VIEWING BACK END OF NUCLEAR FUEL CYCLES SYNOPTICALLY AND COMPARATIVELY

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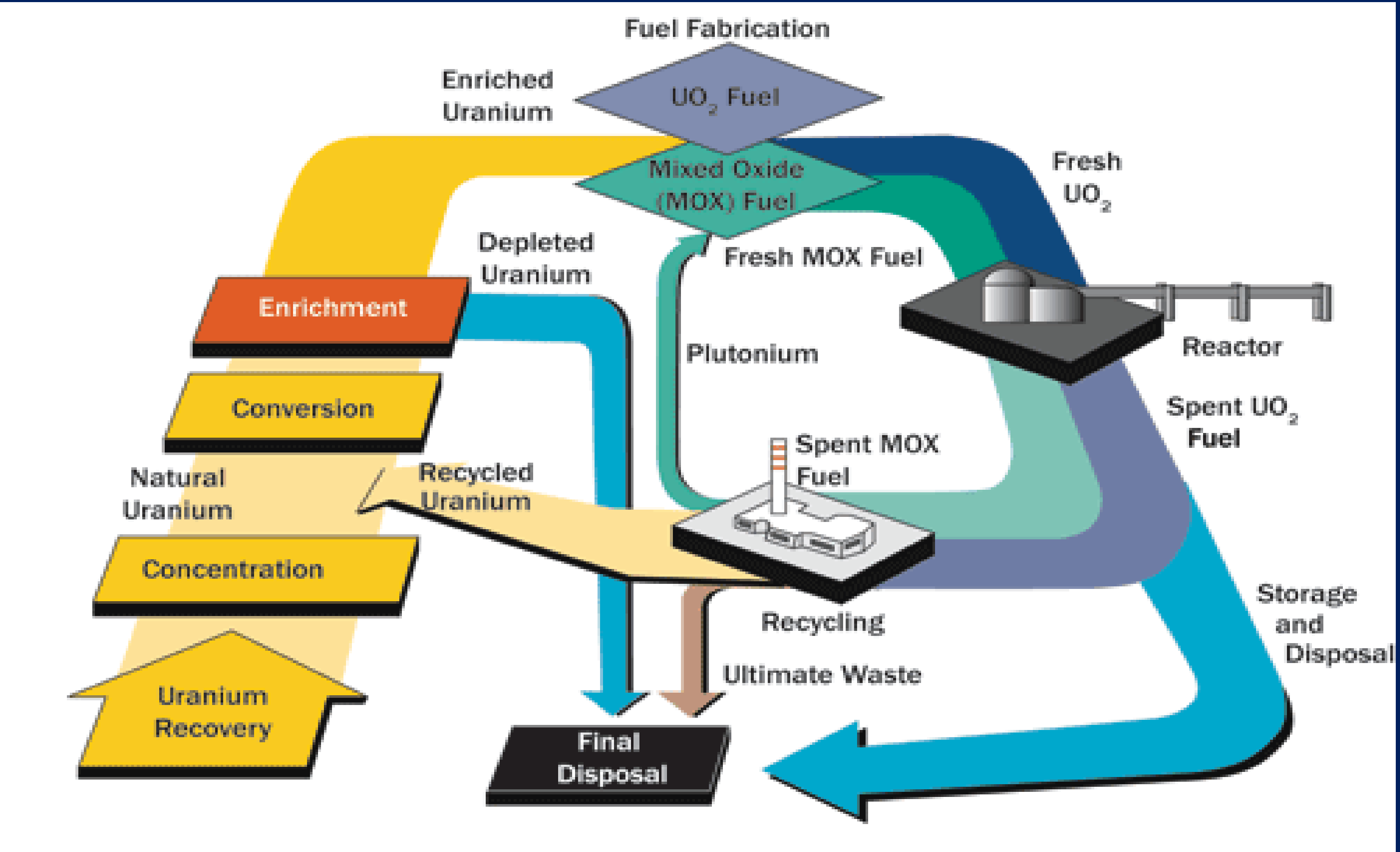
The prevailing laws and regulations will have to be changed no matter what the Blue Ribbon Commission recommends. With its outstanding members and staff and a Noble Laureate as DOE Secretary, the BRC has an unique opportunity to make the process rational, transparent, sustainable, believable and hopefully successful. We cannot repeat the mistakes of the past.

ALMOST UNANIMOUS AGREEMENT ON PURSUING A SYNOPTIC VIEW OF THE BACK END OF THE FUEL CYCLE AND A WILLING, IF NOT ENTHUSIASTIC, REPOSITORY HOST.

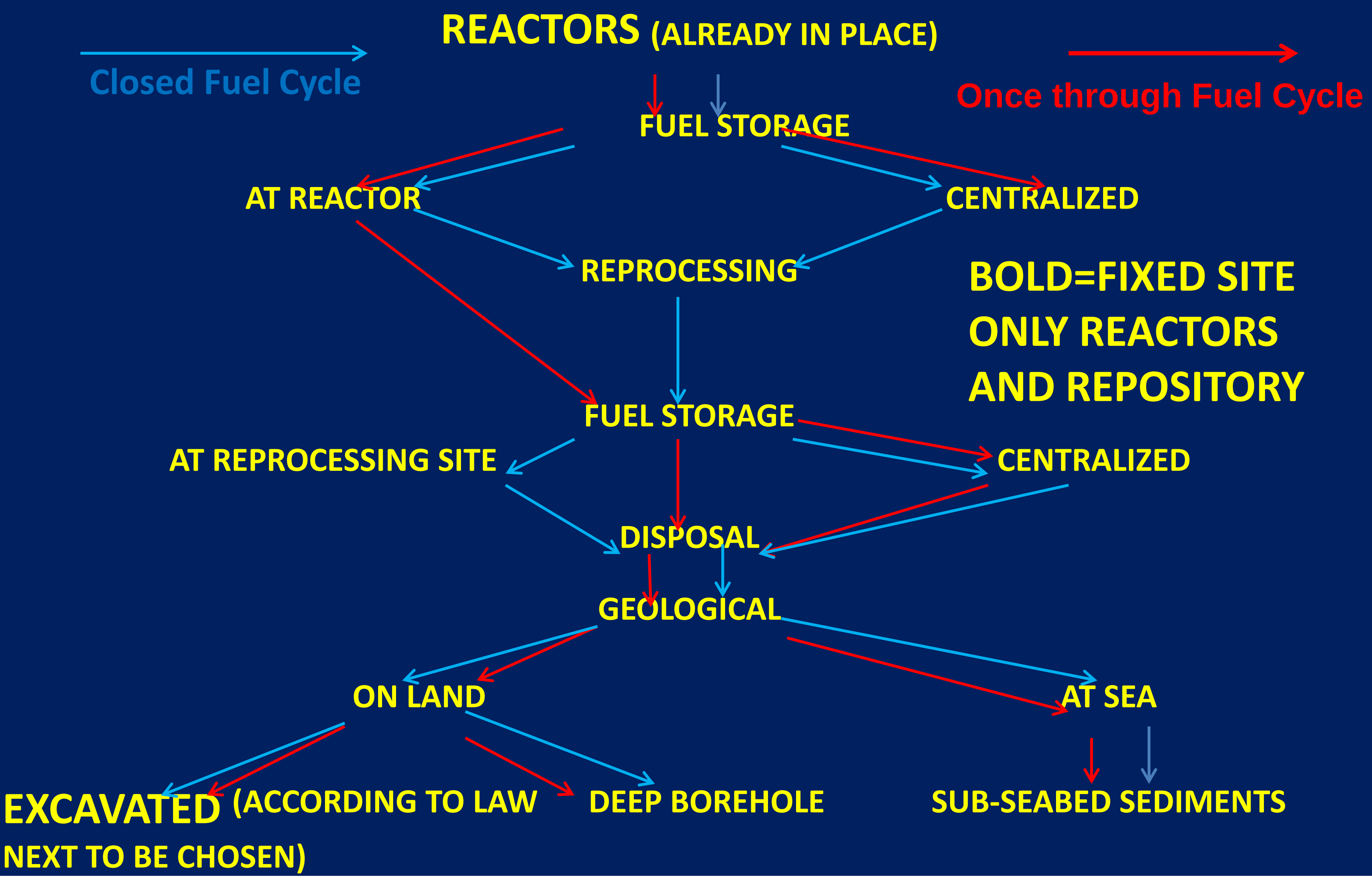
COMPLETE NUCLEAR FUEL CYCLE

http://www.nrc.gov/materials/fuel-cycle-fac/stages-fuel-cycle.html

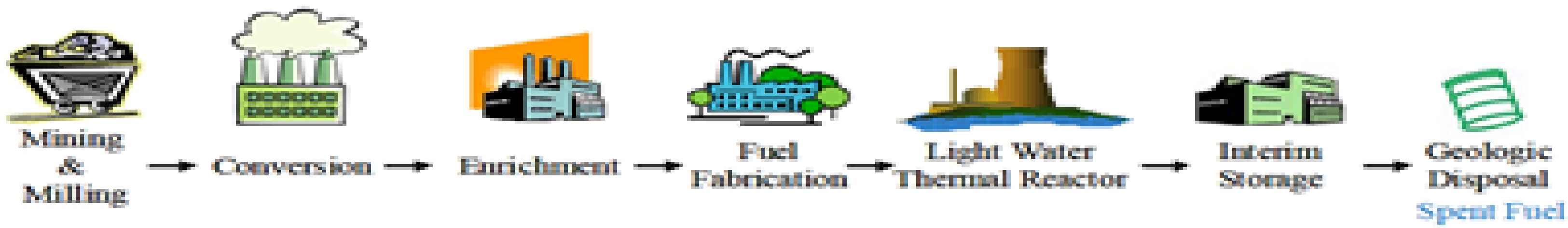


Source: U.S. Nuclear Regulatory Commission

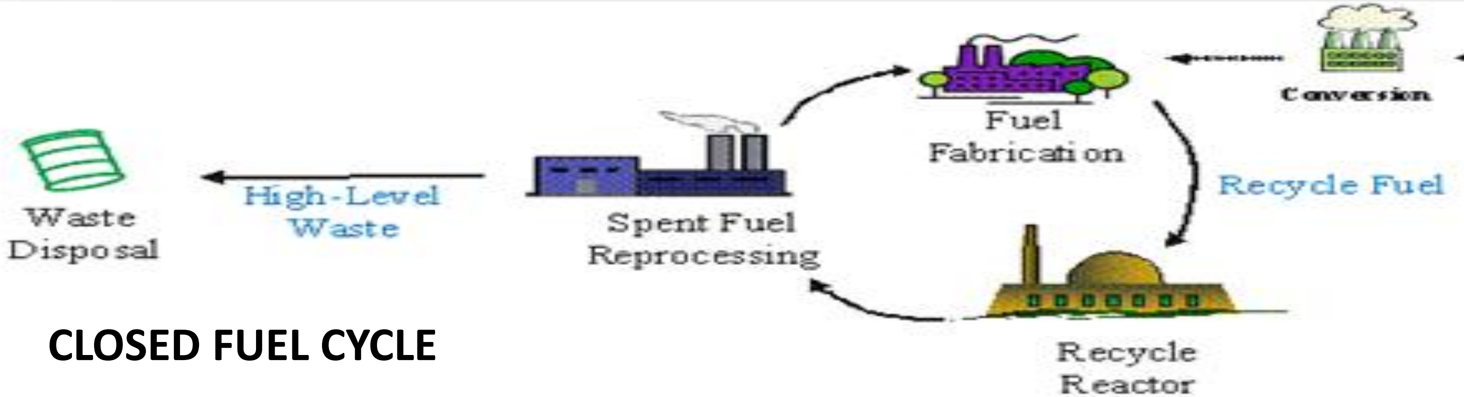
SPENT FUEL FLOW SHEET



OPEN AND CLOSED FUEL CYCLES



OPEN FUEL CYCLE



CLOSED FUEL CYCLE

NOTE THAT TRANSPORTATION BETWEEN THESE PROCESSES IS NOT HIGHLIGHTED

Advanced Nuclear Fuel Cycle Research and Development Testimony to U.S. House of Representatives Committee on Science and Technology Mark T. Peters, Argonne National Laboratory, June 17, 2009

COMPARATIVE ANALYSES OF THE BACK END OF THE NUCLEAR FUEL CYCLE

ELEMENTS TO BE TAKEN INTO ACCOUNT IN COMPARATIVE ANALYSES OF BACK END

ELEMENTS	FUEL STORAGE		REPROCESSING	WASTE STORAGE		DISPOSAL		
	AT REACTOR	CENTRALIZED		AT REPROCESSING SITE	CENTRALIZED	GEOLOGICAL		
						ON LAND		AT SEA
						EXCAVATED	DEEP BOREHOLE	SUB-SEABED SEDIMENTS
TECHNICAL (GEOLOGICAL, SEISMLOGICAL, HYDROLOGICAL, ETC								
TRANSPORTATION ROUTES								
COSTS								
PUBLIC AND POLITICAL ACCEPTANCE								
PROLIFERATION RESISTANT								
OTHERS								

HOW THE POSSIBLE REPOSITORY SITES WERE SELECTED I

A Multiattribute Utility Analysis of Sites Nominated For Characterization For the First Radioactive Waste Repository

A Decision Aiding Methodology, May, 1986, DOE/RW-0074, Nuclear Waste Policy Act, Section 112

The Report is a description of the site screening process intended to help choose the repository sites to be investigated in more detail.

("It is intended to aid in the site-recommendation decision by providing insights into the comparative advantages and disadvantages of each site. Because no formal analysis can account for all the factors important to a decision as complex as recommending sites for characterization, this study will not form the sole basis for the decision.") (P. 1-1-1-2.)

From the Environmental Assessments (EA) of each of the sites, the health and safety impacts of the repository and transportation and the environmental, socioeconomic and economic impacts were abstracted to determine composite utilities and fraction of EPA radionuclide limits for the first 10,000 years after repository closure.

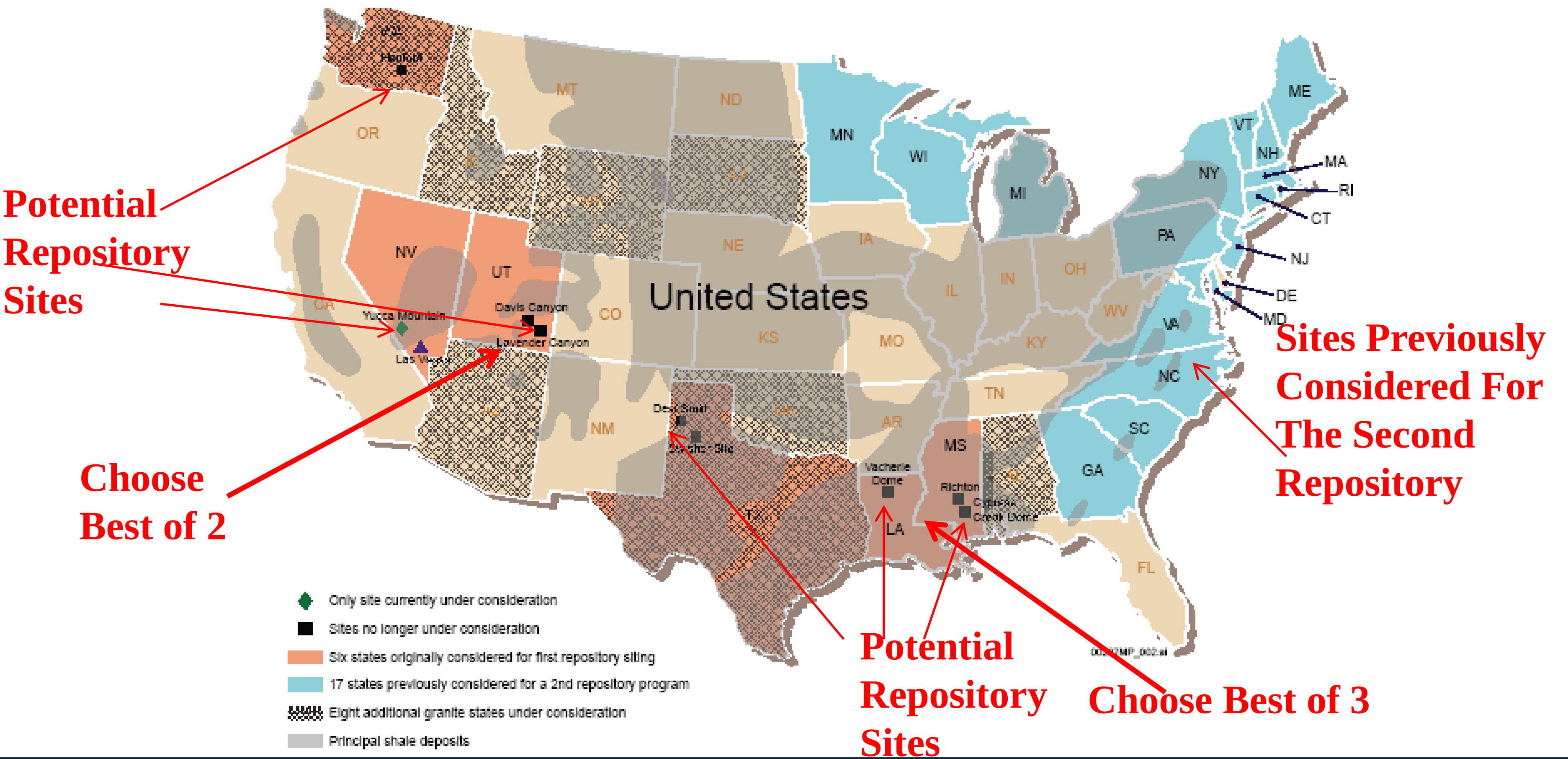
It was stated that "the scaling (weighting-added) factors cannot be used as indicators of the importance of the respective performance measures." (P. 5-1)

HOW THE POSSIBLE REPOSITORY SITES WERE SELECTED II

If one assumes identical waste-transportation and repository costs for all sites, then the composite utility for all sites with 100 percent weighting on the preclosure factors ranged from 97.5 to 100 and for 100 percent weighting on the postclosure factors, the composite utility ranged from 98.5 to 99.3. (ibid P. 5-10) **In other words, considering the accuracy of calculations and the uncertainty in the input data, the composite utility for all sites was the same.**

These results were predictable because the sites were selected based on their meeting EPA's site criteria. In other words, it was a circular exercise- the sites were selected based on the likelihood of their meeting the EPA site criteria and when the calculations were made, not surprisingly they did.

NINE POTENTIAL REPOSITORY SITES



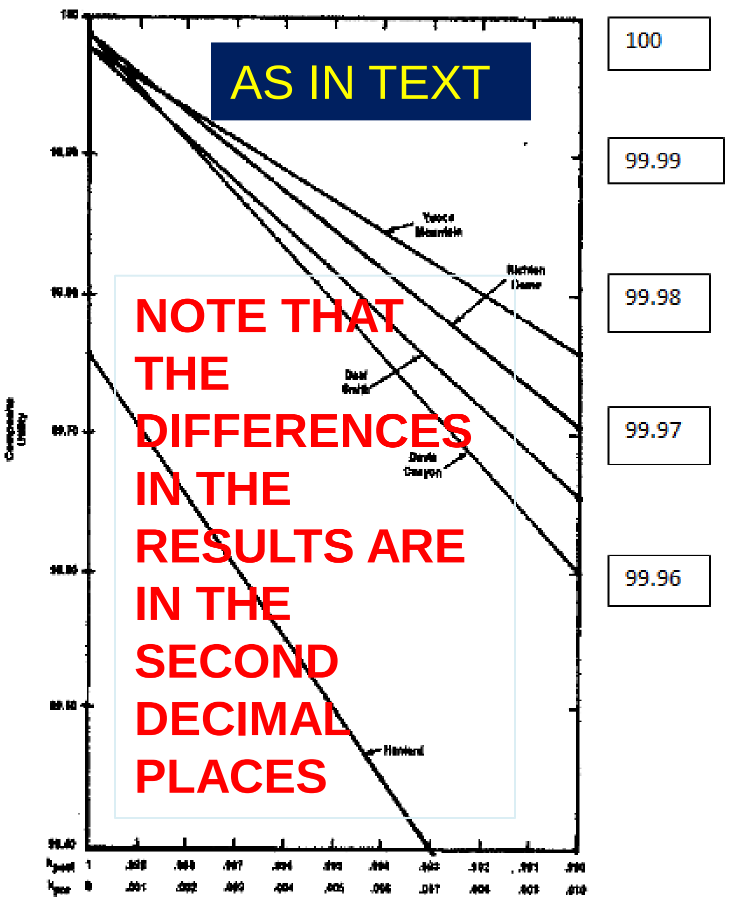
First Repository Program Sites, Second Repository Program Areas Under Consideration, and Shale Deposits Potentially Suitable for a Repository The Report to the President and the Congress by the Secretary of Energy on the Need for a Second Repository, DOE/RW-0595, December, 2008

Table 3-6 Computed Base-Case Expected Releases and Postclosure Utilities

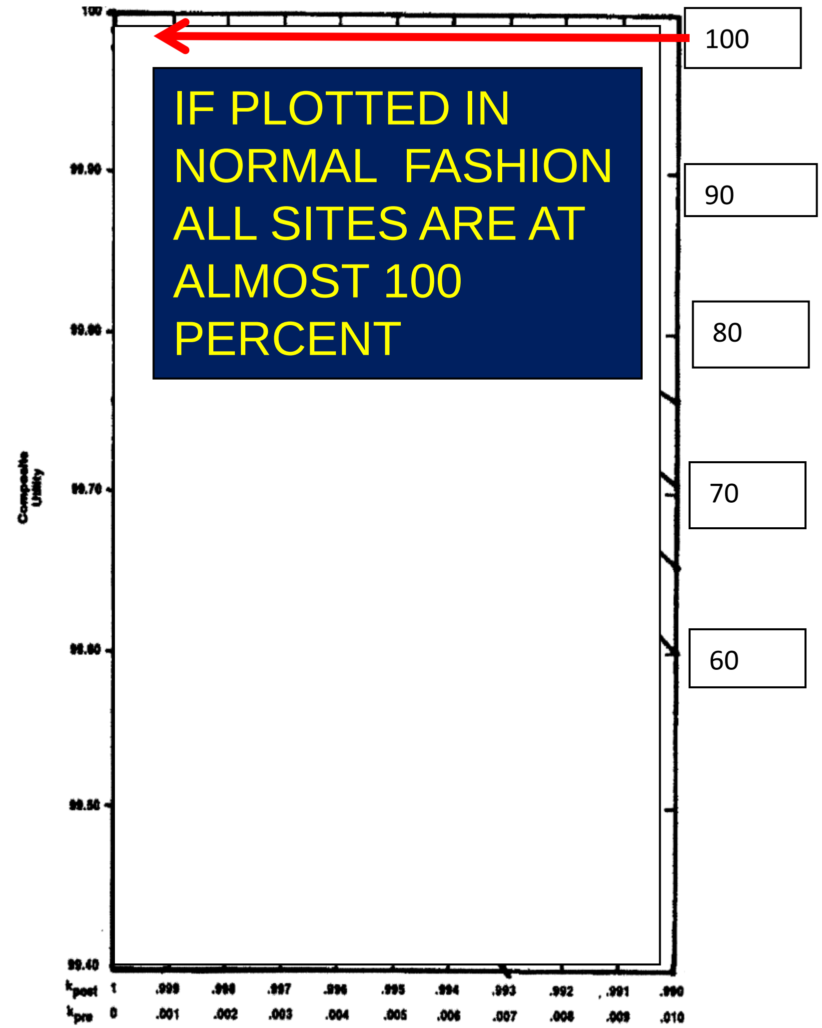
A Multiattribute Utility Analysis of Sites Nominated For Characterization For the First Radioactive Waste Repository - A Decision Aiding Methodology, DOE May 1986, DOE/RW-0074

SITE	EXPECTED POSTCLOSURE UTILITIES	EQUIVALENT RELEASES PER 10,000 YEARS(a)
Salt		
Cypress Creek Dome, Louisiana		
Richton Dome, Mississippi	**99.99**	**1.10 x 10E-4**
Vacherie Dome, Louisiana		
Deaf Smith County Bed, Texas	**99.98**	**2.33 x 10E-4**
Swisher County Bedded, Texas		
Davis Canyon Bedded, Utah	**99.99**	**1.09 x 10E-4**
Lavender County Bedded, Utah		
Welded tuff		
Yucca Mountain Nevada	**99.98**	**2.35 x 10E-4**
Basalt		
Hanford, Washington State	**99.76**	**2.41 x 10E-3**
a= Fraction of EPA limits for the first 10,000 years after repository closure		

HOW THE POSSIBLE REPOSITORY SITES WERE SELECTED COMPOSITE UTILITY OF FINAL 5 SITES III



COMPOSITE UTILITY



Site Composite Utilities for High Postclosure Weightings Calculated Under Base Case Assumptions

HOW THE POSSIBLE REPOSITORY SITES SHOULD BE SELECTED I

These results argue for a much simpler screening method for preliminary site selection similar to that used to select sites for the National Priority List 40 CFR 300 - Contingency Plan-Appendix A--Uncontrolled Hazardous Waste Site Ranking System (HRS); A Users Manual. The HRS serves as a screening device to evaluate the potential for releases of uncontrolled hazardous substances to cause human health or environmental damage. The HRS provides a measure of relative rather than absolute risk. It is designed so that it can be consistently applied to a wide variety of sites. The preliminary choices for the back end of the fuel cycle could made with a much lower effort and far lesser cost and with equal validity. Of course, the new screening tool should be tested against the results of the EAs and for ease of calculation.

HOW THE POSSIBLE REPOSITORY SITES SHOULD BE SELECTED II

- Impossible to determine the 'best' solution even if we could agree on what 'best' means.
- As shown in EAs above and known from many studies, the results of the calculations, the response surface, is likely to be relatively flat so that achieving the 'best' is not necessary.
- Distinguish between present deaths and those that could occur far in the future.
- Distinguish between observed deaths and those that could occur based upon probable, even possible, events.
- Distinguish between deaths based on present demographics, lifestyles and medical knowledge and those that could occur far in the future taking into account the then existing demographics, lifestyles and medical knowledge.
- Waste of time, energy and money to do EAs of nine sites. Eliminate most by simple comparative analyses.
- Eliminate the requirement to study a diversity of geological formations. Looking for 'best' sites could include a diversity of geological formations.

TRANSPORTATION PROBLEMS WITHOUT A SYNOPTIC VIEW

Transportation, Aging, and Disposal (TAD) Canisters for Used Nuclear Fuel Are Not Truckable

Maximum weight of 54 tons; Contain 21 PWR or 44 BWR Fuel Elements

McCullum, Rod and David Blee, Transportation, Aging, and Disposal (TAD) Canisters-The Bridge to System Integration, September 19, 2007, U.S. Nuclear Waste Technical Review Board

Legal Weight Trucks can carry up to 80,000 pounds and Overweight Trucks up to 120,000 pounds. **Janairo P. 45**

"..currently 25 commercial reactor sites do not have rail capabilities." **Lisa R. Janairo and Melissa Baily, August 2010, Transportation Institutional Issues-Involving the U.S. Department of Energy's Civilian Radioactive Waste Program. P. 40**

"..almost one-third of the total 63,000 MTU of commercial spent …shipped to the proposed repository over the first 24 years would originate from sites without direct rail access." **Fred Dilger and Bob Halstead, December 11, 2007, Shipping Site Intermodal Transportation-quoted in Janairo P. 42**

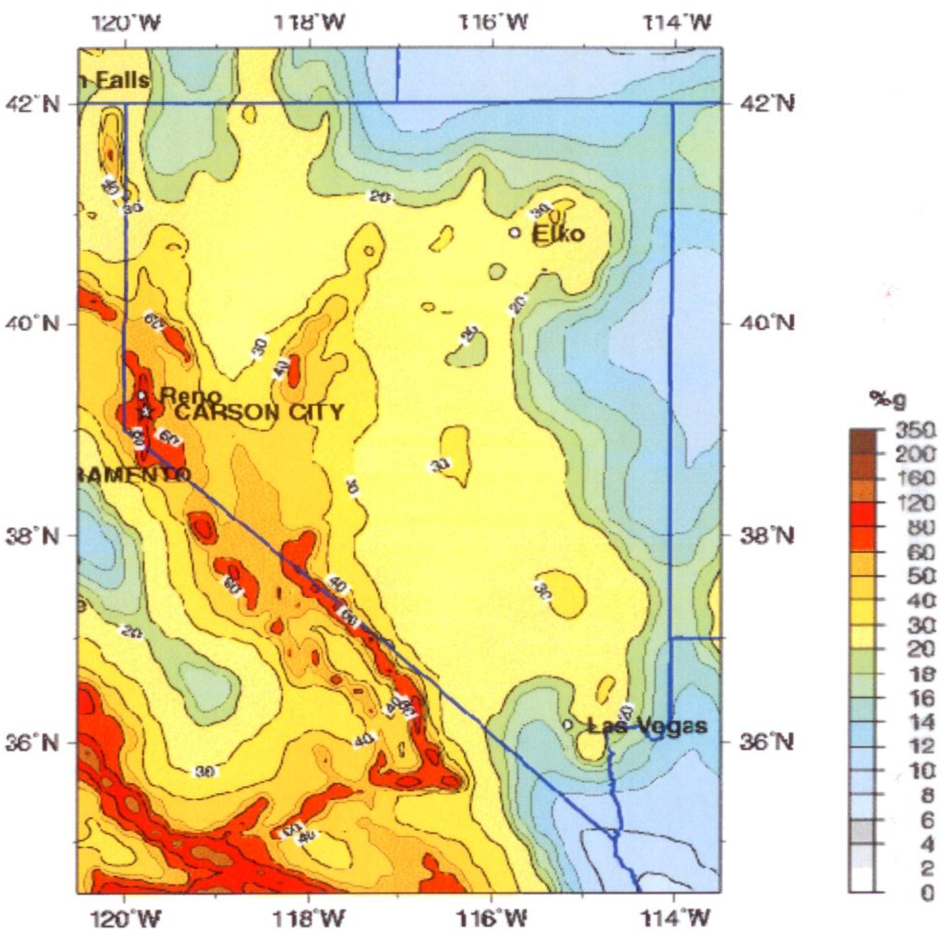
ARE THERE BETTER OPTIONS FOR TRANSPORTATION?

DOE's transportation plans are for a multimodal system-primarily rail and truck. However, "OCRWM never prepared a description, for transportation planning purposes, of what mode each site would use for shipping and how many shipments would take place". Janairo P. 44 DOE has given short shrift to barge shipments ibid P.44- as does the National Academies "The committee strongly endorses DOE's decision to ship spent fuel and high level waste to the federal repository by mostly rail using dedicated trains." Committee on Transportation of Radioactive Waste, 2007, Going the Distance?-The Safe Transport of Spent Nuclear Fuel and High-Level Radioactive Waste in the United States P.4 and further, does not even mention barge transport in section 5.4.1 Mode for Transporting Spent Fuel and High-Level Waste ibid P.16. This is strange as every reactor site had barge access during construction for pressure vessel delivery.

Note that transportation impacts in the EAs were determined solely on the distance traveled and not on the difficulty of the terrain.

For comparative purposes, using average figures, the likelihood of an individual dying from a traffic accident is 770 times as likely as from the EPA permitted dosages from releases from Yucca Mountain. It was noted in a previous slide that the projected dosages are 3 to 4 orders of magnitude less than the permissible doses.

SEISMIC CONDITIONS ALONG THE YUCCA RAIL ROUTES



Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary
National Seismic Hazard Mapping Project (2008)

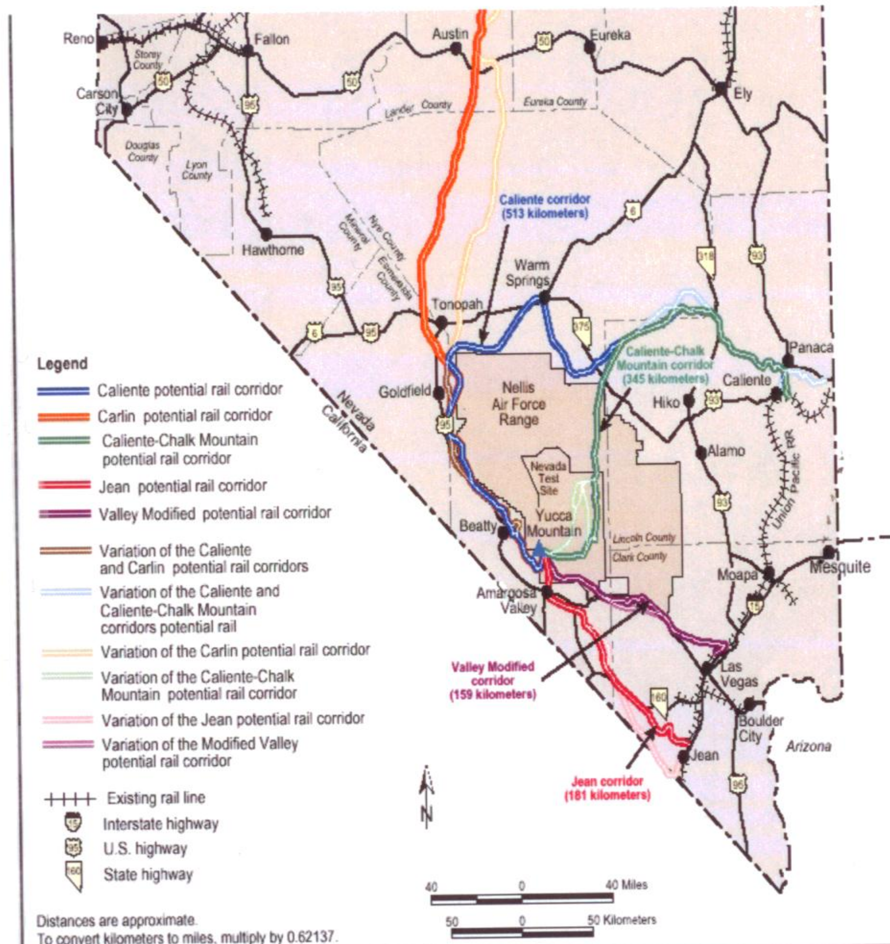


Figure S-13. Potential Nevada rail routes to Yucca Mountain.

We do not know quite as much about the location of faults as is sometimes inferred- "Previously Unknown Fault Shakes New Zealand's South Island"

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AN EXAMPLE OF THE SYNOPTIC APPROACH WITH BARGE TRANSPORTATION AND DISPOSAL IN DEEP SEA SEDIMENTS

COMPARE REALISTIC BACK ENDS OF THE FUEL CYCLE

- Surface and near surface storage at reactors and centralized surface storage facilities.
- Reprocessing plants
- Deep geological disposal on land in excavations and deep boreholes.
- Tunnel under the ocean to a sub-seabed site storage (already in existence in Sweden).
- Sub-seabed sediments storage site.

TRANSPORTATION BETWEEN EACH SITE MUST BE INCLUDED.

CAVEATS IN COMPARING REALISTIC BACK ENDS OF THE FUEL CYCLE

BEFORE ANY DECISION IS MADE, THE OPTION SHOULD BE EXAMINED THEORETICALLY, MODELED AND TESTED AT A PILOT SCALE. THE DECISION MUST ALSO BE BASED ON SOCIAL, ECONOMIC AND ETHICAL CONSIDERATIONS.

BECAUSE OF THE UNCERTAINTIES INVOLVED IN THE SCIENTIFIC AND TECHNICAL WORK AND THE LIKELIHOOD OF A RELATIVELY FLAT RESPONSE SURFACE, MINOR DIFFERENCES IN THE RESULTS OF THE CALCULATIONS OF LONG TERM EFFECTS SHOULD BE IGNORED.

LOCATION OF REPRESENTATIVE NUCLEAR POWER PLANTS, DOE AND US NAVY SHIPYARD SITES

ARE THERE BETTER OPTIONS FOR TRANSPORTATION FROM AND TO THESE SITES?

Swedish Barge Transportation System

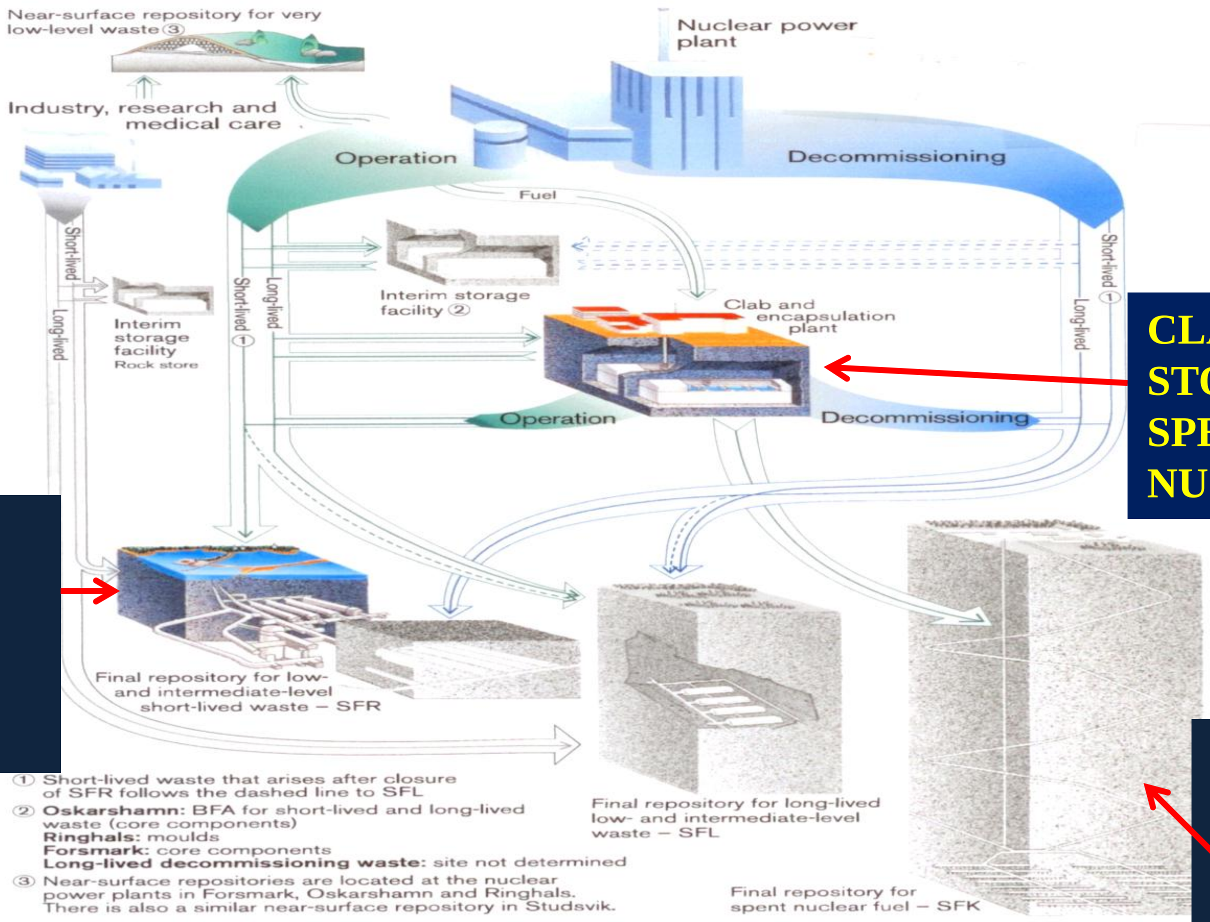


Figure 2-1. Overview of the Swedish system for management and disposal of the waste products of nuclear powe

CLAB INTERIM STORAGE OF SPENT NUCLEAR FUEL

SFR, THE FINAL REPOSITORY FOR RADIOACTIVE OPERATIONAL WASTE

FINAL REPOSITORY FOR SPENT FUEL

Plan 2008 Costs starting in 2010 for the radioactive residual products from nuclear power. Basis for fees and guarantees in 2010 and 2011, SKB 2009, SKB TR-09-23

BASICALLY, ALL NUCLEAR WASTE AND SPENT FUEL IS BY BARGE

THE SWEDISH SIGYN ROLL ON/ROLL OFF SHIP

Length: 90 metres, **Width:** 18 metres, **Deadweight tonnage:** 2,044 tonnes, **Gross tonnage:** 4,166 tonnes, **Loading capacity:**1,400 tonnes, **Draught with full load:**4 metres **, Cruising speed:**12 knots

MAJOR SHIPPER OF SPENT FUEL AND HLW

PNTL INF 3 VESSELS	Pacific Sandpiper	Pacific Heron
Length	104 meters	104 meters
Beam	16 meters	17 meters
Deadweight	3,775 tonnes	4,916 tonnes
Displacement	7,725 tonnes	9,667 tonnes
Engine	2 engines, 1900 HP each	2 engines, 3600 HP each
Maximum Cargo Capacity	24 Casks	20 Casks

PNTL has completed over 170 shipments of used nuclear fuel, vitrified high-level waste, mixed oxide (MOX) fuel and plutonium since it was established in 1975.

NEWER HIGHER CAPACITY RUSSIAN SHIP

Rossita, built at La Spezia, Italy, will transport submarine waste in north-west Russia. Launched 16 December, 2010, it measures 84 metres by 14 metres and can carry up to 720 tonnes up to 3000 kilometres. **20 December 2010 World Nuclear News**

Japan and the United Kingdom already transport spent fuel and nuclear waste across the seas. **R. Smith, Maritime Security and Nuclear Cargoes, 2010 www.unidir.org/pdf/articles/pdf-art2961.pdf**

ADVANTAGES OF BARGE SHIPMENT

- Well established practice. At one time all sites had barge facilities to bring in the pressure vessels and other large, heavy equipment.
- Much greater loads can be carried so that fewer shipments will be required. Therefore, fewer opportunities for terrorist attacks.
- Barge transportation will reduce the number of transfers in shipping compared with a multi-modal system as presently planned.
- The heavy lifting equipment needed should be available at all sites.
- Many of these shipping facilities are not operational now but could be rehabilitated, most likely, at lower cost than a couple of hundred of miles of new railroad track through difficult terrain as at Yucca..

NUCLEAR WASTE AND SPENT FUEL STORAGE-ON SITE (REACTOR) OR CENTRALIZED STORAGE?

"The Commission finds, however, that the while no single factor would favor an MRS (Monitored Retrieval Storage facility) over the No-MRS option, cumulatively the advantages of an MRS would justify the building of an MRS if …the restrictions imposed on its construction were removed." (submission letter)

"..the Commission has decided that some limited interim storage facilities would be in the national interest to provide for emergencies and other contingencies. ". (submission letter)

"The Commission recommends… a Federal Emergency Storage facility with a capacity limit of 2,000 metric tons of uranium. …(and) a User –Funded Interim Storage facility with a capacity limit of 5,000 metric tons of uranium." (submission letter)

Nuclear Waste: Is There A Need For Federal Interim Storage? Report of the Monitored Retrievable Storage Review Commission, November 1, 1989, Alex Radin, Dale E. Klein and Frank L. Parker

CENTRALIZED INTERIM STORAGE SITES

- **Two nuclear navy shipyards on the east coast of the USA, Portsmouth and Norfolk, and one on the west coast.**
- **Easier to locate nuclear facilities where other nuclear facilities already exist. With cutback in defense expenditures, new assignments would be welcome.**
- **Nuclear maintenance and repair facilities already in place.**
- **High capacity cranes already in place.**
- **Enhanced security already in place.**

ADVANTAGES OF NAVAL NUCLEAR SHIPYARDS

NORFOLK NAVAL SHIPYARD

The shipyard can accommodate any ship in the fleet. State-of-the-art technology provides capability to service nuclear as well as conventional ships of all sizes and types, from tugboats to submarines to aircraft carriers.

Their services include reactor safety and the technical aspects of all shipyard nuclear propulsion plant work involving overhaul, maintenance, conversion, refueling, testing, quality control and radiological engineering of the reactor plant.

Further, security at the facility is required and with 800 acres of land, 4 miles of waterfront, 400 cranes, 19 miles of railroad tracks, its own police & fire departments and electric & steam generating plant, space for installations is available as are all essential services.

Finally, it is well known that it is easier to site new nuclear facilities where other nuclear facilities already exist.

http://www.navsea.navy.mil/shipyards/norfolk/default.aspx

DISPOSAL IN SUB-SEABED SEDIMENTS I

Disposal of high level waste (spent fuel) in deep ocean sub-seabed sediments was successfully explored in the 1970s and 1980s.

Recovery of some of the 4.5 billion tons of uranium in the ocean, already demonstrated at a pilot scale at 2-3 times the spot price for uranium, would eliminate the need for reprocessing to conserve uranium resources. This would reduce the opportunities for nuclear proliferation. If externalities were taken into account, e.g. mining site remediation, costs might even be lower than market costs.

The London (Dumping) Protocol of 1996 was modified in 2006 to allow sequestration of CO2 in sub-seabed geological formations (oceanic acidification). Why not for spent fuel?

DISPOSAL IN SUB-SEABED SEDIMENTS II

All of the radioactive material that would have been put into Yucca Mountain is more than an order of magnitude less than what is naturally in the ocean and if delayed for 300 years would be 3 orders of magnitude less.

BECQUERELS (CURIES) DO NOT EQUAL SIEVERTS (REMS).

MOBILITY AND BIOAVAILABILTY MUST BE CONSIDERED.

RADIOACTIVITY IN THE OCEAN	BECQUERELS
Natural	1.50E+22
Directly Dumped	8.50E+16
Fallout	1.5 E+18
Reprocessing Plant Effluent	1.00E+17
Yucca Mountain when full 70,000 MTHM	8.00E+20
Yucca Mountain after 300 years	1.8 E+19

DISPOSAL IN SUB-SEABED SEDIMENTS III

"The results of this radiological assessment show that the disposal of high level waste in sub-seabed sediments could be radiologically a very safe option."
Feasibility of Disposal of High-Level Radioactive Waste Into the Seabed, V. 2 Radiological Assessment, 1988, NEA

Input data are 3,000 GW(e) years (100,000 MTHM burnup)
Main dose is from mollusc consumption and external exposure from beach sediments. (similar for both)

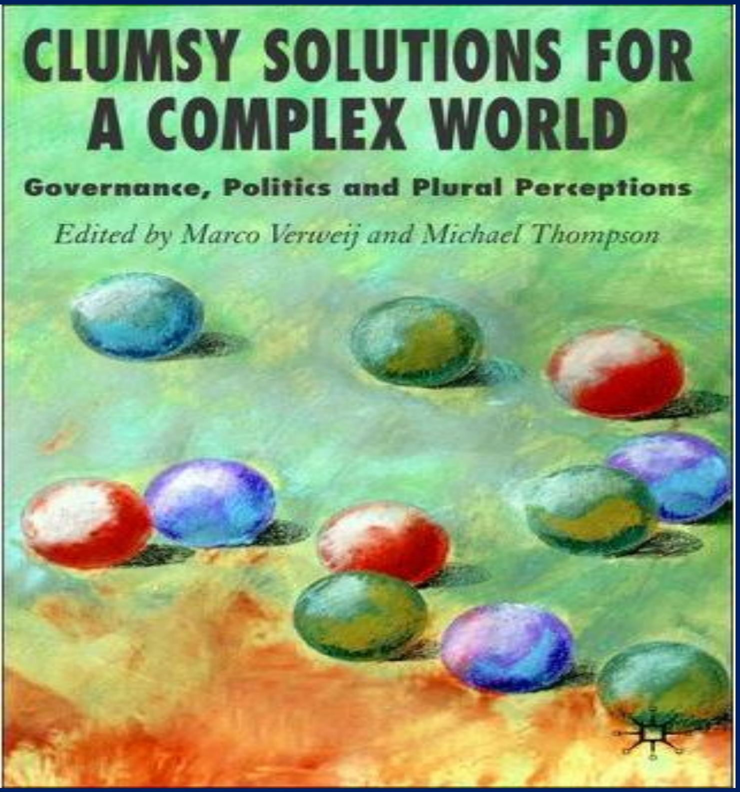
"Individual doses are at all times less than 10E-6 mSv/y".
Disposal Into the Sub-seabed, Performance Assessment of Geological Isolation Systems for Radioactive Waste, 1988, CEC

VIEWS ON AND THE STATUS OF RADIOACTIVE MATERIALS IN AND ON THE SEAS

- **Opposition by island nations to disposal into the seas may be reduced as they are among the first to be affected by global warming and sea rise. They may be more amenable to nuclear .**
- **DCNS is a developing a small reactor, Flexblue-50-250 MWe, for offshore placement under 60-100 meters of water. WNA January 20, 2011**
- **Nuclear power plant-64 MWe- On surface offshore to power Vilyuchinsk. ibid**
- **Six countries, Russia, USA, United Kingdom, India, France, and China have nuclear naval ships and Brazil is considering building one. NTI November 29, 2010**

WHILE THERE IS AND WILL BE OPPOSITION TO NUCLEAR MATERIAL ON, IN AND BELOW THE SEAS (AS WELL AS ON AND BELOW THE LAND'S SURFACE) AS SHOWN ABOVE, THERE IS INCREASED USE OF THOSE SPACES.

NO GUARANTEED WAY TO SUCCESS!



Final Sentence of Fortum and Bernstein's Muddling Through, 1998, Counterpoint Publisher

"Let's Hope It Works"

- NO MATHEMATICALLY OPTIMAL SOLUTIONS ARE POSSIBLE. SO WE MUST STRIVE FOR SOCIETALLY ACCEPTABLE SOLUTIONS
- This book is one of many suggesting that formal optimization methods will not work for these complex problems that will continue over long time periods.
- Such an approach has been advocated for over 200 years.
  - **"Muddling through"**
  - **"garbage can solution"**