Spent Fuel from Nuclear Power Reactors

Overview of a New Study by the International Panel on Fissile Materials (IPFM)

Washington DC

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Center for Science, Technology and Security Policy

American Association for the Advancement of Science

Overview

Frank von Hippel, Princeton University
Co-Chair, IPFM

Country Studies

Country-Author(s)	Rank (GWe)
United States – *Frank von Hippel*	1
France – Mycle Schneider	2
Japan – Tadahiro Katsuta and Masafumi Takubo	3
Russia – Anatoli Diakov and *Pavel Podvig*	4
Germany—*Beate Kallenbach-Herbert*	5
South Korea – *Jungmin Kang*	6
Canada – *M.V. Ramana*	8
United Kingdom – Gordon MacKeron, Frans Berkhout	9
Sweden/Finland – *Johan Swahn*	11/14
Multinational Repositories – *Hal Feiveson*, *M.V. Ramana*	None

Topical Studies

Spent fuel inventories and characteristics

– *Hal Feiveson* (Princeton)

Interim storage and transport

– *Frank von Hippel* (Princeton)

Geological storage

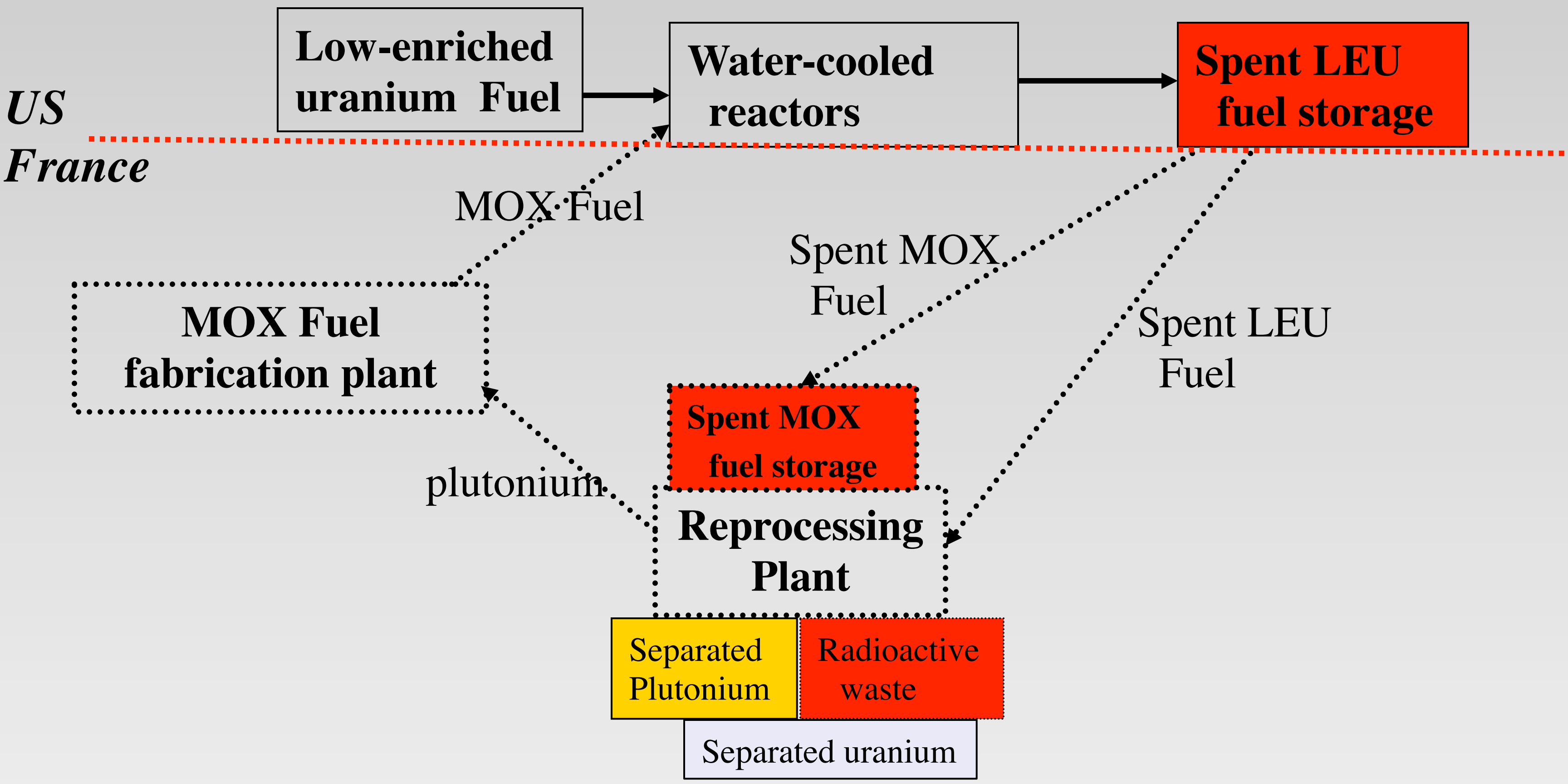
– Rodney Ewing (U. Michigan, Ann Arbor)

International (IAEA) monitoring

– Thomas E. Shea (IAEA, retired)

Today's fuel cycles: Once-through and reprocessing

30% of civilian spent fuel has been reprocessed – mostly by France & UK



Some observations from the 10 country studies

1. Reprocessing does not increase success in repository siting
2. For siting, consultation works better than top-down decisions
3. Favorable geology, waste packaging and backfill are all important and reversibility is important for some countries
4. Dry cask interim storage is becoming prevalent
5. No country is yet willing to take foreign spent power reactor fuel without reprocessing
6. Multinational repositories will have to wait on national ones
7. For some countries a nuclear phase-out decision may help with repository siting

Reprocessing doesn't help

Country	Reprocessing?	Repository Siting Stage
Canada	No	Restarting
France	Yes	Early
Germany	No	Disputed site
Japan	Yes and no	Starting
South Korea	Considering	Zero
Russia	Yes	Zero
Sweden/Finland	No	Sited but not licensed
United Kingdom	Yes	Restarting
United States	No	Zero for spent fuel
		operating for plutonium waste

1996 NAS study concluded benefits of "separation and transmutation" of long-lived radioisotopes in spent fuel would be small and costs would be huge.

IPFM

Consultation works

Top down policy making ends up as
Decide, Announce, Defend, Abandon (DADA)

Country	Repository Siting Stage	Consultation
Canada	Restarting	Early
France	Early	Yes
Germany	Disputed site	No
Japan	Starting	Being attempted
South Korea	Low/intermed-level waste (LILW) storage sited	In final successful effort for LILW repository
	HLW: Zero	--
Russia	Zero	--
Sweden/Finland	Advanced	Completed
United Kingdom	Restarting	Early
United States	Succeeded for WIPP	Forced by Congress for WIPP
	Failed for Yucca Mt.	Congress selected Yucca Mt.

Long-term reversibility may be needed

U.S. Nuclear Waste Policy Act: “any repository…shall be designed and constructed to permit the retrieval of any spent nuclear fuel placed in such repository, during an appropriate period of operation of the facility, for any reason pertaining to the public health and safety, or the environment, or for the purpose of permitting the recovery of the economically valuable contents of such spent fuel.”

Canada: current plan is to have storage be reversible for 240 years after the opening of a repository.

France: guaranteed reversibility for at least 100 years as license condition.

Germany: Considering retrieval of waste from “experimental” Asse site.

But reversibility may reduce geological barrier to proliferation.

Defense in depth – even under ground

Waste packaging, backfill and geology all need to be right.

France has chosen a clay bed.

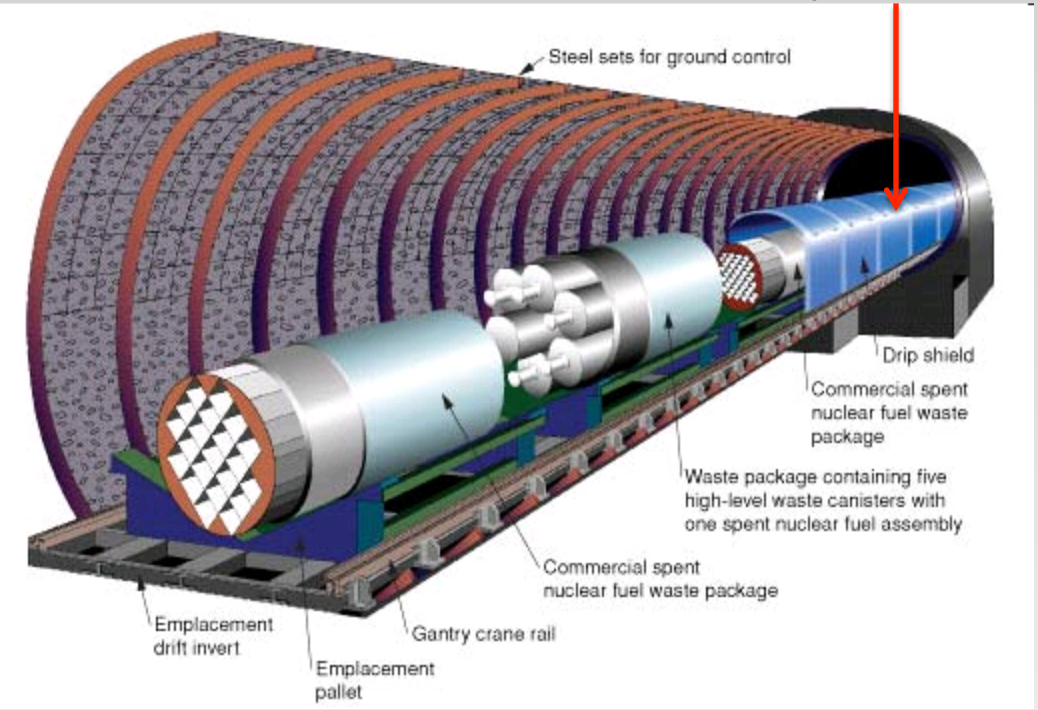
Sweden and other countries propose a copper cask surrounded by clay.

Yucca Mt. first thought dry but then recognized as wet.

Plan to cover fuel packages with titanium drip shields.

Very costly way to compensate for poor geology.

Drip shield



Dry cask storage is becoming prevalent

Country	On-site	Off-site
Canada	Yes	No
France	No	No
Germany	Yes	Yes
Japan	Two sites	Under construction
South Korea	One site	No
Russia	No	Under construction
Sweden	No	Underground central storage pool
United Kingdom	No	No
United States	Yes	Blocked

Hosting foreign spent power reactor fuel

France and U.K. reprocess imported spent fuel but return the high-level radioactive waste. Virtually none have renewed.

Russia takes spent fuel from other countries for either:

1. Reprocessing (and has kept the reprocessing waste thus far)
2. “Temporary storage,” which can be converted into reprocessing.

Russia’s law is very “flexible.” Because of public opposition, however, it has so far taken back only Russian-origin fuel provided for a Soviet/Russian supplied reactor.

Russia currently has three customers Bulgaria, Iran and Ukraine. Reactor sale to Iran includes spent-fuel take-back.

Nuclear Spent Fuel Management: Sweden

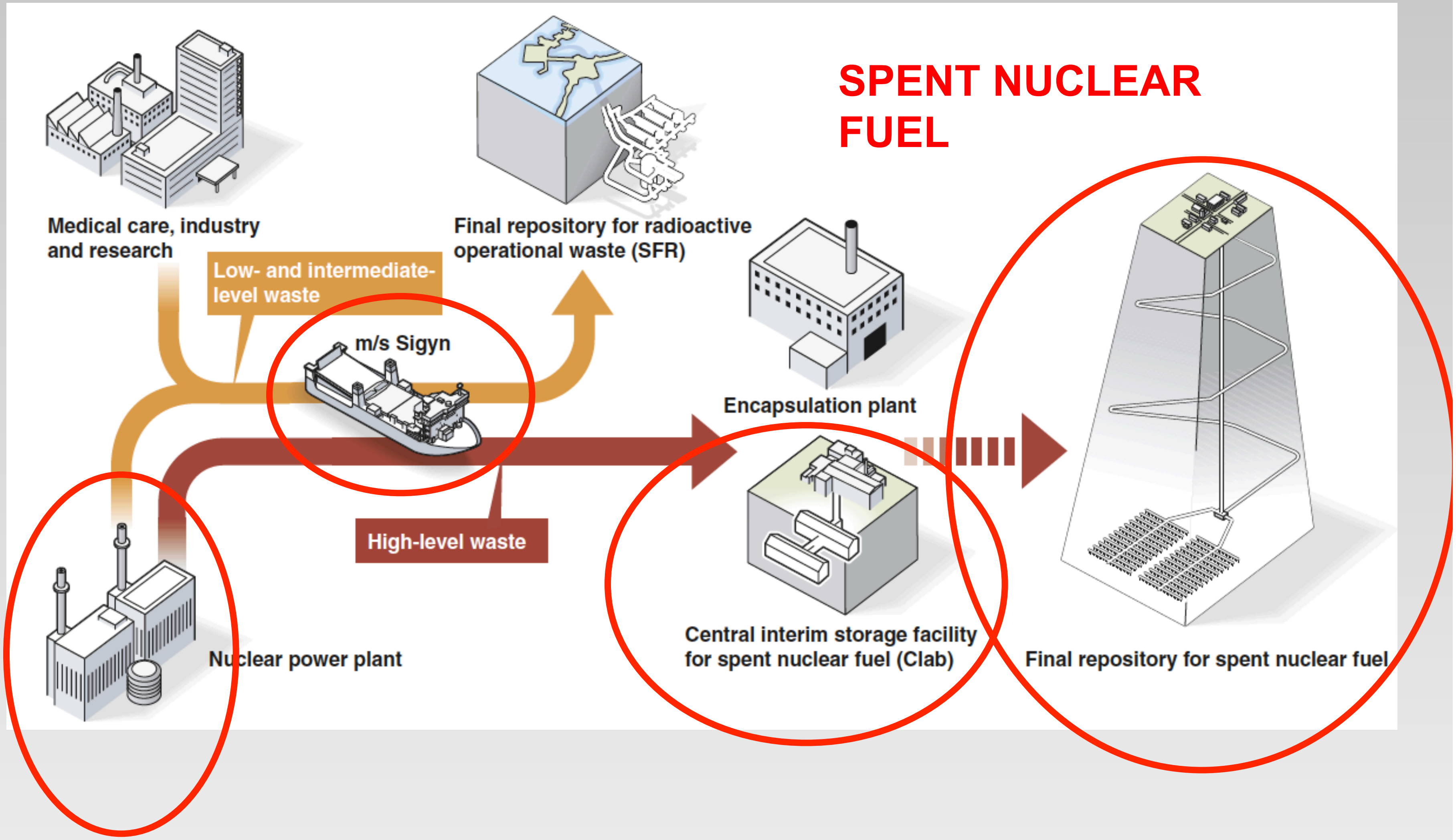
Johan Swahn

Swedish NGO Office for Nuclear Waste Review, MKG

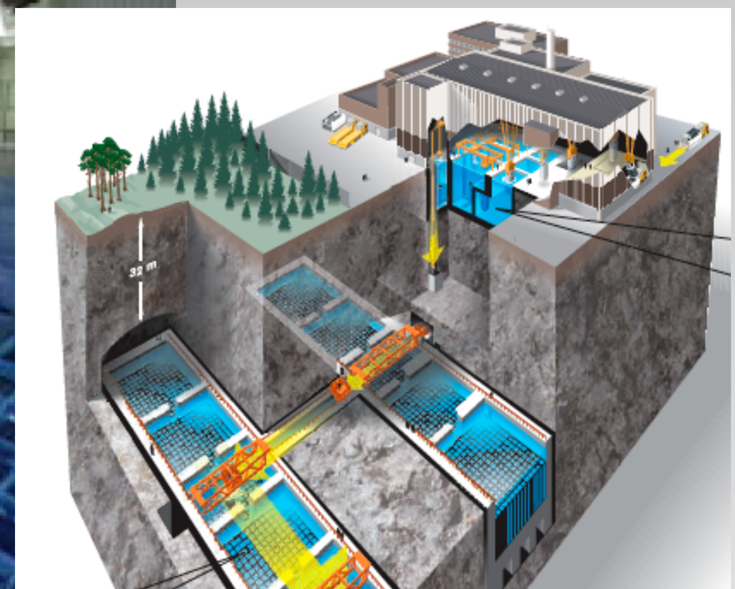
Nuclear Energy in Sweden

- Sweden has10 power reactors at three sites.
- ≈ 40-45% of electricity is nuclear.
- 1980 referendum supported phase-out by 2010 but only two reactors have been shutdown.
- Present Government (conservative-liberal-center) energy policy is split on nuclear. Agrees on promoting renewables.

Nuclear Waste in Sweden



Nuclear Waste in Sweden



Source:SKB

CLAB – Underground, intermediate storage of spent nuclear fuel

Site at Oskarshamn nuclear power plant

The KBS Method

A Swedish method for disposal of spent nuclear fuel has been developed since the early 1970s.

The waste is to be deposited in holes in the floor of tunnels about 500 meters underground in granite bedrock.

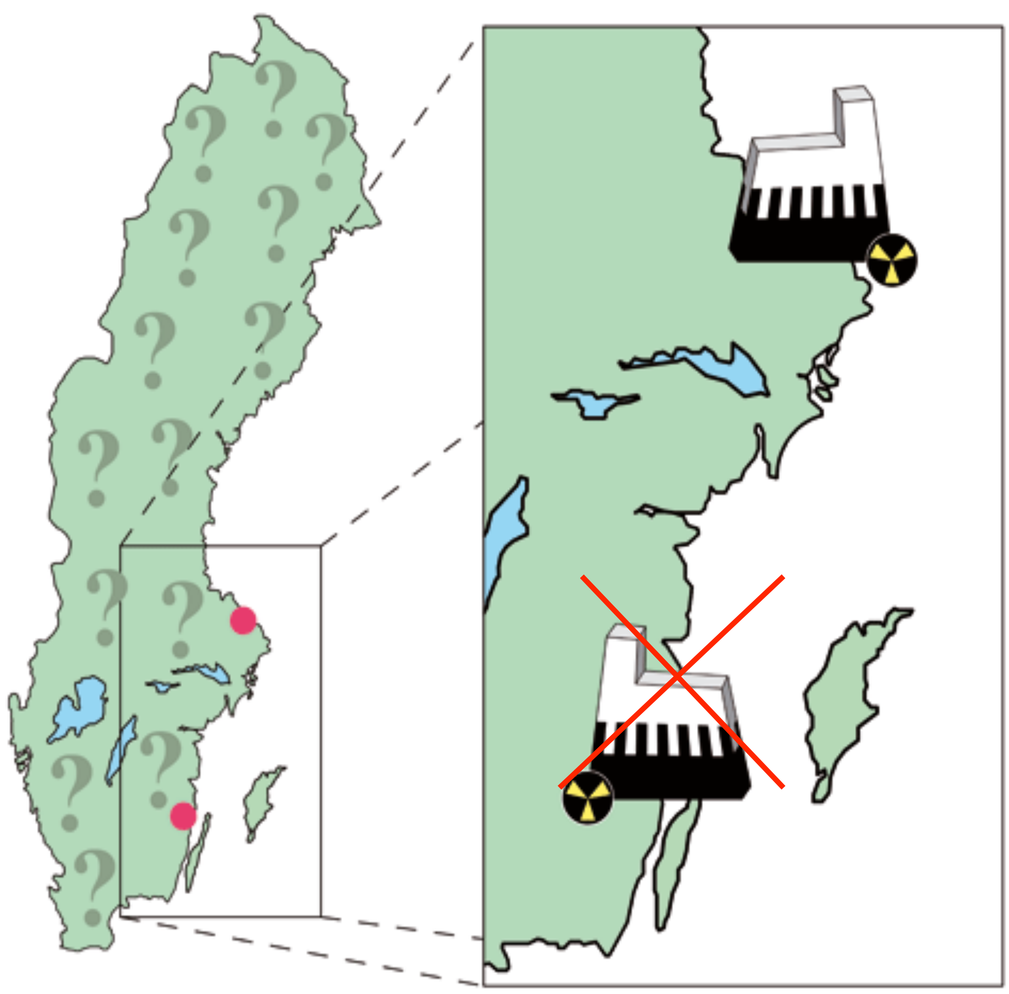
Its long-term isolation relies on two artificial barriers – a copper canister and a clay buffer.

Siting

Siting process started in mid-1970s but met local resistance and collapsed in 1986. Restarted with a voluntary process.

By late 1990s, search had narrowed to two nuclear communities: Oskarshamn and Östhammar.

June 2009 - Forsmark nuclear power plant (Östhammar) chosen as repository site.



License Application and Review

- Nuclear waste company SKB submitted license application for a repository at Forsmark on March 16, 2011
- Application is being reviewed by the Swedish Radiation Safety Authority and the Environmental Court. Final decision on a license will be taken by the Cabinet.
- Main issues will be

  -- Whether the copper cask and the clay fill barriers will behave as modeled in the safety analysis.

  -- The ability of the repository to withstand repeated glaciations.

  -- The neglect of borehole disposal.

  -- Whether an inland site would be better than a coastal site.

Nuclear Spent Fuel Management: Germany

Beate Kallenbach-Herbert,

Öko-Institut, Darmstadt, Germany

Overview

17 reactors in operation, total capacity: 21.5 Gwe

Fukushima accident has strongly influenced Germany's energy policy

30 May - Government reversed policy and announced :

- Final shutdown of 7 oldest reactors plus Krümmel (already shut down after incident in 2007)
- 9 remaining reactors will shutdown by 2022

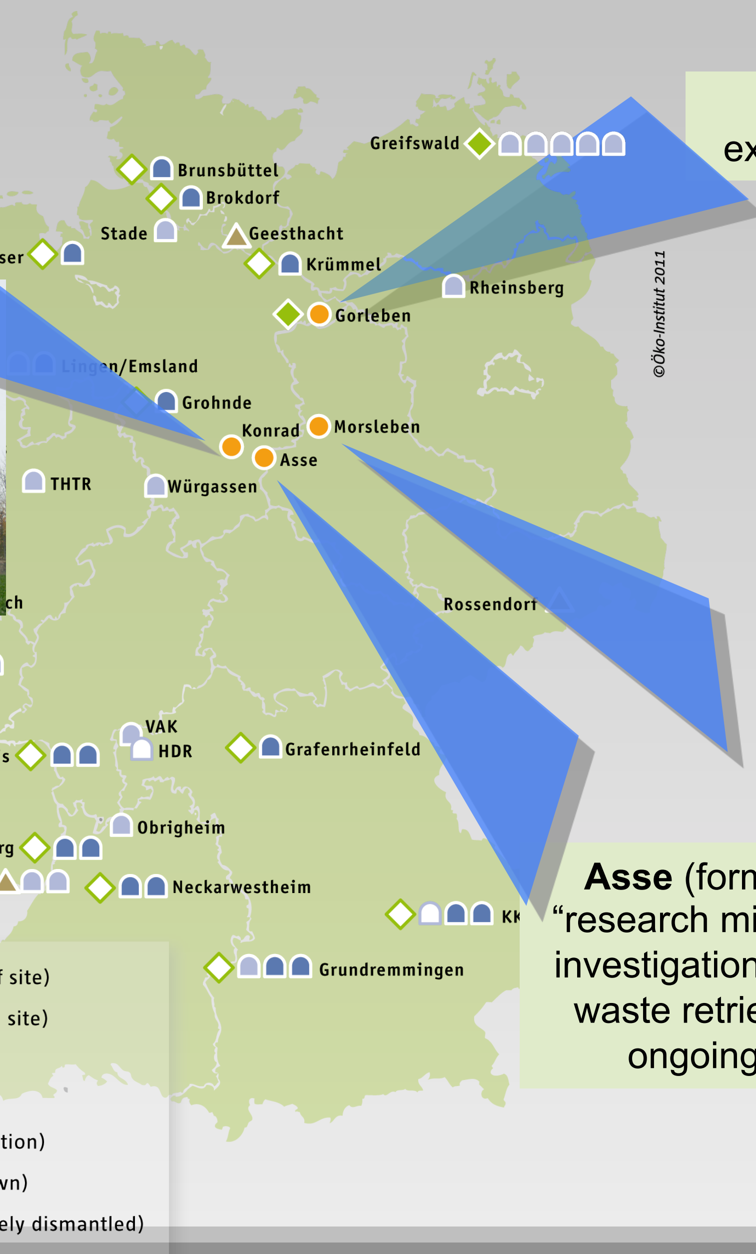
Waste Management

- 1967-1998: **Disposal** of LLW + MLW in Asse (research) mine (1967-1978) and Morsleben repository (1970 – 1998)
- Konrad repository for LLW + MLW under construction since March 2006, start of operation expected about 2017
- **Onsite interim storage** of spent fuel mandatory today
- Interim storage of HLW from past reprocessing at centralized cask storage facility Gorleben.
- Return-shipments of HLW still ongoing

Sites

Schacht Konrad
repository under construction

Gorleben
exploration mine



Morsleben
LAW/MAW repository closure ongoing

Asse (former "research mine"): investigations for waste retrieval ongoing

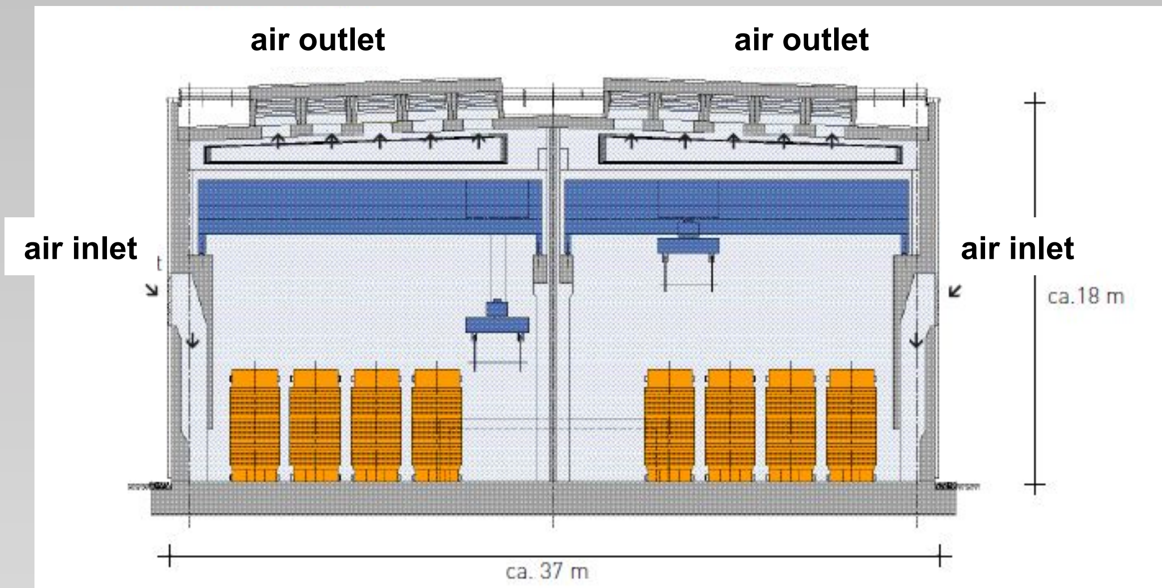
Nuclear waste disposal

- Research activities since 1960s focused on disposal of nuclear waste in salt formations.
- ***Asse salt mine*** was used as research repository for low- and intermediate level waste. Now in trouble. Feasibility assessments for retrieval of over 120,000 barrels of waste under way. Estimated costs $3-5 billion.
- Exploration activities for disposal of high active waste and spent fuel have focused on the ***Gorleben salt dome*** since late 1970s without decision on the suitability of the site.
- Gorleben controversial because of lack of transparency in site selection process and geology.
- Attempts to start a ***new site selection process*** have failed.

Spent fuel interim storage

- 2000: “Nuclear Consensus” of Government and electric utilities resulted in agreements to build on-site dry-cask interim storage facilities at each reactor site.
- Planning, licensing and construction of 12 storage facilities was carried out in about 8 years (1998 – 2006).
- Storage licenses are limited to 40 years
- Capacities limited to the expected amounts of spent fuel and restrictions on operating times were points of major interest for regional representatives and public
- The storage is based on robust dual-purpose casks in buildings with passive air cooling.

Spent fuel interim storage



Cross section interim storage faclity,
source: EnBW

Castor® Casks in storage facility,
source: GNS

Interim storage Philippsburg,
source: EnBW

Impact of Fukushima accident

A new repository site selection process including possible regions in southern Germany is being discussed by Federal and State Governments

Experience shows that a decision on a phase-out schedule for nuclear power creates improved conditions for progress on radioactive waste disposal in Germany

The expansion of renewable energy and of electricity grids will be Germany’s major challenges for the next decade

Nuclear Spent Fuel Management: Russian Federation

Anatoli Diakov, *Pavel Podvig*
International Panel on Fissile Materials

Russian reactor fleet

Type	Units	Spent fuel (tons/yr)	Interim Storage	Reprocessing
VVER-440 (LWR)	6	87	no	yes, at RT-1
VVER-1000	10	210	wet, at RT-2	planned
RBMK (graphite)	11	550	wet, at reactors, central storage planned	no
BN-600 (sodium)	1	6.2	no	yes, at RT-1
EPG-6 (graphite)	4	4	at reactors	no
Naval, research	80+		some	most types

Spent fuel of Soviet/Russian-built reactors abroad

(Finland, Hungary, Slovak Republic no longer ship to Russia)

Type	Units	Spent fuel (tons/yr)	Interim Storage	Reprocessing
Ukraine				
VVER-440	2	30	no	yes, in Russia
VVER-1000	7	150	Dry on site or sent to Russia	
Bulgaria				
VVER-1000	2	37.5	Sent to Russia	
Iran				
Bushehr	1		Sent to Russia	

Spent fuel storage

	Sites	Storage type	Capacity (tons)	Fuel in storage (tons)
VVER sites	5	wet		1,000
RBMK (graphite) sites	3	wet	12,000+	13,000
BN-600, AMB site	1	wet, dry		225
EGP-6	1	wet, dry		140
Mayak	1	wet VVER-440		380
Zheleznogorsk	1	wet VVER-1000	8,400	~8,400
	1	dry VVER-1000	11,300 (under construction)	-
	1	dry RBMK	26,500(under construction)	-

Spent fuel take-back

Fuel of Soviet-built reactors

- Finland, Hungary, Slovakia – shipments stopped
- Bulgaria, Ukraine – shipments continue

Seen as competitive advantage for reactor sales (e.g. Turkey)

Plans for international repository

- 1990s interest in importing foreign-origin spent fuel
- Laws were changed in 2001 to allow import
- Temporary storage and/or reprocessing allowed but not final disposal
- 2006, Rosatom forced by public outcry to announce “no foreign-origin fuel” policy but laws still in force

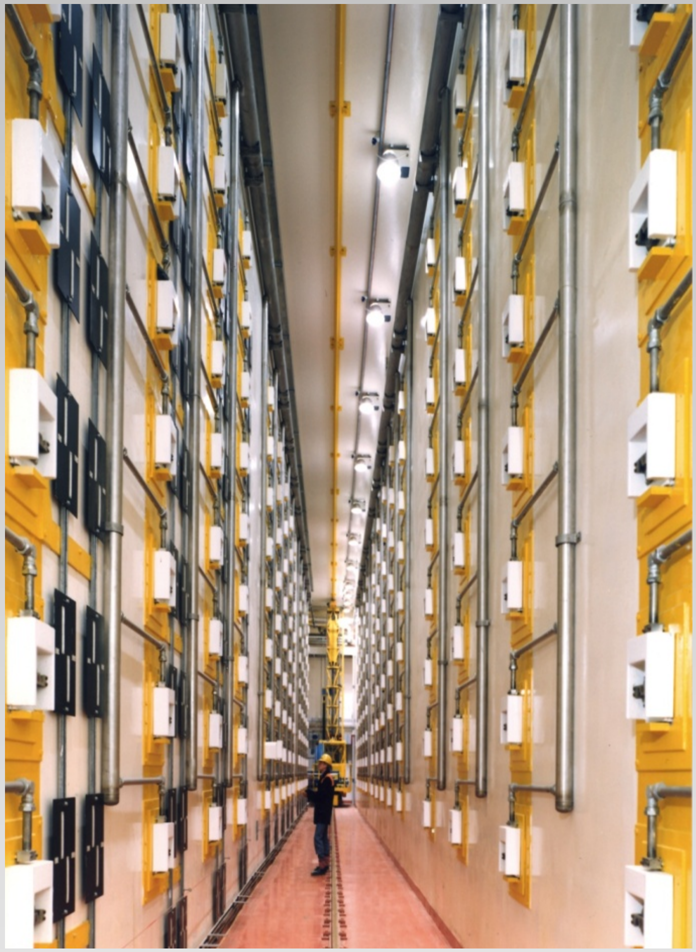
Reprocessing

- RT-1 Plant, Mayak, Ozersk, Urals
  – Capacity: 400 MT/y
  – Actual load: 100 MT/y
  – VVER-440, BN (breeder), naval and research reactor fuel
- Mining and Chemical Combine, Zheleznogorsk, Siberia
  – Expansion of storage capacity to ~40,000 MT
  – Pilot reprocessing plant ca 2015?
  – New large-scale reprocessing plant in 2020-2025?
- Plutonium to be used in breeders
  – BN-600 operational, BN-800 under construction
  – Plutonium fuel for breeders has not been demonstrated

Nuclear Spent Fuel Management: United Kingdom

M. V. Ramana
Princeton
IPFM

Reprocessing



MAGNOX spent fuel and significant fraction of AGR fuel reprocessed

Legacy is ~100 tons of separated plutonium and $100 billion cleanup.

Decide, Announce, Defend – and then Abandon (DADA)

Government, nuclear industry and selected scientists:

- Decided on sites
- Announced them
- Defended them against the inevitable opposition, and
- Eventually were forced to abandon them

1970s - drilling program to find sites for HLW disposal ended after intense local resistance.

In 1981, Government decided to shelve HLW policy for 50 years and concentrate on finding sites for low level and intermediate level wastes.

DADA for ILW and Dissolution of Nirex

1982: Set-up Nirex (industry-body) to identify LLW/ILW sites

Late 1980s: 12 sites shortlisted

Settled on a site near Sellafield

1997: Nirex proposal rejected

1999: House of Lords Science and Technology Committee report:

public and stakeholders need to be engaged from the start, and not just to approve after the fact.

Recommended a new Commission to oversee policy

Committee on Radioactive Waste Management (CoRWM)

CoRWM set up in 2003 and told to give "equal weight" to:

- Inspiring public confidence
- Protecting people and the environment

CoRWM members were appointed from diverse backgrounds

- Founding member of Greenpeace UK
- UK nuclear industry scientist
- Chair of UK Equal Opportunities Commission
- Member of the non-government *National Consensus Conference on Radioactive Waste Management*
- Academic social scientists

2006 CoRWM Recommendations and Policy

CoRWM recommended:

- Geological disposal for all legacy HLW and ILW;
- Interim storage, possibly for up to 100 years, as an integral part of policy
- Siting of major new facilities to be based on voluntarism and partnership
- Local communities allowed to withdraw from negotiations up to a pre-determined point if not satisfied with the terms being offered.

Policy impact:

- October 2006: Government accepted all CoRWM's main recommendations, including the ideas of voluntarism and partnership
- Nuclear Decommissioning Authority established with responsibility for the long-term management of all UK radioactive wastes

Recap

1. Reprocessing does not help.
2. For siting, consultation works better
3. Geology, waste packaging and backfill are all important
4. Dry cask interim storage is becoming prevalent
5. No country is yet willing to take foreign spent power reactor fuel without reprocessing
6. Multinational repositories will have to wait on national ones
7. A nuclear phase-out decision can help with repository siting