# Life Cycle Assessment of electricity from Torness nuclear power plant development

EDF

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# Glossary

| Abbreviations | Definition |
|---|---|
| AD | Associated Development |
| AGR | Advanced Gas-cooled Reactor |
| ALARP | As Low As Reasonably Practicable |
| AP | Acidification Potential |
| AWARE | Available WAter REmaining |
| BAP | Biodiversity Action Plan |
| BDP | Baseline Decommissioning Plans |
| BEIS | Department for Business, Energy and Industrial Strategy |
| BWR | Boiling Water Reactor |
| CA | Canada |
| CCS | Carbon capture and storage |
| CEFAS | Centre for Environment, Fisheries and Aquaculture Science |
| $CH_4$ | Methane |
| CML | Centrum voor Milieukunde Leiden |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| COD | Chemical Oxygen Demand |
| DCO | Development Consent Order |
| EAF | Electric Arc Furnace |
| EDIP method | Environmental Development of Industrial Products method |
| EMF | Electromagnetic field |
| EP | Eutrophication Potential |
| EPD | Environmental Product Declaration |
| EPR | European Pressurised Reactor |
| FES | Future Energy Scenarios |
| FMDT | Final Monitoring Delay Tank |
| GB | Great Britain |
| GCR | Geological Conservation Review |
| GDF | Geological Disposal Facility |
| GHG | Greenhouse Gas |
| GLO | Global |
| GPA | Generic Performance Assessment |
| GPI | General Programme Instructions |
| GSP | Grid Supply Point |
| GWP | Global Warming Potential |
| HAZOP | Hazard and Operability |
| HGV | Heavy Goods Vehicle |
| HLW | High Level (radioactive) Waste |
| HPC | Hinkley Point C |
| HSE | Health and Safety Executive |
| ICE | Institute of Civil Engineers |

| Abbreviations | Definition |
|---|---|
| IES | International EPD System |
| ILMP | Integrated Land Management Plan |
| ILW | Intermediate Level (radioactive) Waste |
| IPCC | Intergovernmental Panel on Climate Change |
| IRR | Ionising Radiation Regulations |
| ISL | Insitu Leaching |
| LC | Life Cycle |
| LCA | Life Cycle Assessment |
| LCI | Life Cycle Inventory |
| LEEIE | Land East of Eastlands Industrial Estate |
| LLW | Low Level (radioactive) Waste |
| LLWR | Low Level (radioactive) Waste Repository |
| luluc | Land Use and Land Use Change |
| MPA | Marine Protected Area |
| mSv | MilliSievert |
| $N_2O$ | Nitrous oxide |
| NA | Namibia |
| NDA | Nuclear Decommissioning Authority |
| NMVOC | Non-Methane Volatile Organic Compounds |
| $NO_x$ | Nitrogen oxides |
| NRVB | NDA Reference Vault Backfill |
| NSNS | Near-surface near-site |
| OSA | Operational Safety Assessment |
| P&R | Park and ride |
| PCR | Product Category Rules |
| PGRC | Phased Geological Repository Concept |
| PM2.5 | Fine Particulate Matter |
| POCP | Photochemical Oxidation Creation Potential |
| PSA | Probabilistic Safety Assessment |
| PWR | Pressurised Water Reactor |
| RER | Rest of Europe |
| Ricardo | Ricardo Energy and Environment |
| RNA | North America |
| RoW | Rest of World |
| RSR | Radioactive Substances Regulation |
| RWM | Radioactive Waste Management |
| SEPA | Scottish Environment Protection Agency |
| SAC | Special Area of Conservation |
| SF | Spent Fuel |
| $SF_6$ | Sulphur hexafluoride |
| SFEF | Spent Fuel Encapsulation Facility |
| SFIRF | Spent Fuel Inspection and Repackaging Facility |

| Abbreviations | Definition |
|---|---|
| SKB | Swedish Nuclear Fuel and Waste Management Company (Svensk Kärnbränslehantering Aktiebolag) |
| $SO_2$ | Sulphur dioxide |
| SPA | Special Protection Area |
| SSSI | Special Site of Scientific Interest |
| SZB | Sizewell B |
| SZC | Sizewell C |
| T&D | Transmission & Distribution |
| $U_3O_8$ | Uranium oxide |
| $UF_6$ | Uranium hexafluoride |
| UK | United Kingdom |
| UKRI | UK Radioactive Waste Inventory |
| VLLW | Very Low Level (radioactive) Waste |
| VOC | Volatile Organic Compound |
| WSF | Water Scarcity Footprint |

# 1 Preface

**Producer**: EDF is the operating company for the Torness nuclear power plant project. EDF's registered address is: 90 Whitfield Street, London, W1T 4EZ, UK.
https://www.edfenergy.com/energy/power-stations/torness

EDF is a major electricity generator, operating several nuclear sites in the UK as well as developing Hinkley Point C (the first new nuclear build in decades) and bringing forward proposals for Sizewell C (SZC), which has an application currently with the Secretary of State for review.

**Product**: Electricity from the Torness nuclear power plant. Electricity belongs to the product category UNCPC Code 17, Group 171 – Electrical energy.

This declaration was prepared by Ricardo Energy and Environment (Ricardo) on behalf of EDF.

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| Review details | | | |
|---|---|---|---|
| Independent review of the declaration according to ISO 14040 (Environmental management – Life cycle assessment – Principles and framework) [1] and ISO 14044 (Environmental management – Life cycle assessment – Requirements and guidelines) [2] | | | |
| | ☐ internal | ☑ external | |
| Third-party reviewer: Julie Sinistore, PhD, Senior Project Director, WSP USA Inc. | | | |

The purpose of this document is to communicate the life cycle environmental impacts associated with the construction, operation and decommissioning of the Torness nuclear power plant, as well as impacts associated with distributing Torness's electricity. It summarises the findings of the full Life Cycle Assessment (LCA) report that provides a detailed presentation of the Torness LCA study. The full LCA report and this document have undergone third party review by WSP USA Inc.

The function of Torness is to generate electricity to be delivered via the grid to consumers. Therefore, a functional unit of 1kWh delivered has been chosen for this study. This aligns with the requirements of the Product Category Rule (PCR)[1] for 'Electricity, Steam and Hot Water Generation and Distribution PCR2007:08, version 4' (Electricity PCR), which has been used as a guide for this study. Please note this document is not an Environmental Product Declaration (EPD) as it does not fully comply with the PCR.

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[1] PCRs lay out category-specific requirements for conducting LCAs and reporting results in Environmental Product Declarations (EPDs)

# 2 Introduction

EDF owns and operates a Torness nuclear power station in Dunbar, Scotland. EDF estimates that Torness generates enough low carbon electricity to supply 1.4 million homes annually, helping to support the UK's net zero ambitions helping to support the UK's decarbonisation ambitions and meet its legal obligation to achieve 'net zero' economy wide carbon emissions by 2050. EDF commissioned Ricardo to prepare a LCA for Torness in order to support its low carbon claims in relation to nuclear energy generation, the results of which it wishes to communicate publicly.

Ricardo has performed this LCA study along the guidelines of the core international LCA standards; ISO 14040 (Environmental management – Life cycle assessment – Principles and framework) [1] and ISO 14044 (Environmental management – Life cycle assessment – Requirements and guidelines) [2]. This resulting public facing document summarises the work done and alongside the methodology followed, has been reviewed against these core ISO standards by a third-party, WSP USA Inc.

The LCA study assesses Torness's impacts across its life cycle, considering:

- The activities 'upstream' of generation, such as the procurement of raw materials and fuel fabrication
- The 'core' activities associated with constructing, operating and decommissioning Torness
- The 'downstream' activities associated with distributing electricity to customers

The assessment considers a selection of key environmental indicators, including Global Warming Potential (GWP) and Acidification Potential (AP). It also reports on a number of resource use and waste output indicators.

In addition to the core ISO standards, the study has referred to the framework established in the Electricity PCR. However, it should be noted that this is not an Environmental Product Declaration (EPD) as has not sought to cover all of the requirements of the Electricity PCR (see Appendix A1 for deviations).

This document summarises the work undertaken to assess Torness's life cycle environmental impacts and the results of the study. The GWP value associated with generating 1kWh of net electricity at Torness has been calculated as 10.44g $CO_2$ eq., whilst that associated with a downstream user receiving 1kWh of electricity generated by Torness has been calculated as 16.46g $CO_2$ eq once the impacts of the transmission and distribution (T&D) networks are taken into account.

As mentioned, appendix A1 lists the key areas where the study and this communication document do not fully align with the Electricity PCR. Other appendices of Torness confidential data have been shared in the full LCA report but are not publicly available in this communication document. It is important to note that this communication document provides a condensed description of the methodology. Full details can be found in the full LCA report "Life Cycle Assessment of Torness nuclear power plant" dated 07/02/2022.

# 3 LCA

## 3.1 Goal and scope

### 3.1.1 Goal

The goal of this study is to assess the life cycle impacts of the 1.3GWe (gross) Torness nuclear power station currently operational in Dunbar, Scotland, UK. This is assessed in terms of the electricity to be generated and delivered to a downstream user.

The study is being undertaken to understand Torness' environmental impact and communicate this to the public and other key stakeholders. Consequently, third-party review of the study against the core international standards for LCA - ISO 14040 and ISO 14044 - has been undertaken to provide assurance of the findings and methodology employed to derive them.

## 3.1.2 Scope

### 3.1.2.1 Product system

Torness comprises two Advanced Gas-cooled Reactors (AGRs) with a combined electrical output of 1.3GWe (gross). AGRs are a type of nuclear power plant which pump pressurised carbon dioxide coolant gas into the reactor core. This gas is heated by the nuclear fission of the uranium within the fuel assembly and is then routed through the boiler to heat the water in the boiler. The resultant pressurised steam flows into a generator, with its energy converted to electricity via turbines.

Construction of the plant began in 1980 with generation commencing in 1988. It was designed for an operational period of 42 years though decommissioning is now expected to begin in 2030 following an extension granted by the UK government. In addition to the main reactors, buildings were constructed during operation, and will be constructed during decommissioning, in order to manage and store waste in the short term.

The plant runs all day, every day, except during planned maintenance periods, assumed to occur every 15 months.

Table 1 below summarises the project’s key characteristics.

Table 1: Overview of Torness details

| Characteristic | Assumption |
|---|---|
| Reactor type | AGR |
| No. of reactors | 2 |
| Fuel | Enriched uranium oxide fuel (currently assumed to by EDF to be of maximum enrichment level of 3.78%) |
| Start of construction | 1980 |
| Start of generation | 1988 |
| Start of decommissioning | 2030 |
| Designed service life | 42 years |
| Fuel cycle | Designed to operate at full power for a “fuel cycle” of 15 months per reactor (including a few weeks for refuelling outage) |
| Location | Dunbar, East Lothian, UK |
| Gross generated | circa 1.3GWe |
| Transmission | Electricity will be transmitted at 400kV and subsequently distributed to the majority of customers through lower voltage distribution networks |

### 3.1.2.2 Functional Unit

The function of Torness is to supply electrical energy to consumers. A functional unit of 1kWh net electricity generated and thereafter distributed to the customer has been selected, hereafter referred to as 1kWh delivered. This value is inclusive of losses within the T&D network. For every kWh of Torness electricity delivered to a customer, 1.12kWh had to be generated (net) at Torness to account for these losses. It is assumed for this LCA that the customer receives medium voltage electricity

Table 2 below compares Torness’s lifetime gross generation and net generation (assuming a 42-year operational life), as well as the amount of Torness electricity delivered after T&D losses over the grid have been taken into account.

Table 2: Comparison of Torness energy outputs under different accounting boundaries

| Gross generated | Net generated | Delivered |
|---|---|---|
| 433,460GWh | 416,124GWh | 365,036GWh |

Operational data for a recent reference period of 15 months has been used and scaled to cover the 42-year operational period. All impacts associated with construction and decommissioning of Torness have been linked to the net generated lifetime value, which has been calculated by extrapolating the recorded operational electricity output for the reference period up to 42 years.

As described above, for every 1.12kWh generated (net) 1 kWh is delivered to a customer. When presenting the results per kWh delivered, the upstream and core impacts associated with generating the 0.12kWh that is lost, are included in the downstream stage, not the upstream and core stages.

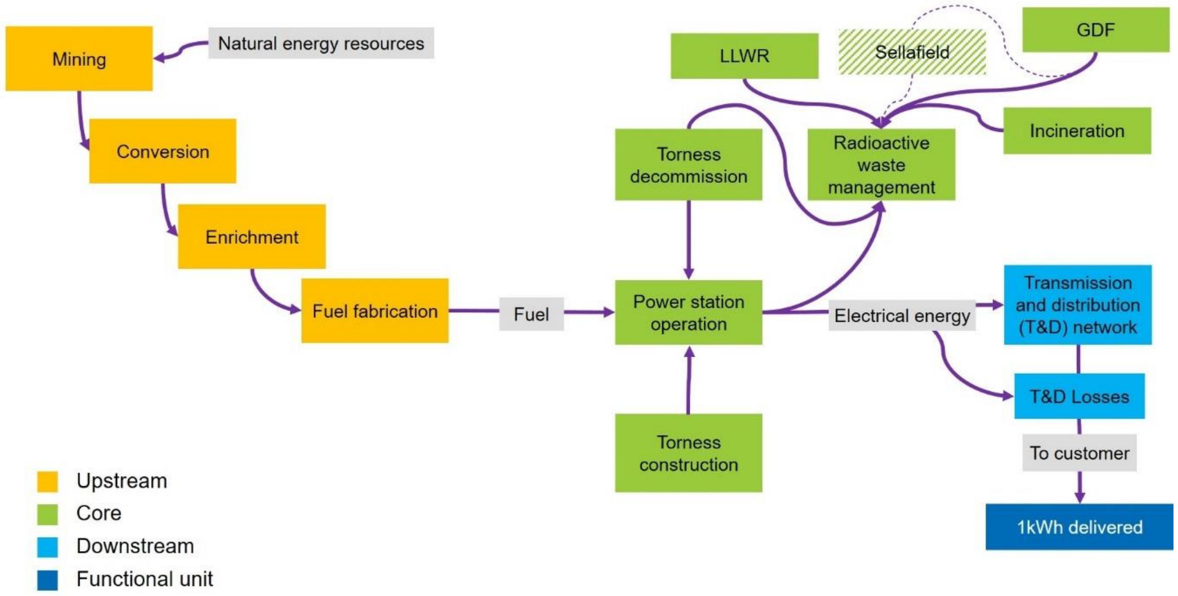
To provide greater transparency the impacts per kWh generated (net) are used to supplement the results per the functional unit of 1 kWh delivered.

#### 3.1.2.3 System boundary

The scope of this LCA is cradle-to-grave, excluding the impacts from use of electricity (i.e., after delivery). As such, the LCA model and the results are divided into three different life cycle stages:

- **Upstream**: activities that occur 'before' the Torness facility, capturing processes associated with the mining, conversion, enrichment and fabrication of nuclear fuel which the plant uses.
- **Core**: capturing the infrastructure and operations associated with energy generation by the plant over its life cycle as well as those facilities associated with the treatment and disposal of radioactive waste at the lower level waste repository (LLWR), the future geological disposal facility (GDF), and via incineration. It should be noted that applicable Torness waste will actually go to a yet to be built or designed future Scottish near-surface near-site (NSNS) storage facility but in the absence of any information on this facility, the UK GDF facility has been used instead in the model. Likewise, spent fuel waste from Torness has and will go to Sellafield where it will remain until a GDF or NSNS is available. However, in the absence of data form Sellafield, the model 'sends' applicable waste to the GDF.
- **Downstream**: capturing processes associated with the operation and infrastructure of the electricity network through which electricity generated at the power plant site is transmitted to customers. This includes accounting for transmission and distribution losses through the network.

Figure 1: System boundary overview schematic



The studied life cycle begins at the extraction point of raw materials and energy carriers from nature, and the final stages include waste generation and delivering of electricity energy to the customer.

### 3.1.2.4 Representativeness

**Temporal**

ISO14044 requires LCA studies to consider the impact of temporal differences within the data modelled. As noted in Table 1 above, the construction of Torness began in the 1980s, and the plant began generating electricity in the 1988 and is set to continue until 2030.

Data has been estimated on the basis of certain assessment periods, such as 15 months of operation for the in-operation inventory (from September 2018 to November 2019 inclusive). Data for construction and decommissioning has been considered as ‘units’ of activity that occur once in the life cycle of Torness and as such, no upscaling has been required.

This assessment has modelled a contemporary grid mix for electricity consumption during construction and operation and has not sought to forecast or back-cast modelling for these stages. This will affect the results. It is worth noting that electricity consumption during construction is responsible for 9.5% of the GWP of delivered electricity, while electricity consumed during operation is responsible for 7%. In addition to electricity consumption, it is important to note that no adjustments have been made to the underlying material input datasets to reflect how their carbon intensity may have also changed during this time period.

The model does however estimate potential changes to the electricity grid mix which will have occurred in 2030 onwards, when the decommissioning of Torness will begin as well as use of a future UK GDF (2040) which is also used as a proxy for the future Scottish NSNS repository. As with construction and operation, it is expected that electricity use during decommissioning will only account for 2% of the total GWP of delivered electricity so this is a relatively minor assumption.

This study assesses GWP using a 100-year horizon.

**Geographic**

In terms of geography, a number of geographies were considered. Downstream, core activities, fuel fabrication, and enrichment have been modelled as occurring in the UK, whilst fuel conversion is assumed to take place in France. Mining operations have been assumed, for the purposes of this study, to take place in Canada, Kazakhstan and Namibia. Where possible, suitable datasets to reflect these assumed geographies, were applied.

Secondary data has been sourced from ecoinvent -a globally recognised life cycle inventory database- to model individual inventory flows. Wherever possible, the most relevant geography has been selected when choosing data. It is understood that the ecoinvent datasets represent technological averages for the given geographies and reflect recent time frames.

#### 3.1.2.5 Allocation procedures

Allocation has been carried out where necessary in accordance with the requirements of ISO 14044. For uranium mining, allocation between the differently mined sources of uranium has been done on a physical basis, based on the global sourcing of uranium by mass. For the enrichment process, 100% of the impacts of the enrichment process have been allocated to the enriched uranium product. For waste treatment only a portion of the offsite radioactive waste facility operation and infrastructure impacts have been allocated to Torness on a physical basis (i.e., by the mass or volume), according to the flow of the ecoinvent dataset used to represent these facilities and their respective treatment processes. The handling/treatment/transportation of operational waste and residues is included according to the polluter pays principle.

#### 3.1.2.6 Data sources and quality

LCA studies require two kinds of information: data regarding the environmental aspects of the product system such as its material and energy flows; and data regarding these flows' life cycle impacts. The former has been supplied by EDF specifically for Torness for the core life cycle stages of operation and decommissioning. As EDF was not the owner of Torness at the time of construction in the 1980s, minimal data is available for the construction stage. However, EDF provided specific values for some materials, transport and wastes, taken from a reference document from the Proceedings of the Institute of Civil Engineers [3]. From the concrete quantity provided, a wider range of construction flows, including energy requirements, were extrapolated from a Boiling Water Reactor (BWR) nuclear plant dataset in ecoinvent in lieu of data for a generic AGR. However, whilst the reactor for these two difference nuclear plant types will vary, it is reasonable to assume that the other core support buildings and hence majority of construction flows, would be similar. Therefore, this can be considered to be the most applicable data available for this study.

Secondary flow data has been collected from the LCA database ecoinvent, v3.7 cut-off database as implemented in SimaPro v9.1.

Data and values for Torness's operation were based on a 15-month operational reference period of data from Torness, whilst decommissioning data was largely based on Torness's Baseline Decommissioning Plans (BDP) and Site Summary document.

Specific data provide by EDF from Torness's upstream fuel fabricator was provided and specific data obtained from Sizewell C (SZC)'s potential future uranium enricher was used, supplemented with data from an enrichment ecoinvent dataset to ensure that no 'key' input or output flows are unaccounted for.

Specific data for the UK future GDF derived from the most conservative of the three scenarios currently scoped was also used to represent the potential Scottish NSNS repository.

Generic datasets have been used to represent the life cycle stages substages for conversion, milling and mining, downstream infrastructure, and offsite waste treatment, as specific data was not available. Generic data (ecoinvent datasets) was also used to represent all upstream infrastructure.

#### 3.1.2.7 Data assumptions

##### 3.1.2.7.1 Electricity assumptions

For the majority of life cycle stages, which are known to occur in the UK, a national production mix process has been selected from ecoinvent. For upstream processes of mining and milling, conversion, enrichment and fuel fabrication, the most applicable region was selected.

For the decommissioning stage, that is estimated to begin in 2030, it has been considered necessary to make assumptions regarding the electricity type that Torness (or activities associated with Torness) will consume at this point in time. For these, estimates of the future UK electricity grid mix were derived. These mixes were based on BEIS 2019 Updated Energy & Emissions Projections, v1.0 11-

12-2020, for Net Zero Lower Demand Projection of electricity generation by source [4] and supplemented with data from the National Grid's Future Energy Scenarios (FES) 2020 Data Workbook data [5]. Full details are given in the LCA report.

###### 3.1.2.7.2 Cut-offs and exclusions

In terms of cut-off and exclusions, the study has used the system boundary detailed in the Electricity PCR as guidance and excluded certain processes in line with that document. These include business travel, commuter travel, R&D activities and downstream electricity usage.

For all four upstream stages (fuel fabrication, enrichment, conversion and mining and milling), infrastructure was included as part of the generic ecoinvent datasets which have been used as a basis for each.

For core operation, no known inflows, have been excluded. Therefore, the life cycle inventory data for core operation can be considered to meet the cut-off criteria detailed in the Electricity PCR.

For core infrastructure, construction data for the major materials (concrete materials, reinforcing steel) was available. The reference document [6] from which these values were taken states that these materials cover the total permanent materials delivered to site, so could be considered to cover all they key components of the Torness plant. Quantities of additional materials that may make up the site (such as copper for wiring) that were not included in the reference document, were extrapolated based on the ecoinvent dataset for BWRs, as were energy requirements. In the absence of other information, it therefore seems reasonable to assume that there are no significant exclusions. Likewise, although assumptions and approximations have been assumed, no known flows associated with decommissioning have been excluded except for the potential Spent Fuel Reprocessing Facility (SFRF) construction materials which is not included but which tests show makes a difference of less than 1% of the assessed impacts over the whole model.

###### 3.1.2.7.3 Limitations

It should be noted that as with any LCA and modelling, this study only considers potential impacts and does not reveal actual impacts on the state of the environment. The quality and uncertainties of the results are based on the quality and accuracy of the primary data provided, and also the secondary data and datasets selected, and any assumptions made.

LCA also cannot directly consider future changes to technology or demand although some attempt at representing the influence of future UK electricity grid mix has been made for the decommissioning and GDF (future Scottish NSNS repository) stages. However, this has not been undertaken for the construction and operation of Torness. The construction of Torness and much of its operational life has occurred in years prior to 2021, but no 'backdating' of electricity mixes has been undertaken, likewise no forecasting has been applied to the remaining 9 years of operation.

The main limitation for Torness is the relative lack of site-specific construction data. Some data has been taken from an ICE document and missing quantities extrapolated from the ecoinvent dataset for a BWR, but it is important to note that this is only assumptive and therefore this should be taken into consideration when consideration the results. There is no way to test how these results would deviate from those which would have been based on full Torness specific data.

Likewise, for the UK GDF (used to also represent a future Scottish NSNS repository) data for one specific assumed scenario of its future construction was used and whilst this is the most available data at this point in time, this will undoubtably change as site location and designs for the GDF evolve, and designs for the Scottish NSNS repository will develop.

For certain processes (largely those representing the upstream stage for mining and conversion, the core stage for offsite waste repositories and disposal facilities, and for infrastructure and operation of the downstream stage for T&D networks), no specific data was available. Therefore, ecoinvent datasets have been used as proxies.

Additionally, as with all modelling, the estimated impact results are only relative statements which do not indicate the end points of the impact categories, exceeding threshold values, safety margins or risks.

## 3.2 Life Cycle Inventory Analysis

The LCA model includes a series of life cycle inventories (LCIs), which describe the cradle-to-grave generation of electricity at Torness, excluding the impacts from use of the electricity downstream (i.e., after delivery). Each inventory is interconnected, with mining inventories feeding into conversion, which feeds into enrichment, and so on all the way through the life cycle up to the reference unit of lifetime net electricity generation over the planned 42-year operation of Torness.

Table 3 summarises the processes covered by the inventory of the key stages of the Torness LCA model.

Table 3: Processes included in the key life cycle inventories

| Stage | Included processes |
|---|---|
| Upstream* | Upstream production of materials, fuel and electricity consumption, emissions, production of materials required, infrastructure, wastes, transport of uranium from previous upstream stage. |
| Core operation | Upstream production of materials required for operation (including radioactive waste packaging), transport of materials and fuel to site, fuel and electricity consumption (including reserve power), water requirements, emissions, transportation of wastes (both radioactive and non-radioactive), treatment and disposal of wastes. Note that for offsite radioactive waste facilities, processes were included to the extent that they are in the ecoinvent datasets used for modelling. |
| Core infrastructure: construction | Upstream production of materials required for construction of the Torness facilities including reactors and other infrastructure, reinvestment of construction materials, transport of materials to site, fuel and electricity consumption, water consumption, transport of wastes from site, treatment/disposal of wastes generated. |
| Core infrastructure: decommission | Upstream production of radioactive waste packaging materials, fuel, electricity and water needed for decommissioning, transport of packaging materials to site, transport of wastes (both radioactive and non-radioactive), treatment/disposal of wastes generated. |
| Downstream | $SF_6$ switchgear inputs, $SF_6$ emissions, T&D infrastructure processes or flows related to land use, digging, construction, transformer stations, cables and poles, and waste treatment processes. Maintenance and dismantling of the T&D networks does not appear to be included in the ecoinvent datasets so should be considered to be excluded. |

* Note that the processes included were based on those available in the ecoinvent datasets used to represent each stage

The following section discuss these stages in more detail.

### 3.2.1 Upstream

Upstream processes relate to the production of the nuclear fuel used at Torness. For the purposes of this study, it is assumed that Torness purchases uranium fuel assemblies from Westinghouse (the fuel assembler), and that enriched uranium sources are from a Urenco enrichment facility in the UK. As the of uranium mining and conversion services to Torness are not known, assumptions of possible suppliers have been made as listed in Table 4. This split used provides a snapshot of a split of uranium production methods in 2019 (from which the majority of the operational reference data for SZB falls) and therefore does not cover the variance in uranium production methods over time.

Table 4: Assumed percentage split and location for the four key upstream fuel stages†

| Upstream production | Split by mass | Company | Location |
|---|---|---|---|
| Underground mining, milling | 21.4% | Orano/Cameco | Cigar Lake and McClean Mill, Saskatchewan, Canada |

| Upstream production | Split by mass | Company | Location |
|---|---|---|---|
| In situ leaching (ISL) | 61.4% | Orano | Muyunkum and Torkuduk, Kazakhstan |
| Open pit mining, milling | 17.2% | CNNC Rossing Uranium | Rossing, near Swakopmund, Namibia |
| **Mining (total)** | **100%** | **See above** | **See above** |
| **Conversion** | **100%** | **Orano** | **Pierrelatte & Malvési, France** |
| **Enrichment** | **100%** | **Urenco UK** | **Capenhurst, UK** |
| **Fuel fabrication** | **100%** | **Westinghouse** | **near Preston, UK** |

† Note that as EDF were not able to share the specific companies and locations of Torness's uranium supply chain, the listed companies and specific locations have been used as assumptions for this project.

All upstream data has been linked to the lifetime mass (730 tonnes) of enriched uranium needed for 42 years of operation, during which the plant is expected to generate 416,123,870MWh of electricity (net). Table 5 shows the reference flow mass from each upstream stage in relation to the required total life operational enriched uranium.

Table 5: Masses of uranium material related to the total life requirement of enriched uranium

| Upstream fuel | Mass (t) |
|---|---|
| Underground sourced milled uranium* | 1,312 |
| ISL sourced uranium | 3,586 |
| Open pit sourced milled uranium* | 1,055 |
| Converted uranium | 5,840 |
| Enriched uranium | 730 |
| Fuel assemblies (total mass including enriched uranium) | 1,486 |

* Includes a 5% uplift of impacts to account for milling losses as per the milling ecoinvent datasets

Transportation impacts from the uranium being transported between the upstream stages and assumed providers is included.

## 3.2.2 Core

### 3.2.2.1 Core operation

In line with the system boundary contained in the Electricity PCR, processes modelled for core operation covered:

- Energy conversion process of the plant
- Maintenance (but not reinvestment of components)
- Reserve power including test operation
- Transportation of waste
- Handling/treatment/deposition of spent nuclear fuel and other radioactive waste
- Handling/treatment/deposition of other operational waste

It is planned that Torness will generate electricity for up to 42 years and site specific data has been supplied by EDF for a representative reference period of 15 months.

The commissioning stage of the plant is the period between construction and operation and is where various components and systems are tested before full service begins. It includes activities such as pipe flushing. As this period occurred decades ago and when Torness was under different ownership, very little data was available for this substage, so a number of assumptions have been applied including that it takes 18 months (which is the same amount of time that the commissioning period of SZC was assumed to take). For this model, commissioning has been assigned to broader the core operation stage.

In relation to off-site facilities for the treatment/deposition of wastes generated during operation of Torness, specific data for most facilities was not available. Therefore, this has been included to the extent that the ecoinvent datasets used to represent these treatments have covered operational impacts.

For the operational impacts of the future Scottish NSNS, no data was available, so the UK GDF for which more specific data was available (supplied by SZC Co and used for the SZC LCA study) was used. This information was based on data extracted from a generic carbon footprint analysis. Due to the early concept of the GDF, this itself is underpinned by a number of assumptions made by Radioactive Waste Management (RWM) Ltd [7] and following discussions between EDF and RWM.

#### 3.2.2.2 Core infrastructure: construction and decommission

As per the Electricity PCR, processes modelled for core infrastructure covered:

- 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
- Reinvestments of material and components during the estimated technical service life

EDF has some, but limited data covering the above requirements as Torness construction occurred in the 1980s and changes of ownership have occurred since. This data has been supplemented with the dataset for a GB BWR facility, that although a different type of plant, was considered likely to be of similar construction to Torness. Therefore, this data has been scaled to Torness using a Torness specific quantity of concrete (this is described in the following section) in order to gap fill.

For reinvestment of materials, it is unclear if the values provided in the Torness reference document cover this or not. Therefore, they should be considered to be excluded.

In relation to off-site facilities for the treatment/deposition of wastes generated during operation of Torness, specific data for most facilities was not available. Therefore, this has been included to the extent that the ecoinvent datasets used to represent these treatments have covered construction and deconstruction impacts.

For construction and decommissioning of the Scottish NSNS repository, data for the future UK GDF was used, as per the source mentioned in previous section.

EDF has estimated quantities of key materials, utility consumption, and waste generated during decommissioning from its baseline decommissioning plan (BDC) and Torness Site Summary document.

### 3.2.3 Downstream

The downstream life cycle stage refers to the distribution of electricity from the site of generation to the downstream electricity users.

Figure 2: Overview of where losses can occur during electricity delivery to the user

The transmission network is a high voltage network which transports electricity from its source of generation (such as from the nuclear power plant ‘gate’) to the distribution network (or to large electrical users directly connected to the transmission network). Losses occur over both networks as well as when stepping up the electricity from its source to the transmission network.

T&D losses effectively mean that more electricity needs to be generated in order to ensure that the customer receives the required amount of electricity. This increased electricity transmitted also infers an uplifting of the impacts associated with the grid itself as it is being ‘used’ more. These losses affect all forms of power generation that are connected to the electricity network.

The Electricity PCR requires that T&D losses be accounted for in the downstream life cycle stage. To model the downstream impacts associated with the nuclear power plant, generic ecoinvent datasets were used, as specific data representing the infrastructure and operation of the UK electricity network was not available to EDF. Therefore, a generic ecoinvent dataset for medium voltage electricity was used, into which the Torness electricity model was fed, and T&D losses applied accordingly as per Table 6.

Table 6: Parameter values modelled to represent T&D losses in the downstream module

| Loss type | Loss modelled | Source |
|---|---|---|
| Transmission loss | 1.7% | National Grid document 2019 [8] |
| Distribution loss | 8%* | National Grid document 2019 [8] |
| Step up loss | 3% | ecoinvent dataset |

*The highest value in the range was used for conservatism

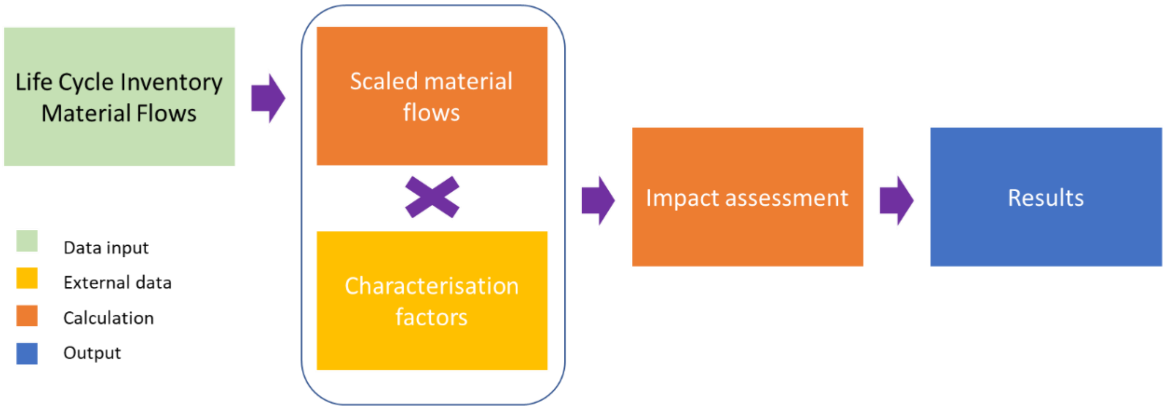
The model representing the generation of electricity at Torness was then fed into this copied dataset.

As mentioned, T&D losses over the grid, will result in a reduction in the quantity of electricity reaching the final user. While 1.12kWh is generated at Torness, these losses mean that the customer ultimately receives 1kWh. The additional upstream and core impacts of generating 1.12kWh versus 1kWh have been assigned to the downstream stage of the model, alongside impacts of the infrastructure and operation of the grid. In order to calculate these impacts, the impacts of generating 1kWh at Torness must first be subtracted from those of delivering 1kWh to the user. This difference will be the downstream impacts related to both the infrastructure and operation of the network ***plus*** impacts from the additional generation by Torness due to losses on the network. Subtracting the infrastructure and operation impacts of the grid will give the T&D loss impacts.

## 3.3 Life Cycle Impact Assessment

Within the SimaPro® software v9.1, the life cycle impact assessment uses the life cycle inventories to calculate results for each of the environmental indicators. First, each inventory is scaled to deliver the correct amount per functional unit (1kWh of delivered Torness electricity). The inventories are built in a cascading hierarchy, where each inventory reads how much ‘primary product’ the next inventory needs, thereby scaling the inventory and related processes accordingly to meet that requirement. Once the inventories are scaled, characterisation factors (which are factors that link process flows with environmental impact) are applied to the scaled material flows. The resulting impact is then summed per life cycle stage. The model flow is illustrated in Figure 3 below.

Figure 3: Model flow diagram



As specified by the Electricity PCR, results are reported at a minimum granularity of life cycle stage (i.e., upstream, core, downstream).

### 3.3.1 Environmental impacts

The results of the Torness LCA are shown below in terms of the core environmental impacts as described in Table 7. Results are reported per life cycle stage in terms of the indicated unit per unit of 1kWh generated and the functional unit of 1kWh delivered to a hypothetical customer.

Results have been analysed further in section 3.4 with a focus on carbon.

### 3.3.2 Resource use

The input of resources for the LCA, per functional unit, are shown in Table 8. This data was extracted from the results inventory.

Note that only data from secondary sources was available for non-Torness controlled stages, for which details of reuse and recycled material were not known. Therefore, it was not possible to disaggregate raw material secondary inputs. In order give a rough overview, the top tier values of steel and aluminium inputs were extracted from these non-Torness specific stages. Assumptions of the average recycled content of the steel and aluminium, as based on the underpinning ecoinvent datasets, were applied to give an approximate value for recycled content. This was only applied for steels and aluminium. Offsite infrastructure was not included and hence no value is declared for total generated so as to not give a false impression. Consequently, no value has been declared for downstream T&D losses. For downstream infrastructure, Table 8 shows no values for secondary resource inputs. This is not necessarily because no secondary materials are used in the construction and operation of the grid, but because no steel or aluminium datasets were displayed in the top tier datasets.

These estimates have not been further analysed as they are a facet of reporting the inventory as opposed to an actual calculation of impacts.

### 3.3.3 Waste and material outputs

The waste and material outputs for the LCA, per functional unit are shown in Table 9.

A custom waste flow was created, summing the materials or wastes going to reuse or recycling for the Torness core stages. This allowed for custom created datasets in the model to report recycled/reused material inputs in the SimaPro resource inventory list. However, it has not been possible to provide a suitable estimate for materials or wastes to reuse or recycling due to the use of secondary data for the non-Torness stages. These have therefore not been declared and will be described as ‘ND’ in the waste outputs table.

These estimates have not been further analysed as they are a facet of reporting the inventory as opposed to an actual calculation of impacts.

Table 7: Key environmental indicator results per functional unit of 1kWh of generated and delivered electricity

| Environmental indicator | Upstream | Core construction | Core operation | Core decommission | **Total generated** | Downstream T&D losses | Downstream other | **Total delivered** |
|---|---|---|---|---|---|---|---|---|
| GWP total (g $CO_2$ eq.) | 2.18 | 4.62 | 2.67 | 0.97 | **10.44** | 1.30 | 4.73 | **16.46** |
| GWP total (kg CO2 eq.) | 2.18E-03 | 4.62E-03 | 2.67E-03 | 9.66E-04 | **1.04E-02** | 1.30E-03 | 4.73E-03 | **1.65E-02** |
| GWP fossil (kg $CO_2$ eq.) | 2.18E-03 | 4.61E-03 | 2.65E-03 | 9.59E-04 | **1.04E-02** | 1.29E-03 | 4.72E-03 | **1.64E-02** |
| GWP biogenic (kg $CO_2$ eq.) | 2.93E-06 | 6.00E-06 | 2.06E-05 | 1.90E-06 | **3.14E-05** | 3.92E-06 | 2.94E-06 | **3.83E-05** |
| GWP luluc (kg $CO_2$ eq.) | 9.91E-07 | 4.48E-06 | 2.20E-06 | 5.34E-06 | **1.30E-05** | 1.62E-06 | 2.58E-06 | **1.72E-05** |
| AP (kg $SO_2$ eq.) | 1.97E-05 | 2.46E-05 | 1.42E-05 | 3.51E-06 | **6.19E-05** | 7.71E-06 | 2.68E-05 | **9.65E-05** |
| EP (kg $PO_4^{3-}$ eq.) | 2.77E-05 | 8.71E-06 | 4.11E-06 | 1.26E-06 | **4.18E-05** | 5.20E-06 | 1.27E-05 | **5.97E-05** |
| POCP (kg NMVOC eq.) | 2.17E-05 | 1.74E-05 | 1.49E-05 | 3.36E-06 | **5.73E-05** | 7.13E-06 | 9.47E-06 | **7.39E-05** |
| Particulate matter emissions (kg PM2.5 eq.) | 1.01E-05 | 1.73E-05 | 4.51E-06 | 1.50E-06 | **3.34E-05** | 4.16E-06 | 8.54E-06 | **4.61E-05** |
| WSF ($m^3$ world eq. deprived) | 1.54E-03 | 6.00E-04 | 7.83E-04 | 1.46E-04 | **3.07E-03** | 3.82E-04 | 4.47E-04 | **3.90E-03** |

Table 8: Inventory of resource inputs per functional unit of 1kWh of generated and delivered electricity

| Resource use per stage | Unit/kWh | Upstream | Core: operation | Core: infra | Total generated | Downstream: T&D | Downstream: other | Total delivered |
|---|---|---|---|---|---|---|---|---|
| **Non-renewable material resources** | | | | | | | | |
| Aluminium | g | 2.52E-03 | 6.45E-04 | 8.05E-03 | 1.12E-02 | 1.38E-03 | 3.31E-02 | 4.57E-02 |
| Clay, bentonite | g | 5.55E-04 | 3.12E-04 | 1.76E-01 | 1.77E-01 | 2.20E-02 | 2.06E-03 | 2.01E-01 |
| Basalt | g | 1.19E-04 | 1.25E-04 | 7.68E-04 | 1.01E-03 | 1.23E-04 | 3.66E-04 | 1.50E-03 |
| Chromium | g | 2.37E-03 | 1.72E-03 | 5.07E-02 | 5.48E-02 | 6.82E-03 | 1.59E-03 | 6.32E-02 |
| Copper | g | 1.28E-03 | 7.07E-04 | 1.54E-02 | 1.74E-02 | 2.16E-03 | 3.99E-02 | 5.95E-02 |
| Dolomite | g | 6.76E-04 | 2.43E-04 | 6.14E-03 | 7.06E-03 | 8.63E-04 | 2.32E-03 | 1.02E-02 |
| Feldspar | g | 4.33E-10 | 3.59E-10 | 2.67E-09 | 3.46E-09 | 4.13E-10 | 8.20E-10 | 4.70E-09 |
| Fluorspar | g | 1.82E-02 | 1.38E-04 | 7.41E-04 | 1.91E-02 | 2.37E-03 | 1.33E-03 | 2.28E-02 |
| Gravel | g | 3.49E-01 | 2.07E-01 | 5.49E+00 | 6.05E+00 | 7.03E-01 | 2.44E+00 | 9.19E+00 |
| Sand | g | 5.30E-02 | 1.60E-02 | 8.19E-02 | 1.51E-01 | 1.78E-02 | 5.85E-01 | 7.54E-01 |
| Rock | g | 1.13E-02 | 5.13E-03 | 2.01E+00 | 2.03E+00 | 2.51E-01 | 4.26E-02 | 2.32E+00 |
| Gypsum | g | 2.29E-03 | 5.08E-04 | 3.18E-02 | 3.46E-02 | 4.28E-03 | 1.23E-02 | 5.12E-02 |
| Iron | g | 4.43E-02 | 1.77E-02 | 5.07E-01 | 5.69E-01 | 6.98E-02 | 1.79E-01 | 8.18E-01 |
| Lead | g | 2.83E-04 | 3.26E-05 | 1.39E-04 | 4.55E-04 | 5.34E-05 | 8.04E-04 | 1.31E-03 |
| Calcite | g | 9.18E-02 | 3.45E-02 | 1.04E+00 | 1.17E+00 | 1.44E-01 | 3.85E-01 | 1.70E+00 |
| Magnesium | g | 2.35E-04 | 2.51E-05 | 8.96E-05 | 3.50E-04 | 3.86E-05 | 1.18E-03 | 1.57E-03 |
| Manganese | g | 3.44E-04 | 8.71E-05 | 1.90E-03 | 2.33E-03 | 2.87E-04 | 1.13E-04 | 2.73E-03 |
| Nickel | g | 1.49E-03 | 1.01E-03 | 2.96E-02 | 3.21E-02 | 4.00E-03 | 1.34E-03 | 3.75E-02 |

| Resource use per stage | Unit/kWh | Upstream | Core: operation | Core: infra | Total generated | Downstream: T&D | Downstream: other | Total delivered |
|---|---|---|---|---|---|---|---|---|
| Olivine | g | 5.67E-09 | 6.94E-07 | 2.26E-08 | 7.23E-07 | 8.97E-08 | 1.33E-08 | 8.26E-07 |
| Sodium chloride | g | 2.59E-02 | 2.11E-01 | 2.29E-02 | 2.60E-01 | 3.21E-02 | 8.05E-03 | 3.00E-01 |
| Soil | g | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Sulphur | g | 1.57E-05 | 2.09E-05 | 1.98E-05 | 5.64E-05 | 6.85E-06 | 3.94E-05 | 1.03E-04 |
| Tin | g | 1.13E-06 | 1.71E-06 | 1.02E-05 | 1.31E-05 | 1.58E-06 | 1.31E-06 | 1.60E-05 |
| Titanium | g | 2.07E-04 | 6.97E-05 | 5.76E-04 | 8.52E-04 | 1.01E-04 | 3.14E-04 | 1.27E-03 |
| Zinc | g | 1.27E-03 | 1.46E-04 | 5.90E-04 | 2.01E-03 | 2.37E-04 | 3.33E-03 | 5.57E-03 |
| Zirconium | g | 3.02E-05 | 1.02E-05 | 9.47E-05 | 1.35E-04 | 1.61E-05 | 5.01E-05 | 2.01E-04 |
| **Renewable material resources** | | | | | | | | |
| Wood | g | 5.34E-11 | 1.59E-10 | 5.37E-10 | 7.49E-10 | 9.31E-11 | 4.58E-11 | 8.88E-10 |
| **Non-renewable energy resources** | | | | | | | | |
| Crude oil | g | 3.24E-01 | 3.24E-01 | 3.76E-01 | 3.25E-01 | 1.02E+00 | 1.09E-01 | 1.06E-01 |
| Hard coal | g | 1.76E-01 | 1.76E-01 | 3.35E-01 | 9.84E-01 | 1.50E+00 | 1.84E-01 | 3.60E-01 |
| Lignite | g | 3.87E-02 | 3.87E-02 | 8.06E-02 | 1.14E-01 | 2.34E-01 | 2.83E-02 | 4.85E-02 |
| Natural gas | g | 2.63E-01 | 2.63E-01 | 4.48E-01 | 6.68E-01 | 1.38E+00 | 1.71E-01 | 4.63E-02 |
| Uranium in ore | g | 1.73E-02 | 2.38E-05 | 5.30E-05 | 1.74E-02 | 2.16E-03 | 1.13E-06 | 1.95E-02 |
| Uranium in ore, primary energy | MJ | 9.65E-03 | 1.33E-05 | 2.96E-05 | 9.69E-03 | 1.21E-03 | 6.30E-07 | 1.09E-02 |
| Peat | g | 6.32E-04 | 2.17E-03 | 3.28E-03 | 6.08E-03 | 7.52E-04 | 1.24E-04 | 6.96E-03 |
| **Renewable energy resources** | | | | | | | | |
| Energy, in biomass | MJ | 1.05E-03 | 3.16E-03 | 1.05E-02 | 1.47E-02 | 1.82E-03 | 9.50E-04 | 1.75E-02 |

| Resource use per stage | Unit/kWh | Upstream | Core: operation | Core: infra | Total generated | Downstream: T&D | Downstream: other | Total delivered |
|---|---|---|---|---|---|---|---|---|
| Energy, potential (in hydropower reservoir), converted | MJ | 1.73E-03 | 8.17E-04 | 4.01E-03 | 6.56E-03 | 8.09E-04 | 1.26E-03 | 8.63E-03 |
| Energy, solar, converted | MJ | 6.77E-07 | 2.34E-06 | 6.16E-04 | 6.19E-04 | 7.69E-05 | 4.50E-07 | 6.96E-04 |
| Energy, kinetic (in wind), converted | MJ | 4.08E-04 | 1.47E-03 | 8.46E-03 | 1.03E-02 | 1.29E-03 | 5.17E-05 | 1.17E-02 |
| **Water resources** | | | | | | | | |
| Ground water | m3 | 1.33E-06 | 1.42E-06 | 4.19E-06 | 6.94E-06 | 8.39E-07 | 4.93E-06 | 1.27E-05 |
| River water | m3 | 9.33E-05 | 4.19E-05 | 3.32E-05 | 1.68E-04 | 2.09E-05 | 9.38E-06 | 1.99E-04 |
| Sea/salt water | m3 | 4.12E-07 | 3.77E-07 | 4.94E-07 | 1.28E-06 | 1.44E-07 | 1.27E-06 | 2.70E-06 |
| Water, specified natural origin | m3 | 2.91E-08 | 4.07E-08 | 2.06E-07 | 2.76E-07 | 3.35E-08 | 8.84E-08 | 3.98E-07 |
| Water, unspecified natural origin | m3 | 1.30E-02 | 7.36E-03 | 4.46E-02 | 6.49E-02 | 8.03E-03 | 1.04E-02 | 8.34E-02 |
| **Use of secondary material** | | | | | | | | |
| Aluminium | g | 1.63E-04 | 0 | 6.89E-04 | ND | ND | 0 | ND |
| Steel | g | 8.23E-04 | 1.58E-03 | 1.36E-01 | ND | ND | 0 | ND |

Table 9: Inventory of waste and material outputs per functional unit of 1kWh of generated and delivered electricity

| Waste and material outputs | Unit/kWh | Upstream | Core operation | Core infrastructure | Total generated | Downstream T&D | Downstream other | Total delivered |
|---|---|---|---|---|---|---|---|---|
| All hazardous (non-radioactive) wastes disposed | g | 7.32E-08 | 4.85E-08 | 1.37E-07 | 2.58E-07 | 3.22E-08 | 9.88E-08 | 3.89E-07 |
| Total radioactive wastes generated | g | ND | 5.94E-03 | 6.71E-02 | ND | ND | ND | ND |
| HLW generated | g | ND | 3.97E-03 | 1.00E-02 | ND | ND | ND | ND |
| ILW and LLW generated | g | ND | 1.97E-03 | 5.71E-02 | ND | ND | ND | ND |
| Depleted uranium, spent $UF_6$ | g | ND | 1.75E-03 | ND | ND | ND | ND | ND |
| Total volume of repository needed for radioactive wastes as disposed | $m^3$ | 9.94E-09 | 3.81E-09 | 3.40E-07 | 3.53E-07 | 4.40E-08 | 1.62E-11 | 3.98E-07 |
| Volume of repository needed for radioactive wastes as disposed, ILW plus SF | $m^3$ | 3.58E-12 | 1.62E-09 | 1.29E-08 | 1.45E-08 | 1.81E-09 | 5.00E-13 | 1.63E-08 |
| Volume of repository needed for radioactive wastes as disposed, LLW | $m^3$ | 9.94E-09 | 2.19E-09 | 3.27E-07 | 3.39E-07 | 4.22E-08 | 1.57E-11 | 3.81E-07 |
| Waste (radioactive and non-radioactive) to recycling | g | ND | 1.91E-01 | 3.55E-01 | ND | ND | ND | ND |
| Materials for reuse (only non-radioactive waste is relevant for Torness) | g | ND | 0.00E+00 | 3.45E+00 | ND | ND | ND | ND |
| Inert waste disposed of | g | 1.21E-04 | 1.34E-04 | 3.78E-03 | 4.03E-03 | 5.02E-04 | 6.79E-03 | 1.13E-02 |
| Other non-hazardous (non-radioactive) waste disposed of | g | 1.58E-04 | 1.25E-04 | 1.14E-03 | 1.42E-03 | 1.77E-04 | 1.91E-04 | 1.79E-03 |

It should be noted that for core operation, for waste to recycling and materials for reuse, results relate purely to the Torness core operation as it was not possible to assess this for the operation of offsite core facilities as largely generic datasets were used.

## 3.4 Life Cycle Interpretation

This section presents a high-level summary of the assessed environmental potential impacts. Note that a more detailed analysis is given in terms of GWP in a later section. Throughout the analysis, the colours indicate the core stages: yellow is upstream, green is core and blue is downstream.

### 3.4.1 Global Warming Potential (GWP) by LC stage

GWP-total is made up of three sub-indicators. Table 10 shows the contribution by life cycle (LC) stage to the total GWP-total value and to each of the GWP sub-indicators, per delivered kWh. The percentages have been RAG (Red-Amber-Green) rated in order to easily identify the highest contributing stage for each of the sub-indicators.

While each of the GWP sub-indicators contributes to GWP-total, they consider different sources. Therefore, while GWP-total may show a hotspot in one life cycle stage there will not necessarily be a matching hotspot within each of the sub-indicators in Table 10.

Table 10: Contribution to the total value for each GWP indicator per delivered kWh

| Environmental indicator | Upstream | Core construction | Core operation | Core decommission | Downstream T&D losses | Downstream other |
|---|---|---|---|---|---|---|
| GWP total | 13% | 28% | 16% | 6% | 8% | 29% |
| GWP fossil | 13% | 28% | 16% | 6% | 8% | 29% |
| GWP biogenic | 0% | 16% | 54% | 5% | 0% | 8% |
| GWP luluc | 6% | 26% | 13% | 31% | 9% | 15% |

The percentage contributions from each LC stage for the GWP total and the GWP fossil indicators are extremely similar as are their absolute results are show earlier in Table 7. This is because over 99% of the GWP-total values for all Torness electricity life cycle stages are driven by the GWP-fossil impacts, from the combustion of fossil fuels during upstream energy usage in the production of materials for example.

Table 10 shows that for GWP-fossil, the highest contributing stage is downstream other, followed closely by core construction, then core operation and upstream. The reasons for this will be covered later in this section and in later sections by focusing on GWP-total. It is important to note that the hotspots for GWP-fossil largely align with the hotspots for GWP-total. Generally speaking, this is largely because the contributing sources for GWP-fossil can be found throughout the supply chain, connected with the combustion of fossil fuels in transport, material production, material/waste processing, as well as from the decomposition from certain heavily used materials, such as limestone (for cement production). Conversely, the contributing sources for GWP-biogenic and GWP-luluc, tend to be clustered around specific activities that are not as prevalent at each life cycle stage (in general).

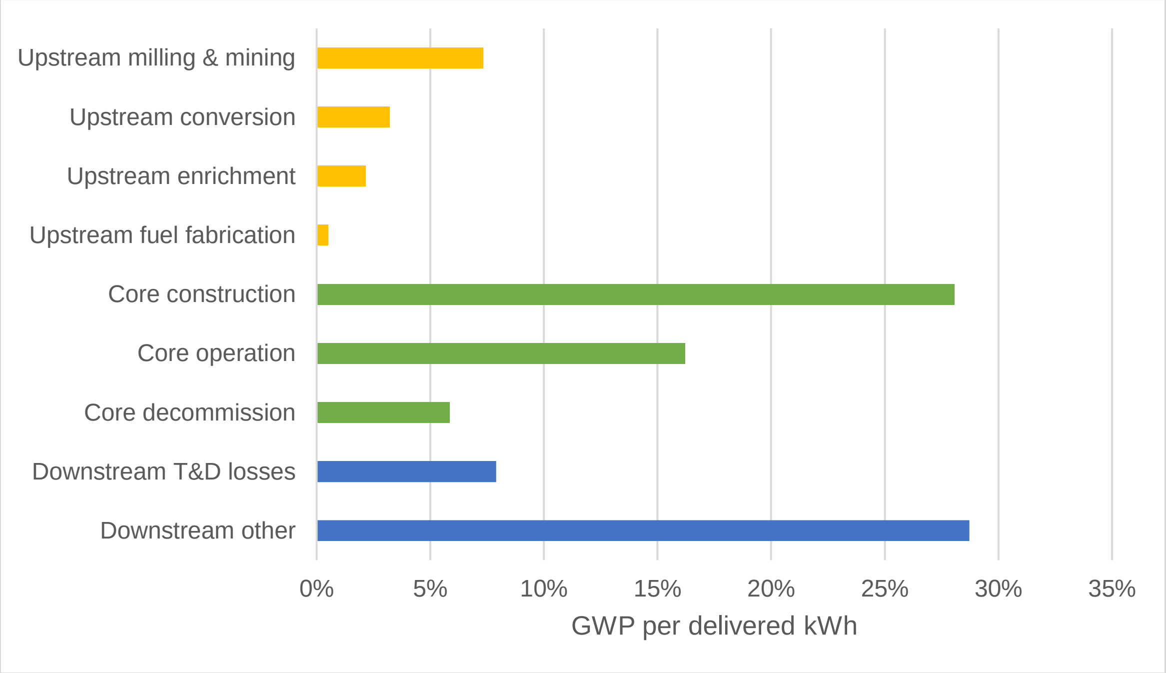
For GWP-biogenic, the core operation stage is the largest contributor, responsible for over half (54%) of the GWP-biogenic total (although this is less than 0.8% of the GWP-total value for this stage). Of the core operation stage, 84%, is associated with the upstream production of methane. The market for methane is a mix of fossil and biogenic sources. The eventual release of this biogenic portion contributes to the GWP-biogenic indicator. The GWP-biogenic contributions from other life cycle stages are much lower. This is because key sources such as methane from biogas combustion and decomposition of biogenic materials, are less prevalent.

For GWP-luluc, almost a third of the total emissions per delivered kWh arise from the decommissioning stage although it should be noted that this equates to only 0.6% of the GWP-total value for this stage. 86% of this GWP-luluc value is associated with the electricity dataset applied, which represents the potential GB grid mix in 2030. More specifically, the emission sources are associated with the hydroelectricity portion of the grid mix used in the decommissioning LC stage, which is higher than the portion in that used to represent the operational stage reference period. GHG emissions generated by changing the use of the land to facilitate pumped storage hydroelectric infrastructure, are responsible for these GWP-luluc emissions.

Core construction is also responsible for just under a third (26%) of the total Torness life cycle GWP-luluc related emissions. About half of this is again due land use changes associated with pumped hydroelectricity infrastructure arising from the ecoinvent current grid GB grid mix with the other half coming from a mix of land use changes associated with upstream production of constituents in certain construction materials.

The rest of the analysis on GWP in this document refers to the GWP-total results opposed to any of the three GWP sub-indicator results. GWP-total is of most interest to EDF and hence this level of analysis was considered sufficient for the purposes of this study. It is important to note that the results per the GWP sub-indicators should not be communicated without context.Figure 4 below therefore shows how each LC stage contributes to the total GWP-total value associated with generating and delivering 1kWh of Torness electricity to a customer.

Figure 4: Contribution by LC stage to total GWP value per delivered kWh



The collective downstream stage is responsible for 37% of the total GWP-total value and 29% arises from the substage ‘downstream other’. This element of the downstream stage encompasses both the infrastructure and operational requirements of the grid itself. Emission leakages of $SF_6$ insulation (a powerful greenhouse gas) is the largest contributor within 'downstream other'. $SF_6$ emissions in the ‘downstream other’ stage area responsible for 98% of all the $SF_6$ emissions and over 99% of the downstream $SF_6$ emissions. They also account for one third of all downstream GWP-total related emissions.

Some $N_2O$ emissions may also arise due to ionisation of air due to proximity to electromagnetic fields and high voltage lines. These values are taken from the generic ecoinvent datasets used to model the downstream impacts. These contribute to approximately one third of the downstream GWP value.

The remaining third of the total downstream GWP value comes from $CO_2$ emissions from additional generation required to counteract T&D losses.

For construction of core infrastructure, the largest drivers are the $CO_2$ fossil emissions from upstream manufacture of the required raw materials. Construction raw material associated emissions cumulatively contribute approximately 13% of the total GWP-total value over all life cycle stages per delivered kWh, and 21% of the total GWP-total value per generated kWh. The number one contributor to these Torness construction material GWP impacts is steel (50%), with stone (20%) and concrete (19%) being the next highest material contributors.

$CO_2$ fossil emissions associated with construction diesel combustion and electricity consumption are the second and third drivers, together contributing 10% of the total GWP value per delivered kWh.

In terms of the GWP contributions from core operation, 40.5% of its total contribution comes from electricity usage, and 34% comes from the upstream manufacturer of the construction materials needed. These respectively contribute just under 7% and 5.5% of the total GWP value per delivered kWh.

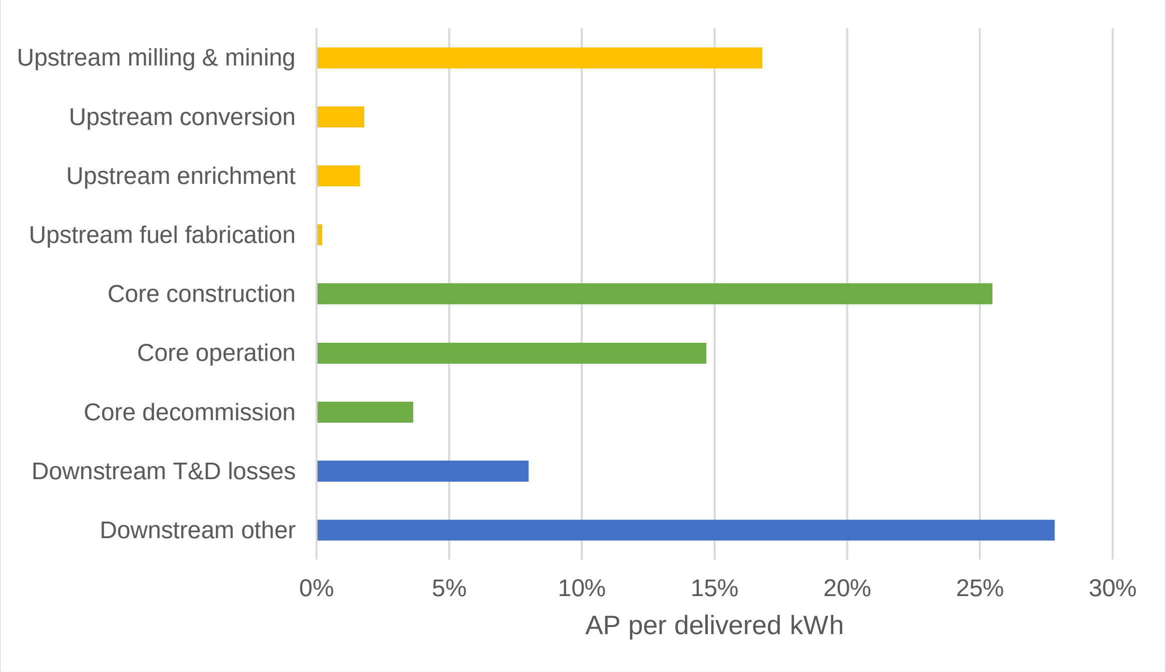
At 55% of the upstream stage GWP, milling and mining contributions are the highest contributor of the upstream stage, contributing 7% and 12% per generated and per delivered kWh, respectively. 93% of these contributions come from $CO_2$ fossil emissions largely linked to the energy consumption of these processes, in particular diesel combustion emissions.

### 3.4.2 Acidification Potential (AP) by LC stage

This indicator takes into the account acidic gases that react with water in the atmosphere to form “acid rain”, which can cause ecosystem degradation. In terms of AP, sulphur dioxide gas emissions are responsible for just over half (51%) of the total value per delivered kWh and 43% of the total value per generated kWh, with a further 42% and 52% arising from emissions of nitrogen oxides, respectively. Hydrogen sulphide emissions to water are responsible for 3% and just less than 2% of the total AP value per delivered and per generated kWh, respectively.

Figure 5 indicates that the ‘downstream other’ stage is again most significant, being responsible for 28% of the total AP value per delivered kWh. Much,73%, of the total value for ‘downstream other’ is from sulphur dioxide to air emissions for example those linked to grid infrastructure and related materials.

Figure 5: Contribution by LC stage to total AP value per delivered kWh



Contributions form the core construction stage are the second largest contributor, responsible for 26% and 40% of the total AP value per generated and per delivered kWh, respectively. 60% of this comes from the construction materials. This is due to a combination of different emissions, including the upstream sulphur dioxide producing impacts of processing the construction materials required, particularly from copper wiring/cabling. The copper wiring required for Torness infrastructure is responsible for 36% of the total AP value associated with Torness's construction materials or 22% of the total core construction value.

A further 20% of the AP value of core construction is associated with upstream electricity production.

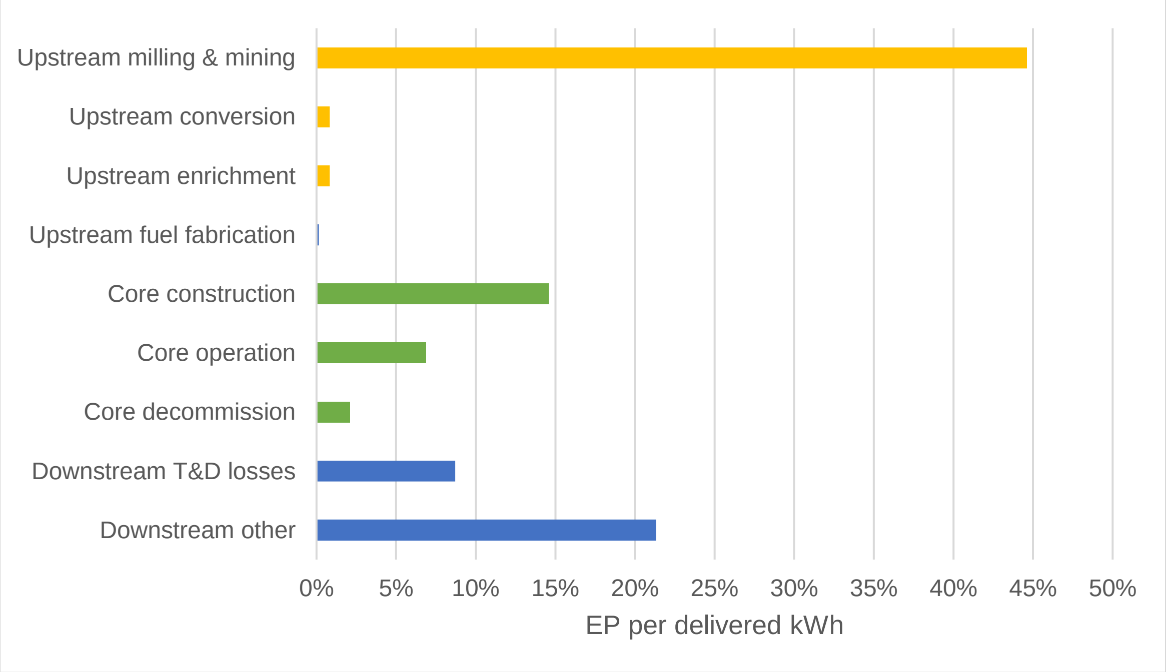
At 17% of the total delivered kWh AP value and 26% of the total generated kWh AP value, the upstream milling and mining stage is the third largest contributing stage with the top contributing emissions being nitrogen oxides to air (68% of milling and mining AP), followed by sulphur dioxide (30% of milling and mining AP). These emissions are linked largely to the diesel combustion emissions that occur during mining.

### 3.4.3 Eutrophication Potential (EP) by LC stage

Eutrophication is a reduction in water quality that can have detrimental effect on the local ecosystem. It is caused by an uncontrolled increase in nutrients such as phosphate and nitrogen, and of organic matter. In terms of EP relating to the generation and delivery of 1kWh from Torness, 39% of the substances that contribute to the total are nitrates and 42% are phosphates. In terms of the total EP value per generated kWh, these values are 49% and 32%. Nitrogen containing oxides contribute 15% to both the total delivered kWh EP value and to the total generated kWh EP value, with COD (chemical oxygen demand) and other nitrogen and phosphate containing chemical species responsible for the remainder.

Figure 6 demonstrates that 45% of the total EP values per delivered kWh comes from the upstream milling & mining stage, with 21% coming from the 'downstream other'. This equates to a 64% contribution from milling & mining in terms of the total per generated kWh EP value.

Figure 6: Contribution by LC stage to total EP value per delivered kWh



For milling & mining, 76% of EP contributions are generated by nitrate emissions to groundwater which mainly arise within the modelled in-situ uranium leaching process as well as by nitrate emissions to air due to diesel combustion during this same process.

Phosphate emissions by the transmission network infrastructure drive the contribution from the 'downstream other' stage. These emissions mainly arise from the copper used, and are linked to the treatment of sulfidic tailings generated during extraction of the copper.

By comparison, the core stages cumulatively contribute 24% to the delivered per kWh EP value and 34% to the generated per kWh EP value. Roughly 62% of the total core stage EP value is from construction, largely related to upstream material manufacture (39% of the core stage EP value). The majority of the remainder for the core stage comes from operation (29% of all core stages). The majority of this is associated with combustions from operational diesel usage (30% of core operation) and upstream manufacture of materials needed (29% of core operation), and the upstream generation of operational grid electricity usage (25% of core operation).

### 3.4.4 Photochemical Ozone Creation Potential (POCP) by LC stage

This indicator quantifies the ability of certain substances to take part in the creation of photochemical oxidants, primarily ground level ozone. These photochemical oxidants decrease air quality with negative effects on animals and the environment.

For the delivered kWh as modelled for Torness, 78% of these substances are nitrogen oxides, 13% are non-methane volatile organic compounds (NMVOCs) with the remainder being a mix of various sulphurous oxides, carbon monoxide, and hexane. In terms of the generated kWh, nitrogen oxides and NMVOCs contribute 80% and just under 12.5% of the total AP value.

The majority (67%) of the milling & mining POCP impacts are associated with the in-situ leaching of uranium dataset, more specifically, from nitrogen oxides and NMVOCs emitted during production and combustion of the diesel needed for the leaching process.

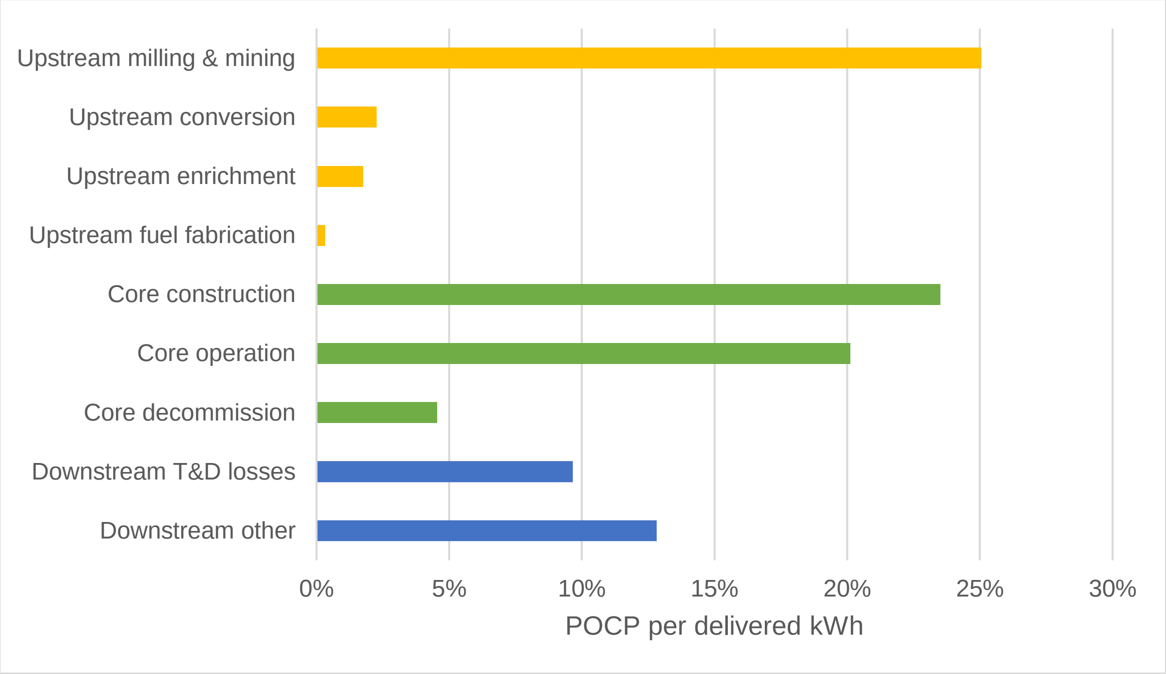
Emissions from the upstream manufacture of the materials required for Torness construction and emissions from Torness operational diesel usage are the main contributors to the core stage POCP allocation. Infrastructure material related emissions in ‘downstream other’ are responsible for most of the downstream stage.

Figure 7 indicates that upstream milling and mining of uranium is responsible for the marginally largest portion of the total POCP value per delivered kWh, contributing approximately 25%. This equates to almost 32% of the total POCP value per generated kWh. The construction of core infrastructure is responsible for 23.5% (or 30% in terms of per generated kWh) with ‘downstream other’ contributing a further 13% to the total POCP value per delivered kWh.

The majority (67%) of the milling & mining POCP impacts are associated with the in-situ leaching of uranium dataset, more specifically, from nitrogen oxides and NMVOCs emitted during production and combustion of the diesel needed for the leaching process.

Emissions from the upstream manufacture of the materials required for Torness construction and emissions from Torness operational diesel usage are the main contributors to the core stage POCP allocation. Infrastructure material related emissions in ‘downstream other’ are responsible for most of the downstream stage.

Figure 7: Contribution by LC stage to total POCP value per delivered kWh



### 3.4.5 Particulate matter by LC stage

Particulate matter is a type of pollution formed from a mixture of solid particles and liquid droplets in the air. Fine particulates are a particular issue due to their 'inhalability' and the method (ReCiPe 2006 mid-point) used to calculate particulate matter, quantities such emissions in terms of particles of sizes smaller than 2.5 microns, PM2.5 equivalents.

In terms of per delivered kWh, fine particulates smaller than 2.5 microns are responsible for 54.5% of the total particulate matter value, with a further 31% coming from sulphur dioxide particles and 14% from nitrogen oxides. The rest of the total is from other sulphur and nitrogen containing compounds. Note that sulphur oxide compounds can react with other compounds in the atmosphere to form small particulates which contribute to particulate matter.

In terms of the core construction stage, particulates associated with upstream extraction and manufacturing of construction materials, and of electricity, are the key drivers, as well as emissions associated with infrastructure of the offsite radioactive waste facilities (required during operation and decommissioning).

The uranium milling and mining generates dusts and PM2.5 via opencast extraction, and diesel combustion required for all three modelled mining types generates nitrogen and sulphur oxides. In total diesel combustion at the milling and mining stage is responsible for ~40% of the total milling & mining PM2.5 value with the treatment of tailings responsible for ~43% of the total PM2.5 value.

Electricity grid infrastructure and its construction generates a range of particulate material, in particular sulphur dioxide which contributes 66% of the 'downstream other' total particulate matter value.

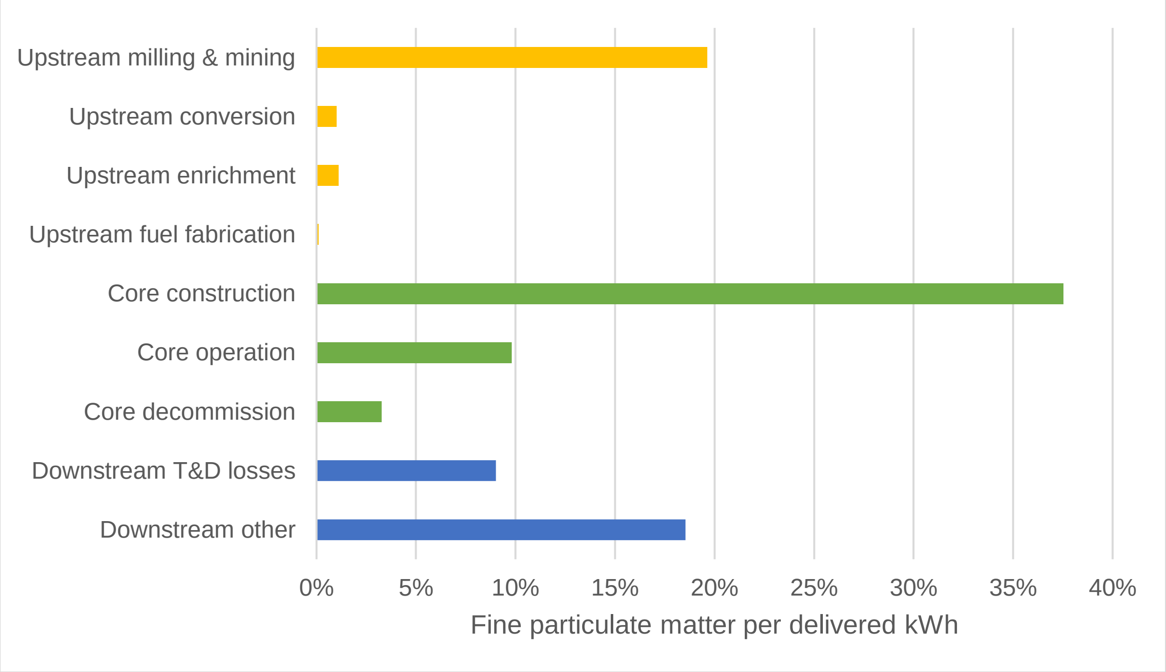
Figure 8 indicates that the core construction stage, the upstream uranium milling and mining stage, and the 'downstream other' stage, are collectively responsible for the majority of the total value. These stages contribute 37.5%, 20% and 18.5% of the total particulate matter value per delivered kWh, respectively. This translates to 27% and 52% in terms of generated kWh for the milling and mining stage, and for the core construction stage, respectively. (As the generated kWh value only covers impacts up until the electricity is ready to be transferred to the grid, no downstream impacts are applicable.)

In terms of the core construction stage, particulates associated with upstream extraction and manufacturing of construction materials, and of electricity, are the key drivers, as well as emissions associated with infrastructure of the offsite radioactive waste facilities (required during operation and decommissioning).

The uranium milling and mining generates dusts and PM2.5 via opencast extraction, and diesel combustion required for all three modelled mining types generates nitrogen and sulphur oxides. In total diesel combustion at the milling and mining stage is responsible for ~40% of the total milling & mining PM2.5 value with the treatment of tailings responsible for ~43% of the total PM2.5 value.

Electricity grid infrastructure and its construction generates a range of particulate material, in particular sulphur dioxide which contributes 66% of the 'downstream other' total particulate matter value.

Figure 8: Contribution by LC stage to total particulate matter value per delivered kWh

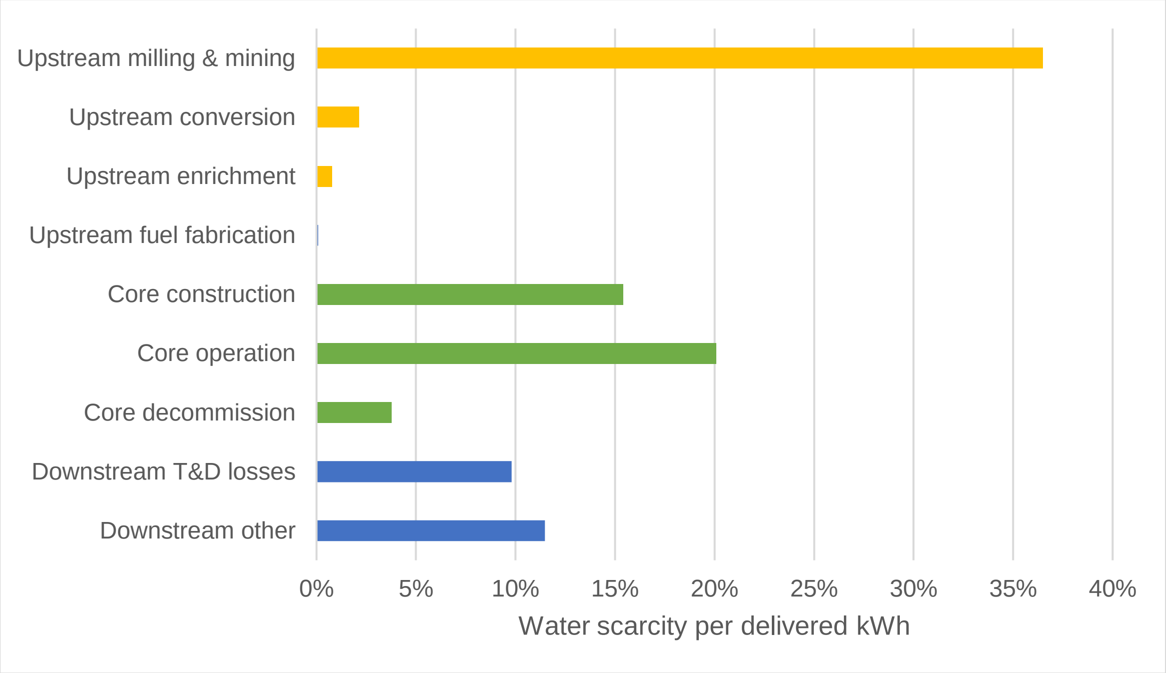


## 3.4.6 Water scarcity by LC stage

The AWARE method [9] reports in terms of potential water deprivation to the ecosystem and humans. It considers many variables including geography of region where water is extracted and agricultural water use. The higher the number, the higher the potential water deprivation or scarcity.

Figure 9 indicates that the stage with the highest potential for water scarcity is the upstream uranium milling and mining stage. This stage is responsible for 36.5% of the total AWARE value. This impact is a combination of the volume of water consumed during this stage and the mine locations' relative water stress level.

Figure 9: Contribution by LC stage to total water scarcity value per delivered kWh



### 3.4.7 Sensitivity analysis

Based on the analysis in the previous section, it can be seen that of the stages directly controlled by EDF, the core construction stage is frequently a dominating contributor per generated kWh for the many of the environmental indicators assessed.

Some of the construction data for Torness was based on an extrapolation of a BWR plant dataset, on a per tonne of concrete basis. Data within the BWR dataset was apportioned to the tonnage of concrete within this dataset and then this was applied to the total tonnage of Torness concrete to prorate values to the other materials and flows.

The BWR concrete value was given as a volume, so a density was applied to convert this to a mass. A concrete density of 2,370kg/m$^3$ to reflect normal concrete was applied, as this is the density documented within the normal concrete dataset. However, heavy weight concrete is required for certain infrastructures in a nuclear power plant as a radiation barrier. If a density more reflective of nuclear concrete was used, then this would generate a different mass of concrete within the BWR dataset which in turn would affect the extrapolated values generated for Torness.

A sensitivity analysis was carried out to see how sensitive the overall results would be to decreases in extrapolated construction data quantities using a density reflective of high-density nuclear concrete as opposed to normal concrete. The density used to convert the BWR concrete volume to tonnage is 3,800kg/m$^3$. This value was supplied in the separate LCA project for HPC and was informed by site contractors.

The use of the higher density concrete value to calculate the BWR concrete mass, results in a decrease in the results for all the core environmental impact categories for the core construction stage. Decreases are also observed in the decommissioning stage (as concrete is required to package wastes) and the downstream T&D loss stage. This latter increase is because T&D covers compensatory generation needed to balance out losses of electricity lost during T&D. Therefore, is it essentially a fraction of the upstream and core impact, hence is affected in the concrete sensitivity.

The total generated and delivered values decrease accordingly. They decrease respectively from 10.44g to 9.40g $CO_2$ eq. per generated kWh, and from 16.46g to 15.30g $CO_2$ eq. per delivered kWh.

These are decreases of are 10% and 7% respectively. These indicate that the results are somewhat sensitive to the change of concrete density applied. Therefore, it important to not take the results as absolute values but to consider the potential range they cover. In reality, the density of the concrete probably ranges across the different components of the site, so the actual results could be considered to sit somewhere between those generated for the baseline and this sensitivity scenario.

### 3.4.8 Global Warming Potential (GWP) focus

The potential carbon impacts are of most interest to EDF, so this section explores the GWP results further. It looks specifically at GWP-total values.

#### 3.4.8.1 Global Warming Potential (GWP) absolute values

The lifetime impact of generating Torness's electricity is calculated to be 4,434,169t $CO_2$ eq. This can be seen in Table 11 below. Of this, the core stages, which are the LC stages that EDF has most control over, are responsible for 3,436,268t $CO_2$ eq.

Table 11: Total lifetime GWP values of Torness

| Environmental impact | GWP (t $CO_2$ eq.) |
|---|---:|
| Upstream | 906,901 |
| Core construction | 1,922,568 |
| Core operation | 1,111,809 |
| Core decommission | 401,890 |
| **Total generated** | **4,343,169** |
| Downstream T&D losses | 540,840 |
| Downstream other | 1,967,409 |
| **Total delivered** | **6,851,418** |

Theoretically, if a downstream user was to receive 100% of the lifetime quantity of electricity generated by Torness, the impacts of counteracting downstream T&D losses and of the grid infrastructure, would add an additional 2,508,249t $CO_2$ eq. This downstream stage is largely beyond EDF's control. Adding this downstream impact onto the total generated impact results in a value of 6,851,418t $CO_2$ eq.

A breakdown of GWP value for distributed electricity by each LC stage is shown in Figure 10 below alongside the equivalent breakdown for generated electricity. It should be reiterated that reference to GWP refers to GWP-total values (i.e., the cumulative values of GWP-biogenic, GWP-fossil or GWP-luluc).

Figure 10: GWP breakdown of 1kWh Torness generated and 1kWh delivered electricity per LC stage

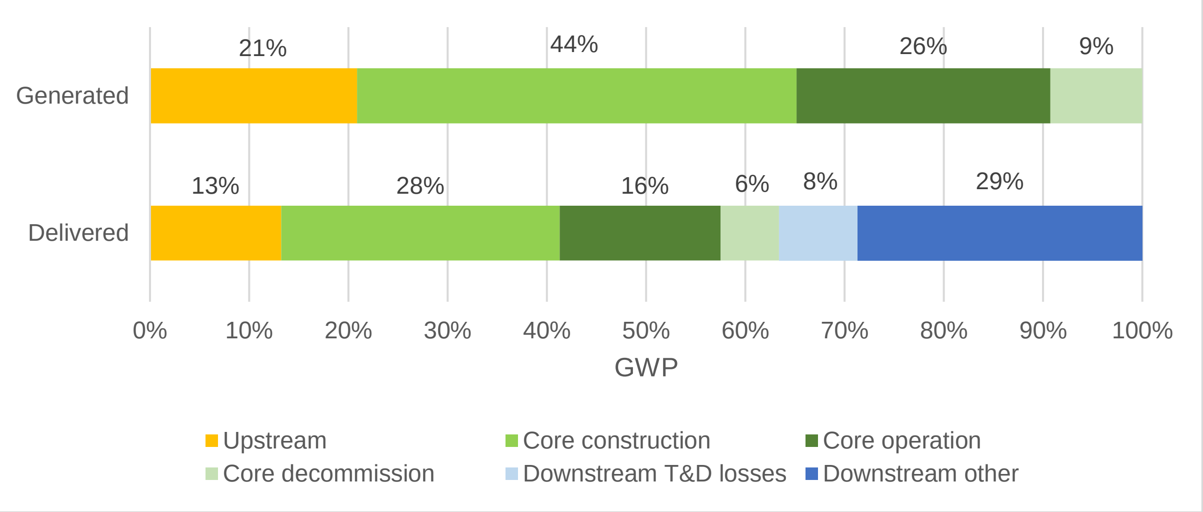


Figure 10 shows when considering the impacts of purely generating 1kWh of electricity at Torness, the upstream stage is just over a fifth of the GWP impacts. This impact represents the nuclear fuel supply chain and is further broken down into its four key stages in next section. The remaining impact can be attributed to the core stage, with 44% coming from core construction (construction of Torness but also infrastructure of offsite facilities such as waste treatment facilities). 26% arises due to operation of Torness and 9% is associated with Torness decommissioning activities.

When considering the additional impacts of distributing this generated electricity to a medium voltage user, additional GWP impacts arise, which shifts the percentage distribution. 37% of the total GWP value associated with a delivered kWh of electricity generated from Torness, comes from downstream impacts. This is made up of largely ‘downstream other’ contributions. This encompasses the infrastructure and operational requirements of the grid itself and includes the impacts of materials needed such as metals for pylons and emission leakages of $SF_6$ insulation (a powerful greenhouse gas), as included in the ecoinvent dataset. These types of impacts are related to the grid itself and would therefore be relevant to any type of electricity transported over the grid.

The other downstream LC stage, ‘Downstream T&D losses’, is responsible for 8% of the total GWP value for a delivered kWh of electricity. This encompasses the additional impacts associated with generating and distributing electricity required to mitigate the losses in the T&D network. These types of losses affect all forms of power generation that are connected to the electricity network.

Upstream impacts are responsible for 13% of the total GWP value of delivering 1kWh of electricity.

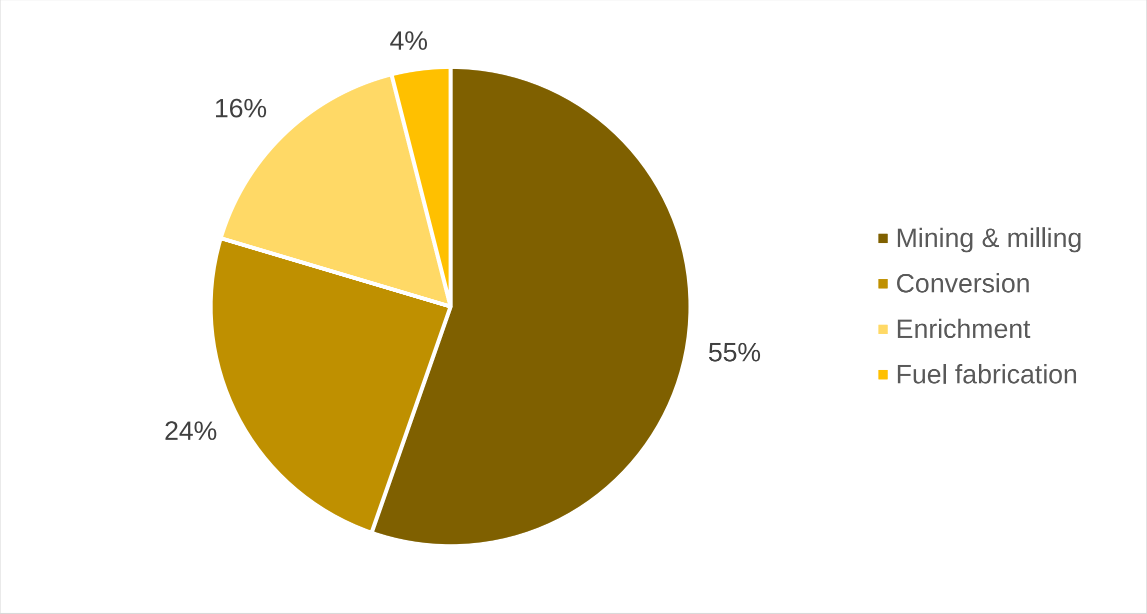
The construction of core infrastructure is responsible for 28% of the total delivered kWh GWP value. Core operation and core decommissioning are responsible for 16% and 6% of the total, respectively. In total, core impacts account for half of the total GWP value.

The following subsections show where the key GWP contributions come from for upstream and core LC stages. Note that the percentages in the labels do not necessarily sum to 100% due to rounding.

#### 3.4.8.2 Upstream

This section provides a breakdown of the four upstream LC stages’ GWP contribution. Together, these stages contribute a GWP value of 2.18g $CO_2$ eq. per kWh delivered, over the 42-year operational life of Torness. Figure 11 shows the split of the GWP-total value over the four upstream stages.

Figure 11: GWP breakdown of LCA stage – upstream



##### 3.4.8.2.1.1 Milling and mining

Figure 11 shows that the majority (55%) of the upstream GWP impacts are associated with the milling and mining of uranium from nature. Milling and mining was modelled using ecoinvent datasets. 58% of the total GWP contribution for milling and mining comes from the ISL mining dataset (Uranium, in yellowcake {GLO} | uranium production, in yellowcake, in-situ leaching | Cut-off, U), within which combusted diesel is the key contributing process (95% of this 58%). ISL mining is responsible for the highest percentage of mined uranium (per the split defined earlier in Table 4) and it is therefore understandable that it accounts for the highest GWP. However, it should be noted that ISL is an energy intensive process due to the pumping requirements of the mining technology.

The datasets representing the milling and mining of uranium from an open cast mine are responsible for 17% of the total milling and mining GWP value. The highest contributor within the open cast mined uranium ore process is milling energy. Conversely mining and milling provide roughly equal contributions within the underground mine source (which cumulatively contributes approximately a quarter of the total milling and mining GWP value). It should be noted that these are facets of the generic ecoinvent dataset so are not site specific.

#### 3.4.8.2.1.2 Conversion

The conversion process, whereby uranium ore is refined and converted to $UF_6$, is responsible for a quarter of the upstream GWP impacts. Its contributions arise mostly from gas usage in the ecoinvent dataset used (63%). Energy for the wet conversion process (as modelled in this study) is needed for processes such as evaporation, calcining and drying. The disposal of the LLW generated is the next highest contributor to the conversion GWP value 15%). Contributing just under 8% of the total conversion stage GWP-total value, the upstream production of the nitric acid used in the ecoinvent conversion dataset, is the third highest contributor.

#### 3.4.8.2.1.3 Enrichment

The enrichment of uranium, as modelled in this study, generates 17% of the upstream GWP impacts. SimaPro network flows indicate that this is largely from the UK electricity grid mix dataset, used for operating the centrifuge process (67%), and due to the embedded enrichment facility infrastructure dataset (24.5%).

#### 3.4.8.2.1.4 Fuel fabrication

The final stage of the nuclear fuel supply chain, prior to its transportation to Torness, is fuel fabrication, where enriched uranium is packaged into fuel assemblies. In this study, fuel fabrication generates 4% of the total upstream impacts, with the main source being emissions from the natural gas usage (85%).

### 3.4.8.3 Core construction

This section explores the percentage breakdown of the GWP value assigned to core construction, part of the core infrastructure stage, is described. Together, these processes or sub-stages generate a GWP value of 4.62g $CO_2$ eq. per kWh delivered.

Figure 12: GWP breakdown of LCA stage - construction of core infrastructure

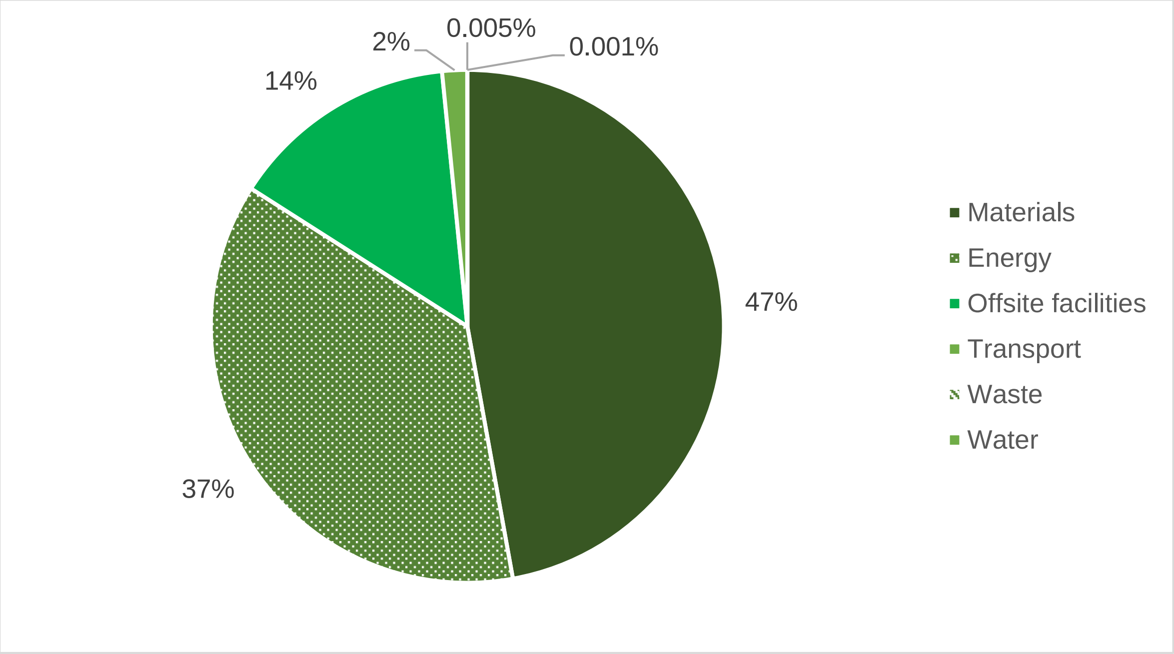


Figure 12 shows that 84% of the GWP value associated with construction of core infrastructure is from energy and material usage, with 47% from the embodied carbon of the construction materials required, largely steels (approximately half of the construction material impacts), stone (20% of the construction material impacts) and concrete (19% of the construction material impacts). 37% of the total construction stage impact is associated with the energy needed to construct Torness. This energy relates to both UK grid electricity (based on current mix) but also diesel, excavation activities and gas usage. The contribution between electricity, and diesel, excavation and gas usage, is split 92%/8%, respectively.

The infrastructure of offsite facilities used for treating/disposing of operational radioactive wastes (as embedded with the ecoinvent datasets for radioactive waste disposal) is responsible for 14%.

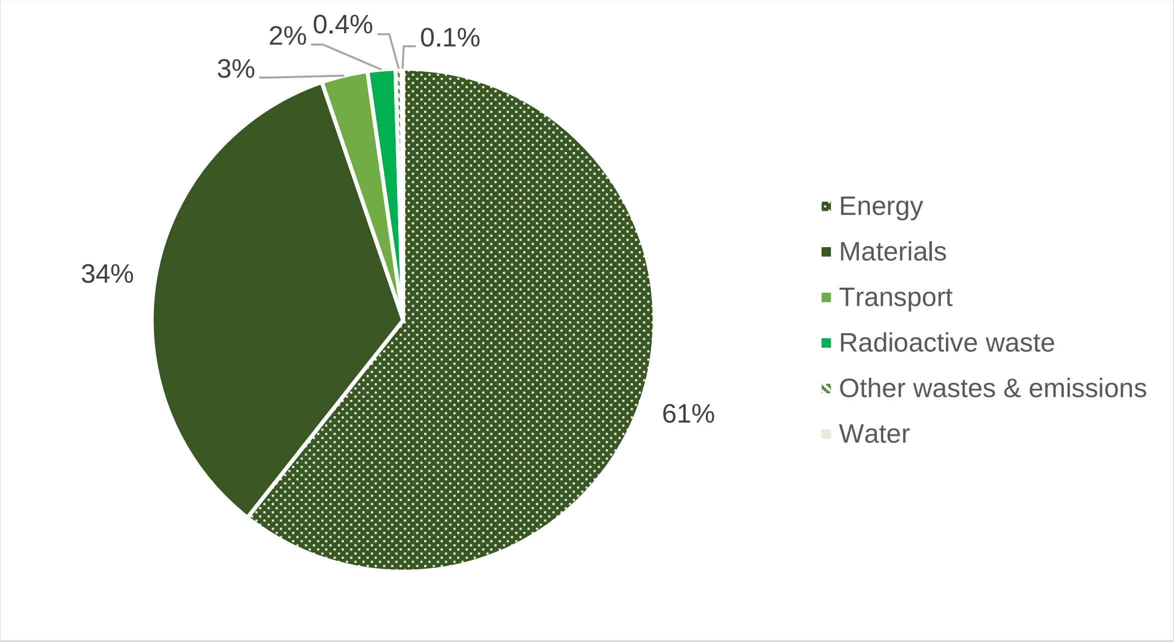
The transportation of construction materials to the Torness site and transport of construction waste offsite, are together responsible for 2% of the core infrastructure construction's GWP. Transport impacts include, amongst others, emissions from fuel combustion and vehicle operation, as well as embodied carbon in the vehicle itself and the road infrastructure (where relevant). Some of this transport is by water.

The treatment and disposal of waste generated during the construction period and the impact of water usage during construction, can be considered to be relatively insignificant in terms of GWP impact, contributing less than half a percent cumulatively.

#### 3.4.8.4 Core operation

This section examines the percentage breakdown of the GWP value assigned to core operation of the Torness over its estimated 42-year life. Together, these processes or sub-stages generate a GWP value of 2.67g $CO_2$ eq. per kWh generated. This includes commissioning of the Torness reactors and related buildings. As with the previous upstream and core processes, this value is the same per kWh delivered, since the extra impacts arising from the generation of electricity required to overcome losses are assigned to the downstream LC stage.

Figure 13: GWP breakdown of LCA stage – core operation



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delivered, since the extra impacts arising from the generation of electricity required to overcome losses are assigned to the downstream LC stage.

Figure 13 shows that in terms of core operation, 61% of the GWP value comes from energy requirements. This consists of electricity imports and diesel usage. These two energy sources respectively contribute at a 66.5%/33.5% split.

34% of the core operation GWP value can be allocated to the materials needed for commissioning and operation of the Torness plant. This includes materials such as stainless steel that are required to package radioactive wastes generated during operation.

Transport of materials to site and of wastes from site to their respective offsite disposal or treatment locations contribute 3%.

A further 2% of core operation's GWP value comes from the offsite treatment and disposal of radioactive wastes. A large portion of this is due to the incineration dataset used to represent LLW incineration, mostly from emissions to air.

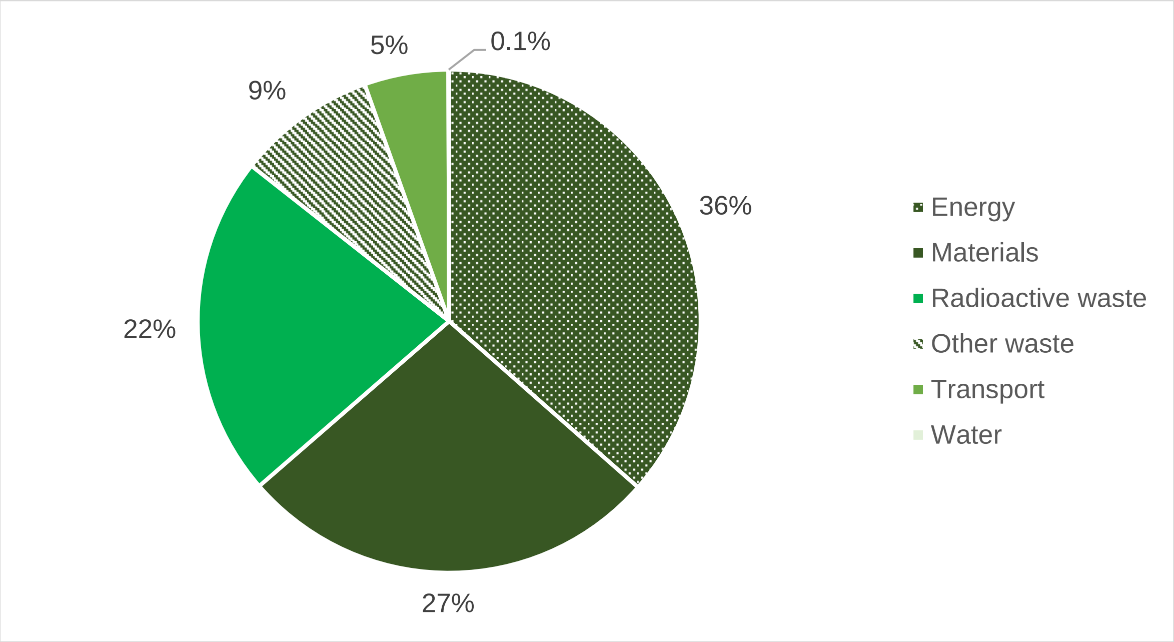
During operation, Torness will generate non-radioactive wastes, and direct emissions to air and water. These cumulatively account for 0.4% of the core operation GWP value in the model.

Water usage contributes a relatively small amount of the operational GWP value (0.1%).

#### 3.4.8.5 Core decommissioning

This section describes the percentage breakdown of the GWP value assigned to core decommissioning of Torness. Together, these processes or sub-stages generate a GWP value of 0.97g $CO_2$ eq. per kWh delivered.

Figure 14: GWP breakdown of LCA stage – decommission of core infrastructure



This section describes the percentage breakdown of the GWP value assigned to core decommissioning of Torness. Together, these processes or sub-stages generate a GWP value of 0.97g $CO_2$ eq. per kWh delivered.

Figure 14 shows that 36% of decommissioning's GWP comes from the energy used. The GWP from energy usage is mainly contributed by the forecast 2030 UK electricity grid mix, and to a lesser extent, diesel. The split of GWP impacts between electricity and diesel is 82%/17%, respectively.

Embodied carbon of the materials needed for decommissioning, essentially packaging of the radioactive wastes, contributes just over a quarter of the decommissioning GWP value. Over 90% of this is from the steel packagings.

The disposal of radioactive waste contributes 22% of the decommissioning GWP value.

The treatment of non-radioactive wastes is responsible for 9%. 45% of this value is due to emissions associated with incineration of LLW, 24% from operational impacts within the GDF dataset, and the remaining amount from operational impacts of the LLWR.

Transport of packaging materials to site and of wastes offsite contributes 5% of the decommissioning GWP value.

The contribution to the GWP value for decommissioning from non-seawater usage, such as that used in cooling pools at the Torness site, is again a negligible amount in terms of GWP.

### 3.4.9 Data quality and commentary

With all models, uncertainty exists. A key aspect of uncertainty within this study is that approximations of the likely quantities and types of materials, utilities and associated transport, have been used to represent construction as limited Torness specific (historic) construction data was available. These values were extrapolated from an ecoinvent BWR dataset on a per tonne of concrete basis. Whilst this extrapolation introduces some uncertainty into the model, it is based on ecoinvent data from which some assurance of data quality can be taken. The extrapolation provides a conservative coverage of additional materials and energies for which no Torness specific data was available.

An exclusion from the construction stage are facilities constructed during decommissioning. However, a test during modelling was done to see if adding in data for the SFRF facility used in the SZB model made a difference to the overall results, but results changed by less than 0.01% of the total value per environmental impact category so it can be considered to be insignificant. Therefore, the requirement has been met for data to be included for elementary flows to and from the product system contributing to a minimum of 99% of the declared environmental impacts.

A further degree of uncertainty is introduced in the form of assumptions that have needed to be applied to derive primary data in the format required for the LCA, for example (but not limited to) assumptions of the density of materials and assumed locations of disposal sites. However, EDF has applied rationale and adopted a conservative approach when applying these assumptions so resulting figures can be considered to not be underestimates.

Asides from fuel fabrication, EDF were not able to disclose details of Torness's upstream supply chain. Therefore, specific data was not available. In this absence, specific data supplied by SZC's potential uranium enricher was used. Whilst this data may not reflect the exact suppliers which EDF uses, it can be considered to be the most reliable data available for modelling at this point in time. Both the datasets for fuel fabrication and enrichment have been supplemented or gap filled using ecoinvent datasets to ensure that no 'key' input or output flows are unaccounted for. A dataset was created for the UK future GDF based on data provided by SZC Co which was derived from the most conservative of the three scenarios currently scoped. In terms of the uranium sources at mining and milling stages, splits representing realistic potential mining types for virgin sources was assumed and can be considered to be conservative.

To represent the life cycle stages substages for conversion, milling and mining, downstream infrastructure and offsite waste treatment ecoinvent datasets were chosen based on their technological and geographical relevance. In the absence of specific data, they are therefore considered suitable and representative for purpose in this instance. Generic data (ecoinvent datasets) was also used to represent all upstream infrastructure. It is understood that the ecoinvent datasets represent technological averages for the given geographies and reflect recent time frames.

All ecoinvent data processes present a certain level of uncertainty. Uncertainty analysis of the selected ecoinvent datasets in the model was carried out within SimaPro. Looking at the uncertainty within the ecoinvent datasets themselves, it indicates with 95% confidence that results range from 15.10g to 18.00g $CO_2$ eq. / kWh delivered and from 9.31g to 11.70g $CO_2$ eq. / kWh generated.

Where specific data from EDF has been provided, it can be assumed that the quality of data is high. Where this was not available, the use of ecoinvent dataset ensures some level of quality.

Minimal datasets were used within the model where an exact or same material type was not available within the ecoinvent database and the closest considered alternative ecoinvent dataset was used instead. This is relevant to the dataset used to represent the future Scottish NSNS repository, where the data for the future UK GDF was used instead. However, radioactive waste disposal impacts account for less than 2% of the total GWP value per delivered kWh, and most of this is due to incineration of LLW. Therefore, it can be assumed that for the GWP impacts associated with proxy data do not exceed 10% of the overall GWP impact from the product system.

It should be noted that data filling for the construction stage was gap filled by extrapolation from a BWR ecoinvent dataset in lieu of data for a generic AGR. However, whilst the reactor for these two difference nuclear plant types will vary, it is reasonable to assume that the other core support buildings and hence majority of construction flows, would be similar.

The assessment of the data quality parameters as carried out in the full LCA report conclude that the overall data quality of the study is sufficient to allow conclusions to be made in accordance with the goal and scope. However, results should be interpreted with some caution as most construction data is an extrapolation of data from an ecoinvent dataset as opposed to specific data. As with any LCA modelling, it is important to note that estimated impact results are only relative statements which do not indicate the end points of the impact categories, exceeding threshold values, safety margins or risks.

# 4 Additional Environmental Information

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

## 4.1 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).

### 4.1.1 Protection of the operating personnel

For all relevant Torness 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 all facilities representing the full nuclear fuel cycle.

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 millisieverts (mSv) [10]. However, UK legislation requires doses to workers to be as low as reasonably practicable and EDF operates a policy of minimising risks according to this principle. It also operates to a more restrictive Company Dose Restriction Level of 10mSv.

Table 12: Average annual dose to personnel at the facilities in the nuclear fuel cycle for the Torness reference period

| Fuel cycle stage | Facility, Location | Average annual dose to personnel (mSv per year) 2018 | 2019 |
|---|---|---|---|
| Mining and milling | Orano/Cameco, Cigar Lake and McClean Mill, Canada [11] | 0.47 | 0.57 |
| | Orano, Muyunkum and Torkuduk mines, Kazakhstan [12] | 2.5* | 2.5* |
| | CNNC Rossing Uranium, Rossing mine, Namibia [13] | 1.2 | 1.4 |
| Conversion | Orano, Malvési, France [14] | 0.038 | 0.039 |
| | Orano, Pierrelatte, France [15] | 0.05 | 0.03 |
| Enrichment | Urenco facility, Capenhurst, UK [16] | 0.39‡ | 0.26‡ |
| Fuel Fabrication | Westinghouse, nr Preston, UK [17] | 0.32† | 0.32† |
| Generation | Torness, Scotland, UK [17] | 0.53 (2016 - 2020 5 year average) | |

* Average for June 2018 to July 2019, average for all Orano mining employees, not mine specific; ‡ Average of four different Urenco enrichment sites; † Estimated off graph for latest available data found for all Springfield Fuel ltd employees, only 2016 value found.

### 4.1.2 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. This can result 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. These annual discharge limits for Torness are shown in the following table, along with the actual discharge values since 2018. It can be seen that for each of the listed discharge species, the annual discharges are within the annual limit.

Table 13: Discharge authorisation limits to three significant figures

| Discharge species | Annual discharge limit [17] [18] [19] | Annual discharges 2018 [17] | 2019 [18] | 2020 [19] | Unit |
|---|---|---|---|---|---|
| **Gaseous releases** | | | | | |
| Tritium | 11,000 | 1,320 | 1,110 | 862 | GBq |
| Carbon-14 | 4,500 | 1,330 | 1,360 | 1,450 | GBq |
| Iodine-131 | 2.00 | 0.00592 | 0.00173 | 0.00165 | GBq |
| Particulate beta | 0.400 | 0.0104 | 0.00741 | 0.00665 | GBq |
| Argon-41 | 75,000 | 5,090 | 7,290 | 6,530 | GBq |
| Sulphur-35 | 300 | 46.8 | 41.8 | 36.4 | GBq |
| **Liquid releases** | | | | | |
| Alpha | 0.500 | 0.00381 | 0.00161 | 0.00706 | GBq |
| Tritium | 700,000 | 295,000 | 323,000 | 299,000 | GBq |
| Cobalt-60 | 10.0 | 0.363 | 0.247 | 0.177 | GBq |
| All other non-alpha | 150 | 4.34 | 4.38 | 3.08 | GBq |
| Sulphur-35 | 3,000 | 528 | 845 | 348 | GBq |

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 1mSv 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 [18].

In general, most of the activity entering the food chain is due to the effects of discharges at Sellafield, 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) 2019 monitoring report [19] in Table 14. These should be compared with public dose limits of 1mSv from artificial sources and typical natural exposures of 2.3mSv.

Table 14: Dose to members of the local population in a 0.5km to 1km radius

| Pathway | Exposure (mSv) to Prenatal children of local 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 | <0.005 | - | - |
| Total | <0.025 | <0.015 | <0.011 |

## 4.2 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).

### 4.2.1 Torness

#### 4.2.1.1 Regulation

The activities at Torness are governed by various Acts of Parliament. Of particular importance is the Nuclear Installations Act 1965 (as amended) [20], 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 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).

#### 4.2.1.2 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 [21].

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 100km – woven through them. It also serves as a biological shield that reduces radiation emissions.

#### 4.2.1.3 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 [21]. 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 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.

### 4.2.2 Final repository

#### 4.2.2.1 Nuclear safety

The analysis presented in this section is based upon research undertaken by the Nuclear Decommissioning Authority (NDA) and relates to its Phased Geological Repository Concept (PGRC) 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.

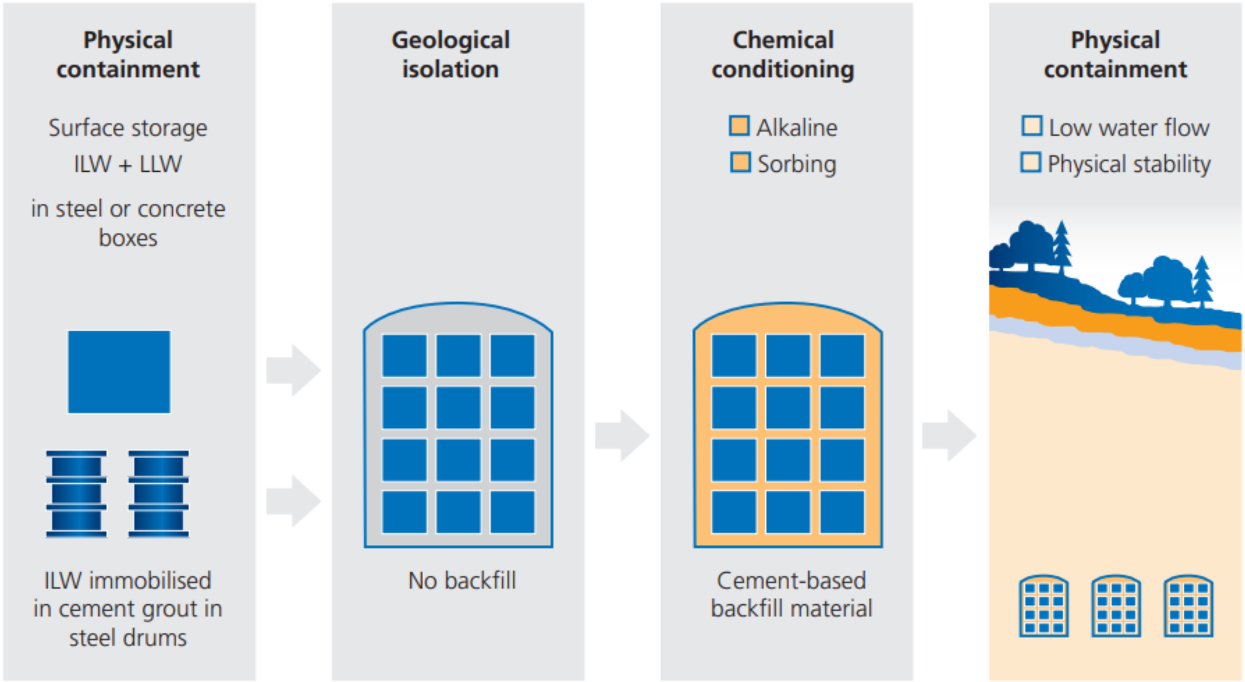
The development of the final disposal concepts has been undertaken in accordance with NDA's Generic Operational Safety Assessment procedures [23]. Its scope includes examination of the on-site transport of the waste packages, transfer of the waste packages below ground, emplacement of the waste packages 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.

This study 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 15. 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 15: The multi-barrier disposal concept [22]



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 [24].

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 (OSA) showing that the current limits stated in the Ionising Radiation Regulations (IRR) [25] can be met and that no significant challenges to the viability of the concept have been identified. Furthermore, most of the activities planned for PGRC are comparable to those carried out on licensed nuclear sites in the UK, and other nuclear sites throughout the world.

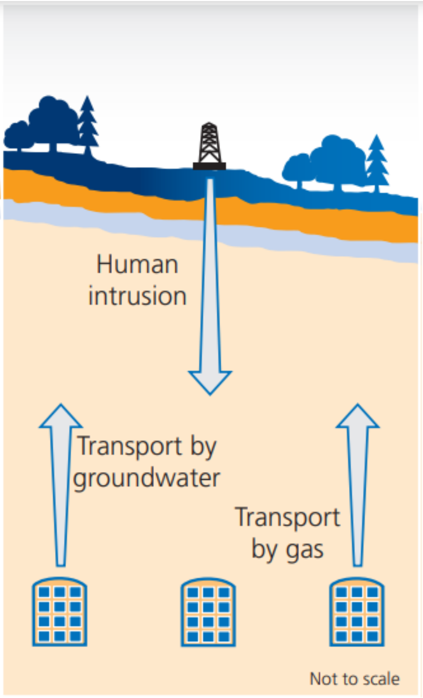
#### 4.2.2.2 Nuclear safety risks at the final waste repository

**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 16: Schematic illustration of main assessment pathways (not to scale) [22]

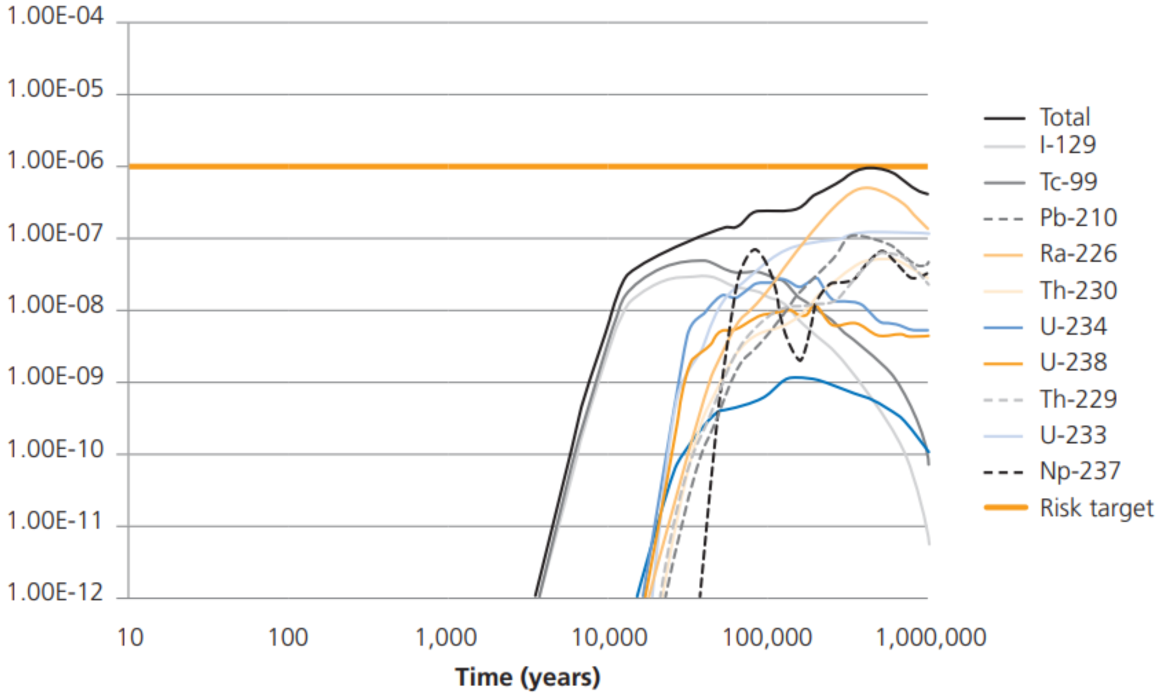


**Groundwater pathway**

The reference case radiological risk versus time plot for the groundwater pathway, is shown in Figure 17. 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 17 are for the whole inventory of UK waste arisings. The specific contribution from the Sizewell B power station waste will also be below the regulatory risk target.

Figure 17: Reference case radiological risk against time [22]



**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 breakthrough of gas at the surface is estimated to occur at around 6,000 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.

### 4.2.2.3 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/spent fuel Concept [26]. This essentially refers to the UK future GDF. 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 (GPA) [26]. 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/ spent fuel 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/spent fuel is lower than the radiological risk from naturally occurring radon by a factor of 40.

The potential for a criticality in the Reference HLW/spent fuel concept has been assessed and shows there is no risk of criticality.

#### 4.2.2.4 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 9m onto a rigid surface, an 800ºC fire for 30 minutes and a water immersion test equivalent to a water depth of 200m.

PSAs 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 Health and Safety Executive (HSE) as “broadly acceptable” [27].

## 4.3 Environmental risks

Environmental risks at Torness are managed in accordance with EDF’s Environmental policy [28]. 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 15 below.

Table 15: Environmental risks

| Priority | Description |
|---|---|
| 1 | Heating & Ventilation (HV) 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 |

| Priority | Description |
|---|---|
| 8 | Active Emissions |
| 9 | Management Control |
| 10 | Cooling Water Abstraction |

## 4.4 Land use

The total area of the Torness site is approximately 144ha, of which around 30ha is permanently exploited for operational activities.

### 4.4.1 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 most current land use classification (from 2005), provides an indication of the change in land use type that has occurred as a result of the Torness facility. Such classification can be seen in map format in Figure 18 and Figure 19 respectively.

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 sections.

Figure 18: Land use classification of the Torness estate pre-construction (1977)

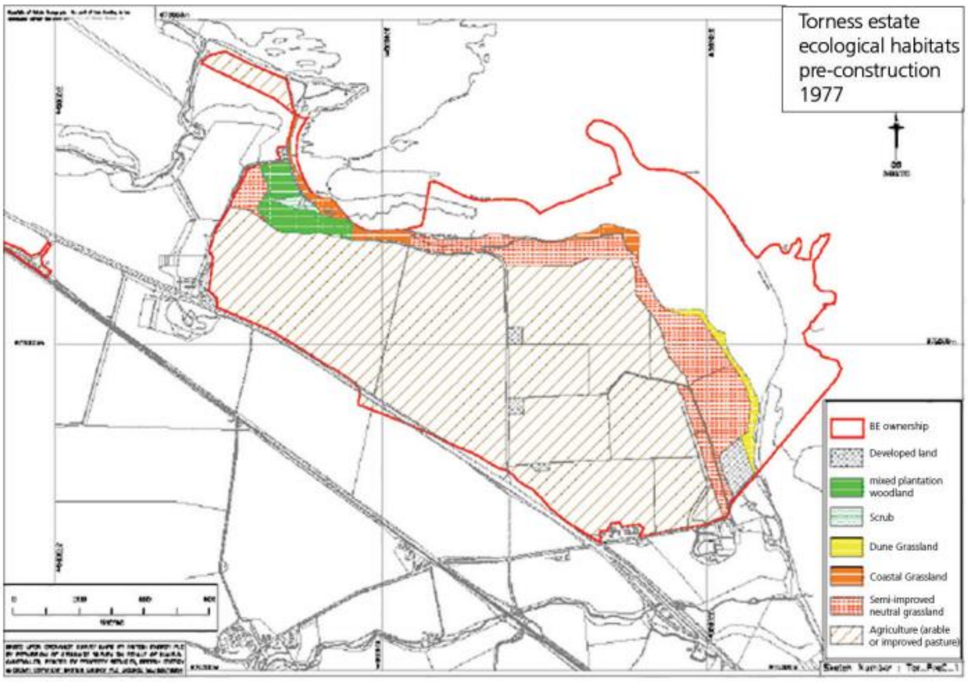


Figure 19: Land use classification of the Torness estate post-construction (2005)

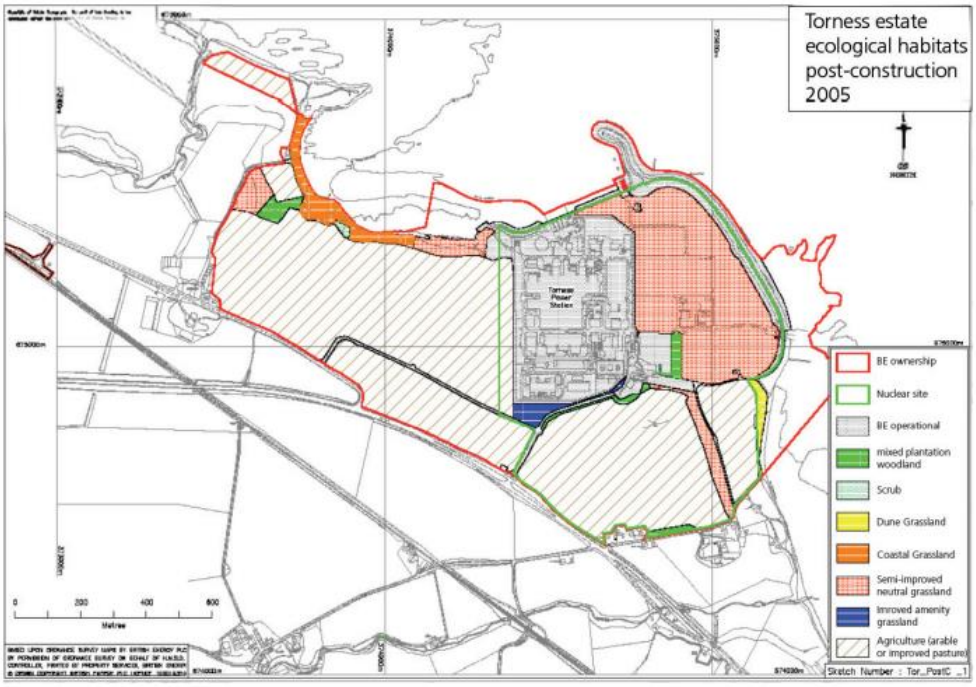


Table 16 describes the change in land use types from the pre-construction era to the most recent period accounted for, 2020, by total area.

Table 16: Land use classification of the Torness estate pre and post construction

| Land use classification | Area in 1977 (ha) | Area in 2020 (ha) |
|---|---|---|
| Artificial | 0 | 29.7 |
| Agricultural | 84.6 | 71.5 |
| Forest and semi-natural | 20.3 | 42.5 |
| Wetlands | 0 | 0 |
| Water bodies | 0 | 0 |
| Unspecified | 0 | 0 |
| Total | 104.9 | 143.7 |

Note that due to change over ownership since construction, it was not possible to fully account for prior land use classification of the current 144ha of the Torness site.

## 4.4.2 Statutory designations

### 4.4.2.1 International

The Firth of Forth, stretching for more than 100km of Eastern Scottish shoreline, is designated as a Special Protection Area (SPA). It comprises the estuary of the river Forth, extensive wetlands, sand and gravel banks, mudflats, reedbed and offshore islands and is home to a number of internationally important waterfowl. The Forth Islands are also an SPA, home to fulmar, gannet and puffin among other seabirds.

### 4.4.2.2 National

The Firth of Forth is also a Special Site of Scientific Interest (SSSI) and covers to mudflats, saltmarshes and reedbeds that are invertebrate-rich and nationally important feeding grounds for birds. Botanically rich grasslands are also found in the SSSI and are home to nationally rare plant species. It is also designated a RAMSAR site because of the waterfowl that make their home in the wetlands.

The Isle of May, one of the Forth Islands, is an SSSI and is home to over 250,000 seabirds. The surrounding sea is also protected, designated a Marine Protected Area (MPA). The Firth of Forth Banks Complex supports a rich ecosystem including crabs, starfish, seals and dolphins, which also makes it a vital feeding ground for the bird population.

#### 4.4.2.3 Local

In the local area is Aberlady Bay, a local nature reserve and John Muir Country Park, home to 400 species of plant, a variety of insects including butterflies and moths, and various species of bird, some of which breed in the park.

Torness sits within the Whitsands, Barns Ness, Skateraw and Thorntonloch coastal sites which comprise coastal grasslands and sandy and rocky shores. These grasslands are home to wildflowers that thrive in salty soiles, such as the autumn gentian, white horehound and yellow-horned poppy.

### 4.4.3 Biodiversity

#### 4.4.3.1 Current biodiversity

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’s Torness estate extends to some 144ha and comprises mainly arable land, grassland and foreshore adjoining the operational site. Much of the foreshore and coastal fringe of EDF’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 Outer Firth of Forth and St Andrews Bay Complex is a proposed marine SPA that lies offshore adjacent to the Estate coastal boundary. Within the site are numerous firths, inlets and sandy bays that provide important refuges for wintering and breeding birds. To the south is the St Abbs and Eyemouth Voluntary Marine Reserve covering 1,030ha 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), which contains diverse marine habitats including mud and sand flats, reefs and sea caves. 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. St Abb’s Head to Fast Castle, south-east of Torness, is a SAC that has been designated for supporting vegetated sea cliffs.

Since 2015, Torness has held the Wildlife Trust’s Biodiversity Benchmark award.

#### 4.4.3.2 EDF and biodiversity

EDF’s Biodiversity Action Plan (BAP) identifies the priority habitats and species at each of EDF’s sites; sets and monitors biodiversity targets for EDF and identifies ways in which staff and local communities can be involved through education, participation and partnership [29]. 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 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 eight bat boxes and 16 bird boxes. Tree sparrow (UK BAP priority species) immediately nested in one of the bird boxes in 2012 whilst four 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.

## 4.5 Electromagnetic fields

The term “electromagnetic field” (EMF) refers to the lower frequency range of the electromagnetic spectrum (0 to 300GHz). 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.

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) [30]. This became law in the UK on 1st July 2016. Control is also exercised through the general duties in the Health and Safety at Work etc Act 1974 [31], the Management of Health and Safety at Work Regulations 1999 [32] and by reference to International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines [33]. In 2010 the ICNIRP issued new guidelines for the frequency range 1Hz to 100kHz. 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 1800μT for magnetic fields and 46kV/m for electric. EDF strives to keep its operation within these limits where possible.

## 4.6 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.

# 5 References

[1] International Organization for Standardization, “ISO 14040:2006 / AMD 1:2020; Environmental management - Life cycle assessment - Principles and framework,” ISO, 2006.

[2] International Organization for Standardization, “ISO 14044:2006; Environmental management - Life cycle assessment - Requirements and guidelines,” ISO, 2006.

[3] P. Kershaw, D. Weatherseed and J. Pollin, “Torness Nuclear Power Station: Civil Engineering Construction,” *Proceedings of the Institution of Civil Engineers,* vol. 78, no. 5, pp. 1139-1163, 1139-1163 1985 1985.

[4] Department of Business, Energy and Industrial Strategy (BEIS), “Publications: Supplementary data for Annex O: BEIS 2019 Updated Energy & Emissions Projections, v1.0 11-12-2020, Projection of electricity generation by source: Major Power Producers,” 11 December 2020. [Online]. Available: https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2019. [Accessed 4 May 2021].

[5] National Grid, “Future Energy Scenarios 2020 Documents: Data Workbook; Tab SV.26: Electricity output by technology (excluding non-networked offshore wind),” 2020. [Online]. Available: https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents. [Accessed 14 April 2020].

[6] P. Kershaw, D. Weatherseed and J. Pollin, “Torness Nuclear Power Station: Civil Engineering Construction,” *Proceedings of the Institution of Civil Engineers,* vol. 78, no. 5, pp. 1139-1163, 1985.

[7] Radioactive Waste Management, “Geological Disposal: Generic Carbon Footprint Analysis; Technical Note no. 27754118,” 2016.

[8] National Grid ESO, “Transmission Losses,” June 2019. [Online]. Available: https://www.nationalgrideso.com/document/144711/download.

[9] A. B. J. B. L. e. a. Boulay, “The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining (AWARE),” *International Journal of Life Cycle Assessment,* vol. 23, p. 368–378, 2018.

[10] Health and Safety Executive, “Occupational exposure to ionising radiation,” March 2017. [Online]. Available: https://www.hse.gov.uk/statistics/ionising-radiation/cidi.pdf. [Accessed 10 February 2021].

[11] Cameco Corporation, “CNSC Commission Member Document (CMD): Request for Licensing Decision: Regarding Cigar Lake Operation; Table 3.8-1: Summary of dose statistics during licence term.,” 5 Feburary 2021. [Online]. Available: https://www.cameco.com/uploads/downloads/relicensing_cigar_lake/Cigar_Lake_2021_Licence_Renewal_CMD.pdf. [Accessed 1 December 2021].

[12] Orano, “Orano Mining: Corporate Social Responsibility Report 2020,” June 2021. [Online]. Available: https://www.orano.group/docs/default-source/orano-doc/groupe/publications-reference/orano_mining_rapport_rse_en.pdf. [Accessed 13 December 2021].

[13] CNNC Rossing Uranium, “Rossing Uranium: Report to stakeholders 2019,” April 2020. [Online]. Available: https://www.rossing.com/files/2019%20Rossing%20Report%20to%20Stakeholders%20July%202020.pdf. [Accessed 13 December 2021].

[14] Orano, “Rapport d'information du site Orano Malvesi: Edition 2020,” June 2021. [Online]. Available: https://www.orano.group/docs/default-source/orano-doc/groupe/publications-reference/tsn-orano-malvesi_vf.pdf?sfvrsn=3be54e73_25. [Accessed 13 December 2021].

[15] Orano, “Rapport d'information du site Orano Tricastin: Edition 2020,” June 2021. [Online]. Available: https://www.orano.group/docs/default-source/orano-doc/groupe/publications-reference/orano-tricastin_rapportinformation2020.pdf?sfvrsn=5cd09328_34. [Accessed 13 December 2021].

[16] Urenco, “Sustainability report 2020,” 12 July 2021. [Online]. Available: https://www.urenco.com/cdn/uploads/supporting-files/SR-2020.pdf. [Accessed 13 December 2021].

[17] Westinghouse, “Springfields Site Stakeholder Group: Site Reports - April 2017,” 2017. [Online]. Available: https://www.westinghousenuclear.com/Portals/2/documents/Springfields%20Site%20Report%20-%20April%202017.pdf. [Accessed 13 December 2021].

[18] Scottish Government, “Scotland's Marine Atlas: Information for the national marine plan,” 2011. [Online]. Available: https://www.gov.scot/publications/scotlands-marine-atlas-information-national-marine-plan/pages/16/. [Accessed 5 August 2021].

[19] Centre for Environment, Fisheries and Aquaculture Science, “Radioactivity in Food and the Environment, 2019,” 2020.

[20] UK Government, “Nuclear Installations Act,” 5 August 1965. [Online]. Available: https://www.legislation.gov.uk/ukpga/1965/57. [Accessed 27 May 2021].

[21] Health & Safety Executive, “The Tolerability of Risk From Nuclear Power Stations,” Office for Nuclear Regulation, 1992.

[22] Nirex, “The viability of a phased geological repository concept for the long-term management of the UK's radioactive waste,” United Kingdom Nirex Limited, 2005.

[23] Radioactive Waste Management, “Geological Disposal: Generic Operational Environmental Safety Assessment, NDA Report no. DSSC/315/01,” December 2016. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/635079/NDA_Report_no_DSSC-315-01_-_Geological_Disposal_-_Generic_Operational_Environmental_Safety_Assessment.pdf. [Accessed 14 March 2021].

[24] RWM, “Summary Report: RWM's approach to environmental and sustainability assessment,” 200. [Online]. Available: https://rwm.nda.gov.uk/publication/summary-report-rwms-approach-to-environmental-and-sustainability-assessment/. [Accessed 11 October 2021].

[25] UK Government, “The Ionising Radiations Regulations 2017 (SI 2017/1075),” November 2017. [Online]. Available: https://www.legislation.gov.uk/uksi/2017/1075/pdfs/uksi_20171075_en.pdf. [Accessed 10 February 2021].

[26] RWM, “Generic repository studies generic post-closure performance assessment Nirex Report N/080 July 2003,” 2003. [Online]. Available: https://rwm.nda.gov.uk/publication/generic-repository-studies-generic-post-closure-performance-assessment-nirex-report-n080-july-2003/. [Accessed 11 October 2021].

[27] EDF Energy, “Integrated Company Practice: Management of PWR Fuel,” EDF Energy, 2020.

[28] EDF Energy, “Company Policy: Environment Policy,” 2021. [Online]. Available: https://www.edfenergy.com/sites/default/files/edf_environment_policy.pdf#:~:text=EDF%E2%80%99s%20Environment%20Policy%20is%20aligned%20to%20EDF%20Group,that%20helps%20us%20to%20meet%20our%20environmental%20targets.. [Accessed 16 August 2021].

[29] EDF Energy, “Biodiversity Action Plan,” EDF Energy, 2016.

[30] European Union, “Directive 2013/35/EU on the minimum health and saftery requirements regarding the exposure of workers to the risks arising from physical agents (electronic fields),” 2013. [Online]. Available: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:179:0001:0021:EN:PDF. [Accessed 16 August 2021].

[31] UK Government, “Health and Safety at Work etc. Act,” 1974. [Online]. Available: https://www.legislation.gov.uk/ukpga/1974/37/contents. [Accessed 5 August 2021].

[32] UK Government, “The Management of Health and Safety at Work Regulations,” 1999. [Online]. Available: https://www.legislation.gov.uk/uksi/1999/3242/contents/made. [Accessed 5 August 2021].

[33] INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION (ICNIRP), “ICNIRP Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Published in HEALTH PHYSICS 74 (4):494-522; 1998,” 1998. [Online]. Available: https://www.icnirp.org/cms/upload/publications/ICNIRPemfgdl.pdf. [Accessed 13 October 2020].

[34] EDF, “The Inspector General’s report on Nuclear Safety and Radiation Protection 2019; ... AND RADIATION PROTECTION RESULTS,” 2019. [Online]. Available: https://www.edf.fr/sites/default/files/contrib/groupe-edf/producteur-industriel/nucleaire/Notes%20d%27information/igsnr-2019-report-uk.pdf. [Accessed 25 May 2021].

[35] The Energy and Climate Change Committee, “Energy network costs: transparent and fair? 5 Losses and leakages, Network losses,” [Online]. Available: https://publications.parliament.uk/pa/cm201415/cmselect/cmenergy/386/38607.html. [Accessed 5 January 2021].

[36] International Organization for Standardization, “ISO 14025:2006 Environmental labels and declarations — Type III environmental declarations — Principles and procedures,” 2006.

[37] Orano, “Rapport d’information due site Orano Malvesi; Exposition radiologique des salariés d’Orano Malvési,” 2019. [Online]. Available: https://www.orano.group/docs/default-source/orano-doc/groupe/publications-reference/orano_tsn_malvesi_2019.pdf?sfvrsn=623341c3_12. [Accessed 25 May 2021].

[38] Orano, “Rapport d’information du site Orano Tricastin; Dosimétrie moyenne des salariés Orano Tricastin,” 2019. [Online]. Available: https://www.orano.group/docs/default-source/orano-doc/groupe/publications-reference/oranotricastin_tsn_2019_rapport.pdf?sfvrsn=7d5ef035_18. [Accessed 25 May 2021].

[39] UK Government, “Environmental Permitting (England and Wales) Regulations,” 2010. [Online]. Available: https://www.legislation.gov.uk/ukdsi/2010/9780111491423/contents. [Accessed 5 August 2021].

[40] EDF Energy, “Sizewell B Nuclear Power Station Emergency Plan,” 2020. [Online]. Available: https://www.edfenergy.com/sites/default/files/sizewell_b_nuclear_power_station_emergency_plan_0.pdf. [Accessed 8 August 2021].

[41] Office for Nuclear Regulation, “The Tolerability of Risk from Nuclear Power Stations,” 1992. [Online]. Available: https://www.onr.org.uk/documents/tolerability.pdf. [Accessed 5 August 2021].

[42] Nuclear Decommissioning Authority, “Geological Disposal Generic Operational Environmental Safety Assessment,” 2016. [Online]. Available: https://rwm.nda.gov.uk/publication/geological-disposal-generic-operational-environmental-safety-assessment/. [Accessed 5 August 2021].

[43] EDF Energy, “SIzewell Estate Pre Construction Land Management Plan,” 2017.

[44] D. R. Davies and C. R. A. C. Richardson, “Proceedings of the Institution of Civil Engineers; Civil Engineering; Volume 108; Issue 5; Power station design; pp. 15-29,” February 1995. [Online]. Available: https://www.icevirtuallibrary.com/doi/abs/10.1680/icien.1995.27312. [Accessed 27 July 2021].

[45] CNNC Rossing Uranium, “Moving Foward to the New Era: Stakeholder Report 2020,” April 2021. [Online]. Available: https://www.rossing.com/files/RUL%20Stakeholder%20Report%20-%202020.pdf. [Accessed 13 December 2021].

[46] EDF, “The Inspector General's report on Nuclear Safety and Radiation Protection 2020,” January 2021. [Online]. Available: https://www.edf.fr/sites/default/files/contrib/groupe-edf/producteur-industriel/nucleaire/Notes%20d%27information/report-2020-uk-v06b-web.pdf. [Accessed 13 December 2021].

# A1 Deviations from the Electricity PCR

Table 17: Summary of deviations from the Electricity PCR requirements

| PCR section | Requirement | Comment |
|---|---|---|
| 4.3.1.1: Upstream Processes & 4.3.1.2: Core Processes | The PCR indicates that the “storage of auxiliary materials and chemicals at energy conversion site” should be included in the upstream results, but that “storage processes of any inputs or outputs of the energy conversion performed by the company” should be included in the core results. | Torness includes storage facilities. The impacts associated with storage were modelled within the core stage, not the upstream stage. |
| 4.3.1.1: Upstream Processes | The PCR indicates that infrastructure associated with upstream processes should be included with exclusion motivated by the cut-off rules. | Torness does not have access to data on conversion and mining & milling sites’ infrastructure burdens. Assumptions were made based on global uranium sourcing and a generic ecoinvent data set was used. Infrastructure is included to the extent that it is included in the selected ecoinvent datasets. |
| 4.3.2.3: Geographical boundaries | The PCR states that "data for core operation shall be site-specific." | For off-site core operation, data for the potential UK GDF was based on design plans (so not historical data) and for other offsite waste facilities, specific data was not available so ecoinvent data was used. This was used to represent the potential future Scottish NSNS repository. |
| 4.7.2: Core processes & 4.10.2.3: Nuclear technologies | The PCR states that “Specific data shall be used for amounts of inputs and outputs in activities of handling/treatment/storage of fuel related waste”. | Ricardo interprets this to refer to operational data for offsite radioactive waste treatment facilities. Radioactive waste from Torness goes to the UK LLWR, incineration, and recycling treatment. Some SF goes to Sellafield until the GDF becomes available. No specific data was available for these sites. Therefore, best fit generic ecoinvent datasets have been used. For recycling, impacts were cut-off at the point they reach the recycling facility. For the SF to Sellafield, the GDF dataset has been used. This has also been used to represent the future Scottish NSNS repository. |
| 4.7.2: Core processes & 4.10.2.3: Nuclear technologies | Similar to the above, infrastructure data is also to be reported for these offsite facilities. | Again, specific data was not available. Infrastructure has been covered to the extent that it is in the generic ecoinvent datasets used to represent these treatment facilities/disposal sites. These do not appear to include dismantling of the disposal sites. |
| 5.4.4: Environmental Performance | The PCR requires that the LCA results be reported in terms of the three core modules (upstream, core, downstream) and total. | To provide additional insight, Ricardo has reported to a more granular level, in terms of upstream, core construction, core operation, core decommission, total generated, downstream T&D losses, downstream other and total delivered. These results can be combined by the reader to obtain results per the three core stages as required. |

| PCR section | Requirement | Comment |
|---|---|---|
| 5.4.4.2: Use of Resources | The PCR requires that results are expressed as:<br>Primary energy resources – Renewable (MJ, net calorific value) – used as energy carrier and used as material<br>Primary energy resources – Non-renewable (MJ, net calorific value) – used as energy carrier and used as material | Ricardo has reported primary energy resources in a similar way to the Vattenfall EPD (https://portal.environdec.com/api/api/v1/EPDLibrary/Files/edd6ae95-c679-42c1-98c7-b5818d841c5b/Data) in terms of raw input flow inventories as opposed to applying an assumption (for example) that crude oil input flows are used to plastic (material) or petrol (energy). |
| 5.4.4.2: Use of Resources | The PCR requires that results are expressed in terms of secondary material used. | This is possible for the Torness site but not for upstream, downstream, or offsite (non-EDF) facilities/sites as this information on inventory data was not available. Therefore, these have been reported as 'ND' (not declared). |
| 5.4.4.3: Waste Production and Output Flows | The PCR requires that results are reported as “Low-level, no treatment (such as mining/milling wastes), in case of nuclear power, for upstream and downstream stages”. | Low level radioactive waste (LLW) without further treatment was not estimated or declared as it was not clear what ‘treatment’ referred to. Even LLW which go to final repositories will incur impacts, so it was not considered relevant to try to account for this indicator. |
| 5.4.4.3: Waste Production and Output Flows | The PCR also requires that results are reported as components for reuse, materials for energy recovery and material for recycling, for upstream, core and downstream stages. | This data was not available for stages which are not under the control of EDF as ecoinvent data was used (where waste is followed to the grave so generated amounts not readily available). Results have been reported at top level for components of the core stage controlled by EDF (i.e., not the offsite waste repositories for which generic ecoinvent datasets were used). |
| 5.4.5.2: Additional environmental information not based on LCA | The PCR requires that specific environmental information that is not related to the LCA shall be reported. | It was not possible to fully cover all of the non-LCA requirements of the PCR. The below rows indicate those particular aspects of the non-LCA information that the PCR specifies shall be reported but where it has not been possible to completely meet the requirement. |
| 5.4.5.2: Additional environmental information not based on LCA - Radiology | The PCR requires that the following issues shall be addressed: "in the case of nuclear power, during normal operation in the reference year/period in the main life cycle stages, fuel production, operation of energy conversion plant, and management of fuel residues expressed as dose in mSv." | Ricardo instead obtained (from online review) recent available annual mSv values to personnel for the upstream stages for the specific companies assumed for this LCA. These are for specific sites, which may or may not be part of Torness’s supply chain.<br>For the management of fuel residues, a value has not been provided. |
| 5.4.5.2: Additional environmental information not based on LCA - Risk related issues | The PCR requires that the following issues shall be addressed: "Risk related issues - radiology and human toxicological risks" | This has been addressed qualitatively in sections such as "Regulation" and “Nuclear safety”. |

| PCR section | Requirement | Comment |
|---|---|---|
| 5.4.5.2: Additional environmental information not based on LCA - Risk related issues | The PCR requires that the following issues shall be addressed: "Risk related issues - environmental risks"<br>• "Mishaps with environmental impact, that happen less frequent than once in three years should be identified and the impacts quantified<br>• Potential undesired events with high or very high impact but low or minute probability (e.g., nuclear reactor meltdown…etc.) shall be identified and described qualitatively." | EDF has not quantified environmental risks in absolute terms but 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. The report provides qualitative overviews of the findings of certain risk assessments, indicating whether risks were found to be tolerable and if not, what action is being taken. Key safety aspects, largely barrier methods, to prevent high impact events have been addressed in the communication document. |
| 5.4.5.2: Additional environmental information not based on LCA - Land use and land use change | The PCR specifies that the following issues shall be addressed "land use and land use change expressed in square meters of specified land category according to Corine Land Cover Classes before and after exploitation where before is the area in the situation before the start of the activities within the lifecycle and after is the area in the time period corresponding to the validity of the EPD. Focus is on the core module meaning that all core module land use shall be classified but also land exploited by fuel suppliers (mining, forestry or agriculture) shall be quantified and classified. Other significant land use in up- and down-stream processes should be included (https://land.copernicus.eu/user-corner/technical-library/copy_of_Nomenclature.pdf)". | Regarding land use, primary data is not readily available beyond the Torness site and EDF has chosen to report land use changes for Torness only. Due to change of ownership, data for the pre-construction period is limited.<br>The PCR also specifies that the number of years be given that the areas are occupied, expressed as the area occupied per year of operation. This has not been given due to lack of data. |
| 5.4.5.2: Additional environmental information not based on LCA - Impacts of biodiversity | The PCR requires that the following issues shall be addressed "Direct regional impacts concerning nature conservation issues like biodiversity and visual impact connected to land use." | Information for upstream, downstream, and offsite core facilities was not readily available so only information on onsite biodiversity has been provided. |
| 5.4.5.2: Additional environmental information not based on LCA – Visual impacts | The PCR requires that the following issues shall be addressed: “Visual impacts” | This has not been explicitly addressed although an image of the plant is shown on the cover page. |

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# Review of the LCA Report (Dated May 24th, 2022) “Life Cycle Assessment of Torness nuclear power plant,” and EPD-style document (Dated May 24th, 2022) “Life cycle assessment of electricity from Torness nuclear power plant development”

## Prepared by Ricardo Energy & Environment, Ricardo-AEA Ltd.

## Review Statement Prepared by the Critical Reviewer:

## Julie Sinistore, PhD

May 24th, 2022

The Critical Reviewer has completed the review of the report and Environmental Product Declaration (EPD)-style document named above. The review has found that:

- the approaches used to carry out the LCA aspects of this analysis are consistent with the ISO 14040 (2006a) and ISO 14044 (2006b) principles;
- the methods used to carry out the LCA appear to be scientifically and technically valid;
- the interpretations of the results are defensible; and
- the report is transparent concerning the study steps.

The review was conducted according to the aforementioned standards as the EPD-style document is intended to be communicated externally. The review was conducted in three stages. The reviewer first reviewed the first draft of the report and submitted written comments to the study authors. The report authors responded to these comments and submitted a revised draft of the LCA report and EPD-style document based on that report. A second round of comments were submitted to the report authors from the reviewer. The study was then finalized by the report authors, and the reviewer performed a third, and final, review. The reviewer’s comments and responses to those comments have been documented in an Excel file called “WSP Critical Review EDF Torness LCA report - round 2 - May 2022 post rev2 - WSP.”

This review should in no way be construed as an endorsement of the products or the results of this study.

Note that the EPD-style document is not an EPD nor is it intended to be construed or communicated as one. These documents were not reviewed per the relevant EPD standard ISO 14025. The EPD-style document was prepared to be consistent with the relevant Product Category Rule (PCR) for electricity from nuclear power, however, it was determined that some information required by the PCR would not be available for use in this study, therefore, an EPD could not be completed and verified. A complete list of the exact deviations from the PCR is provided in appendix A1 in the EPD-style document and appendix A13 in the LCA report. The reviewer has concluded that the documents include all of the mandatory elements required by the ISO standards 14040 and 14044 standards. Additional elements not included in an LCA arise from the requirements of the PCR such that, if the missing information required by the PCR becomes available, the EPD will be able to be developed and verified at a later time.

This review statement applies only to the documents named above, dated May 24th, 2022, and not to any other versions, derivative reports, excerpts, press releases, or similar publications.

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