Plutonium separation vs. spent fuel storage

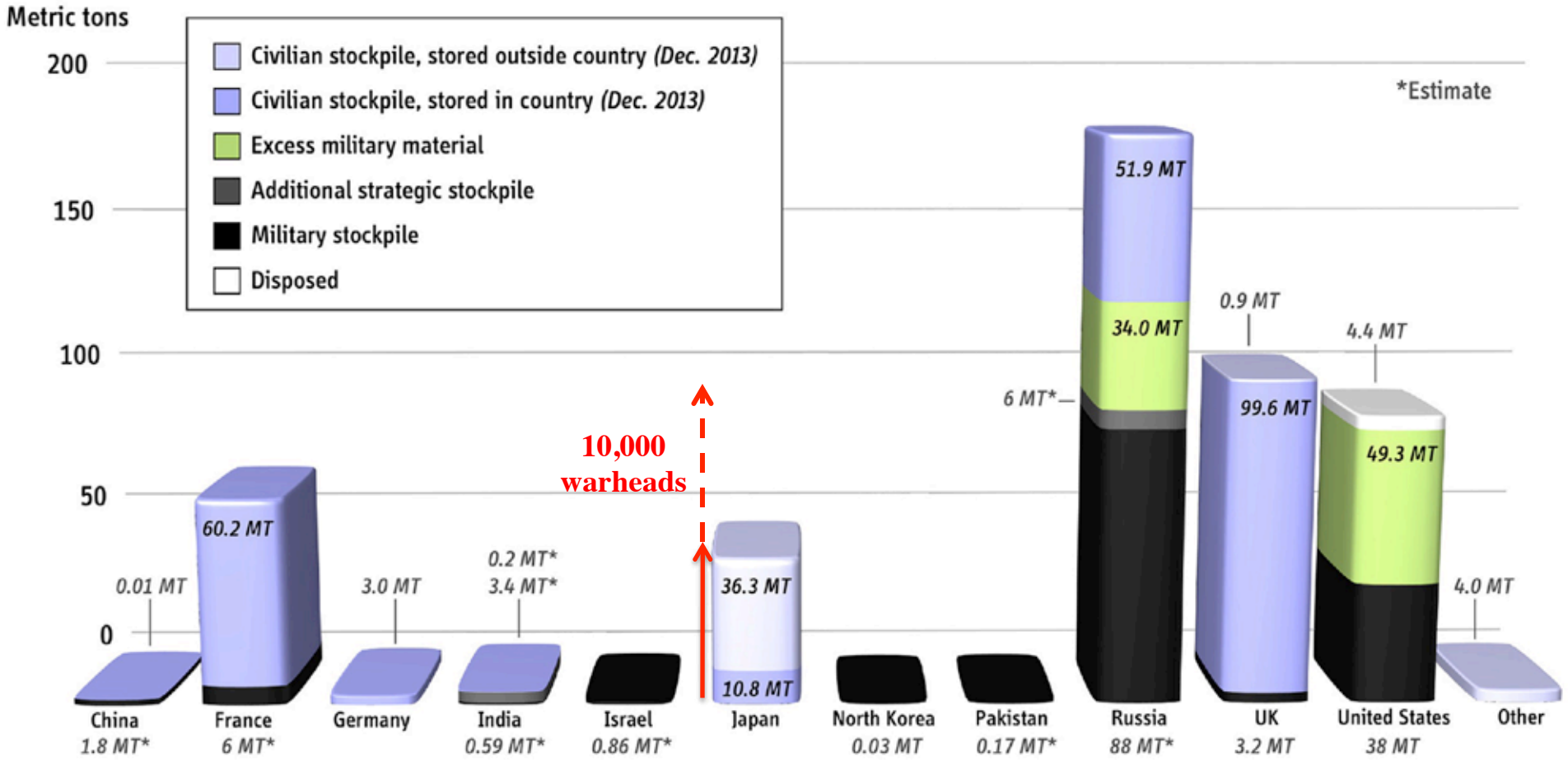
Frank von Hippel
Program on Science and Global Security, Princeton University and
International Panel on Fissile Material
Panel, New Diplomacy Initiative
Tokyo, 6 November 2015

Outline

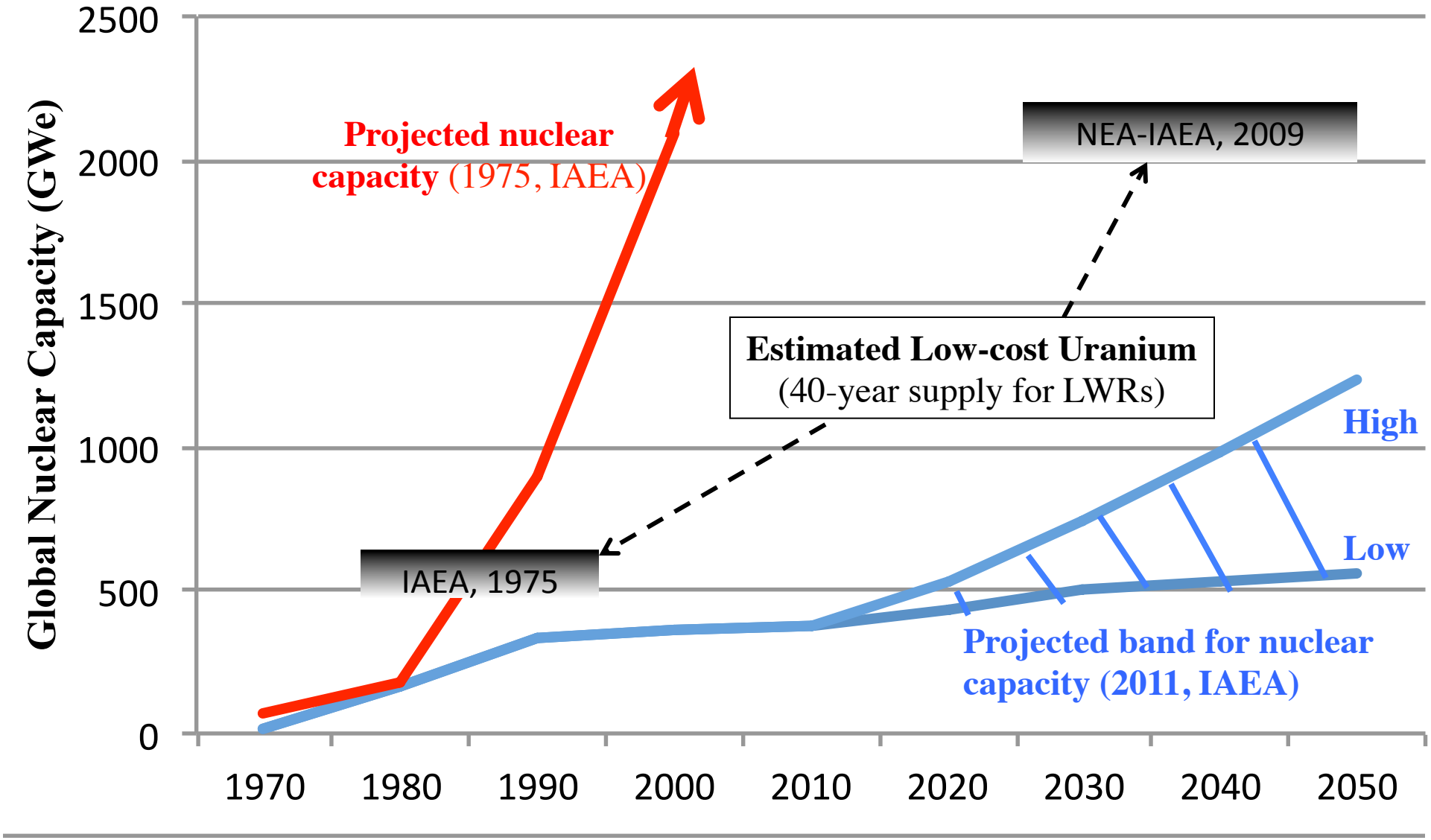
- Why civilian plutonium separation began
- Why the decision was mistaken
- The high costs of plutonium separation and recycle
- The alternative to reprocessing: dry cask spent fuel storage and why it is safer.

Why do we have enough separated *civilian* (purple) plutonium for >30,000 Nagasaki weapons?

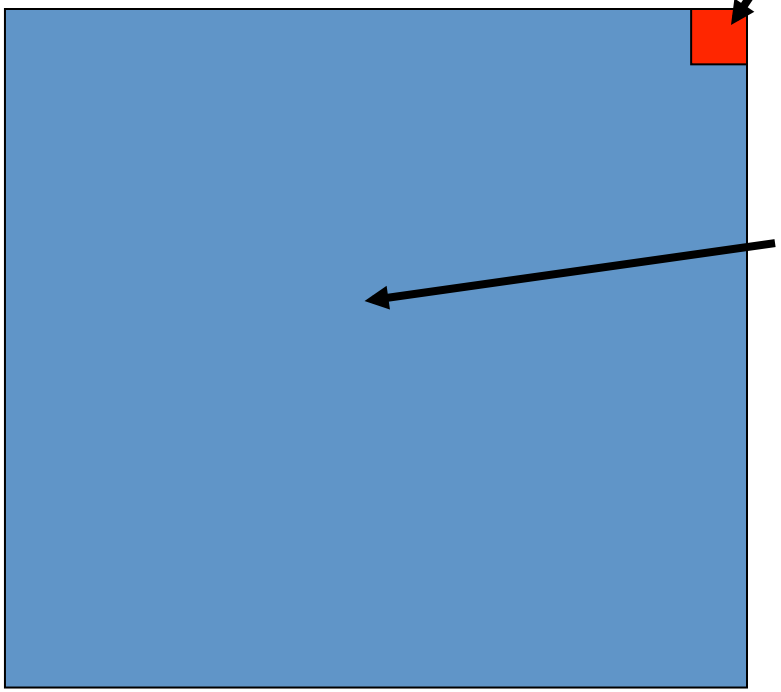
(Source: *Global Fissile Material Report 2015*)



Answer: Fears of uranium scarcity in the 1960s and 1970s led to proposals to develop "breeder" reactors fueled by chain-reacting plutonium bred from abundant U-238.



The proposed solution: Move from U-235 to U-238 as a fuel and you can "burn the rocks"

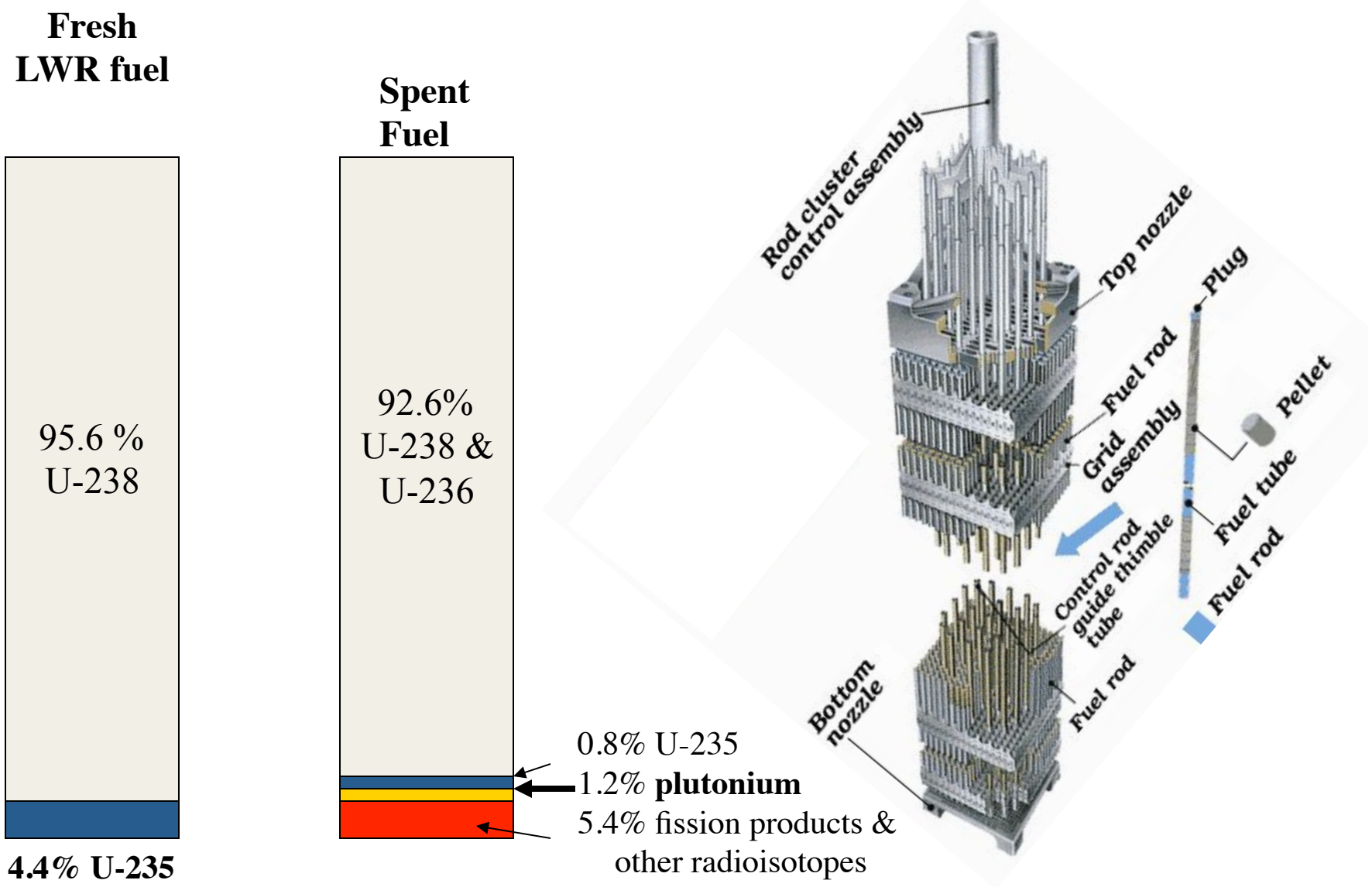


U-235 (0.7% of natural uranium) chain-reacts and provides most the energy in current-generation (mostly water-cooled) reactor fuel

U-238 (99.3%) doesn't chain react but turns into chain-reacting Pu-239 after it absorbs a neutron

Even the 3 grams of U-238 in an average ton of crustal rock has a releasable energy of 10 tons of coal

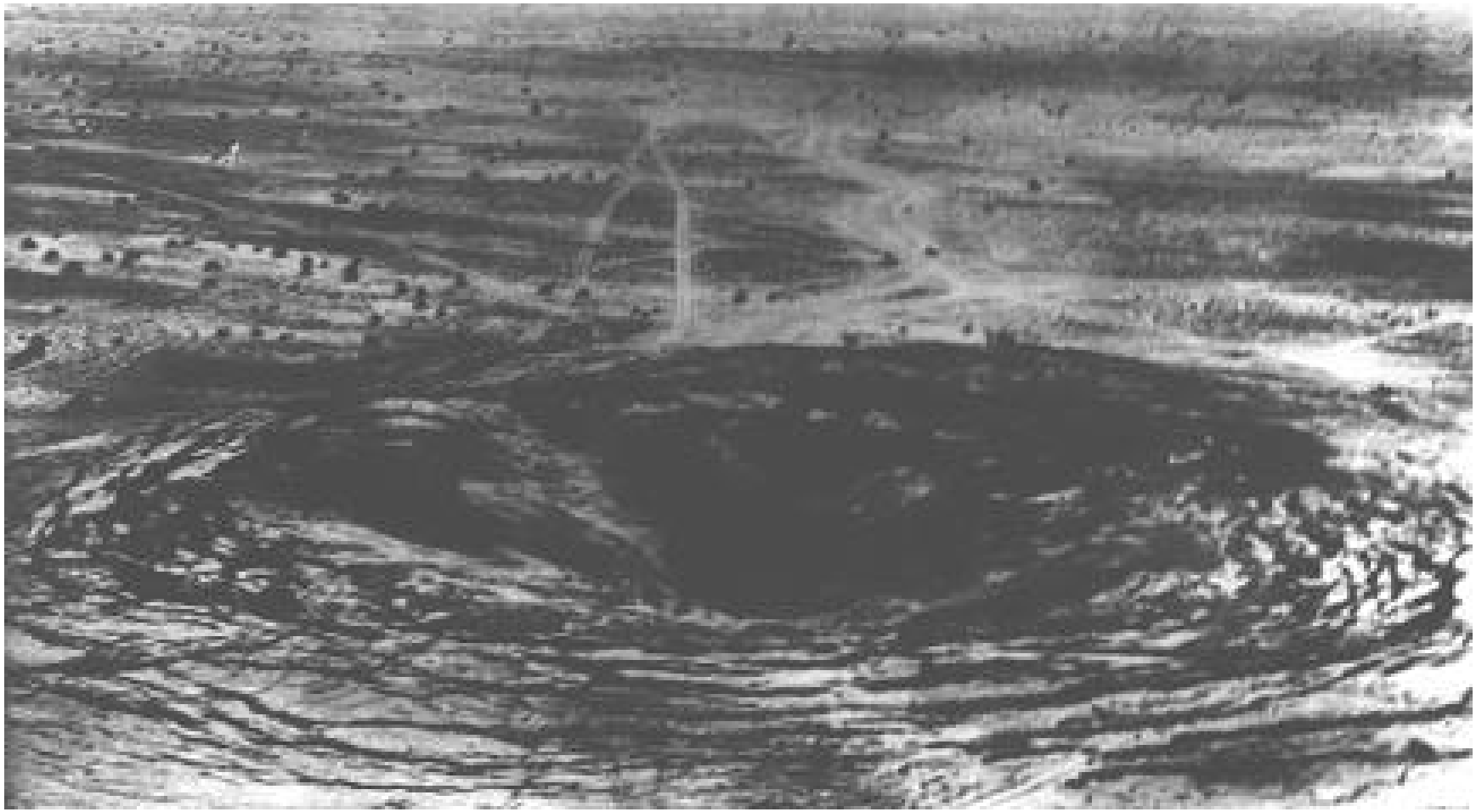
Plutonium in light water reactor spent fuel would be separated as startup plutonium for breeder reactors



1974. India used first plutonium separated for its breeder program for a "peaceful nuclear explosion"

1977. President Carter: "Do we need breeders?"

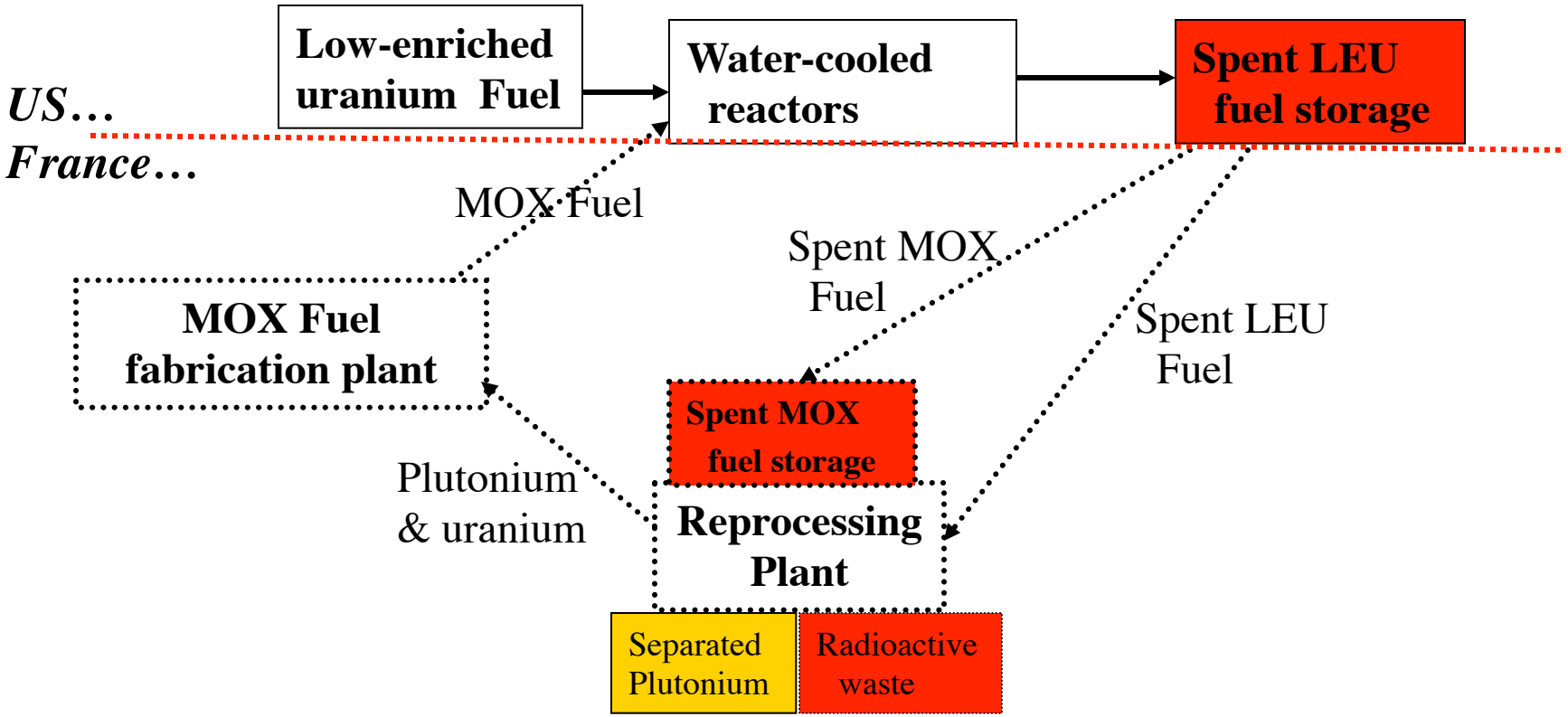
Answer: "Breeders not competitive."



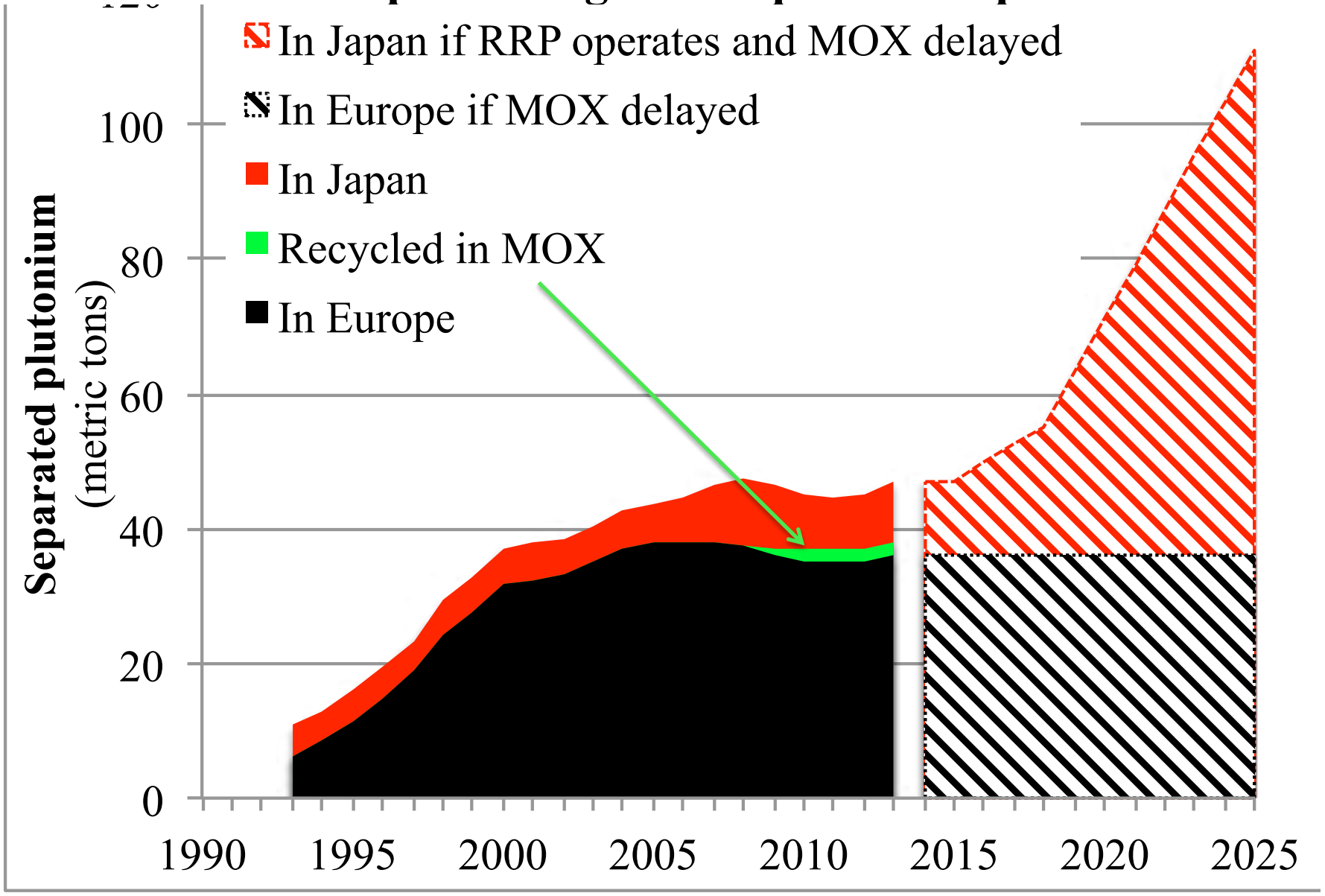
Crater from India's 1974 underground nuclear test.

France decided to use its separated plutonium in water-cooled reactor fuel to save ~12% of natural uranium.

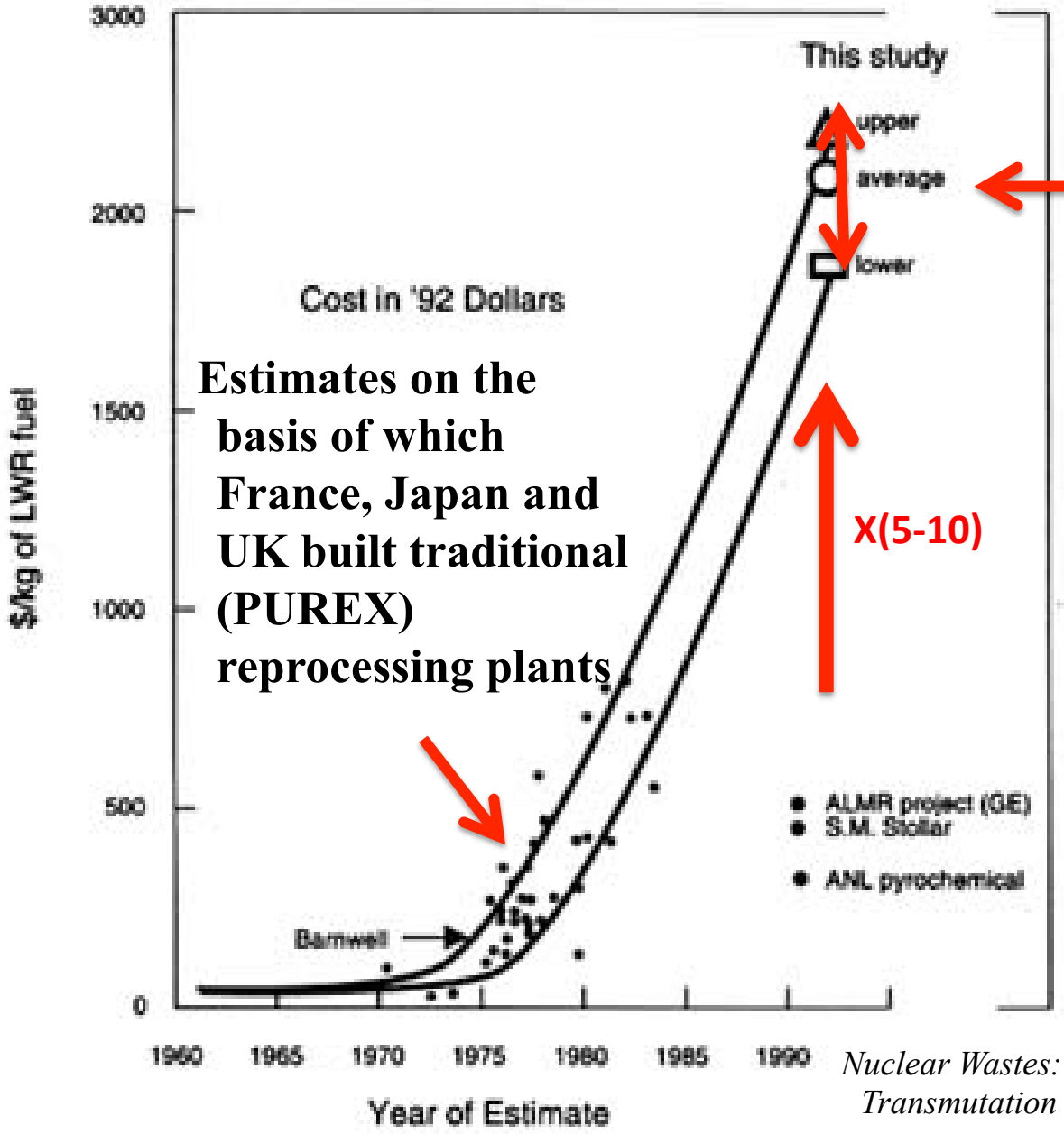
Japan decided to do the same – as did Germany, Belgium and Switzerland – with France & UK doing their reprocessing.



Japan's MOX program has failed so far. Would have to become *very* successful to prevent explosive growth of Japan's stockpile if Rokkasho Reprocessing Plant operates as planned.



Reprocessing costs were grossly underestimated by advocates



Actual costs of French, Japanese and UK reprocessing plants.

Estimates by U.S. reprocessing advocates in early 1990s.

Nuclear Wastes: Technologies for Separations and Transmutation (National Academy Press, 1996) p. 117.

Conclusions of Economic Reviews

France (2000). ***Plutonium and uranium recycle costs five times more than the savings in LEU fuel costs.****

Today, the cost may be ~10 times because of loss of foreign customers.

Japan (2011). ***Plutonium and uranium recycle costs ten times more than the savings in LEU fuel costs.*****

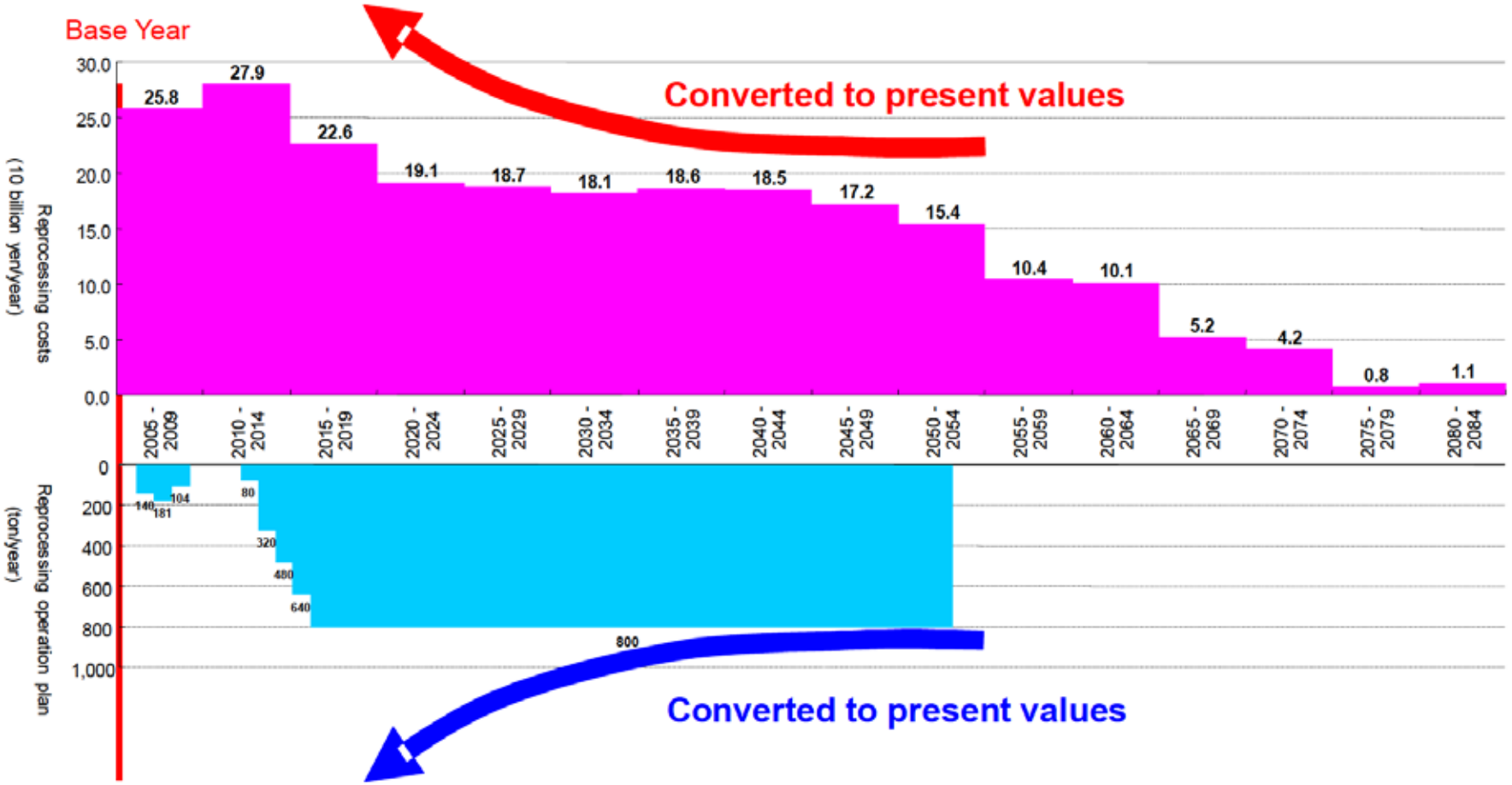
Yet both countries have chosen to continue with plutonium recycle because it has been judged too disruptive to change policies.

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

***JAEC, Technical Subcommittee on Nuclear Power, Nuclear Fuel Cycle, etc. *Estimation of Nuclear Fuel Cycle Cost, 2011.*

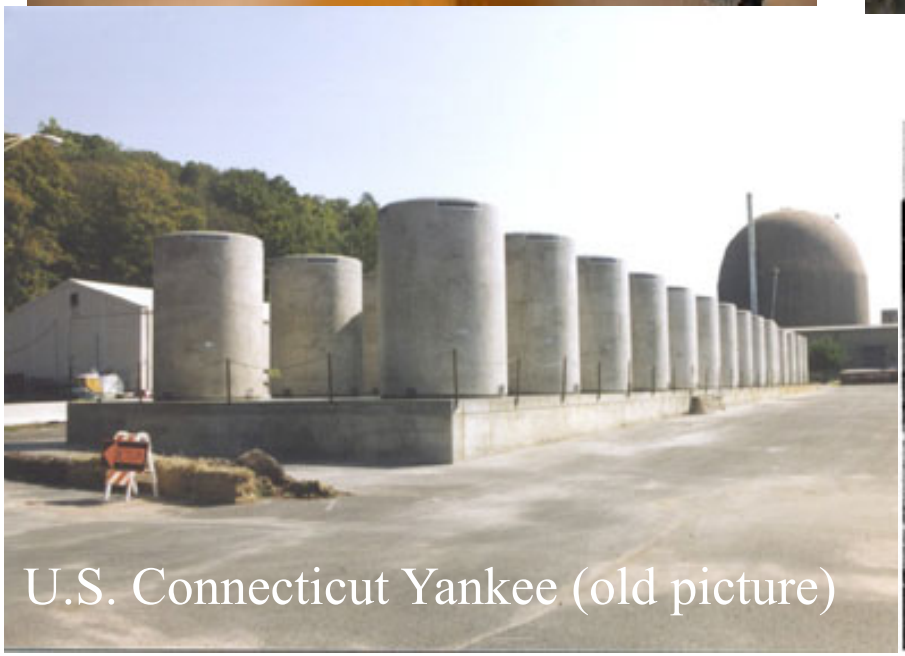
Operating Rokkasho will cost ~ ¥200 billion/yr. (¥250,000/kg)
~7x cost of dry-cask spent fuel storage

Cost Estimates (Reprocessing, etc.)

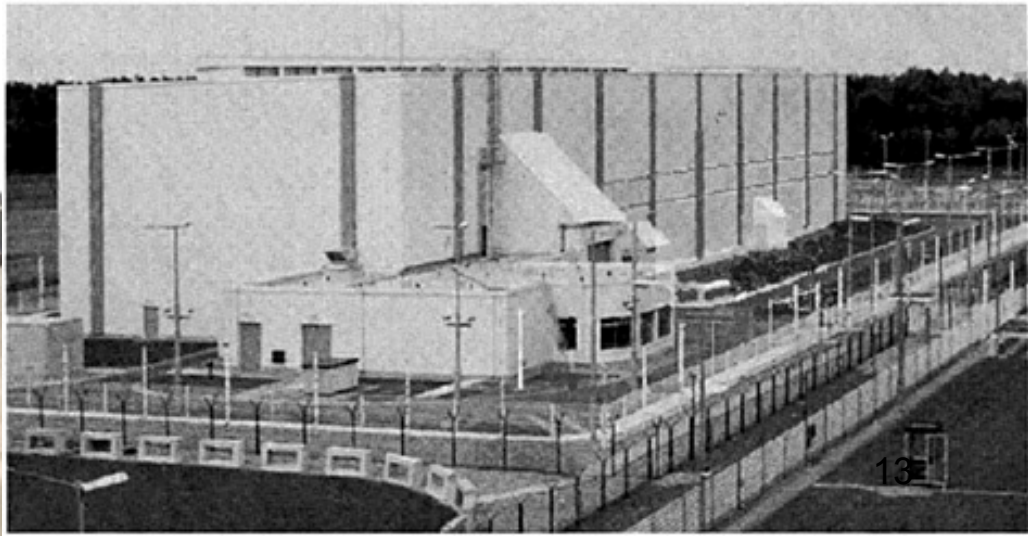


Cost per ton = Reprocessing cost [converted to base year's value] / Reprocessing Amount [converted to base year's value]

Most countries manage older spent fuel with safe onsite dry cask storage. (Japan has dry cask storage at Fukushima-Daiichi and Tokai.)

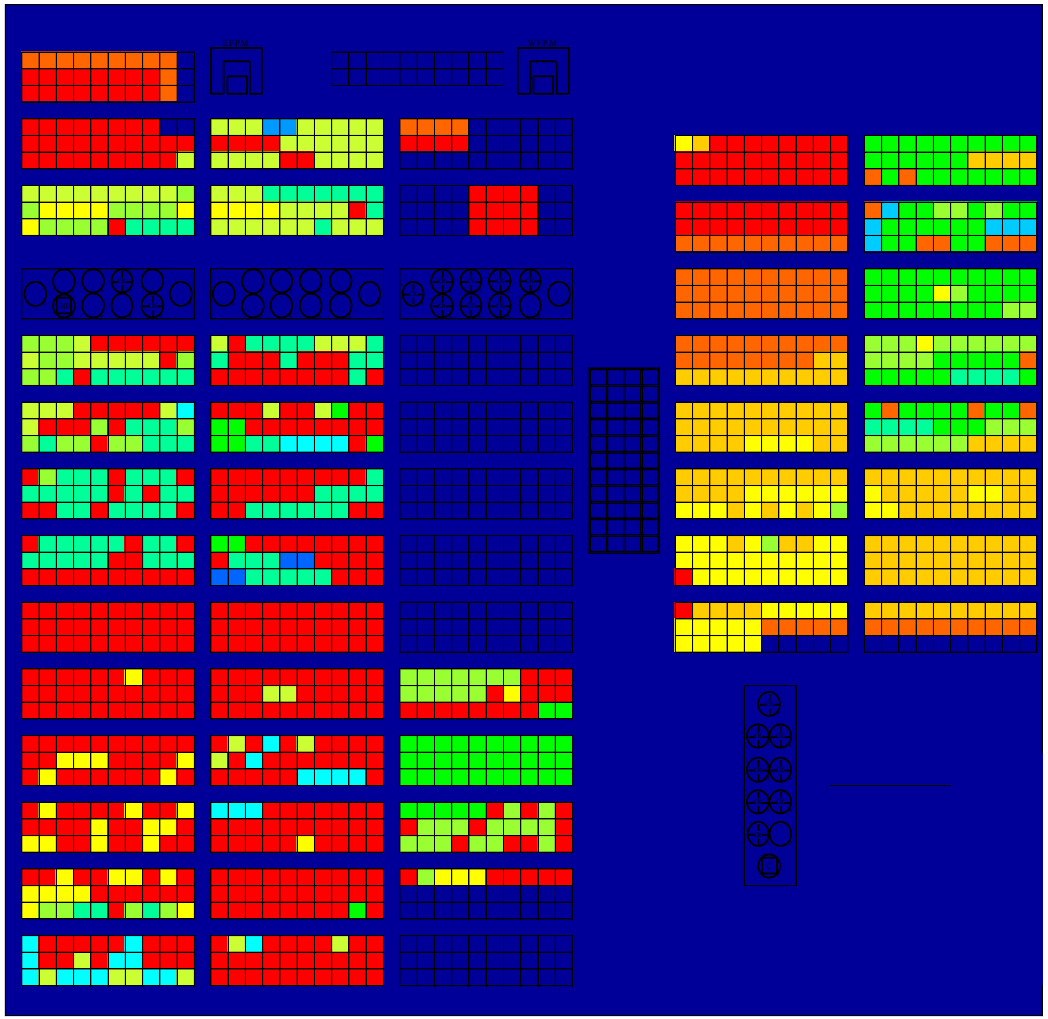


Lingen NPP, Germany



Dry-cask storage also alternative to dense-packed storage pools. Spent fuel fire in Pool #4 could have forced evacuation of Tokyo

UNIT 4 SFP HEAT GENERATION RATE DISTRIBUTION



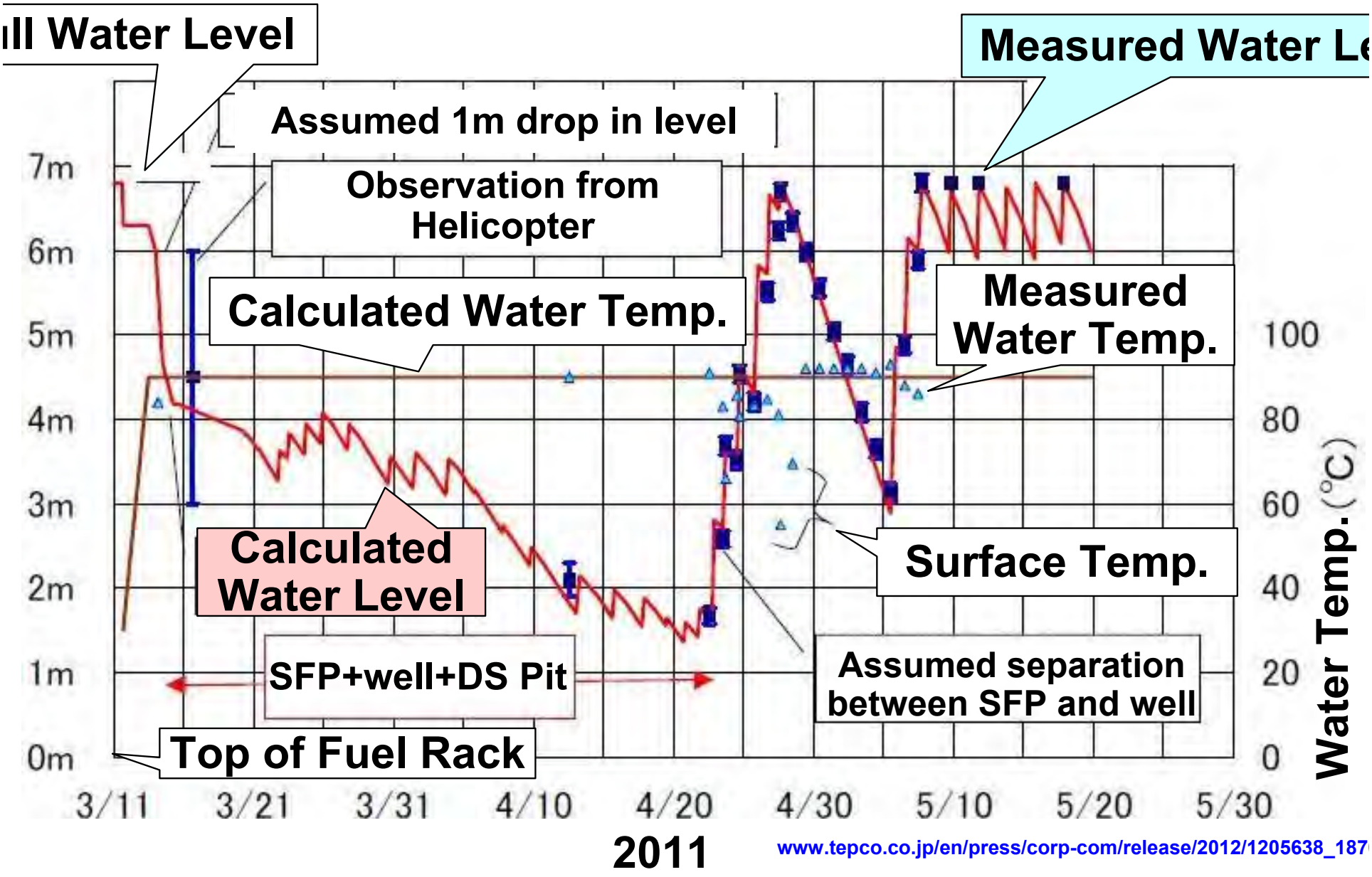
IF	3.60 kW
1	1.12 kW
2	0.55 kW
4	0.40 kW
5	0.30 kW
8	0.24 kW
9	0.23 kW
10	0.22 kW
12	0.21 kW
14	0.20 kW
16	0.19 kW
24	0.16 kW

~5 years cooling

Fresh fuel

BWR fuel assembly contains ~ 170 kg U

Fuel in pool #4 remained covered only because of leakage *in*



www.tepco.jp/en/press/corp-com/release/2012/1205638_187

Lowest water level at top of fuel rack +1.5 m

U.S. Nuclear Regulatory Commission has found that consequences of a fire in a high-density pool would be *100 times worse than Fukushima*

(average consequences for the Peach Bottom site in Pennsylvania)

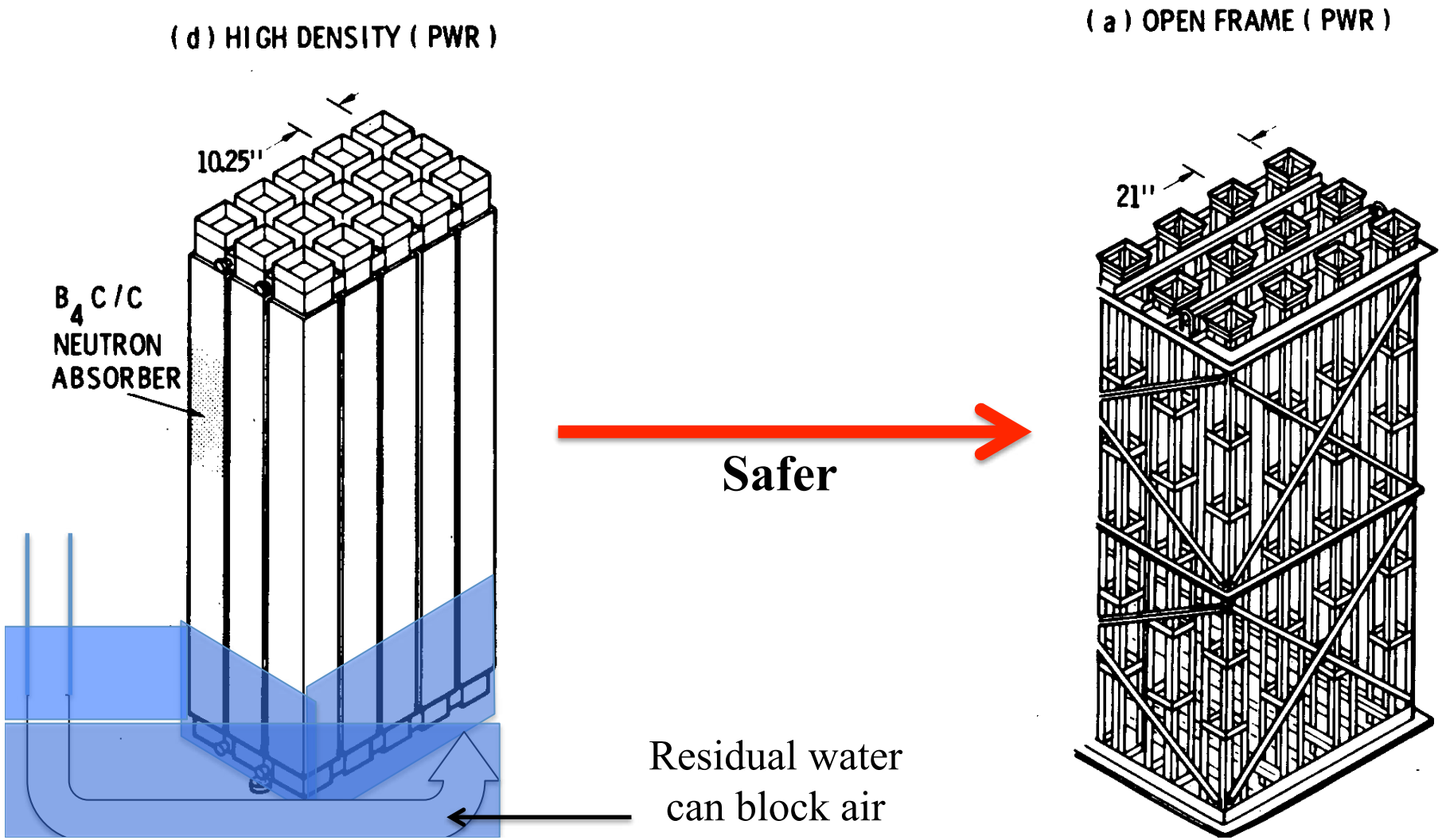
	High Density	**Low Density**	**Fukushima Daiichi**
Release (PBq)	925	4	6-20
Cancer deaths	43,100	1,100	~1000
Area (km^2)	46,600	221	~650
Displaced	10.9 million	72,000	~100,000

Primary reason for difference is that NRC found there would be enough hydrogen generated for an explosion that would destroy the reactor building for the high-density but not low-density pool.

Source. http://pbadupws.nrc.gov/docs/ML1328/ML13282A564.pdf; http://pbadupws.nrc.gov/docs/ML1328/ML13282A563.pdf

In case of partial loss of water, high-density-rack storage makes air cooling ineffective.

If fuel over 5 years old were loaded into dry casks, safer open-frame racks could be used.



Some of the Commissioners on Japan's Nuclear Regulation Authority (NRA) understand the danger

On 19 September 2012, in his first press conference, NRA Chairman, Shunichi Tanaka urged

"Spent fuel not requiring active cooling should be put into dry casks … for five years or so cooling by water is necessary…I would like to ask utilities to go along those lines…"

On 29 October 2014, Chairman Tanaka and Commissioner Fuketa urged the president of Kyushu Electric Power Company, to introduce dry-cask storage.

Does the NRA not have the authority to order the utilities to do this or do the other Commissioners not agree?