A LCA approach as a decision tool for nuclear waste management

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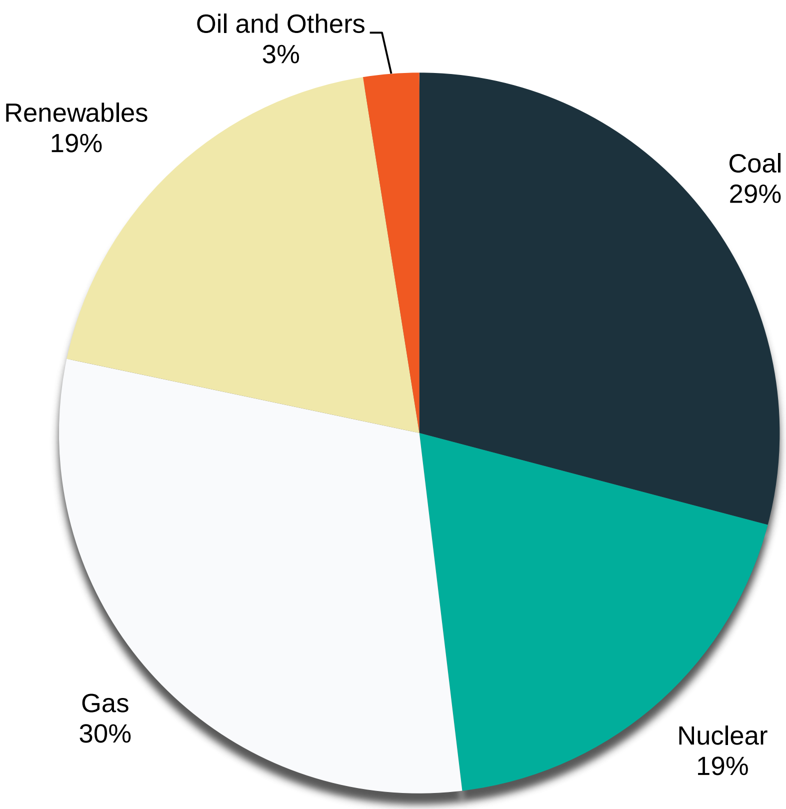
Nuclear in the UK

UK Electricity Generation by fuel type



Department of Energy & Climate Change, "Energy Trends: March 2015"

- Government's Carbon Plan is to reduce CO_2 emissions by 80% by 2050
- Best Scenario: Nuclear energy contribution ~40-50% by 2050

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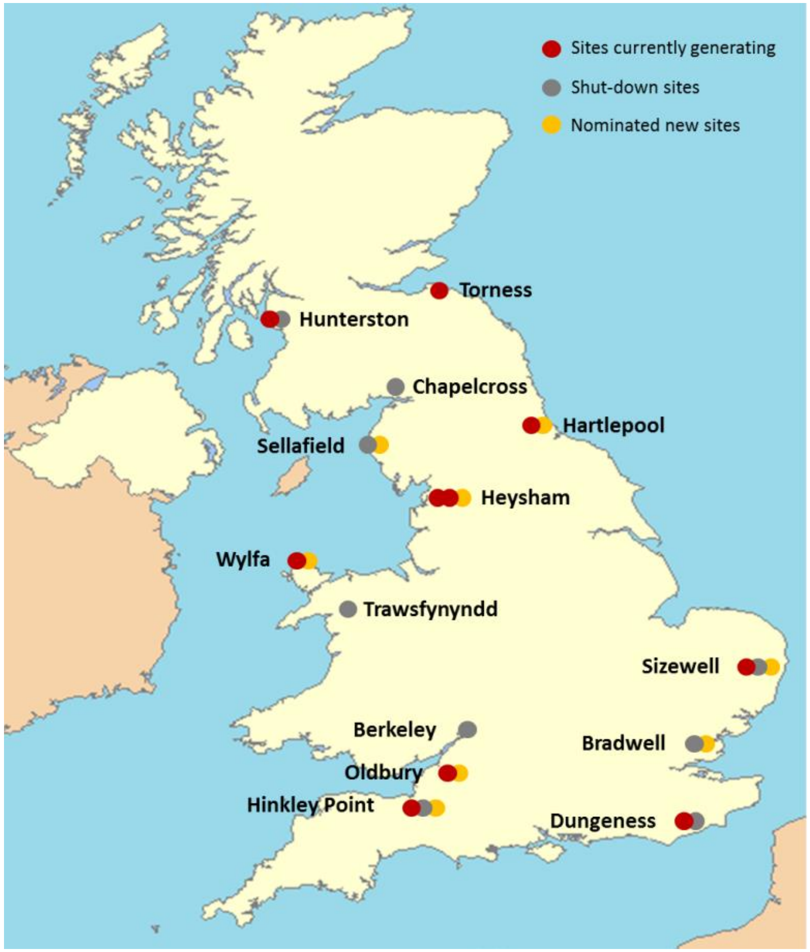
Nuclear in the UK



UK nuclear power generation reactors' map

Power reactors fleet

Plant	Type	Present capacity (MWe net)	Expected shutdown
Wylfa 1	Magnox	490	Dec 2015
Dungeness B	AGR	2 x 545	2028
Hartlepool	AGR	2 x 595	2024
Heysham I	AGR	2 x 580	2019
Heysham II	AGR	2 x 615	2023
Hinkley Point B	AGR	2x 610 (operating at 70%)	2023
Hunterston B	AGR	2x 610 (operating at 70%)	2023
Torness	AGR	2 x 625	2023
Sizewell B	PWR	1188	2035
Total: 16 units		**10,038 MWe**	

Power reactors planned and proposed

Site	Type	Capacity (MWe gross)	Planned Start-up
Hinkley Point C-1	EPR	2x 1670	2023 -2024
Sizewell C-1	EPR	2x 1670	?
Wylfa Newydd 1	ABWR	2x 1380	2025
Oldbury B-1	ABWR	2x 1380	late 2020s
Moorside 1	AP1000	3x 1135	2024?
Total:11 units		**15,600 MWe**	

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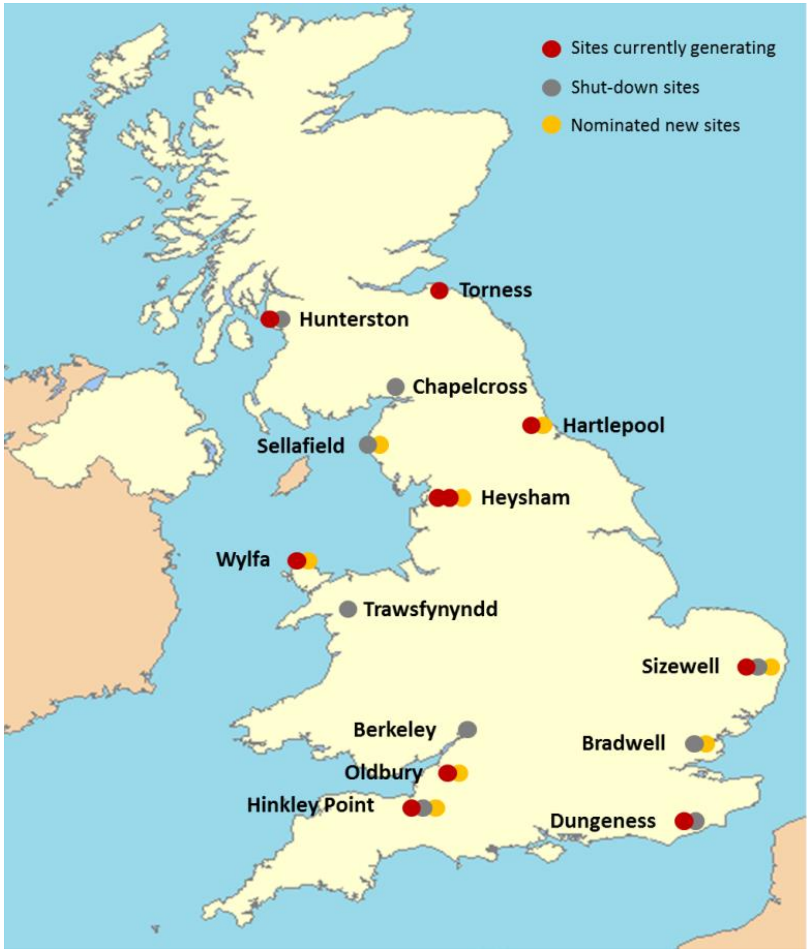

UK nuclear power generation reactors' map

UK power reactors to be decommissioned

Reactor	Type	MWe net	Startup	Shutdown
Berkeley 1 & 2	Magnox	2x 138	1962	1988-89
Bradwell 1 & 2	Magnox	2x 123	1962	2002
Calder Hall 1,2,3 & 4	Magnox	4x 50	1956-57-58-59	2003
Chapelcross 1,2,3 & 4	Magnox	4x 49	1959	2004
Dungeness A1 & A2	Magnox	2x 225	1965	2006
Hinkley Point A1 & A2	Magnox	2x 235	1965	2000
Hunterston A1	Magnox	2x 160	1964	1989-90
Oldbury 1 &2	Magnox	2x 217	1967-68	2011-12
Sizewell A1 & A2	Magnox	2x 210	1966	2006
Trawsfynydd 1 & 2	Magnox	196	1965	1993
Wylfa 2	Magnox	490	1971	2012
Total: 26				

Reprocessing plant: Sellafield

- Thermal oxide reprocessing plant (thorp)
- Magnox fuel reprocessing plant

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Aims of the project

- Develop a High-level conceptual Life Cycle Assessment to define how to assess **environmental impact performance of nuclear wastes**

- **Develop a Life Cycle Assessment scenario** including all stages in the nuclear fuel cycle *(from mining and milling, through fuel fabrication and energy production, to waste management and disposal)*

On-going work:

✓Review of existing nuclear fuel cycle configurations

✓Review of existing methodologies to evaluate radiological impact of radionuclides

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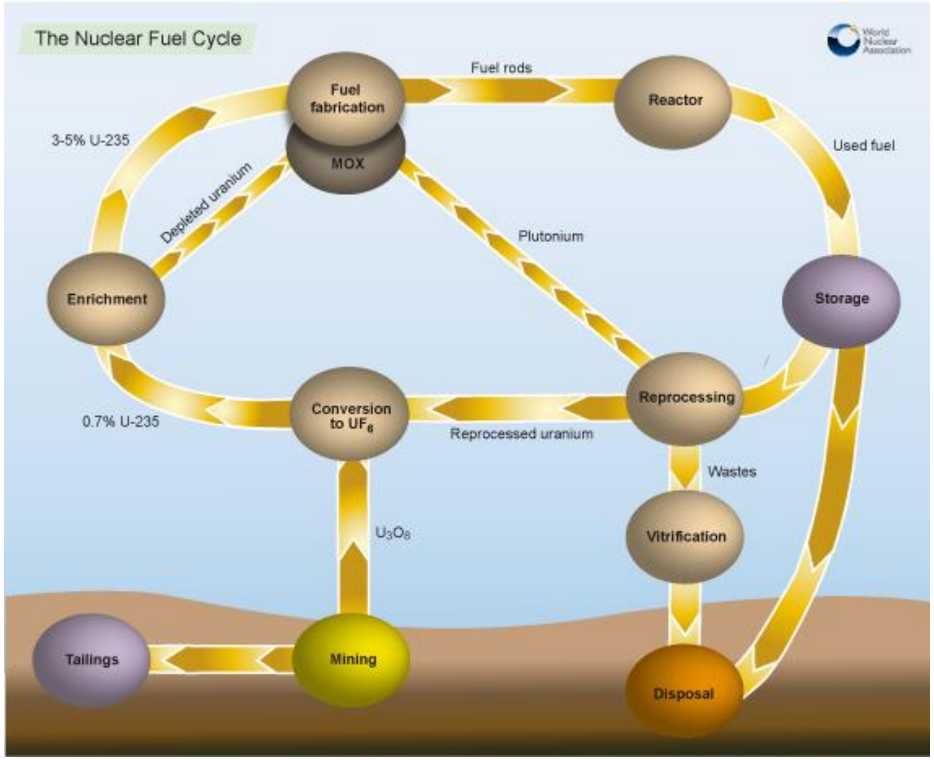
Nuclear fuel cycle

Nuclear fuel cycle options:

➢ **Open or 'Once-through'**
- Direct disposal of Spent Nuclear Fuel (SNF)
- *USA, Canada, Sweden, Finland, Spain*

➢ **Partially closed or Single recycle**
- Uranium and Plutonium recycled as MOX
- *UK, France, Japan, Russia, China*

➢ **Closed or Full recycle**
- Uranium, Plutonium and Minor Actinides recycled in advanced burner reactors
- *Not implemented yet*



Benefits:

➢ **Open fuel cycle**
- Cost
- Safety (*Nuclear proliferation*)

➢ **Closed fuel cycle**
- Resource longevity
- Waste volume

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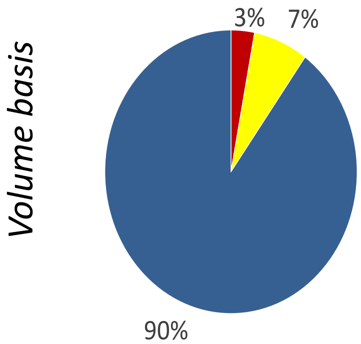
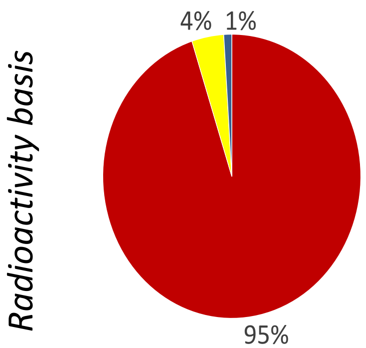
Nuclear wastes





Low Level Waste (LLW) → Near-surface disposal facility

Intermediate Level Waste (ILW) → Near-surface disposal facility

Intermediate Level Waste (ILW) → Geological disposal facility

High Level Waste (HLW) → Interim storage *(~50 years)* → Geological disposal facility *(not implemented yet)*

Life Cycle Assessment

What is it?

Life Cycle Assessment (LCA) is a tool used to help understanding the impact of human interactions with the environment by identifying and quantifying the environmental burden of an activity

How?

- Consider all energy and materials used and wastes released to the environment
- Assess their impact to the environment

Impact	Unit Equivalent
Extracted Energy	MJ
Abiotic Depletion	Kg Oil
Global Warming	Kg CO_2
Acidification	Kg SO_2
Ecotoxicity	Kg Cr
Nutrification	KfgPO_4
Odour	Kg NH_3
Ozone Depletion	Kg CFC 11
Summer Smog	Kg NO_x
Winter Smog	Kg dust
Carcinogenic	Kg PAH
Heavy metals	Kg Pb

Standard impact categories

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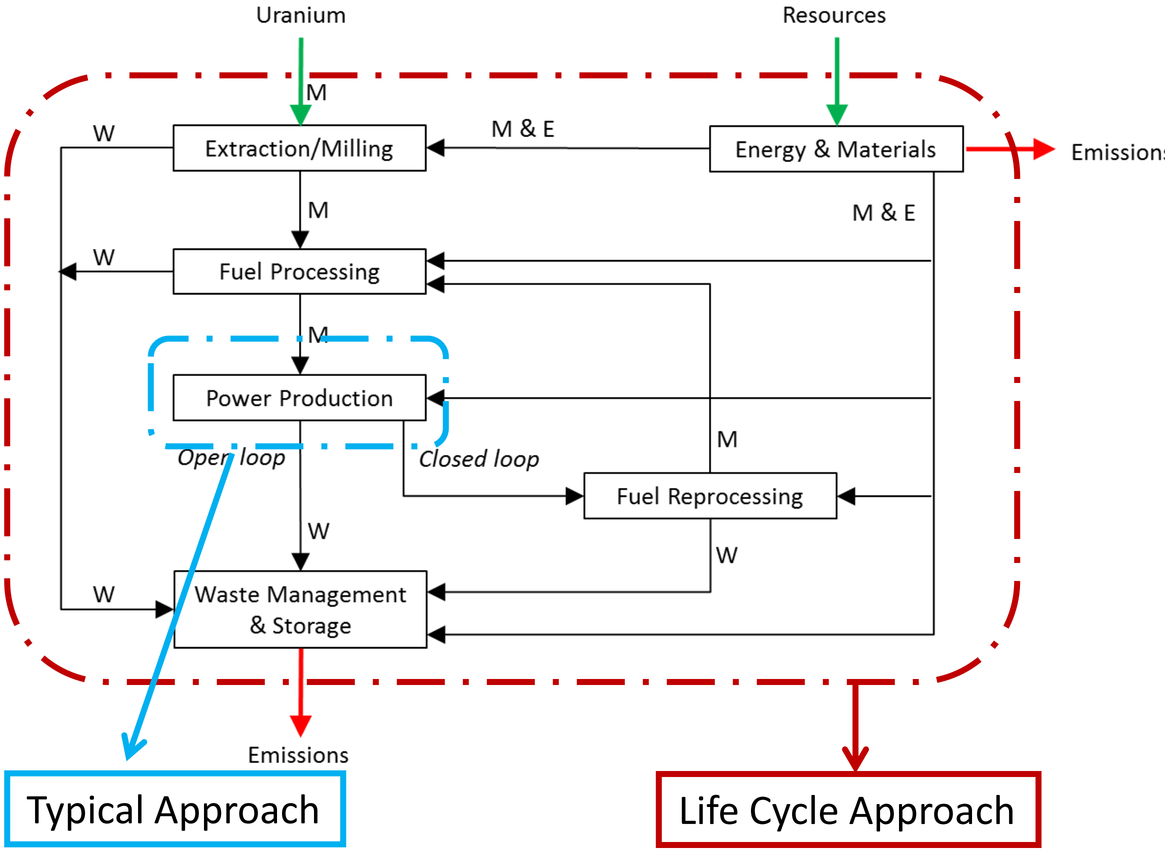
Why?

Taking a Life Cycle (also called “cradle to grave”) approach ensures that sub-optimisations are avoided and that environmental burdens are not simply shifted to other parts of the life cycle

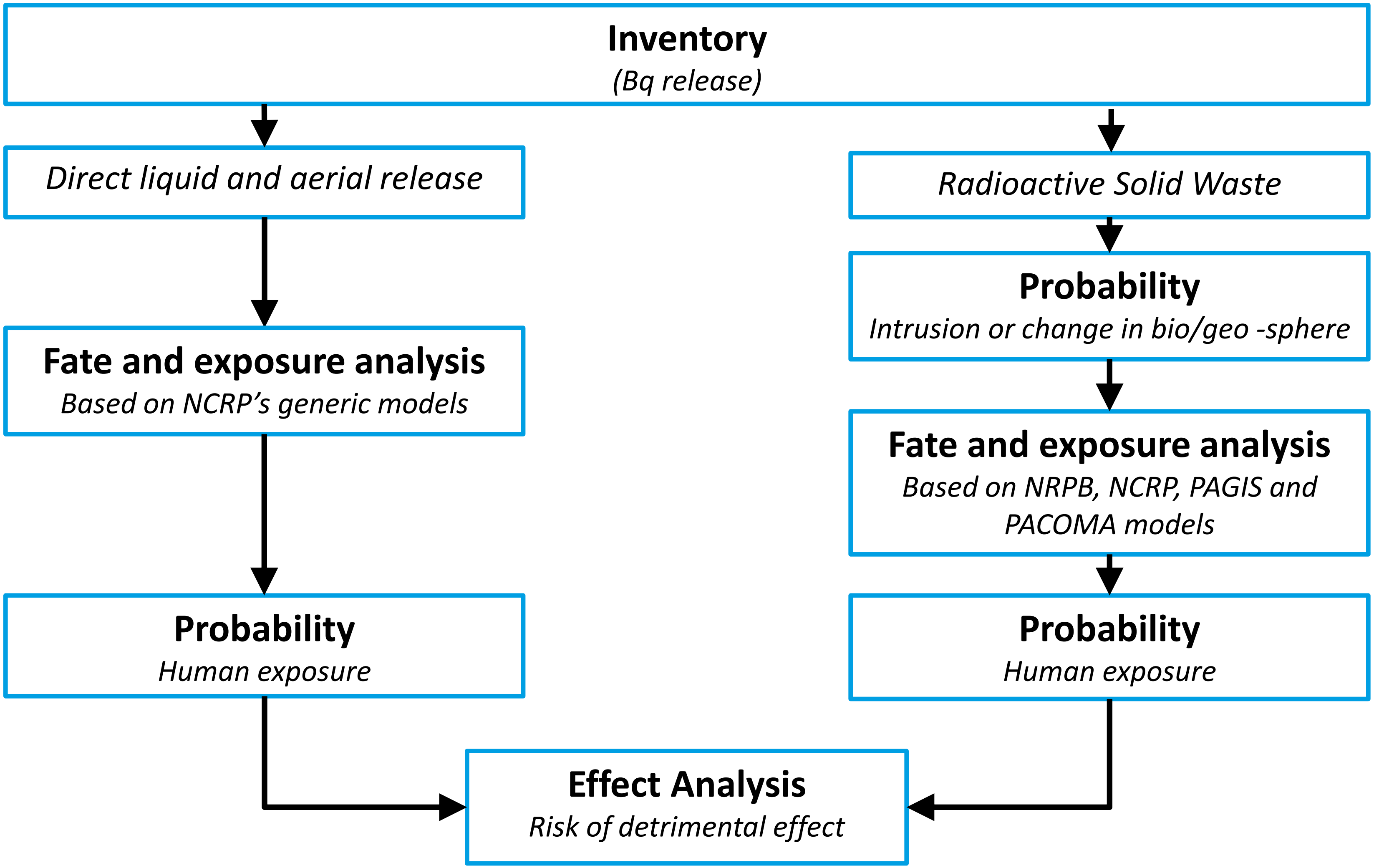


Radiological Impact Assessment

<u>A standardised methodological framework</u> is needed to deal with the radiological component of LCA, especially with regard to nuclear waste.

Approach	Impact type	Emissions	Applicability	Fate & exposure analysis	Result metric
Critical Volumes	Human	Direct aerial and liquid	General	No	Inverse of ALI
Site-Specific	Human	Direct aerial and liquid	Site dependent	Site specific models	Effective dose
Damage-based	Human	Direct aerial and liquid	Europe-only	French nuclear cycle study	DALY
Risk-based	Human	Direct aerial & liquid, and solid waste	General	Generic models	Risk of detrimental effect
Environmental Irradiation	Environmental	Direct aerial and liquid	General	Generic models (only fate analysis)	Environmental pollution
SED scores	Human & Environmental	Solid waste	General	No	Hazard

Risk-based Approach



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Risk-based

- It takes into account both the probability of incurring a dose and the probability of detrimental health effect

Advantages

- Both solid waste and direct emission impacts are accounted
- Generally applicable

Flaws

- Results can only be used for comparative assessment and cannot be used to determine actual risks or doses to individuals
- Not very specific

Conclusions and Future work

- To achieve CO_2 reduction targets many countries (e.g. UK) projects to improve nuclear industry
- Nuclear waste management is a key aspect and driver for decision within nuclear industry

➢ Life Cycle Assessment can be used to help decision-making processes within nuclear industry

- No standard impact category is able to evaluate environmental impacts of nuclear wastes

➢ Risk-based assessment seems to be the best approach to evaluate radiological impacts and especially to deal with <u>nuclear wastes</u>

➢ **Future work:** Identify an open loop scenario to perform a Life Cycle Assessment

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Thanks