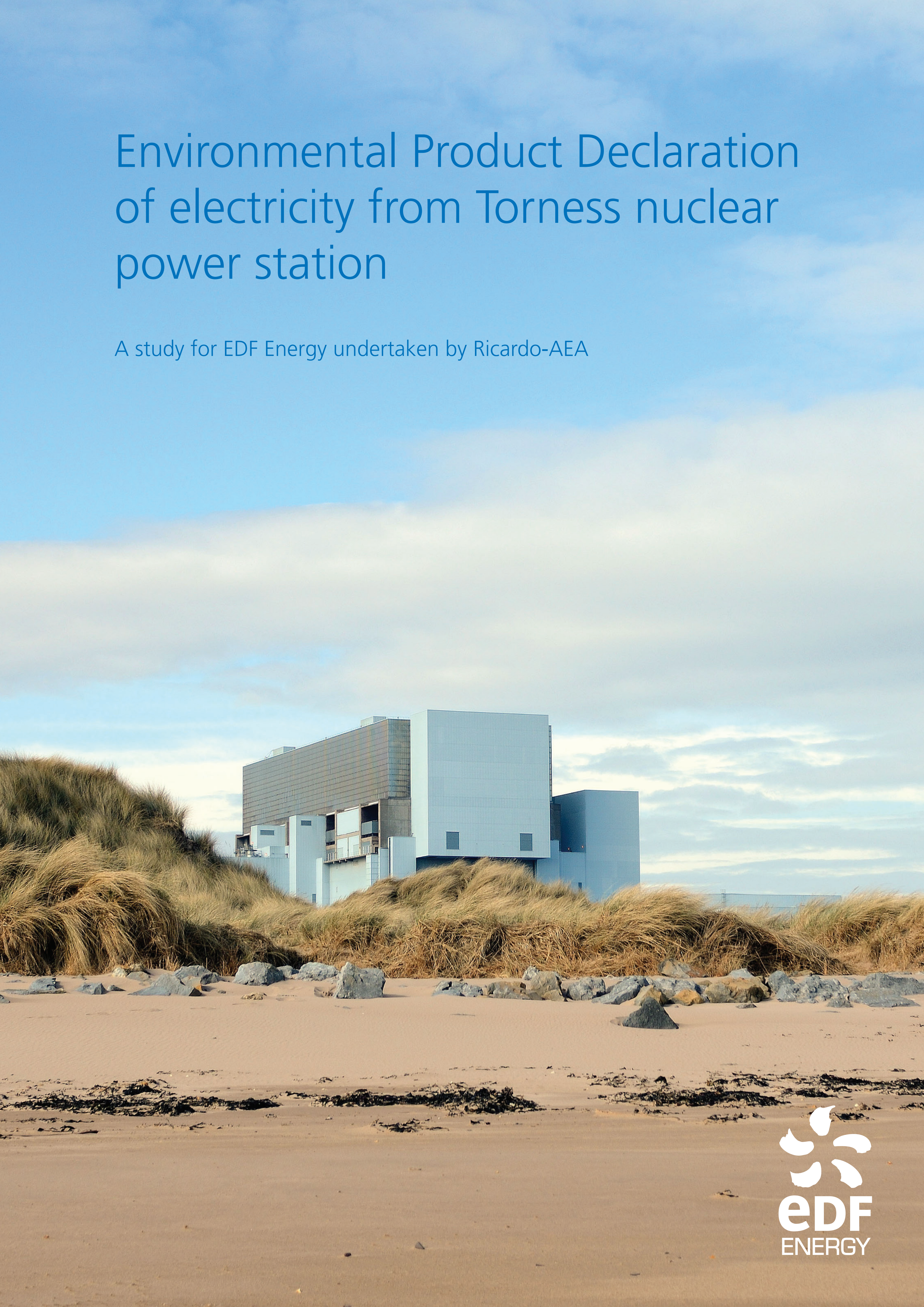
Environmental Product Declaration of electricity from Torness nuclear power station

A study for EDF Energy undertaken by Ricardo-AEA



Key findings

This document constitutes the Environmental Product Declaration (EPD) of electricity from the Torness nuclear power station. The EPD has been prepared by Ricardo-AEA on behalf of EDF Energy.

The declared product is 1 kWh net[1] of electricity generated at Torness and thereafter distributed to the customer during a reference period of 24 months during 2011 and 2012.

The environmental impacts associated with the generation of electricity at Torness have been assessed as part of a Life Cycle Assessment (LCA). LCA is a clearly structured framework based on international standards that facilitates the quantification and assessment of emissions and resource use along the entire electricity production chain. This includes impacts across all of the process stages in the nuclear fuel cycle, including uranium mining and milling, enrichment, fuel fabrication, power generation, and waste disposal.

The results of the analysis indicate that the environmental impacts associated with the mining and milling of the uranium fuel, the construction and the operation of the nuclear power station and the reprocessing of spent fuel dominate the results.

The construction stage is a large contributor to the lifecycle CO_2 emissions, representing 31% of the total. These emissions are largely determined by the electricity used during the commissioning of the plant and embodied energy associated with the construction material used (e.g. steel and concrete). The construction stage is also an important source of ozone-depleting substances and acidifying gases.

The mining and milling stage is the second largest contributor to the emission of greenhouse gases and the largest contributor to emissions of acidifying gases. SO_2 emissions from the production of the sulphuric acid that is used in the uranium milling process are an important contributor to the latter impact category.

The reprocessing of spent fuel is the third largest source of GHG emissions and emissions of ozone depleting substances. This is based on the assumption that approximately half of the lifetime spent fuel arising from Torness is reprocessed. If a higher level of reprocessing is assumed then this share would increase, and vice versa.

The environmental impacts associated with the conversion, enrichment and fuel fabrication stages are generally smaller in comparison to the other stages. The environmental impacts associated with the operation of the station are also of lesser significance.

The waste management stages include the construction and operation of the waste facilities, as well as the conditioning and packaging of the radioactive waste. The impacts of these stages are relatively small in most cases, although emissions of eutrophicating substances are more important.

The total lifecycle greenhouse gas emissions per kWh of electricity generated at Torness power station have been calculated to be 8.35 g CO_2e/kWh. This is a slightly larger value than the calculated carbon footprint for Torness that was presented in the last EPD update in 2009. The increase reflects changes in the supply chain, the inclusion of additional decommissioning impacts in the EPD, changes in assumptions of the volumes of waste and reprocessed spent fuel, as well as changes in the operational performance of the plant.

Radioactive substances are handled during the course of the normal operation of the facilities in the nuclear fuel cycle. These substances emit ionizing radiation that may result in doses to the people working at the facility and to people outside the facility. The occupational dose at Torness during the reference period was within the respective national regulatory limits.

[1] 1 kWh net means that electricity used within the power plant is subtracted from the amount of kWh generated in that plant.

Contents

1 Introduction

1.1 The declared product

This document constitutes the Environmental Product Declaration (EPD) of electricity from the Torness nuclear power station. Torness is operated by EDF Energy, which is owned by EDF Group. This is an update to the original Torness EPD that was prepared in 2005 and updated in 2009. The EPD has been prepared by Ricardo-AEA on behalf of EDF Energy.

The declared product is 1 kWh net[2] of electricity generated at Torness nuclear power station and thereafter distributed to the customer during a reference period of 24 months during 2011 and 2012[3].

The nuclear power plant at Torness is a base-load plant of the UK electricity system running at maximum power output throughout the year. The station is operated round the clock, except for a few weeks every 3 years that are set aside for refuelling and maintenance.

1.2 The environmental product declaration and the international EPD system

The primary purpose of the international EPD® system is to support companies in the assessment and publication of the environmental performance of their products and services. EPD® is a system for the international application of Type III environmental declarations conforming to ISO 14025 standards. The international EPD® system and its applications are described in the general programme instructions.

The principal documents for the EPD® system are in order of hierarchical importance:

- Product Category Rules (PCR), UN CPC 171 & 173 (Product Category Rules for preparing an Environmental Product Declaration for Electricity, Steam, and Hot and Cold Water Generation and Distribution), Version 2.02
- General Programme Instructions for Environmental Product Declarations, EPD®, Version 2.01.
- 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 LCA. Additional environmental information is presented in accordance with the PCR:

- information on land use
- information on biodiversity
- information on radiation during normal operation of the main facilities involved in the electricity production chain
- information on safety and risk-related issues
- information on electromagnetic fields
- information on noise.

[2] 1 kWh net means that electricity used within the power plant is subtracted from the amount of kWh generated in that plant.
[3] This period was chosen to capture the complete impacts from the AGR fuel cycle.

1.3 EDF Energy, LCA and EPD

EDF Energy's mission is focused on putting sustainable and responsible business at the heart of what the company does.

Our mission: "Driving progress for people-a successful and responsible long-term energy business, trusted by customers and powering a thriving society and a healthy environment".

This makes sustainable and responsible business core to the way we act today and how we plan for the future.

To deliver our mission, we have established six company ambitions. These 'Better Energy' Ambitions build on our progress so far to embed the themes of sustainability in our business operations, planning and behaviours. Three of our Ambitions are particularly relevant to Torness:

- **to achieve Zero Harm to people**
- **to power society without costing the Earth**
- **to deliver safe, secure and responsible nuclear electricity**
- to be the best and most trusted for customers
- to achieve strong financial and ethical performance
- to empower our people to be a force for good.

For more information about our sustainability programme please visit our website: http://www.edfenergy.com/sustainability/.

2 Manufacturer and product

2.1 EDF Energy

EDF Energy is the UKs largest generator of low carbon electricity.

EDF Energy owns and operates eight nuclear power stations in the UK with a combined capacity of almost 9 Gigawatts (GW). One is a pressurised water reactor (PWR) and seven stations have twin Advanced Gas-Cooled Reactors (AGR). See Table 2.1 for more details.

The focus of this EPD is the Torness (AGR) power station.

Table 2.1 EDF Energy's eight nuclear power stations in the UK

Station	Reactor type	NET capacity in Megawatts (MW)[4]
Hunterston B	2 AGRs	890
Hinkley Point B	2 AGRs	880
Hartlepool	2 AGRs	1,180
Heysham 1	2 AGRs	1,155
Dungeness B	2 AGRs	1,040
Heysham 2	2 AGRs	1,220
Torness	2 AGRs	1,185
Sizewell B	1 PWR	1,198

Notes Capacities are stated net of all power consumed for the stations' own use, including any power imported from the National electricity grid.

EDF Energy also operates gas and coal-fired power plants within the UK, three in total.

2.1.1 Environmental management system

EDF Energy implements an environmental management system at the Torness site, certified and registered according to ISO 14001. The environmental management system is an integral part of Torness' management system, which comprises the whole organisation, planning, accountability, routines, and processes. The objective of the environmental management system is to ensure compliance with, and maintenance of, EDF Energy's environmental policy, and addresses radiological as well as conventional environmental issues.

The Technical and Safety Support is responsible for the full implementation of external environment, electrical safety, workplace conditions, and radiological policies as well as for ensuring adherence to laws and regulations. The division is also responsible for reporting to the authorities and for information in these areas.

[4] The capacities quoted reflect expectations for the reference energy generation from the units from 1 January 2013.

2.2 Product system description

2.2.1 Torness nuclear power station

Torness nuclear power station is located on the East Lothian coast of Scotland, 35 miles from Edinburgh. The station comprises two AGRs, which are practically identical. The key characteristics of the power station are summarised in the Table 2.2, below.

The station started generation on the 25 May 1988 and has been designed to have an operational life of 35 years[5].

In combination, EDF Energy's Torness and Hunterston B power stations are currently responsible for generating over 30% of Scottish electricity output. During the reference period Torness delivered an annual average of 8,798 GWh[6] of electricity to the grid.

Table 2.2 Characteristics of the power station

Characteristic	Assumption
Reactor design	Advanced Gas-Cooled Reactors (AGR)
No. of reactors	2
Fuel	Enriched uranium oxide fuel (enrichment level 3.30% in 2011 and 3.25% in 2012)
Date commissioned	1988
Technical service life	35 years
Fuel cycle	Designed to operate at full power for a "fuel cycle" of three years per reactor (including a few weeks for refuelling outage)
Location	Near Dunbar, East Lothian, on the east coast of Scotland
Transmission	Electricity is transmitted at 400 kV, and subsequently distributed to the majority of customers through lower voltage, and through more localised networks (from 132kV to 230V)

2.3 Nuclear fuel cycle of Torness in the reference period (2011 and 2012)

The nuclear fuel cycle describes the various stages and activities that are involved, on a life-cycle basis, in the production of electricity from uranium. As shown in Figure 2.1, the generic nuclear fuel cycle consists of a series of steps including the extraction of the uranium ore, fuel production, the use of fuel in the nuclear power station and disposal of radioactive waste and spent fuel. All of these stages should be captured in the LCA.

In practice, the nuclear fuel cycle for a specific generation facility may be more complex, and reflect a more diverse range of supplies from multiple locations. It may also include both virgin uranium from ore and uranium recycled from other uses. In the current analysis all uranium fuel used at Torness is assumed to originate from virgin uranium ore. When considering the management of spent fuel, it is assumed that a certain proportion of the historical spent fuel arising at Torness will be reprocessed, and could potentially be recycled and reused.

During the reference period, the fuel supplied to Torness nuclear power station was manufactured by Westinghouse at Springfields in the UK. For the other stages in the fuel cycle uranic materials were procured centrally by EDF Energy Group, from a variety of different suppliers, and it is not possible to specify the individual facilities that supplied to Torness during this period.

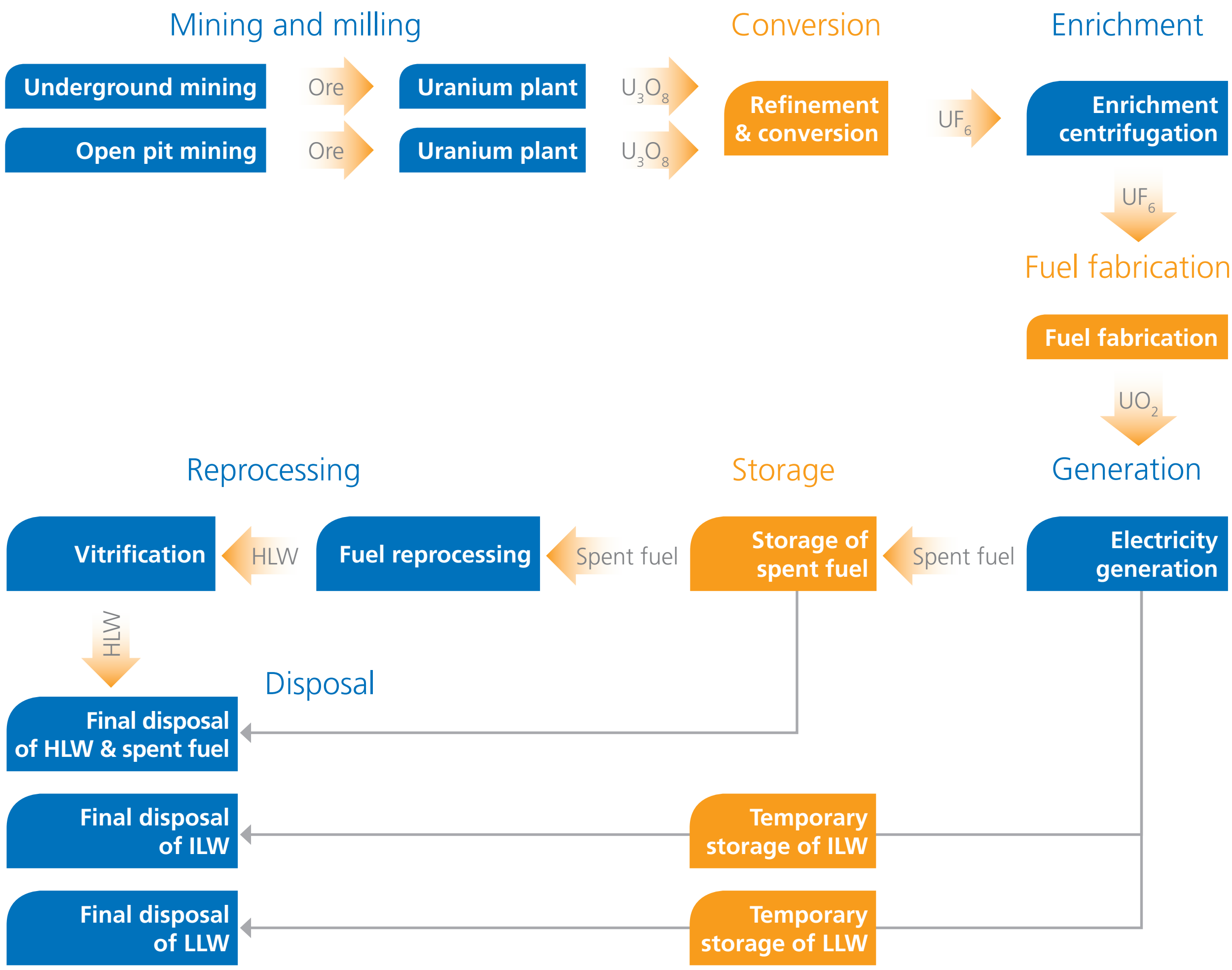
Therefore, as the basis for the Torness EPD, the suppliers for the mining and milling of the virgin ore, its conversion, refinement and enrichment are based on the facilities of suppliers to the EDF Group during the reference period[7]. The supply chain is therefore representative of EDF Energy's wider portfolio of suppliers.

[5] One of EDF Energy's business imperatives is to focus on extending the life of its nuclear reactors. This will only be carried out when it is technically, economically and safe to do so.

[6] The electricity delivered to the grid in 2011 was 9,000 GWh and 2012 it was 8,596 GWh.

[7] 2012 Reference Document Annual Financial Report. EDF Group.

Figure 2.1 The nuclear fuel cycle



Key:
Ore = Uranium ore
UF_6 = Uranium hexafluoride
HLW = High level waste
U_3O_8 = Uranium oxide concentrate (Triuranium octoxide) – also known as 'yellowcake'
UO_2 = Uranium dioxide – which form the reactor pellets in the fuel rods
ILW = Intermediate level waste

The different stages in the fuel cycle can be categorised into three basic modules, in accordance with the Product Category Rules. These are.

- **Core module** – this includes processes and infrastructure associated with the nuclear power station and radioactive waste disposal facility.
- **Upstream module** – this captured the activities in the fuel cycle prior to the electricity generation stage.
- **Downstream module** – this includes processes and infrastructure associated with the transmission and distribution of the electricity generated at the power station.

2.3.1 Core module

The core module of the EPD deals with the operation element of Torness. It includes the construction, reinvestment and decommissioning of the station, plus other relevant facilities on site at Torness.

The core module also includes the construction and operation of facilities for the interim storage of spent fuel (SF) and intermediate level waste (ILW), the temporary storage of low-level nuclear waste (LLW), and the final storage and treatment of SF, high level waste (HLW), ILW and LLW in purpose built repositories.

The site and specific packaging arrangements for final disposal of SF within the UK are not yet determined. Therefore, an assessment of the impacts of the final disposal of SF has been based upon a reference scenario developed by Nirex (now the Nuclear Decommissioning Authority (NDA); the reference concept for the deep geological disposal of UK high level waste and spent fuel.

For ILW, the Scottish Government Higher Activity Waste Policy requires that Higher Activity Waste (generally ILW) at Torness will be subject to "near site near surface storage". However, exactly what type of storage this will entail is currently uncertain. Therefore, in preparing the EPD, Nirex's phased geological repository disposal concept for the final storage ILW and certain types of LLW has been used to assess the impacts associated with final storage of ILW. This concept is generic and could be applied to a wide range of sites in the UK. It also represents the best available evidence for assessing the impacts from ILW management in the UK.

The analysis of the storage requirements for the final repositories is based on 2013 radioactive waste inventory, which includes the waste produced by the proposed nuclear new build fleet. The storage requirements for ILW take into account EDF Energy's latest expectation on the waste volumes associated with Torness.

The volumes of SF sent for storage have been estimated based upon the relative contribution of Torness to the total SF arising from the whole AGR fleet. A similar estimate has also been made of the HLW arising from the reprocessing of historical stocks of spent fuel from Torness. The reprocessing of the spent fuel is assumed to have taken place at the Thermal Oxide Reprocessing Plant (Thorp) at Sellafield. The HLW arising from reprocessing the fuel is assumed to be stored in the same repository as the spent fuel.

LLW is either stored temporarily on site before being disposed of in the LLW repository near Drigg in Cumbria, sent for incineration at the Fawley incinerator in Hampshire or sent for further processing/recycling e.g. at the metallic recycling facility operated by Studsvik UK in Cumbria.

The facilities that are involved in the core processes are presented in Table 2.3 below.

Table 2.3 Facilities involved in the core processes

Facility, location	Operation
Torness nuclear power station, UK	Electricity generation
Storage, Torness, UK	Interim storage of ILW
Near site near surface storage, location in the Scotland as yet undetermined	ILW disposal
Incineration of LLW, Fawley incinerator, UK	LLW disposal (incineration)
Metallic recycling facility, Cumbria, UK	Metal recycling
Encapsulation facility, location in the UK as yet undetermined	Encapsulation of spent fuel
Spent fuel reprocessing, Sellafield, UK	Thermal Oxide Reprocessing Plant
Deep geological repository for HLW and spent fuel, location in the UK as yet undetermined	Storage of nuclear waste

2.3.2 Upstream module

The upstream module includes the sites and facilities involved in the production and transportation of fuel and auxiliary substances that are inputs to the electricity generation process.

The manufacturing of the uranium oxide (UO_2) fuel comprises the uranium mining and refining, the conversion to uranium hexafluoride (UF_6), and the enrichment and the fabrication of the fuel assembly. The uranium originates from various sources and as the UO_2 fuel elements are loaded in the reactor intermittently, the origin of the uranium used in the fuel elements varies from year to year.

As described below, the upstream module is based upon representative suppliers to EDF Group for the reference period. The mining stage is based upon two extraction processes (open and underground mining), and two separate suppliers are assumed for the enrichment stage. For all other stages in the fuel cycle a single process site has been selected.

The reference facilities are presented in Table 2.4 below.

Table 2.4 Fuel cycle stages and facilities captured within the EPD for Torness

Fuel cycle stage	Process	Facility, Location	Company
Mining and milling	Underground mine and milling	Olympic Dam, Australia	BHP Billiton
	Open pit mine and milling	Ranger Mine, Australia	ERA (Rio Tinto)
Refinement and conversion	Uranium refinery and conversion facility	COMURHEX Malvési, France	AREVA NP
		COMURHEX Pierrelatte, France	
Enrichment	Gas centrifugation	Capenhurst, UK	URENCOLtd
	Gas centrifugation	Russia	Tenex
Fuel Fabrication	Fabrication facility	Springfields, UK	Westinghouse

For each stage in the fuel cycle the uranium quantities from each process have been calculated according to Torness's requirements for generation, in accordance with the operational data for the reference period. Assumptions regarding transportation of uranium are based on transportation routes for the fuel cycle facilities in the reference fuel cycle. The data used for the stages, mining and milling, refinement and conversion, enrichment, and fuel fabrication is based on data provided by the supplier and environmental reports for the respective facilities. In the absence of complete raw data sets, generic data from the Ecoinvent[8] database has been used.

[8] The international Ecoinvent database is currently the world leading life cycle inventory data source with more than 2,500 users in more than 40 countries. The LCI datasets are based on industrial data and have been compiled by internationally renowned research institutes and LCA consultants.

2.3.2.1 Mining and milling phase

The upstream module could include both virgin uranium from ore and uranium recycled from other uses. The current analysis assumes that all of the uranium used in the fuel originated from virgin sources. It therefore, includes the impacts associated with the mining and milling of the ore, and the subsequent processing. These impacts would not have been captured to the same extent if the fuel was assumed to have used reprocessed uranium.

Uranium oxide (U_2O_8), the product of uranium mining and milling activities, can be supplied from a range of global sources. The largest supplier of uranium oxide globally is Kazakhstan, followed by Canada and Australia[9]. In the current analysis, two sites were selected to illustrate the environmental impacts from uranium mining. These were the Olympic Dam mine and the Ranger mine. Both mines are located in Australia.

These facilities were chosen for three reasons. Firstly, independently audited environmental data was available for both mines. Secondly, both mines have a relatively low uranium concentration in the ore (0.05% for Olympic Dam and 0.17% for Ranger), which means that the resources used in the extraction process, per kg of uranium oxide, is likely to be greater than from mines with a higher ore concentration. On this basis, the sites are less likely to underestimate the impacts from this stage in the fuel cycle. Finally, the sites represent different types of mine. Olympic Dam is an underground mine, with uranium extracted as co-product with other minerals. In contrast, Ranger is an open pit mine.

The choice of facilities is therefore considered to provide a good representation of the environmental impacts from this stage in the fuel cycle. The only potential limitation is that the selection does not capture a third mining method, in-situ leach (ISL, or ISR) mining. ISL has been steadily increasing in the share of the total world uranium oxide production. However, no data was available for representative facilities for this mining method, so it could not be included in the analysis.

2.3.2.2 Refinement and conversion phase

EDF Group's 2012 Reference Document states that a significant part of the Group's refinement and conversion needs were covered by the COMURHEX plant owned by AREVA. Therefore, the COMURHEX facilities at Malvési and Pierrelatte were used as the reference facilities for the Torness EPD.

At the Malvési site the milled uranium oxide is purified to a very high level and converted into uranium tetrafluoride (UF_4). It is then transformed into uranium hexafluoride (UF_6) at the Pierrelatte plant.

Primary environmental data on the activities that take place at each of these sites was available from two environmental reports published by AREVA in 2012[10]. This was supplemented with generic data from the Ecoinvent database for certain environmental impacts that were not reported directly.

9 World Nuclear Association, Uranium production figures, 2002-2012.

10 Rapport d'information sur la sûreté nucléaire et la radioprotection de l'INB ECRIN Édition 2012 and Données chiffrées et informations sur la sûreté nucléaire et la radioprotection du site AREVA Tricastin Édition 2012.

2.3.2.3 Enrichment phase

EDF Group's 2012 Reference Document states that a significant proportion of its enrichment needs were met by URENCO and TENEX. Therefore, it was assumed that half of the enrichment needs for Torness during the reference period were provided by URENCO (based on URENCO Capenhurst site using the data for 2008) and the other half by TENEX (using Ecoinvent data)[11].

There are two enrichment process types in large-scale commercial use; gaseous diffusion and gas centrifuge. Gaseous diffusion consumes about 40 times more energy than the gas centrifuge method. Both TENEX and URENCO use gas centrifugation enrichment technology[12]; the more energy efficient technology.

The materials balance for the enrichment stage is more complicated than some of the other stages in the fuel cycle, as the resource requirements will vary according to the required U-235 concentration of enriched uranium. This is defined in terms of the separative work (i.e. the amount of effort required for enriching uranium), and reflects the required concentration of enriched uranium, the initial U-235 concentration of uranium being enriched, and the uranium concentration of the tails. For the purposes of the Torness analysis, the environmental impacts have been normalised per seperative work unit, and applied to the estimated separative work required to meet the enrichment needs of Torness[13].

2.3.2.4 Fabrication phase

The final stage of the fuel preparation is fabrication. The fuel supplied to Torness in the reference period was fabricated at Springfields, in the UK, by Westinghouse. Primary data was provided by Westinghouse for use in the Torness EPD. This provided an allocation of the total environmental impacts on the Springfields site that relate to the production of fuel used at Torness.

2.3.3 Downstream module: electricity distribution within the UK network

The downstream module is concerned with the distribution of the product to the customer. It is not possible to determine exactly where electricity generated at Torness is ultimately used. This is because the power station is attached to the high voltage grid system in Scotland, which in turn is linked to England via two interconnectors and separately to Northern Ireland. The electricity could therefore be supplied to a wide range of end users.

The downstream module comprises the distribution chain, i.e. all processes from delivery to the grid to its receipt by the customer. The grid is made up of transmission and distribution systems consisting of numerous lines, cables, transformers, and switchyards. Losses associated with the use phase of electricity relate to both the transmission and distribution of electricity.

Data on the downstream impacts of the electricity distribution network was drawn from the Ecoinvent database. This is based on Swiss data for the construction and use of a high voltage, medium voltage and low voltage electricity transmission and distribution network.

The Digest of UK Energy Statistics reports 28.9 TWh of losses across the UK network in 2012. Approximately 6.8 TWh (1.9% of electricity available) were lost from the high voltage transmission system of the National Grid and 21.1 TWh (5.8%) between the grid supply points (the gateways to the public supply system's distribution network) and customers' meters. 1 TWh (0.3%) is lost by theft and meter fraud[14].

[11] Research was carried out to see if primary data could be located; however, there was none available.

[12] http://www.tenex.ru/wps/wcm/connect/tenex/site.eng/activities/enriched-uranium/ and http://www.urenco.com/page/22/Enrichment-process.aspx.

[13] At Torness the uranium dioxide fuel is enriched to 3.30% in 2011 and 3.25% in 2012 (natural uranium is 0.7% U-235).

[14] Digest of United Kingdom Energy Statistics 2013.

2.3.4 Uncertainties

The overall environmental impacts associated with a given stage in the nuclear fuel cycle are relatively well established. Data is available for a number of facilities, which allows the validation of results from individual sites. Therefore, while the impacts will vary from one site to the next, and also potentially over time, the overall magnitude of the impacts can be assessed with reasonable confidence.

For certain stages in the fuel cycle detailed environmental data was available for use in the calculations. This was the case for the operation of the Torness plant and the fuel fabrication stage at Springfields. For other stages in the fuel cycle, including the impacts associated with mining and milling, and the refinement and conversion stage, the analysis was based upon published and independently audited environmental reports. However, for some stages in the fuel cycle primary data was unavailable, or only partially available. Therefore, estimates of the environmental impacts drew upon data from the Ecoinvent database.

This was the case for the environmental impacts from enrichment at the TENEX site, the reprocessing of spent fuel at Sellafield and for the construction of the radioactive waste repositories and incineration plant. The Ecoinvent database was also used for supplementary information on certain environmental impacts in relation to: mining and milling, conversion and enrichment, where information was limited in the primary dataset. In general, the use of generic data is not considered as preferable to primary data. However, this does not necessarily mean that the use of such data increases the uncertainty of the overall environmental impacts. Indeed the use of this data is important for reducing the uncertainty in the overall analysis of total impacts.

For other process stages, namely the construction and decommission of the power station and the construction and operation of the final repositories, uncertainties relate to activities that were carried out in the past (in the case of the construction of Torness) or are planned to occur in the future. The analysis presented is based on the best estimate of the impacts from these stages, focussing on the most significant issues. However, there are still large inherent uncertainties with these estimates.

3 Life cycle assessment methodology

The life cycle assessment (LCA) methodology was applied according to the ISO 14025 standard to quantify the environmental impact of the electricity generation at Torness and its subsequent distribution. LCA is a clearly structured framework based on international standards that facilitates the quantification and assessment of emissions to the environment and resource use along the entire electricity production chain.

There are generally two approaches that can be applied in the application of an LCA. The first method is process chain analysis (PCA). PCA is a bottom up approach that requires the collection of data on the main production processes, or steps in the life cycle, which are then aggregated up in order to assess the impacts of the product as a whole. The second approach is input-output analysis (IOA) which uses data that is already aggregated at a sectoral or sub-sectoral level and then uses expenditure data in order to estimate direct and indirect environmental impacts from different sectors.

The PCA method allows for a very detailed analysis, but may suffer from truncation (i.e. incompleteness resulting from the omission of environmental loads associated with certain upstream processes). In contrast, the use of IOA allows a more complete analysis to be undertaken. However, its reliance on sector average emissions introduces uncertainties, particularly where the variation in environmental performance within a given sector is large.

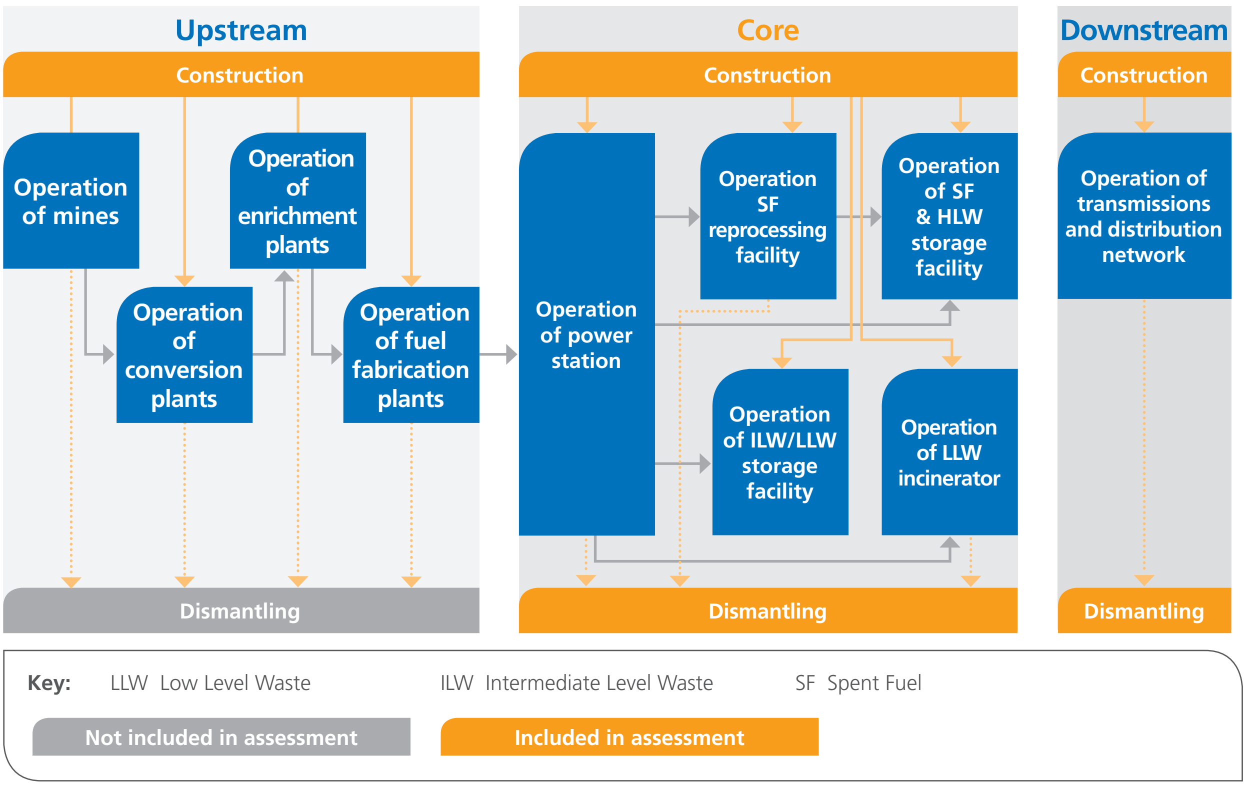
The approach used in the current study is a PCA approach. The analysis has drawn upon site specific data and Ecoinvent data in order to reflect the impacts associated with specific facilities in the fuel cycle.

3.1 System boundary

The LCA captures the full nuclear fuel cycle and associated processes ‘from cradle to grave’. The reference period is 24 months during 2011 and 2012.

The system boundary for Torness has been defined in accordance with the specific Product Category Rules (PCR) for preparing an EPD for Electricity Generation and Distribution. The process stages included within the LCA are described in Figure 3.1 below. In accordance with the PCR, impacts have been captured for each of the upstream, core and downstream modules.

Figure 3.1 Process stages covered by the EPD



In accordance with the PCR, the specific process and infrastructure elements that have been included within the system boundary are described below.

Fuel cycle stage	Included elements
Core module: processes	• Energy conversion process of plant(s). • Maintenance (for example lubrication, but not reinvestment of components). • Reserve power and reserve heat including test operation. • Transportation of waste. • Handling/treatment/deposition of spent nuclear fuel and radioactive waste. • Handling/treatment/deposition of other operational waste. • Reprocessing of spent fuel.
Core module: infrastructure	• Reactor building and other infrastructure including digging, foundations, roads etc. within the site, and respective construction processes. • Reactor, machinery, cables, tubes and other equipment for the conversion process and reserve power. • Power plant transformer. • Connection to the power network. • Transportation of inputs and outputs. • Facilities for handling of radioactive waste (on site and elsewhere) and facilities on site for handling of waste, residues and wastewater. • Facilities for handling and/or reprocessing spent fuel. • Reinvestments of material and components during the estimated technical service life.
Upstream module: fuel production	• Extraction of natural energy resources e.g uranium mining. • Processing of fuel e.g. refinement and conversion. • Preparation of fuel e.g. fabrication. • Fuel storage process. • Transportation: extraction → refinery → conversion plant.
Upstream module: production of auxiliary inputs	• Extraction of natural resources for auxiliary inputs (fuels and electricity used by suppliers, materials, chemicals). • Production of fuels and electricity used by suppliers producing auxiliary inputs. • Storage of auxiliary inputs at energy conversion site. • Transportation: extraction → processing → energy conversion plant.
Upstream module: upstream infrastructure	• Suppliers' factory buildings. • Suppliers' machines.
Downstream module: downstream processes	• Average transmission / distribution losses associated with the transmission and distribution of electricity to a consumer, defined with respect to connection voltage.
Downstream module: downstream infrastructure	• Infrastructure of the distribution system, construction, reinvestments and dismantling.

3.2 Core module

Comprehensive environmental data of the operation of Torness was taken from the environmental management system and other measurements.

The PCR requires that impacts associated with infrastructure are considered for all facilities involved in the core processes. This includes impacts associated with the construction and decommissioning of Torness.

Specific data on the material used in the construction of Torness were obtained from an engineering study[15]. For other construction related impacts e.g. energy use during plant commissioning, generic data from the Ecoinvent database was used. A service lifetime of 35 years was assumed for the station. Limited information was available on reinvestments of material and components, so this was omitted from the analysis. Assumptions relating to the decommissioning of the plant were based upon previous analysis of data for other nuclear power stations in the UK[16].

In addition to these processes, the manufacturing of the transport and storage casks for spent nuclear fuel, and the reprocessing of spent fuel, was based on data from the Ecoinvent database. Data on the deep repositories were taken from reports prepared by the NDA. Generic transport distances for the consumption of auxiliary materials were assumed as provided in the Ecoinvent database.

3.3 Upstream module

Analysis of the upstream processes is based on specific environmental data available for the facilities involved in the uranium mining, conversion, enrichment and fuel assembly. The data were obtained from environmental reports, data supplied directly by suppliers to EDF Energy or from the Ecoinvent database.

Generic transport distances for the consumption of auxiliary materials were assumed as provided in the Ecoinvent database. Construction of the upstream processes plants is included, which is in accordance with the PCR.

Table 3.1 below describes the assumed supply distribution between facilities for the representative fuel supply chain for Torness. This represents the assumed proportion of Torness's requirements, during the reference period, that is assumed will be met by each facility in the fuel cycle.

Table 3.1 Facility locations and their relative proportion in Torness's fuel cycle

Fuel cycle stage	Facility, Location	Proportion of Torness requirement
Mining and milling	Ranger Mine, Australia	50%
	Olympic Dam, Australia	50%
Refinement and Conversion	Malvési, France	100%
	Pierrelatte, France	
Enrichment	Capenhurst , UK	50%
	Tenex, Russia	50%
Fuel Fabrication	Springfields, UK	100%

15 PJ Kershaw, DC Weatherseed & J Pollin (1985) Torness Nuclear power station: civil engineering construction. ICE Proceedings. 78 (5), 1139 –116.

16 Wallbridge, S Banford, A Azapagic, A. (2013). Life cycle environmental impacts of decommissioning Magnox nuclear power plants in the UK. The International Journal of Life Cycle Assessment. 18 (3), 990 – 1008.

3.4 Downstream processes

Analysis of downstream processes associated with the operation of the UK electricity transmission and distribution network was based upon records within the Ecoinvent database. This included impacts associated with the construction of the network, as well as losses during the electricity transmission and distribution.

3.5 Allocation rules

When products other than uranium are involved in the process, allocations have been made, where possible, on a process basis i.e. the inclusion of the inputs and outputs that relate to the activities on site that are involved in the uranium cycle, and the exclusion of non-uranium process impacts. Where this data is not available, the PCR recommends that emissions are split according to the value (economic characteristics) of the products produced.

The following technology specific allocations have been made, in accordance with the PCR.

- Allocation of treatment/handling of spent fuel and residues follows the 'polluter pays' allocation method. This means that the generator of the waste has to carry the full environmental impact until the point in the product´s life cycle where the waste is transported to a waste disposal site (i.e. final repository).
- At the Olympic Dam mine, products other than uranium are involved in the process. Therefore, the environmental impacts have been allocated on an economic basis i.e. on the basis of the market value of the different products during the reference year.
- At the Springfields fuel fabrication facility an allocation was made on a process basis, where environmental impacts at a process level were allocated to the different products.

3.6 Boundaries towards risk assessment

Environmental impacts due to accidents and undesired events are not part of the LCA, but part of the environmental risk assessment. However, environmental burdens occurring more than once in three years are considered normal operations, and were included in the LCA.

Torness suffered significant losses of generation in 2011 due to marine ingress at the cooling water intake (largely in the form of seaweed and jelly fish) and also due to storm surges at sea, leading to heavy impacts on the intake's filter drumscreens. In response a series of workshops were held in November 2011 and April 2012 to identify and initiate mitigating activities. Work undertaken has included: improvements to the drumscreen wash water system; installation of autoventing on RSW pumps; installation of new radar level instruments; and improvements to functional instrumentation[17].

[17] N.B. Since mid-2013, EDF Energy has instigated workstreams in 3 areas: 'Prediction & Reaction' – e.g. the use of Met Office software programmes to improve weather prediction; 'Resilience' – e.g. installation of radar instruments, CCTV cameras and material condition improvements; and 'Protection' – e.g. the appointment of a Programme Manager and the development of a hydrodynamic model."

3.7 Omitted or incomplete processes

Due to data limitations it has not been possible to capture all processes fully. The following processes have not been captured fully within the current analysis.

- Impacts associated with the construction of the plant were based upon engineering data in relation to the main construction materials. The list of construction materials was incomplete, so may omit certain impacts associated with construction stage. Data was also unavailable on the resource use during the construction process and during the plant commissioning. To address this gap, generic data from the Ecoinvent database has been used.
- Impacts associated with reinvestments of material and components were omitted due to lack of data. These impacts are expected to be small in comparison to the overall construction of the plant.
- Impacts associated with the transmission and distribution of electricity is based upon generic data from the Ecoinvent database. It is unclear to what extent these estimates may reflect the UK grid. However, since these impacts are dominated by impacts associated with the infrastructure, the importance of these emissions may be less significant.
- For certain product impacts e.g. certain chemicals, it has not been possible to collect reliable life cycle data. This may lead to an underestimate in the total impacts, however, this is not thought to be significant for any of the sites. For other product impacts, the coverage has been extended from what was possible in the original EPD. This has meant that impacts associated with the use of sulphur and explosives during the mining and milling stage have been captured.
- For the enrichment stage of the fuel cycle, primary data on the environmental impacts associated with enrichment by Tenex were unavailable, so data from the Ecoinvent database were used. This data is similar to the site-specific data obtained from the URENCO enrichment operations, which provides some validation of the Ecoinvent data.

4 Ecoprofile of electricity generation

The assessment results are summarised[18] in Table 4.1 below. This shows the lifecycle inventory for Torness. It represents the impacts and wastes, across all of the fuel cycle facilities described for Torness. Results of the LCA are presented in the tables below and detailed in the sections that follow. Quantities are expressed per declared unit of 1 kWh generated electricity (net) at Torness during a reference period of an average taken from the 2011 and 2012 calendar period. In addition, the results are also expressed as 1 kWh electricity distributed to a customer connected to the electricity distribution network.

The ecoprofile consists of various types of LCA 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 of inventory results are CO_2 emissions or the consumption of fresh water.
- Life Cycle Impact Assessment (LCIA) results: in the impact assessment, inventory results that contribute to the same environmental impact (e.g. climate change due to increasing greenhouse gas concentrations in the atmosphere) are grouped and their importance in relation to a specific basic substance is characterized with a factor (e.g. global warming potential of greenhouse gases in relation to CO_2).
- Material flows: selected materials that are subject to waste treatment or recycling are presented in this category.

4.1 Use of resources

The most used resources associated with the production of 1 kWh of electricity at Torness are shown in Table 4.1 below.

Table 4.1 Resource use per kWh

Resource Use	Unit	per kWh net electricity Torness	per kWh net electricity at customer on GB Grid
Non-renewable material use			
Gravel	kg	8.60E-03	1.20E-02
Calcite	kg	1.27E-03	2.16E-03
Iron	kg	3.67E-04	1.44E-03
Clay	kg	8.07E-04	1.29E-03
Nickel	kg	4.06E-05	6.79E-05
Chromium	kg	1.66E-05	2.76E-05
Barite	kg	6.72E-06	9.44E-06
Aluminium	kg	7.51E-06	6.28E-05
Fluorspar	kg	3.54E-05	4.16E-05
Copper	kg	1.49E-05	4.61E-04
Magnesite	kg	5.98E-06	7.31E-06
Zinc	kg	5.25E-07	1.46E-06
Kaolinite	kg	2.83E-06	3.33E-06
Uranium	kg	2.82E-05	3.06E-05
Zirconium	kg	1.09E-10	1.46E-10

[18] Note. The table is not exhaustive and presents only the most significant results.

Resource Use	Unit	per kWh net electricity Torness	per kWh net electricity at customer on GB Grid
Renewable material resources			
Wood	m^3	1.98E-07	1.01E-06
Non-renewable fossil primary energy resources			
Coal	kg	1.96E-03	3.60E-03
Crude Oil	kg	1.18E-03	1.76E-03
Natural Gas	m^3	5.98E-04	9.82E-04
Non-renewable nuclear primary energy resources			
Uranium	kg	2.82E-05	3.06E-05
Renewable primary energy resources			
Energy, in biomass	MJ	2.07E-03	9.62E-03
Converted kinetic energy in wind power	MJ	3.24E-04	4.66E-04
Converted potential energy in hydropower	MJ	4.17E-03	9.53E-03
Converted solar energy	MJ	3.55E-06	5.54E-06
Water consumption			
Freshwater	m^3	9.82E-05	1.47E-04
Saltwater	m^3	3.46E-02	8.83E-02

4.1.1 Use of fossil resources

Fossil resources are used directly at the sites and facilities in the fuel supply chain, as well indirectly through the embedded energy in products and materials consumed. This includes, for example, energy used in the production of the materials needed for the construction of the plant.

Direct fossil fuel use includes heating and cooling at the fuel cycle facilities, as well as process related energy use (steam, heat). In the supply chain fossil fuel is used directly as an energy supply for processes (e.g. enrichment) or in the manufacturing of materials essential to the process (e.g. steel, chemicals, cement).

Energy is also used in the production of electricity, which is then consumed as part of the fuel cycle. It has not been possible to follow the consumption of electricity to the cradle (i.e. to calculate the resource use associated with all electricity consumed as part of the fuel cycle) for each of the individual sites in the fuel cycle. Instead, the resource use has been estimated using generic resource use estimates for each of the different generation technologies.

4.1.2 Use of other resources

Material resources are related to the manufacturing of building materials and materials for operation of the power station and the site for final disposal of the radioactive waste. This includes quantities of resources such as gravel for the construction of the nuclear power plant, and copper and iron ore, for use in the encapsulation of spent fuel.

4.2 Emissions of pollutants

The emissions of pollutants associated with the production of 1 kWh of electricity at Torness is shown in the Table 4.2 below.

Impact assessment allows the effects of the resource use and emissions generated to be grouped and quantified into a limited number of impact categories which may then be weighted for importance. Weighting factors must be applied to specific substances to yield the total environmental impact; in regard to greenhouse gases, ozone depletion, acidification, ground-level ozone, and eutrophication. For example, oxides of nitrogen (NO_x) values must be multiplied by 0.0217 before adding it to values of other acidifying substances, and by a factor 6 in regard to eutrophication (oxygen-consumption).

Table 4.2 Pollutant emissions per kWh

Pollutant Emissions	Unit	per kWh net electricity Torness	per kWh net electricity at customer on GB Grid
Airborne emissions – impact assessment results			
Greenhouse gases (100 years)	kg CO_2 eq	8.35E-03	1.99E-02
Ozone-depleting gases	kg CFC-11 eq	1.03E-09	1.35E-09
Acidifying substances	kg SO_2 eq	6.34E-05	1.71E-04
Airborne emissions contributing to given impact assessment results			
Ammonia	kg	8.88E-07	3.05E-06
Carbon dioxide, fossil	kg	7.69E-03	1.28E-02
Carbon monoxide	kg	2.53E-05	6.51E-05
Dinitrogen monoxide	kg	8.03E-07	6.76E-06
Methane, tetrachloro-, CFC10	kg	2.97E-10	3.32E-10
Methane, bromochlorodifluoro-, Halon 1211	kg	2.54E-11	3.69E-11
Methane, bromotrifluoro-, Halon 1301	kg	4.27E-11	5.99E-11
Methane, biogenic	kg	2.10E-07	2.82E-07
Methane, fossil	kg	1.55E-05	2.60E-05
Nitrogen dioxide (NO_2)	kg	6.54E-09	7.10E-09
Nitrogen oxides (NO_x)	kg	3.40E-05	5.74E-05
NMVOC, non-methane volatile organic compounds	kg	7.66E-06	1.26E-05
Sulphur dioxide	kg	3.75E-05	1.15E-04
Other relevant non-radioactive airborne emissions			
Carbon dioxide, biogenic	kg	1.55E-04	7.89E-04
Particles, < 10 µm	kg	3.14E-05	4.33E-05
Particles, < 2.5 µm	kg	2.42E-05	3.43E-05
Particles, > 10 µm	kg	6.07E-05	7.31E-05
Arsenic	kg	1.29E-07	2.51E-07
Cadmium	kg	5.09E-09	4.36E-08
Dioxins	kg	2.32E-18	2.52E-18
PAH, polycyclic aromatic hydrocarbons	kg	1.25E-09	6.10E-09

Pollutant Emissions	Unit	per kWh net electricity Torness	per kWh net electricity at customer on GB Grid
Radioactive airborne emissions			
Carbon-14	Bq	1.16E+02	1.26E+02
Krypton (all isotopes)	Bq	3.69E+01	4.01E+01
Radon (all isotopes)	Bq	9.13E+05	9.92E+05
Xenon (all isotopes)	Bq	1.06E+03	1.15E+03
Argon-41	Bq	1.07E+00	1.17E+00
Waterborne emissions – impact assessment results			
Eutrophying substances	kg PO_4--- eq	2.07E-05	1.33E-04
Waterborne emissions contributing to given impact assessment results			
Nitrate	kg	1.43E-05	2.38E-05
Phosphate	kg	1.28E-05	1.20E-04
COD, Chemical Oxygen Demand	kg	2.07E-05	4.17E-05
Ammonium	kg	3.07E-06	3.38E-06
Other relevant non-radioactive waterborne emissions			
Oils	kg	4.62E-06	6.47E-06
Radioactive waterborne emissions			
Strontium (all isotopes)	Bq	1.47E+00	1.63E+00
Cesium (all isotopes)	Bq	1.31E+01	1.42E+01
Other relevant non-radioactive emissions to soil			
Oils	kg	4.76E-06	6.68E-06

4.2.1 Greenhouse gas emissions

Emissions of CO_2 contribute over 92% of the Global Warming Potential (GWP) total for Torness. The total greenhouse gas emissions per kWh of generation for Torness have been calculated to be 8.35g CO_2e/kWh. CO_2 emissions are dominated by the construction and mining and milling phases, which are responsible for 31% and 22% of all CO_2 emissions respectively. Emissions from reprocessing of spent fuel are also important.

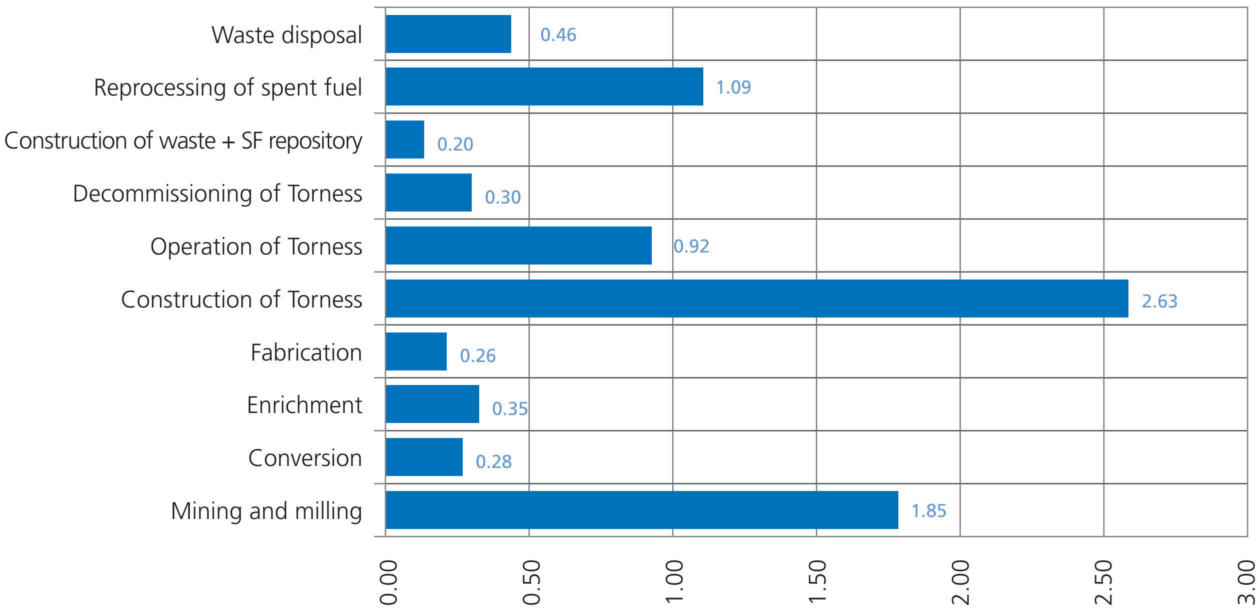
At the construction phase, 58% of CO_2 emissions are associated with electricity used during the commissioning of the plant. In the absence of specific data for Torness this is based upon data for a similar sized plant from the Ecoinvent database. This assumes that 5.31 x 108 kWh of grid electricity were used during of the commissioning of Torness. The greenhouse gas emissions associated with this electricity consumption have been estimated using data on the average UK electricity generation mix during the construction period (1980 – 1988), based upon data from the Digest of UK Energy Statistics. The remainder of the CO_2 emissions that are associated with the construction phase arise from the manufacture of steel and concrete, and to a lesser extent diesel consumption.

A range of processes associated with the mining and milling phase are also a source of greenhouse gas emissions. Some emissions arise from direct combustion of fossil fuels at the mine sites, including vehicle movements. Other emissions are associated with the production of materials used in the mining and milling process, including certain chemicals.

As part of the reprocessing of spent fuel, emissions of greenhouse gases are associated with: diesel and electricity consumed during operation; manufacture of chemicals used in the operation and the production of steel, cement and glass used in the conditioning of the HLW and ILW. The remainder of the CO_2 emissions that are associated with the reprocessing of spent fuel are attributed to the radioactive and non-radioactive solid waste streams and to a lesser extent to transportation of fuel, wastes and material.

The relative importance of the difference stages in the fuel cycle on the overall greenhouse gas emissions are shown in Figure 4.1 below.

Figure 4.1 Emissions of greenhouse gases to air (g CO_2e/kWh)[19]



4.2.2 Emissions of ozone-depleting substances

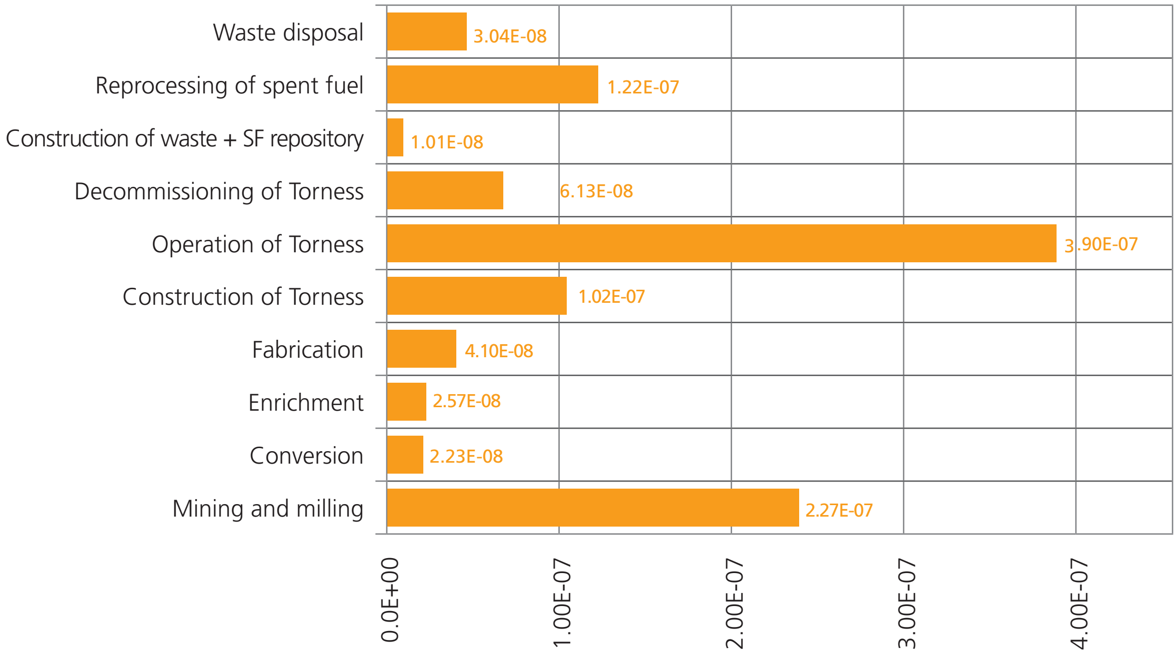
Ozone-depleting substances (ODS) are man-made substances that cause damage to the stratospheric ozone layer and have contributed to the ozone hole over the Antarctic. Halons, hydrochlorofluorocarbons (HCFCs) and chlorofluorocarbons (CFCs) are all types of ODS, the use of these ODS gases is being phased out at the station and across current and off-site activities.

The main substances contributing to ozone depletion are Halon 1301 (50%), CFC-10 (35%) and Halon 1211 (13%). These emissions arise across all process stages, but in particular during the operation of Torness, mining of the uranium and reprocessing of spent fuel.

Emissions of ozone depleting substances are dominated by releases further up the process chain. This includes emissions of Halon 1301 associated with the refinement of crude oil, and emissions of Halon 1211 and HCFC 22 associated with the transport of natural gas. Likewise, emissions of CFC-10 are associated with the production of sodium hypochlorite and anionic resin used in the operation of Torness, and hydrochloric acid that is used in processing of bentonite which is associated with reprocessing of spent fuel and waste disposal.

[19] Emissions from the commissioning of the plant are included in the construction stage.

Figure 4.2 Emissions ozone depleting substances (g CFC-11 equivalent/kWh)



Many of the graphs in this report and the summary use scientific shorthand – the letter 'E'. The number following E (exponent) represents the power to which the base should be raised.

When the exponent is positive, it is equal to the number of following zeros or decimal places. For example, 1.22+E03 is equivalent to 1.22 x 10^3 or 1220. When the exponent is negative, it indicates the number of decimal places to the left, for example 1.22E-03 is 0.001220.

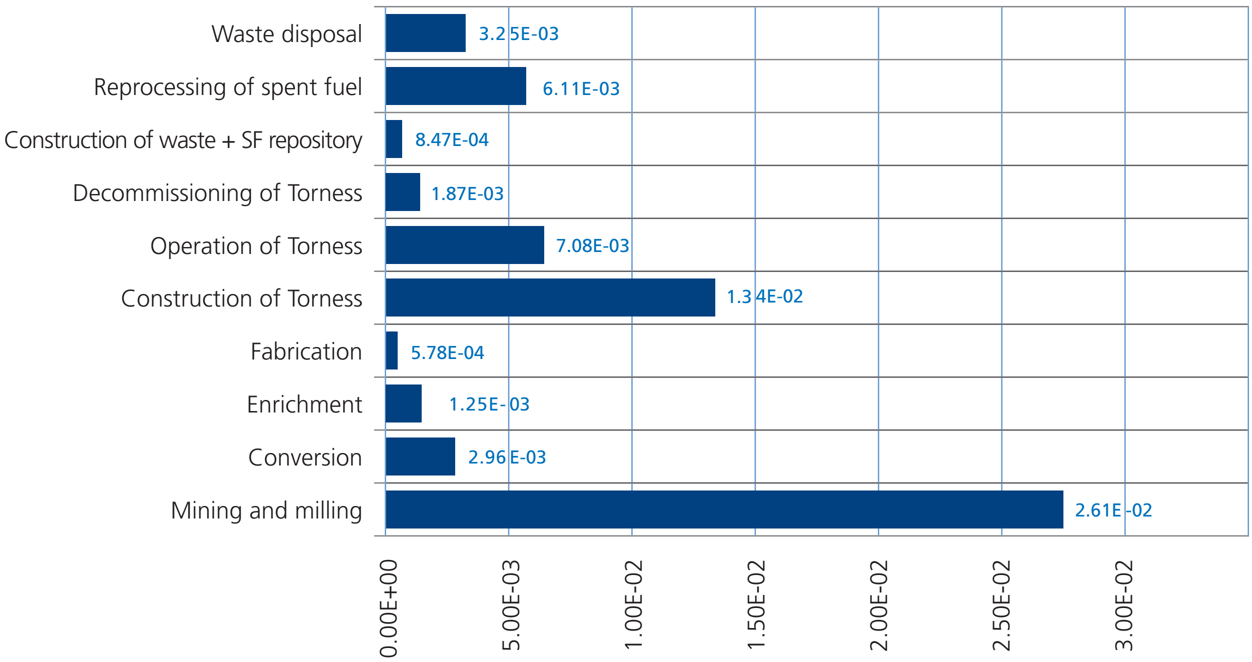
4.2.3 Emissions of acidifying gases

Sulphur dioxide (SO_2) and nitrogen oxides (NO_x) cause 71% and 27% of emissions of acidifying gases, respectively, with the remainder largely being made up of ammonia (NH_3). During the Torness fuel cycle, the mining and milling phase was the largest emitter of acidifying gases. This is again mainly associated with the emissions of SO_2 which are generated in the production of sulphuric acid, which is used as a leaching agent in the uranium milling process. A small amount of emissions of NO_x also arise from chemicals used to make the explosives for blasting.

Both the construction and operation phases are also important sources of acidifying gases. At the construction phase, over 70% of these emissions are associated with the combustion of fossil fuel to generate the electricity that is consumed during the commissioning of the plant.

In relation to the operation of Torness, 50% of emissions are associated with the consumption of diesel. The manufacture of sodium hypochlorite and sulphuric acid are also important.

Figure 4.3 Emissions of acidifying gases (g SO_2 eq/kWh)



4.2.4 Emissions of substances potentially contributing to oxygen consumption

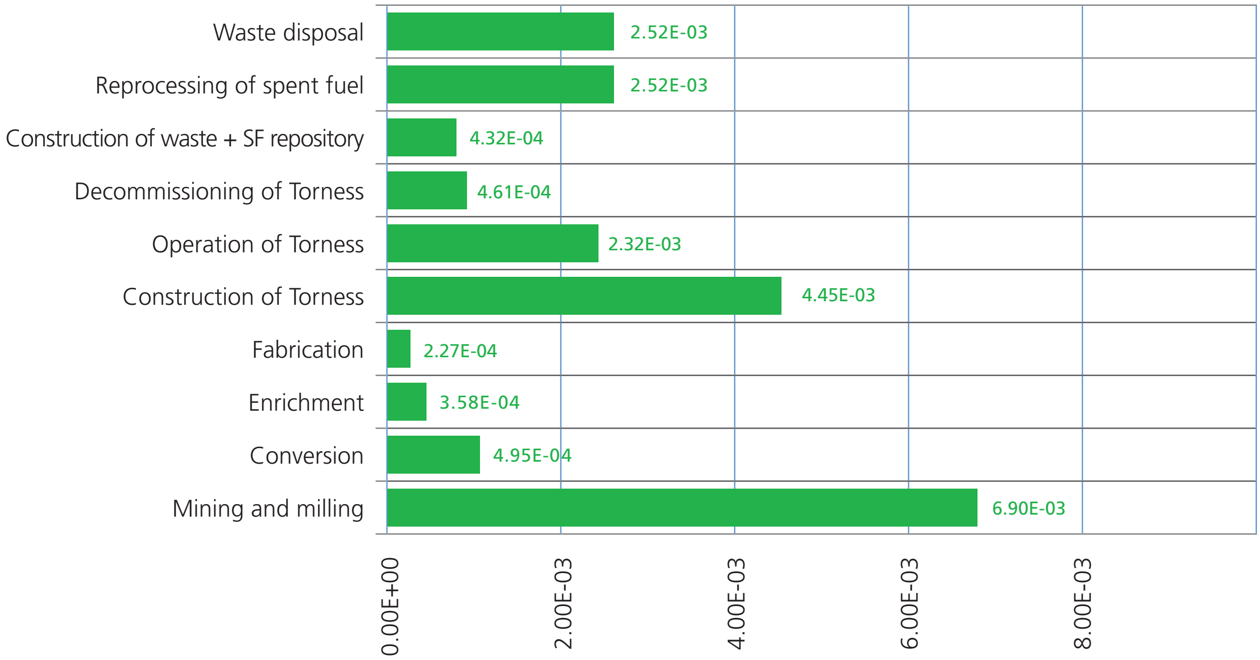
Eutrophication is the enrichment of water (lake or river) with nutrients, leading to the excessive growth of organisms and a lack of oxygen. The main eutrophying emissions relating to the production of electricity at Torness are phosphate released into water which contributes 62% of the total impacts. Releases of nitrogen oxides are also important and represent 21% of the total.

The mining and milling, and construction phases are once again the main contributors to the overall impacts.

Impacts on eutrophication at the mining and milling phase, are associated with the release of phosphate related to the disposal of the mine tailings which is responsible for 41% of the emissions. Waste disposal associated with other primary fuels consumed as part of the construction phase are also sources of phosphate. NO_x emissions, largely associated with blasting, are a smaller source of emissions from this phase.

Impacts at the construction phase are is associated with a variety of sub-processes including the combustion of fossil fuels during the production of electricity, copper and steel.

Figure 4.4 Eutrophicating substances (g PO_4- eq/kWh)



4.2.5 Emissions of toxic substances

The processes and stages involved in the fuel cycle combined, release a wide range of potentially toxic substances into the environment. However, at each individual point source the amounts of toxic substances are small. For instance minute emissions of arsenic, cadmium and lead are associated with the treatment and disposal for radioactive waste. This is associated with the refining of copper which is used to encapsulate spent fuel. Likewise, at the construction phase, minute emissions of mercury and poly aromatic hydrocarbons occur, mainly from the generation of electricity and manufacture of reinforced steel.

Emissions of particulate matter arise from the incomplete combustion of fossil fuels, and also from mining activities such as the mechanical disturbance of rock. The mining and milling phase is the largest contributor of emissions of particulate matter.

4.2.6 Dominance analysis

The results of the various life cycle stages, considering each of the pollutant emissions described above, are shown in Table 4.3 below.

Table 4.3 Relative contribution of each of the process phases to each of the impact categories

Impact category	Mining and Milling	Conversion	Enrichment	Fabrication	Construction of Torness	Operation of Torness	Decommissioning of Torness	Construction Repository	Reprocessing of Spent Fuel	Waste Disposal
Acidification	41.12%	4.67%	1.98%	0.91%	21.10%	11.17%	2.96%	1.34%	9.63%	5.12%
Eutrophication	33.35%	2.22%	1.73%	1.31%	21.51%	11.20%	2.23%	2.09%	12.17%	12.19%
Global warming (GWP100)	22.13%	3.40%	4.25%	3.14%	31.47%	11.07%	3.64%	2.39%	13.06%	5.47%
Ozone layer depletion (ODP)	22.02%	2.16%	2.49%	3.97%	9.91%	37.80%	5.95%	0.98%	11.78%	2.95%
Photochemical oxidation	37.12%	11.08%	2.01%	1.18%	21.28%	8.73%	2.02%	2.06%	9.90%	4.62%

The overall comparison of the life cycle phases shows that the environmental impacts associated with the mining and milling of the uranium fuel, the construction and the operation of the nuclear power station and the reprocessing of spent fuel dominate the results. These processes typically require large amounts of electricity or thermal energy, or use material that have an energy intensive production such as steel or copper.

Downstream impacts associated with the transmissions and distribution impacts have not been included in the analysis presented above. However, these impacts are important. In the table below a comparison is made of the relative contribution of the upstream (i.e. mining, conversion, enrichment), the core (construction, operation and decommission of the plant and waste repository) and the downstream (electricity transmissions and distribution) modules.

Table 4.4 Relative importance of the downstream module to the other environmental impacts

Impact category	Unit	Per kWh at consumer on UK Grid	Upstream	Core	Downstream
Abiotic depletion	kg Sb eq	9.38E-05	22%	40%	37%
Acidification	kg SO_2 eq	1.71E-04	18%	19%	63%
Eutrophication	kg PO_4--- eq	1.33E-04	6%	10%	84%
Global warming (GWP100)	kg CO_2 eq	1.99E-02	14%	28%	58%
Ozone layer depletion (ODP)	kg CFC-11 eq	1.35E-09	23%	53%	24%
Photochemical oxidation	kg C_2H_4 eq	7.76E-06	20%	19%	61%

The impact of the downstream stage relates to the construction and maintenance, as well as overall losses associated with the electricity transmission and distribution (c. 8%).There is a notable impact on global warming. This arises from the releases of sulphur hexafluoride associated with the transmission of the network. This has a global warming potential of 22,800 times that of CO_2. As described above, these emissions are based upon estimates within the Ecoinvent database.

4.3 Waste

Fuel-related radioactive waste originates from the operation of Torness, but also from some of the other fuel chain facilities. ILW and LLW is produced during the operation and decommissioning of the Torness site and spent fuel is produced as a by-product of electricity generation. It has been assumed that approximately half of the spent fuel arising over the lifetime of the plan will be reprocessed with the remainder in long-term storage prior to final disposal. Reprocessing of the spent fuel produces LLW and ILW, as well as some HLW.

Low level waste is either stored temporarily on site before being disposed of in the LLW repository near Drigg or sent for incineration at the Hythe Incinerator. In 2011 we started reprocessing and recycling metal waste at Studsvik (via Low Level Waste Repository Ltd). All intermediate level waste and spent fuel is stored on site before final disposal in the future and spent fuel is stored temporarily on-site before being transferred to Sellafield.

The amount of direct radioactive waste arising from the operation and decommissioning of Torness is summarised in Table 4.5 below. The values are expressed in terms of the volume of packaged waste for disposal.

Table 4.5 Waste and spent fuel production (total lifetime volumes)

Type of waste[20]	Quantity*	Units
Operational intermediate level waste (ILW)	775	m^3
Operational low level waste (LLW)	936**	m^3
Decommissioning ILW	4647	m^3
Decommissioning LLW	11388	m^3

Note: * Volumes above are packaged volumes sent for final disposal (i.e. after any processing / treatment) as quoted in the 2013 UK RWMI.

** This only accounts for waste on site at 01/04/13 and future arisings until the projected end of generation in 2023. It does not take account of any previous disposals.

Regarding non-radioactive waste, the main sources are the rock and mineral waste associated with the mining and milling activities, and the non-recyclable waste material from the construction and operation of Torness.

[20] HLW and SF quantities are not given here due to commercial sensitivities.

5 Additional environmental information

This section provides additional environmental information that is not part of the lifecycle analysis, but is considered an important environmental aspect of the production of electricity at Torness.

5.1 Radiation protection

The handling of radioactive substances in various forms is part of the daily operations of facilities in the nuclear fuel cycle. The emission of ionizing radiation from these substances may result in doses to the people working in the facility (dose to personnel) as well as to people outside the facility (dose to third party).

5.1.1 Protection of the operating personnel

In all of the fuel cycle facilities, regulations to protect working people are stipulated. A low level of radiation exposure, however, cannot be ruled out. In order to illustrate the radiation exposure, average individual doses are shown for each of the facilities in the table below.

For comparison, in the UK, annual statutory dose limits for exposure to ionising radiation arising from sources other than medical and natural background are set at levels which ensure that the risk of harm to any person receiving such doses is low. The current annual statutory dose limit for classified workers is 20 mSv. However, UK legislation requires doses to workers to be as low as reasonably practicable and EDF Energy operates a policy of minimising risks according to this principle. It also operates to a more restrictive Company Dose Restriction Level of 10 mSv.

Table 5.1 Average annual dose-to-personnel at the facilities in the nuclear fuel cycle during the reference period

Fuel cycle stage	Facility, Location	Average annual individual dose to personnel [mSv per year]
Mining and milling	Ranger Mine, Australia	1.20
	Olympic Dam, Australia	3.50
Refinement and Conversion	Malvési, France	0.50
	Pierrelatte, France	0.07
Enrichment	Capenhurst, UK URENCO Ltd	0.48
	Tenex	0.34
Fuel Fabrication	Springfields, UK	0.46
Generation	Torness, United Kingdom	0.023

5.1.2 Protection of third parties

The controlled release of radioactive substances to air and water within clearly regulated and safe limits is normal during operation of facilities in the nuclear fuel cycle. These emissions may impact in particular people living in the vicinity of the facilities (local effect).

5.1.2.1 Torness

Radiation doses to the public can arise from the controlled release of radioactive substances to air and water within clearly regulated and safe limits which are normal during operation of nuclear facilities. This results in a small dose to members of the public from consumption of local foods and exposure over intertidal sediments. Discharges from Torness are monitored and are subject to strict control as required by the Scottish Environment Protection Agency (SEPA) which issues permits specifying the maximum limits within which discharges should be kept. The annual discharge limits for Torness are shown in the following table, along with the actual discharge values.

Table 5.2 Discharge authorisation limits

Discharge release type	Annual limit (AL)	2011	2012
Gaseous releases	(MBq)	%age of AL	%age of AL
Tritium	11,000,000	24.4	14.1
Carbon-14	4,500,000	22.1	23.1
Iodine-131	2,000	0.16	0.16
Argon-41	75,000,000	6.7	5.4
Beta emitting radionuclides associated with particulate material	400	0.72	0.96
Sulphur-35	300,000	5.5	16.8
Liquid releases	(MBq)	%age of AL	%age of AL
Tritium	700,000,000	49.3	47.9
Sulphur-35	3,000,000	0.67	19.8
Cobalt-60	10,000	1.6	2.6
Alpha emitting radio-nuclides	500	1.1	0.9
Other radionuclides (non-alpha, excluding those already listed)	150,000	2.4	2.5

To determine the effect of these discharges on the general public SEPA carries out monitoring around the station. SEPA is required to ensure that the amount of radiation that an individual is exposed to from the authorised disposal of radioactive waste does not exceed 1 mSv per annum. SEPA's environmental monitoring programme allows a retrospective assessment to be undertaken to ensure that the conditions and discharge limits in an operator's licence continue to provide the required protection of the public[21].

In general, most of the activity entering the food chain is due to the effects of discharges at Sellafield (see below) weapons testing and Chernobyl fallout, and only a small fraction will be due to Torness.

Nonetheless, doses to the most exposed members of the public in the vicinity of Torness are summarised from the Centre for Environment, Fisheries and Aquaculture Science (Cefas) 2013 monitoring report[22] in Table 5.3. These should be compared with public dose limits of 1 mSv from artificial sources and typical natural exposures of 2.2 mSv.

[21] Baxter, J.M., Boyd, I.L., Cox, M., Donald, A.E., Malcolm, S.J., Miles, H., Miller, B., Moffat, C.F., (Editors), 2011. Scotland's Marine Atlas: Information for the national marine plan. Marine Scotland, Edinburgh. pp. 191 http://www.scotland.gov.uk/Publications/2011/03/16182005/35.

[22] Radioactivity in Food and the Environment, 2012 RIFE – 18.

Table 5.3 Exposure to local population in a 0.5 to 1km radius

	Exposure (mSv) to local adult inhabitants (0.5-1km)	Exposure (mSv) to seafood consumers	Exposure (mSv) to infant inhabitants and consumers of locally grown food
Fish and shellfish consumption	<0.005	<0.005	-
Other local food	<0.005		0.006
External radiation from intertidal areas or the shoreline	<0.005	<0.005	-
Gaseous plume related pathways	<0.005	-	<0.005
Direct radiation from site	0.020	-	-
Total	**0.020**	**<0.005**	**0.006**

5.2 Radiological safety and human health risks

Fuel production and power plant operation have the potential for very low frequency, but high consequence events. Accidents associated with the final waste repository would have relatively low consequences (compared with reactor faults).

5.2.1 Torness

5.2.1.1 Regulation

The activities at Torness are governed by various Acts of Parliament. Of particular importance is the Nuclear Installations Act 1965 (as amended), which requires a license to be granted to construct, operate and decommission a nuclear site. The site license places conditions on the licensee to ensure the safe management of the site. The site nuclear operations are regulated by the Office for Nuclear Regulation (ONR). In addition, environmental activities are regulated by the Scottish Environmental Protection Agency SEPA.

5.2.1.2 Nuclear safety

Design and operation of nuclear power plants incorporates protection against technical faults as well as hazards such as fire, flooding and earthquakes. These systems are intended to prevent the release of activity to the environment.

- Prevention – Safety was a key design criterion for the Torness plant. The credible fault scenarios have been identified and analysed, and plant operating, maintenance and testing procedures are in place to avoid the occurrence of these faults.
- Protection – The plant is designed with protection against all credible faults. This protection provides all essential safety functions necessary to prevent a release of activity to the environment. The essential safety functions are for trip, shutdown, post trip cooling and monitoring of the reactor. The protection systems are designed with redundancy, diversity and separation, in order to minimise the risk of failure of these functions.
- Mitigation – In the unlikely event that main protection systems fail to avoid a release of activity, there are arrangements to minimise the risk of exposure to the operator, public and environment. These include the instructions for the plant operator to carry out recovery actions and accident management, and also the provision of an emergency plan.

Torness has the following specific barriers against the release of radioactive emissions.

- The solid fuel itself provides containment. It is in the form of very stable and hard ceramic pellets that contain the fission products produced in the nuclear reaction.
- The fuel pellets are contained within a stainless steel cladding that is designed to be leak tight and resistant to damage by heat, corrosion and radiation.
- The steel-lined concrete pressure vessel provides overall containment of the reactor. Its walls are more than five and a half metres thick and are reinforced by thousands of steel cables – with a total length of more than 100 kilometres – woven through them. It also serves as a biological shield that reduces radiation emissions.

5.2.1.3 Nuclear safety risks at Torness

The risks due to operation at Torness are managed in such a way as to meet with the requirements of the UK Office for Nuclear Regulation guidelines on Tolerability of Risk from Nuclear Power Stations. These guidelines we derived by considering societal attitudes to risk from a variety of sources, such as large industrial plant including nuclear power station operation. They define three levels of risk, according to the likelihood of an event causing the death of one or more members of the public. The first is a frequency cut-off above which it is not permissible to operate (the upper tolerable level). Below this is a region termed the Tolerable if ALARP region, where the ALARP (As Low as Reasonably Practicable) principle requires the licensee to do everything practicable to minimise risks. Lastly is the acceptable level of risk, for which the risk is sufficiently low that no further actions to reduce it are necessary (the broadly acceptable level).

In order to satisfy these requirements EDF Energy has adopted frequency limits for events of various consequences, ranging from minor releases to a significant release of activity, such as may result from core melt. In order to show that these frequency targets are met, all credible reactor faults are identified and analysed. These faults include failure of the shutdown systems as well as faults with the primary and secondary coolants. A probabilistic risk assessment is used to calculate the actual risk in each category. In addition to this, deterministic rules are applied to ensure that for each fault the number of independent lines of protection is commensurate with the fault frequency.

5.2.2 Final repository

5.2.2.1 Nuclear safety

The analysis presented in this section is based upon research undertaken by the NDA and relates to its Phased Geological Repository concept for ILW/LLW[22] and its Reference HLW/SF concept. As mentioned above, for ILW, the Scottish Government Higher Activity Waste Policy requires that Higher Activity Waste (generally ILW) at Torness will be subject to “near site near surface storage”. However, exactly what type of storage this will entail is currently uncertain. Therefore, in preparing the EPD, Nirex’s phased geological repository disposal concept for the final storage ILW and certain types of LLW has been used to assess the impacts associated with final storage of ILW.

The reference case is generic, in the sense that it could represent a range of potentially suitable sites. It is not based on a specific real site, but nevertheless, it is intended that the reference case is reasonably realistic, in that the values of parameters of the system are physically reasonable. It is intended that the levels of uncertainty in the parameters should be realistic, in that they should be of the level that might be expected after a suitable site investigation programme.

The development of the final disposal concepts has been undertaken in accordance with NDA’s Generic Operational Safety Assessment procedures. Its scope includes examination of the on-site transport of the waste packages, transfer of the waste packages below ground, emplacement of the waste packages in the vaults and other general associated activities, such as maintenance or cleaning of equipment, or the operation of the ventilation system. To identify the faults or hazards that could be associated with these different activities NDA uses the HAZOP (Hazard and Operability) process.

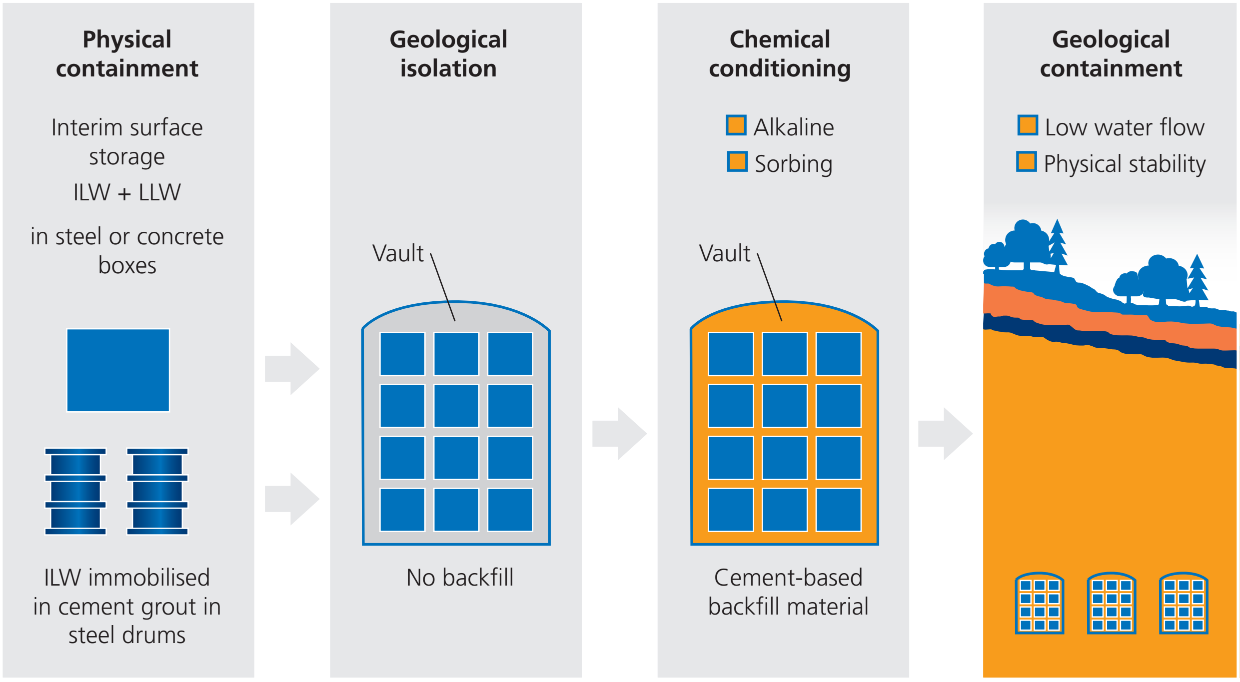
[22] Nirex. (2005). Nirex Inputs to Environmental Product Declaration for Torness Power Station. Available: http://www.nda.gov.uk/documents/upload/Nirex-inputs-to-environmental-product-declaration-for-Torness-power-station-A-Technical-Note-2005.pdf. Last accessed 13/03/14.

This EPD assumes waste will be disposed of in such facilities, although the final decision on the preferred waste option has yet to be made.

Effective barriers against radioactive emissions are a priority consideration in the design of the final disposal facilities. Successive phases of packaging, emplacement, backfilling and repository sealing and closure build up a multi-barrier disposal concept (Figure 5.1). These include:

- **physical containment** by immobilisation and packaging of wastes in steel or concrete containers
- **geological isolation** by emplacement of the waste packages in vaults excavated deep underground within a suitable geological environment
- **chemical conditioning** by backfilling the vaults with a cement-based material (the NDA Reference Vault Backfill – NRVB) at a time determined by future generations
- **geological containment** achieved by the suitable geological environment, after final sealing and closure of the repository at a time determined by future generations.

Figure 5.1 The multi-barrier disposal concept (NDA 2005)



Where faults and hazards cannot be eliminated they are subject to the following detailed assessments.

- A design basis accident analysis, to judge whether there are sufficient safety measures within the design and what safety status these features should be assigned. The higher the safety status, the more critical the system is to ensuring safety.
- A Probabilistic Safety Assessment (PSA) to determine the potential annual risk from operations at the facility to both workers and members of the public.

Events and accidents would include instances such as flooding, fire, adverse weather, rock falls, seismic events etc. The NDA has undertaken work on seismic events and glaciation, primarily when investigations were still underway at Sellafield (these ceased in 1997). Assessments of how a repository may evolve in response to both seismicity and major disruptive events (e.g. glaciation) would be key considerations in a repository siting process. However, the effects of these and other natural disruptive events are highly site specific and are therefore not explicitly considered.

The overall outcome is an Operational Safety Assessment showing that the current limits stated in the Ionising Radiations Regulations can be met and that no significant challenges to the viability of the concept have been identified. Furthermore most of the activities planned for Phased Geological Repository Concept are comparable to those carried out on licensed nuclear sites in the UK, and other nuclear sites throughout the world.

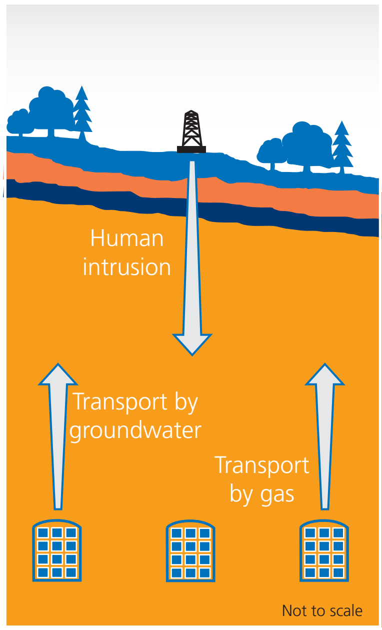
5.2.2.2 Nuclear safety risks at the final waste repository

ILW/LLW repository

Three major pathways have been identified for the return of radionuclides to the environment:

- groundwater (including natural discharge and abstraction from a domestic well)
- gas
- human intrusion.

Figure 5.2: Schematic illustration of main assessment pathways (not to scale)

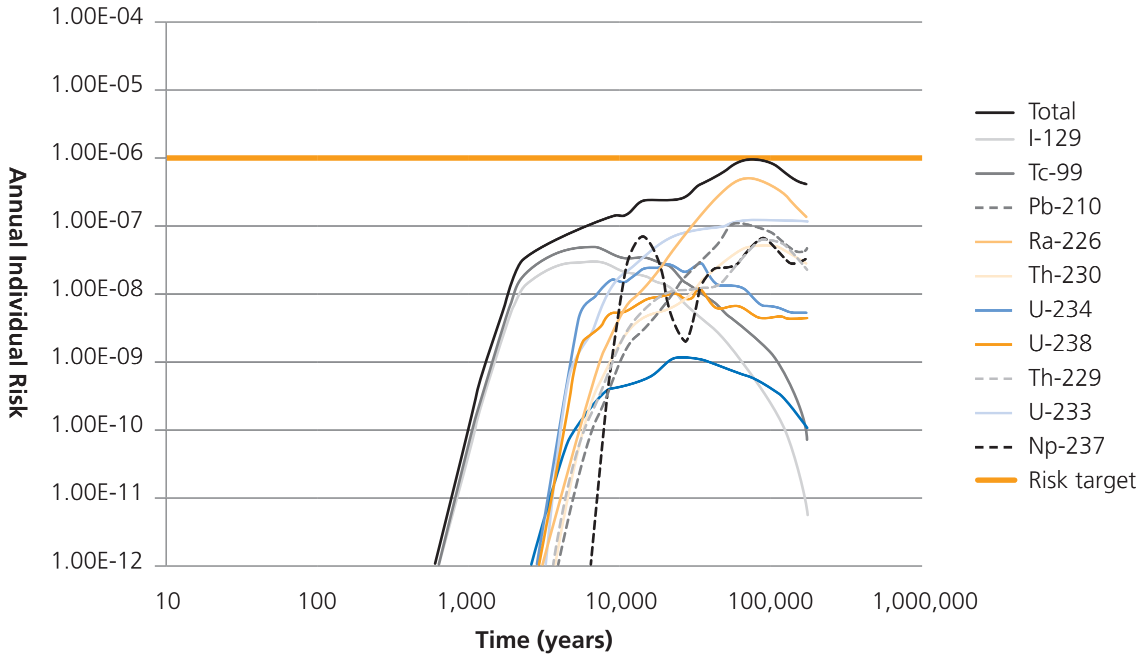


Groundwater Pathway

The reference case radiological risk versus time plot for the groundwater pathway, is shown in Figure 5.3. It also identifies the key radionuclides for this pathway. In accordance with the definition of the reference case, the total radiological risk remains below the broadly acceptable level of 10^{-6} per year at all times.

The results presented in Figure 5.3 are for the whole inventory of UK waste arisings. The specific contribution from the Torness power station waste will also be below the regulatory risk target.

Figure 5.3 Reference case radiological risk against time



Gas Pathway

The radioactive gases of main concern in the assessment of the gas pathway are carbon-14 bearing methane, radon and tritium. However, given the relatively short half-lives of radon (radon-222, the longest-lived radon isotope, has a half life of less than 4 days) and tritium (12 years), any significant delay in the transit of these radionuclides from a repository to the land surface would negate their radiological significance. The break through of gas at the surface is estimated to occur at around 6000 years after repository closure – the risk from repository-derived tritium and radon is therefore assessed to be insignificant.

Human Intrusion Pathway

Two human intrusion pathway scenarios are identified. In the first scenario (the 'geotechnical worker scenario'), core from exploratory drilling is subjected to laboratory analysis by a geotechnical worker. The second scenario (the 'site occupier scenario') concerns the distribution of spoil from the exploratory drilling operations onto the land surface in the vicinity of the borehole site. Some radionuclides would then remain in the soil in the vicinity of the site for considerable periods of time, affecting individuals who occupy the site after the end of drilling activities and make use of the land for growing food. The risks to individuals in these scenarios are not quantified but would depend upon the details of the event.

5.2.2.3 HLW/SF Repository Concept

As part of a collaborative project with the Swedish Nuclear Fuel and Waste Management Company (SKB), the NDA has performed a preliminary post-closure safety assessment for the Reference HLW/SF Concept. Calculations have been carried out for the groundwater, gas and human intrusion pathways. The potential for a criticality has also been assessed. A probabilistic calculation of risk has been carried out using this model assuming one canister of each of PWR fuel, AGR fuel and HLW has a defect that ultimately results in failure.

A model has been developed for assessing the risk from the groundwater pathway which draws on a conceptual model and data developed by SKB for the KBS-3 concept, and uses the same geosphere and biosphere model as the NDA's Generic Performance Assessment (GPA03). The annual individual risk was found to be substantially below the acceptable risk target.

The conclusions of the assessment of the gas pathway are that radioactive gas generation from a failed canister of PWR fuel, AGR fuel or HLW is not significant, and does not pose an unacceptable radiological risk.

For the assessment of inadvertent human intrusion into a deep geological repository for the Reference HLW/SF Concept, annual individual radiological risks for the geotechnical worker scenario are calculated to be below the regulatory risk target. In the case of the site occupier scenario, the radiological risk from radon associated with the HLW/SF is lower than the radiological risk from naturally occurring radon by a factor of 40.

The potential for a criticality in the Reference HLW/SF Concept has been assessed, and shows there is no risk of criticality.

5.2.2.4 Nuclear safety risks from the transport of radioactive materials

Radioactive waste can be transported by road, rail or sea and must meet stringent international transport regulations. More hazardous waste will be transported inside robust containers designed to withstand the severe tests prescribed by the regulations i.e. a free fall from 9 metres onto a rigid surface, an 800°C fire for 30 minutes and a water immersion test equivalent to a water depth of 200m.

Probabilistic safety assessments of the proposed transport operation show the radiological accident risks to be very low and orders of magnitude less than the levels accepted by the HSE as “broadly acceptable”.

5.3 Environmental risks

Environmental risks at Torness are managed in accordance with EDF Energy’s Environmental policy. Briefly, the policy involves complying with relevant legislation and regulations, minimising environmental impact and waste, promoting energy efficiency, developing a sense of environmental responsibility among staff and openly reporting environmental performance. Torness’s Environmental Management System is certified to the ISO 14001:2004 standard.

A key part of Torness’s environmental management is the systematic environmental risk reduction process continually employed on site. The process involves 1) identifying the most significant areas of environmental risk for further assessment; 2) carrying out an environmental impact assessment to identify recommended barriers to minimise or prevent the threats; 3) implementing the recommendations in order of significance. The process is reviewed annually. Whilst the process does not quantify risks in absolute terms it does subjectively take account of the frequency and consequences as part of the scoring system and then ranks them in order of their significance.

At the time of writing this report, the most significant risks, identified and managed via the above process are listed in Table 5.4 below.

Table 5.4 Environmental risks

Priority	Description
1	Heating & Ventilation Refrigerant management
2	Fuel Oil Supply to Combustion Plant
3	Active Drainage
4	HV Switchgear
5	Contaminated Ventilation
6	Radioactive Solid Low Level Waste Management
7	Transformer Oil Containment
8	Active Emissions
9	Management Control
10	Cooling Water Abstraction

5.4 Land use

The total area of the Torness site is 130 ha, of which around 30 ha is permanently exploited for operational activities.

5.4.1 Land use classification for the Torness site

A classification has been made of the land use in and around the Torness site. Using aerial photographs of the site, an estimate has been made of the land use classification in 1977 prior to the construction of the Torness facility. Comparing the land use classification pre-construction to the current land use classification, provides an indication of the change in land use type that has occurred as a result of the Torness facility. Table 5.5 describes the change in land use types quantitatively, by total area. Figure 5.4 and Figure 5.5 respectively, describe in map form the location of the different land use types in and around the site prior to the generation plant's construction, and currently.

The major change in the classification has been due to an increase in the land area available due to the reclamation of land from the sea as part of the plant's construction. It has not been possible to quantify changes in biodiversity that may have resulted from the land use changes. Instead a qualitative description of the biodiversity in and around the Torness site is provided in the following section.

Table 5.5 Land use classification of the Torness estate pre and post construction

Land use classification	Areas in hectares		% change
	1977	2004	
Agriculture (Arable / Improved Grassland)	84.6	70.8	-16%
Semi-Improved Neutral Grassland	13.8	22.4	62%
Mixed Plantation Woodland	2.9	1.8	-38%
Coastal Grassland	2.0	2.4	20%
Dune Grassland	1.2	0.6	-50%
Scrub	0.4	0.1	-75%
Developed Land	0.0	1.8	-
BE Operational	0.0	29.2	-
Improved Amenity Grassland	0.0	0.9	-
Total	**104.9**	**130.0**	**24%**
Total land under EDF Ownership	**143.7**	**143.7**	**-**

5.4.1.1 Description of the land use classification for the Torness site

East Lothian is bounded by the Firth of Forth merging into the North Sea to the north and east and by the Southern Uplands to the south and west. The low coastline is backed by the undulating lowlands incised by steep sided wooded valleys leading up to the steep upland moorlands of the Lammermuir Hills. The soils are among the most fertile in Scotland and the area has long been settled and farmed.

EDF Energy's Torness estate extends to some 144 ha and comprises mainly arable land, grassland and foreshore adjoining the operational site. Much of the foreshore and coastal fringe of EDF Energy's ownership forms part of the Barns Ness Coast SSSI which extends from Broxburn, just south of Dunbar in the north, to the Power Station breakwater at Torness Point in the south. The SSSI was notified in 1984 for the botanical and geological interests of its coastland habitat. The area is also a designated Geological Conservation Review (GCR) Site.

To the north, the Firth of Forth is a Special Protection Area and Ramsar Site under the Birds Directive 1994 and the UK Habitat Regulations 1998. The area is an important wetland area which supports large numbers of wintering wildfowl and waders. To the north of Dunbar is the John Muir Country Park established in 1976 and encompassing 3 square miles of the coastline and important for wildfowl and wading birds. To the south is the St Abbs and Eyemouth Voluntary Marine Reserve covering 1,030 ha of coast between Pelticowick to Hairy Ness and offshore to the 50m depth contour. The Reserve is now part of the Berwickshire and North Northumberland Coast Special Area of Conservation (SAC). The Scottish Wildlife Trust has a nature reserve at Thornton Glen to the west and two wildlife sites along the length of the Dry Burn to the north and Thornton Burn to the south.

Figure 5.4 Land use classification of the Torness estate pre construction (1977)

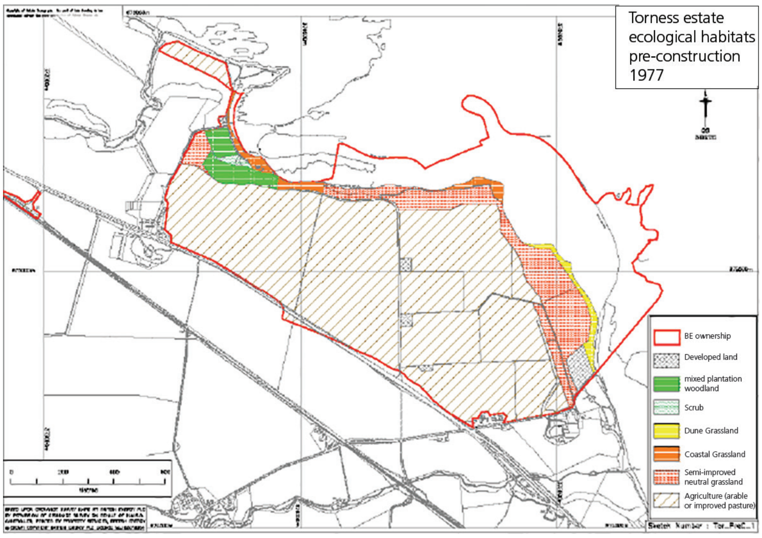
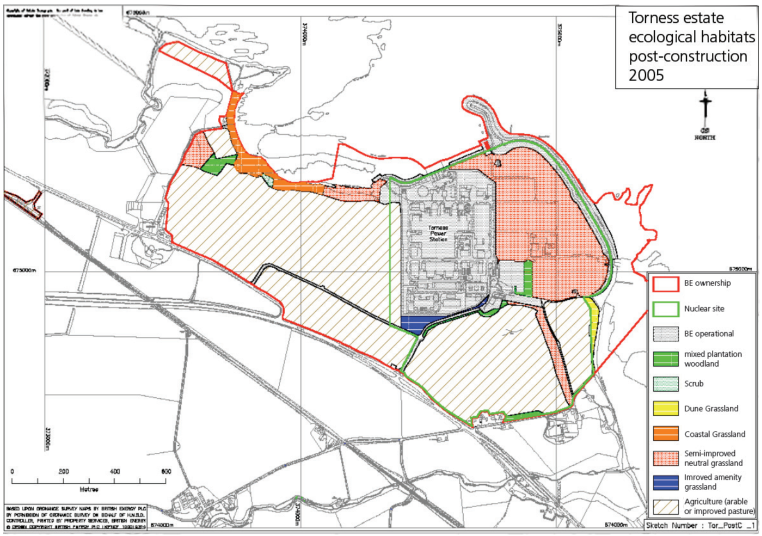


Figure 5 5 Land use classification of the Torness estate post construction (2005)



5.4.2 Biodiversity

5.4.2.1 Biodiversity Pre Construction

The habitats shown on the Pre Construction Plan (Figure 5.4) have been identified so far as is possible, from a 1977 air photograph. This shows that the habitats appear to have changed little between 1977 and 2005. The foreshore was within the Barns Ness SSSI originally designated in 1952 and renotified in 1972. The majority of the land was in intensive arable use with some improved or semi improved pasture. Along the coastline were narrow strips of slightly more diverse coastal and dune grassland.

5.4.2.2 EDF Energy and Biodiversity

EDF Energy's Biodiversity Action Plan (BAP) identifies the priority habitats and species at each of EDF Energy's sites; sets and monitors biodiversity targets for EDF Energy and identifies ways in which staff and local communities can be involved through education, participation and partnership. The Torness site includes one UK BAP priority habitat, coastal dune grassland, whilst 16 UK BAP priority species are present, the majority of them showing evidence of breeding.

Maintaining this biodiversity requires continued active management and EDF Energy has developed Integrated Land Management Plans (ILMPs) for each of its power station sites including Torness, to ensure that this management is effective and sustainable. These plans set out objectives, prescriptions and targets for managing the land aimed at protecting and enhancing biodiversity, conserving the local landscape character and historical heritage, encouraging public recreation, education and community participation whilst at the same time meeting the needs of the business.

After completion of the station construction, some woodland and shrub planting was undertaken at Thorntonloch and parallel to the main station access road. This continues to provide landfall shelter and a source of food for migrant birds particularly in autumn. In 2002 an additional 3000 native shrubs and trees were planted on the southern edge of the former contractors' area to provide additional feeding and shelter.

Recent initiatives have included the biannual sowing of a wild bird feed crop, the planting of 80 wildflower plugs and a wildflower field margin, the trial mowing of grassland plots with the aim of increasing floristic diversity and the erection of 8 bat boxes and 16 bird boxes. Tree sparrow (UK BAP priority species) immediately nested in one of the bird boxes in 2012 whilst 4 boxes were used by the tree sparrows in 2013. New interpretation panels and a self-guided leaflet will help to inform staff and visitors about the diverse wildlife on the site.

5.5 Electromagnetic fields

The term "electromagnetic field" (EMF) refers to the lower frequency range of the electromagnetic spectrum (0 to 300 GHz). Fields of different frequencies interact with the body in different ways. 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.

Electric fields are created by differences in voltage: the higher the voltage, the stronger will be the resultant field. The strength of the electric field is measured in volts per metre (V/m). Any electrical wire that is charged will produce an associated electric field. This field exists even when there is no current flowing. Electric fields are strongest close to a charge or charged conductor, and their strength rapidly diminishes with distance from it. Conductors such as metal shield them very effectively. Other materials, such as building materials and trees, provide some shielding capability. Therefore, the electric fields from power lines outside the house are reduced by walls, buildings, and trees. When power lines are buried in the ground, the electric fields at the surface are hardly detectable.

Magnetic fields are created when electric current flows: the greater the current, the stronger the magnetic field. The strength of the magnetic field is measured in amperes per metre (A/m). But more common is to specify to a related quantity, the flux density (in microtesla, μT). Magnetic fields are not blocked by common materials such as the walls of buildings.

The main source of electromagnetic fields in Torness is the conversion of kinetic energy into electricity in the generator.

There is at present no UK legislation specific to EMFs. However, in June 2013, the European Commission published Directive 2013/35/EU on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields). This will become law in the UK by 1st July 2016. At present control is exercised through the general duties in the Health and Safety at Work etc Act 1974, the Management of Health and Safety at Work Regulations 1999 and by reference to ICNIRP guidelines. ICNIRP are the International Commission on Non-Ionizing Radiation Protection. In 2010 they issued new guidelines for the frequency range 1 Hz to 100 kHz. These guidelines are currently used both by industry and HSE Inspectors when assessing risk from exposure to electromagnetic fields. For occupational exposure the limits set out in the ICNIRP guidelines are 1800 μT for magnetic fields and 46 kV/m for electric.

5.6 Noise

Noise can be a potential health and safety issue and often considered to be a nuisance. Therefore, the planning authorities stipulated maximum permissible noise levels, duration and timings before the initial consent was given for the construction lifecycle stages of Torness. Noise control measures were incorporated at the design stage.

Appendices

Appendix 1 List of acronyms

AGR – Advanced Gas Cooled Reactor

ALARP – As Low as Reasonably Possible

BAP – Biodiversity Action Plan

CFC – Chlorofluorocarbon

CO_2 – Carbon dioxide

EMF – Electromagnetic field

EPD – Environmental Product Declaration

GWh – Gigawatt hour

GWP – Global Warming Potential

HAZOP – Hazard and Operability

HCFC – Hydro Chlorofluorocarbon

HLW – High Level Waste

ILMP – Integrated Land Management Plan

ILW – Intermediate Level Waste

ISL – In-situ Leach Mining

kWh – Kilowatt hour

LLW – Low Level Waste

LCA – Life Cycle Assessment

mSv – Millisievert

MW – Megawatt

NDA – Nuclear Decommissioning Authority

NO_x – Oxides of nitrogen

NRVB – Nirex Reference Vault Backfill

ODS – Ozone Depleting Substance

PCR – Product Category Rules

PWR – Pressurised Water Reactor

PSA – Probabilistic Safety Assessment

SF – Spent Fuel

SO_2 – Sulphur dioxide

SEPA – Scottish Environment Protection Agency

SSSI – Sites of Special Scientific Interest

U_3O_8 – Triuranium octoxide (Uranium oxide concentrate)

UF_6 – Uranium hexafluoride

UO_2 – Uranium oxide

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