



Radioactive Waste
Management

ViSI: RWM's digital safety case management tool

Oliver Hall & Lucia Gray

The safety case



“An environmental safety case is a set of claims concerning the environmental safety of disposals of solid radioactive waste, substantiated by a structured collection of arguments and evidence.”

Environment Agency – Guidance on Requirements for Authorisation



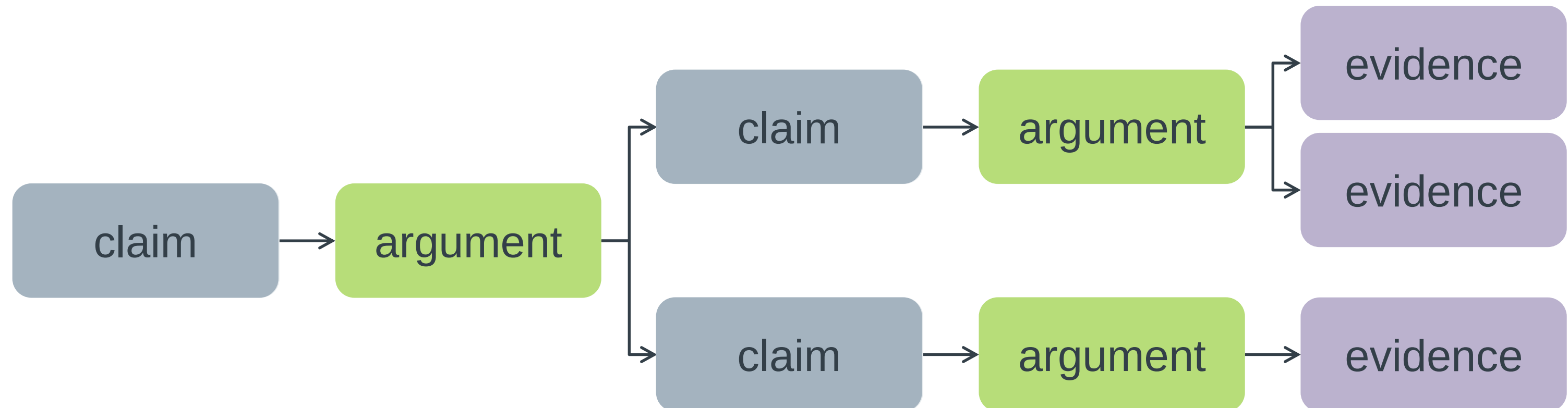
“A safety case is a logical and hierarchical set of documents.” “The safety case clearly sets out the trail from safety claims through arguments to evidence.”

Office for Nuclear Regulation – Safety Assessment Principles for Nuclear Facilities

- RWM is looking to emphasise this logical, structured format in its safety cases and is currently developing a generic claims, arguments, evidence (CAE) diagram which illustrates the safety case in an explicit CAE structure.

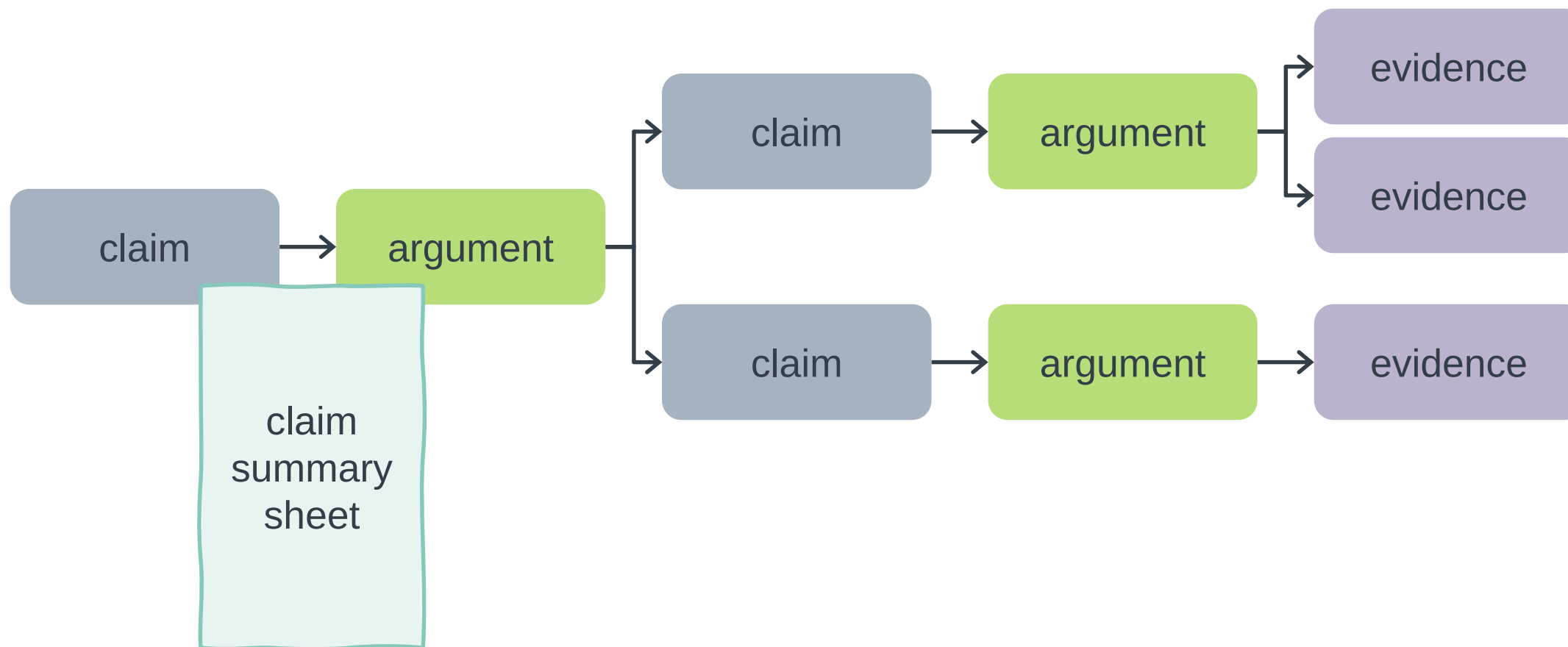
CAE terminology

- **claims** are assertions put forward for general acceptance.
- **evidence** provides the basis of justification for a claim.
- **arguments** provide an explanation of how the collective sub-claims/evidence demonstrate a claim.



Summary sheets

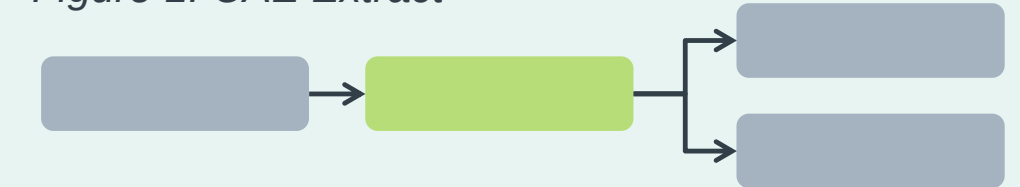
- Each claim in the diagram has an underlying summary sheet associated with it.



CLAIM X: Title

Introduction ?

Figure 1: CAE Extract



Basis and interpretation ?

Argument ?

Summary of subclaims and evidence ?

-

-

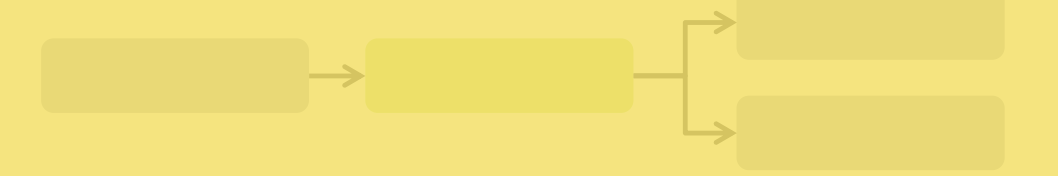
- ?
 - Provides the safety case context for the claim by explaining why we are making the claim from a safety case perspective.
 - Includes an extract from the CAE diagram, showing the claim, the sub-claims and evidence that underpin it, and the argument that links them.
- ?
 - Describes the claim RWM is making.
 - Provides relevant guidance, regulatory and legislative context and any interpretation that has been applied.
 - Includes links to documents explaining RWM's own stance, and to sponsor and system requirements within RWM's requirements management system, which may inform the claim or be derived as a consequence of it.
- ?
 - Provides an explanation of the logical connection between the claim and its subclaims/evidence, but does not make any assertions about the logical correctness of any subclaims.
- ?
 - Provides a brief summary of the subclaims and evidence that underpin the claim, with links to corresponding pages.



CLAIM X: Title

Introduction ?

Figure 1: CAE Extract



Basis and interpretation ?

Argument ?

Summary of subclaims and evidence ?

-

-

ViSI

- **ViSI: Visualisation of System Information**

ViSI is a digital safety case management system designed to display RWM's environmental safety case and the underpinning knowledge in an accessible and traceable way.

- ViSI is now available on the NDA's secure cloud platform for authorised external users

ViSI's vision statement - goal

- ViSI's goal is to:
 - manage the large and growing body of safety case information,
 - author safety case content, manage configuration and control changes to it,
 - provide a 'golden thread' of traceability between safety claims articulated within the safety case and evidence provided in the underlying knowledge base,
 - support RWM in planning its technical programme by aiding research identification and prioritisation, while also aiding concept selection and waste management, and
 - allow users to navigate, view and search all content intuitively.

ViSI's vision statement - approach

- The approach taken is to:
 - use digital technologies to allow users to intuitively write, navigate, view and search all content, interrogate the safety case and trace the 'golden thread',
 - introduce an explicit presentation of the ESC claims, arguments and evidence structure, and
 - make ViSI available, as needed, to RWM staff, its supply chain and Regulators.

ViSI's safety case document collection

All safety case documents and diagrams can be loaded from the home page.

ESC Bibliography Glossary S&T Plan Publication ETL Pipeline Help

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Environmental Safety Case

Radioactive Waste Management

Documents

DSSC

- Overview of the generic Disposal System Safety Case
- Technical Background to the generic Disposal System Safety Case
- Data Report
- Generic Environmental Safety Case
- Generic Post-closure Safety Assessment
- Generic Post-closure Performance Modelling
- Waste Package Evolution Status Report
- Behaviour of Radionuclides and Non-radiological Species in Groundwater
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- Concept Status Report

2016 Science & Technology Plan

- S&T 2016

2020 Science & Technology Plan

- S&T 2020

Live Science & Technology Plan

- S&T Live

CAE Summary Sheets

- CAE Summary Sheets

NEA IFEP

- NEA IFEPs (pdf) (TeX)

Diagrams

- View Top-level Claims CAE Diagram
- View CAE Branch: Borehole sealing Diagram
- View CAE Branch: Monitoring Diagram
- View CAE Branch: Inventory Diagram
- View CAE Branch: Assessments Diagram
- View CAE Branch: Post-closure Criticality Diagram
- View NEA International FEP List V3 Diagram



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4.2. Wasteform environmental safety functions

4.2.1. Limitation of the release of contaminants

Oxide fuels are in the form of ceramic uranium dioxide pellets that provide a stable matrix, but the spent fuel will be substantially cracked after irradiation in a reactor and, potentially, over very long timescales, as a result of internal pressurisation from helium production by alpha-decay (see the Waste Package Evolution Status Report Section 6.1.2). However, the fuel will display high chemical stability when contacted by groundwater and, apart from the rapid release of radionuclides at the grain boundaries and in accessible parts of the fuel (the instant release fraction), the rate of release of radionuclides after container failure will be low (see the Waste Package Evolution Status Report Section 6.3). Oxide fuel cladding and other fuel assembly components are mostly made of corrosion-resistant metals (Zircaloy, which is a zirconium alloy, stainless steel or nickel alloys). Cladding that is intact at the time of container failure will provide an additional barrier to the release of radionuclides contained within the fuel and fuel assembly components (see the Waste Package Evolution Status Report Section 6.5), although the safety function provided by the cladding is not expected to be significant in terms of post-closure environmental safety.

The disposal routes for metallic fuels, such as Magnox spent fuel, and some of the various spent fuels and nuclear materials termed exotic fuels, are yet to be determined (see the Waste Package Evolution Status Report Sections 2.3.3 to 2.3.4). Magnox fuel (uranium metal) and cladding (magnesium alloy) will corrode relatively quickly when accessed by groundwater under disposal conditions (Waste Package Evolution Status Report Sections 6.4 and 6.5). The feasibility of options for the disposal of un-dismantled Magnox fuel (that is the fuel and its cladding), without encapsulation and immobilisation in an encapsulation or embedding medium, is being considered.

Highly active liquor (a by-product of spent fuel reprocessing) is immobilised as a solid, vitrified product (HLW) within a stainless steel canister (see the Waste Package Evolution Status Report Section 2.2). Although expected to crack during cooling as the vitrified product is formed (see Waste Package Evolution Status Report Section 5.2.1), the HLW glass will be highly durable under disposal conditions. The vitrification canister that holds the HLW may be perforated by localised corrosion processes relatively quickly on exposure to groundwater and is not expected to provide a significant containment safety function. However, after canister breach, the release of radionuclides from the HLW glass is expected to occur slowly, congruently with the dissolution of the glass matrix (see Waste Package Evolution Status Report Section 5.1.2). A layer of silica-rich gel is expected to gradually form on the surface of the HLW as the more soluble components are dissolved. This silica-rich gel preferentially incorporates radionuclides such as plutonium and americium and acts as a protective barrier, limiting the dissolution rate for the underlying unaltered glass. Precipitation of secondary phases during glass dissolution may remove radionuclides from solution, although they could result in the formation of colloids that could transport radionuclides (see the Behaviour of Radionuclides and Non-radiological Species in Groundwater Status Report Section 3.1.1).

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3.1. Encapsulation and embedding processes

3.1.1. Cement-based wasteforms (ILW)

3.1.2. Polymeric wasteforms (ILW)

3.1.3. Glass and ceramic wasteforms (ILW and plutonium)

3.2. Non-encapsulated waste (ILW/LLW, spent fuel)

3.2.1. Spent fuel

3.2.2. Graphite and other ILW

3.2.3. DNLEU

Chapter 4. Environmental conditions during waste management

4.1. Environmental conditions during interim storage and the operational period of the GDF

4.1.1. HLW and spent fuel

4.1.2. ILW/LLW

4.2. Environmental conditions during the post-closure period of a GDF

4.2.1. HLW and spent fuel

4.2.2. ILW/LLW

4.3. Environmental conditions inside waste packages

Chapter 5. Evolution of vitrified HLW

5.1. Overview of HLW evolution processes

5.1.1. Initial state and pre-closure period

5.1.2. Post-closure period

5.2. Initial state

5.2.1. Cracking

Title: Hot-Isostatic Pressing of Chlorine-Containing Plutonium Residues and Wastes, in TMS2013 Supplemental Proceedings

Author: Stewart, M.W.A. and Moricca, S.A. and Vance, E.R and Day, R.A and Maddrell, E.R. and Scales, C.R. and Hobbs, J.

Type: proceedings

Publisher:

Number:

Date: 2013

Figure 3-3. Borosilicate glass incorporating surrogates of Magnox sludge and plutonium-contaminated waste. The glass block is about 15 cm by 10 cm (imagesource)

Safety case documents are displayed as navigable, structured web pages in ViSI.

RWM Bibliography

Radioactive Waste Management

Bibliographic Item: WPESR53

Field	Value
Author	Stewart, M.W.A. and Moricca, S.A. and Vance, E.R and Day, R.A and Maddrell, E.R. and Scales, C.R. and Hobbs, J.
Eventtitle	TMS2013 Supplemental Proceedings
Note	John Wiley & Sons, Inc., Hoboken, NJ, USA. doi: 10.1002/9781118663547.ch83
Title	Hot-Isostatic Pressing of Chlorine-Containing Plutonium Residues and Wastes, in TMS2013 Supplemental Proceedings
Date	2013
URL	https://onlinelibrary.wiley.com/doi/pdf/10.1002/9781118663547.ch83

References to other sections, RWM's bibliography and pages displaying metadata are rendered as hyperlinks.

ViSI demonstration – document collection

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Search Diagrams

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- Science and Technology Plan
- 2020 Science and Technology Plan
- Nuclear Energy Agency - International FEP List V3

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- View NEA International FEP List (Draft - TN2) Diagram
- View 2018 Claims, Arguments and Evidence (Current) Diagram
- View NEA International FEP List V3 Diagram
- View OESA CAE [DRAFT] Diagram

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ViSI's safety case diagram collection

ViSI can render hierarchical diagrams, like branches of the CAE diagram, dynamically.

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- S&T 2020

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- S&T Live

CAE Summary Sheets

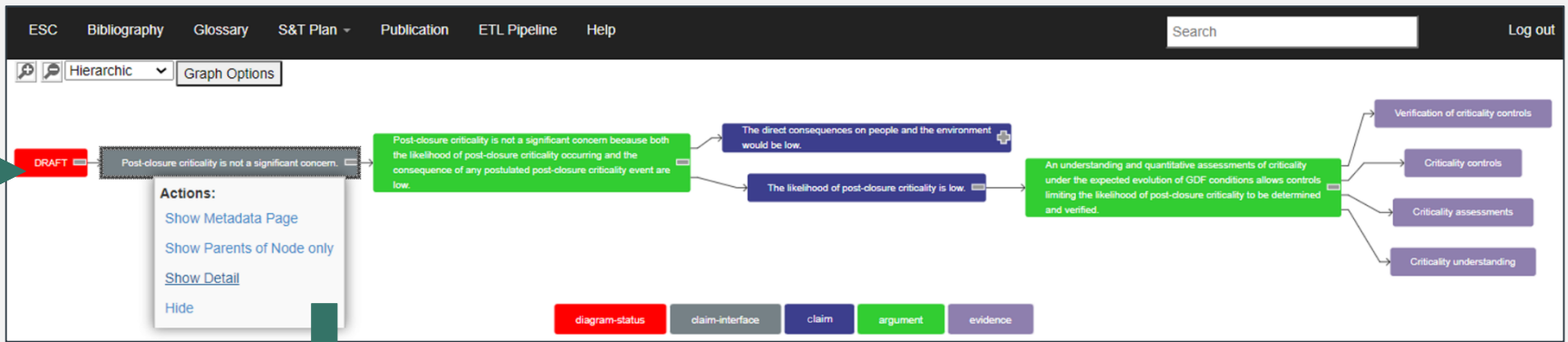
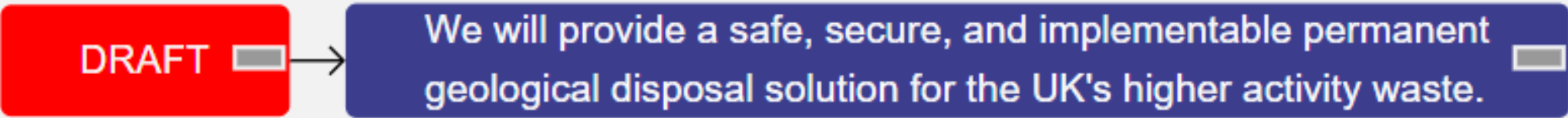
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All claims trace back to the root node.

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1.1. CLAIM: Post-closure criticality is not a significant concern.

1.1.1. Introduction

The inventory of wastes for geological disposal includes fissile material. If enough fissile material were to be bought together under disposal conditions, then an uncontrolled nuclear fission chain reaction (criticality) could occur. Criticality releases radiation and generates energy, and this will continue until the system becomes sub-critical as conditions change (i.e. the chain reaction ceases to be self-sustaining). If criticality were to occur in a GDF, as well as releasing radiation, the energy generated could affect the properties and thus the performance of the surrounding barrier system, potentially with a detrimental impact on the safety provided by the GDF. The importance through its inclusion in the international FEP list in FEP 4.2.6, FEP 2.3.6.6, FEP 3.2.6.5.

It is therefore important that we are able to demonstrate that post-closure criticality does not pose a significant concern to GDF safety. This is addressed through the claim and underlying subclaims in the extract of the CAE diagrams shown in Figure 1.

Figure 1. CAE extract (click on the claims and arguments to navigate to the relevant section of this page)

1.1.2. Claim basis and interpretation

The need to consider GDF post-closure criticality safety is highlighted in the environment agencies' Guidance on Requirements for Authorisation (GRA) of geological disposal facilities on land for radioactive wastes. The GRA requires that in "...design, construction, operation and closure..." of the disposal facility, account is taken of "...effects that may arise from properties of the waste...", including "...criticality through concentration of fissile nuclides" [GRA, Paras. 6.4.20]. In particular, the GRA requires that this issue is addressed by packaging and disposing of wastes in a way that ensures that "...the possibility of a local accumulation of fissile material, such as to produce a neutron chain reaction, is not a significant concern" [GRA, Paras. 6.4.27, 7.3.31 [1]].

The Environmental Safety Case thus needs to include a demonstration that post-closure criticality is not a significant concern, which requires assessing the likelihood of criticality occurring as well as the safety consequences of a postulated critical excursion (i.e. an uncontrolled nuclear fission chain reaction) after GDF closure.

1.1.3. Argument

The expected evolution of conditions in the GDF and derived controls on the packaging and disposal of fissile waste will ensure that post-closure

Users can access underpinning information by clicking nodes in the diagram.

Criticality [waste package]

FEP Number

2.3.6.6

Content Details

URI: fep:nea/ifep;published;V3.0/fep/ifep-2.3.6.6;

Copy

Description

The possibility and effects of spontaneous nuclear fission chain

References to other sections are rendered as hyperlinks.

ViSI demonstration – FEP diagram

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2016 Safety Case

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- View NEA International FEP List V3 Diagram
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Quick Search the Diagram [Advanced Search](#)



Using ViSI – Finding information

All content is indexed and searchable. Users can quickly reach the sections of the safety case and underpinning reports they need.

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2.5. Sorption

The term sorption is used here to describe a range of processes that involve the uptake of dissolved species by material surfaces. Sorption has the effect of lowering the dissolved concentration of the species and so retards its transport in groundwater. The rates, strength and reversibility of sorption reactions are dependent on the species, the nature of the sorbing surface and the environmental conditions.

The term sorption is used here to describe a range of processes by which entities such as dissolved ions, gas or other molecules are partitioned between a solution (groundwater or porewater) and a solid surface (for example, the surface of a mineral).

Sorption processes occur at surfaces and, as defined here, do not involve the formation of three-dimensional solid phases. However, in some instances there may be a gradation from sorption processes to processes that do involve the formation of three-dimensional solid phases, such as co-precipitation and solid solution formation – see Section 2.6.2. For example, Figure 2-5 shows a conceptual model for the uptake and incorporation of $^{14}\text{CO}_3^{2-}(\text{aq})$ by calcite, which involves an initial process of sorption followed by recrystallization and diffusion [2].

The occurrence of processes such as sorption, co-precipitation and precipitation on immobile surfaces during chemical transport leads to a retardation of the solute in question relative to the migration of species that are not involved in such reactions (conservative tracers) and which generally migrate by advection at the average speed of the water or by diffusion.

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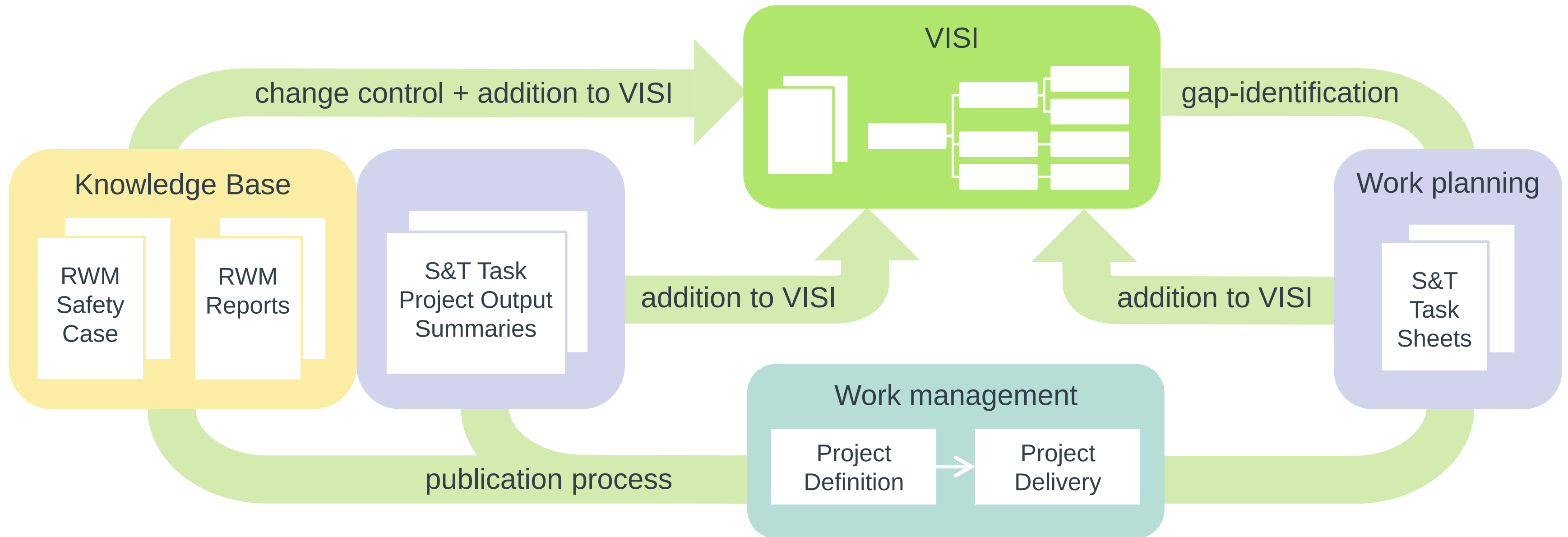
+ Search Options

Results

Document	Section Title	Text	
Behaviour of Radionuclides and Non-radiological Species in Groundwater	Sorption	site will be an important part of the work undertaken during the period of characterising a potential site for the GDF. RWM will carry out an experimental programme of this type once candidate sites have been identified and samples are available. We also expect to build confidence in the understanding of geosphere sorption by studying the behaviour of naturally occurring radionuclides in natural geological systems.	View Document
CAE Summary Sheets	Local buffer/backfill containment function: The local buffer/backfill will sufficiently control the rate of release of contaminants	; ESC 7: LHGW Disposal in Lower Strength Sedimentary Rock ; ESC 7.4.3: Limitation of the release of contaminants. Clay-based local buffer A clay-based local buffer (such as the bentonite buffer used in the illustrative disposal concepts for HHGW disposal in HSR and LSSR) may: develop a low-permeability as it saturates and swells, such that the transport of contaminants is limited; filter colloids, such that the transport of contaminants in colloidal form is limited; induce mildly alkaline conditions such that the low solubility of some radionuclides is supported; have a high capacity for sorption , such that the migration of some contaminants is limited. This is discussed in the following sections of the Generic Environmental Safety Case : ESC 4: HHGW Disposal in Higher Strength Rock ; ESC 4.4.3: Limitation of the release	View Document
	Likelihood of Criticality: The	safety margin. As conditions in the GDF evolve and waste packages degrade, gradual dissolution and relocation of fissile and other materials is likely	View

Document search shown above. Search of bibliographic, glossary and figure data also present.

Using ViSI as part of RWM's business cycle



Application to the RSO

ViSI can be used:

- as a means of accessing and intuitively navigating through safety case information,
- to explore the links between information,
- to explore the claims, arguments and evidence behind the safety case,
- to identify gaps where additional research would be beneficial, and
- to identify the impact of ongoing or proposed research on the safety case and other areas and support needs driven research.

Ongoing or proposed research can be incorporated into ViSI.

Questions/discussion

1. What would you like to use ViSI for?
2. What would you like to see ViSI able to do?
3. Any other questions, comments or suggestions?

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