Summary of Non-US National and International Radioactive Waste Management Programs 1981

**K. M. Harmon
J. A. Kelman**

June 1981

**Prepared for the U.S. Department of Energy
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**Pacific Northwest Laboratory
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Richland, Washington 99352

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ACRONYMS^(a) AND ABBREVIATIONS

AFR	Away-from-reactor
AVM	Waste vitrification plant at Marcoule, France
BWR	Boiling water reactor
CANDU	Canadian deuterium uranium reactor
FBR	Fast breeder reactor
FINGAL/HARVEST	British waste vitrification process
FIPS	West German process for vitrifying high-level waste, developed at Jülich
FRP	Fuel reprocessing plant
GCR	Gas-cooled reactor
GWe	10 ⁹ watts of electricity (1000 MWe)
HFR	High Flux Reactor at Petten, Netherlands
HLLW	High-level liquid waste
HLW	High-level waste
HTGR	High-temperature gas-cooled reactor
HTR	High-temperature reactor
HWLWR	Heavy water moderated, light water cooled reactor (same as LWCHW)
HWR	Heavy water reactor
LGR	Light water cooled, graphite moderated reactor
LLW	Low-level waste
LMFBR	Liquid metal fast breeder reactor
LOTES	Low-temperature solidification (waste calcination) process developed by Eurochemic
LWCHW	Light water cooled, heavy water moderated reactor (same as HWLWR)
LWR	Light water reactor
MOX	Mixed (plutonium-uranium) oxide
tHM	Metric tons (tonnes) heavy metal
MTR	Materials test reactor

(a) Acronyms for agencies, institutes, etc. are given in the Overview section for each country.

tU	Metric tons uranium
tSWU	Metric tons of separative work (uranium enrichment)
PAMELA	West German and Eurochemic process for converting high-level waste to glass beads and embedding them in a metal alloy
PFR	Prototype Fast Reactor (UK)
PHWR	Pressurized heavy water reactor
PIVER	Pilot Verres, French HLLW vitrification process
R&D	Research and development
THTR	Thorium high-temperature reactor
TRU	Transuranic
VERA	West German process for vitrifying high-level waste, developed at Karlsruhe
WAK	Fuel reprocessing pilot plant near Karlsruhe

SUMMARY OF NON-US NATIONAL AND INTERNATIONAL
RADIOACTIVE WASTE MANAGEMENT PROGRAMS
1981

INTRODUCTION

Many nations and international agencies are working to develop improved technology and industrial capability for nuclear fuel cycle and waste management operations. The effort in some countries is limited to research in university laboratories on treating low-level waste from reactor plant operations. In other countries, national nuclear research institutes are engaged in major programs in all phases of the fuel cycle and waste management, and there is a national effort to commercialize fuel cycle operations.

Since late 1976, staff members of Pacific Northwest Laboratory have been working under US Department of Energy sponsorship to assemble and consolidate openly available information on foreign and international nuclear waste management programs and technology. This report summarizes the information collected on the status of fuel cycle and waste management programs in selected countries making major efforts in these fields as of the end of May 1981.

NUCLEAR FUEL CYCLE AND WASTE MANAGEMENT ACTIVITIES

Six tables are included in this section:

Table 1, "Industrial Nuclear Power Production," lists the nations operating, building, or planning to build nuclear power stations and provides the latest data available concerning present commitments (plants built, under construction, or on order) and long-term projections.

Table 2, "Industrial Fuel Cycle Activities," lists the nations which are operating or planning to construct major fuel cycle facilities.

Table 3, "Forecast of Spent Fuel Arisings," shows discharged fuel.

Table 4, "Spent Fuel and Waste Management R&D Activities," lists the nations and international agencies which have active programs for waste treatment and waste isolation--either R&D or commercial-scale.

Table 5, "Membership in International Agencies," lists nations and their affiliations with international agencies directly concerned with the nuclear fuel cycle and waste management activities.

TABLE 1. Industrial Nuclear Power Production

Country	Committed (GWe)(a)		Projected (GWe)	
Argentina	PHWR:	0.33 (1981) 0.93 (1982)	4.0	(2000)
Australia			1.0	(2000)
Austria		(b)		
Belgium	LWR:	1.65 (1981) 5.5 (1984)		
Brazil	LWR:	0.63 (1981) 3.1 (1988)	47	(2000) -32%
Bulgaria	LWR:	1.32 (1981) 1.76 (1982)	5.8	(1995) -40%
Canada	BLWR: PHWR:	0.25 (1981) 5.9 (1981) 15 (1991)	45	(2000)
Chile			0.6	(1988)
China, People's Republic			15	(2000)
Cuba	LWR:	0.44 (1985)	1.76	(1990)
Czechoslovakia	GCHWR: LWR:	0.11 (1981) 0.88 (1981) 4.4 (1988)	7.3	(1990)
Egypt	LWR:	0.6 (1988)	6.6	(2000)
Finland	LWR:	2.16 (1990) -35%	3.2-5.2	(2000)
France	GCR: GCHWR: LMFBR: LWR:	2.2 (1981) 0.07 (1981) 0.23 (1981) 1.43 (1983) 16.3 (1981) 48.8 (1990)	LMFBR: 25	(2000)
Germany, Democratic Republic of	LWR:	1.83 (1981) 2.7 (mid 1980s) -9%	9	(1990) -15%
Germany, Federal Republic of	PHWR: LMFBR: THTR: LWR:	0.05 (1981) 0.30 (1986) 0.30 (1984) 9.7 (1981) 21.9 (1986) 26 (Indef.)	53	(2000)
Greece			0.8	(1989)
Hungary	LWR:	1.76 (1985)		
India	LWR: PHWR:	0.40 (1981) 0.40 (1981) 1.2 (1984)	10	(2000)
Iraq	LWR:	0.9 (?)		
Israel			1.8	(1990)
Italy	GCR: LWCHW: LWR:	0.15 (1981) 0.04 (1984) 1.24 (1981) 3.2 (1985) 6.5 (Indef.)	12	(2000)

TABLE 1. (contd)

Country	Committed (GWe) ^(a)		Projected (GWe)	
Japan	GCR:	0.16 (1981)	80	(1996)
	LWCHW:	0.20 (1981)		
	LMFBR:	0.30 (1987)		
	LWR:	14.8 (1981)		
		23.6 (1987)		
Korea (South)	PHWR:	0.63 (1982)	10	(1991)
	LWR:	0.56 (1981)		
		6.8 (1989)		
Kuwait			3.6	(2000) -30%
Libya	LWR:		0.3	(Indef.)
Mexico	LWR:	1.31 (1984)	10-20	(2000)
Netherlands	LWR:	0.49 (1981)		
Pakistan	PHWR:	0.12 (1981)	16	(2000) -60%
Philippines	LWR:	0.62 (1985)		
Poland	LWR:	0.88 (1986)	23	(2000) -25%
Romania	LWR:	0.44 (1983)	4	(1990) -18%
		1.04 (1987)		
South Africa	LWR:	1.84 (1984)		
Spain	GCR:	0.48 (1981)		
	LWR:	3.3 (1981)		
		13 (1989)		
Sweden	LWR:	6.4 (1981)		
		9.4 (1985)		
Switzerland	LWR:	1.94 (1981)		
		3.8 (1987)		
Taiwan	LWR:	2.2 (1981)		
		4.9 (1985)		
Turkey	LWR:	0.44 (Indef.)	5	(1990)
United Kingdom	HWLWR:	0.09 (1981)	25-40	(2000)
	LMFBR:	0.25 (1981)		
	GCR & AGR:	9.6 (1981)		
		14.1 (1988)		
USA	LWBR:	0.06 (1980)		
	HTGR:	0.33 (1981)		
	LGR:	0.86 (1981)		
	LWR:	61 (1981)		
		142 (1994)		
		162 (Indef.)		
USSR	LMFBR:	0.95 (1981)	100	(1990)
	LGR:	10.9 (1981)		
		14.9 (Indef.)		
	LWR:	4.6 (1981)		
		6.6 (1982)		
		8.9 (Indef.)		
Yugoslavia	LWR:	0.62 (1983)	3.5	(2000)
World	408 Total			

(a) GWe of plants in commercial operation or scheduled for operation by the end of the year listed. Forecasts of nuclear power capacity were taken from the February 1981 issue of Nuclear News and recent issues of Nucleonics Week, The Energy Daily, Nuclear Engineering International, and Energy in Countries with Planned Economics.

(b) 690-MWe Tullnerfeld BWR, completed in 1978; startup vetoed by public vote in November 1978; future is uncertain.

TABLE 2. Industrial Fuel Cycle Activities

Country	Uranium Mining and Milling	Uranium Enrichment	MOX Fuels Fabrication	Spent Fuels		Waste Immobilization	
				Storage and Transportation	Reprocessing	Non-HLW	HLW
Argentina	X						
Australia	X	Potential					
Belgium			X		Potential	X	Potential
Brazil	Potential	Potential					
Canada	X			X		X	
Central African Empire	X						
China	X	X					
France	X	X	X	X	X	X	X
Gabon	X						
Germany, Federal Republic of	X	Potential	X	X	Potential	X	Potential
India	X				X		X
Italy	X		X		Potential	X	Potential
Japan	X	X	X	X	X	X	Potential
Mexico	X		Potential		Potential		
Netherlands		X					
Pakistan	X	Potential			Potential		
South Africa	X	X					
Spain	X						
Sweden	Potential			X			
Turkey	Potential						
United Kingdom		X	X	X	X	X	Potential
USSR	X	X	X		X		

TABLE 3. Forecast of Spent Fuel Arisings(1)

Country	Fuel Discharged (cumulative tU)				
	1980	1985	1990	1995	2000
Argentina	418	1,126	2,338	3,916	6,180
Austria	0	0	0	0	0
Belgium	194	632	1,346	2,372	3,656
Brazil	0	64	342	1,280	3,010
Canada	3,266	8,046	15,399	26,939	45,175
Chile	0	0	0	0	80
Denmark	0	0	0	0	88
Egypt	0	0	0	32	261
FRG	962	2,716	5,543	9,240	13,630
Finland	56	433	773	1,323	2,143
France	5,838	10,709	18,939	29,319	41,331
Greece	0	0	0	16	165
India	342	1,040	2,090	3,560	5,786
Indonesia	0	0	0	16	112
Ireland	0	0	0	48	128
Israel	0	0	0	0	161
Italy	1,071	1,545	2,373	3,317	4,581
Japan	2,093	5,139	10,285	17,557	26,909
Korea, South	17	403	1,358	3,047	5,811
Mexico	0	54	254	829	2,473
Netherlands	119	196	274	420	613
Norway	0	0	0	0	92
Pakistan	49	109	169	245	449
Philippines	0	0	64	208	460
Portugal	0	0	0	88	354
South Africa	0	68	299	529	759
Spain	843	1,519	2,711	4,408	6,438
Sweden	463	1,402	2,659	3,933	5,252
Switzerland	323	684	1,123	1,869	2,773
Taiwan	71	479	1,149	1,995	3,123
Thailand	0	0	0	0	80
Turkey	0	0	0	67	485
United Kingdom	18,321	25,243	35,377	40,090	42,880
United States	7,357	18,611	36,969	58,564	82,723
Yugoslavia	0	64	173	489	982
Worldwide	41,803	80,282	142,007	215,716	309,143
Committed Reprocessing Worldwide	26,675	45,447	64,624	80,469	91,154

(1) Information assembled from NAC Report No. C-8023, "Worldwide Spent Fuel Disposition Analysis," September 1980.

TABLE 4. Spent Fuel and Waste Management R&D Activities

Country	HLW Conditioning and Storage	TRU Wastes	Low- and Intermediate- Level Wastes		Airborne Wastes	Cladding Hulls	Remedial Action		Spent Fuel			Geologic Waste Isolation	
			Treatment and Immobilization	Disposal			Mill Tailings	O&D	Interim Storage and Transportation	Terminal Storage	Reprocessing	Continental	Seabed
Argentina			X								X		
Australia	X		X				X						
Austria	X		X									X	
Belgium	X	X	X		X	X			X		X	X	
Brazil			X								X	X	
Canada	X		X		X		X	X	X	X	X	X	X
CEC-Ispra		X						X				X	
China, People's Republic	X	X	X		X								
Denmark			X									X	
Eurochemic	X	X	X	X		X		X					
Finland			X	X								X	
France	X	X	X	X	X	X	X	X	X		X	X	X
Germany, Federal Republic of	X	X	X	X	X	X		X	X	X	X	X	
India	X	X	X			X		X			X	X	
Italy	X	X	X					X			X	X	
Japan	X	X	X	X	X		X	X	X		X	X	X
Mexico											X		
Netherlands			X		X			X				X	X
Spain	X		X					X	X		X	X	
Sweden	X	X	X	X			X	X	X	X		X	
Switzerland		X	X	X				X	X	X		X	
United Kingdom	X	X	X	X	X	X	X	X	X		X	X	X
USSR	X	X	X	X	X	X			X		X	X	X

TABLE 5. Membership in International Agencies^(a) (February 1977)

<u>Country</u>	<u>OECD/NEA</u>	<u>OECD/IEA</u>	<u>CEC</u>	<u>CMEA</u>	<u>Eurochemic</u>	<u>Foratom</u>	<u>Nordic Council</u>
Australia	X						
Austria	X	X			X	X	
Belgium	X	X	X		X	X	
Bulgaria				X			
Canada	X	X					
Cuba				X			
Czechoslovakia				X			
Denmark	X	X	X		X	X	X
Finland	X					X	X
France	X		X		X	X	
Germany, Democratic Republic of				X			
Germany, Federal Republic of	X	X	X		X	X	
Greece	X		X				
Hungary				X			
Iceland	X						X
Ireland	X	X	X				
Italy	X	X	X		X	X	
Japan	X	X					
Luxembourg	X	X	X		X	X	
Mongolia				X			
Netherlands	X	X	X		X	X	
New Zealand	(b)	X					
Norway	X	X			X	X	X
Poland				X			
Portugal	X				X	X	
Rumania				X			
Spain	X	X			X	X	
Sweden	X	X			X	X	X
Switzerland	X	X			X	X	
Turkey	X	X			X		
United Kingdom	X	X	X			X	
United States	X	X					
USSR				X			
Yugoslavia	(b)			(b)			

(a) All countries listed belong to IAEA.

(b) Special status

NATIONAL AND INTERNATIONAL PROGRAM OVERVIEWS

Brief program overviews of fuel cycle, spent fuel, and waste management activities are provided for countries and international organizations with substantial programs in these areas.

ARGENTINA

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

Argentina's power policy has fluctuated with changes in government but is now directed toward developing extensive nuclear power (PHWR) production capability and achieving heavy water, nuclear equipment, and fuel cycle (including reprocessing) self-sufficiency. Technology and production plants have been purchased abroad, chiefly from Canada, West Germany, and Switzerland. The country is considering FBR development, based on the Th-²³³U fuel cycle.

Argentina has one operating power station, Atucha-1, two others under construction, and four more planned for startup by 1977. As the only Latin American country with an operating commercial reactor, Argentina is leading an effort to make Latin American nuclear development more independent and is carrying out technical cooperation programs with Peru and Brazil.

ORGANIZATION

The Comisión Nacional de Energía Atómica (CNEA), Buenos Aires (National Atomic Energy Commission), owns and operates all facilities.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 1981--0.93 PHWR, 2000--3.5 (23%).
2. Uranium mining and milling, tU/yr: 1980--200, 1984--700. Known uranium reserves are 28,000 t, with an additional 25,000 t estimated.
3. Fabrication of UO₂ fuels: Yellowcake production in 1978 was 159 t, and plans call for about 1000 t/yr by 1984. UO₂ conversion capacity is expected to be 300 t/yr by 1982, and a fuel element pilot plant is to be expanded to a capacity of 250 t/yr.

FUEL CYCLE AND WASTE TREATMENT R&D

1. Fuel reprocessing: An "experimental" reprocessing plant is being built at the Ezeiza Atomic Centre near Buenos Aires. This 20-kg/day-capacity plant is to begin cold tests in 1981 and shift to hot operation in 1982.
2. Waste treatment: The Argentine government has announced plans to build an experimental solidification plant for undefined "high activity" wastes. Startup is expected in 1985.

AUSTRALIA

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

Australia has made no commitment to nuclear power station construction, but in Western Australia the Premier has announced that the state will need a 1000-MWe station by 1990, and two possible sites north of Perth have been selected. An eventual need for nuclear power is also projected for other states such as South Australia.

Australia has the potential to become one of the major uranium-producing countries of the world, with reasonably assured resources estimated at 292,000 tU and is evaluating the feasibility of a uranium enrichment venture, probably in partnership with the European enrichment consortium, Urenco. Details have been outlined for an enrichment plant to be under construction by 1988.

ORGANIZATION

The Australian Atomic Energy Commission (AAEC) is an agency of the Ministry of State for Minerals and Energy. Nuclear research and development is carried out mainly at the AAEC Research Establishment, Lucas Heights, at Sutherland, New South Wales (near Sydney) with contributions from some of the universities. For example, the Australia National University (ANU) at Canberra has a small group working on the SYNROC process for high-level waste solidification, invented by an ANU professor.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 2000--1.0.
2. Uranium mining and milling: Potential capabilities, tU/yr: 1980--600, 1981--1800, 1985--12,000 and 1990--20,000.

SPENT FUEL AND WASTE MANAGEMENT R&D

Objectives

Major objectives include providing the technology for optimum utilization of Australia's uranium ore reserves, management of mining and milling wastes, and treatment and disposal of fuel cycle wastes at such time as the nation develops commercial nuclear power and an associated fuel cycle.

High-Level Waste Immobilization

Although Australia has no plans for commercial spent fuel reprocessing and terminated its R&D on reprocessing of HTGR fuels in the 1960s, the government is sponsoring the development of the SYNROC process for immobilizing the radionuclides in high-level wastes.

The SYNROC process, conceived at ANU, Canberra, produces a mixture of synthetic mineral phases characterized by two key properties: great geochemical stability and the ability to incorporate into solid solution all the important radionuclides present in the waste. Basic

SYNROC ingredients are TiO_2 , ZrO_2 , Al_2O_3 , CaO , BaO , and up to 10 wt% waste calcine. The formulation reaction of the ingredients to form the synthetic mineral phases, and fabrication of the waste form can be accomplished by some form of solid state process, such as hot pressing or sintering.

SYNROC studies are continuing at ANU, with the emphasis on process basics, and at the Lucas Heights laboratory, where the focus is on process scale-up. SYNROC is also one of the waste forms being evaluated in the US for possible use in immobilizing US defense wastes.

Management of Mine and Mill Tailings

The AAEC studies of technology to reduce the environmental impact of uranium mining and milling have been focused mainly on improvements in the control of radium and radon. The program includes:

1. study of radium and heavy metal concentrations in tailings and process waste solutions
2. determination of factors affecting the natural leaching of radium for tailings
3. laboratory studies of the feasibility of chemical extraction of radium by leaching in strong salt solutions
4. determination of radon release from ores and tailings under various conditions; assessment of the feasibility of removing radon from air streams
5. studies of surface hydrology at prospective mines and mills.

Geologic Waste Isolation

Australia has large ore bodies located near the surface in areas subject to high seasonal rainfall and periodic flooding. Past movement of radionuclides (^{238}U , ^{234}U , and ^{230}Th) under these extreme (but natural) conditions is being analyzed by AAEC to provide a basis for the construction of a model of radionuclide movement through clay over a time span of about one-half million years.

AUSTRIA

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

Austria has built one nuclear power plant, the Tullnerfeld 730-MWe BWR at Zwentendorf, near Vienna, and at one time planned two additional 1000-MWe nuclear plants. In a 1978 plebiscite, however, the Austrian voters rejected the startup of Tullnerfeld by a small margin, leaving the future of Austrian nuclear power highly uncertain. The government may hold a new referendum on the subject in 1981.

Until the Tullnerfeld decision, the Austrian nuclear utilities had planned to have their spent fuels reprocessed by COGEMA at La Hague, with the vitrified HLW returned to Austria for disposal. Contracts with COGEMA were cancelled in 1979.

Although nuclear power generation is illegal in Austria, the government is proceeding with waste treatment and waste isolation R&D and has joined with Egypt in studies of potential cooperative waste storage in Egypt.

ORGANIZATION

Waste treatment and disposal R&D are the responsibility of the Austrian Atomic Energy Research Company (SGAE), which is headquartered in Vienna and has a laboratory at Seibersdorf. Kernkraftwerks-Planungsgesellschaft has been assigned to search for suitable repository sites.

WASTE MANAGEMENT R&D

The SGAE laboratory at Seibersdorf is continuing its waste management R&D, so that assured technology will be available in case Austria eventually turns to nuclear power. Principal R&D areas are:

1. alternatives for HLW immobilization, such as coated calcine particles and compacts of waste granules in a metal matrix
2. immobilization of LLW in cement or bitumen
3. geologic waste isolation, probably in granite.

The laboratory is conducting supporting studies in the fields of geology, hydrogeology, heat transfer effects, corrosion of materials, radionuclide migration, and risk analysis.

BELGIUM

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

Belgium is committed to a nuclear power capacity of 5.5 GWe (LWR) by 1984. The Belgian government and utilities are also working toward well-rounded advanced reactor and fuel cycle capability through 1) participation in multinational projects such as the Dragon HTR (OECD), Kalkar LMFBR (Federal Republic of Germany and The Netherlands) and the Eurodif enrichment plant (France and other partners), 2) development of MOX fuel fabrication, waste treatment, and geologic waste disposal facilities, and 3) evaluation of domestic fuel reprocessing.

Fuel reprocessing and waste management plans, yet to be acted upon by the government, are based on the following assumptions.

1. The Eurochemic fuel reprocessing plant is now owned by Belgium and could be modernized and used to treat domestic fuels.
2. Eurochemic's waste treatment facilities are also to be turned over to a Belgium company for use with Belgian wastes.

3. An AVM-type HLW vitrification plant is to be built at Mol to immobilize existing Eurochemic wastes and to treat future Belgian HLW.
4. An underground long-term storage site will be constructed for high-level treated waste and plutonium fuel fabrication waste. Deep clay formations are presently being investigated.
5. Low-level, treated wastes will be discharged into the Atlantic Ocean.

Major Milestones

• Refurbish Eurochemic reprocessing plant	After 1984
• Take over Eurochemic waste treatment facilities	Late 1981
• Slagging incinerator	1980
• HADES geologic test repository	1983
• Industrial repository	1990

ORGANIZATION

Government sponsored nuclear R&D in Belgium is coordinated and performed primarily by the Nuclear Energy Research Center (Centre d'Étude de l'Énergie Nucléaire, CEN/SCK) at Mol. Commercial fuel cycle and waste management activities are handled by Belgoprocess and Belgowaste, companies owned and controlled jointly by the government (through CEN/SCK) and by Synatom, a joint venture of the three principal utility groups in Belgium. Eurochemic, a multinational company sponsored by a group of OECD/Nuclear Energy Agency nations, is also located at Mol.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 1981--1.6 LWR; 1985--5.5 (45%).
2. Uranium enrichment: Belgium has part ownership in the Eurodif gaseous diffusion plant in France.
3. MOX fuels: The Belgonucleaire plant at Dessel fabricates MOX fuels for recycle to LWRs. Capacity--60 t/yr.
4. Fuel reprocessing: The Eurochemic plant at Mol, Belgium, with a capacity of 60 tHM/yr of low-enriched uranium fuels, operated from 1966 to 1974 and may be refurbished and resume operation under Belgium ownership.
5. HLW solidification: The Eurochemic Company is obligated to solidify the high-level liquid waste remaining from the fuel reprocessing operations of the Eurochemic plant at Mol, Belgium, and plans to build a French AVM-type vitrification plant at Mol. Because Eurochemic is to transfer ownership of all their Mol facilities to Belgium by mid-1982, and because the Eurochemic AVM plant is not scheduled for startup before 1983-84, a Belgian company is to assume responsibility to vitrify the old Eurochemic plant waste (800 m³).

6. Non-high level waste treatment: CEN/SCK operates a batch plant, and Eurochemic has placed in service a continuous plant, "EUROBITUM," for bituminizing cladding and other intermediate-level wastes. EUROBITUM capacity is 650 m³/yr.

FUEL CYCLE AND WASTE MANAGEMENT R&D

Fuel cycle and waste management R&D in Belgium is concentrated in the Mol area, where CEN/SCK, Belgonucleaire and Eurochemic are located. The following major programs, including Eurochemic activities, are proposed or in progress.

Fuel Recycle

In keeping with Belgian plans to develop plutonium recycle and fast breeder reactor capability, Belgonucleaire built and operates pilot-scale facilities at Mol for MOX fuel fabrication. In a related effort, CEN/SCK, Belgonucleaire and ENI are building the HERMES pilot plant for FBR fuel reprocessing head-end studies. HERMES startup is scheduled for 1982.

Waste Treatment

Eurochemic has maintained a HLW solidification R&D program for several years and developed the Vitromet waste form (glass marbles in a metal matrix). The Eurochemic staff is currently assisting DWK (the German Fuel Cycle Company) in their program to demonstrate a joule-heated ceramic melter vitrification system in the new PAMELA pilot plant at Mol.

Non-high-level waste treatment studies by CEN/SCK include:

1. treatment and immobilization of intermediate-level wastes from chemical fuel decladding operations
2. immobilization of non-high-level wastes (development of a waterless cement matrix)
3. incineration of solid wastes, including Pu-contaminated materials, in a high-temperature slagging incinerator
4. control of volatile radionuclides in the off-gas from nuclear reactors and fuel reprocessing plants.

Eurochemic has installed pilot plant facilities for treatment of waste Purex solvent (the Eurowatt plant) and is to be the site of an acid digestion pilot plant for combustible TRU wastes, which is to be built and operated by FRG.

CEN/SCK is adding an off-gas loop to the HERMES fuel reprocessing head-end pilot plant, for off-gas purification studies.

Waste Disposal

With cosponsorship from CEC, Belgium is developing clay repository technology (site and media characterization, corrosion effects, repository design, risk analysis, and in situ tests) and intends to have a test repository operational at Mol by 1983. The work is coordinated by CEN/SCK.

Evaluation of preliminary tests indicates that tunnels and underground facilities can be constructed in the Boom clay formations at Mol, at depths up to 250 m, and that a thermal

load of about 15 kW per hectare can be tolerated. Heater experiments and the construction of a test chamber (350 m long by 30 m wide) under the Mol site are planned.

BRAZIL

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

Brazil remains committed to an aggressive LWR nuclear power program, with plans to enrich their own uranium, reprocess their spent fuel, and manufacture their own equipment. Much of their fuel cycle technology and pilot plant/demonstration equipment is supplied by the Federal Republic of Germany under a broad coverage agreement. Brazil is looking to foreign services for fast breeder reactor and waste management technology.

Major Milestones

- Uranium enrichment demonstration plant 1990
- Pilot reprocessing plant 1990

ORGANIZATION

Nuclear power policy is planned, executed, and controlled through the Brazilian Ministry of Mines and Energy. Directly subject to the Ministry is the Brazilian Nuclear Energy Commission (CNEN), which has regulatory, standardization, licensing, planning, surveillance, safety evaluation, and operator training functions.

Also subject to the Ministry are two companies responsible for the execution of the program: Eletrobrás, a holding of the Brazilian electricity utilities and Nuclebrás, a federal nuclear power enterprise. Nuclebrás is responsible for plant engineering, project preparation, civil construction, and equipment erection.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 1980--0.62 LWR, 1987--3.1, and 2000--40.
2. Uranium mining and milling, tU/yr: 1981--550 t/yr "yellowcake."

FUEL CYCLE AND WASTE MANAGEMENT R&D

A joint Brazilian/West German pilot plant to demonstrate the Becker nozzle process is being built by a Nuclebrás-Steag-Interaction subsidiary at Belo Horizonte. Initial capacity is to be 200,000-300,000 SWU/yr. Startup is expected in 1986.

Nuclebrás is building a 10-kg/d pilot fuel reprocessing plant in the Rio de Janeiro area. Design and technical assistance have been provided by West Germany. Startup is planned for 1984.

A Department of Energy grant has provided funds for a joint New York University/Pontificia Universidade Catolica study of the transport of nuclides from a rich thorium deposit located at Morro do Ferro.

CANADA

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

Canada has been aggressive in building a nuclear power industry and an export business based on the Canada deuterium uranium (CANDU) PHWR system, which burns natural uranium UO_2 fuel.

Past Canadian fuel cycle policy has been to store spent CANDU fuels owned by the utility in water-filled bays at the power generating sites, deferring any serious reprocessing work on the grounds that reprocessing of CANDU fuels was not economical. Current plans are to transfer spent fuels from the reactor fuel basins to a centralized interim storage facility at a federal "Fuel Cycle Center" which might be owned and operated by either the utility or the federal government. Ontario Hydro plans to build such a storage facility and is designing for future expansion capacity to meet Canadian needs well into the next century.

During the mid-1970s, Canada planned an integrated waste management center which included a reprocessing plant and waste immobilization units. With development of the US no-reprocessing position in 1977, Canada deferred actions to implement this concept. While reprocessing has not been completely rejected by Canada, the country is developing techniques for retrievable storage of spent fuels as well as disposal of reprocessing wastes, probably in a granite formation.

It is believed that the $Th-^{233}U$ fuel cycle, with spent fuel reprocessing, can be used efficiently in the CANDU-type reactor system without substantial changes in reactor design. A Canadian objective is to develop the thorium-burning CANDU.

Major Milestones

● Demonstration repository--
site selection	1982-1985
● Demonstration repository--
construction and inactive tests	1985-1991
● Demonstration repository--
active tests	Beyond 1991
● Spent fuel immobilization
pilot plant	Mid 1980s
● Commercial repository	After 2000
● Underground Research Laboratory (WNRE)	1983-1984

ORGANIZATION

Atomic Energy of Canada Limited (AECL) a federal agency, is responsible for the development of nuclear power systems for domestic use and export. Organized as a "Crown Company" in 1952, AECL's stock is held by the Minister of Energy, Mines and Resources. The company is governed by a board of directors drawn from commerce, industry, universities, and utilities. In 1978, AECL was reorganized into a holding company with four subsidiaries:

1. AECL Research Company, responsible for the Chalk River and Whiteshell research laboratories. Whiteshell is responsible for all radioactive waste management R&D except that done for reactor wastes, which has been assigned to Chalk River
2. AECL Engineering Company, responsible for design and marketing of the CANDU reactor system
3. AECL Chemical Company, responsible for the Canadian heavy water plants
4. AECL Radiochemical Company, responsible for radioisotopes and other medical applications.

Other Canadian organizations with major roles include:

1. Atomic Energy Control Board (AECB), a federal agency with responsibility for licensing and safety, security, and environmental concerns
2. Ontario Hydro, a utility headquartered in Toronto, which has made a major commitment to nuclear power production and which works closely with AECL in areas of technology which are of direct concern to a nuclear utility
3. Geologic Survey of Canada, a branch of the Department of Energy, Mines and Resources
4. Mining Research Laboratories of Ottawa, also part of the Department of Energy, Mines and Resources
5. Inland Waters Directorate, Department of Environment.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 1980--5.5 PHWR (CANDU), 1990--14.13, 2000--45.
2. Uranium mining and milling, tU/yr: 1978--6450, 1985--12,500.
3. Spent fuel storage: Ontario Hydro plans to build a centralized storage facility to allow storage in a water pool for 5 years and natural-draft storage in air for 50 years.
4. Management of reactor wastes: Ontario Hydro's Radioactive Waste Operations Site at the Bruce power station has facilities for waste incineration, compaction, and in-ground storage.

SPENT FUEL AND WASTE MANAGEMENT R&D

Objectives

1. Canada will develop and evaluate advanced fuel cycles for the CANDU reactors. The fuel cycles under consideration use thorium, in conjunction with either the plutonium produced in current CANDU reactors or enriched uranium. The program includes fuel development and studies of reprocessing flowsheets for thorium fuels.
2. Canada will develop techniques and facilities for conditioning of spent fuels and reactor and fuel reprocessing wastes prior to disposal.
3. Canada will develop and evaluate techniques for safe disposal of radioactive wastes. The major effort is applied to preparing for a repository in a granite pluton.

Spent Fuel Management

AECL and Ontario Hydro are testing advanced techniques for packaging and storing spent fuels. Present programs emphasize:

1. development of canisters for spent fuels to be emplaced in a repository. Most of the work to date has been done on providing a protective shell for intact fuel bundles which will prevent their collapse under geostatic pressures in the repository (Whiteshell). Two alternatives are being studied: a containment system designed to immobilize the fuel completely for 300-500 years, until most of the radioactivity has decayed; and an advanced system designed to provide containment for a much longer period
2. studies of those properties of irradiated fuels which determine its performance as a waste form (Whiteshell)
3. testing and evaluation of in-air storage of spent fuels (Whiteshell and Chalk River) and transportation and central storage of spent fuels (Ontario Hydro).

Whiteshell has assembled a 300-g/day mini fuel reprocessing plant with six banks of mini mixer-settlers. Installed in hot cells, it is used for Thorex process studies and for preparation of Thorex HLW to be used in vitrification tests.

Treatment of High-Level Wastes

AECL's Chalk River Laboratories studied the incorporation of fission products in aluminosilicate glasses about 20 years ago. In 1960, glass blocks containing high-level fission products were placed in swampy ground below the water table. Water samples taken since that time have shown almost negligible fission product leach rates. Chalk River is currently preparing to solidify 16 m³ of radioactive liquid waste produced during reprocessing studies in the 1950s.

Whiteshell investigators are currently studying the immobilization of spent fuel wastes in glass and ceramic materials. Their objective is to develop a ceramic melter vitrification process for high-activity wastes from reprocessing thorium fuels. Whiteshell also has a waste form characterization program under way.

Treatment of Other Wastes

Other waste treatment studies include:

1. treatment and immobilization of reactor wastes by reverse osmosis, combustion, and bituminization. The major facility for this development is the Waste Treatment Centre at Chalk River, designed for full-scale demonstration of the processes of interest
2. recovery of volatile radionuclides from fuel reprocessing operations and incorporation of noble gases in solids such as zeolites (Whiteshell)
3. management of uranium mill tailings, with work on radium control, environmental impacts and use of grout around tailings ponds (various organizations).

Waste Disposal

Many potential repository sites have been located, most of them in granite formations in the Precambrian shield of Ontario Province, and most of the Canadian geologic disposal effort is applied to granite repository technology. Other media including salt, limestone, and shale are considered possible alternatives, but work on these is very limited.

The current Canadian program is focused on the development of the Underground Research Laboratory (URL), which is to be mined out of a virgin granite formation near the Whiteshell establishment. The URL project is to be used to demonstrate methods and techniques for locating and assessing typical granitic rock formations being considered for waste repositories, and to obtain site characteristics from surface and subsurface explorations in pristine rock, develop predictive models, and eventually confirm the site characteristics through underground experiments. Drilling of boreholes for site characterization has started, and design of the laboratory and of the experimental program is under way. The US Department of Energy is supporting the project, financially and technically, under a technology exchange agreement with AECL. The URL is expected to be ready for operation in 1983-1984.

Supporting studies (hydrology, rock mechanics, migration of radionuclides, safety assessment, etc.) are conducted at Whiteshell and by components of the Department of Environment; the Department of Energy, Mines and Resources; and a number of other organizations.

CHINA

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

China has extensive coal, hydropower, and probably oil resources; but their uneven distributions, coupled with large distances and inadequate transportation and power transmission systems, make full utilization very difficult. Hence the Chinese leaders are looking to a big nuclear power program for certain areas of the country. They are starting with the development of a 300-MWe PWR, using indigenous technologies, and a prototype HWR of 125 MWe. China plans to develop thermal reactors and breeders and fusion in the long term.

Nuclear experts have advised the government to construct six 1000-MWe units. They recommended that two be built near Hong Kong in the South, two near Shanghai in the East, and two in Liaoning Province, all regions where acute power shortages exist. Uranium resources are adequate for these plans, and there is high potential for discovery of more.

ORGANIZATION

The government's Second Ministry of Machine Building is responsible for all fields of nuclear power development. In 1980 the Scientific and Technological Commission created a special panel, staffed by 38 nuclear specialists and science administrators, to deal with matters regarding nuclear fuel, equipment, safety, etc.

Nuclear R&D appears to be handled primarily by the Atomic Energy Research Institute of the Academy of Sciences, located in the Peking (Beijing) area.

COMMERCIAL NUCLEAR ACTIVITIES

Power production, GWe: 1990--3, 2000--15.

FUEL CYCLE AND WASTE MANAGEMENT R&D

China's current nuclear program, developed for weapons production, is well developed on a small scale. China has facilities for uranium conversion, uranium enrichment by gaseous diffusion, fuel element fabrication, and reprocessing of spent fuel from plutonium production reactors in a purex-process plant. Heavy water, zirconium, and other materials are available in small quantities. Several production and research reactors are operating.

Chinese scientists have gained experience in nuclear waste disposal: high-level and intermediate-level wastes are now stored in tanks; low-level waste, after treatment, is discharged into rivers; gaseous wastes are discharged through high stacks after filtration and dilution. R&D is being done on fuel reprocessing; high-level waste vitrification; fixing of intermediate-level waste in bitumen, cement, or plastics; treatment of LLW containing trans-plutonium elements; recovery of krypton-85; and extraction of fission products and actinides from HLW.

DENMARK

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

In 1976, the Minister of Energy presented an energy plan to Parliament which called for five nuclear power stations to be completed by 1995. Because of public opposition, however, the decision to introduce nuclear power has been postponed several times. In May 1980 the decision was again delayed for at least 2 years. In the meantime, the utility organizations ELSAM and ELKRAFT have continued to plan for nuclear power. They have investigated potential power station sites and have sponsored design, feasibility, and site characterization studies for a salt dome repository.

ORGANIZATION

The Atomenergikommisionen (Danish Atomic Energy Commission), located in Copenhagen, has overall responsibility for nuclear energy matters. R&D in the nuclear field is performed primarily by the Research Establishment Risø, at Roskilde.

WASTE MANAGEMENT R&D

Danish investigators (Risø) have been studying radioactive waste treatment and disposal for a number of years. They made, in fact, the first known tests of a joule-heated ceramic melter for vitrifying simulated HLLW. They have since been interested in the treatment of low-level wastes, TRU properties, and geologic disposal of high-level wastes.

In 1977, ELKRAFT AND ELSAM initiated a two-phase study of Denmark's waste disposal potential. Phase I, a preliminary evaluation of waste disposal practices and programs, was

completed with the publication of a report entitled "Disposal of High-Level Waste from Nuclear Power Plants in Denmark." Phase II, a 2-year project funded at \$10 M by the utilities, was expected to be completed in 1980. The plan was to look at four salt domes in Denmark, select two sites, complete an initial design, and do some field work, including drilling two or three boreholes.

In September 1980 ELSAM representatives reported that a number of salt domes in the northern part of Jutland had been evaluated, that two sites had been drilled to a depth of 3500 m below sea level, and that hydrologic studies and measurement of the properties of the drilling caves are under way. Facility design, materials testing, and safety assessments are also proceeding.

Investigators at the Risø National Laboratory are studying the migration of radionuclides through soils in a project partly financed by the CEC. Emphasis has been placed on the effect of various complexing agents upon migration.

FEDERAL REPUBLIC OF GERMANY

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

Major resources in the Federal Republic of Germany (FRG) are being applied to the installation of LWR power stations, closure of the LWR and THTR fuel cycles, and demonstration of THTR and LMFBR technology. Several years ago, adequate provision for nuclear waste management became a precondition for issuing construction permits for additional reactors in West Germany. In response to this requirement, the FRG nuclear utilities set up a nuclear fuel reprocessing company (DWK) that started planning for a complete spent fuel recycle and waste disposal and management center, the Nukleares Entsorgungs Zentrum (NEZ), at Gorleben, Lower Saxony. The NEZ provided for interim spent fuel storage (3000 t), reprocessing (1400 t/yr), uranium and plutonium conversion and storage, MOX fuel fabrication, conditioning of radioactive wastes, and disposal of solidified wastes in a salt repository--all at the same site. A 12-km² area near the town of Gorleben, Lower Saxony, was selected and purchased, and site characterization and facility design activities were begun. In May 1979, the government of Lower Saxony decided that construction of the large reprocessing plant at Gorleben was not politically feasible and recommended that reprocessing be done elsewhere in smaller plants.

Current FRG strategy includes: 1) thorough evaluation of the final storage of spent fuels as an alternative to reprocessing; 2) indefinite storage of spent fuels at one or more AFRs, probably in dry storage, until the choice can be made between domestic reprocessing and final storage of unprocessed fuels; 3) interim reprocessing of FRG fuels (1700 t) by COGEMA at La Hague; 4) construction of one or more small (350-t/yr) reprocessing plants; 5) resumption of LLW disposal in the Asse salt mine provided a license can be obtained; and 6) construction of a salt dome repository at Gorleben for HLW or spent fuels and a rock repository for non-TRU wastes. Meanwhile, evaluation of the Gorleben site for HLW repository use and the abandoned Konrad iron mine for non-TRU wastes is proceeding.

Major Milestones

● Complete the characterization of the Gorleben site	1985
● Policy decision between domestic fuel reprocessing and spent fuel disposal	After 1985
● Hesse fuel reprocessing plant	1990
● PAMELA HLW vitrification pilot plant	1986
● HOVA HLW vitrification plant for the WAK pilot plant	1990
● Konrad iron mine repository	1985
● Gorleben repository	1995

ORGANIZATION

The federal government coordinates the FRG nuclear programs; sponsors fuel cycle and waste management R&D; and is charged by law to design, build, and operate any radioactive waste disposal facilities. The privately owned utilities are responsible for the fuel cycle, including spent fuel storage, reprocessing and/or disposal and/or treatment of the associated wastes. The nuclear utilities are also to pay the cost of waste disposal by the government.

Development of fuel cycle and waste management technology is handled primarily by the following institutes and companies:

1. ALKEM GmbH, Hanau. MOX fuels development and fabrication; TRU waste treatment.
2. BGR, Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources), Hannover. BGR is studying geology-related effects in salt-dome repositories, rock salt properties, rock mechanics, etc.
3. BMFT, Bundesministerium für Forschung und Technologie (Federal Ministry for Science and Technology, Bonn. Promotion and coordination of nuclear research and engineering.
4. BMI, Bundesministerium des Innern (Ministry of the Interior), Bonn. Atomic safety, radiation and protection, and supervision of the state licensing procedures.
5. DWK, Deutsche Gesellschaft für Wiederaufarbeitung von Kernbrennstoffen mbH (German Fuel Reprocessing Company), Hannover. DWK was organized in 1977 by 12 utilities to provide spent fuel transport and storage, reprocessing, and waste management services for their nuclear power stations. Spent fuel reprocessing and waste management are the responsibility of two DWK divisions:
 - GWK, Gesellschaft zur Wiederaufarbeitung von Kernbrennstoffen mbH (Company for Reprocessing of Nuclear Fuels), Leopoldshafen-Eggenstein, adjacent to the Karlsruhe Nuclear Research Center. DWK took over ownership of GWK from a group of German chemical companies. GWK now has responsibility to manage fuel cycle R&D for DWK. This includes operation of the WAK plant and DWK's HLW vitrification R&D program.
 - KEWA, Kernbrennstoff-Wiederaufarbeitungs-Gesellschaft mbH (KEWA Nuclear Fuel Reprocessing Company), Hannover. KEWA is the DWK engineering division.

6. GSF/IFT, Gesellschaft für Strahlen-und-Umweltforschung, Institut für Tieflagerung (Society for Radiation and Environmental Research/Underground Storage Institute), Braunschweig. IFT is responsible for providing the scientific foundations for safe underground storage of radioactive wastes. Major functions include studies of rock mechanics, geology, hydrology, and safety. One arm of this institute, the Operating Department of Underground Storage, conducts R&D operations at the Asse salt mine. GSF/IFT is also evaluating the use of the Konrad iron mine for low-level waste disposal.
7. HMI, Hahn-Meitner Institut für Kernforschung Berlin GmbH (Hahn-Meitner Institute for Nuclear Research), Berlin. The Institute is responsible for FRG's fuel cycle safety assessment project and for continuing work on the formulation and properties of high-level waste glasses.
8. KFA, Kernforschungsanlage Jülich GmbH (Jülich Nuclear Research Center), Jülich. KFA is the principal West German facility for research, development, and demonstration of HTGR technology, with the fuel cycle program leading all HTGR fuel cycle development effort in West Germany. The project organization includes systems analysis for fuel cycle operations, fresh fuel fabrication and fuel development, and all fuel cycle operations (including reprocessing of HTGR fuels and waste management).
9. KfK, Kernforschungszentrum Karlsruhe GmbH (Karlsruhe Nuclear Research Center) Karlsruhe. KfK has extensive R&D programs in the areas of LWR spent fuel reprocessing and the treatment and conditioning of wastes from the LWR fuel cycle. The center is also the home of the CEC's European Transuranium Institute.
10. NUKEM GmbH, Hanau. NUKEM offers commercial fuel cycle and waste management engineering services and is currently involved with the design of the FRG PAMELA vitrification pilot plant.
11. PTB, Physikalisch-Technische Bundesanstalt (Federal Physical-Technical Institute), Braunschweig. By federal law, PTB has the assignment to design, license, and operate final disposal sites such as the Asse II mine and the Gorleben repository.
12. Transnuklear GmbH, Hanau. A subsidiary of NUKEM, Transnuklear provides spent fuel and waste transport services and is a partner with BNFL (UK) and Transnucléaire (France) in Nuclear Transport Limited.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 1982--0.3 THTR, 1985--0.3 LMFBR and 19.6 LWR, 2000--53 LMFBR, indefinite future--25.9 LWR.
2. Uranium mining and milling: 100 tU/yr.
3. Uranium enrichment: Uranit mbH, a partner with British and Dutch companies in the URENCO consortium, plans to build a 1000-tSWU/yr gas centrifuge plant at Gronau. Construction is expected to start in 1981.

4. Spent fuel storage: DWK plans for up to three 1500-t spent fuel storage facilities, one at Gorleben and one potentially at Ahaus. They are to be based on the dry storage concept in which licensed fuel shipping casks based on the CASTOR cask concept would be used for storage.
5. Fuel reprocessing: DWK proposes to build at least one 350-t/yr fuel reprocessing plant, probably in the state of Hesse. To handle the immediate spent fuel storage problem, DWK has contracted with COGEMA for the facility at La Hague (France) to reprocess 1700 t.
6. HLW vitrification: DWK has selected the French AVM waste vitrification process for installation at the WAK reprocessing pilot plant at Karlsruhe. The company also is basing its license application for the waste treatment facility at the Hesse fuel reprocessing plant on the AVM process. The waste canisters are to be stored in air-cooled, underground interim storage facilities until they have cooled sufficiently to allow placement in the salt dome repository.
7. Waste isolation: planning is proceeding in three directions:
 - Procure a license for LLW disposal in the Asse II salt mine. Asse II was used for large-scale experimental disposal of low- and intermediate-level wastes for many years, but the operating permit expired, and the state of Lower Saxony is requiring a formal licensing action before further disposal will be allowed.
 - Convert the retired Konrad iron mine (at Salzgitter, 45 km from Asse) into an industrial repository for non-alpha-bearing wastes.
 - Construct a salt-dome repository at Gorleben for solidified HLW and/or spent fuel.

SPENT FUEL AND WASTE MANAGEMENT R&D

Objectives

1. Develop and demonstrate
 - advanced spent fuel reprocessing technology for LWR, LMFB, and HTGR fuels
 - technology for packaging, transporting, storing, and disposing of spent fuels
 - German technology for solidification of LWR HLW as a backup to the French AVM process, and for HTGR HLW
 - technology for the volume reduction and immobilization of TRU wastes, reactor wastes, and other non-high-level wastes
 - technology for isolation and disposal of spent fuels and all fuel cycle wastes in salt dome or hard-rock repositories.
2. Conduct a thorough evaluation, including safety, cost, and total systems studies, of alternative fuel cycle and "entsorgung" (spent fuel management and waste disposal) concepts.

Fuels Fabrication

West Germany's primary fuel development programs are conducted by ALKEM in facilities at Hanau and by KFA at Jülich. ALKEM, with a MOX fuels pilot plant rated at 18 t/yr, develops and demonstrates technology for fabrication of LWR and LMFBR fuels. KFA, assigned overall HTGR responsibility, develops and tests $\text{ThO}_2\text{-UO}_2$ fuels.

Spent Fuel Management

The Federal Republic of Germany is turning to a dry storage system for spent fuels, in which low-cost "Castor" malleable cast iron, fuel transport casks are to be used as long-term containers for fuel assemblies. Extensive R&D has been done in developing fabrication technology and in securing a license.

Studies of spent LWR and LMFBR fuel reprocessing continue at Karlsruhe where the following facilities are available:

1. KfK's Institute for Hot Chemistry with extensive hot cell facilities for reprocessing studies
2. TEKO Hall, designed for large-scale cold tests of reprocessing methods, processes, and components
3. the WAK pilot plant.

Thorium fuel reprocessing technology is the responsibility of KFA's Institute of Chemical Technology at Jülich, which has a 2-kg/day hot reprocessing pilot plant (Jupiter) under construction.

High-Level Waste Immobilization

The French AVM process is the reference for FRG's proposed commercial-scale HLW vitrification plants, but the FRG authorities want a backup process based on domestic technology. Hence the country's HLW immobilization R&D program is based on the objective of providing a large-scale radioactive demonstration of a ceramic melter process which has been studied at KfK, for several years. The demonstration is to be achieved in a new pilot plant, PAMELA, soon to be constructed at the Eurochemic site in Mol, Belgium. PAMELA is to produce a borosilicate glass, either as marbles which can be embedded in a low-melting alloy, or as glass blocks. Supporting process and equipment development studies are conducted at KfK and in Eurochemic laboratories, while product characterization work is the responsibility of the Hahn-Meitner Institut.

The FIPS process, designed to vitrify thorium fuel cycle wastes for the HTGR program, has been developed at KFA, Jülich.

Treatment of Other Wastes

Other waste treatment studies include:

1. volume reduction of TRU wastes by acid digestion and pyrolysis (ALKEM, NUKEM, and KfK)
2. handling and packaging of cladding hulls (Karlsruhe)

- properties of hulls (e.g., heat generation, tritium release)
 - immobilization of hulls in concrete
3. volume reduction of liquid wastes by evaporation and/or chemical treatment
 4. combustion and mechanical volume reduction of solids (Jülich and Karlsruhe)
 5. incorporation of non-HLW in concrete, bitumen, and resins (Karlsruhe, NUKEM)
 6. management of airborne effluents:
 - in-plant control and storage (Jülich and Karlsruhe)
 - cryogenic processes for noble gas recovery (Karlsruhe)
 - ion implantation of noble gases in a metal matrix (Karlsruhe).

Geologic Disposal of Spent Fuel and Wastes

Since 1965, the Federal Republic of Germany's efforts to develop geologic waste disposal technology have been focused on work at the Asse salt mine. The mine has been used for large-scale experimental disposal of low- and intermediate-level wastes. R&D activities have included development of cavern construction technology, testing of various techniques for placing waste containers in repositories, rock mechanics studies, in situ measurements of thermal and hydrologic parameters and safety analyses (BGR, GSF/IfT, and PTB). KfK and GSF/IfT are cooperating in a program to develop technology for the in situ solidification (in a cement matrix) of low- and intermediate-level wastes in a shaped salt cavern. KfK is also studying radionuclide migration. West Germany also intends to convert the Konrad iron mine (at Salzgitte) into an industrial repository for non-alpha-bearing wastes.

HMI has the lead in a major West Germany program (\$12 million spread over 4 years) to assess the safety of the post-reactor fuel cycle, including final disposal of wastes in salt. The Gorleben salt dome repository is to have the capacity for 23,000 drums/year of non-HLW (10,000 @ 200L/drum and 13,000 @ 400L/drum; 10,700 200-L drums/year of HLW; and 1600 70-L canisters/year of HLW glass).

In the fall of 1980, BMFT announced a major R&D program to evaluate the technology for geologic disposal of spent fuel as an alternative to fuel reprocessing. KfK was assigned to set up an interdisciplinary group to manage the project. The program scope includes:

1. development of conditioning and packaging concepts, ranging from packaging complete assemblies to packaging after chopping and degassing
2. studies of repository design, safety, canister retrievability, and potential repository sites.

FINLAND

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

Finland has four nuclear power plants, two with reactors supplied by the USSR and two with reactors supplied by ASEA-Atom in Sweden. The present nuclear power capacity of 2.2 GWe is expected to increase to between 3.2 and 5.2 GWe by the year 2000.

Fuel cycle and waste management policy depends on the reactor supplier. Spent fuel from the USSR-built PWRs (440 MWe each) is to be returned to the Soviet Union for handling and disposal, with no wastes to be returned to Finland. Spent fuel from the Swedish PWRs (660 MWe each) may be sent to another country for reprocessing or placed in terminal storage by Finland. In either event, Finland anticipates the need for a geologic repository for spent fuel or for solidified high-level waste.

ORGANIZATION

The Finnish government oversees nuclear affairs through the Atomic Energy Commission, which is a component of the Energy Department in the Ministry of Trade and Industry. The nuclear power stations, two state-owned power companies, are operated by Imatran Voima Oy (IVO) and Teollisuuden Voima Oy (TVO). These companies have established the Nuclear Waste Commission of Finnish Power Companies (Voimayhtiöiden ydinjätetoimikunta, YJT) to coordinate studies related to the management of their nuclear wastes.

Waste management R&D is carried out mainly by the Technical Resource Center (Valtion Teknillinen Tutkimuskeskus, VTT) and the Geological Survey of Finland, both located at Espoo, near Helsinki.

WASTE MANAGEMENT R&D

Finnish R&D programs are directed primarily at developing technology to condition reactor wastes and to dispose of reactor wastes and either spent fuels or fuel reprocessing wastes. The two power companies are evaluating various reactor waste treatment methods--incineration, cementation, and bituminization. The companies are also evaluating the disposal of reactor wastes (including the debris from dismantling) in a geologic repository and (with VTT) the placement of low-level wastes in shallow land disposal sites.

In 1977, the Geological Survey of Finland started a project to evaluate the possibility of disposing of Finland's spent fuels and/or solidified HLW in one of the country's granite formations. An inventory is being made of possible sites; geologic, hydrologic, and radio-nuclide migration are being studied, and other supporting studies are in progress. In addition to the Geologic Survey, participants include the University of Helsinki and the Helsinki University of Technology; VTT; and the Institute of Radiation Protection. Finland is also a participant in the NEA joint R&D studies in the Stripa mine in Sweden.

VTT investigators at Espoo are also conducting risk assessment studies and an economic evaluation of the back end of the fuel cycle.

FRANCE

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

France is very aggressive in developing nuclear power capability and in exporting equipment, plants, and technology. Present emphasis is on installation of PWR power stations--30

identical 950-MW units are scheduled to come on-line in the future, one every 2 months. Emphasis is also being placed on expansion of LMFBR capacity (25 GWe by the year 2000), expansion of uranium enrichment and fuel reprocessing capacity to satisfy foreign and domestic requirements, and development of industrial waste treatment technology and plants.

National plans for waste management are:

- to vitrify all HLLW, provide interim storage for up to 100 years for the waste glass canisters in an engineered surface facility, then isolate in a suitable geologic formation
- to process LLLW by conventional techniques, producing a decontaminated stream which can be discharged into the environment and a radioactive concentrate which will be immobilized in bitumen, concrete, or a resin and stored
- if feasible, to develop and use processes for isolating alpha-emitters.

Major Milestones

● PURR reprocessing plant for FBR fuels (Marcoule)	1989-1990
● UP-3A reprocessing plant (La Hague)	1986
● UP-3B reprocessing plant (La Hague)	1989-1990
● AVH waste vitrification plant (La Hague)	mid-1980s
● Pilot plant repository for alpha wastes	1985

ORGANIZATION

The French Atomic Energy Commission (Commissariat à l'Énergie Atomique, CEA), operating under the direct authority of the Ministry of Industry and Research, is responsible for controlling all nuclear activities from research to defense. Commercial fuel cycle activities, once managed by the CEA, are now the responsibility of a CEA subsidiary, COGEMA (Compagnie Générale des Matières Nucléaires). COGEMA was formed in January 1976 to manage the CEA fuel cycle complex on an industrial basis. The policy is to offer integrated services covering the entire nuclear fuel cycle, including fuel management, and to develop an active exporting policy in this field. Company activities consequently cover uranium mining and exploration, enrichment (participation in Eurodif, Sofidif, Coredif, and operation of Pierrelatte), reprocessing (ownership and operation of the La Hague and Marcoule fuel reprocessing plants), fuel fabrication, transportation of radioactive materials, and engineering and construction of fuel reprocessing plants through its subsidiary Société Générale pour les Techniques Nouvelles (SGN). SGN has acted as contractor for reprocessing plants in Japan and Pakistan (project cancelled) as well as in France and has been active in design and development of equipment for reprocessing and vitrification plants.

COGEMA is an equal shareholder with BNFL (UK) and KEWA (FRG) in United Reprocessors GmbH.

Research and development in the areas of fuel reprocessing and high-level waste management are handled primarily by CEA's Chemical Division, which is headquartered in the

Fontenay-aux-Roses Nuclear Research Center (CEN-FaR). TRU waste R&D is centered at Cadarache. Fuel reprocessing and waste treatment centers and research centers doing waste management research and development include:

1. Cadarache Centre d'Études Nucléaires (Cadarache Nuclear Research Center) is located in the south of France, 65 km from Marseille.
2. Fontenay-aux-Roses Centre d'Études Nucléaires (FaR) (Fontenay-aux-Roses Nuclear Research Center) is located in a suburb of Paris.
3. Grenoble Centre d'Études Nucléaires (Grenoble Nuclear Research Center).
4. La Hague Centre, near Cherbourg in northwestern Normandy. The La Hague Centre is the site of major COGEMA fuel reprocessing and low- and intermediate-level waste storage facilities.
5. Marcoule Centre is located in southern France about 120 km (airline) from Marseille. Marcoule is the site of another COGEMA reprocessing plant, the AVM HLW vitrification plant, and major CEA R&D facilities.
6. Saclay Centre d'Études Nucléaires (Saclay Nuclear Research Center) is located near Paris.

Two other CEA divisions with major waste management responsibility are:

1. The National Agency for Radioactive Waste Management (Agence Nationale pour la Gestion des Déchets Radioactifs, ANDRA) was formed in late 1979 by the French government and replaces the Office of Waste Management which was responsible for development, installation, and operation of intermediate storage facilities and geologic repositories. ANDRA will have full responsibility for final disposal of nuclear waste.
2. The Institute of Nuclear Protection and Safety (L'Institut de Protection et de Sûreté Nucléaire, IPSN) is charged with safety analysis for nuclear installations and developing regulations.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 1980--12; 1985--35; 1990--54 (including 4.4-5.9 LMFBR).
2. Uranium enrichment:
 - Pierrelatte and Eurodif are operating gaseous diffusion plants. (Eurodif is a multinational project owned by Belgium, France, Italy, and Spain.)
 - A CEA pilot plant (50-100 tSWU/yr) is to be built to demonstrate a new French chemical exchange process which operates efficiently only for low enrichments. Startup is planned for 1983.
3. Fuel fabrication: The Cadarache MOX plant makes fuels for the French LMFBRs. Capacity is 15 t/yr for LWR fuels; 5 t/yr for FBR fuels.

4. Spent fuel reprocessing:

- UP-1 (COGEMA, Marcoule) is designed for natural uranium, gas-graphite reactor fuels. Capacity is 900 to 1200 tHM/yr.
- PURR (COGEMA, Marcoule) is a new plant designed for MOX fuels from fast breeder reactors. Design capacity is 100 tHM/yr. Startup is planned for 1989-1990.
- SAP (CEA, Marcoule) is a pilot plant used for process development. Current effort supports France's FBR fuel cycle program. Capacity is 25 kg/day.
- UP-2 (COGEMA, La Hague) is designed and constructed for natural uranium, gas-graphite reactor fuels. UP-2 now has a chop-leach head-end to allow treatment of LWR oxide fuels. Present capacities are 1000 tHM/yr for natural uranium metal fuels and 400 tHM/yr for oxide fuels. From 1976 through May 1980, UP-2 successfully reprocessed 240 t LWR fuels. Expansion of the oxide head-end to 800 tHM/yr capacity is planned. COGEMA intends to reprocess gas-graphite fuels only at Marcoule in the future, leaving UP-2 for LWR fuels.
- UP-3 (COGEMA, La Hague) is a twin-line plant being built to handle LWR oxide fuels. The first line, UP-3A, is to start up in 1986 and is to service foreign customers. UP-3B, to come on-line in 1989-1990, will handle domestic French fuels. Each line is sized at 800 tHM/yr.
- AT-1 (COGEMA, La Hague) is a pilot-scale plant (200 kg/yr) used to reprocess Rapsodie (LMFBR) spent fuels.

5. High-level waste solidification:

- AVM (COGEMA, Marcoule) is the world's first industrial-scale vitrification plant. Using a two-stage process (rotating tube calciner and induction-heated metal melter), AVM has a design capacity of one waste canister (360 kg glass) per day. Waste canisters are stored in an onsite underground vault. France has sold AVM technology to other countries, notably the Federal Republic of Germany and the United Kingdom. An AVM-type plant is also to be installed at the Eurochemic site in Belgium. Hot operations started in June 1978, and by July 1980, AVM had produced 136 t HLLW glass (380 canisters) from 280 m³ HLLW (from about 7000 t GCR fuel).
- AVH (COGEMA, La Hague) is to be the first vitrification plant at La Hague. It will have a design feed rate of 49 t/hr HLLW versus 30-36 t/hr for AVM.

6. Treatment of non-high-level wastes: A number of nuclear energy centers are operating waste incinerators and pilot plants for incorporating non-high-level wastes in bitumen, concrete, or resins.

7. Disposal of non-high-level wastes (ANDRA):

- Centre de la Stockage de La Manche (near the La Hague plant) has waste packages stored on the surface, in concrete ditches, or in special shafts. Capacity is 300,000 m³.

- Centre de la Stockage No. 2 (near St. Étienne) is not available yet. Startup is planned for 1982-1983.

SPENT FUEL AND WASTE MANAGEMENT R&D

Objectives

Develop and demonstrate technology, for domestic use and for commercial export, for all aspects of the LWR and LMFBR fuel cycles and their associated waste management processes and facilities. Current areas of emphasis include reprocessing of LMFBR spent fuels and recycle of uranium and plutonium; treatment and immobilization of reactor and fuel cycle wastes; surface storage of low- and intermediate-level wastes; and geologic or subseabed disposal of high-level and alpha-bearing wastes.

Management of Spent Fuels

1. Tests for qualification of shipping containers are conducted at CEN Fontenay-aux-Roses. Activities include fire, shock, and vibration tests; experiments with wet shipments (to provide cooling); and risk studies. (Fontenay-aux-Roses)
2. Development of reprocessing technology for LMFBR and LWR fuels. Emphasis is on dismantling of fuel assemblies, continuous dissolution, and annular pulsed columns.

High-Level Waste Solidification

Since June 1978, France has successfully operated the AVM, a demonstration plant for vitrification of high-level wastes, using HLW from the reprocessing plant at Marcoule. Present R&D is directed to improving melter design in order to increase melting rates and extend melter life; improving offgas treatment techniques; evaluating waste glass properties; and developing the capability to handle the wastes from LMFBR fuels (CEA establishment at Marcoule).

Treatment of Non-High-Level Wastes

France continues to emphasize work on the volume reduction and immobilization of trans-uranic wastes and fuel cladding hulls. Specific projects include americium recovery (Marcoule); washing and crushing of wastes for volume reduction (Cadache); immobilization of TRU in concrete, bitumen, polymer, and glass waste forms; electrical melting of hulls, decontamination by treatment with molten glass and/or molten salts, and embedment in glass (Marcoule).

Bituminization processes and equipment for LLW and ILW have been developed and tested at Cadache, Marcoule, and Saclay, and a pilot plant to immobilize reactor wastes in a thermosetting resin has been installed at the Chooz power station.

French investigators, primarily at Fontenay-aux-Roses, are working on improved methods for management of tritium and ¹²⁹I in fuel reprocessing plant effluents.

Geologic Waste Disposal

French waste disposal policy is based on these basic assumptions: 1) a geologic repository must be used for all radioactive wastes except low-level wastes which are essentially

free of long-lived radionuclides; 2) a multibarrier scheme is necessary for a geologic repository; 3) borosilicate glass is a satisfactory waste form for high-level waste; and 4) until a repository is available, the vitrified high-level wastes can be stored safely in an engineered surface storage facility.

The French R&D program has emphasized crystalline rock formations, with support in this area from the CEC indirect action program. Officials continue to emphasize that France is investigating several types of formations, including seabed, and that no final decision has been made as to the type of geology. The crystalline rock R&D program has followed two main lines of research.

1. an inventory of crystalline massifs and selection of two sites for extensive exploration and evaluation
2. study of radionuclide migration processes to evaluate the effectiveness of the geologic barrier.

Current and planned R&D, managed and conducted primarily by the Paris School of Mines and the Bureau of Geological and Mineral Research, has these major features:

1. deep exploratory drilling into selected granite formations
2. development of a conceptual model of a suitable crystalline host-rock formation from reliable field data
3. improvements in selected investigative techniques
4. barrier development
5. assessment of the effect of the repository in the geological environment
6. tests of the ability to backfill and seal shafts and boreholes against vertical upward movement of groundwater
7. construction of a test repository for TRU wastes (target date: 1985)
8. preliminary evaluation of salt and shale formations
9. active participation in the NEA Seabed Working Group.

INDIA

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

A distinguishing characteristic of the nuclear policy and programs of India is the degree of self-sufficiency that is aimed for in all parts of the fuel cycle. India is unique because it is the only developing country with such extensive programs. The country currently has about 1800 MWe of nuclear capacity either in operation or under construction. The three operating commercial nuclear power reactors have a total capacity of 640 MWe or about 2.5% of the total installed power in the country.

The first nuclear power station at Tarapur, northeast of Bombay, consisted of twin 210-MWe BWR, a turnkey project awarded to General Electric. However, overall fuel cycle strategy is based on natural uranium reactors followed by fast breeders and, because of extensive deposits of thorium--some of the largest reserves in the world, eventually reactors based on the self-sustaining thorium-²³³U cycle. A second power station, in Rajasthan state, consists of one operating 220-MWe PHWR and a twin unit in an advanced stage of commissioning. Third and fourth stations, at Kalpakkam (new Madras) and Narora in the state of Uttar Pradesh, both with twin 235-MWe PHWR, are under construction. At least 5000 MWe of natural uranium heavy water reactors are believed to be necessary to launch the second stage of the power program, i.e., the fast breeders.

Reprocessing of spent fuels started in 1964 in a pilot plant at Trombay near Bombay. A second small plant (100 t/yr) has been built at Tarapur, and other small ones are planned as they are needed. Primarily because of transportation problems, the reprocessing plants are to be situated adjacent to the power stations they will service.

Facilities for heavy water production, fuel fabrication, waste management, and component fabrication all further the policy of self-reliance.

ORGANIZATION

Atomic energy matters in India are administered by the Department of Atomic Energy, which includes the Atomic Energy Commission, the Nuclear Fuel Complex, and the various nuclear power stations. Nuclear research and development is administered by the Atomic Energy Commission and performed primarily by the Bhabha Atomic Energy Centre (BARC) at the Trombay site or one of BARC's satellite installations.

BARC was established in 1959 as a multidisciplinary facility for research and development. Located at BARC are four test reactors; radiochemistry and isotope laboratories; an isotope production and processing unit; pilot plants for production of heavy water, zirconium, titanium, etc.; a thorium plant; a uranium metal plant; a fuel reprocessing plant; the Fuel Irradiation and Processing Laboratory; and supporting facilities. In addition to the Trombay installation, BARC has research laboratories at Guaribidanur and Kashmir; the Reactor Research Centre for Fast Reactor Development at Kalpakkam; and the Variable Energy Cyclotron at Calcutta. BARC handled the underground test of a nuclear device in May 1974.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 1980--0.42 LWR and 0.44 PHWR, 1985--1.33 LWR and PHWR, 1990--5.
2. Uranium mining and milling: 200 tU/yr. India is currently producing uranium commercially from only one source, Jaduguda in Bihar state.
3. Fuel reprocessing: India has installed two fuel reprocessing plants and completed designs for a third. They are situated in the following locations:

- Trombay (BARC): A 60-tHM/yr Purex pilot plant for LWR fuels; Trombay produced the plutonium used in India's nuclear weapons test and is now shut down; it will later reprocess research reactor fuels. The plant uses chemical dejacketing, pulse columns for codecontamination, partitioning and uranium purification, and anion exchange for final plutonium purification. It was designed for direct maintenance.
 - Tarapur: A 100-t/yr plant for LWR and PHWR fuels. This facility, idle since construction was completed in 1975, is scheduled to begin operation in 1981. It uses a Purex flowsheet, with neptunium recovery and conversion of the plutonium product to PuO_2 .
 - Kalpakkam: A second 100-t/yr "industrial-scale" plant to handle PHWR fuels but with a separate process stream for FBR fuels from a test reactor.
4. HLLW solidification: A waste immobilization plant with a designed capacity to treat 20-25 t of HLW per hour is under construction at Tarapur, scheduled for startup in 1982. Similar plants are planned for BARC and Kalpakkam.
 5. Non-HLW treatment: BARC has a liquid-waste treatment plant.

RESEARCH AND DEVELOPMENT

Objectives

Develop native nuclear science and engineering capability in accord with the national goal of complete nuclear self-sufficiency; develop technology and manufacturing capability for a completely domestic fuel cycle, including waste treatment and disposal.

Spent Fuel and Waste Treatment

A reprocessing laboratory has been established at Kalpakkam. Current emphasis is upon equipment development and testing.

India has based its vitrification plant design on a semicontinuous pot process developed at BARC, in which preconcentrated HLW is calcined then melted in an Inconel-600 vessel.

Other non-HLW studies include work on 1) the partitioning of TRU wastes and their conversion into insoluble aluminosilicates and 2) the decontamination and densification of cladding hulls.

Underground Disposal

India intends to develop a repository for high-level and TRU wastes. A geologic survey for potential repository sites has been conducted and supporting R&D is under way at BARC. According to early reports, igneous rocks and sedimentary formations were showing the best potential. A late 1980 report indicated that a 3000-m deep gold mine had been selected as a repository site and plans were being made for disposal of HLW at the 1000-m level.

ITALY

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

Italy has outlined an ambitious nuclear power program which includes the addition of up to twelve 1000-MWe reactor plants to the present nuclear capability (1.4 GWe); participation in the Eurodif enrichment plant project in France; partnership in LMFBR demonstration plants in France and West Germany, perhaps leading to a domestic FBR system; and development of fuel cycle self-sufficiency. However, accomplishment of these objectives is questionable at present because of economic problems, plant siting difficulties, and public opposition.

Long-term Italian policy assumes domestic reprocessing of spent fuels, recycle of uranium and plutonium, vitrification and long-term (interim) storage of HLW, and eventually geologic disposal of the conditioned HLW. Preliminary studies have indicated the technical acceptability of clay deposits in southern Italy for repository sites, but these formations appear to be unacceptable politically. Some of the Italian islands are now being considered.

ORGANIZATION^(a)

The Ministry of Industry has overall responsibility for nuclear energy matters with decisions subject to approval by Parliament. Italian organizations with major fuel cycle R&D roles include the National Committee for Nuclear Energy (CNEA); CNEA's Casaccia, Trisaia, and Saluggia centers; AGIP Nucleare, a company with commercial interests in many aspects of the nuclear fuel cycle; and NUCLECO, formed to treat and dispose of low- and intermediate-level wastes.

The Casaccia Center, located in Rome, has a varied nuclear R&D program. The Trisaia Center, at Rotondella in southern Italy, is the site of the ITREC Fuel Reprocessing Pilot Plant and of clay repository studies. The Saluggia Center, located near Torino in northern Italy, is the site of the EUREX fuel reprocessing pilot plant, the construction of which was partly funded by Euratom.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 1980--0.15 GCR and 1.2 LWR; 1986--3.4; 1990--13.4 (principally LWR).
2. Uranium mining and milling (tU/yr): 1985--120.
3. MOX fuel fabrication: AGIP Nucleare is building a 14-t/yr plant at Rotondella to fabricate fast breeder PuO_2/UO_2 fuels for the Super Phenix FBR core. Startup is scheduled for 1982.

(a) The European Community has a Joint Research Center laboratory at Ispra in northern Italy. JRC-Ispra programs are considered in the international section.

4. Spent fuel reprocessing: Italy has two pilot-scale reprocessing plants (see R&D--CNEN), and the construction of an industrial-scale plant is being evaluated by CNEN and AGIP Nucleare. The probable capacity of the industrial-scale plant is 1200 tHM/yr. It may be located near EUREX (Torino area) or ITREC (Rotondella area).

SPENT FUEL AND WASTE MANAGEMENT R&D

Objectives

Develop domestic capability to reprocess LWR and FBR fuels and to treat and dispose of all wastes associated with the nuclear fuel cycle.

Spent Fuel Reprocessing

The EUREX pilot plant at the Saluggia Center was initially designed for MTR fuels. EUREX now has a chop-leach head-end and capability for LWR oxide fuels. Capacity of MTR fuels is 30 kg/day and of LWR oxides is 50-100 kg/day.

The ITREC pilot plant at the Trisaia Center was built for thorium fuel reprocessing and has a chop-leach head-end. The plant's current assignment is FBR fuel reprocessing R&D. Alternative fuel cycle techniques, including "coprocessing" to yield a mixed uranium-plutonium product stream, are under investigation.

High-Level and TRU Waste Treatment

A HLW pot vitrification process, ESTER, has been developed at the Casaccia Center and subjected to radioactive tests in JRC-Ispra hot cells. Further testing is being done in a nonradioactive pilot plant (IVET-1) at the Trisaia Center, in preparation for building a hot plant (IVET-2) to treat the HLW from the ITREC fuel reprocessing plant. IVET-2 is scheduled for completion in 1985. Present plans also call for construction of IVEX, a second hot vitrification plant, to handle wastes from EUREX at Saluggia. IVEX is expected to use the same process as IVET-2.

TRU waste treatment studies include development of:

1. a molten-salt incineration process (treatment of combustibles with O_2/N_2 in a molten alkaline sulfate bath) at 600°C (AGIP Nucleare)
2. TRU waste washing techniques and facilities
3. partitioning flowsheets.

Waste Disposal

CNEN has started a program to characterize clay deposits throughout Italy in support of the national search for a repository site. This effort follows work in southern Italy in evaluating argillaceous sediments near the Trisaia Center. Supporting R&D includes in situ tests of thermal and radiation effects, engineering development, and risk assessment. CNEN-Casaccia and JRC-Ispra are contributing to geologic isolation safety assessments. Operations in a test repository are expected to start by the mid-1980s.

JAPAN

NUCLEAR FUEL CYCLE POLICY AND PLANS

The Japanese government considers nuclear energy essential to meet anticipated energy demands. the basic strategy is to proceed from purchased LWR technology to domestic development of heavy-water-moderated, boiling light-water-cooled reactors and fast breeder reactors. Japan also considers fuel recycle and waste management capability to be essential. Until the first commercial plant is built, Japan's spent fuels are to be reprocessed by COGEMA (La Hague, France) and BNFL (THORP plant, UK).

Solidified HLW will probably be held in engineered storage facilities for 50-100 years, with subsequent geologic or seabed disposal. Present geologic repository research is directed to the selection of potential geologic formations with the following under consideration: granite rocks, diabase, shale, zeolite tuffs, and limestone. The government will be in charge of the isolation with the cost of the isolation supported by the waste originator.

Disposal of low-level solid waste is expected to be accomplished by both sea dumping and land isolation. Lower activity and nontransuranic wastes would be dumped into deep ocean after immobilization in stable forms such as cement, concrete, or bitumen. Higher level wastes and those unsuitable for ocean dumping would be isolated on land, probably in an engineering storage facility.

Major Milestones

• HLW solidification pilot plant (PNC)	1987
• Commercial reprocessing plant	~1990
• HLW solidification commercial plant	~1995
• Return of HLW from COGEMA and BNFL	~1990
• Experimental sea-dumping of LLW	~1981
• Selection of candidate geologic or seabed repository formations	~1985
• Selection of repository test site for in situ test with a simulated waste package	~1995
• Selection of demonstration site for in situ test with actual waste package	~2005
• Startup of disposal site	After 2015

ORGANIZATION

Several government agencies have major fuel cycle and waste management responsibility:

1. The Japan Atomic Energy Commission (JAEC) advises the Prime Minister with regard to nuclear energy policy.
2. The Nuclear Safety Commission (NSC), established in 1978, is responsible for regulation of the nuclear industry, especially with regard to safety.

3. The Science and Technology Agency (STA) was established to promote and administer research and development for the government.
4. The Japan Atomic Energy Research Institute (JAERI) conducts nuclear energy R&D, supplies radioisotopes, and trains nuclear scientists and engineers from outside the Institute. JAERI has headquarters in Tokyo. Its primary fuel cycle/waste management R&D activities are centered at the Tokai Research Establishment, about 120 km northeast of Tokyo.
5. The Power Reactor and Nuclear Fuel Development Corporation (PNC) develops and demonstrates new types of power reactors and fuel cycle processes, equipment, and techniques. PNC is in charge of developing a HLW solidification process and building a HLW treatment pilot plant at Tokai Mura. The corporation is also developing technology by uranium enrichment, nuclear fuel technology, and fuel reprocessing. PNC has its headquarters in Tokyo and major installations at Tokai Mura and Oarai-Machi.
6. The Ministry of International Trade and Industry (MITI) is a cosponsor (with various private companies) of the Radioactive Waste Management Center (RMC), which is responsible to develop systems for sea dumping and land isolation of low-level wastes; provide sea dumping and land isolation on a contract basis; provide associated environmental monitoring and safety analyses services.

Industry is responsible for the commercial fuel recycle, for developing technology (with government help), and industrial capability for disposal of LLW, and is to pay for HLW disposal. Many private companies participate in waste management R&D.

NSC, STA, and the Ministry of Transportation are jointly responsible for establishing criteria for waste and transportation technology and practices.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 1980--14.2 LWR, 0.2 LWCHW and 0.16 GCR; 1985--0.3 LMFBR and 19.8 LWR; 1990--60; 1996--80 GCR; 2000--100-250.
2. Uranium mining and milling: Current uranium output is 30 tU/yr.
3. Uranium enrichment: The initial stages of a gas centrifuge plant have begun operation at the Ningyo Pass mine site. Full operation (75 tSWU) with 7000 machines is scheduled for 1981.
4. MOX fuels: Japan relies on private industry to fabricate uranium fuels and on PNC for development and fabrication of MOX fuels. PNC's Plutonium Fuel Fabrication Facility (PFFF) has two fabrication lines--a FBR fuel line with a 50-kg MOX/day capacity.
5. Fuel reprocessing: Japan has contracts in place with COGEMA (France) and BNFL (UK) to provide fuel reprocessing service (3200 t) until Japan's domestic plants can carry the load. Japanese facilities and activities include:
 - Tokai Mura plant (PNC), a nominal 210-t/yr Purex plant for LWR oxide fuels which started operations in late 1977, but has been plagued with equipment problems. The process includes a chop-leach head-end and a mixer-settler solvent extraction system.

- Construction of an industrial two-line, 6-tU/day reprocessing plant, which is to be built and operated by a consortium of about 100 companies known as Japan Nuclear Fuel Services, Ltd. Startup is planned for 1990.
6. HLW solidification: Japan's stated intent is to have a demonstration vitrification plant operating by 1987 to support the Tokai Mura reprocessing plant. PNC, Japan's fuel cycle company, has considered several types of technology: fluid-bed calcination, followed by sintering, melting, or hot-pressing; and the ceramic melter. Present emphasis is to develop and demonstrate the ceramic melter.
 7. Non-HLW Management: JAERI has a 30- ℓ /hr bituminization plant at Oarai, and PNC plans to build a similar 200- ℓ /hr plant. Combustible solids incinerators are in service at Tokai and Oarai.

RESEARCH AND DEVELOPMENT

Objectives

Develop and demonstrate technology for:

1. transition from a LWR-based nuclear power system to one based on FBRs
2. a high-temperature, gas-cooled reactor that can provide process heat for a variety of purposes
3. domestic fuel production and recycle capability (enrichment, conversion, fabrication, and reprocessing) to support the Japanese LWR and FBR systems
4. conditioning and packaging of reactor and fuel cycle wastes
5. spent fuel and waste transport
6. disposal of non-high-level wastes, either underground or by sea-dumping
7. geologic or subseabed disposal of conditioned HLW.

Spent Fuel Management

With her major nuclear facilities located on or near the nation's coastlines, and plans to have over 3200 t of spent fuel processed in England (BNFL) and France (COGEMA), Japan is placing major emphasis on the development of marine transport technology and capability.

Two major programs are under way:

1. drop impact, fire, and deep-water immersion tests of full-scale transport package and models (STA)
2. a joint study with the US on the use of a mid-Pacific island site for long-term storage of spent fuels.

Japan is also proceeding with spent fuel reprocessing R&D, directed to support the construction of a commercial-scale plant for LWR fuels and to process development for FBR fuels. Major new pilot plant facilities are in design and/or under construction.

Waste Treatment

Japanese laboratories have explored a number of alternatives for HLW immobilization. Process development work currently emphasizes ceramic melters, and preparations are being made for extensive hot and cold process testing and demonstration (PNC). Laboratory work continues on ceramic and glass-ceramic waste forms, canisters, and waste form properties (PNC and JAERI).

Techniques and equipment for TRU waste and LLW treatment and disposal is under way at a number of sites.

1. Acid digestion (PNC and JGC), incineration (JAERI), and partitioning of TRU wastes.
2. Bituminization (JGC) and incineration (Hitachi) of LLW.
3. Plasma arc melting of noncombustible wastes (Daido Steel).
4. Development and testing of packages for sea dumping (JAERI). Experimental sea dumping (RMC).
5. Collection, purification, and containment of ^{85}Kr (Hitachi, Kobe Steel, PNC).

Waste Disposal

The Japanese are working to locate a geologic repository site, probably in a granite, shale, or basalt formation, and to develop the necessary supporting technology. Studies of geologic, seismic, mechanical, and geochemical properties of selected formations will lead to in situ tests with simulated and actual waste canisters. Extensive safety studies are in progress (PNC and JAERI).

MEXICO

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

Mexico has two 654-MWe nuclear power plants (BWRs) under construction and due for commercial operation in 1982 and 1983. Future plans for nuclear power include expansion to a 20-plant system by the year 2000.

The country also plans to develop extensive uranium resources, which could be as high as 600,000 t, and domestic fuel cycle capability.

ORGANIZATION

Until 1978, Mexico's nuclear policies were carried out by the National Institute of Nuclear Energy (INEN). At that time, INEN was divided into a National Atomic Energy Commission; a state company charged with exploration and exploitation of national reserves (Uramex); and a National Nuclear Research Institute (ININ), charged with research and development.

FUEL CYCLE R&D

Mexico is reportedly building several fuel cycle R&D facilities at the Salazar Nuclear Center: a reprocessing pilot plant; a plutonium oxide production and storage pilot plant; a mixed-oxide fuel fabrication pilot plant; and a plutonium scrap recovery laboratory.

NETHERLANDS

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

In 1975 the Dutch government approved plans for three new 1000-MWe nuclear facilities and expansion of the Almelo uranium enrichment plant to 1250 tSWU/yr. However, subsequent government changes and adverse public opinion have repeatedly delayed furtherance of these plans. The government has called for resolution of waste management questions before deciding on further nuclear power plants, and in late 1980 initiated a 2-year public information campaign and debate on energy policy in general in order to gauge public feeling before making any decisions about nuclear power.

The country plans to have spent fuel reprocessed in France and England and is looking for sites for a salt dome repository for disposal of the resulting high-level wastes.

In spite of these problems, the Netherlands is continuing to conduct LWR, FBR, homogeneous reactor, and fusion R&D, and supports CEC reactor development programs.

ORGANIZATION

The Ministry of Economic Affairs has overall responsibility for nuclear energy matters; the decisions are subject to approval by Parliament. Other organizations with major fuel cycle and waste management roles include:

- KEMA, the laboratories of the joint electric utilities at Arnhem.
- The Petten Research Establishment of Energieonderzoek Centrum Nederland (ECN) which provides numerous services relating to operation of the Dutch nuclear power plants such as radwaste handling, radiation dosimetry, and training of personnel. ECN is responsible for disposal of Holland's low-level waste.
- The Geological Survey of the Netherlands at Haarlem.
- The Ministry of Public Health and Environmental Protection at Leidschendam.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 1980--0.49 LWR, long-term--3.5.
2. Uranium enrichment, tSWU: 1978--200, future (potential)--1250.

SPENT FUEL AND WASTE MANAGEMENT R&D

Volume Reduction of Combustible Wastes (KEMA)

1. Scouting studies: combustion in molten Na_2CO_3 (project abandoned); biological digestion by microorganisms.
2. Incineration: a small-capacity incinerator is under development.
3. Acid digestion: a small pilot plant has been built and is in operation.

Underground Disposal (ECN and other agencies)

In 1979, the government submitted a report to Parliament which indicated that radioactive waste can be stored safely in underground salt domes in state-owned property in the northeastern region of the country. Plans were made to drill exploratory holes, about 500 m deep in salt domes under state-owned property, but these plans have been independently deferred. Plans also exist to examine the possibility of constructing a repository in a salt diapir below the seabed, and the Netherlands is participating in the NEA Seabed Working Group studies.

With CEC financial support, the Dutch are working in several areas of geologic waste disposal technology: theoretical studies of thermal effects in salt dome repositories; measurement of distribution coefficients of various radionuclides in various soil samples; hydrogeologic evaluations; and safety assessment.

Airborne Waste Disposal

Feasibility study--see disposal of pressurized cylinders of ^{85}Kr .

PAKISTAN

NUCLEAR POWER POLICY AND PROCEDURES

Pakistan's known energy resources are scarce. The nation currently imports 85-90% of its fuel. Oil and gas now account for more than 78% of the energy use but less than 67% of its known energy resources. Its coal, oil, and gas reserves are less than 1% of the world per capita average. And further expansion in hydroelectric power is viewed as unlikely because of the inaccessibility of sites. Hence Pakistan looks largely to nuclear power to increase its electricity production to meet future requirements.

Currently Pakistan operates only one power reactor--a 137-MWe CANDU supplied by Canada, which went on-line in 1972. Plans for the future call for 24 reactors (16 GWe), chiefly LWRs, to be operational by the year 2000.

Another Pakistan objective is to develop a complete domestic fuel cycle, with plants for refining uranium ore, enriching uranium, fabricating fuel, and reprocessing spent fuel. Construction of these plants is reportedly proceeding rapidly.

ORGANIZATION

Nuclear matters are organized and controlled by the Pakistan Atomic Energy Commission. The spent fuel reprocessing plant is being built at the Pakistan Institute of Science and Technology, Rawalpindi.

SPAIN

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

Spain's first nuclear power plant, a 153-MWe PWR, became operational in 1969, and national energy policy since that time has included extensive development of nuclear power capacity. The present goal is to reach the 13,500-MWe level by 1987. The country is developing domestic and foreign uranium ore sources and has an 11% interest in EURODIF (international uranium enrichment). Spain has reprocessing contracts with BNFL and COGEMA for the fuel from three reactors and has plans to build new reprocessing and waste management pilot plant facilities, but in general has adopted a wait-and-see attitude toward the back end of the fuel cycle.

ORGANIZATION

Nuclear activities in Spain are handled by the following agencies:

1. Junta de Energia Nuclear (Nuclear Energy Agency, JEN), Madrid. JEN is primarily a nuclear energy R&D organization. Headquarters and JEN's Juan Vigon National Nuclear Energy Center are in Madrid, and JEN is building a new research center at Soria, north of Madrid.
2. Empresa Nacional del Uranio SA (National Uranium Company, ENUSA), Madrid. ENUSA, owned 60% by the government and 40% by seven private utilities, has the task of providing nuclear fuel and fuel cycle services for the Spanish nuclear industry.
3. Consejo de Seguridad Nuclear (Council of Nuclear Safety, CSN). CSN was established in 1980 to handle siting, licensing, plant inspections, and environmental protection matters for the government.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 1980--0.48 GCR and 1.52 LWR; 1987--13.5 GWe (principally LWR).
2. Uranium mining and milling, tU/yr: current--200; 1985--600.
3. Fuel element fabrication, tU/yr: under construction--600.

FUEL CYCLE AND WASTE MANAGEMENT R&D

JEN and the Spanish utilities are applying a modest level of effort in a number of areas:

1. Interim storage of spent fuels. This includes studies of AFR storage, techniques to increase the capacity of reactor pools, and the behavior of high-exposure fuels in pool and air storage.
2. Spent fuel reprocessing. JEN operated a small fuel reprocessing plant at the Juan Vigon Center for a few years to reprocess spent MTR fuels, and plans to build a 2-t/yr pilot plant in the Soria Center.
3. Waste treatment. JEN has done limited laboratory-scale R&D on a variety of techniques for HLW solidification and has, at Juan Vigon, a pilot waste incinerator, a liquid waste treatment plant, and a facility for sorting and compacting solid wastes.
4. Waste disposal. Spain hopes to develop a repository for high-level and other wastes and plans to start up a pilot repository by the late 1980s. For several years Spain has stored non-HLW drums in an abandoned iron mine located in the Sierra Morena. A search is being made for other repository sites and supporting R&D is in progress.
5. Decommissioning of nuclear facilities.

SWEDEN

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

With a lack of coal and oil resources, Sweden embarked on a major nuclear power program during the late 1950s with emphasis on LWRs. In 1977, public opposition and a new government produced a law which required a reactor operator, before any new reactor could be fueled, to 1) provide assurance that the spent fuel can be reprocessed and the waste can be stored safely, or 2) prove that safe terminal storage of spent fuel can be affected. The Swedish Nuclear Fuel Supply Company reacted by establishing a crash program to meet the requirements of the new law. By late 1978, this project (the Nuclear Fuel Safety Project, KBS) had negotiated a contract with COGEMA to reprocess some of Sweden's spent fuel and had completed a major study which defined schemes for the geologic disposal of either vitrified HLW or spent fuel. In June 1979, the study was accepted by the government and permission given to load fuel into a new reactor.

Sweden's present nuclear power policy, mandated by a majority of the voters in a March 1980 referendum, calls for completion of a total of 12 power stations (9.4 GWe, LWR) by 1985-1986. Fuel cycle plans allow for either of two schemes: reprocessing of spent fuel by foreign reprocessors, BNFL and COGEMA, or disposal of unprocessed spent fuels. In the

reprocessing case, vitrified HLW is to be received back from the reprocessor, stored in air for 40 years, encapsulated in lead and titanium canisters, and emplaced in a crystalline rock repository at a depth of 500 m. In the second no-reprocessing case, the spent fuel is to be encapsulated in a heavy-wall copper canister and emplaced in a crystalline rock repository. Placement in the repository would occur 40 years after removal of the fuel from the reactor. Interim storage would occur in a water pool AFR (CLAB).

Major Milestones

• CLAB AFR facility for spent fuels	1985
• Repository for reactor wastes	1988
• HLW repository design complete	2000
• HLW repository operational	2020
• Interim HLW dry storage facility	1990

ORGANIZATION

The national government, through the Ministry of Industry, manages much of the nuclear industry through shareholdings in key companies: SSPB, the Swedish State Power Board (100% government-owned; electricity generation); SKBF, the Swedish Nuclear Fuel Supply Company (50% owned by SSPB; fuel cycle and waste management); ASEA-Atom (50% government-owned; reactor manufacture); and AB Energiteknik at Studsvik (100% government-owned; nuclear R&D).

In 1980, KBS status was changed from that of a temporary project to a permanent division of SKBF, the meaning of the KBS abbreviation was changed from "Nuclear Fuel Safety" to "Handling and Final Disposal of Nuclear Power Waste" (*Kärnkraftavfallets Behandling och Slutförvaring*), and the KBS duties were enlarged to include detailed studies of all kinds of wastes from nuclear power production and reprocessing.

Waste management R&D at Studsvik and various universities is coordinated by PRAV, the National Council for Radioactive Waste, which also reports to the Ministry of Industry. Financing for PRAV-sponsored studies is provided by the electrical utilities through SKBF.

Licensing responsibilities are assigned to the Swedish Nuclear Power Inspectorate for nuclear facilities and to the National Institute of Radiation Protection for radiological work.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 1980--7.3 LWR (25%); 1985--9.4.
2. Uranium mining and milling, tU/yr: potential--1500.
3. Fuel reprocessing: contracts have been signed with COGEMA (France) and BNFL (UK) for reprocessing of Swedish fuels.

SPENT FUEL AND WASTE MANAGEMENT R&D

Objectives

Provide the technology for treatment of reactor and other low- and intermediate-level radioactive wastes; interim and terminal storage of spent fuels as well as reactor and reprocessing wastes; transport of spent fuels and wastes; and decommissioning of nuclear facilities.

Treatment of Low- and Intermediate-Level Wastes

Sweden must dispose of reactor waste, including radioactive core components and non-high-level waste from foreign fuel reprocessing operations. Supporting R&D includes design studies on cutting and packaging reactor hardware; evaluation of alternatives for volume reduction of combustible wastes; the use of zeolites and titanates to improve reactor waste treatment; actinide fractionation; development of common waste conditioning techniques-- embedment in cement, bitumen, or resins; compaction and conditioning of fuel cladding hulls and other suitable materials by hot isostatic pressing; and decontamination and decommissioning tests.

Underground Disposal

Swedish underground repositories, to be constructed in granite formation, are being considered for spent fuels, high-level wastes, and reactor wastes. Supporting R&D includes studies of:

1. HLW glass properties and durabilities in expected repository environments
2. corrosion of prospective canister materials: titanium and alumina for HLW glass; copper and alumina for spent fuels
3. the properties of bentonite and bentonite/quartz mixtures when used for barrier materials
4. techniques for borehole, shaft, and rock joint plugging and sealing
5. rock mechanics and seismotectonics
6. migration and transport of radionuclides away from the waste or spent fuel canister after emplacement in the repository
7. geology and hydrology
8. disposal system safety.

KBS is using the Stripa mine in Sweden for in situ tests. Field work for a series of US DOE (LBL)-KBS tests at Stripa is virtually complete, and several countries have now joined in a new series of tests under NEA coordination.

SWITZERLAND

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

Switzerland's long-range power plans call for as many as nine nuclear power stations, with five of them (2.88 GWe) to be operational by 1982. Spent fuel is to be reprocessed at the La Hague plant in France, and the waste is to be returned to Switzerland for disposal.

With major public opposition to nuclear power, the Swiss nuclear utilities are now faced with the requirement that by 1985 they be able to guarantee safe and final elimination for their wastes, or lose the operating permits for their nuclear stations.

Major Milestones

● Acid digestion plant for plutonium wastes	1982
● Field laboratory in a granite formation	1982
● Feasibility of safe and final disposal demonstrated	1984
● Initial receipt of HLW glass from COGEMA (France)	1992
● Surface storage facility or ultimate repository for LLW/ILW	1995
● Geologic repository for HLW or spent fuels	2020

ORGANIZATION

Two agencies in Switzerland have the major roles in fuel cycle and waste management R&D: the Federal Institute for Reactor Research (EIR) at Wurenlingen, and the National Cooperative Association for the Storage of Radioactive Wastes, known either as NAGRA (German acronym) or CEDRA (French acronym). EIR and all nuclear activities are controlled by the Department of Interior. NAGRA was formed by a coalition of private and governmental interests to get a repository in place.

The Federal Energy Office (within the Department of Transport, Communication and Energy) is responsible for setting criteria for waste management practices, including geologic disposal. The Federal Council is advised by a Working Group for Waste Management with representatives from various agencies.

COMMERCIAL NUCLEAR ACTIVITIES

Power production, GWe: 1980--1.94 LWR, 1983--2.9 LWR, and indefinite future--4.9 LWR.

SPENT FUEL AND WASTE MANAGEMENT R&D

Objectives

1. Demonstrate that radioactive wastes can be disposed of safely in Switzerland.

2. Develop technology for the safe treatment (volume reduction and immobilization) of TRU and low- and intermediate-level wastes.

Non-High-Level Wastes

EIR is investigating techniques for volume reduction of combustible TRU wastes (incineration and acid digestion) and for improving the properties of cement-matrix waste forms.

Underground Disposal

Swiss geologic disposal studies are directed toward the use of intermediate-depth caverns for low- and intermediate-level wastes and the construction of a deep-hole repository for either vitrified HLW or spent fuel elements. The program includes:

1. Development of granite repository technology and site information:
 - characterization of up to 12 sites, including borehole drilling and hydrogeological and geophysical studies
 - installation of a granite field laboratory in the Alps for hydrogeological studies of rock fracture and water flow, geophysical studies, and plugging and sealing tests
 - design studies for deep-hole (2500 m) storage and for mined repositories
 - safety analysis.
2. Evaluation of shallow land burial of short-lived LLW and rock caverns (100-600 m below the surface) for actinide-free LLW and ILW with intermediate half-life radionuclides (NAGRA).
3. Radionuclide transport studies (EIR):
 - K_d measurements
 - transport modeling.
4. Development of quality control techniques for HLW canisters to be received from foreign reprocessors of Swiss spent fuels.
5. Participation in international (NEA) joint R&D project at Stripa, Sweden.
6. Development of spent fuel canisters and techniques for dry storage of spent fuels.

UNION OF SOVIET SOCIALIST REPUBLICS

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

The Soviet Union proposes to supply 20% (100 MWe) of the nation's electrical power with nuclear plants by the year 2000, and is encouraging the other Eastern European nations to emphasize nuclear power in their own programs. Two types of light-water-cooled reactors are in use and under construction: PWRs and graphite-moderated. National planners are also forecasting that eventually about one-third of the nuclear power capacity will be provided by LMFBRs.

Fuel cycle industrial-scale activities are presently limited to mining and enrichment of uranium, fabrication of fuels for LWRs and LMFBRs, and spent fuel storage. In the future, the domestic fuel cycle will be expanded to include spent fuel reprocessing and HLW vitrification. Eventually, a geologic repository for HLW glass is to be built.

The Eastern European countries and other foreign purchasers of Russian reactors will return their spent fuels to the Soviet Union.

ORGANIZATION

The overall responsibility for nuclear development in the Soviet Union rests with the USSR State Committee on Utilization of Atomic Energy and the Ministry of Energy and Electrification.

Other agencies and research centers of importance to Soviet radioactive waste management R&D programs include:

1. Institute of Physical Chemistry, Moscow, a branch of the USSR Academy of Sciences (geologic waste disposal, waste form properties)
2. V. G. Khlopin Radium Institute, Leningrad (chemical separation, fuels reprocessing, geochemistry)
3. All-Union Scientific Research Institute for Inorganic Materials, Moscow (properties of solid waste forms)
4. Chemical Plant Research Institute, Sverdlovsk (vitrification pilot plants).

FUEL CYCLE AND WASTE MANAGEMENT R&D

Soviet spent fuel and waste management R&D programs are based, at least in part, on the assumption of a LWR fuel cycle which includes spent fuel reprocessing. Hence work is under way on reprocessing, with a small pilot plant operational at the Khlopin Radium Research Institute, and on the treatment and disposal of reprocessing and reactor wastes.

Waste Treatment

Two nonradioactive waste vitrification pilot plants have been built for HLW vitrification studies--the KS-KT-100 plant, which uses a two-stage process (fluid bed calcination followed by melting in a concrete-refractory storage pot); and a single-stage continuous process using a two-zone melter. Capacities of the KS-KT-100 and the melter are 20 kg/hr glass and 100 l/hr HLLW feed, respectively. The products are phosphate glasses. Other high-level waste forms are also being evaluated, including vitromets (glass beads in metal matrices, and ceramics).

Two methods for treating spent fuel cladding--thermal decladding and meltdown of hulls--are under development. Efforts are being made to discover improved methods of partitioning TRU wastes.

Low- and intermediate-level waste treatment and disposal R&D includes studies of:

- incineration and acid digestion for volume reduction
- immobilization by cementation or by encasement in thermoplastic materials
- disposal of bituminized wastes in shallow trenches in clay formations.

USSR laboratories are also developing processes for handling off-gases and storing ⁸⁵Kr.

Waste Disposal

For a number of years the Soviet Union has practiced disposal of non-HLW by injection of liquids into deep, porous strata. The nation is also evaluating geologic disposal of solid wastes in salt, granite, and sandstone formations. Activities include criteria development, repository design and engineering, testing of prototypes, and studies of bulk rock behavior.

UNITED KINGDOM

NUCLEAR FUEL CYCLE POLICY AND PROGRAMS

The United Kingdom nuclear power program is based on 1) a first generation of gas-cooled reactors (Magnox-clad, natural uranium metal fuels), 2) a second generation of advanced gas-cooled reactors (AGR: SS-clad, UO₂ fuels), 3) a third generation of power reactors which might be LWRs or AGRs, 4) development and demonstration of FBRs, 5) development of comprehensive fuel cycle and waste management capability for all domestic reactor systems, and 6) provision of fuel cycle services to foreign customers.

Past United Kingdom fuel cycle practices have included:

- Reprocessing of GCR and AGR fuels at the Windscale Magnox plant and closely monitored storage of concentrated HLLW in the acid form in small stainless steel tanks. One hundred tonnes of LWR oxide fuel have also been processed at Windscale, using the Windscale Head-End Plant and the Magnox Plant solvent extraction system.
- Reprocessing of LMFBR fuels from the Dounreay Fast Reactor (DFR) in the DFR reprocessing plant accompanied by recycle of plutonium.
- Underwater storage of magnesium alloy cladding from Magnox reactor fuels.
- Release of low-level effluents from Windscale through a 2-mile pipeline into the Irish Sea (intermediate-level wastes are stored for about 10 years for decay of short-lived isotopes before disposal by sea-dumping in the North East Atlantic.

Fuel cycle plans for the future include:

- Continued reprocessing of Magnox fuels in the Windscale Magnox Plant. After 1985, LWR fuels are to be campaigned occasionally through the Oxide Head-End and Magnox solvent extraction systems at Windscale.
- Construction of a new reprocessing plant (THORP) for LWR and AGR oxide fuels at the Windscale site.

- Construction of a HLW vitrification plant at Windscale using the French AVM process.
- Reprocessing of LMFBR fuels from the Prototype Fast Reactor at Dounreay in the new PFR reprocessing plant.
- Engineered storage of solidified wastes until a repository is available.
- Development of geologic and deep ocean (seabed and subseabed) waste disposal technology.

Major Milestones

Fuel Reprocessing

● Butex Fuel Reprocessing Plant (FRP)	1952-1964
● Magnox FRP	1964-
● Windscale Head-End Plant	1969-1973
1985-
● DFR FRP	1961-1975
● PFR FRP	1980-
● Thermal Oxide Reprocessing Plant (THORP)	1987-
● CDFR FRP	1993-

MOX Fuel Fabrication

● 20-t/yr plant	1984-
● 50-t/yr plant	1987-

HLW Vitrification

● HLW vitrification pilot plant at Windscale	1982-
● Windscale vitrification plant	1987-
● Dounreay Waste Vitrification Plant	Late 1980s-

Terminal Waste Storage

● HLW repository site selection	1984
● Pilot disposal operation	1992-
● Repository operation	2000-

ORGANIZATION

Major fuel cycle and waste management responsibilities in the United Kingdom are assigned as follows:

1. United Kingdom Atomic Energy Authority (UKAEA), an agency of the Department of Energy, sponsors and administers reactor, fuel cycle, and waste management R&D. The Authority operates through the Headquarters Group in London, the Northern Division (headquarters at Risley), the Research Group (headquarters at Harwell), and the Safety and Reliability Directorate at Culcheth, Cheshire, which advises on the formulation and application of safety and reliability policy.

The Research Group has two research sites:

- The Atomic Energy Research Establishment (AERE), Harwell. About one-half of Harwell's effort is directly concerned with problems of reactor development and nuclear power, including fuel reprocessing, waste treatment, and waste disposal.
- The Culham Laboratory, Abingdon (nuclear fusion and plasma physics).

The Northern Division is responsible for the design and development of nuclear reactors, including the UK's LMFBR, and the LMFBR fuel cycle. The UKAEA has R&D facilities at the following Northern Division sites:

- Risley Nuclear Power Division Establishment, which incorporates the Northern Division Headquarters, the Engineering Division, the Risley Engineering and Materials Laboratory, and supporting groups.
 - Dounreay Nuclear Power Development Establishment (DNPDE), the major site for fast breeder reactor and fast reactor fuel cycle development.
 - Reactor Fuel Element Laboratories, Springfields (development and environmental testing of fuels, engineering for thermal and fast reactors, development of advanced waste treatment processes).
 - Reactor Development Laboratory, Windscale (development of AGR fuels and plutonium fuels for fast breeder reactors).
 - Atomic Energy Establishment, Winfrith (thermal and fast reactor research).
2. British Nuclear Fuels Limited (BNFL), an essentially autonomous organization owned by the government with all the shares held by the UKAEA. BNFL provides commercial fuel supply services for domestic and foreign customers. BNFL headquarters are located at Risley. The company is divided into three divisions covering uranium enrichment (Capenhurst), fuel manufacture (Springfields), and spent fuel reprocessing (Windscale). BNFL holds a one-third interest in each of three international consortia: Urenco (uranium enrichment by gas centrifuge); United Reprocessors GmbH, URG (reprocessing); and Nuclear Transport Limited, NTL.
 3. The Department of Environment (DOE) has responsibility to divest and coordinate UK waste management technical activities, including the geologic disposal program. Waste management R&D is performed by other departments and by two DOE agencies, the Institute of Geological Sciences (Harwell) and the Institute of Oceanographic Sciences (Wormley, Godalming).
 4. Health and Safety Executive (Health and Safety Commission) is responsible for occupational health and safety in all nuclear establishments. One of its agencies, the Nuclear Installations Inspectorate (Liverpool) licenses construction and operation of nuclear installations.
 5. National Radiological Protective Board (NRPB), Harwell, is responsible for all radiological protection R&D services.

6. Ministry of Agriculture, Fisheries and Food (MAFF). Maff's Fisheries Radiobiological Laboratory (FRL) at Lowestoft conducts radiological research in the aquatic environment. MAFF, the Department of Environment, and the Scottish Development Department have joint responsibility for authorizing routine discharges of radioactivity to the environment.

COMMERCIAL NUCLEAR ACTIVITIES

1. Power production, GWe: 1980--0.09 HWLWR, 0.25 LMFBR and 8.3 GCR and AGR; 1982--11.4 GCR and AGR; 2000--25 to 40 (up to 75%).
2. Uranium enrichment: BNFL has a 500-tSWU/yr gaseous diffusion plant at Capenhurst and a Urenco gas centrifuge plant. Expansion of the Urenco facility from its present 200 tSWU/yr to 400-600 tSWU/yr is planned.
3. MOX fuels fabrication (BNFL-Windscale):
 - a 5- to 10-tHM/yr plant in operation
 - a 1-tHM/yr pilot plant for FBR fuels production in operation
 - a 20-tHM/yr plant; startup is scheduled for 1984
 - a 50-tHM/yr plant; startup is scheduled for 1987.
4. Spent fuels reprocessing:
 - Windscale (BNFL, Seascale): a 5-t/day Purex-type plant which is used for Magnox (natural uranium metal) fuels from UK's gas-cooled reactors. A 400-t/yr chop-leach head-end for LWR oxide fuels was added in 1969 and operated intermittently until 1973. Revision of the oxide head-end is planned, with startup scheduled for 1981. The main role of the oxide head-end will be to test new processes for THORP.
 - Thermal Oxide Reprocessing Plant (THORP, BNFL): A new plant to be built at Windscale which reprocesses LWR oxide fuels for domestic and foreign customers. A nominal capacity of 1200 tHM/yr is expected with startup scheduled for 1987.
 - PFR Reprocessing Plant (DERE, Dounreay): The Dounreay plant, with a capacity of 9-10 t/yr, was installed to treat spent fuels from the Dounreay fast reactors. After a number of years' service, it was decontaminated, remodeled, and now reprocesses spent fuels from the Dounreay 250-MW PFR.
 - Windscale vitrification plant: An AVM-type plant to solidify Windscale HLW, to be operational in 1987.

FUEL CYCLE AND WASTE TREATMENT R&D

Objectives

1. Develop advanced technology and improved equipment for:
 - reprocessing FBR and other oxide fuels
 - treating and immobilizing fuel reprocessing and reactor wastes.
2. Provide the technological basis for a HLW waste repository, either land or seabed based.

Spent Fuel Reprocessing

BNFL is studying improved processes and equipment for handling AGR and LWR oxide fuels, with a nonradioactive test unit and a small radioactive pilot plant at Windscale. Fast reactor fuel reprocessing R&D is under way at Dounreay, with emphasis on spent fuel from the proposed Commercial Demonstration Fast Reactor (CDFR).

Waste Treatment

The UKAEA and BNFL have had a rising-level, in-pot vitrification process (FINGAL-HARVEST) in development for several years at Harwell and Risley, with nonradioactive pilot-scale studies and with preparations for a radioactive pilot plant, a cold full-scale prototype, and a commercial demonstration plant. This effort has been supported by a variety of product characterization studies and other laboratory work. BNFL has now chosen the AVM process for the Windscale vitrification plant, but work continues on second-generation processes such as a technique depending on the use of microwave heating for calcination and melting (Springfields).

Considerable effort is devoted to the treatment and immobilization of non-high-level wastes: volume reduction, fixation and characterization of TRU wastes, and fuel cladding hulls (AERE-Harwell and BNFL-Windscale); treatment of reactor wastes (Central Electricity Generating Board, CEGB); incineration (BNFL-Windscale); control and storage of volatile radionuclides (Harwell); spent solvent cleanup and disposal (Harwell); and fixation of nuclides in various matrices (Harwell).

Waste Disposal

Improved techniques for control of liquid and airborne effluents and for packaging of solid low-level wastes for sea dumping are under investigation at Harwell and Windscale, and the evaluation of various options for disposal of high-level and alpha-bearing wastes also has high priority. Options being considered include disposal in a deep geologic formation (crystalline rock, argillaceous, or evaporite), on the seabed, and below the seabed. R&D work for this project includes high pressure/high temperature geochemical studies, measurements of the migration of radionuclides, evaluation of granite formation properties, and oceanographic investigations. A number of sites have been selected for exploratory drilling, and a conceptual design for a repository in hard rock has been prepared.

INTERNATIONAL

INTRODUCTION

Several international organizations, with somewhat overlapping memberships, devote major attention to nuclear fuel cycle and radioactive waste management problems. Common objectives are to foster cooperation and information exchange among their members, identify and minimize duplication of R&D effort, and develop information for the assessment of radioactive waste management practices. These organizations include:

- International Atomic Energy Agency (IAEA), an independent organization which belongs to the United Nations family. The IAEA embraces developing and developed countries as well as nations having either privately or centrally controlled economic systems.
- Nuclear Energy Agency (NEA), a semiautonomous subsidiary of the Organization for Economic Cooperation and Development (OECD). Membership is primarily European, with a sprinkling of other nations with privately-controlled economies.
- Commission of the European Communities (CEC), the agency which administers the cooperative economic and energy-related activities initiated under the European Coal and Steel Community, the European Economic Community, and Euratom. The Member States are also NEA members.
- Council for Mutual Economic Assistance (CMEA), the counterpart of the OECD for countries with centrally-controlled economies. The mission of the CMEA is to promote economic and industrial cooperation among the Member States (Bulgaria, Cuba, Czechoslovakia, German Democratic Republic, Hungary, Mongolia, Poland, Rumania, USSR, and Yugoslavia). The CMEA has a Standing Commission on the Use of Atomic Energy for Peaceful Purposes, which holds meetings to review national waste management programs and define areas for additional cooperation.
- Nordic Council, organized for discussion and action in areas of common interest among its members. Member States cooperate in various waste treatment R&D programs. Council membership includes Denmark, Finland, Iceland, Norway, and Sweden; headquarters are in Stockholm.
- European Atomic Forum (FORATOM), a consortium of European national associations or forums which are interested in the industrial applications of nuclear energy. FORATOM'S waste management efforts are directed, in general, toward expanding public knowledge concerning the issues and resolving outstanding concerns. There are also two three-member international consortia which have major roles in international fuel cycle affairs.
- Nuclear Transport Limited (NTL), formed by British Nuclear Fuels Limited (BNFL) in the United Kingdom, Transnucléaire in France, and Transnuklear in the Federal Republic of Germany. NTL was formed to provide international transport services for spent nuclear fuels and other radioactive materials. NTL purchases capital equipment, provides marketing services, and subcontracts actual transport operations to the partners. Headquarters are at BNFL's Risley site.
- United Reprocessors GmbH (URG), comprises three nuclear fuel cycle companies: BNFL (UK), COGEMA (France), and DWK/KEWA (FRG). URG was established to coordinate the three companies' fuel reprocessing R&D and their international marketing of reprocessing services. Headquarters are at Karlsruhe, FRG.

In part, the IAEA, NEA, and CEC pursue their general objectives by sponsoring international symposia, seminars, and workshops, either unilaterally or in cooperation with another organization. The IAEA and NEA also sponsor the work of consultants and expert groups in preparing technical reports and safety documents.

Additional information concerning the IAEA, NEA, and CEC is provided in the following sections.

INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)

Membership

Membership includes one-hundred ten nations.

Background

The IAEA has a number of specific objectives for its radioactive waste management programs:

- to disseminate up-to-date information concerning safe methods for managing radioactive wastes and maintaining acceptable radioactivity levels in effluents from systems which handle radioactive materials
- to coordinate and/or promote the development of technology for safe management of radioactive wastes
- to issue safety guidance on all aspects of radioactive waste management
- to assess the consequences of releases of radionuclides into the environment from nuclear activities
- to provide technical advice, training, and assistance to Member States, upon request
- to conduct or participate in studies considering regional or worldwide planning of the nuclear fuel cycle.

These objectives are met primarily by organizing and conducting various kinds of meetings, usually among experts from Member States and by preparing and publishing reports. The meetings include Symposia, often cosponsored by another organization such as the NEA or CEC; Advisory Groups (with representatives assigned by their governments) convened to review and advise on program content, methods of conducting programs, etc.; Technical Committees which review Agency programs or reports in depth; consultants brought in from Member States to perform a specific technical task such as preparing or modifying a technical report; Coordinated Research Programme meetings to coordinate the research in a specific technical area among various institutes; and Review Groups, assembled occasionally to review program progress and direction.

Five types of reports are issued by the IAEA: Safety Series (IAEA Safety Standards, IAEA Safety Guides, Recommendations, and Procedures and Data); Technical Reports Series; unpriced Technical Document, proceedings of symposia; and "Waste Management Research Abstracts."

Organization

The IAEA is governed by the General Conference, consisting of a representative from each Member State, and by the 34-member Board of Governors, the Agency's executive body. Detailed work of the Agency is handled by the Secretariat.

The IAEA makes extensive use of technical committees and consultants. The committees are generally established on an ad hoc basis, with a specific, short-term assignment, although there are also technical committees which work on a continuing basis.

IAEA Waste Management Program for 1981-1986

General program directions for 1981-1986 are summarized below.

1. Spent Fuel Management

- Evaluation of alternative storage technologies for spent fuel (1981-1982)
- Review of reprocessing technologies (1981-1982)
- Joint research coordination effort with NEA on monitoring the behavior of spent fuel and related equipment during extended storage in water-filled basins (1981-1982)
- Technical support for studies of international plutonium storage and spent fuel management (1981-1982)
- Review of the safety aspects of reprocessing technology and storage (1983-1986).

2. Handling and Treatment of Radioactive Waste

- Development of new or revised guidance and preparation of technical reports on the treatment, handling, and immobilization of high-level waste, intermediate-level waste, gaseous effluents, uranium and thorium mill tailings, and retired nuclear facilities (1981-1982)
- Preparation of guidance, including updating of publications issued before 1977, for the design and operation of waste treatment and storage facilities, waste classification, and the management of radioactive and nonradioactive wastes from selected nuclear facilities (1983-1986)
- The handling and storage of high-level waste, TRU waste, and intermediate-level waste will be given increased attention. A review will be made of the technology for recovering plutonium from Pu-containing wastes (scrap) (1983-1986)
- Consideration will be given to the waste management implications of advanced fission (including fast breeders) and fusion reactors (1983-1986)
- Effort will continue to secure international cooperation in harmonizing principles and reviewing national policies with regard to radioactive gaseous and liquid discharges from nuclear facilities, as well as the conditioning and interim storage of waste (1983-1986).

3. Underground Disposal of Radioactive Wastes

- Preparation of Safety Series Documents, Safety Guides, and Technical Reports (1981-1984)
- Studies of waste acceptance criteria and design construction, operation, shutdown and surveillance of repositories (1983-1986)

- Completion of general and safety analysis activities; preparation of related codes and guides; publication of regulatory procedures for underground disposal (1983-1986)
- Preparation of waste acceptance criteria for the various basic underground disposal techniques (1983-1986)
- Symposia on site investigations, safety assessments, and design and construction of underground repositories (1983-1986).

4. Environmental Aspects of Nuclear Energy

- Preparation of Technical Reports (1981-1984)
- Review and verification of data and models related to the transfer of radionuclides through aquatic and terrestrial pathways to man (1981-1982)
- Analyses of the environmental impact of long-lived radionuclides, advanced reactor concepts, and related variations of the fuel cycle (1983-1986)
- Review of the IAEA Definition and Recommendations for the London Dumping Convention (1983-1986).

5. Safe Transport of Radioactive Materials

- Continuation of the development and application of a simple model for assessing the risk from transportation (1981-1986)
- Preparation of Technical Reports (1981-1983).

OECD NUCLEAR ENERGY AGENCY (NEA)

Membership

Australia	France	Japan	Sweden
Austria	Germany (FRG)	Luxembourg	Switzerland
Belgium	Greece	Netherlands	Turkey
Canada	Iceland	Norway	United Kingdom
Denmark	Ireland	Portugal	United States
Finland	Italy	Spain	

(New Zealand and Yugoslavia cooperate in certain projects.)

Background

The European Nuclear Energy Agency (ENEA), forerunner of the NEA, was established in February 1958 by the Organization for European Economic Cooperation (OEEC), with a three-fold objective: to establish joint projects; to solve specific legal problems related to nuclear energy; and to provide a forum in which the national nuclear energy programs of the Member States could be discussed and perhaps coordinated. In 1960 the OEEC evolved into the Organization for Economic Cooperation and Development (OECD). In 1972 the ENEA was renamed "Nuclear Energy Agency" when Japan became the first non-European member. The US became a full member of OECD in 1960 and changed from associate to full-member status in NEA in 1976.

Early in its existence, the ENEA fostered the establishment of several joint projects by groups of interested Member States. Notable examples of this are the Eurochemic fuel reprocessing demonstration plant at Mol, Belgium, built and operated by 13 countries; the Halden Reactor Project; and the Dragon High-Temperature Reactor Project.

In the waste management field, until 1975 ENEA and then NEA were primarily involved in collecting and disseminating information for the Member States, occasionally sponsoring or cosponsoring international symposia and seminars, and preparing specific documents on radioactive waste management practices. In 1975 the NEA established its Radioactive Waste Management Committee (RWMC) with the assigned purpose of initiating, encouraging, and coordinating cooperative R&D activities among the Member States. In 1980, following a several-year period of holding workshops, sponsoring symposia and seminars, and initiating NEA coordination of multilateral projects, the RWMC devoted a special meeting to consideration of its role in waste management and defined the following objectives:

1. to back up national radioactive waste management and demonstration programs through
 - a) generic studies of related technical issues, b) issuing international consensus statements, recommendations, and guides on criteria, methods, and procedures, and c) continually improving the data base available to Members
2. to improve the effectiveness of national R&D programs through
 - a) developing mechanisms to improve the coordination of national R&D programs in selected areas, b) promoting and coordinating joint international R&D projects with limited scope and membership, and c) undertaking and reporting international evaluations of the results of such programs and projects
3. to assist Members in improving public understanding of radioactive waste management issues and options, particularly in the field of waste disposal.

The NEA also interacts with two other OECD bodies in waste management matters: the International Energy Agency, which is concerned with nuclear energy as one of a number of alternative energy sources; and the OECD Environment Committee.

Organization

The work of NEA is carried out under the authority of the OECD Council and under the general guidance of the Steering Committee for Nuclear Energy made up of representatives of all Member countries, the Commission of the European Communities and the International Atomic Energy Agency. The Steering Committee . . . is in turn assisted by other committees and working groups of specialists appointed by the Member countries from the relevant ministries, administration or governmental institutions. These committees, acting generally as think tanks or as organisers of practical forms of intergovernmental co-operation, keep the scientific and technological developments in their fields under continuing review and direct the work of NEA towards those problem areas in which the Agency can make a useful and disinterested contribution.^(a)

There is also a small Secretariat, its function being to assist the Steering Committee and its subsidiary committees and working groups.

(a) OECD Nuclear Energy Agency: Functions and Main Activities, September 1979.

Radioactive waste management matters are handled by the Nuclear Safety Division, the Radiation Protection and Waste Management Division, and three standing committees: Committee on Safety of Nuclear Installations (CSNI), Committee on Radiation Protection and Public Health (CRPPH), and the Radioactive Waste Management Committee (RWMC).

Spent Fuel and Radioactive Waste Management Activities

Current working groups, studies, and projects are listed below.

1. Radioactive Waste Management Committee (RWMC)

- Group of National Nominees on Alpha-Bearing Waste (three workshops, 1978-1980)
- Workshop in Intermediate-Level Wastes (London, May 1980)
- Report on "Off-Gas Monitoring in Nuclear Facilities" (in preparation)
- Coordinating Group on Geologic Disposal
 - Series of workshops.
 - International Sorption Information Retrieval System (ISIRS) Project, a program to set up a computerized data bank containing information from several countries in the sorption of radionuclides by various geologic formations and other materials. Participants: Canada, Finland, Japan, Netherlands, Sweden, Switzerland, United Kingdom and United States.
 - In situ test program in the Stripa mine in Sweden. Groundwater flow through the rock formation, radionuclide migration rates, barrier properties, and mechanical properties of the rock are to be studied. Participants: Finland, Japan, Sweden, Switzerland and United States. Potential associate members: Canada, Federal Republic of Germany, France, and United Kingdom.
 - Seabed Working Group. The group meets annually to promote information exchange and international cooperation in subseabed waste disposal studies. Participants: Canada, France, Japan, Netherlands, United Kingdom, and United States.
 - Newsletter on Radionuclide Migration in the Geosphere.
 - Experts on the Decommissioning of Nuclear Facilities seminar; preparation of state-of-the-art reports, Decontamination Methods and Remote Cutting Techniques.
 - Ad hoc group on Cooperative Reactor Decommissioning Tests in Sweden.

2. Committee on Radiation Protection and Public Health (CRPPH)

- Report on waste disposal philosophy (joint with RWMC) (in preparation)
- Study on the legal, administrative and financial aspects of the long-term management of radioactive waste (joint with RWMC)
- Coordinating Group on Management of Uranium Mine and Mill Tailings (joint with RWMC). Working group studies of national problems and practices
- Expert Group on Release of Effluents from the Nuclear Fuel Cycle; produced reference and is preparing a policy paper entitled "Conclusions of the Task Group on Long-Lived Effluent Releases from the Nuclear Fuel Cycle" (joint with RWMC)

- Multinational Consultation and Surveillance Mechanism for Sea Dumping of Radioactive Waste; preparation of a coordinated research and environmental surveillance program plan relevant to the North East Atlantic dump site.

3. Committee on Safety of Nuclear Installations (CSNI)

- BEFAST Project (Behavior of Spent Fuel Assemblies During Extended Storage), a survey of national experience with the corrosion of spent fuel assemblies and the behavior of fuel storage pool equipment
- International Study of the Safety of Spent Fuel Transportation, a project to test and validate codes related to criticality, shielding, and heat transfer (proposed by the US in 1979).

4. Eurochemic Project

Under OEEC/ENEA sponsorship, 13 Member States organized the European Company for the Chemical Reprocessing of Irradiated Fuels (Eurochemic) in 1957. Established to provide European countries with technical know-how in fuel reprocessing, the company built the Eurochemic Demonstration Reprocessing Plant at Mol, Belgium and operated it from 1966 to 1974. Since the shutdown of this plant, Eurochemic forces have 1) completed a major decontamination job on the plant and turned it over to Belgium for possible renovation and use in Belgium's domestic fuel recycle program and 2) built and are operating a number of waste treatment and storage pilot plants. Eurochemic is still obligated to solidify the liquid high-level wastes left over from reprocessing plant operations and is cooperating with Belgium in the construction of a vitrification plant for those wastes. Eurochemic is scheduled to turn all facilities over to Belgium and terminate all activities by July 1982.

The Eurochemic staff is still involved in waste management R&D, primarily in support of their pilot plant operations and of the Federal Republic of Germany's PAMELA pilot plant project at Mol.

COMMISSION OF THE EUROPEAN COMMUNITIES

Membership

Belgium	Ireland
Denmark	Italy
France	Luxembourg
Germany (FRG)	Netherlands
Greece	United Kingdom

Background

The European Coal and Steel Community (ECSC) was created in 1951 to pool the coal and steel production of the six member states. In 1957 the European Economic Community (EEC) and the European Atomic Energy Community (Euratom) were formed by the same six Member States. In 1967 the ECSC, EEC, and Euratom commissions were merged into the Commission of the European Communities (CEC), which assumed the responsibility to formulate and implement policy for the three communities.

Euratom objectives were to: develop nuclear research capability; establish nuclear safety standards; encourage the development of nuclear power; and exchange information and capital for nuclear enterprises among the member states. Euratom resources included a Joint Research Centre (JRC) with research establishments at: Ispra, Italy (JRC-Ispra); Mol, Belgium (Central Bureau for Nuclear Measurements); Petten, Netherlands (Petten CCR); and Karlsruhe, FRG (European Institute for Transuranium Elements, EIT).

The provisions of the original treaty establishing Euratom are still in effect, and Euratom objectives for the cooperative development of nuclear energy are a major CEC program.

Supported by funds received through taxing the Member States, the CEC contributes heavily to two types of waste management R&D programs: the "direct action" programs carried out at Euratom JRC sites, primarily the Ispra and Karlsruhe laboratories; and the "indirect action" programs conducted by the Member States under a joint-funding arrangement in which the CEC pays up to one-half of the costs of designated projects. Direct action programs are generally planned, budgeted, and approved on a 4-year cycle, indirect action programs on a 5-year cycle.

Results of the CEC-sponsored R&D programs are disseminated freely among the Member States, but CEC approval is required for transmitting such information outside the community.

Organization

The European Communities have a dual executive.

1. The Commission proposes and supervises the execution of laws and policies. The Commission has 13 members, including the president and four vice-presidents. Each commissioner is responsible for at least one Community activity.
2. The Council of Ministers consists of one minister from each Member State and is the chief decision-making body.

The Commission's administrative organization consists of departments called "directorates general." Fuel cycle and waste management activities come under the Research, Science and Education Director General, while the Joint Research Centre makes up a separate directorate general.

The Joint Research Centre-Ispra in northern Italy is a multidisciplinary nuclear research centre with a test reactor, electronic computers, 40 laboratories, and various test facilities. The center conducts programs in reactor and nuclear plant safety, treatment and storage of radioactive wastes, hydrogen production by chemical cycles, solar energy, remote sensing of resonances, environment, standards and reference substances, etc.

The Karlsruhe Establishment (European Transuranium Institute), located at the KfK site near Karlsruhe, has extensive laboratory facilities, fully equipped for handling highly radioactive substances. Programs include basic research on transuranic elements, especially plutonium, and research into their industrial uses.

Research and Development Programs

The Community radioactive waste management program is designed to correlate R&D activities by the Member States and the Joint Research Centre establishments in areas of mutual interest. Areas covered are:

1. Direct Action

- risk evaluation (geologic disposal)
- protective barriers (long-term stability of conditioned wastes; waste/rock interactions)
- actinide separation (techniques to minimize the arisings of alpha wastes)
- actinide monitoring (nondestructive plutonium assay in wastes).

2. Indirect Action

- treatment and conditioning of non-high-level wastes; waste form characterization
- storage and disposal
- evaluation of processes, tentative criteria and waste management strategies
- legal, administrative, and financial concepts.

Direct action projects are described in the following sections.

Testing and Evaluation of Solidified HLW

As part of the project to evaluate hazards of radioactive waste disposal, the Ispra Centre is studying the long-term behavior of borosilicate glass made from high-activity waste, with emphasis on radiation damage and leaching phenomena. The studies include:

- irradiation of borosilicate glasses containing uranium in the HFR reactor at Petten to simulate fission fragment damage
- behavior of glass which contains actinides, to assess the long-term effects of alpha particles and helium buildup
- fundamental studies of radiation damage mechanisms, through irradiation of silica and borosilicate glass samples with heavy ions and with electrons
- leaching studies simulating typical repository conditions in which the glass is in contact with limited quantities of water; studies simulating accident conditions when the glass is contacted by large quantities of water have been completed.

TRU Wastes

Actinide Separation (JRC-Ispra). Ispra personnel have been active for several years in TRU waste partitioning and transmutation studies, with laboratory and theoretical work on:

- separation of the americium + curium + lanthanides fraction from HLW, using solvent extraction and oxalate precipitation techniques
- actinide transmutation in thermal and fast reactors.

In 1980 the work on transmutation was phased out and partitioning studies were oriented toward techniques for removing TRU from low-level wastes as a means of reducing TRU waste volumes and optimizing waste management practices. Initially, emphasis is to be placed on cladding hulls, ILW, and residues from fuel dissolution and from precipitation of process solutions.

Actinide Monitoring (JRC-Ispra and JRC-Karlsruhe). Nondestructive assay techniques are being developed and tested for monitoring the actinide content of various waste streams. The preparation of international models, setting up of reference monitors, and integral experiments in nuclear plants are included.

Geologic Waste Disposal (JRC-Ispra)

Risk Assessment. The Ispra staff has developed a generalized risk analysis model for geologic waste disposal. The model includes both a probabilistic treatment of the failure of geologic containment and a deterministic consequence analysis model and is presently being applied to studies of the Boom clay formation in Belgium in cooperation with CEN/SCK, Mol.

Interactions with the Environment. JRC-Ispra activity in this area has mainly been aimed at investigating the migration of the actinides through geologic media by laboratory measurements of migration phenomena, assessment of the chemical forms of plutonium in ground-water, and by modelling of the migration of different plutonium chemical species through porous media.

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