Wildegg-Brugg power plant		Value calculated without uncertainty	Median (50th percentile)	Minimum value (2.5th percentile)	Maximum value (97.5th percentile)
Environmental impact	**Unit**				
Greenhouse gases	g CO_2-equiv.	3.2	3.6	2.5	5.0
Ozone-depleting gases	g CFC-11-equiv.	$2.5 \cdot 10^{-7}$	$2.7 \cdot 10^{-7}$	$1.7 \cdot 10^{-7}$	$4.6 \cdot 10^{-7}$
Formation of ground-level ozone	g ethylene-equiv.	$2.6 \cdot 10^{-3}$	$2.9 \cdot 10^{-3}$	$1.8 \cdot 10^{-3}$	$4.8 \cdot 10^{-3}$
Acidifying substances	g SO_2-equiv.	$1.6 \cdot 10^{-2}$	$1.9 \cdot 10^{-2}$	$1.2 \cdot 10^{-2}$	$2.6 \cdot 10^{-2}$
Eutrophying substances	g PO_4^{3-}-equiv.	$2.8 \cdot 10^{-3}$	$6.3 \cdot 10^{-3}$	$2.3 \cdot 10^{-3}$	$1.3 \cdot 10^{-2}$
Depletion of fossil resources	MJ-equiv.	$3.1 \cdot 10^{-2}$	$3.5 \cdot 10^{-2}$	$2.3 \cdot 10^{-2}$	$4.9 \cdot 10^{-2}$

All results are rounded.

[8] SF/HLW/ILW: Spent fuel/high-level waste/long-lived intermediate-level waste

[9] LLW: Low- and intermediate-level waste

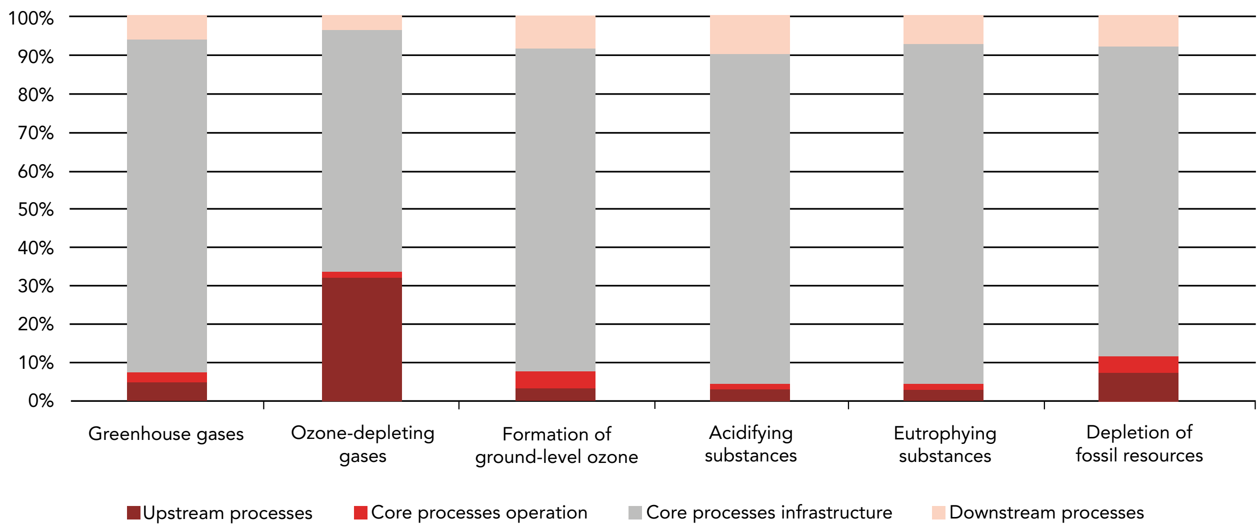
1 kWh net electricity at Axpo customer		Value calculated without uncertainty	Median (50th percentile)	Minimum value (2.5th percentile)	Maximum value (97.5th percentile)
Environmental impact	**Unit**				
Greenhouse gases	g CO_2-equiv.	3.4	3.9	2.7	5.4
Ozone-depleting gases	g CFC-11-equiv.	$2.6 \cdot 10^{-7}$	$2.9 \cdot 10^{-7}$	$1.7 \cdot 10^{-7}$	$4.6 \cdot 10^{-7}$
Formation of ground-level ozone	g ethylene-equiv.	$2.8 \cdot 10^{-3}$	$3.2 \cdot 10^{-3}$	$2.1 \cdot 10^{-3}$	$5.2 \cdot 10^{-3}$
Acidifying substances	g SO_2-equiv.	$1.8 \cdot 10^{-2}$	$2.1 \cdot 10^{-2}$	$1.4 \cdot 10^{-2}$	$2.8 \cdot 10^{-2}$
Eutrophying substances	g PO_4^{3-}-equiv.	$3.1 \cdot 10^{-3}$	$6.9 \cdot 10^{-3}$	$2.7 \cdot 10^{-3}$	$1.5 \cdot 10^{-2}$
Depletion of fossil resources	MJ-equiv.	$3.3 \cdot 10^{-2}$	$3.8 \cdot 10^{-2}$	$2.6 \cdot 10^{-2}$	$5.4 \cdot 10^{-2}$

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 taken grid and lubricants.
- Core processes operation: Water use for turbining as well as consumption of gasoline in cars and diesel in emergency power equipment.
- Core processes infrastructure: Materials and energy used for construction and dismantling of the power station (dams, channels, 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 the environmental impact of the infrastructure and particularly the construction of the power plant dominates the results. The main impact arises from the fabrication of building materials for the power plant – mainly cement, but steel production is also a significant factor. Steel is used for example in the form of sheet piles and for reinforced concrete. The production and use of energy for construction also contributes in this category: the main source being the use of diesel in construction machinery and coal in the locomotives. Coal fired locomotives were typically used for material transport during the construction period from 1949 to 1953. The main substances contributing to the impact category "ozone depletion" are chlorofluorocarbon emissions. Those substances are important components in fire-extinguishing systems, installed in certain power production facilities. Therefore, the production of electrical energy used in the Holderbank power station causes the upstream contributions to this particular impact category.

3.6 Differences versus the earlier version of the EPD® for Wildegg-Brugg

Updated material and energy flows
In the presented EPD® material and energy flows related to the new reference year 2017/2018 are considered.

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 building, operation and decommissioning activities related to the Wildegg-Brugg power plant will have changed the land use from its natural condition. In accordance with the PCR instructions, this land use is systematically classified and quantified using the land use classes (CLC) of the EU CORINE programme. 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 (i. e. use for industry, mining or forestry).

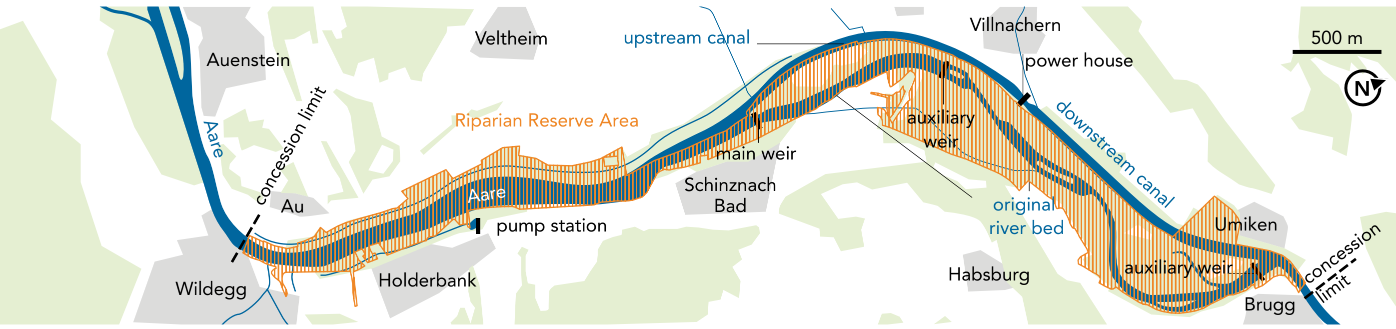
Prior to the construction of Wildegg-Brugg power plant, the original course of the Aare comprised many different distributaries with no main channel. During flooding the course varied continually. According to the CORINE land cover classes, the area of approximately 314 hectares could be described as inland marshes (CORINE code 411). After the construction of Wildegg-Brugg power plant, the area is classified as artificial water courses (CORINE Code 511).

4.2 Biodiversity

4.2.1 Riparian reserve Wildegg-Brugg: Umiker Schachen[10]

"Umiker Schachen" belongs to the Aargau Riparian Reserve, a network of the remaining flood zone areas along the rivers Aare, Reuss, Limmat and Rhine. Together they represent over 14 square kilometres where the natural river landscape has been preserved as far as possible. The natural river dynamics have been upset by canals in many flood plain areas. In the Riparian Reserve, the river is once again being allowed to create its own landscape. The reserve also protects important habitats for a diversity of animals and vegetation. The Wildegg-Brugg section of the reserve stretches from the Wildegg bridge to the railway bridge in Brugg and comprises 314 hectares of reservoir, side channels, riparian woodland and gravel island habitats.

Prior to 1900, the original course of the Aare comprised many different distributaries with no main channel. During flooding the total width was 500 m and the course of the individual arms varied continually as large quantities of gravel and sand were shifted by the river.



The Umiker Schachen Riparian Reserve Area of national importance (shaded in orange).

[10] Sources: AGIS, Geoportal Canton Aargau, www.ag.ch, retrieved 24.9.2009; Riparian Reserve Area Progress Report Aargau: Tätigkeitsbericht 2008, Umwelt Aargau Nr. 43 Februar 2009; Entwicklungskonzept Auenschutzpark Aargau, Grundlagen – Ziele – Massnahmen; Teilgebiet Wildegg-Brugg; ANL AG Natur und Landschaft, 27.4.2001.

4.2.2 Impact of the power plant on its environment

Flora

The land cover requirement of the power station itself is minimal and therefore after completion of the construction work, it can be neglected. During the operation of the plant, the environmental impact is limited to the effect on the river banks. The diversion of water away from the old Aare river bed results in the immobilisation of the alluvial deposits. The gravel banks no longer shift from season to season and plant life begins to take root. The roots of new plants stabilise the gravel, trapping sediment and speeding the succession process. Given the intention to preserve the typical riparian character and habitats, such stabilisation is undesirable and it also poses safety risks during flooding. Without intervention, the trend towards stabilisation would be more rapid. Therefore a strategy for the management of dynamic river formations has been established to coordinate the monitoring and clearing of vegetation.

Despite the impact of the power plant, the flora of Umiker Schachen is very diverse. Softwood riparian woodlands line the banks. Large white willows compete for every inch of soil on the lower Aare island where the banks fall steeply and directly into the water. Their population is, however, declining as the occasional storm or flood tears away older and rotten trees. Fast-growing herbaceous plants such as stinging nettles and Himalayan balsam spread rapidly, benefiting from the light and the ready supply of nutrients. The former alluvial meadows have now become moist riparian hardwood woodland with a predominance of ash trees. Since the beginning of the last century, such riparian hardwood woodlands have given way to a typical mixed birch forest. On account of the bark beetle invasion of spruce trees, which are atypical for this habitat, most of the spruce population was cleared in 2008 and replaced with native black poplars.

Fauna

The biodiversity in the Umiker Schachen area dropped after the power plant was built. The sealing of the upstream canal with concrete put an end to the interflows between the river and groundwaters. The consequent drop in the groundwater level meant that various ponds that had been supplied by groundwater dried up, eliminating valuable habitats. Despite these effects, various studies have shown an encouragingly diverse range of fauna in the Umiker Schachen area. A selection of the fauna is listed below with an indication of the species risk level, where available, based on the Red List[11] classifications (RE: Regionally Extinct, CR: Critical Risk, EN: Endangered, VU: Vulnerable, NT: Near Threatened, LC: Least Concern):

- Nesting birds: Little Grebe (LC), Great Crested Grebe (LC), Tufted Duck (VU), Goosander (VU), Hobby (NT), Kestrel (NT), Water Rail (LC), Cuckoo (NT), Kingfisher (VU), Green Woodpecker (LC), Gray-headed Woodpecker (VU), Lesser Spotted Woodpecker (LC), Golden Oriole (LC) Dipper (LC), Nightingale (NT), Redstart (NT), Whitethroat (NT), Wagtail (LC), Red-backed Shrike (LC), Hawfinch (LC).
- Migratory birds: Hen and Marsh Harrier (VU), Honey Buzzard (NT), Osprey (RE), White and Black Stork (VU), Little Egret, Black-crowned Night Heron (EN), Garganey (EN) Common Goldeneye (VU), Northern Pintail, Wigeon, Red-crested Pochard (NT) Northern Shoveler (EN), Red-breasted Merganser (VU), Eider Duck (VU), Greater Scaup, Black Tern.
- Waders: Common Sandpiper (EN), Ringed Plover (EN), Greenshank, Green Sandpiper, Common Snipe (CR) and Redshank (RE).
- Mammals: Bat (Common Noctule (NT), Lesser Noctule (NT), Daubenton's Bat (NT), Greater Mouse-eared Bat (VU), Common Pipistrelle (LC), Nathusius's Pipistrelle (LC), Longeared Bat (VU)), Hare (VU), Beaver (CR), Edible Dormouse (LC), Hazel (VU) Dormouse, Yellow-necked Mouse (LC), Badger (LC), Stoat (LC).
- Reptiles: Grass Snake (EN), Sand Lizard (VU), Lizard (LC), Tortoise (CR).
- Amphibians: European Treefrog (EN), Smooth Newt (EN), Great Crested Newt (EN), Alpine Newt (LC), Palmate Newt (VU), Common Frog (LC), Common Toad (VU), Edible Frog (NT), Midwife Toad (EN), Yellow-bellied Toad (EN) Natterjack Toad (EN), Grass Frog (LC).

[11] Sources: Keller V., Gerber A., Schmid H., Volet B., Zbinden N. (2010): Rote Liste Brutvögel, Gefährdete Arten der Schweiz, Stand 2010, BAFU und Vogelwart Sempach; J.-C. Monney (2005), Rote Liste der gefährdeten Reptilien der Schweiz, BUWAL; Rote Liste der gefährdeten Tierarten der Schweiz, BUWAL 1994; Bohnenstengel T., Krättli H., Obrist M.K., Bontadina F., Jaberg C., Ruedi M., Moeschler P. (2014): Rote Liste Fledermäuse. Gefährdete Arten der Schweiz, Stand 2011, BAFU; B. R. Schmidt, S. Zumbach 2005, Rote Liste der gefährdeten Amphibien der Schweiz, BUWAL; Y. Gonsetz & C. Monnerat 2002, Rote Liste der gefährdeten Libellen der Schweiz, BUWAL

- Dragonflies: Small and Standard Red-eyed Damselfly (LC), Scarce Blue-tailed Damselfly (LC), Eurasian Bluet (NT), Norfolk Hawker, Scarce Chaser (LC), Brown Skimmer (LC), Green Clubtail (EN), Common Clubtail (NT), Western Clubtail (VU), Small Pincertail (NT).
- Moths: some 275 different species with 20 types or variations.

Fish and aquatic ecology

The hydroelectric generation has the greatest ecological impact on the original river bed. The flow rate is relatively low because the auxiliary weirs hold the water back. Even when the main weir gates open, these weirs reduce the flow rate and it takes exceptional flood waters before the flow rate is sufficient to begin alluvial shifting processes. Because of this lack of current, suitable breeding conditions for fish that prefer fast-moving water (rheophiles) are only found directly below the barrage. Below the upper auxiliary weir one finds several spawning grounds of the common sneep, which is an endangered species throughout Switzerland. Despite repeated gravel mobilisation projects, the high degree of clogging of the bed and banks means only very limited areas of natural spawning grounds remain in the original river bed. The longitudinal networking of the Aare between Wildegg and Brugg is supported by three fish ladders on the original river bed and one between the upstream and downstream canals. In 2014, cantonal authorities investigated the existing fish ladders. The check revealed an insufficient fish movement. Therefore, the fish ladders need to be refurbished within the upcoming years according to article 10 of the Federal Law on Fisheries (BGF). At the fish ladder of the main weir, barbels, daces, chub and perch were most commonly found. These species were also most common in the original river bed. Other species found in the original river bed, such as graylings and European bullheads, were rarely seen in the fish ladders.

Biodiversity

A total of 81 bird, 25 mammal, 11 amphibian, 4 reptile, 34 dragonfly and 550 plant species are found in the Umiker Schachen. This amounts to roughly half of all the different species that inhabit Canton Aargau. This makes Umiker Schachen one of the most significant Swiss riparian areas, despite the impact of the hydroelectric power plant. It is home to a very diverse flora and fauna that includes some threatened species. There is hardly any place in the Canton that has such a high degree of biodiversity. On the other hand, some of the species that inhabit Umiker Schachen are weak in terms of individual numbers or population strength.

4.3 Hydrology, water morphology and hydrogeology[12]

4.3.1 Hydrology

The residual flow turbine in the main weir feeds the original river bed with 11.5 m^3/s. If the Aare flow rate exceeds the maximum discharge rate of the power plant of 420 m^3/s plus the capacity of the residual flow turbine, then the excess water will be discharged over the weir into the original river bed. The daily flow measurements recorded from 1993 to 2005 at the hydrological measuring station in Brugg show that this happens on about 75 days a year – mainly in the summer. These high-water events introduce a significant dynamic effect to the flows in the original river bed.

4.3.2 River morphology

In its natural state, the Aare would transport between 10 000 and 20 000 m^3 of bed load (sand, gravel and stones) from Emme to the Rhine each year. This intensive transport process results in the creation of gravel banks, islands and the formation of distributaries (braiding). The straightening of sections of the river, embankments, weirs, dams and bed load collectors in the tributaries has massively reduced the bed load quantities. This resulted in the erosion of gravel banks and a tendency of erosion has been observed in the undammed sections of the river. This reduces the quality of the aquatic habitat. In the original river bed, the lack of incoming bed load is now causing the clearing of the main channel, which is deepening and widening while the remaining bed is clogging and siltation of adjacent flats is leading to the establishment of bush vegetation.

[12] Sources: Monitoring report: Reaktivierung des Geschiebehaushaltes der Aare zwischen der Wigger und dem Rhein; Monitoring und Erfolgskontrolle, Schälchli, Abegg + Hunzinger, 18.2.2005; Entwurf Auenschutzpark Aargau; Restwasserstrecke Kraftwerk Wildegg-Brugg, Variantenstudium Gewässermorphologie, Grundlagen Flora und Fauna, Ökologisch begründetes Restwasserregime, Schälchli, Abegg + Hunzinger, 28.9.2001.

4.3.3 Groundwater and spring water

The construction of the power plant and its operation has interfered with the interflow between surface (river) water and groundwater. The auxiliary weirs prevent an excessive drop in the groundwater levels in the riparian corridor that would leave the vegetation cut off from the groundwater supply. If this were to happen, the vegetation of the riparian woodland would be likely to change with the loss of native flora and fauna that would require a very long recovery period. The auxiliary weir was originally built on the assumption that the level of the Aare affects the Schinznach Bad hot springs. As a consequence of the 2011 revised Federal Act on the Protection of Waters, there are ongoing investigations if the auxiliary weirs could possibly be opened or dismantled.

4.4 Environmental risks[13]

Environmental risks are posed by unexpected incidents or accidents that could lead to damaging emissions from the power plant. Emissions from most foreseeable accidents would be minimal to insignificant because the substances released (e.g. oil) would be contained by safety devices within the power plant. One imaginable risk would be if the main reservoir dam were to break suddenly. Detailed studies conducted in the context of Regulations Concerning the Safety of Dams (StAV, SR 721.102) showed that a dam collapse during a flow rate of HQ_1 (the annual average flood level) would cause floods of less than 1 metre depth at intensities classified as "slight risk" affecting the site of the Schinznach Bad Thermal Baths. If the weir were to burst at some level between the Q_{346} flow rate – (flow rate of the Aare on at least 346 days in the year) and the maximum discharge rate of 420 m^3/s, then it is highly unlikely that any other buildings would be affected by the flood wave.

4.5 Electromagnetic fields[14]

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 power transmission or electrical appliances. Technically, magnetic fields arise from the motion of electric charges. The strength of the magnetic field is measured in amperes per metre (A/m). But 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. The relevant legislation is the Swiss Protection Ordinance on Non-ionizing Radiation (NISV, SR 814.710) that stipulates emission limits of 100 μT in so-called sensitive areas such as residential rooms. Measurements throughout the plant have proven that these limits are not exceeded in any areas accessible to personnel or visitors. Therefore, there is no electromagnetic hazard for local residents or people entering the power plant.

4.6 Noise and vibrations[15]

The Wildegg-Brugg power plant is surrounded by agricultural or forest zones. The nearest building is the sewage works of the Villnachern Commune, which is located in an industrial zone. The nearest residential properties are at least 200 m away. The Swiss Federal Noise Protection Ordinance (Lärmschutzverordnung, SR 814.41) limits environmental noise emissions to 70 dB(A) during the daytime and 60 dB(A) during the night. SUVA[16] limits govern noise levels inside the building and relating to safety at work. The plant does not exceed any environmental or SUVA limits during any phase of operation including start-up and powerdown and operation at maximum capacity.
The vibrations caused by the operation of the turbines are not perceptible outside the power plant.

[13] Source: Analysis of flooding risks for Wildegg-Brugg Power Plant: Flutwellenberechnung aus Wehr- und Dammbruch beim Kraftwerk Wildegg-Brugg, Nordostschweizerische Kraftwerke AG, 24.4.2007.

[14] Source: Measurements of electromagnetic fields Wildegg-Brugg Power Plant: 8-kV-Generatorschaltanlage Maschinengruppe 2 (MG 2), Magnetfeldmessung, Messprotokoll, Nordostschweizerische Kraftwerke AG.

[15] Source: Measurements on noise and vibration: SUVA Schallmessungsprotokoll KW Villnachern (KWWB), march 1994.

[16] SUVA: The Swiss Accident Insurance Institution.

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 Wildegg-Brugg run-of-river power 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 28 May 2022.
The registration number is S-P-00205.

5.2 Mandatory statements

5.2.1 General statements

Note that EPDs from different EPD programmes may not be 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 the International EPD® System.
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 3.1.

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
www.axpo.com

International EPD® programme information
www.environdec.com
Information on the International EPD® System, EPD®s and PCRs, and General Programme Instructions GPI, v 2.5.

Background LCA data
www.ecoinvent.org
The ecoinvent database version 3, Swiss Centre for Life Cycle Inventories.

7 Frequently used abbreviations

CLC Classes	CORINE Land Cover Classes
EPD	Environmental Product Declaration
ISO	International Organisation for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
NMVOC	Non-methane volatile organic compounds
NOK	Nordostschweizerische Kraftwerke AG (Now Axpo)
PCR	Product Category Rule

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