ENVIRONMENTAL PRODUCT DECLARATION

in accordance with ISO 14025 for

HYDROPOWER FROM KRÅNGEDE HYDROPOWER PLANT

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PROGRAMME-RELATED INFORMATION

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GENERAL INFORMATION ABOUT THE ORGANISATION

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1 PRODUCT DESCRIPTION

1.1 About Fortum

Fortum is a leading energy company that provides its customers with electricity, heating and cooling as well as smart solutions to improve resource efficiency. In Sweden, Fortum is one of the major energy companies with a focus on production of electricity, district heating and cooling, electricity sales and smart solutions for the future.

Fortum's head office is located in Helsinki, Finland, and the company operates, along with its subsidiaries, in four business segments;

- Generation, comprising the Company's power generation, physical operation and trading, as well as expert services for power producers
- City solutions, consisting of combined heat and power generation (CHP), district heating and cooling activities and business-to-business heating solutions; as well as waste magament solutions and solutions for sustainable cities.
- Russia, including power and heat generation and sales in Russia
- Consumer Solutions, responsible for Fortum's electricity sales and other energy solutions for end consumers.

Fortum has core operations in ten countries (Finland, Sweden, Norway, the Russian Federation, Poland, Lithuania, Latvia, Estonia, India and the United Kingdom). Global energy production amounted in 2017 to 73 TWh of electricity and 29 TWh of heat. In Sweden, installed power is 4 543 MW electricity and 35 MW of heat.

Sustainability is a core part of Fortums strategy to meet the challenges of today. 99,8% of Fortums electricity and heat production is ISO 14001 certified. 98,4% were OHSAS 18001 certified. Fortum Hydro applies a certified environmental management system in accordance with ISO 14001 since 2000.

Fortum is the owner/part-owner of 132 hydro power plants, 119 in Sweden and 13 in Finland. Together they produced 20 TWh of electricy in 2017. This corresponds to 28% of Fortum's total power output, and represents 10% of the electricity production in Sweden.

1.2 Hydropower

Hydropower is the most important form of renewable energy in the Nordic countries. There are approximately 2000 hydropower plants in Sweden that combined produce around 65 TWh of electricity during a normal year, representing approximately 45% of the Swedish electricity consumption. This makes hydropower the largest source of renewable energy in Sweden.

Hydropower has a key function in the energy system due to its flexibility, allowing production from hydropower to meet fluctuations in electricity demand more swiftly than other energy sources. Due to this quality, hydropower is used as a frequency control in Sweden and other Nordic countries. The ideal frequency of the Nordic grid is 50 Hz. It is desirable to keep the frequency around 50 Hz in order not to harm important components of the system. Not all hydropower plants have this function, but Krångede is one of them.

When hydropower was built it affected the local ecosystems in and around affected rivers. Fortum actively implements projects aimed at mitigating these effects, while recognising the importance of hydropower when combating climate change. Implementing the right action in the right place is crucial to achieve the desired outcome.

Another crucial measure is to upgrade the hydropower plants and through that bring new renewable energy to the energy market. The installed power of an old hydropower plant can be increased by improving the overall efficiency of the plant and by doing so produce more electricity. During the past ten years, Fortum has upgraded the hydropower capacity by over 116 megawatts through power upgrades. At the same time, the amount of renewable energy generated increased by an average of 250 gigawatt hours.

1.3 About Krångede power plant

This EPD is valid for the hydro power plant Krångede, located along the river Indalsälven in the county of Jämtland. The plant is number eight in the river when counting backwards from the Bothnian Sea, where the river meets the sea. The upstream reservoir constitutes the Gesunda lake.

Krångede was commissioned in 1936 and has a vertical drop of 60 meters. The installed power of the plant is 259 MW.

Table 1 Key data for the power plant

Key data	
Installed power	259 MW
Commissioned year	1936
Full load hours	6106 hours
Average production	1619 GWh
Size of magasine	30 million m^3

Krångede is Fortums largest hydro power plant and during a normal year the production reaches over 1,6 TWh.

Figure 1 The machine hall at Krångede power plant

The power plant is an underground station and Figure 2 illustrates how the machine hall and intake building is connected. There are six turbines at Krångede and they are all of the Francis turbine type, see Figure 3 for an illustration of the turbine. The nominal effect for the turbines varies between 42,3 MW (lowest) and 44,28 MW (highest). Three of the turbines were installed in the late 1990's and the three newer turbines were installed between 2003 and 2007.

Three of the generators are made by Electrosila, the oldest of them were installed in 2003 and the newest were installed 2007. The other three generators are made by ABB Generation, the oldest one was installed 1997 and the newest in 2003.

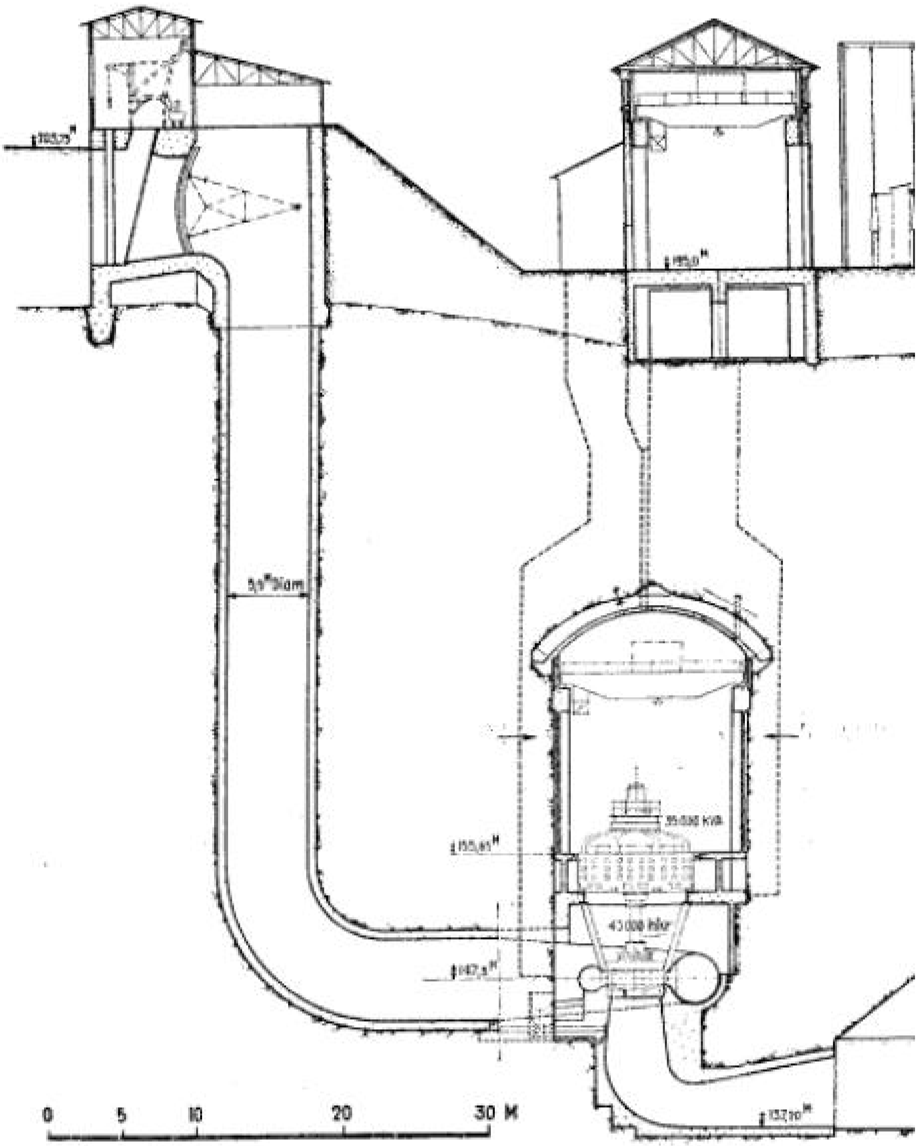

Figure 2 The water intake building is illustrated to the left in the figure and the machine hall is located in the bottom to the right. Between the buildings the penstock is illustrated.

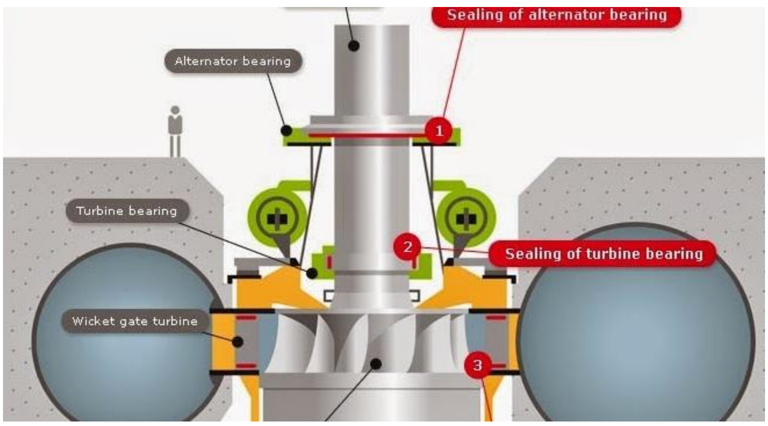

Figure 3 Illustration of a Francis turbine

The dam is a buttress dam and is 350 meters long, with an average height of 25 meters.

In 1922 the Water Court in Sweden permitted the Krångede power plant to extract 500 m^3/s of water from Indalsälven. A new judgement was granted by Östersunds District Court in 1995 but the extraction of water from the river remained unchanged at 500 m^3/s. The permit also requires yearly water regulations and short-term regulations to be followed under given conditions.

Gesunda is a lake upstream of Krångede power plant and functions as a reservoir for the power plant. The lake is regulated by the dam next to the intake building. Gesunda is situated at 203 meters above sea level and has a surface area of about 30 km^2 with a average depth of 17 meters. The capacity in Gesunda as an annual reservoir is 60 Mm^3. 45% of the annual mean water catchment can be stored in the reservoir.

Adjacent to the building with intakes for water, there are three switchgear buildings where the distribution switchgear and generator switchgear are located for the units.

The outdoor switchgear is an AC-switchgear with three outgoing 220 kV overhead lines and one incoming 220 kV overhead line from Gammelänge power station. The three main transformers are placed at the switchgear yard, with two units connected to each main transformer. The outdoor switchgear area belongs to and is operated by the Swedish National Grid (Svenska Kraftnät, SVK) and SVK and Fortum have a close contact regarding maintainance and operation of the switchgear.

The stationary reserve power generator is able to run the elevators inside the machine building during a power outage. The mobile reserve power generator's main function is to close and open the spillway tainter gates as well as to regulate the water flow during a power outage.

2 LCA INFORMATION

The declared unit is defined as 1 kWh net electricity generated and thereafter distributed to a customer connected to the regional grid with the voltage of 40 kV och 130 kV.

Production data used represents the normal yearly production[1] and is 1619 GWh.

The expected technical service life time for the hydropower plant has been set to 100 years, for machinery to 60 years and for the power station buildings, dams and waterways to 100 years. For reference flows, see Table 2.

Data for operation represents the year 2017.

2.1 System boundaries

The LCA is cradle-to grave and is in accordance with the PCR (2007:08) divided into the following processes (see also Figure 4):

- Upstream processes
- Core processes
- Core infrastructure
- Downstream processes
- Downstream infrastructure

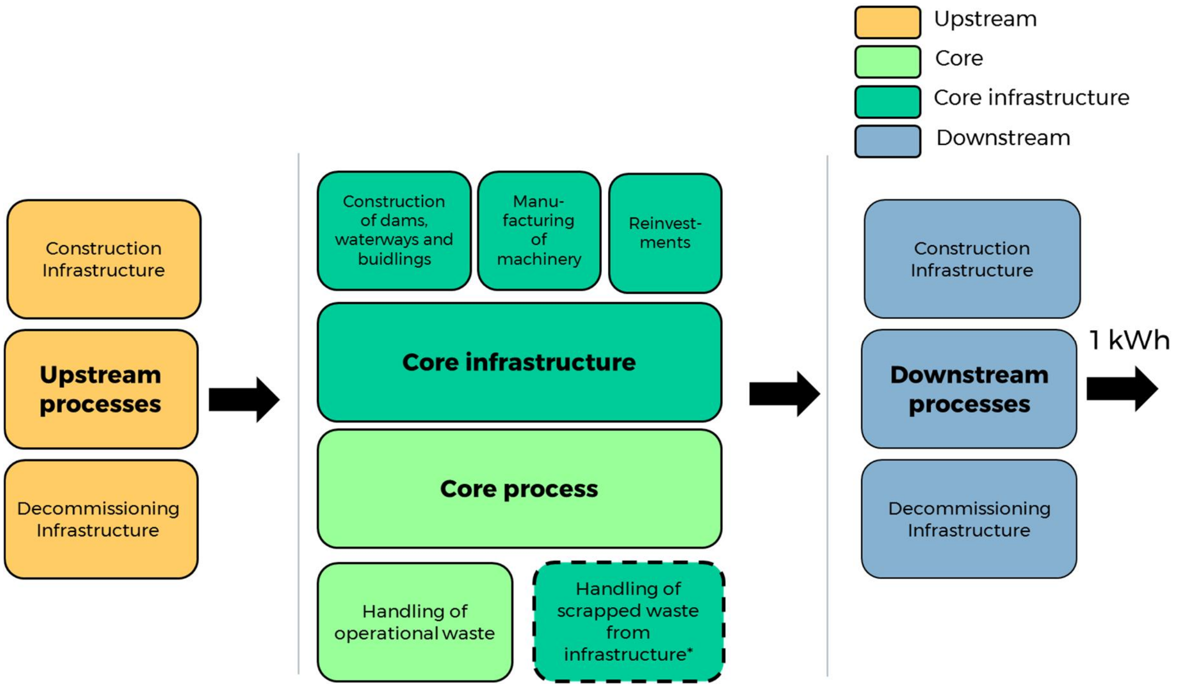

Figure 4 System diagram describing the processes included in the LCA (*scrapped metal is handled according to the Polluter Pays principle)

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[1] Normal production is the normalised value for annual production based on water flows during a 50-year reference period.

Boundaries towards risk assessment: The LCA includes emissions and releases that occur more often than every third year.

2.1.1 Upstream

In the upstream module, the production and transportation of oils and chemicals for operation of the power plant as well as production and transportation of fuels for reserve power, is included.

2.1.2 Core processes

Emissions from operation, waste transportation and treatment is included in this module. Emissions from operation include emissions from the use of the reserve power and maintenance-related travels. No other emissions from the core processes were identified.

The operational waste consisting of metals is transported for material recycling while other operational waste is incineretad for energy recovery. Waste treatment is included according to the "Polluter pays" principle (GPI), i.e. waste incineration is included in the assessment, while waste recycling is not.

No inspection trips are reported due to on-site personnel, however, occasional trips due to accidents occur and are included in the assessment.

Part of the produced electricity is used for the operation of the powerplant, which is derived from the normal annual production. Apart from the electricity, the residual heat is reused within the facility. No additional electricity or heat are purchased.

2.1.3 Core infrastructure

The core infrastructure module includes construction of and reinvestments in the machinery (turbine, generator, transformer, cables, etc) for the energy conversion in the power plant. This includes raw material extraction and manufacturing processes for materials for the machinery, their transportation to the power plant and final waste disposal at the end of their life.

The core infrastructure module includes construction of the dam, buildings, waterways and roads at the site of the power plant, including raw material extraction and manufacturing processes for concrete, reinforcement steel and other materials, their transportation to the construction site as well as waste disposal at the end of their life. The rock blasting and transportation of the rock masses and energy use for the construction work is included.

Dismantling is not probable due to the fact that the powerplant is a large-scale hydropower plant and therefore the dismantling of the dam, buildings and waterways, and restoration of land is excluded. The estimated technical service life is after 100% of reinvestments in machinery and concrete in dams and buildings has taken place, which means that the output of the life cycle is a functional plant.

Construction of hydropower dams may lead to the creation of reservoirs and indundation of land, potentially causing a release of nutrients to the water and formation of greenhouse gases. The potential emissions from indundated land is included in the core infrastructure module.

2.1.4 Downstream process

Downstream process module includes operation and maintenance of the distribution system, as well as environmental impacts caused by distribution losses.

Total grid losses within the Swedish electricity system during 2010-2015 were on average 7% (Svensk Energi, 2016). The functional unit of this EPD is 1 kWh of electricity distributed to a customer connected to the regional grid (medium voltage), hence the distribution losses include losses in a high and medium voltage grid. According to Svenska Kraftnät the transmission losses in the high voltage grid were 2,9% in 2017. No data is available for losses in the regional grid and therefore a generic loss of 0,93% from Ecoinvent 3.0 was used. Based on this data the calculated transmission and distribution losses for this EPD is 3,83%.

The distribution losses are included in the analysis in the form of the corresponding amount of extra electricity that needs to be generated by the hydropower plant in order to compensate for the losses, i.e. 3,83% of the impact from total generated electricity is added to the Downstream process module.

2.1.5 Downstream infrastructure

In the downstream infrastructure process the construction, reinvestments and dismantling of the infrastructure of the distribution system (transmission grid and regional network) is included.

The Swedish grid comprises transmission on three different levels: high voltage (400 and 220 kV) medum voltage or regional grid (40 and 130 kV) and low voltage och local grid (below 40 kV). High voltage and medium voltage grids are the focus of this EPD as the functional unit is 1 kWh net electricity distributed to a customer connected to the regional grid.

The transmission and distribution systems consist of power lines and power poles, cables, switch yards and transformer stations. According to Svenska Kraftnät (2017) the major part of the high and medium voltage grid in Sweden is overhead power lines with a technical service life of 70 years.

2.1.6 Reference flows

All calculations are made in relation to the normal yearly production. A small part of the produced electricity (780 MWh/year) is used internally and thus is derived from the normal yearly production resulting in a reference flow of 1618 GWh (instead of 1619 GWh, which is the actual normal yearly production).

Lifespan of the hydropower plant is considered to be 100 years. As the dismantling of the powere plant is unlikely, 100% reinvestments in machinery, dams and buildings is considered. The number of reinvestments are counted as a whole number of service lives needed to have a functional plant after 100 years. For example, if the service life of waterways is 100 years, one reinvestment, i.e. two service lives, are considered. The reference flow for Core infrastructure is 100 years of normal yearly production. For the core processes, downstream processes and upstream processes one year is considered with the reference flow of the normal yearly production. The reference flow for Downstream infrastructure is 70 years of the normal yearly production as the service life for grid is 70 years. The service life and reference flows for each module are presented in Table 2.

Table 2 Technical service life and reference flows

Lifecycle stage	Technical service life	Reference flow (kWh)
Upstream	1 year	1 618 220 000

Core processes	1 year	1 618 220 000
Core infrastructure	Dams and waterways: 100 years (1 resinvestment) Machinery: 60 years (1 reinvestment) Roads: 80 years (1 reinvestment) Cables: 30 years (3 reinvestments) Batteries: 15 years (6 reinvestments)	161 822 000 000
Downstream processes	1 year	1 618 220 000
Downstream infrastructure	70 years	113 275 400 000

2.2 Methodological decisions and assumptions made

Methodlogical decisions and assumptions made are described in the LCI report.

2.3 Life Cycle Impact Assessment (LCIA)

Assessment of environmental performance has been made using the CML method as implemented in SimaPro 8.5 software. The method has been modified to include biogenic carbon dioxide to the global warming potential impact.

2.4 Allocation rules and calculation approaches

2.4.1 Allocation

All processes included in Core infrastrucutre and Core processes are allocated to electricity production. Processes included in Downstream infrastructure and Downstream processes is allocated based on the incoming energy in the high voltage and regional grid.

The Ecoinvent 3.0 data used (Wernet et al., 2016) is of the type "cut-off by classification", which is based on an approach that primary production of materials is always allocated to the primary user of material. If a material is recycled, the primary producer does ot receive any credit for the provision of any recyclable materials.

For the calculation of the impoundment effects, only the changes in the reservoir have been taken into account, i.e. the area of the changed land/water surface and not the whole lake.

2.4.2 Calculation of emissions due to impoundment

The greenhouse gas emissions, COD and net[2] release of phosphorus to the water due to impoundment and inundation of land have been calculated according to the recommendations given in the PCR (2007:08). The detailed describtion of the methods used can be found in the LCI report.

[2] Net release due to both release and retention of phosphorus which gives a net-negative release

2.4.3 Cut-off and 1%-rule

All major raw materials and all essential energy is included. All data and processes have been considered relevant and all the data obtained have been analysed.

The following are not included in the analysis:

- Maintenance of the premises, such as cleaning or grass cutting.
- Bulding elements such as ventilating system, windows, gypsum, water and sewage systems were not included as they were estimated to contribute less than 1% to the environmental impact. The power plant consists for the most part of the dam and water ways, and even machine room - both under and over the ground - consists mainly of concrete and steel. The listed elements contribute to 5% or less to the climate impact of a residential building (IVL, 2015) and it is estimated that the Krångede power plant has a much lower share of those elements in the whole construction.

2.5 Data

The databases were chosen according to the PCR. The majority of the data used is specific or selected generic data as suggested by the PCR and complemented by Swedish generic data - which is estimated to contribute less than 10% to each module. The complementary data is used for the following processes: construction of the roads on site, land excavation, as well as operation and maintenance of the grid. The operation of the network, namely leackage of SF_6, contributes the most – 5% of the overall impact - to the global warming potential. The contribution of the roads on site and operation and maintenance of the network contribute between 0,1% to 2% of the overall impact depending on the impact category. The contribution of the land excavation to the environmental impacts is less than 0,1%.

The majority of the selected generic data is from Ecoinvent 3.0 (Wernet et al., 2016). Whenever possible the datasets for market products were chosen, where the transportation from a production plant to a market is included. Transportation from the market distribution center to the site was added. In cases when data represented only production, the transportation from the production was added.

Upstream

Specific data has been used for the amounts and specification of materials, fuels and substances used in maintenance and operation. The selected generic data from Ecoinvent was used for background data for production of the products and their transportation. Transportation distances were estimated based on the specific conditions for the power plant and information on suppliers.

Core

Specific data has been used for environmental data related to the core processes and core infrastructure, e.g. amounts of material for construction and specification of installed machinery.

Selected generic data, mainly from the database Ecoinvent and small share from ILCD, has been used as background data for the production of materials and products, including transport to a regional market, plus background data for transports from market to site. The data represents a global or European market with the respective electricity mixes used for manufacturing. For manufacturing of machinery, specific electricity mixes for the countries where manufacturing took place (according to EPD:s for those products) were assumed.

Swedish generic data from Klimatkalkyl model 6.0 (Trafikverket, 2018) was used for rock blasting processes and road construction.

Downstream

Specific Swedish data was used for transmission losses in the high voltage grid, while selected generic data was used for transmission and distribution losses in the medium voltage grid.

Swedish generic data was used for amounts and types of fuels used for maintenance of the grid (Andersson, 2016) as well as SF_6 leakage (Energiföretagen, 2017). Selected generic data from Ecoinvent was used for the background processes of fuel production.

Selected generic data from Ecoinvent was used for the construction and dismantling of the transmission and distribution network. The datasets represent construction of the transmission and distribution network in Switzerland and thus a Swiss electricity mix is used. The waste treatment in the end-of-life was added based on the amounts and type of input materials. Transportation of waste to waste treatment was estimated.

3 ENVIRONMENTAL PERFORMANCE

3.1 Potential environmental impacts

Potential environmental impacts are presented in Table 3. The largest contributors in all categories are core infrastructure and distribution infrastructure.

Core infrastructure contributes 66% of the total to the global warming potential. The largest contributors to the global warming potential from core infrastructure are the dam construction and reinvestments, transformers, generators, assembly hall and machine room, and intake building/construction. Concrete and steel production are the main contributing materials. Inundation of land contributes 3% of the overall global warming potential from Core infrastructure or 2% from the total distributed electricity.

Construction of the transmission and distribution network contributes 23% of the total, mainly due to copper and aluminium production.

Contribution to the photochemical oxidation originates mainly from the concrete and steel production of the dam and other constructions, generators and transformers. Copper and aluminium in transmission network contribute to the impact from distribution infrastructure.

Copper, steel and concrete from the production for generators, transformers and dam are the main contributors to acidification. Copper production is also the main contributor to eutrophication. Inundation contributes 7% of the overall impact due to COD emissions.

Table 3 Potential environmental impacts per kWh

	Unit	Upstream	Core processes	Core Infrastructure	Total production	Downstream processes	Downstream Infrastructure	Total distribution
Global warming potential (GWP100a)	g CO_2 eq	0,0005	0,043	0,800	**0,843**	0,010	0,282	**1,22**
Out of which biogenic	*g CO_2 eq*	0,000007	0,021	0,167	**0,188**	0,007	0,012	**0,207**
Out of which from inundation of land	*g CO_2 eq*	0	0	0,022	**0,022**	0,0008	0	**0,023**

Photochemical oxidation	g NMVOC	0,000009	0,00006	0,00372	**0,00379**	0,00016	0,00013	**0,00408**
Acidification	g SO_2 eq	0,000003	0,00008	0,00441	**0,00449**	0,000204	0,00384	**0,00853**
Eutrophication	g PO_4^{3-} eq	0,000001	0,00005	0,00245	**0,00249**	0,0001	0,00248	**0,00508**
Out of which from inundation of land	*g PO_4^{3-} eq*	0	0	0,000354	**0,000354**	0,000014	0	**0,000367**

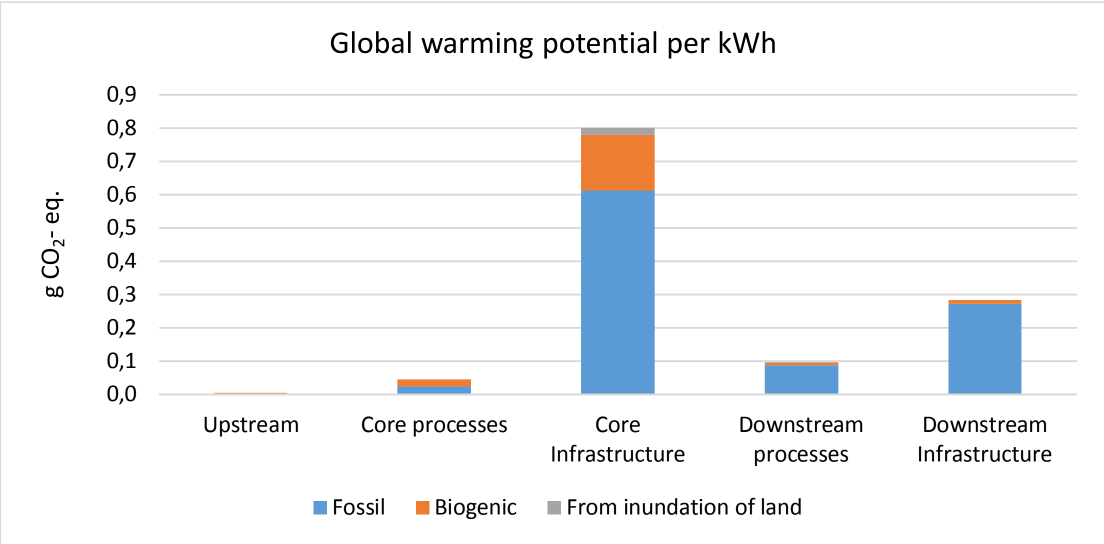

Figure 5 Global warming potential per kWh, expressed in g CO_2-eq.

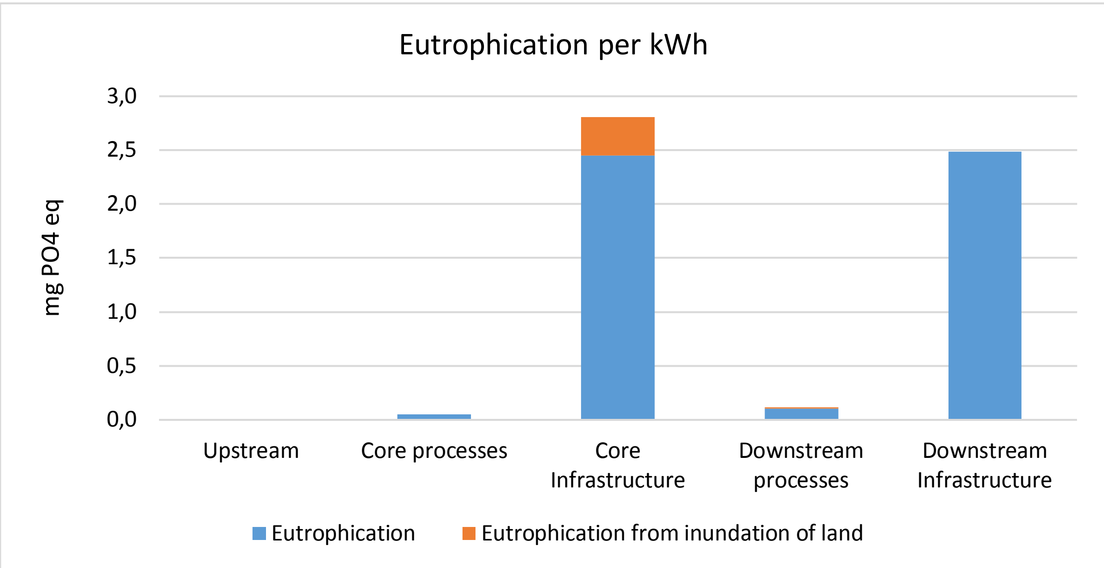

Figure 6 Euthropication potential per kWh, expressed in mg PO_4-eq.

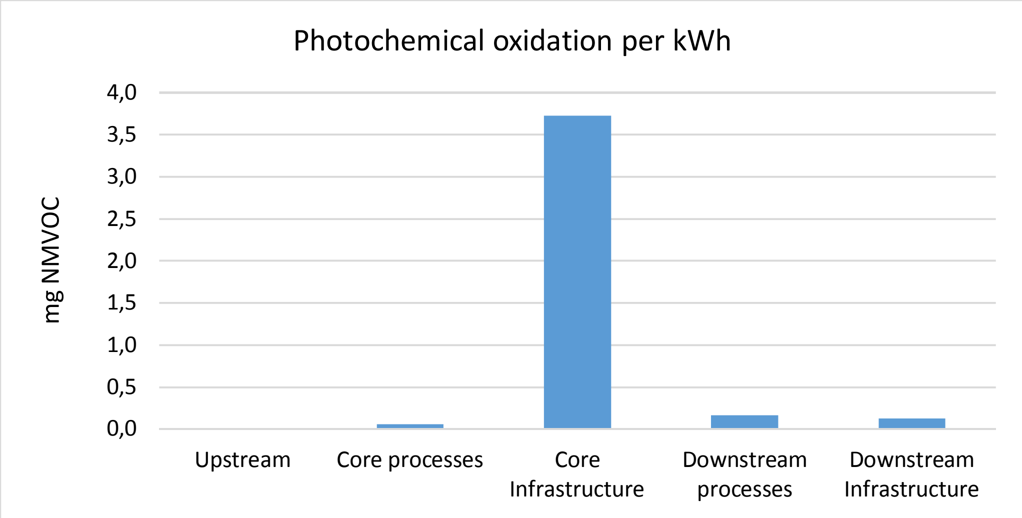

Figure 7 Photochemical ozone creation potential per kWh, mg NMVOC

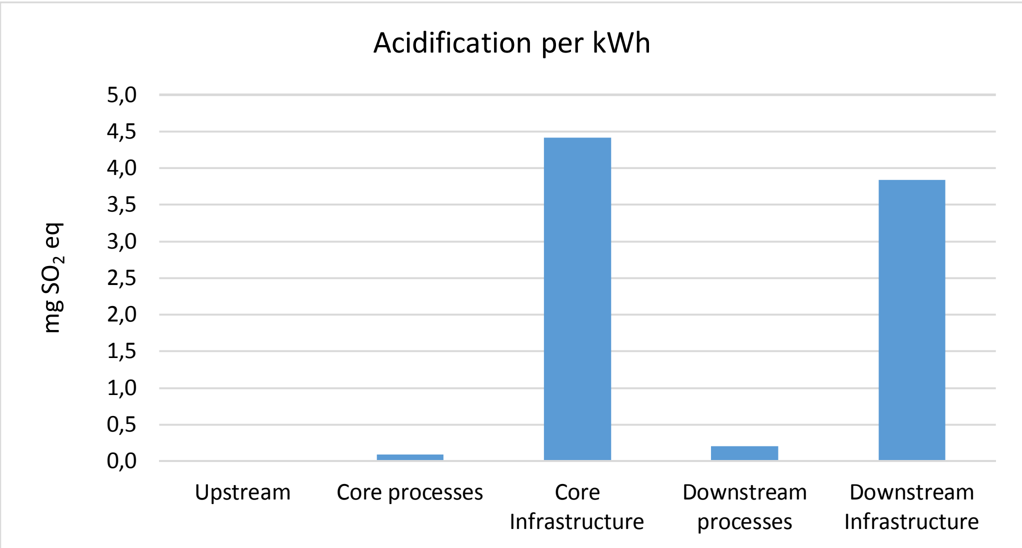

Figure 8 Acidification potential per kWh, mg SO_2-eq.

The major part of the potential environmental impact is related to the construction of the power plant (48% - 91%) as well as distribution infrastructure (up to 49%), see dominance analysis in Figure 9 below. Environmental impact from distribution losses contributes between 32% (for GWP) to 96% (for Eutrophication) of the impact from Downstream processes or 2 - 4% of the overall impact from Total distributed electricity.

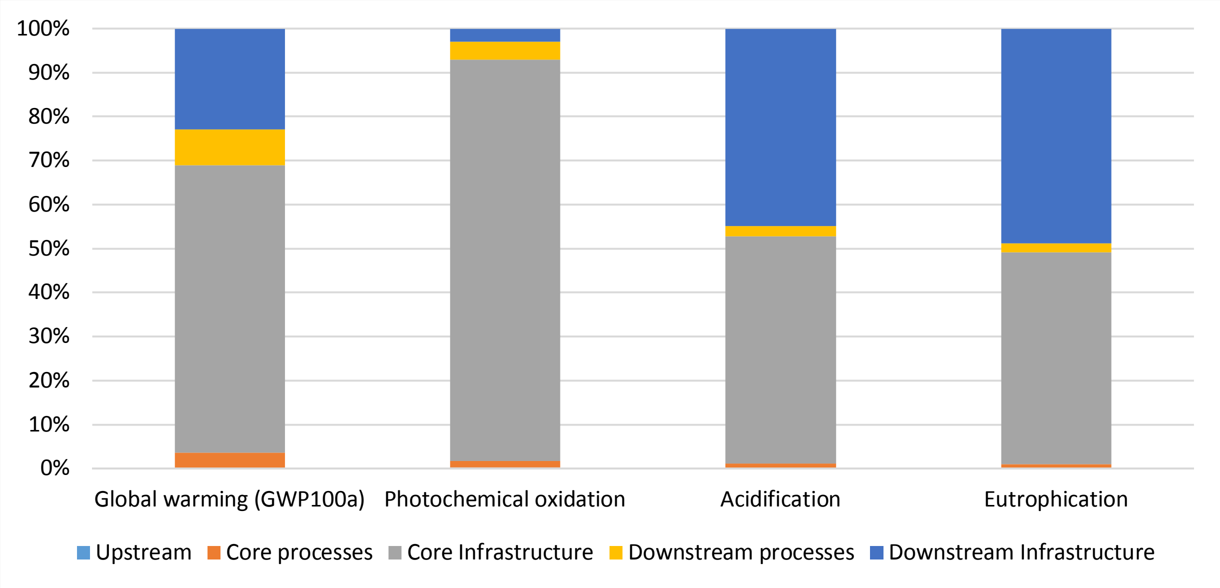

Figure 9 Overview of results per life cycle stage for the four environmental impact categories

3.2 Use of resources

Table 4 Use of resources per kWh

	Unit	Upstream	Core Processes	Core infrastructure	Total generated	Downstream processes	Downstream infrastructure	Total distributed
Non-renewable resources								
Energy								
Coal (resource)	g	7,97E-05	3,70E-03	1,20E-01	**1,24E-01**	4,97E-03	7,15E-02	**2,01E-01**
Lignite (resource)	g	2,77E-05	1,88E-03	2,81E-02	**3,00E-02**	1,24E-03	1,31E-02	**4,43E-02**
Natural gas (resource)	g	5,81E-05	8,40E-04	2,75E-02	**2,84E-02**	1,33E-03	8,74E-03	**3,85E-02**
Crude oil (resource)*	g	4,39E-04	6,66E-04	8,90E-02	**9,01E-02**	1,06E-02	1,50E-02	**1,16E-01**
Peat (resource)	g	1,60E-07	8,01E-04	8,92E-04	**1,69E-03**	6,56E-05	2,28E-05	**1,78E-03**
Uranium in ore (resource)	g	1,04E-09	4,80E-06	5,68E-06	**1,05E-05**	4,06E-07	2,09E-07	**1,11E-05**
Primary energy demand nuclear	MJ	5,18E-07	2,40E-03	2,84E-03	**5,24E-03**	2,03E-04	1,05E-04	**5,55E-03**
Material resources								
Aluminium in bauxite	g	4,31E-07	4,02E-04	2,74E-05	**4,30E-04**	9,65E-03	1,68E-05	**1,01E-02**
Calcite	g	9,19E-06	1,84E-01	1,15E-03	**1,86E-01**	1,76E-02	7,16E-03	**2,10E-01**
Chromium in chromite	g	1,99E-07	4,55E-03	1,69E-05	**4,57E-03**	1,76E-04	1,75E-04	**4,92E-03**
Clay	g	9,08E-06	1,88E-02	3,60E-04	**1,91E-02**	1,13E-02	7,49E-04	**3,12E-02**
Copper in sulfide	g	2,06E-07	2,42E-03	1,47E-05	**2,43E-03**	4,41E-03	9,33E-05	**6,94E-03**
Gangue, bauxite	g	4,58E-06	4,27E-03	2,91E-04	**4,57E-03**	1,03E-01	1,79E-04	**1,07E-01**
Gravel	g	5,65E-05	1,54	9,89E-03	**1,55**	9,31E-02	5,97E-02	**1,70**
Iron in ore	g	5,61E-06	1,08E-01	4,51E-04	**1,08E-01**	2,32E-02	4,19E-03	**1,36E-01**
Nickel in ore	g	1,30E-07	8,21E-03	1,06E-05	**8,22E-03**	2,62E-04	3,15E-04	**8,79E-03**
Shale	g	2,46E-08	7,06E-03	6,28E-06	**7,06E-03**	1,87E-04	2,71E-04	**7,52E-03**
Input of resources (excluding water)	g	9,22E-05	1,89	1,31E-02	**1,90**	2,68E-01	7,33E-02	**2,24**

Resources not followed from cradle	g	0	6,66E-04	0	**6,66E-04**	0	2,55E-05	**6,92E-04**
Renewable resources								
Energy								
Primary energy from solar energy	MJ	2,29E-10	2,51E-09	4,75E-07	**4,78E-07**	2,62E-08	3,25E-08	**5,36E-07**
Primary energy from wind power	MJ	3,87E-08	1,58E-04	1,79E-04	**3,37E-04**	1,31E-05	6,05E-06	**3,56E-04**
Energy, from hydro power	MJ	2,23E-07	9,02E-04	1,25E-03	**2,15E-03**	8,32E-05	2,45E-04	**2,48E-03**
Energy, geothermal	MJ	6,19E-09	8,04E-08	3,46E-06	**3,54E-06**	1,54E-07	1,03E-06	**4,73E-06**
Biomass	g	6,37E-06	1,19E-02	3,66E-01	**3,78E-01**	1,45E-02	9,76E-03	**4,02E-01**
Electricity use in power plant	kWh		4,82E-04		**4,82E-04**	1,85E-05		**5,00E-04**
Material resources								
Wood	m3	1,06E-11	2,01E-08	6,15E-07	**6,35E-07**	2,43E-08	1,82E-08	**6,77E-07**
Secondary resources	g	0,00	2,03E-08	3,70E-04	**3,70E-04**	1,42E-05	6,35E-09	**3,84E-04**
Water use								
Water, cooling	g	2,37E-02	15,6	32,7	**48,3**	1,93	8,66	**58,9**
Water, groundwater	g	0,00	0,00	2,12E-01	**2,12E-01**	8,11E-03	0,00	**2,20E-01**
Water, surface water	g	0,00	8,53E-03	1,01E-01	**1,10E-01**	4,35E-03	3,05	**3,17**
Water, unspecified natural origin	g	1,45E-06	2,91E-05	3,48E-03	**3,51E-03**	1,50E-04	4,47E-04	**4,11E-03**
Water, sea	g	3,47E-05	7,20E-04	6,37E-02	**6,45E-02**	2,55E-03	1,29E-02	**8,00E-02**
Water, river	g	9,83E-04	6,58E-01	1,60	**2,26**	9,37E-02	1,11	**3,46**
Water, well	g	2,96E-04	2,00E-02	4,57E-01	**4,77E-01**	1,94E-02	2,35E-01	**7,31E-01**

* Crude oil in this row includes also oil used for other purposes other than energy demand, e.g. production of polymer materials

3.3 Waste production and output flows

Table 5 Waste production in the core processes per kWh

Non-hazardous waste		
Combustible waste to incineration	g	6,67E-04
Wood waste, untreated, to incineration	g	6,06E-04
Mixed metal scrap to recycling	g	1,20E-03
Hazardous waste		
Spill oil	g	8,72E-04

Table 6 Waste to disposal, LCI inventory per kWh

		Upstream	Core Processes	Core infrastructure	Total generated	Downstream processes	Downstream infrastructure	Total distributed
Non-hazardous waste								
Waste to landfill	g	5,87E-04	4,07E-02	1,65	**1,69**	6,66E-02	4,33E-01	**2,19**
Waste to incineration	g	9,92E-07	1,32E-03	9,28E-02	**9,41E-02**	3,61E-03	7,20E-03	**1,05E-01**
Waste to recycling	g	6,65E-06	2,39E-03	8,12E-03	**1,05E-02**	4,16E-04	7,32E-03	**1,83E-02**

Other non-hazardous waste, treatment unknown	g	6,17E-08	6,06E-06	5,19E-02	**5,19E-02**	1,99E-03	1,03E-04	**5,40E-02**
Hazardous waste								
Hazardous waste to incineration	g	1,88E-07	8,80E-04	1,13E-03	**2,01E-03**	7,99E-05	1,02E-03	**3,10E-03**
Radioactive waste	m^3	2,11E-13	3,97E-11	3,53E-11	**7,52E-11**	6,62E-12	1,31E-11	**9,49E-11**
Other hazardous waste, treatment unknown	g	0	9,50E-10	8,97E-06	**8,98E-06**	3,44E-10	1,68E-13	**8,98E-06**

3.4 Other environmental indicators

LCI emissions contributing to given impact categories, emissions of toxic and radioactive substances, particles and oil are presented in Table 7 to 11. Level of cut-off is specified for each individual table.

Table 7 LCI emissions contributing to given impact categories[3] per kWh

		Upstream	Core Processes	Core infrastructure	Total generated	Downstream processes	Downstream infrastructure	Total distributed
Airborne emissions								
GWP								
Carbon dioxide, unspecified	g	0	0	2,18E-04	**8,34E-06**	0	2,26E-04	**2,26E-04**
Carbon dioxide, fossil	g	4,62E-04	1,64E-02	5,76E-01	**5,93E-01**	2,58E-02	2,24E-01	**8,43E-01**
Carbon dioxide, biogenic	g	7,47E-06	2,11E-02	1,67E-01	**1,88E-01**	7,26E-03	1,19E-02	**2,07E-01**
Methane	g	1,84E-06	3,64E-05	1,40E-03	**1,44E-03**	6,53E-05	8,63E-04	**2,37E-03**
SF_6	g	3,65E-11	5,66E-08	7,33E-08	**1,30E-07**	2,72E-06	4,36E-07	**3,29E-06**
Dinitrogen monoxide	g	1,16E-08	3,80E-06	2,57E-05	**2,95E-05**	1,20E-06	1,13E-05	**4,20E-05**
Photochemical oxidation								
Carbon monoxide, fossil	g	8,42E-07	2,90E-05	4,28E-03	**4,31E-03**	1,71E-04	1,65E-03	**6,14E-03**
Carbon monoxide, biogenic	g	1,31E-08	2,08E-05	6,75E-04	**6,96E-04**	2,67E-05	6,30E-05	**7,86E-04**
Sulfur dioxide	g	2,21E-06	3,41E-05	2,47E-03	**2,50E-03**	1,20E-04	3,08E-03	**5,71E-03**
Formaldehyde	g	8,35E-10	1,83E-07	2,63E-05	**2,65E-05**	1,02E-06	5,12E-07	**2,80E-05**
Nitrogen oxides	g	1,23E-06	4,44E-05	2,44E-03	**2,49E-03**	1,06E-04	8,01E-04	**3,40E-03**
NMVOC, non-methane volatile organic compounds	g	7,86E-06	6,12E-06	7,60E-04	**7,74E-04**	3,53E-05	1,55E-04	**9,65E-04**
Acidification								
Ammonia	g	2,46E-08	8,90E-06	9,40E-05	**1,03E-04**	4,19E-06	5,64E-05	**1,64E-04**
Nitrogen oxides	g	1,23E-06	4,44E-05	2,44E-03	**2,49E-03**	1,06E-04	8,01E-04	**3,40E-03**
Sulfur dioxide	g	2,21E-06	3,41E-05	2,47E-03	**2,50E-03**	1,20E-04	3,08E-03	**5,71E-03**

[3] Cut-off at 0,5% of contribution to each of the specified impact categories

Hydrogen chloride	g	4,04E-08	7,55E-07	3,83E-05	**3,91E-05**	1,62E-06	3,30E-05	**7,38E-05**
Hydrogen fluoride	g	5,40E-09	2,85E-07	5,01E-06	**5,30E-06**	2,15E-07	3,35E-05	**3,90E-05**
Eutrofication								
Nitrogen oxides	g	1,23E-06	4,44E-05	2,44E-03	**2,49E-03**	1,06E-04	8,01E-04	**3,40E-03**
Ammonia	g	2,46E-08	8,90E-06	9,40E-05	**1,03E-04**	4,19E-06	5,64E-05	**1,64E-04**
Waterborne emissions								
Eutrophication								
COD	g	4,27E-06	4,34E-05	1,79E-02	**1,79E-02**	7,57E-04	5,40E-04	**1,92E-02**
Nitrate	g	1,43E-07	4,30E-05	4,76E-04	**5,20E-04**	2,08E-05	6,39E-04	**1,18E-03**
Phosphate	g	4,75E-07	2,92E-05	1,64E-03	**1,67E-03**	6,50E-05	2,28E-03	**4,01E-03**
Phosphorus[4]	g	3,41E-10	2,84E-09	1,14E-07	**1,17E-07**	7,51E-09	4,13E-08	**1,66E-07**

[4] Including phosphorus retention resulting from inundation of land

Table 8 LCI emissions of particle matter per kWh

		Upstream	Core Processes	Core infrastructure	Total generated	Downstream processes	Downstream infrastructure	Total distributed
Particulates, < 10 um	g	0	0	1,12E-08	**1,12E-08**	4,29E-10	0	**1,16E-08**
Particulates, < 2.5 um	g	3,31E-07	1,08E-05	7,25E-04	**7,36E-04**	2,96E-05	3,16E-04	**1,08E-03**
Particulates, > 10 um	g	3,54E-07	2,21E-05	8,69E-04	**8,91E-04**	3,53E-05	4,20E-04	**1,35E-03**
Particulates, > 2.5 um, and < 10um	g	1,12E-07	8,25E-06	5,70E-04	**5,78E-04**	2,25E-05	2,47E-04	**8,48E-04**

Table 9 LCI emissions of toxic substances[5] per kWh

		Upstream	Core Processes	Core infrastructure	Total generated	Downstream processes	Downstream infrastructure	Total distributed
Airborne emissions								
Cadmium	g	5,97E-11	3,56E-09	5,20E-07	**5,23E-07**	2,03E-08	9,99E-07	**1,54E-06**
Chromium VI	g	1,95E-11	3,00E-09	3,94E-07	**3,97E-07**	1,52E-08	1,27E-08	**4,25E-07**
Copper	g	6,53E-10	5,59E-08	5,83E-06	**5,89E-06**	2,27E-07	8,42E-06	**1,45E-05**
Nickel	g	5,37E-10	2,63E-08	3,35E-06	**3,38E-06**	1,33E-07	5,72E-06	**9,24E-06**
Lead	g	4,99E-10	5,47E-08	4,96E-06	**5,02E-06**	1,93E-07	7,85E-06	**1,31E-05**
Zinc	g	1,16E-09	1,01E-07	4,78E-06	**4,88E-06**	1,89E-07	3,12E-06	**8,20E-06**
Carbon disulfide	g	2,54E-09	1,67E-07	2,68E-05	**2,70E-05**	1,04E-06	4,89E-05	**7,69E-05**
Mercury	g	1,64E-11	8,91E-10	7,90E-08	**7,99E-08**	3,17E-09	1,81E-08	**1,01E-07**
Selenium	g	4,48E-11	2,82E-09	1,70E-07	**1,73E-07**	6,80E-09	3,08E-07	**4,87E-07**
Tin	g	4,64E-11	2,47E-09	4,15E-07	**4,17E-07**	1,61E-08	3,97E-07	**8,31E-07**
Vanadium	g	4,28E-10	2,15E-08	5,23E-07	**5,45E-07**	2,63E-08	1,73E-07	**7,44E-07**
Waterborne emissions								
Copper	g	1,41E-08	1,13E-05	5,93E-05	**7,07E-05**	2,75E-06	8,69E-05	**1,60E-04**
Nickel	g	1,34E-08	8,91E-07	4,35E-05	**4,44E-05**	1,74E-06	2,43E-05	**7,05E-05**
Vanadium	g	2,39E-09	2,64E-07	5,44E-06	**5,70E-06**	2,24E-07	1,13E-05	**1,72E-05**
Zinc	g	4,62E-08	2,65E-06	2,95E-04	**2,98E-04**	1,15E-05	5,17E-04	**8,27E-04**
Chromium VI	g	2,14E-09	1,66E-07	1,69E-05	**1,71E-05**	6,63E-07	9,58E-06	**2,73E-05**
Cadmium	g	6,70E-10	4,18E-08	5,38E-06	**5,42E-06**	2,08E-07	9,71E-06	**1,53E-05**
Cobalt	g	4,40E-09	2,94E-07	3,29E-05	**3,32E-05**	1,28E-06	2,81E-05	**6,26E-05**
Silver	g	9,44E-11	6,13E-09	3,29E-07	**3,35E-07**	1,32E-08	5,42E-07	**8,91E-07**
Thallium	g	7,81E-11	3,97E-09	5,13E-07	**5,17E-07**	1,99E-08	9,17E-07	**1,45E-06**
Lead	g	1,03E-09	4,35E-07	3,85E-05	**3,89E-05**	1,49E-06	7,72E-06	**4,81E-05**
Emissions to soil								
Chromium VI	g	3,05E-11	5,18E-08	8,49E-08	**1,37E-07**	5,35E-09	2,11E-05	**2,13E-05**
Zinc	g	3,36E-10	7,25E-08	1,29E-06	**0**	5,56E-08	2,07E-07	**0**

[5] Cut-off at 0,1% of contribution to each of the following impact categories (ReCiPe (H) Midpoint): Human toxicity carcinogenic, Human toxicity non-carcinogenic, Freshwater aquatic ecotoxicity, Marine aquatic ecotoxicity, Terrestrial excotoxicity

Table 10 LCI emissions of oil per kWh

		Upstream	Core Processes	Core infrastructure	Total generated	Downstream processes	Downstream infrastrucure	Total distributed
Waterborne emissions								
Oils, unspecified	g	1,24E-06	2,06E-06	2,74E-04	**2,77E-04**	3,24E-05	5,76E-05	**3,67E-04**
OIls, biogenic	g	1,14E-12	3,50E-10	2,89E-08	**2,93E-08**	1,13E-09	6,59E-10	**3,11E-08**
Emissions to soil								
Oils, unspecified	g	1,32E-06	2,16E-06	2,89E-04	**2,92E-04**	3,51E-05	4,79E-05	**3,75E-04**
OIls, biogenic	g	1,87E-10	2,70E-07	1,09E-05	**1,12E-05**	4,29E-07	2,95E-07	**1,19E-05**

Table 11 Emissions of radioactive substances[6] per kWh

		Upstream	Core Processes	Core infrastructure	Total generated	Downstream processes	Downstream infrastructure	Total distributed
Airborne emissions								
Actinides, radioactive, unspecified	Bq	1,91E-08	2,64E-07	8,40E-06	**8,68E-06**	3,68E-07	1,61E-05	**2,52E-05**
Carbon-14	Bq	8,66E-06	6,34E-03	8,97E-03	**1,53E-02**	7,30E-04	4,96E-04	**1,65E-02**
Cesium-134	Bq	1,29E-13	1,28E-09	1,40E-09	**2,68E-09**	1,03E-10	2,87E-11	**2,81E-09**
Cesium-137	Bq	2,38E-12	2,31E-08	2,45E-08	**4,76E-08**	1,83E-09	5,27E-10	**4,99E-08**
Cobalt-58	Bq	4,51E-13	3,49E-09	3,69E-09	**7,18E-09**	2,77E-10	9,42E-11	**7,55E-09**
Cobalt-60	Bq	3,10E-12	2,61E-08	2,76E-08	**5,37E-08**	2,07E-09	6,60E-10	**5,65E-08**
Hydrogen-3, Tritium	Bq	1,73E-05	9,89E-03	1,86E-02	**2,85E-02**	1,36E-03	1,23E-03	**3,11E-02**
Iodine-129	Bq	4,47E-10	1,68E-06	2,45E-06	**4,13E-06**	1,60E-07	9,64E-08	**4,39E-06**
Iodine-131	Bq	1,61E-08	9,23E-06	5,03E-05	**5,96E-05**	2,39E-06	3,78E-06	**6,57E-05**
Iodine-133	Bq	3,67E-11	2,55E-07	2,70E-07	**5,25E-07**	2,02E-08	7,48E-09	**5,53E-07**
Krypton-85	Bq	2,10E-07	3,34E-04	8,47E-03	**8,81E-03**	3,39E-04	4,91E-05	**9,19E-03**
Lead-210	Bq	8,49E-08	6,20E-06	5,99E-05	**6,61E-05**	2,72E-06	7,16E-05	**1,40E-04**
Nobel gases, radioactive, unspecified	Bq	4,30E-03	16,2	23,6	**39,8**	1,54	9,28E-01	**42,2**
Polonium-210	Bq	1,46E-07	9,55E-06	1,05E-04	**1,15E-04**	4,74E-06	1,27E-04	**2,47E-04**
Radon-222	Bq	1,76E-02	94,2	115	**209**	8,09	3,72	**221**
Xenon-133	Bq	1,49E-05	1,09E-01	1,15E-01	**2,24E-01**	8,64E-03	3,08E-03	**2,36E-01**
Water								
Actinides, radioactive, unspecified	Bq	7,27E-10	2,73E-06	3,98E-06	**6,71E-06**	2,60E-07	1,57E-07	**7,13E-06**
Americium-241	Bq	0	0	2,07E-10	**2,07E-10**	7,92E-12	0	**2,15E-10**
Antimony-124	Bq	4,99E-08	6,30E-06	2,96E-05	**3,59E-05**	1,49E-06	1,12E-05	**4,86E-05**
Carbon-14	Bq	5,46E-09	4,92E-08	2,59E-06	**2,64E-06**	1,14E-07	1,23E-06	**3,98E-06**
Cesium-134	Bq	4,63E-10	9,09E-07	1,32E-06	**2,23E-06**	8,68E-08	1,02E-07	**2,41E-06**
Cesium-137	Bq	8,83E-08	3,53E-04	5,00E-04	**8,54E-04**	3,30E-05	1,90E-05	**9,06E-04**
Cobalt-58	Bq	2,40E-08	1,64E-04	1,75E-04	**3,40E-04**	1,31E-05	4,91E-06	**3,58E-04**
Cobalt-60	Bq	1,40E-08	1,05E-04	1,12E-04	**2,18E-04**	8,39E-06	2,96E-06	**2,29E-04**
Hydrogen-3, tritium	Bq	4,81E-04	9,21E-01	1,40	**2,32**	9,03E-02	1,06E-01	**2,51**
Iodine-129	Bq	0	0	2,99E-08	**2,99E-08**	1,15E-09	0	**3,11E-08**

[6] All substances that contribute to Ionising radiation calculated with ReCiPe (H) Midpoint method

Iodine-131	Bq	9,74E-09	1,51E-06	6,05E-06	**7,57E-06**	3,12E-07	2,18E-06	**1,01E-05**
Manganese-54	Bq	7,30E-10	6,15E-06	6,58E-06	**1,27E-05**	4,90E-07	1,57E-07	**1,34E-05**
Ruthenium-106	Bq	0	0	2,07E-10	**2,07E-10**	7,92E-12	0	**2,15E-10**
Silver-110	Bq	8,15E-09	7,63E-05	8,14E-05	**1,58E-04**	6,07E-06	1,81E-06	**1,66E-04**
Strontium-90	Bq	4,35E-07	1,70E-04	1,30E-03	**1,47E-03**	5,93E-05	1,02E-04	**1,63E-03**

4 ADDITIONAL INFORMATION

When hydropower was built it affected the local ecosystems in and around our rivers. Fortum actively implements projects aimed at mitigating this effect, whilst recognising the importance of hydropower when combating climate change. Implementing the right action in the right place is crucial to achieve the desired outcome.

Fortum is actively involved in research and development projects aimed at reducing local environmental impacts. Fish management requires water system specific solutions, and Fortum strives to reduce the impact on fish stocks, restoring fish habitats, implementing transports of fish to their spawning areas and building fish ways. In addition to the power plant specific obligations, Fortum participates in voluntary environmental projects to reduce the environmental impact of hydropower productions together with municipalities, local authorities and research institutes.

4.1 Land use

The PCR (2007:08) requires that a study on land-use changes is carried out and the effects on biodiversity concerning the specific product and/or its processes are mapped. In this case, land-use changes and the effects on biodiversity were analysed in relation to the Krångede hydropower station and its production of hydropower in northern Sweden.

4.1.1 System boundaries

See system boundaries for the land use study in Figure 10 below. The system boundaries include a total area of 3430 ha.

It is assumed that the Krångede hydropower station and its reservoir have a technical lifetime of 100 years. Continuous reinvestments ensure further use and no deconstruction is assumed.

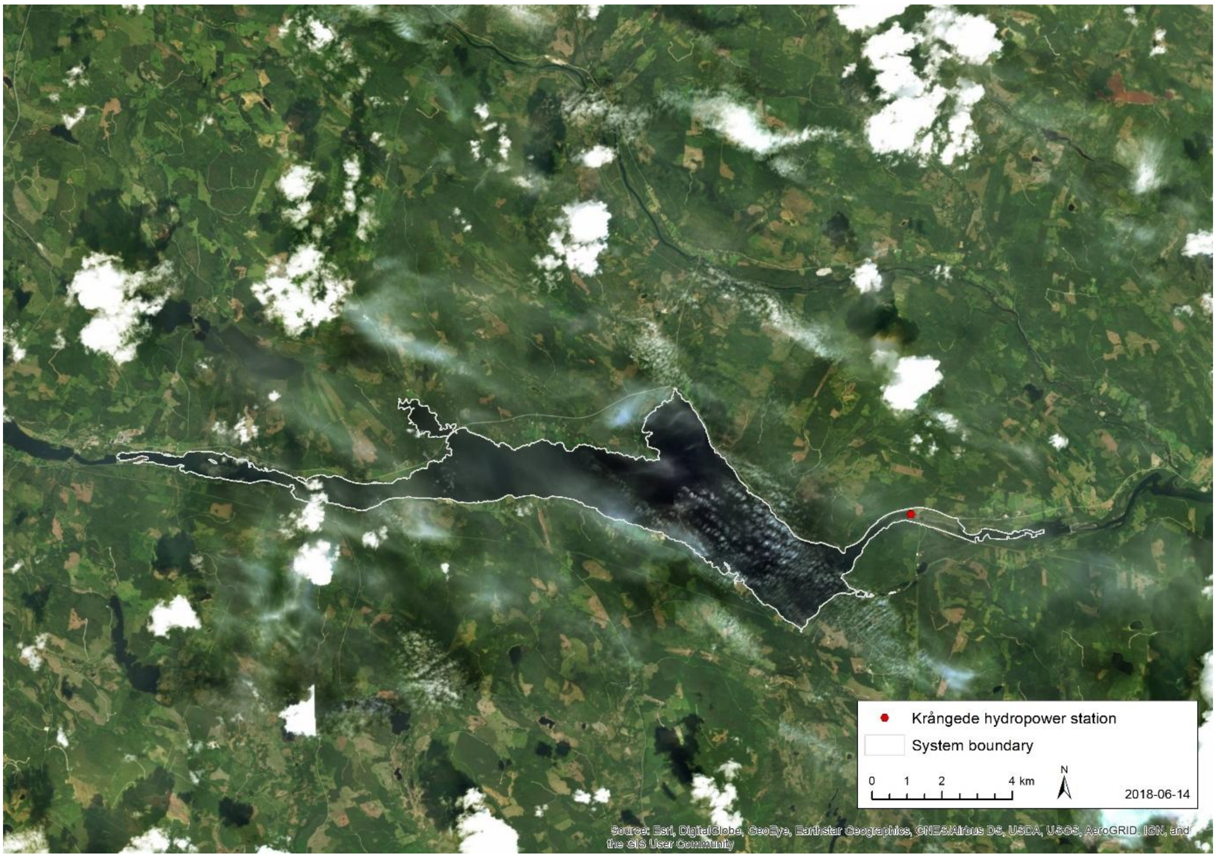

Figure 10 System boundaries for the land use study

4.1.2 Method

The first step of the study was to delineate a relevant system boundary. There is no standardised method to identify and delineate system boundaries in the EPD System. Krångede hydropower station is situated along Indalsälven, a river significantly affected by hydropower (contains a total of 25 hydropower stations) and there are several large resorvoires upstream. These include Storsjön och other resorvoires in the Hårkan and Långan tributaries, which together dominate the flow of water in Indalsälven all the way down to the sea. As a result, the fluctuation of the water levels in the reservoir upstream of Krångede is not so large, varying from 202 meters above sea level (RH00) and 204 meters above sea level (RH00). Consequently, it was decided to delineate the system boundary as the water body upstream of the hydropower station - up until the first hydropower station upstream – as well as the affected area downstream. Within GIS (Geographic Information System), the system boundary was delineated using a dataset of a modelled normal water flow (so called Q_{normal}) that was cut off at the first hydropower station upstream and digitised downstream where the affected area of the dry furrow ended. In addition, the property boundary of the Krångede hydropower station, including an older property that has now been sold to another owner, was merged with the digitised water body. The final system boundary has a total area of nearly 3430 hectares. This area constituted the study area to analyse land-use changes and the effects on biodiversity.

According to the PCR (2007:08), land-use change should be studied using as a minimum the Level 1 nomenclature (five classes) from the CORINE land cover dataset. These five main land-use classes consists of: forests and semi-natural areas; wetlands; water bodies; artificial surfaces; and agricultural areas. Level 1 nomenclature was used to study land-use change within the system boundary for two time periods: an estimation prior to the construction of the Krångede hydropower station and the current situation.

Using a high resolution Swedish land-cover dataset with national coverage from 2016 called KNAS (*Kontinuerlig naturtypskartering av skyddade områden*), different land cover classes were translated and converted to match the CORINE main land cover classes. Due to issues concerning resolution and generalisations, additional detailed information on land cover was overlayed on top of KNAS. The result was a model of today's land cover. In order to map the historical land-use, a historic map from 1903 (*Generalstabskartan*) was used. With additional help of historical photographs, the map and the photographs provided an indication of where land use changes have occurred. These changes were manually digitized and classified according to assumptions made regardning historical land cover. Lastly, a GIS analysis was carried out to identify spatially where and what kind of land-use changes could have occurred.

4.1.3 Results

The result of the land-use change analysis from 1903 to the current date, indicates that the primary changes have been a loss of forests due to the construction of the hydropower plant and related exploitation, slightly less water historically upstream and more water downstream due to the absence of damming. Historically, natural fluctuations in water levels would result in more wetlands/and or shorelines upstream and no dry furrow downstream.

The actual area of change has been estimated and summarised in the table below.

Table 12 Land-use change within the system boundary.

	Area (ha), historical	Area (ha), today	Change in area (ha)
Forests and semi-natural areas	100,5	90,0	-10,5
Wetlands	13,8	10,5	-3,3
Water bodies	3290	3290	2,73
Agricultural areas	0,23	0,23	0
Artificial surfaces	23,1	34,1	11,0

It is important to note that these areas are estimations and not necessarily precise calculations. However, an estimation is useful to map the potential changes. Due to a lack of historical data of high resolution, it was not possible to achieve a more accurate analysis of land-use change. Therefore, the result of the land-use change should be considered only as an indication. Furthermore, additional changes could have occurred between the years 1903 and 2018 since data was used from the two separate periods and no analysis was done during the period in-between.

4.2 Impacts on biodiversity and nature

4.2.1 Background

The loss of habitats and species is considered to be one of the biggest problems of our time. Therefore, Sweden has signed and ratified the Convention on Biodiversity. In the Convention, biodiversity is defined as the variety of living organisms of all origins, including land-based, marine and other aquatic ecosystems, as well as the ecological complexes in which these organisms are included. This includes diversity within species, between species and of ecosystems. The Convention has been incorporated into Swedish environmental work through the National Environmental Quality Objectives, which state that the current biodiversity must be preserved and exploited in a sustainable way for present and future generations. The habitats and ecosystems of the species as well as their functions and processes shall be safeguarded.

In order to take into account biodiversity, current knowledge in relevant areas is required. Therefore, nature conservation inventories (NVI) are necessary as a basis for building and developing a sustainable society with sustained or enhanced biodiversity. This standard defines the concept of natural value inventory for biodiversity, herewith referred to in this report as NVI (SIS 2014, see reference).

The purpose of an NVI is to identify and define the geographical areas of the landscape that are of positive importance to biodiversity, as well as to document and assess the nature of these. The result of an NVI is a crucial prerequisite for making assessments of sensitivity and consequences.

4.2.2 Method and system boundaries

To identify potential impacts from the power plant on nature areas an NVI was carried out. The inventoried area comprises a 100-200 meter wide corridor around the Gesunda lake. The site visits focused on areas identified as interesting in earlier inventories, see Figure 11. Sites were judged on habitat quality and species richness values according to the method for biodiversity survey used and placed in different categories of nature values from low to high.

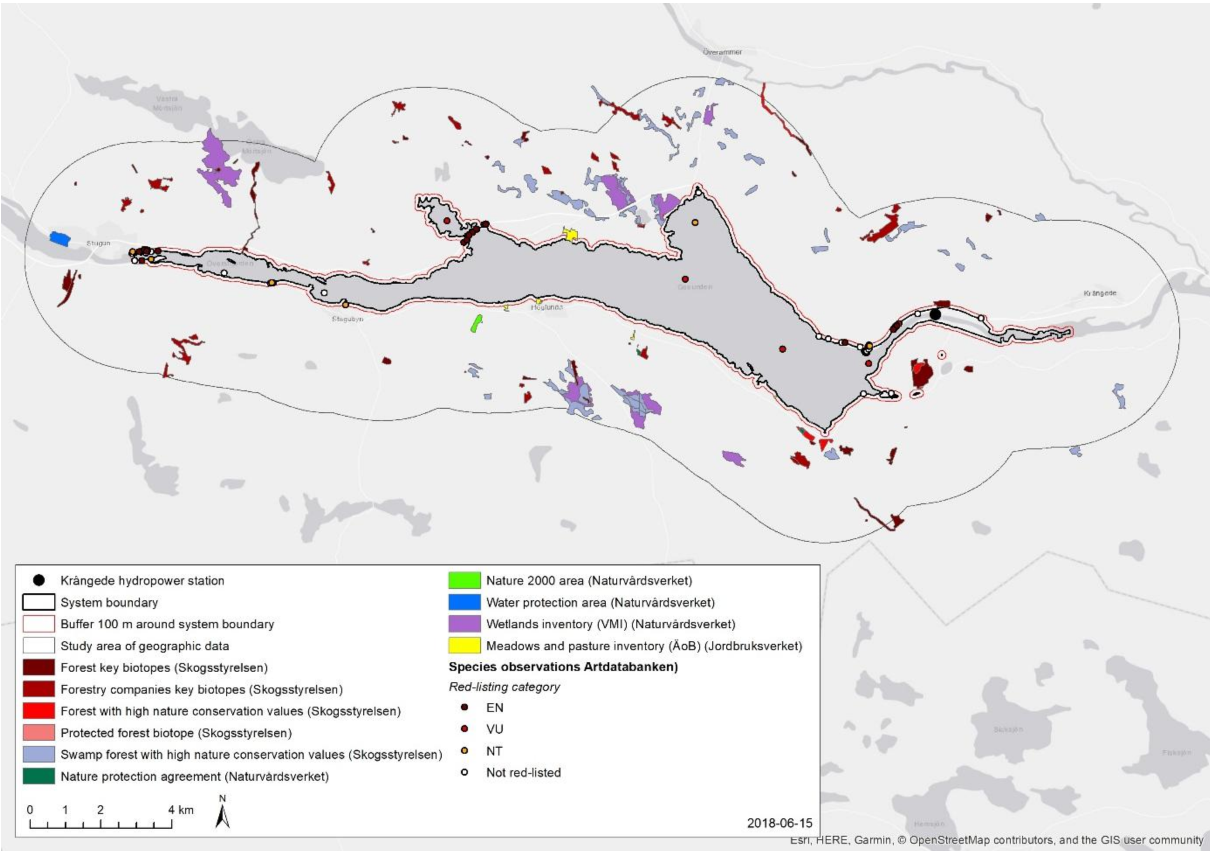

Figure 11 Inventory zone (buffer zone 100 m) and system boundaries for land use (3 km, not studied in the biodiversity survey) including natural areas identified as of high value from earlier studies by the Swedish Forest Agency (Skogsstyrelsen), the Swedish Environmental Protection Agency (Naturvårdsverket), the

Swedish Board of Agriculture (Jordbruksverket) and the Swedish Species Information Centre (Artdatabanken); se legend in the map.

As a complement to the field study, a litterature study was conducted to describe the effects on biodiversity. Additionally, open source GIS-data from governmental agencies was used to map areas of high nature conservation value. A list of the specific reports and datasets can be found in the land use report.

4.2.3 Results from the literature study

According to the literature study, no detailed studies on the effects of biodiversity due to the operation of Krångede hydropower station were found. Therefore, it is instead noted that hydropower in general has a negative impact on the biodiversity, especially within the limnetic environment. GIS-data of areas with high nature conservation value show that there are a number of locations around the Krångede hydropower station and Gesunda lake that are important for biodiversity. These areas are primarily wetlands, wet forests and coniferous forests. However, the location of these biotopes are not considered to be affected by the hydropower station.

In conclusion, the operation of Krångede hydropower station is not considered to have any significant negative effects on terrestrial biodiversity. This is also the conclusion in the nature inventory report that WSP has carried out. However, the hydropower station has clearly affected the limnetic biodiversity due to the current damming upstream and the dry furrow downstream. Damming affects natural water fluctuations, sedimentation and impose an increased risk for fish dying in the turbines. The power plant itself and the dry furrow may certainly affect the migration of some fish species.

The fish fauna following the building of the power-plant in Krångede is probably about the same as prior to the construction. The stream at Krångede was namely already earlier a barrier for upstream dispersion for most fish species due to a high and uneven vertical drop. Furthermore, longdispersal salmonids would not have been able to migrate up to the waterbed of Gesunda because of the large migration barriers at the Hammar fall at Hammarstrand not far downstream. A comparison of the current fish fauna uppstream and downstream Krångede is to be read in the separate NVI report.

4.2.4 Results from the Biodiversity Survey

Most of the land within 200 meters from the shoreline of the water reservoir has few important values in terms of biological diversity, see Figure 12. However, there are exceptions. One of them is a shallow peninsula sensitive to water level changes near Stugun with an interesting habitat and the occurrence of the highly threatened leguminous plant *Astragalus penduliflorus*. This plant also occurs at some sites which have been assigned a lower value of importance as a habitat, but which by the presence of the threatened plant species still are of high conservation value.

Three small areas of undisturbed forest were also marked out with a value of notable importance and subject to water level fluctuations. Historical studies of land-use in this report point out that it was mainly forest areas which were lost during the construction of the power plant and the rise of water level in Gesunda lake. Given the diversity of species present in mature woodlands in this area it is considered that these forests should be protected from forestry activities. This will ensure that they have the chance to colonise developing forests.

The dry-laying of the rapids at Krångede when building the power plant probably had a strong negative impact on the occurrence of mosses and lichens there. For example, the lichen

Fuscopannaria confuse, which used to grow on trees in the mist from the waterfall, was not found during the survey.

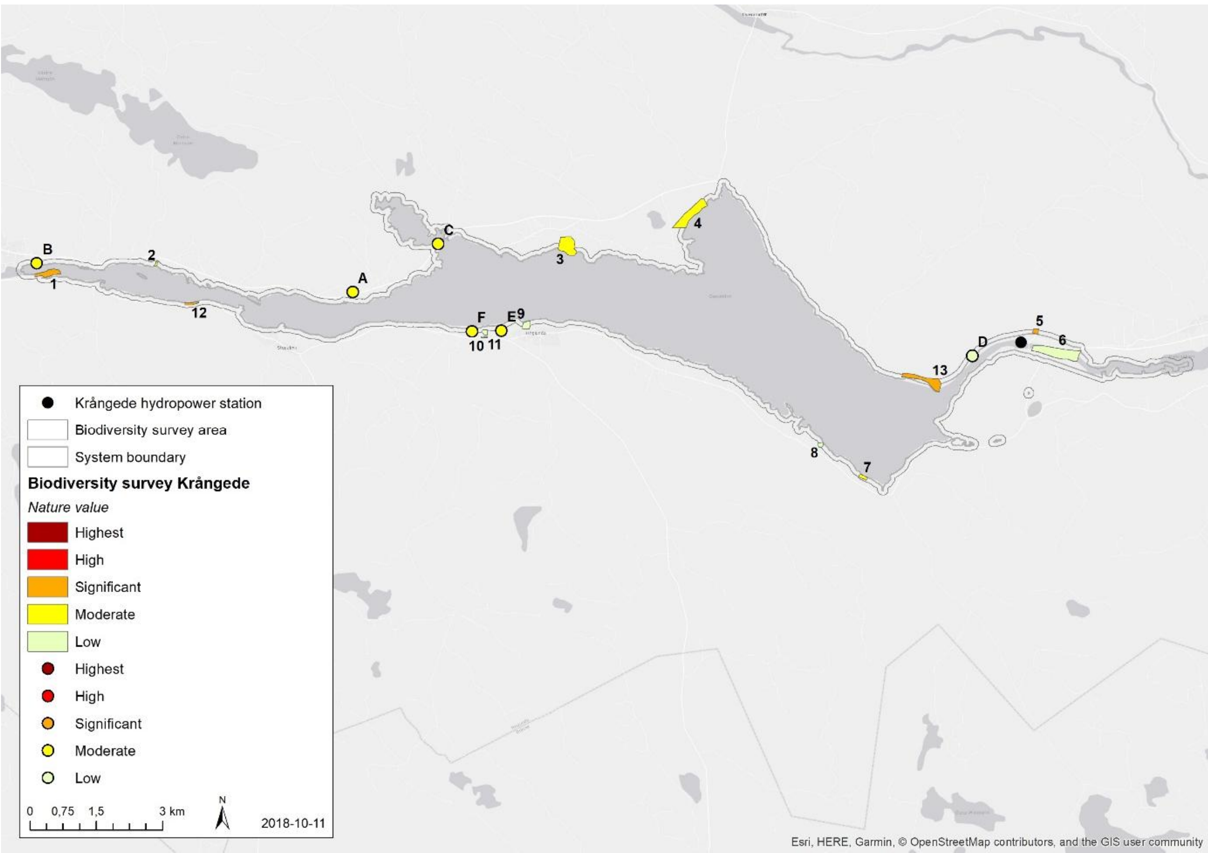

Figure 12 Thirteen areas and six points with potential natural conservation values were marked within the inventoried area, of which some could be disreguarded due to a lack of natural conservation values (low values in the figure legend) according to SIS standard.

4.3 Environmental risks

4.3.1 Risks for dam failure

The power companies of Sweden have developed guidelines for dam safety (RIDAS). The first edition of these guidelines was launched in 1997 and the latest published version was released in 2016 (Energiföretagen, 2016). This document contains guidance on how to classify hydropower dams regarding dam safety on a scale from A to E. Krångede power plant and dam has a dam classification B, which is the second highest dam safety classification and means that an accident or dam failure would result in a large impact on society. In case of an accident, the society would be affected by 1) major regional and local consequences or disturbances and 2) a risk of loss of human life that is not negligible.

Krångede also has the grade I classification considering dimensioned flows (I, II or III). This means that the consequences of a dam failure during high flows are likely to cause severe consequences and entails that the dam has very high requirements considering water outlets and spillways.

Fortum is, according to the Swedish Environmental Code, obliged with self-control within the area of dam safety, in line with RIDAS guidelines and recommendations. This self-control includes operational supervision once a week; inspection of the dam twice a year; an in-depth dam inspection every third year and dam safety evaluation every twelfth year. The self-control includes also preventive maintenance and regular function tests.

The dam is considered to have a good safety level for its age but needs extra investments to fully deliver on the safety margins for dimensioned flow according to the guidelines of The Swedish Committee for Design Flood Determination. The deviations are not considered to have considerable impacts on the dam safety, however projects are planned to correct these.

4.3.2 Releases to the environment

Fortum has also identified a number of environmental risks at Krångede. These risks are mainly related to the release of different chemicals such as oil, diesel or mercury to the air, water or ground environment. These substances can either have a negative impact on the local environment or contribute to climate change. They can leak out of the facility into the air, waterways or drainage system. The risks are quantified according to probability and consequence.

The most common risk is the risk for leakage of oil or diesel to the ground or water environment. This can occur either from the generators (oil) or the reserve power station (diesel) to the water, or from the transformers to the ground.

A quantification has been made, showing that the potential releases during operation due to accidents or machinery breakdowns can be expected to be around 10^{-4} g/kWh for oil to the ground (mainly transformer accident) respectively 10^{-5} g/kWh for oil or diesel to water (mainly from generator or reserve power aggregate). These potential releases can be compared to the emissions of oil calculated in the LCA, that are estimated to around 10^{-4} g/kWh for both oil to water and soil, of which only a minor part (<1%) comes from the core process (note that this is LCI emissions – there are no oil spills to the river from the turbines).

The risk of oil leaking has been studied thoroughly and precationary measures have been taken to prevent oil spill to ground or water. Machinery containing oil, where there is a risk for leakage, is equipped with safety precautions (for example degreasers) keeping any spill contained within the power plant. All equipment is sealed in and under cover of a roof, meaning that the risk for oil reaching the surrounding environment is minor. The turbines, which are the only machine parts directly in contact with the flowing water, are Francis turbines – meaning that no oil lubricated parts come into contact with water (see Figure 3).

Until recently, one of the highest risks at the power station was the release of SF_6 from tranformers. This was due to a breaker that was constantly leaking, causing emissions of SF_6. The breaker was exchanged in the Spring of 2018.

4.4 Noise

The Swedish Environmental Protection Agency has recommended that the noise levels from power transmission lines should not exceed 40-45 dB(A) (Naturvårdsverket, 1986, cited in Svenska Kraftnät 2010). However, Svenska Kraftnät (u.d.) also concludes that it is very rare that power lines of the voltage of the Swedish grid create noise above this level. Power lines with higher voltage are more likely to create disturbing noise levels.

The power lines can sometimes produce a crackling or fizzing sound during specific weather conditions, such as very high humidity. This phenomenon is known as corona discharges and is an electrical discharge that takes place when the medium surrounding a conductor (a power line in this case) becomes ionized. By modifying the electrical field surrounding the conductor, the corona discharge can be accelerated or deaccelerated.

The noise caused by the power plant is not significant as it is an underground station. Noise levels before erection of the power plant, due to the natural flow of water, are higher than after.

4.5 Electromagnetic fields

Electromagnetic fields, often abbreviated as EMF, are used as a collection term for electric and magnetic fields. These fields occur when generating, transferring, distributing or using electricity and exist almost everywhere in today's society: around power lines, transformers, microwave ovens and blow dryers. There is however a difference between high and low frequencies of EMF (low frequencies are considered to be between 3 kHz to 300 GHz). EMF of high frequency has been found to be dangerous to human health, even if the exposure only lasts for a short period of time. Exposure to low frequencies are a consequence of the electrified society and the effect on human health have been debated for a long time. The main concern has been to evaluate whether long-term exposure to EMF causes cancer or not. The scientific research done in the area is not conclusive and often contradictory. Despite extensive research, to date there is no evidence that exposure to low-frequency electromagnetic fields is harmful to human health. (WHO, 2018a; WHO 2018b).

There are no binding limits for exposure to EMF. However, several organizations have developed guidelines for EMF exposure. ICNIRP (International Commission on Non-Ionizing Radiation Protection) – a non-governmental organization formally recognized by the World Heath Orgnization (WHO) – defines the following recommended exposure limits (ICNIRP, 2009): 1000 µT for a working environment and for the general public a limit of 200 µT at 50 Hz. The EU Council of Ministers recommends a restriction of exposure to electro-magnetic fields in accordance with the ICNIRP´s recommendations.

Directly underneath a 220 kV power line the magnetic field is approximately 10-20 µT, about the same size as the magnetic field surrounding a har dryer or a vacuum cleaner (Svenska Kraftnät u.d.).

5 PROGRAMME-RELATED INFORMATION AND VERIFICATION

The EPD owner has the sole ownership, liability, and responsibility for the EPD. EPDs within the same product category but from different programmes may not be comparable.

This EPD has been prepared in accordance with the International EPD® System, following the General Programme Instructions (GPI ver 2.5) and the Product Category Rules for Electricity, Steam and hot/cold water (PCR ver 3.0).

The EPD has been third-party verified by the accredited verifier Caroline Setterwall, ABB AB, on the 13:th of November 2018.

5.1 Omission of life cycle stages

All life cycle stages required according to the PCR have been included in the EPD. No data obtained has been omitted. Use of electricity by the customer is not included, in accordance with the PCR.

5.2 Explanatory material

For more information about Fortum, please visit www.fortum.com. For explanatory materials, please see list of references in the back.

Product category rules (PCR): Product Category Rules for Electricity, Steam and hot/cold water 2007:08 ver 3.0 UN CPC code 171 and 173
PCR review was conducted by: The Technical Committee of the International EPD® system. Chair: Massimo Marine. Contact via info@environdec.com.
Independent third-party verification of the declaration and data, according to ISO 14025:2006: ☐ EPD process certification ☒ EPD verification
Third party verifier: Caroline Setterwall, ABB AB *Sign* Caroline Setterwall Approved by: The International EPD® System
Procedure for follow-up of data during EPD validity involves third party verifier: ☒ Yes ☐ No

6 REFERENCES

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Background reports (Swedish)

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WSP, 2018b. *Markanvändning och påverkan på biologisk mångfald – EPD för Vattenkraft från Krångede.*

WSP, 2018c. *Naturvärdesinventering – EPD för Vattenkraft från Krångede.*

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