What to do with Nuclear Waste?

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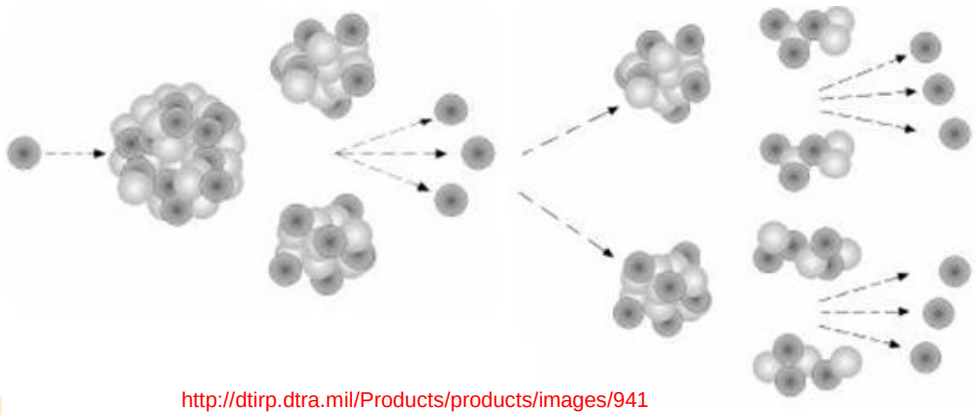
Introduction

- Fission – *isotopes* of some elements can be split and will release part of their energy as heat
- Chain Reaction – series of fissions
- Self-Sustaining Chain Reaction – if enough uranium is brought together under the right conditions, a continuous chain reaction occurs



http://dtirp.dtra.mil/Products/products/images/941p-fig7.jpg

Nuclear Power Facts

- There are now 436 commercial nuclear power reactors operating in 30 countries
- They provide about 15% of the world's electricity
- 56 countries operate a total of about 280 research reactors
- 220 reactors power ships and submarines

http://www.atomicarchive.com/History/coldwar/images/tmi.jpg

Ernest Rutherford

- British physicist, Ernest Rutherford was called the father of nuclear science because of his contribution to the theory of atomic structure

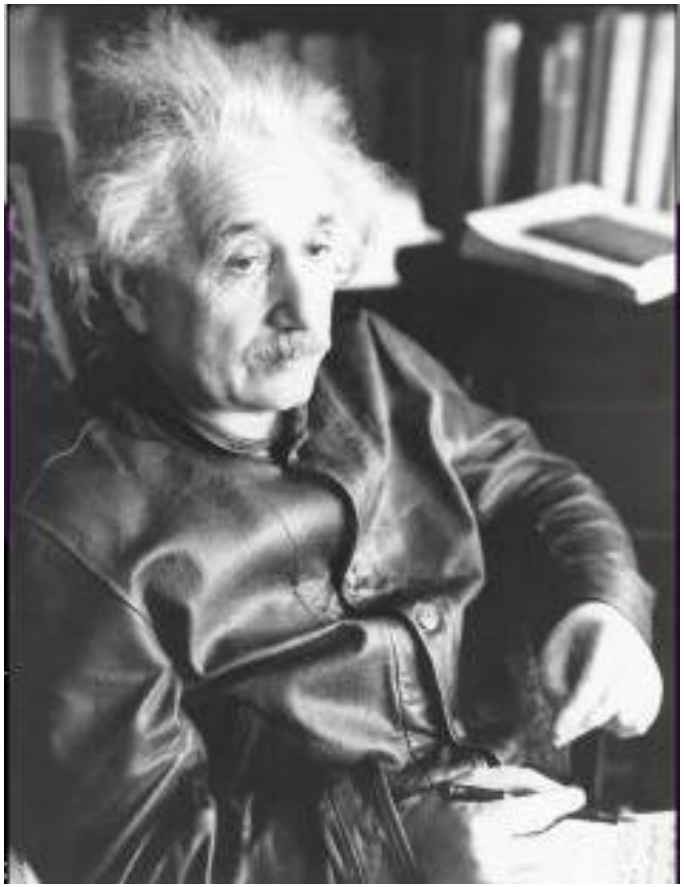
- In 1904 he wrote:

"If it were ever possible to control at will the rate of disintegration of the radio elements, an enormous amount of energy could be obtained from a small amount of matter"

Albert Einstein

- Albert Einstein developed his theory of the relationship between mass and energy one year later

- The mathematical formula is $E=mc^2$
  - "energy equals mass times the speed of light squared"

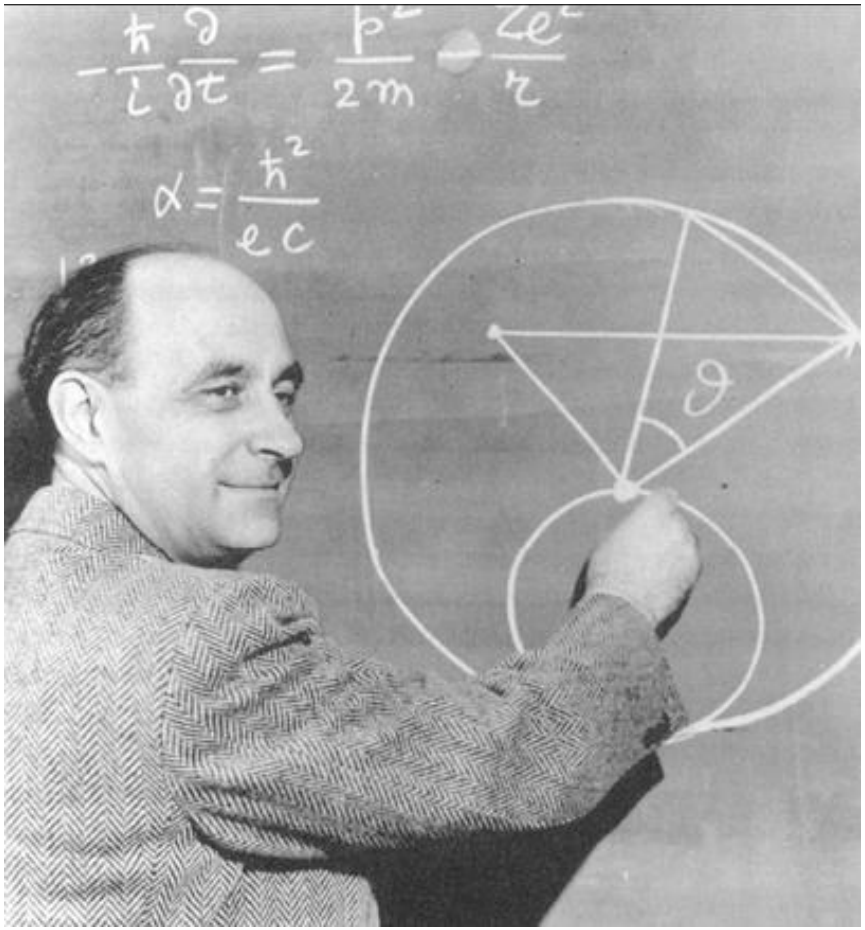


http://www.nuclear.gov/pdfFiles/History.pdf

Discovery of Fission

- In 1934, physicist Enrico Fermi conducted experiments that showed neutrons could split many kinds of atoms

- When he bombarded uranium with neutrons, he got elements that much lighter than uranium



http://www.nuclear.gov/pdfFiles/History.pdf

Discovery of Fission

- Otto Hahn and Fritz Strassman fired neutrons containing the elements *radium* and *beryllium* into uranium
- Hahn and Strassman contacted Lise Meitne who added the atomic masses of the fission products
- Meitner used Einstein's theory to show the lost mass changed to energy

First Self Sustaining Nuclear Reactor

December 2, 1942:

- Demonstration of Chicago Pile-1 (world's first nuclear reactor)
- Fermi ordered the control rods to be withdrawn a few inches at a time
- At 3:25 p.m. the nuclear reaction became self-sustaining

http://www.nuclear.gov/pdfFiles/History.pdf

Nuclear Power History

- **1945 July 16**: The U.S. Army's Manhattan Engineer District (MED) tests the first atomic bomb at Alamogordo, New Mexico, under the code name *Manhattan Project*

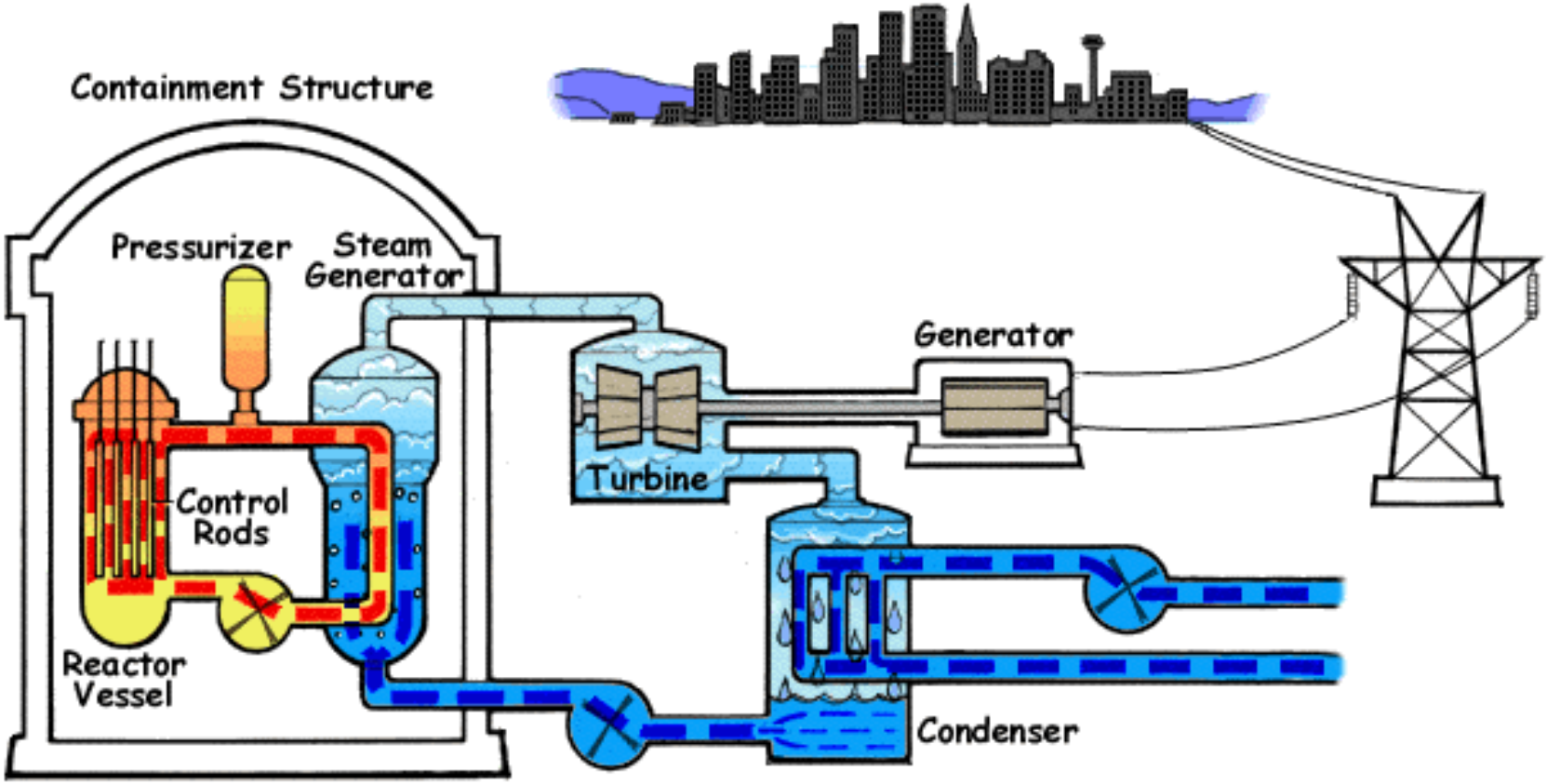
- **1946 August 1**: The Atomic Energy Act of 1946 creates the Atomic Energy Commission (AEC) to control nuclear energy development and explore peaceful uses of nuclear energy

- **1951 December 20**: In Arco, Idaho, Experimental Breeder Reactor I produces the first electric power from nuclear energy, lighting four light bulbs

Nuclear Power History

- **1957 December 2**: The world's first large-scale nuclear powerplant begins operation in Shippingport, Pennsylvania
- **1963 December 12**: Jersey Central Power and Light Company announces its commitment for the Oyster Creek nuclear powerplant,
- **1971**: Twenty-two commercial nuclear powerplants are in full operation in the United States
- **1984**: The atom overtakes hydropower to become the second largest source of electricity after coal

How Nuclear Power Works



http://www.cleansafeenergy.org/Portals/0/student-pwr.gif

Yucca Mountain

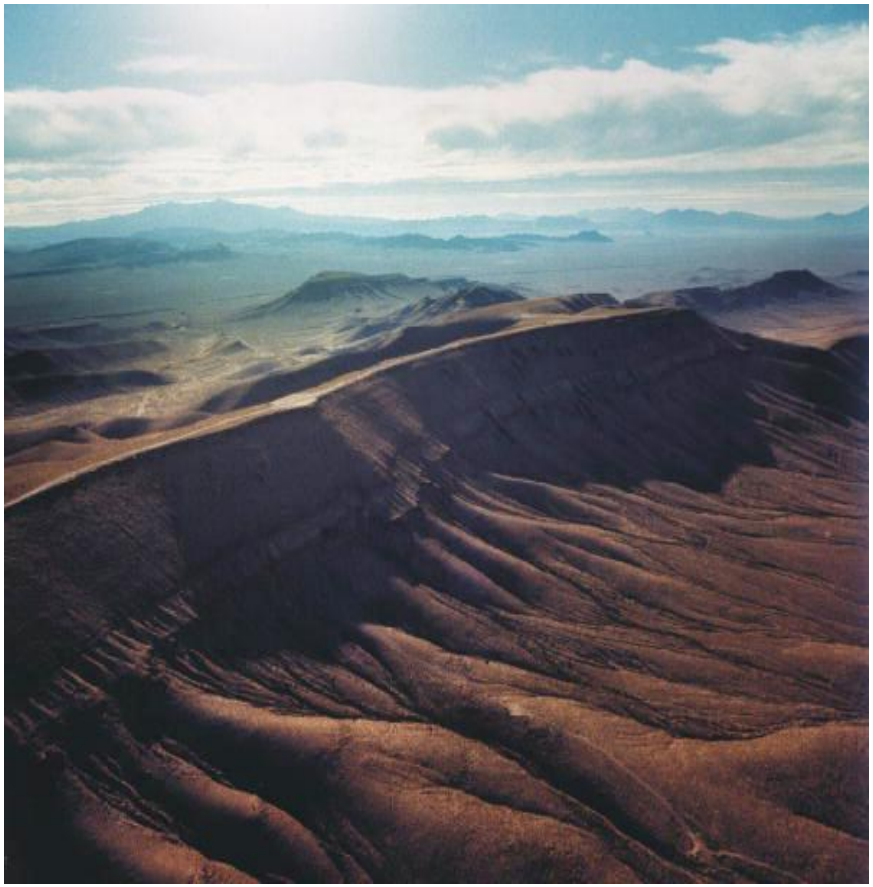
- Need for national repository for spent nuclear fuel
- Reasons for choosing Yucca Mountain
- Advantages / Disadvantages
- Proposed completion + Cost
- Safety + Transportation
- Future Work

Spent Nuclear Fuel

- Stored at facility
- High-level radioactive waste
- Environmental concerns
- Permanente disposal options

http://web.ead.anl.gov/uranium/uses/images/HydrostaticTest.jpg

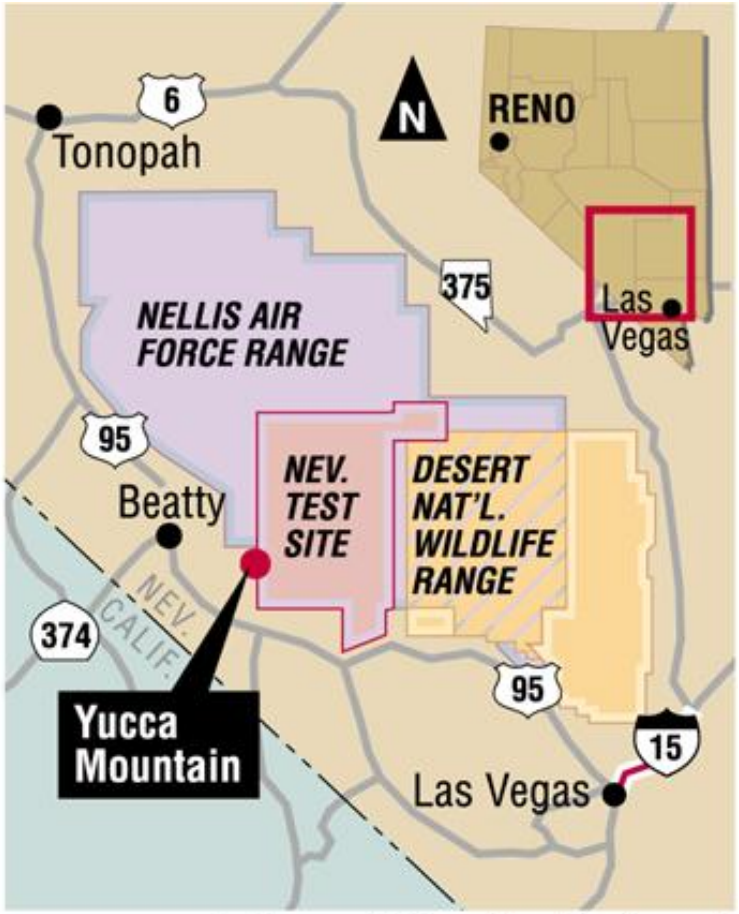
Timeline



http://www.newscientist.com/blog/shortsharpscience/uploaded_images/YuccaMountain-762092.jpg

- 1975 search for repository begins
- 1982 Nuclear Waste Policy Act (NWPA)
- 1984 three potential sites for repository
- 1987 Yucca Mountain chosen
- 2002 Congress approved construction

Site Characteristics



J. Kurowski/Reno Gazette-Journal

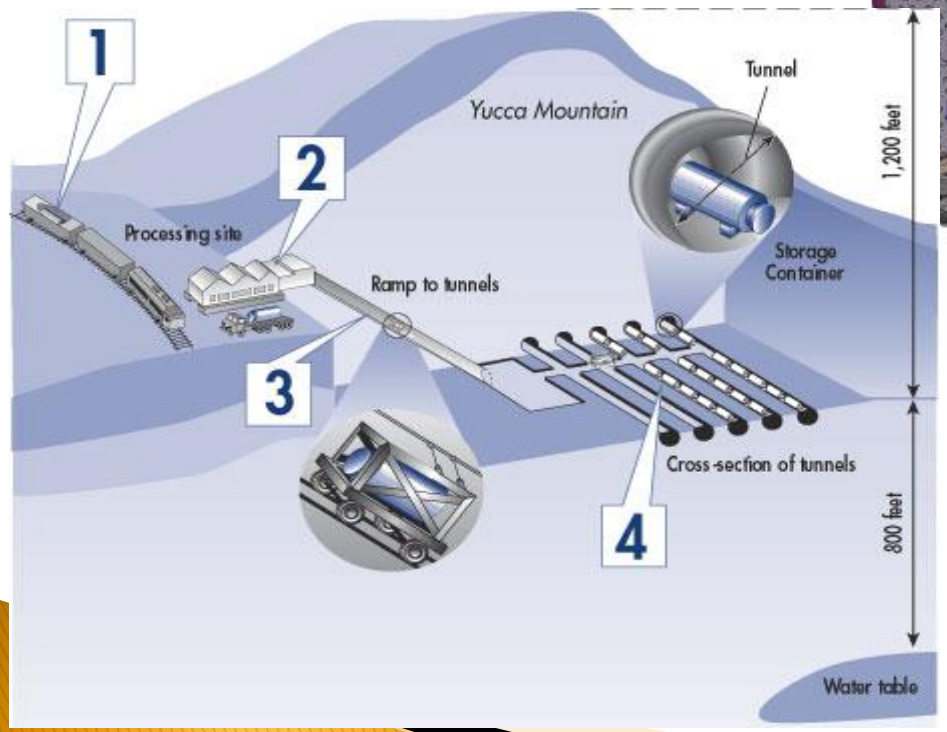
http://www.seismo.unr.edu/htdocs/yucca_map.jpg

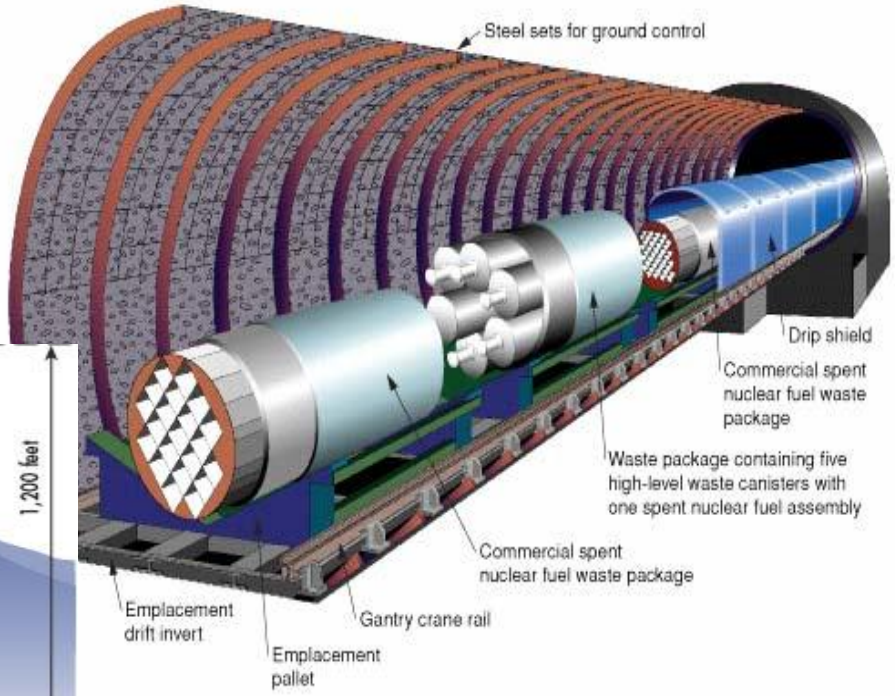
- 1,200 ft high volcanic ridge
- 90 miles northwest of Vegas
- Mountain comprised of "tuff"
- Low annual precipitation
- Deep water table

Design

https://www-pls.llnl.gov/data/assets/images/science_and_technology/materials/yucca_mountain/yucca_2.jpg

1.) Canisters of waste, sealed in special casks, shipped to site
2.) Shipping casks removed, inner tube with waste placed in a steel, multilayered storage container





3.) An automated system sends storage containers underground to the tunnels
4.) Containers are stored along the tunnels, on their sides

http://www.stockinterview.com/News/11082006/Yucca-mountain.gif

Geology

Advantages

- Desert location
- Isolated from population
- Surrounded by federal land
- Deep underground
- Geologic barriers
- Engineered barriers and flexible design

Disadvantages

- Seismic region
- Volcanic cinder cones near site
- Pathways connecting to groundwater table
- Evidence of hydrothermal activity

Funding

- The NWPA requires utilities to pay $0.001 per kilowatt-hour to the Nuclear Waste Fund
- Life cycle cost: $96 billion (2007 dollars)
  - Between 1983 to 2133 (150 years)
- Repository completion: 2017
- First shipment of spent nuclear fuel: 2020

Waste Containment

- Radioactive nuclear waste placed into large metal *casks*
- Casks must withstand:
  - Drop from 30 ft to unyielding surface
  - Fully engulfing fire at 1475ºF for 30 minutes
  - Immersion in 3 ft of water

http://www.iaea.org/OurWork/ST/NE/NEFW/images/casks.jpg

Transportation

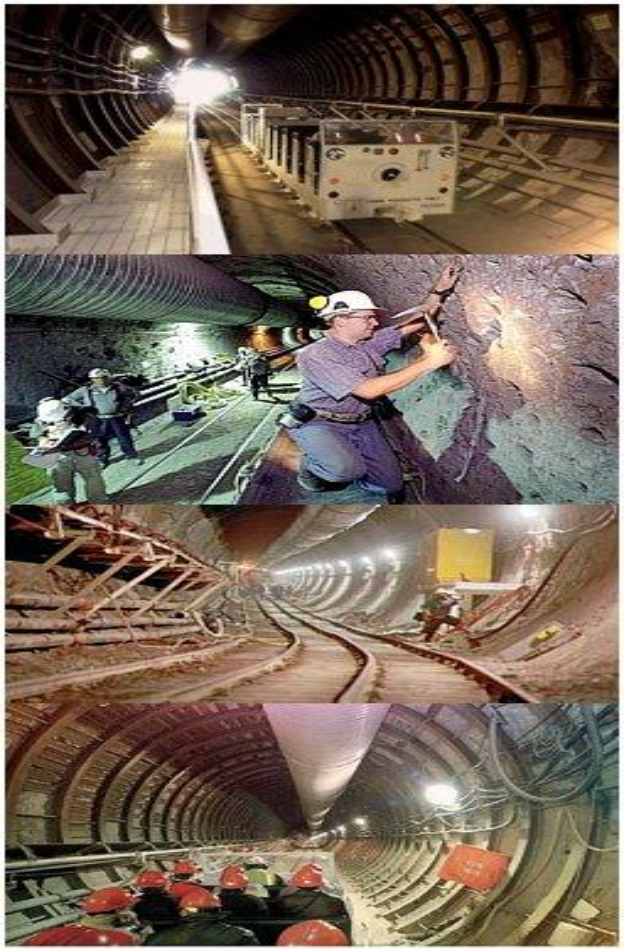
- Shipping by either rail or truck
- Routes TBD
- Waste transportation starts 2010 the earliest
- 10.4 to 16.4 million people living within one-half mile of transport by 2035
  - Safety, transportation, Cask testing, truck versus rail, emergency response, accident liability

Transportation Safety

- Since 1965:
  - Transported more than 10,000 spent fuel assemblies
  - Over 2,700 shipments of waste over more than 1.6 million miles
- Accidents
  - 4 highway, 4 rail
- Security
  - Escorts, constant monitoring, safeguarded schedule, coordinated logistics with local law

Future Work

- Complete construction
- Design transportation systems
- Pass government acts and regulations
- Monitor repository for 50-300 years
  - Seal tunnels
  - Create national monuments and landmarks



http://www.yuccamountain.org/faq.htm#why

Reprocessing Nuclear Waste

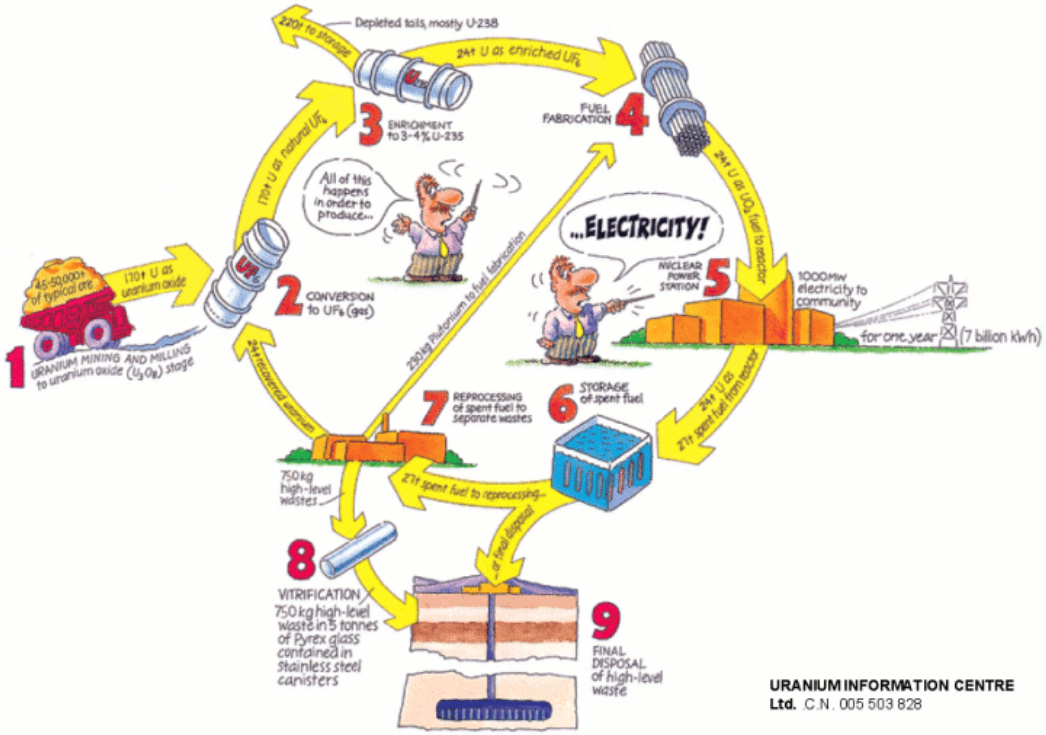
- How It Works
- Uses for Reprocessed Fuel
- Advantages/Disadvantages
- Environmental Impact
- Examples of Reprocessing plants

How It Works

- Fuel rods are made up of ceramic pellets
- Fuel rods last for 1-3years before needing to be replaced
  - 3 options for spent fuel
    - Remain at site from which they are removed from service
    - Move to a more permanent site for storage
    - Be reprocessed to remove uranium and plutonium

How It Works

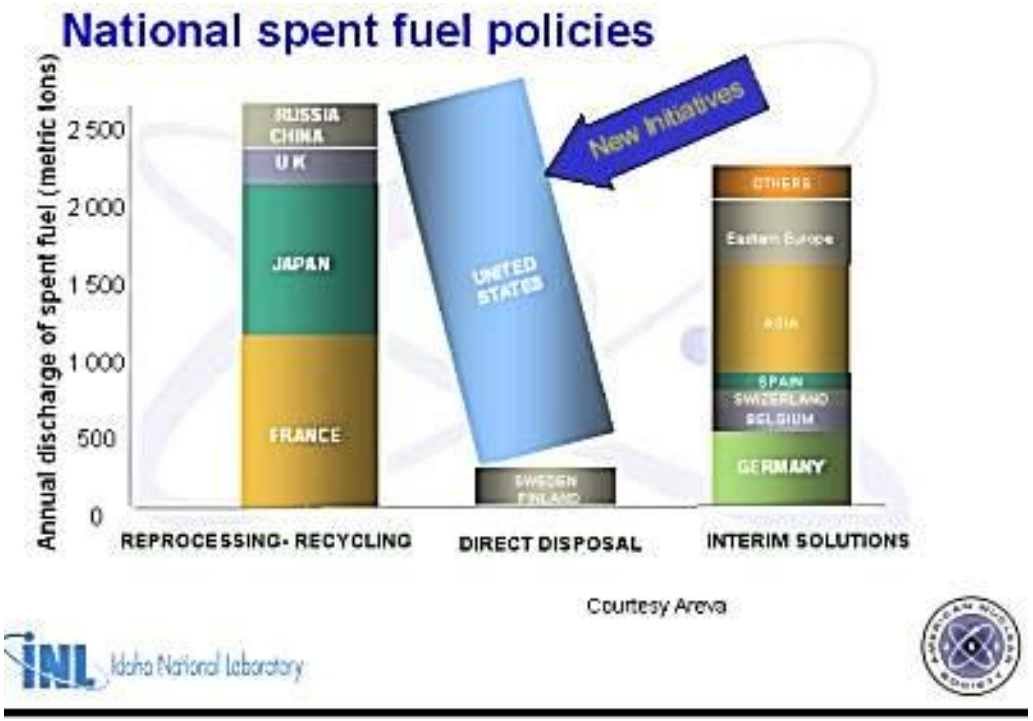
- Plutonium and Uranium are removed and chemically separated
- Enrich uranium
- Create mixed oxide reactor fuel



http://www.stockinterview.com/News/10052007/nuclear-fuel-cycle.gif

Uses for Reprocessed Fuel

- Mixed oxide fuel used in nuclear power plants
- Can use plutonium from process for nuclear weapons



http://www.carlist.com/autonews/2006/image/spent_fuel.jpg

Pros/Cons

Advantages	Disadvantages
Reduce nuclear waste Make nuclear fuel Reduce toxicity of nuclear waste	Makes weapon grade plutonium Doesn't get rid of nuclear waste completely

Environmental Impact

- Two types of monitoring used to determine plants' impact
  - Continuous Monitoring
    - Measures release levels and enables corrective action to be taken quickly if needed
  - Environmental Sampling and Analysis
    - Monitors presence of radionuclides at various points in the land and marine environments and along pathways to man

Example: UK

The Thermal Oxide Reprocessing Plant (THORP) in UK. This commercial facility treats spent fuel from UK and overseas reactors, separating the high-level waste from uranium & plutonium. The smaller black building on the right is the vitrification plant for this waste.

http://chemcases.com/nuclear/nc-13.htm

Example: France

- La Hague industrial complex
- Occupies 740 acres
- Approximately 6000 people work at site full-time
- Been in service since 1966
- Many power companies reprocess their fuel at this site

Conclusion

Yucca Mountain vs. Reprocessing Nuclear Waste

Which one is better?