Managing spent fuel in the United States: The illogic of reprocessing

(report on www.fissilematerials.org)

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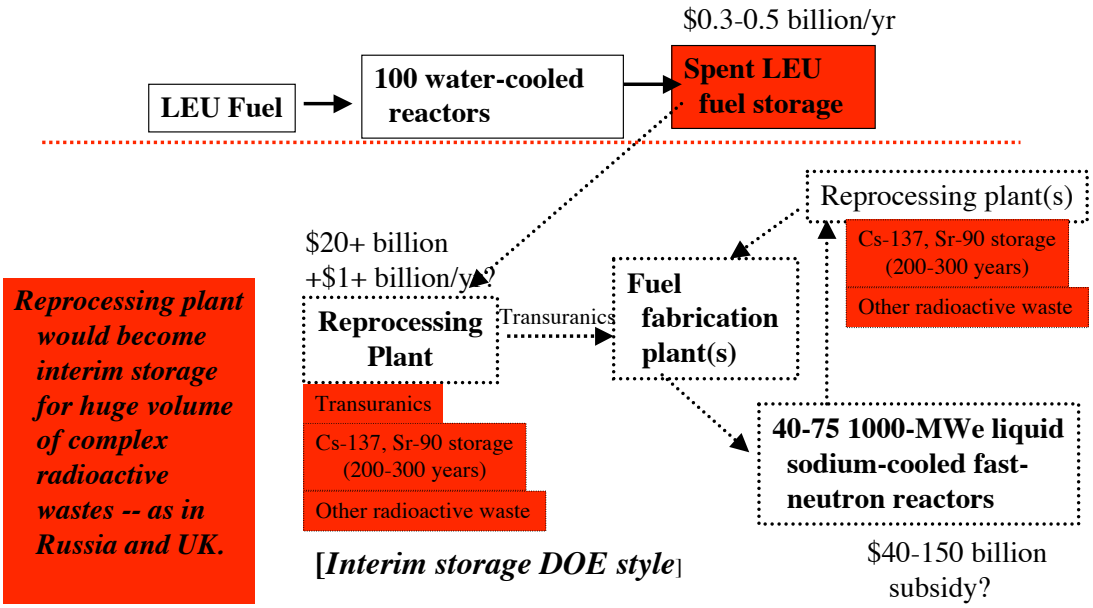
Nuclear utilities want DOE to start removing spent fuel from reactor sites and are suing to recover their extra costs for storage since 1998 ($0.3-0.5 B/yr)

2006: DOE proposed ($200+ billion) program to subsidize construction of a reprocessing plant and 40-75 fast-neutron reactors to fission the transuranics (mostly plutonium)
(assessed unfavorably in DOE-funded National Academy of Sciences study, 1996)



Sodium-cooled reactors have not been commercialized, however -- despite 50 years and tens of $B of effort

U.S.: Experimental breeder 1 (1-2 MWt, 1951-63)
-- Fermi I (66 MWt, 1966-72, fuel meltdown, sodium explosion)

U.K.: Prototype Fast Reactor (254 MWe, 1974-94, CF during first 10 years 10%)

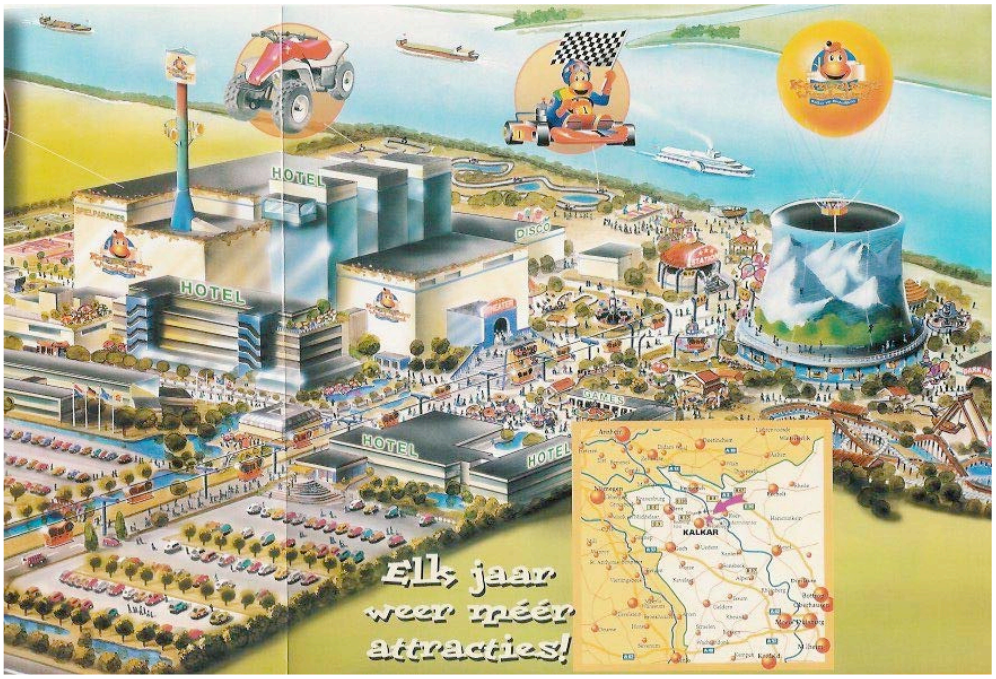
Russia: BN600 (600 MWe, 1980-, 15 sodium fires but 74% CF)

Germany: Kalkar SNR300 (300 MWe, $5 billion, 1985, never operated)

France: Superphénix (1.2 GWe, $7 billion, 1985-98, CF 6%)

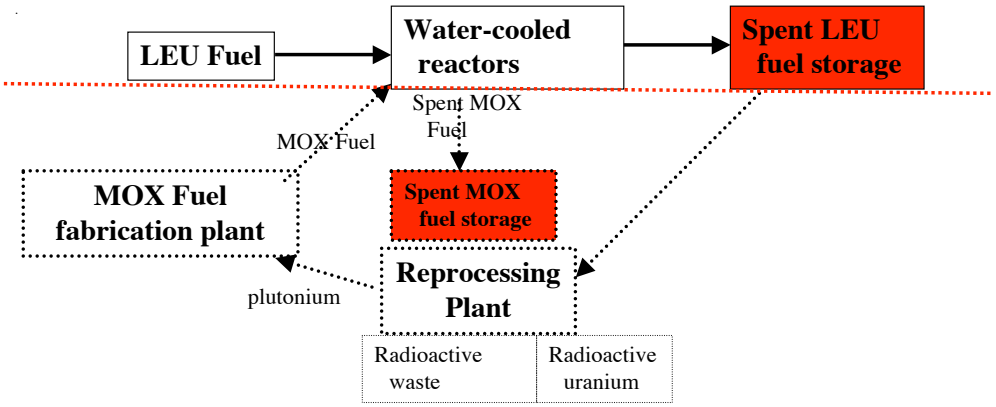
Japan: Monju (280 MWe, 1994-5, shutdown since by sodium fire)

Sodium-cooled reactors are "*expensive to build, complex to operate, susceptible to prolonged shutdown as a result of even minor malfunctions, and difficult and time-consuming to repair.*"
-- Admiral Rickover



$5 billion Kalkar breeder reactor was sold in 1995 for 2.5 million Euros for an amusement park: www.kernwasser-wunderland.de

DOE now appears to have accepted AREVA's view that U.S. should separate & recycle plutonium once in "mixed oxide" (MOX) fuel and store the spent MOX fuel at the reprocessing plant -- as in France



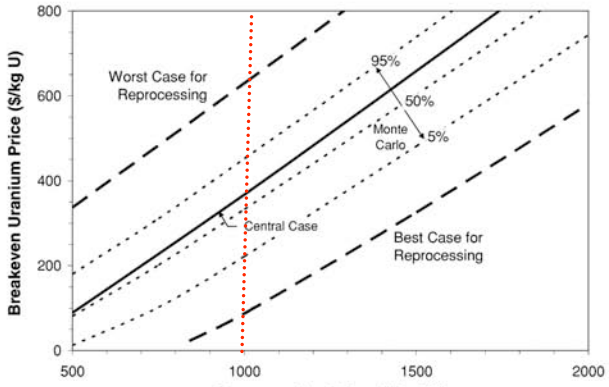
Interim storage, French style

Transforming LEU spent fuel into MOX spent fuel doubles the cost of disposal. (Report to France's Prime Minister, 2000.)

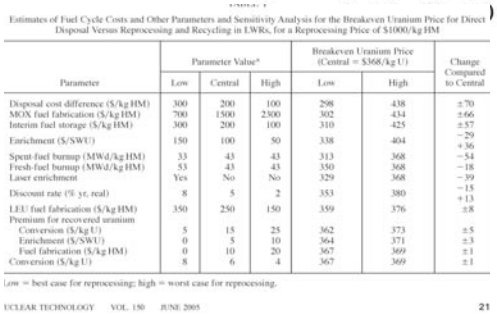
Table 2. Spent-fuel disposal costs in four scenarios for the French Fuel Cycle[61]
(Billions of 2006 $, 58,000 tons of spent fuel)

	Percentage of Spent LEU Fuel Reprocessed			
	100% (Derived scenario)	**67%**	**27%** (Reprocessing ends in 2010)	**No Reprocessing**
Back end costs	84	74	61	41
Front end cost savings from plutonium recycle	-10	-8	-2	0
Net costs	74	66	59	41

Report to the Prime Minister [of France]: Economic Forecast Study of the Nuclear Power Option, (2000)



"The Economics of Reprocessing Versus Direct Disposal of Spent Nuclear Fuel" by Bunn, Holdren, Fetter and van der Zwann, *Nuclear Technology,* June 2005, p. 209.



Estimates of Fuel Cycle Costs and Other Parameters and Sensitivity Analysis for the Breakeven Uranium Price for Direct Disposal Versus Reprocessing and Recycling in LWRs, for a Reprocessing Price of $1000/kg HM

Parameter	Parameter Value*			Breakeven Uranium Price (Central = $368/kg U)		Change Compared to Central
	Low	Central	High	Low	High	
Disposal cost difference ($/kg HM)	300	200	100	298	438	±70
MOX fuel fabrication ($/kg HM)	700	1500	2300	302	434	±66
Interim fuel storage ($/kg HM)	300	200	100	310	425	±57
Enrichment ($/SWU)	150	100	50	338	404	−29 +36
Spent-fuel burnup (MWd/kg HM)	33	43	43	313	368	−54
Fresh-fuel burnup (MWd/kg HM)	53	43	43	350	368	−18
Laser enrichment	Yes	No	No	329	368	−39
Discount rate (% yr, real)	8	5	2	353	380	−15 +13
LEU fuel fabrication ($/kg HM)	350	250	150	359	376	±8
Premium for recovered uranium						
Conversion ($/kg U)	5	15	25	362	373	±5
Enrichment ($/SWU)	0	5	10	364	371	±3
Fuel fabrication ($/kg HM)	0	10	20	367	369	±1
Conversion ($/kg U)	8	6	4	367	369	±1

Low = best case for reprocessing; high = worst case for reprocessing.

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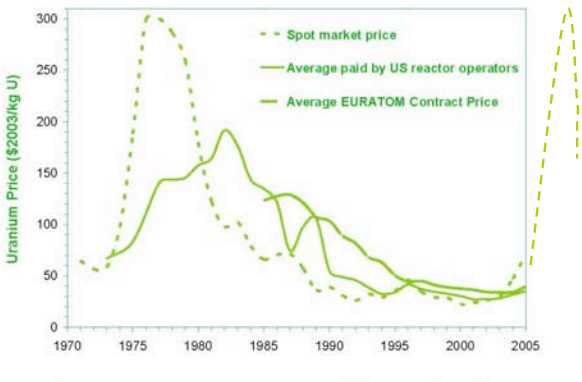

Why reprocessing costs so much more than storage

La Hague reprocessing plant (1 square mile, $20+ billion capital cost (overnight), $1+ billion/yr operational cost, vs $0.3-0.5 B/yr incremental cost for additional spent-fuel storage)

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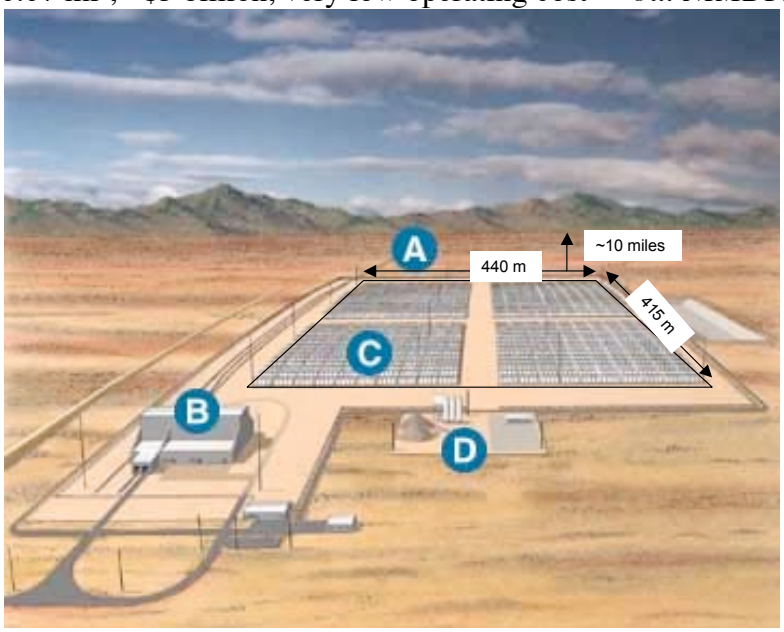
Interim dry cask storage (*on-site or centralized*) comparatively low cost.

Artist's conception of Private Fuel Storage, Skull Valley Reservation, Utah. 40,000 tons of spent fuel (lifetime throughput of Rokkasho reprocessing plant) on 0.07 mi^2, ~$5 billion, very low operating cost -- *but NIMBYed*



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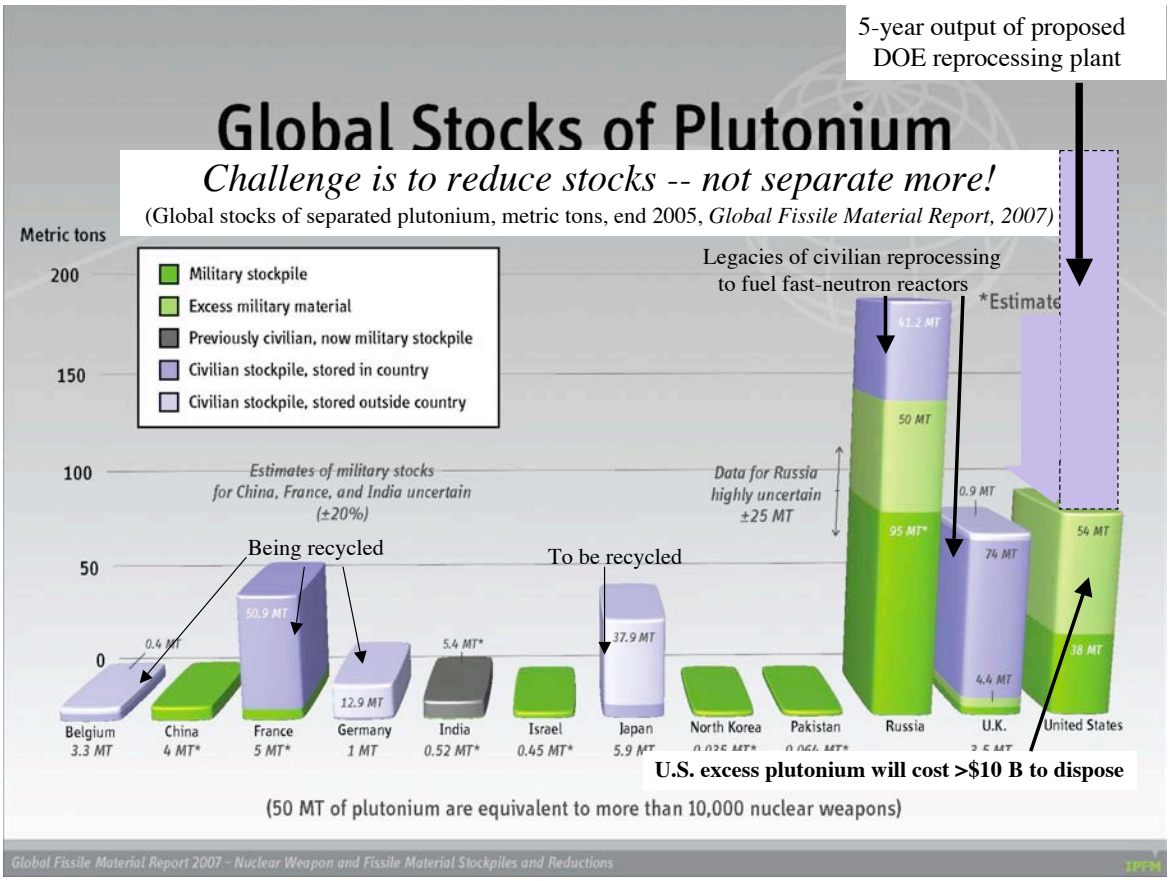
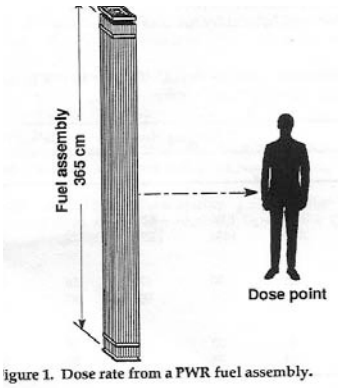


Separated plutonium can be carried away easily.
Spent fuel is self-protecting for more than a century.

Separated plutonium

2.5 kg Pu in light-weight container. Can be processed in a glove box. 3-4 cans enough for Nagasaki-type bomb.
(Mayak Reprocessing Plant, 2004)

PWR Spent fuel assembly
(1000 pounds and 12 feet long)

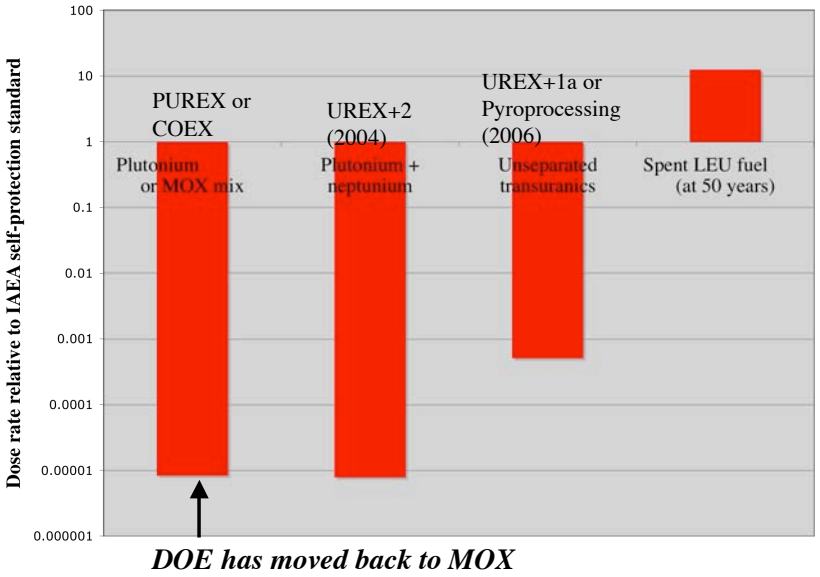


igure 1. Dose rate from a PWR fuel assembly.

5 kg Pu. 1000 rems/hr at 1 meter 50 years after discharge. Requires 20-ton container to transport & remote reprocessing behind thick walls to recover.

DOE's "proliferation resistant" transuranic mixes not much more self protecting than separated plutonium

(Dose rate from 1 kg of transuranics: fraction of IAEA self-protection standard;
"Limited Proliferation Resistance Benefits from Recycling Unseparated Transuranics and Lanthanides from Light-Water Reactor Spent Fuel" by J.Kang and FvH, *Science and Global Security,* 2005)



U.S. nonproliferation policy on reprocessing

Since India used its first separated civilian plutonium to make a bomb in 1974, U.S. policy has been: ***"We don't reprocess. You don't need to either."***

Very successful: ***No additional countries have launched "civilian" reprocessing in the past 30 years and several have stopped.***

Bush Administration proposed new policy, ***"The weapon states and Japan will do it for you."***

Negative reactions. DOE has dropped the requirement for participation in the Global Nuclear Energy Partnership and is encouraging South Korea to reprocess in violation of the 1992 Korean Pennisula Denuclearization agreement ("pyroprocessing is not reprocessing").

Merchant Reprocessing has failed in any case

(Countries with separated plutonium in red.)

Countries that reprocess or plan to (billions of Watts)		**Customer Countries that have quit or plan to** (billions of Watts)		**Countries that have not reprocessed** (billions of Watts)	
China (incomplete plant)	6.4	Armenia (in Russia)	0.4	Argentina	0.9
France (67%)	63.4	**Belgium (home/France)**	5.8	Brazil	1.9
India (?)	3.6	Bulgaria (Russia)	2.7	Canada	12.9
Japan (90% planned)	44.3	Czech Repub (Russia)	2.6	Lithuania	1.3
Netherlands (in France)	0.5	Finland (Russia)	2.7	Mexico	1.4
Russia (15%)	21.7	**Germany**(home/Franc/UK)	20.3	Pakistan	0.4
UK (quitting)	11.8	Hungary (Russia)	1.7	Romania	0.6
		Japan (France/UK)	44.3	Slovenia	0.7
		Slovak Repub (Russia)	2.5	South Africa	1.8
		Spain (France, UK)	7.6	South Korea	16.8
		Sweden (France/UK)	8.9	Taiwan	4.9
		Switzerland (France/UK)	3.2	U.S. (since 1972)	97
		Ukraine (Russia)	13.1		
Total (70%)	**151.8**	**Total**	**116.1**	**Total**	**141.4**

Spent fuel will have to be removed from reactor sites eventually. But no reason to panic.

- Only 5% of U.S. spent fuel is *not* at sites with operating reactors.
- At an operating nuclear power plant, consequences of accidents and attacks on dry-cask-stored fuel would be orders of magnitude less than from attacks on reactors or storage pools.
- All U.S. nuclear power plant sites can accommodate spent fuel from 60 years of operation.
- Anti-nuclear groups no longer oppose interim on-site dry-cask storage if it is “hardened” (e.g. surrounded by berms).

Summary

Reprocessing would:

- Exchange interim, on-site storage of self-protecting spent-fuel for interim stockpiling of plutonium or transuranic material that is easily carried and from which plutonium could easily be separated.
- Cost two (LWR recycle) to ten (fast-reactor recycle) times more than on-site storage.
- Provide cover for other countries to develop nuclear-weapon options.

Growing Skepticism in Congress

June 2007: House Appropriations Committee Report on House FY08 Energy and Water Development Appropriations Bill,
(Report 110-185, 11 June 2007, pp. 66-68)

- "aggressive program proposed by the Department is at best premature."
- "Department has failed to convince the Committee that advanced separations technologies coupled with fast reactors is a viable, comprehensive approach to recycling spent fuel."
- "Embarking on a costly process leading to major new construction projects is unwise, particularly where there is no urgency."
- "before the Department can expect the Committee to support funding for a major new initiative, the Department must provide a complete and credible estimate of the life-cycle costs of the program."

October, 2007: **National Research Council**
Review of the DOE's Nuclear Energy Research and Development Program
(http://books.nap.edu/catalog.php?record_id=11998, Summary, pp. 8-9)

"All committee members agree that the GNEP program should not go forward and should be replaced by a less aggressive research program"

"there has been insufficient external input, including independent, thorough peer review of the program."

"DOE claims that the GNEP is being implemented to save the United States nearly a decade in time and a substantial amount of money. In view of the technical challenges involved, the committee believes that the opposite will likely be true.

"…none of the cycles proposed, including UREX+ and the sodium fast reactor, is at a stage of reliability and understanding that would justify commercial-scale construction at this time."

December 2007: Congressional Joint Declaratory Statement to accompany the FY 2008 Omnibus Appropriations Bill

President Bush requested $405 for GNEP and DOE hoped by end of 2008 to let construction contracts for a reprocessing plant and a fast-neutron reactor.

The Omnibus Appropriations Bill "provides $181 million for the Advanced Fuel Cycle Initiative." Of this amount, $151 million is for continued research and development on spent fuel recycling and advanced reactor design, and ***no funds are provided for facility construction for technology demonstration or commercialization***."[emphasis added]

For FY2009, the House has decided to have a continuing resolution until President Bush (and Senator Domenici) leave office.

So the decision is left to the next Congress and Administration.