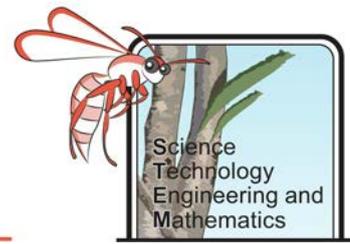


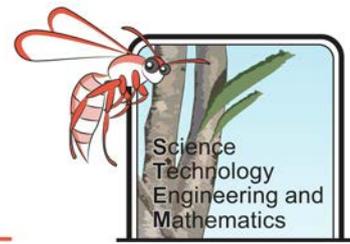
Burying Nuclear Waste – Student Booklet



How to use this document

1. Open this file in Adobe Reader. If you do not have this program you can download it for free here: <https://acrobat.adobe.com/au/en/acrobat/pdf-reader.html>
2. Download the file and **save** it to your computer as Project Name _Your Name e.g. Going for Gold_Joe Bloggs. **It is really important you do this otherwise none of your input will be saved.**
3. Fill in your answers in the spaces provided in the document.
4. Where there are image boxes take photos or scans of your work and upload the picture file. If you cannot do this, for any reason, upload the pictures as separate files and save them as Project Name_Your Name_Image number e.g. Going for Gold_Joe Bloggs_Image 1.
5. Save your work as you go along.
6. When you have finished email or upload your completed document (and image files) as your teacher has instructed.

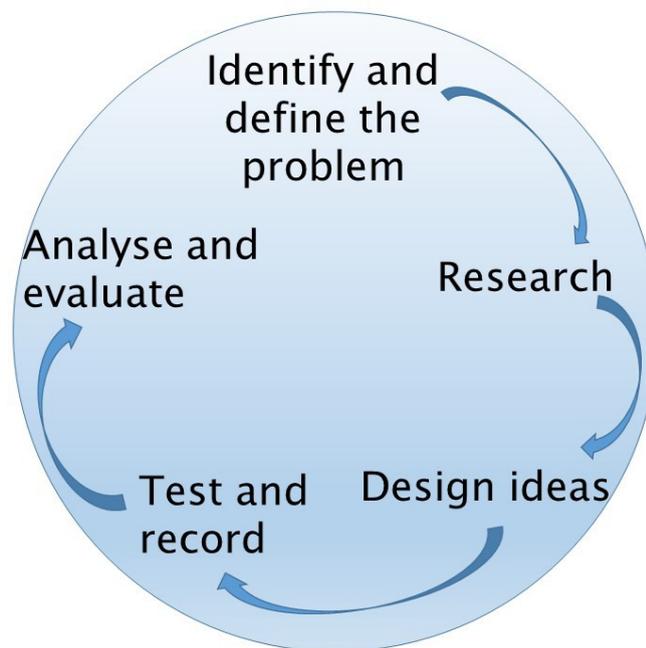
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The Challenge

With populations increasing at an exponential rate and the volume of electronic devices being used in everyday lives escalating, not to mention the increased use of transport, it is vital that Australia can provide a future energy mix that supports modern lifestyles. Nuclear power is undoubtedly a means of producing vast amounts of energy with relatively low emissions and without reliance on the weather, however, one of the main issues with nuclear power is what to do with the waste.

Your challenge is to investigate the issues with nuclear waste and to produce a report, which could be provided to government, outlining if and where nuclear waste could be safely buried.



Background Information

Nuclear power plants mainly use enriched uranium as their source of fuel. In a nuclear power plant the fuel is compacted into fuel rods, which are surrounded by a fluid in the reactor. The fuel undergoes a controlled chain reaction which gives off heat, thus heating the surrounding fluid. The hot fluid then heats water, creating steam which turns turbines, to generate electricity.

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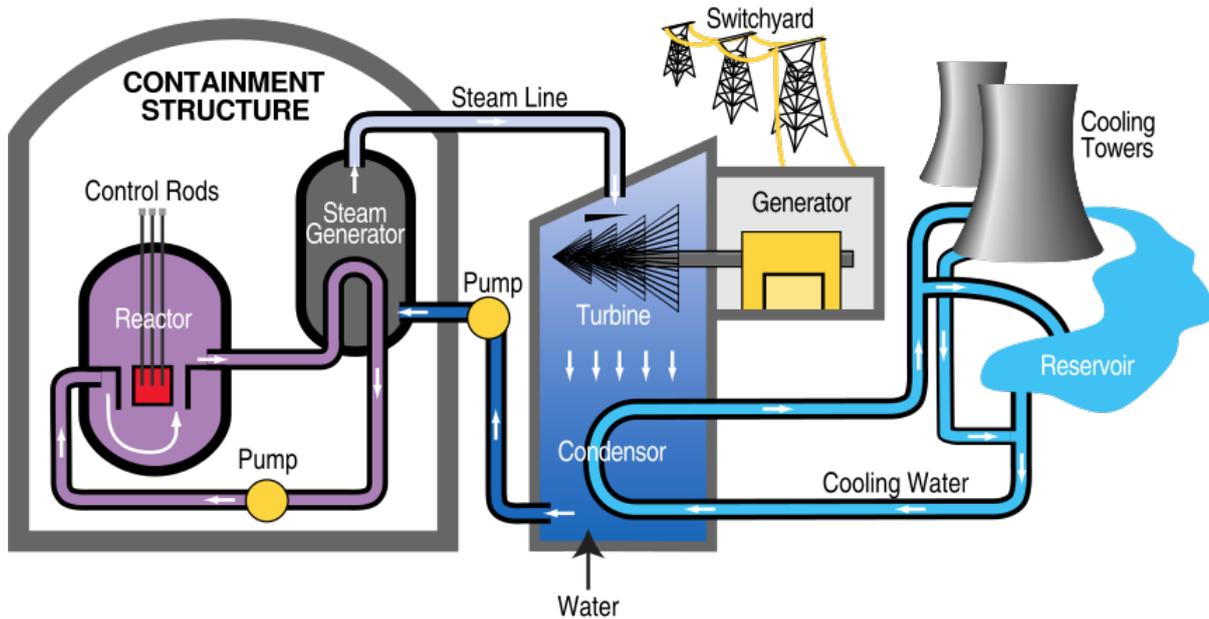
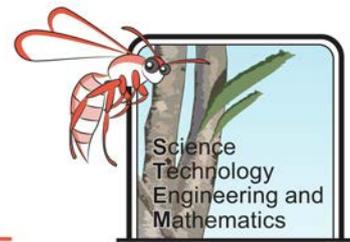


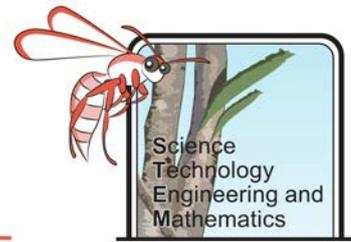
Figure 1. Image showing the key parts of a nuclear reactor and how it generates electricity. (Tennessee Valley Authority, 2018)

Nuclear waste is radioactive, and therefore it is very important that it is disposed of safely. At present the most common method of nuclear waste disposal is to bury it in a geologically stable area (far from any faults or volcanic areas). The waste is buried around 500 – 1,000 m below the surface, with the aim to permanently isolate it from the human environment.

Some issues with burying the waste can be that the material that it is stored in starts to crack, allowing water in; which can become contaminated. Some radioactive isotopes also can remain radioactive for very long periods of time (several hundreds of thousands of years), which makes it very hard to monitor and to be confident that there will be no geological changes affecting it over this time period.

A suitable solution to deal with nuclear waste is one of the most important factors in making decisions around nuclear power generation in Australia.

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Background Research

1. What type of radiation is produced by a nuclear reactor?

Suggested site: health/nuclear-radiation-and-health-effects.aspx

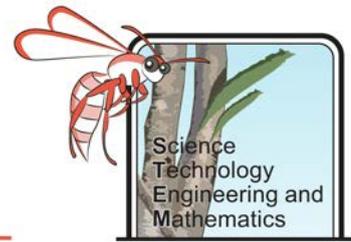
2. How does a nuclear reactor create electrical energy? Explain the process using a labelled diagram. Insert this below or attach as a separate document.

Suggested site: <http://www.world-nuclear.org/nuclear-basics/how-does-a-nuclear-reactor-make-electricity.aspx>

3. What are the potential hazards to human health of nuclear waste?

Suggested site: <https://www.epa.gov/radiation/radiation-health-effects>

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4. What are the different levels of nuclear waste, and how are they treated?

[sources/radioactive-waste-safety](#) or <https://ukinventory.nda.gov.uk/about-radioactive-waste/how-do-we-manage-radioactive-waste/>

5. How is nuclear waste monitored, once disposed of?

Suggested sites: <https://phys.org/news/2017-12-physicists-method-nuclear.html> and <https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/radioactive-waste-safety>

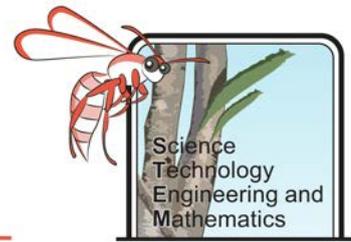
6. What other activities produce nuclear waste (other than power generation)?

Suggested site: https://en.wikipedia.org/wiki/Radioactive_waste#Medicine

7. Which countries currently use nuclear power (list at least 10)?

Suggested site: https://en.wikipedia.org/wiki/Nuclear_power_by_country

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8. How old are the oldest rocks in Australia?

Suggested site: <https://australiascience.tv/oldest-rocks-in-the-pilbara-pre-date-plate-tectonics/>

9. What tectonic setting does Australia have? (Hint: look at a map of tectonic plates of the world). Add a labelled diagram.

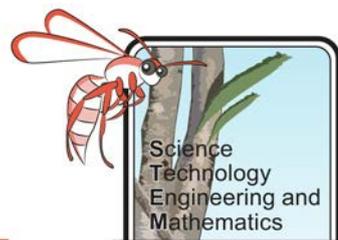
Suggested sites: <https://www.worldatlas.com/articles/major-tectonic-plates-on-earth.html> and <http://www.ga.gov.au/scientific-topics/national-location-information/landforms/australian-landforms-and-their-history>

10. Have there been any proposed burial sites for nuclear waste in Australia in the past?

Location	Reference

Suggested sites: <http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/appendices/radioactive-waste-repository-store-for-australia.aspx> and https://en.wikipedia.org/wiki/Nuclear_power_in_Australia

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Decay Rate Modelling

Objective

To model radioactive decay of elements, using popcorn.

Equipment

- Popcorn kernels
- Microwave
- Paper sandwich bag
- Weighing scales

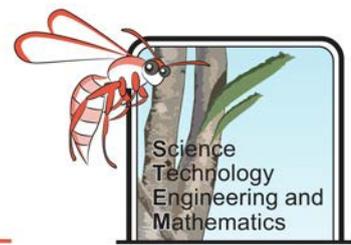
Method

1. Weigh out 20 g of popcorn kernels and put them in the paper sandwich bag. Fold over the top of the bag twice.
2. Put the bag in the microwave with the fold facing upwards.
3. As soon as you hear the first pop make a note of the time and let the microwave run for another 10 s.
4. Pour the popcorn out of the bag and count and record the number of kernels (Kernalite) and popped corn (Popcornium) in the results table.
5. Repeat the experiment allowing the microwave to run for 20, 3060 s.

Results and Analysis

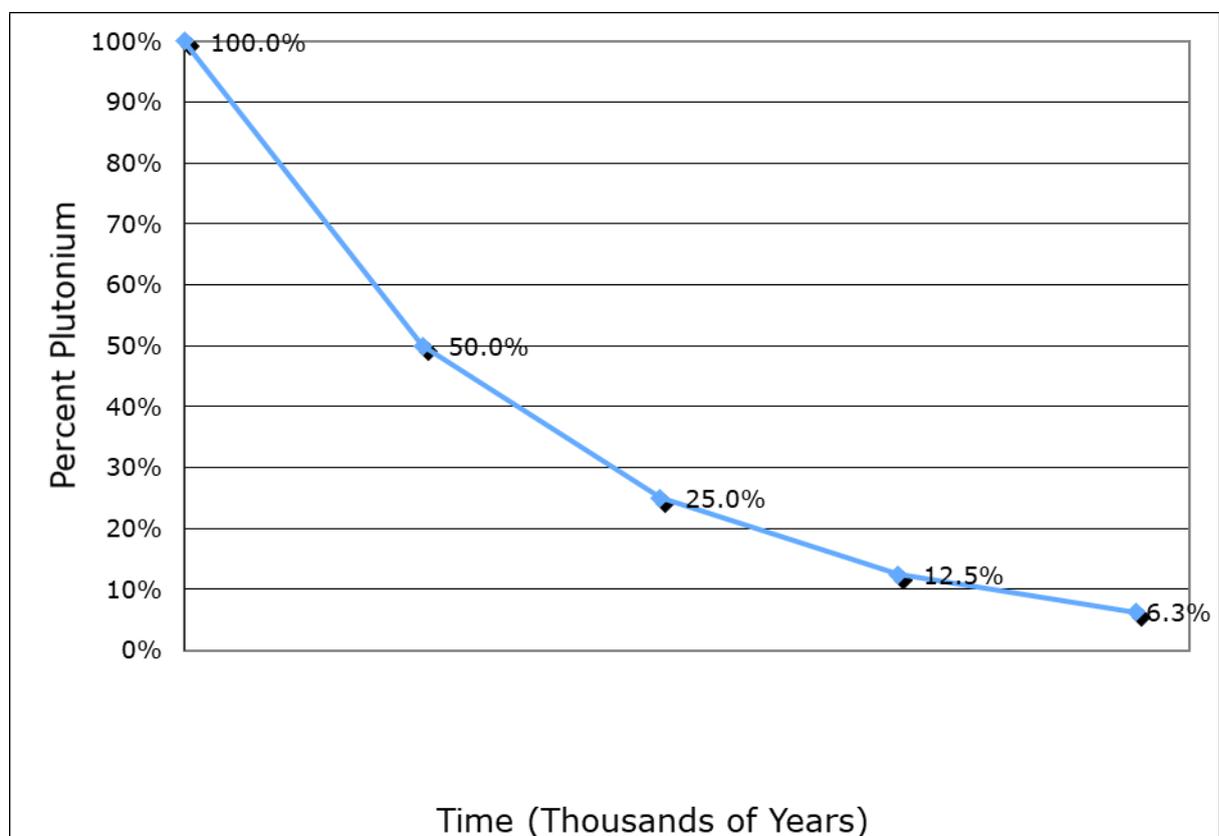
Bag Number	Popping time (seconds)	Number of Kernalite Ke (parent)	Number of Popcornium Pc (daughter)	Total Ke + Pc	% Ke (parent) /Total *100	% Pc (daughter) /Total *100
1	10					
2	20					
3	30					
4	40					
5	50					
6	60					

1. Record data into the table above.
2. Work out the percentage of parent (Ke) and daughter (Pc) for each bag.
3. Using the data in the table plot a graph of % Ke versus time (s) ensuring you add a line/curve of best fit. Attach this as a separate file.



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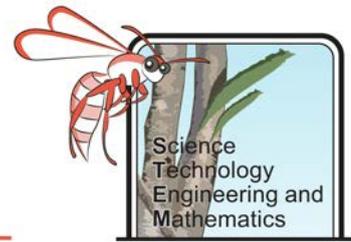
4. What is the half-life of the popcorn? (How long does it take for the number of Ke (kernalite/kernels) to reach 50%?)
5. The radioactive waste from spent fuel rods consist primarily of cesium-137 and strontium-90, but it may also include plutonium. The half-lives of these radioactive elements can differ quite extremely. Plutonium has a half-life that can stretch to as long as 24,000 years (Wikipedia, 2018). Add numbers to the horizontal axis on the graph to show this.



Evaluation

1. How similar was your popcorn decay curve to a radioactive decay curve?
2. What did the kernels popping represent in the model?

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Probability of Earthquakes

Objective

To determine the probability of an earthquake occurring which may disturb buried nuclear waste, causing leakage.

Background Information

Earthquakes are generally reported by their magnitude, or more correctly – Moment Magnitude. This is a modified version of the Richter scale, which was devised in the 1930s by Charles Richter.

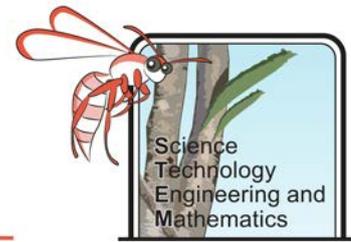
You will have heard the magnitude of earthquakes being reported on the news, and probably have a good understanding that the larger the earthquake the more energy is released. However, the Moment Magnitude is not a linear scale, in fact for each unit of increase (1, 2, 3...) the earthquake will be 10 times bigger and release around 32 times more energy.

Magnitude	Earthquake Effects
< 2	Rarely felt by people and may, at most, make light fittings swing.
2 – 3	Sometimes felt, but not usually recognised by people as an earthquake – feels like a passing truck.
3 – 4	Felt by most people nearby, may cause cracks to appear in plaster.
4 – 5.5	Felt by all nearby, can cause chimneys to collapse and damage to buildings, depending on the quality of construction.
5.5 +	Buildings will be damaged, ground will be cracked and underground pipes broken.

Method

1. Considering the information in the table above, which magnitude (threshold magnitude) would concern you if you lived near buried nuclear waste? Explain why.

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- Go to the USGS Earthquakes database to search for historical earthquakes in Western Australia: <https://earthquake.usgs.gov/earthquakes/search/>

The screenshot shows the 'Basic Options' section of the USGS Earthquake database search interface. It is divided into three columns: Magnitude, Date & Time, and Geographic Region. Under Magnitude, the '4.5+' radio button is selected. Under Date & Time, the 'Custom' radio button is selected, with 'Start (UTC)' set to '1978-02-14 00:00:00' and 'End (UTC)' set to '2018-02-21 23:59:59'. Under Geographic Region, the 'Custom' radio button is selected, and a 'Draw Rectangle on Map' button is visible. There are also sections for 'Advanced Options' and 'Output Options' which are currently collapsed.

Figure 2. Screenshot of USGS Earthquake database search, showing available options to select.

- Customise your magnitude, putting the minimum as your answer to question 1. Customise your date and time, so that you can see all the earthquakes in the past 50 years. Choose your geographic region by drawing the rectangle on the map to select as much of Australia as you can, without including other countries or lots of surrounding ocean.
- In the output options select CSV – which will enable you to open the data set in an Excel spreadsheet.
- Do the same for another country, such as Finland, or France, which has numerous underground nuclear waste storage depositaries. Selected country =

Results and Analysis

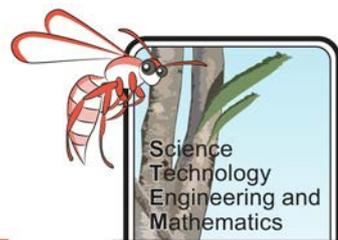
- How many earthquakes in the past 50 years were there above your chosen threshold in each country?

Australia:
(selected country):

- What was the largest magnitude earthquake in the past 50 years for each?

Australia:
(selected country):

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Case Studies

Objective

To use case studies to compare the strengths and weaknesses of different burial sites for nuclear waste.

Background Information

Many countries have been using nuclear power as a source of energy for decades and therefore have accumulated nuclear waste. There are many burial sites globally, some of which have been hosting waste since the 1980s. Most of the sites, fortunately, have not had any issues or reports of nuclear waste leaching into the surrounding areas, however, this has not been the situation for all.

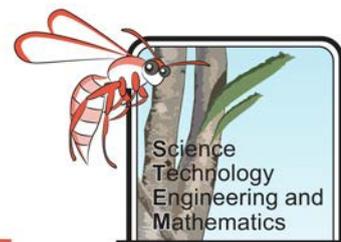
Method

1. Research different waste disposal sites to complete the table below.

Results and Analysis

Site	Country	Status	Geology	Has anything gone wrong, if so what and why?
Asse	Germany			
<i>Suggested sites</i>		https://en.wikipedia.org/wiki/Asse_II_mine		https://euobserver.com/beyond-brussels/132085
WIPP, Yucca Mountain	USA			
<i>Suggested sites</i>		https://en.wikipedia.org/wiki/Yucca_Mountain_nuclear_waste_repository#Geology and https://www.usatoday.com/story/news/politics/2018/06/03/yucca-mountain-congress-works-revive-dormant-nuclear-waste-dump/664153002/		
Hanford, Washington	USA			
<i>Suggested sites</i>		https://en.wikipedia.org/wiki/Hanford_Site		https://www.tricityherald.com/news/local/hanford/article214069424.html

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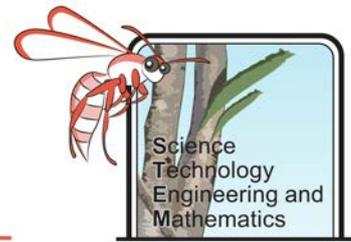
Site	Country	Status	Geology	Has anything gone wrong, if so what and why?
Grimsel	Switzerland			
<i>Suggested sites</i>		http://www.grimsel.com/		https://lenews.ch/2017/12/13/swiss-fact-switzerland-has-enough-nuclear-waste-to-fill-zurich-train-station/

Evaluation

1. Have there been any reports of loss of life, including local flora and fauna, following an accident at a waste storage location?

2. From this research, are there any particular geological formation types that you would recommend/not recommend to be at potential storage sites?

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Designing a Solution

Objective

To design and test a model burial site for radioactive waste.

Equipment

- Balloon with food colouring in, filled to about the size of a ping pong ball
- Material to bury the balloon in - e.g. plaster of Paris, salt, clay, sand
- Transparent plastic cup
- Wooden kebab skewer

Method

1. Brainstorm which material(s) you think will be best to bury your nuclear waste in so that it doesn't leak.

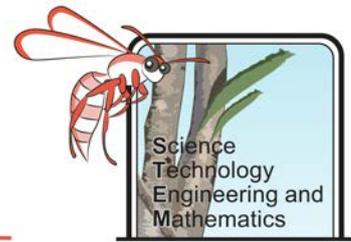
Which material have you chosen and why?

2. Bury your balloon and wooden stick in your chosen material so the stick is just touching the surface of the balloon.
3. Take a photo of your set up. Attach as a separate file.
4. Leave your experiment overnight to allow the material to settle/dry
5. Take another photo of your set up.
6. Slowly push down on the wooden stick (to represent the piercing of the casing nuclear waste has been buried in) and shake the cup gently (to represent an earthquake).
7. Make and record any observations.

Results and Analysis

1. How effective was your model at preventing the "waste" from leaking? Explain your answer.
2. How realistic do you think the model was? Make comparisons to different rock types which could be used to bury waste in.

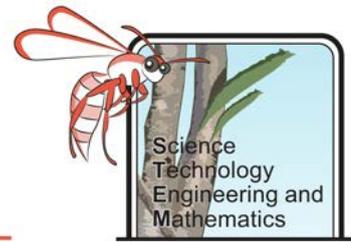
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Evaluation

1. What improvements would you make to:
 - a) The model
 - b) The experimentto make it a more realistic test?

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Reporting to Government

Objective

Present the findings of your research, via a written report, presentation or video, outlining if and where nuclear waste could be safely buried in Australia.

Method

Include in your presentation:

- Why you think an area is suitable/not suitable
 - discussing the geological setting (possible earthquakes/the suitability of the rock types etc.) You should include a geological map, showing the rock types in the area, and a hazard map.
- What depth do you suggest burying the waste at, and why.
- Use supporting evidence from your investigations and case studies to explain why it would be suitable/not suitable to bury nuclear waste.

You may wish to make a model design of your intended plan, showing how you will seal and store the waste.