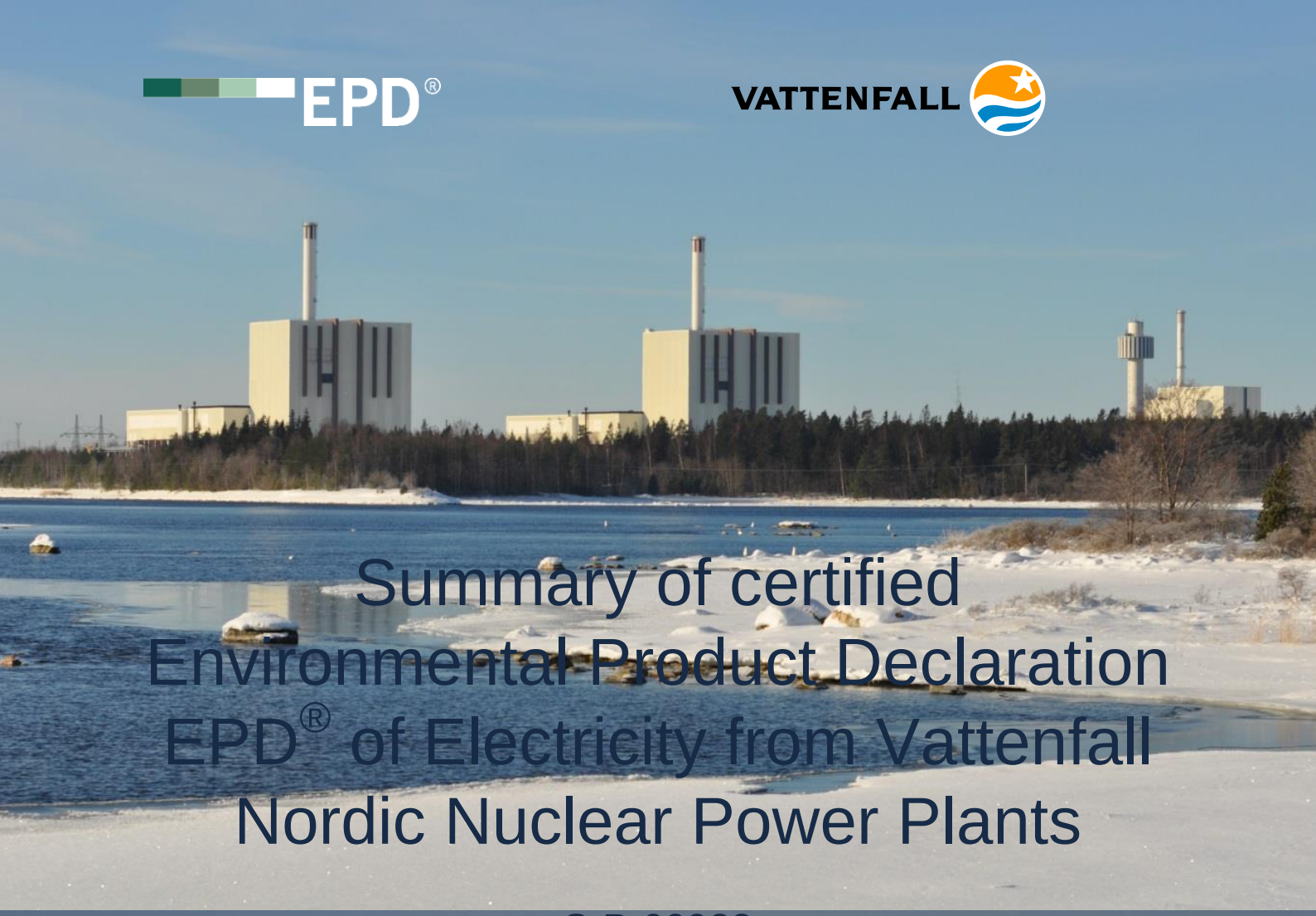


Summary of certified Environmental Product Declaration EPD® of Electricity from Vattenfall Nordic Nuclear Power Plants

S-P-00923
2016-12-31
Vattenfall AB Nuclear Power
UNCPC Code 17, Group 171 – Electrical energy
Vattenfall AB
Confidentiality class:

Valid until: 2019-12-31

Summary

PRODUCER. Forsmarks Kraftgrupp (FKA) and Ringhals AB (RAB) are responsible for the electricity generation on the nuclear power sites, located north of Östhammar on the Swedish East coast and north of Varberg on the Swedish West coast respectively. The companies are partly owned by Vattenfall AB SE–162 87 Stockholm, telephone +46 8 739 50 00 (FKA 66%, RAB 70,4%). Both have environmental management systems certified and registered according to ISO 14001 and OHSAS 18001.

PRODUCT AND DECLARED UNIT, Electricity belongs to the product category UNCPC Code 17, Group 171 – Electrical energy.

The two sites comprise four Boiling Water Reactors (BWR) and three Pressurised-Water Reactors (PWR) of together app. 7206 MW and generate app. 47 TWh an average year. The reactors are of generation II type and a once-through fuel cycle is applied i.e.no reprocessing of fuel. Forsmark and Ringhals are base load plants. The declared unit is 1 kWh electricity net generated and thereafter distributed to a customer connected to the Swedish regional grid (70/130 kV).

THE EPD® PROGRAM managed by EPD International AB is based on ISO 14025, Type III Environmental Declarations. The relevant governing documents in hierarchical order are: Product Category Rules UN CPC 171 AND 173, version 3.0, General Programme Instructions for an environmental product declaration, EPD® version 2.5, ISO 14025, ISO 14040, ISO 14044.

ENVIRONMENTAL PERFORMANCE, based on LCA, see section 3 of the complete EPD® documentation.

System Boundaries. The EPD® comprises the generation of electricity in the nuclear power plant; Upstream processes i.e. uranium fuel production and production of auxiliary supplies and Downstream processes i.e. distribution of electricity. Further construction and dismantling of the nuclear power plant and the facilities for radioactive waste handling have been included, Core – Infrastructure. The use stage of electricity at the consumer is not included. The technical lifetime is 60 years.

The complete certified declaration also contains descriptions of environmental risks, ionizing radiation issues and impacts on biodiversity in accordance with the EPD® system instructions.

Environmental Information. A short summary of compiled data is presented below per generated and distributed kWh electricity

Upstream	Mining & milling, refinery and conversion, enrichment and fabrication of nuclear fuel. Production of auxiliary substances and chemicals for NPP operation and radioactive waste handling.
Core	Operation of NPP and facilities for handling radioactive waste. Incineration or deposit of conventional waste from operations.
Core infrastructure	Construction and decommissioning of the nuclear power plants and radioactive waste facilities, including necessary reinvestments.
Downstream	Operation of electricity networks, i.e. emissions from inspection trips. Extra generation in NPP to compensate for losses in the distribution system.
Downstream infrastructure	Includes manufacturing of materials (for lines, cables, pylons, transformers, buildings, and switching stations), ground work and handling of discharge material incl. transportation.

Distribution of electricity implies losses, which must be compensated for by increased generation. The loss to an average large industrial customer connected to the regional distribution network (70/130 kV) amounts to 3% (included in the downstream column below). The losses are different for different types of customers and often higher in the countryside. The average loss to a household customer varies between 7–9%

Ecoprofile

Input

Resource	Unit/ kWh	Upstream	Core	Core infra-structure	Total generated	Down-stream[1]	Downstream - infrastructure	Total - distributed
Copper in ore	g	1,5E-02	1,2E-06	6,8E-03	2,2E-02	6,6E-04	1,1E-02	3,3E-02
Fossil energy resources	kWh	1,2E-02	7,4E-05	9,9E-04	1,3E-02	6,2E-04	4,8E-03	1,8E-02
Gravel, stone & sand	g	9,8E-01	3,5E-03	5,8E+00	6,8E+00	2,0E-01	1,3E+00	8,3E+00
Iron in ore	g	1,2E-01	5,5E-04	7,5E-02	1,9E-01	5,9E-03	6,4E-01	8,4E-01
Limestone	g	2,4E-01	1,0E-05	6,3E-01	8,7E-01	2,6E-02	0,0E+00	9,0E-01
Potential energy through hydro turbines[2]	kWh	1,4E-03	4,1E-07	3,9E-04	1,8E-03	5,5E-05	1,8E-04	2,0E-03
Renewable fuel	kWh	4,2E-04	1,7E-06	3,7E-04	7,9E-04	2,4E-05	8,3E-05	9,0E-04
Soil	g	2,2E-01	1,9E-06	9,0E-01	1,1E+00	3,8E-02	0,0E+00	1,2E+00
Uranium in ore	g	2,6E-03	8,0E-09	6,6E-06	2,6E-03	7,9E-05	9,2E-07	2,7E-03
Zirconium sand	g	4,4E-04	3,3E-07	2,1E-05	4,6E-04	1,4E-05	4,0E-06	4,8E-04
Electricity use in the power plant[3]	kWh	1,6E-02	0,0E+00	0,0E+00	1,6E-02	4,9E-04	0,0E+00	1,7E-02
Water, different sources	g	4,6E+04	1,0E+01	1,1E+04	5,7E+04	1,7E+03	4,4E+03	6,3E+04
Input of material from the technosphere (app. 50 substances)	g	7,9E-03	2,7E-05	9,7E-04	8,9E-03	3,4E-04	1,1E-03	1,0E-02

Output

Pollutant emissions	Unit/ kWh	Upstream	Core	Core infra-structure	Total generated	Down-stream[1]	Downstream infrastructure	Total - distributed
Greenhouse gases	g CO2-equiv. (100years)	3,6E+00	2,0E-01	3,8E-01	4,2E+00	2,7E-01	1,5E+00	6,0E+00
Acidification Potential	g SO2-equiv.	3,5E-02	9,1E-04	2,4E-03	3,9E-02	1,4E-03	1,2E-02	5,2E-02
Photochem. Ozone Creation Potential	g Ethene-equiv.	2,5E-03	1,5E-04	2,3E-04	2,8E-03	1,3E-04	1,9E-03	4,9E-03
Eutrophication Potential	g Phosphate-equiv.	7,6E-03	3,6E-04	4,0E-04	8,4E-03	3,1E-04	5,0E-03	1,4E-02
C-14 to air	kBq	5,9E-05	5,4E-02	1,4E-05	5,4E-02	3,9E-07	2,6E-06	1,6E-03
Kr-85 to air	kBq	6,8E-05	6,2E-03	4,9E-04	6,8E-03	4,4E-08	6,1E-07	2,0E-04
Rn-222 to air	kBq	9,8E-01	2,4E-04	2,0E-01	1,2E+00	3,9E-04	2,9E-02	3,6E-02
Particulate matter to air	g	9,2E-03	1,7E-04	6,3E-03	1,6E-02	3,1E-05	1,1E-02	4,7E-04
Polyaromatic hydrocarbons	g	1,1E-06	1,2E-07	7,7E-08	1,3E-06	1,9E-08	2,9E-06	3,9E-08

Other information

Output

	Unit/ kWh	Upstream	Core	Core infra-structure	Total generated	Down-stream[1]	Downstream infrastructure[7]	Total - distributed
Hazardous waste								
Hazardous waste to disposal	g	2,5E-02	4,2E-03	1,6E-03	3,1E-02	9,2E-04	0,0E+00	3,2E-02
Hazardous waste to incineration	g	2,0E-03	3,0E-03	0,0E+00	5,0E-03	1,5E-04	0,0E+00	5,1E-03
Radioactive waste								
Volume of deposit for high-level radioactive waste[4]	m3	5,3E-15	7,3E-09	1,1E-14	7,3E-09	2,2E-10	0,0E+00	7,5E-09
Volume of deposit for low/medium-level radioactive waste	m3	3,1E-13	4,4E-08	5,0E-08	9,5E-08	2,8E-09	0,0E+00	9,8E-08
Low-level radioactive waste without further treatment	g	1,8E-02	8,6E-08	5,1E-05	1,8E-02	5,3E-04	0,0E+00	1,8E-02
Spent fuel[5]	g	0,0E+00	2,8E-03	0,0E+00	2,8E-03	8,3E-05	0,0E+00	2,8E-03
Uranium in spent fuel	g	0,0E+00	2,6E-03	0,0E+00	2,6E-03	7,7E-05	0,0E+00	2,7E-03

Other information, cont. **Output**

	Unit/ kWh	Upstream	Core	Core infra-structure	Total generated	Down-stream[1]	Downstream infrastructure[7]	Total - distributed
Waste to recycling[b]								
Aluminium	g	0,0E+00	0,0E+00	1,9E-04	1,9E-04	5,8E-06	0,0E+00	2,0E-04
Crushed concrete	g	0,0E+00	0,0E+00	6,8E-01	6,8E-01	2,0E-02	0,0E+00	7,0E-01
Copper scrap	g	3,2E-05	2,6E-06	2,4E-03	2,4E-03	7,2E-05	0,0E+00	2,5E-03
Lead scrap	g	0,0E+00	0,0E+00	1,3E-03	1,3E-03	3,8E-05	0,0E+00	1,3E-03
Steel scrap	g	2,0E-04	8,5E-05	7,2E-02	7,2E-02	2,2E-03	0,0E+00	7,4E-02
Other waste to recycling	g	1,5E-02	1,1E-01	2,8E-04	1,2E-01	3,7E-03	0,0E+00	1,3E-01
Waste to disposal	g	4,0E+01	1,4E-02	6,0E-01	4,1E+01	1,2E+00	0,0E+00	4,2E+01
Waste to incineration	g	4,7E-04	1,0E-02	3,4E-02	4,5E-02	1,4E-03	0,0E+00	4,7E-02
Waste water	g	4,6E+04	9,6E+00	1,1E+04	5,7E+04	1,7E+03	4,4E+03	6,3E+04

1 Distribution losses of 3% of generated electricity are included in the Downstream column.
2 Hydropower is reported as used potential energy (1 kWh hydroelectricity = 1.14 kWh potential energy).
3 It is assumed that this electricity is generated by the NPP itself. The environmental impact is accounted for since this amount of electricity has been subtracted from the reference flow.
4 High-level radioactive waste from electricity generation in upstream processes is assumed to be further processed and is not classified as waste in the generic data.
5 Spent fuel includes the complete fuel assemblies that has been in the reactor core.
6 Use of recycled material is classified as secondary resources according to GPI 2.5
7 All waste flows are transformed into resource use and emissions through appropriate waste management processes. Thus no waste amounts reported from Downstream infrastructure.

Conclusions of the LCA

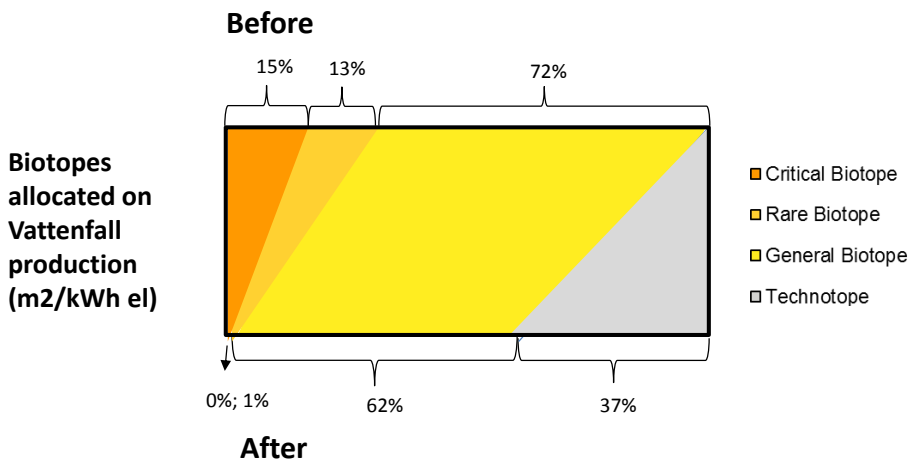
The major environmental impact is attributable to the activities in the upstream processes especially during mining of uranium.

ADDITIONAL ENVIRONMENTAL INFORMATION

Land use and Impact on Biodiversity

Vattenfall's Biotope Method is used to quantify impacts on biodiversity as a direct consequence of the utilisation of land and water for economic activities. Affected areas are categorised into Critical biotope, Rare biotope, General biotope and Technotope. In the table and figure below the identified biotope changes are shown. See section **Error! eference source not found.** for more information.

	Biotope Change (ha)	Biotope Change Allocated (ha)	Allocated areas (m^2/kWh el) Before	After	Biotope Change per kWh electricity (m^2/kWh el)
Critical Biotopes	-4076	-15	15%	0%	$-5 \cdot 10^{-6}$
Rare Biotopes	-2637	-12	13%	1%	$-4 \cdot 10^{-6}$
General Biotopes	55	-6	72%	62%	$-3 \cdot 10^{-6}$
Technotopes	6660	33	0%	37%	$1 \cdot 10^{-5}$



Safety, Barriers and Radiation
The nuclear power industry is strictly regulated and closely monitored by authorities. The operator of a NPP is the owner of and responsible for the nuclear fuel from mining to final repository. In addition to strict design criteria including redundant control systems there are safety considerations at three levels. See section **Error! Reference ource not found.**.

Radioactive substances in various forms are handled during normal operation of facilities in the nuclear fuel cycle. These substances emit ionizing radiation that may result in doses to the people working in the facility (dose-to-personnel), and to people outside the facility (dose-to-third party).

Dose to personnel. The table below show the average dose to personnel at the different facilities in the nuclear fuel life cycle.

	Unit	Upstream facilities	NPP-operation	Nuclear waste handling
Average individual dose	**mSv**	0,1 – 1,7	1,2 – 1,6	0,002 – 1,5

Dose to critical group/dose to representative individual is an assessed effective dose (mSv) that is received by an individual living in the vicinity of the facility. This is commonly a hypothetical individual that is assumed to represent a person that is more exposed due to its habits and consumption pattern, The critical group /representative individual may be defined differently between countries due to the type of facility, the emissions as well as the surrounding environment.

Maximum calculated annual effective dose 2015 from FKA and RAB was 0,00013 and 0,00031 mSv respectively to a 7-12-year individual in the critical group. For comparison, if you live in Sweden the annual radiation dose is about 0,6 mSv from naturally occurring radioactive substances in soil and building materials. The total dose varies, but the average is about 4 mSv including for instance medical radiation and radon in homes.

Environmental Risk Assessment
The conclusion is that risks in the nuclear fuel chain are acceptable since accidents with severe consequences in return have low probability due to rigorous safety arrangements. See chapter 4.5.

Noise
Maximum level at the gate of the nuclear power plant is 38 dB(A) at FKA and 43 dB(A) at RAB


Ringhals nuclear power plant


Forsmark nuclear power plant

Information from the Certification Body and Mandatory Statements

General
To be noted: EPD®s from different EPD® programmes may not be comparable. When comparisons are made between different products in this product category it should be noted that energy can be supplied through different energy carriers like heat/steam or electricity, but the amount of kWh needed will differ with different energy carriers due to different energy quality and conversion/distribution efficiencies.

Omissions of Life Cycle Stages

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

Means of Obtaining Explanatory Materials
ISO 14025 prescribes that explanatory material must be available if the EPD® is communicated to final consumers. This EPD® is aimed for industrial customers and not meant for private customer communication.

Information on Verification

EPD® programme: The International EPD® system managed by EPD International AB, www.environdec.com
Product Category Rules: Product Category Rules, CPC 171 Electrical Energy, version 3.0
PCR review was conducted by: The Technical Committee of the International EPD® system. Full list of TC members available on www.environdec.com/TC
Independent verification of the declaration and data, according to ISO 14025, has been performed within Vattenfall's certified EPD® Management process. X Internal
Internal and external verifiers: Lasse Kyläkorpi, Vattenfall AB, and Caroline Setterwall, ABB
Third party verification of Vattenfall´s EPD Management process has been conducted by the *accredited Certification body*: Bureau Veritas Certification
External verifier: Göran Brohammer **This EPD® is valid until:** 2019-12-31