Reprocessing and recycle:
Why renewed interest? How would they relate to Yucca Mountain?

Victor Gilinsky

presentation to the

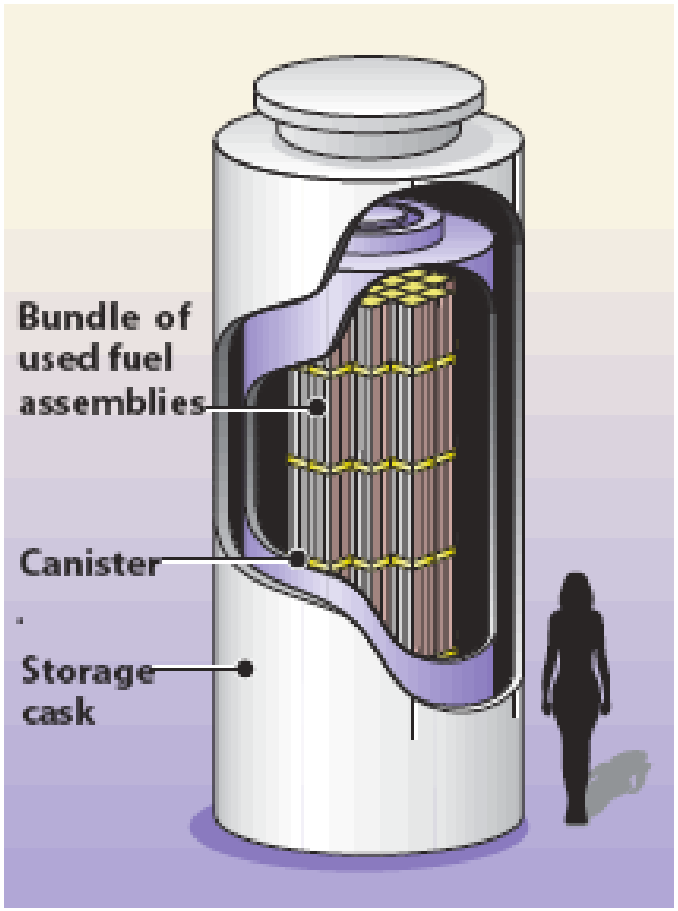
Nevada High Level Radioactive Waste Committee

at the

May 14, 2008 meeting

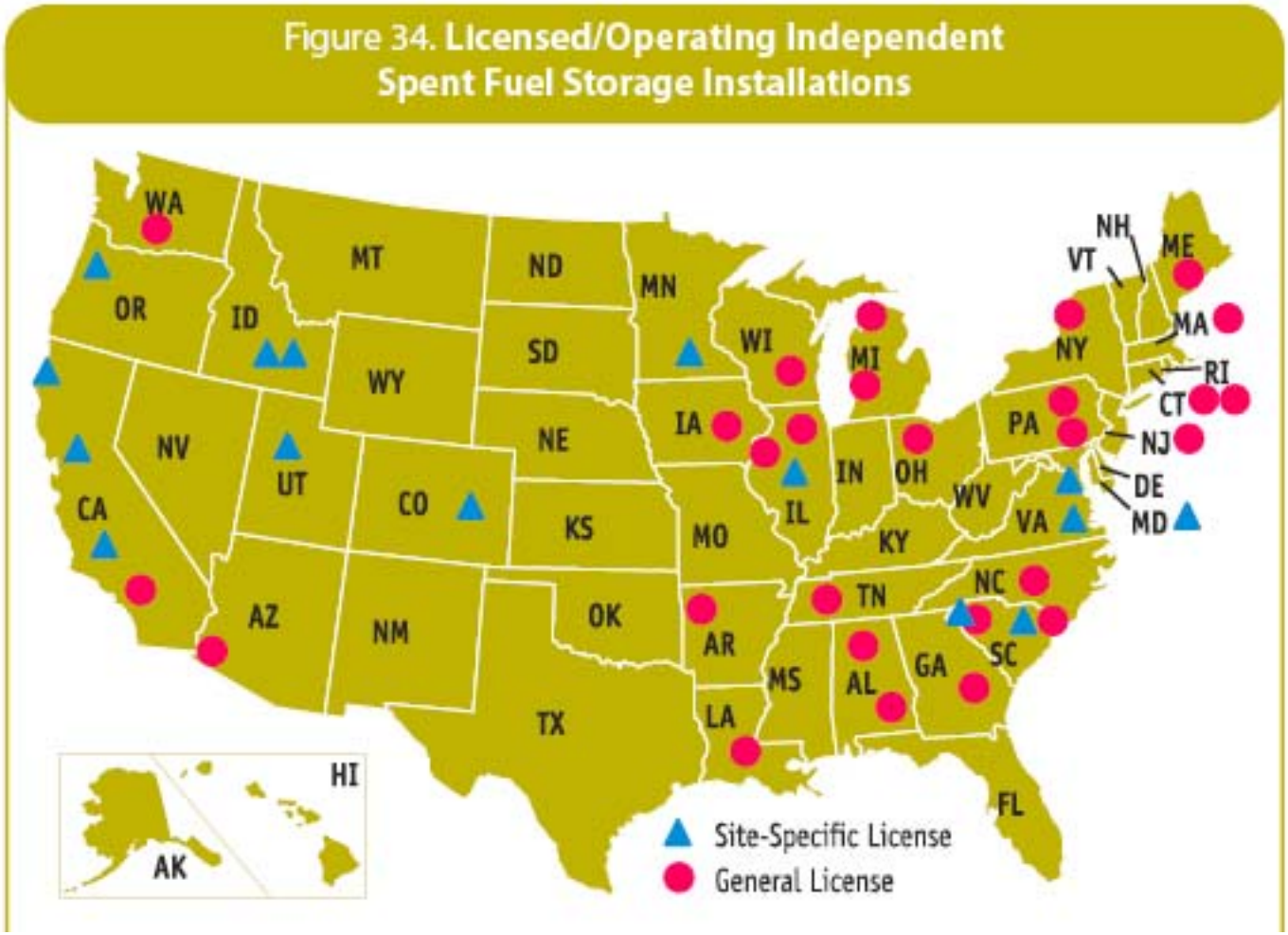
Las Vegas

“Dry cask” storage: simple, cheap



~10 tons per cask, two casks per year per reactor

De facto waste policy: surface storage



lifetime output of one power reactor
~100 casks

NAS 2008 report panned DOE's proposed reprocessing and recycle

- On resources:
  - . . . *There are fully acceptable methods of storing spent fuel safely for decades without reprocessing and fuel recycling, and no serious shortage of uranium for reactor fuel is likely to emerge for many years.. . .*

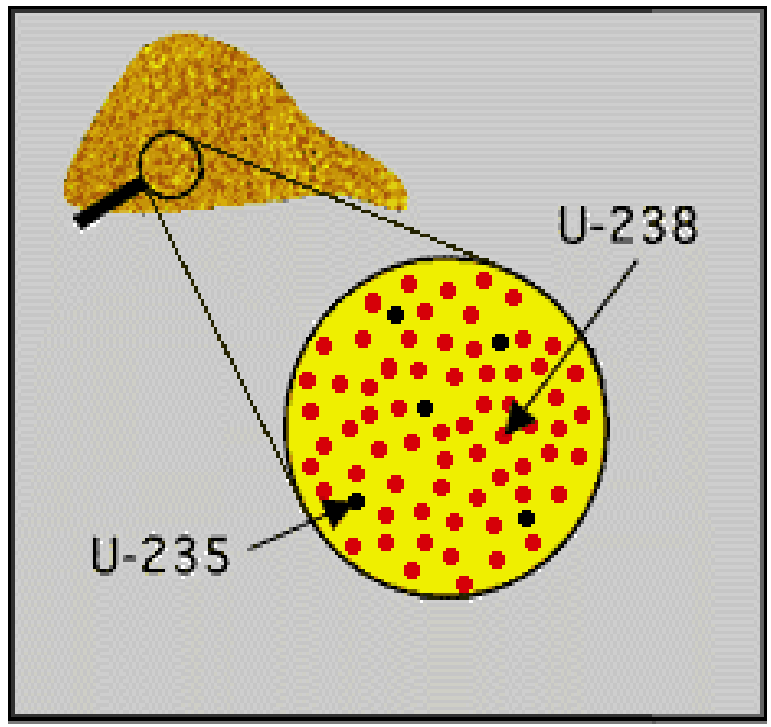
    Robert W. Fri, Chair, Committee on Review of DOE's Nuclear Energy Research and Development Program, National Academies, before the House Science and Technology Committee, April 23, 2008
- On building advanced full-scale reprocessing and related plants *now* as DOE proposed:
  - . . . *the committee concludes that the need for an accelerated program to deploy commercial-scale reprocessing and fast reactors to reduce the nuclear waste repository burden has not been established.*

A closer look: reprocessing & recycle

- What is it and how did it get started?
- Why did the US stop commercial reprocessing?
- Why is reprocessing uneconomic today and likely to remain so for a long time?
- And if reprocessing is not economic, why are some other countries operating reprocessing plants?
- Why are some nuclear partisans so fiercely attached to reprocessing?
- How did it resurface recently?
- What is DOE’s current rationale in relation to waste?
- In particular, how would it relate to Yucca Mountain?

Nuclear fuel technologies were invented for WWII bomb project

- The starting point of everything nuclear is uranium--over 99% of it (U-238) is pretty much inert; less than 1% (U-235) can support a chain reaction, like in a bomb
- The WWII scientists invented two ways of using the uranium for a bomb: one was “enrichment,” used to concentrate the U-235 (as for the Hiroshima bomb)



“Reprocessing” was invented to extract plutonium for bombs

- They discovered that if they irradiated the inert U-238 with neutrons, some of it turned into plutonium
- This was in some ways an even better nuclear explosive than U-235. (The Nagasaki bomb was made of plutonium.)
- To irradiate U-238 they invented the ***nuclear reactor***
- And to extract the tiny amount of plutonium (<1%) from the irradiated uranium fuel and highly radioactive waste, they invented ***chemical reprocessing***
- This involves dissolving the fuel in nitric acid and using very sophisticated chemistry, and is especially difficult as all the operations have to be handled remotely because of the intense radioactivity

Old thinking about nuclear power

- When post-WWII thinking turned from bombs to using nuclear energy for power generation, people believed uranium was very scarce (very wrong, as it turns out)
- That meant nuclear power couldn't make an important contribution if it was based on "burning" the rare U-235
- In principle, you could make full use of the 99% inert U-238 by first turning it into plutonium
- To extract the plutonium you had to *reprocess* the spent fuel, just like in the bomb program
- The idea became fixed in the nuclear community that reprocessing was essential to using nuclear energy
- Lots of countries got interested . . .

Reprocessing to get stuff for bombs

- But almost all of them first used the technology for bombs
- By the 1970 a half dozen countries (plus US) were reprocessing to get plutonium for bombs --Soviet Union, Britain, France, China, India, Israel
- Other countries like Pakistan, Taiwan, and South Korea and other countries were showing an unhealthy interest.
- The US got worried that the continued spread of reprocessing technology was going to lead to lots of countries having nuclear bombs


1009
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Magnitude
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1
Age
Past hour
Past day
Past week
Plates
Boundaries
Convergence
© 2008 Europa Technologies
Image © 2008 DigitalGlobe
USGS
©2007 Google
Pointer 39°46'51.27" N 125°45'13.26" E
Streaming 100%
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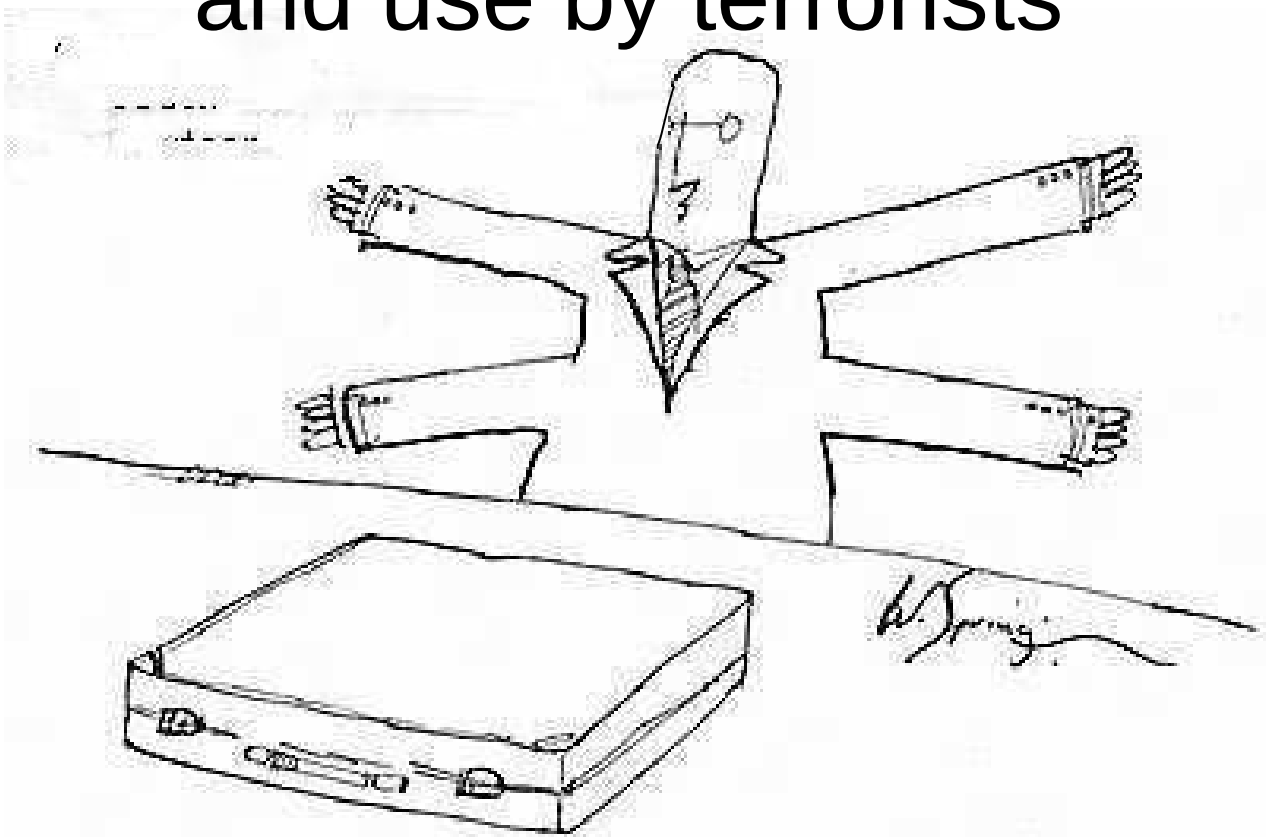
Another worry was plutonium theft and use by terrorists



"This is an absolute outrage. I am a citizen of this country! And if I was smuggling plutonium, then where's the proof?"

1976 US decides reprocessing poses international security problems

- To limit proliferation and access to plutonium by terrorists, in 1976 Pres. Ford decided we would discourage reprocessing around the world, and to set an example would also end US reprocessing
  - "*I have concluded that the reprocessing and recycling of plutonium should not proceed unless there is sound reason to conclude that the world community can effectively overcome the associated risks of proliferation.*"

    Pres. Ford, October 28, 1976
- (Jimmy Carter is usually credited or blamed for this, but he only confirmed Ford's action)

Reprocessing: new thinking about economics reinforces ban

- In time we found that not only was there a security problem, but
  - there was lots of uranium in the world;
  - nuclear power wasn't expanding nearly as fast as projected so it was getting used up more slowly;
  - reprocessing was many times more expensive than earlier projected, so it didn't make commercial sense (Japan's plant cost over $20 billion)
- But none of this mattered to those fixed on what they saw as an inevitable plutonium future
- Nuclear bureaucracies, laboratories, and industrial enterprises committed to plutonium technology never accepted the US decision and continued to try to push for a "closed fuel cycle"

Ford/Carter to Reagan to Bush

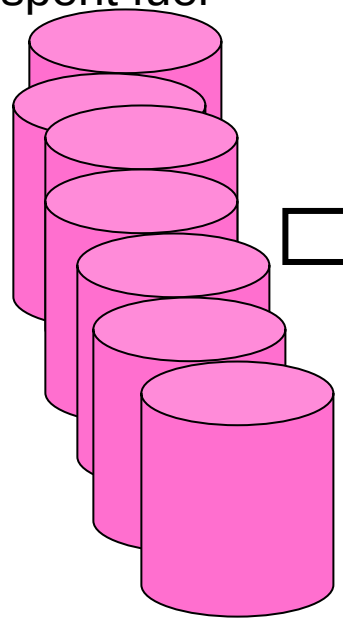
- Reprocessing advocates got Reagan to reverse the Ford/Carter “ban” on reprocessing, but he cannily didn’t provide any subsidy, so it went nowhere
- But they finally managed to sell George Bush on the idea that a new kind of reprocessing and recycle would solve problems of proliferation and waste: hence *GNEP--Global Nuclear Energy Partnership*
- The driving rationale is that advanced reprocessing would simplify waste disposal
- Which brings us to Yucca Mountain
- But first a word about commercial reprocessing

World commercial reprocessing

- Commercial reprocessing and recycle, as carried out in France and Britain and now in Japan, with some subsequent recycle of plutonium, adds very little to the fuel supply~20%, and *at great expense*.
- We already use plutonium in reactor -- about 40% of power from US reactors comes from plutonium
- Very difficult to recycle more than once because you build up contaminants that mess up the process
- After one cycle you still have spent fuel to dispose of
- So there is little gain--say, 20%--in terms of repository space

Why recycling in current reactors doesn't make sense

7 kilograms radioactive spent fuel



Reprocess, extract 50 grams of plutonium

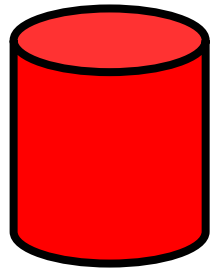
at about $2,000 per kilogram of spent fuel or $14,000 total for reprocessing

Add 950 gms uranium

fabricate

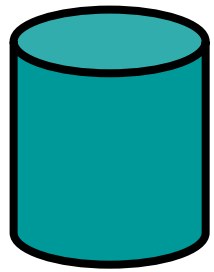
about $2,000/kg for fabrication

1 kg MOX fuel



Cost of MOX (plutonium) fuel about $16,000/kg

Equivalent to 1 kg of fresh low enriched uranium fuel worth about $3,000/kg



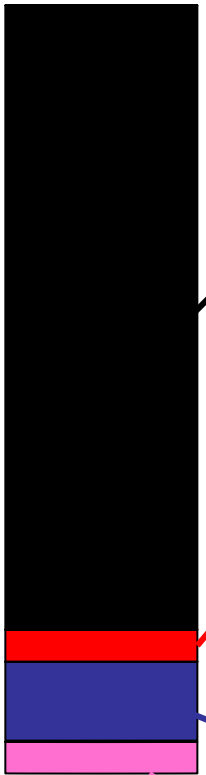
Why do the French and others do it?

- First their nuclear bureaucracies are more powerful and ideological--believe in future plutonium use
- *Reprocessing of foreign fuel was a moneymaker* (just because something is not economic doesn't mean you can't make money at it--so long as someone foots the bill, in this case the Japanese did)
- Note the British don't reprocess their own LWR fuel and will likely phase out reprocessing altogether (and will be left with 100 tons of plutonium)

DOE's new idea: Global Nuclear Energy Partnership

- The Bush administration launched GNEP to promote what they hope will be a huge nuclear expansion
- It starts with the idea that Yucca Mountain will be the only available repository (even that??), and asks, how can it be made to suffice for the projected expansion?
- GNEP proposes a new sophisticated form of reprocessing--yet to be developed--that would supposedly allow Yucca Mountain to be used for hundreds of US and foreign reactors
- The design limitation on Yucca Mountain is heat--so GNEP proposes to remove the heat

GNEP would "solve" waste problem by keeping hottest stuff *on surface*



SPENT FUEL CONSTITUENTS (fresh fuel 100% uranium)	WHAT GNEP WOULD DO WITH IT AFTER REPROCESSING TO SEPARATE CONSTITUENTS
95% uranium plus 3% other elements from fission	Low level waste
0.3% cesium & strontium	Very hot--store *on surface* for hundreds of years (WHY NOT JUST LEAVE THE SPENT FUEL ON THE SURFACE?)
1% plutonium plus some americium, curium, neptunium	Burn in new "fast burner reactors" (yet to be developed--very difficult)
0.1% iodine and technetium (water-soluble long-lived fission products)	Store in Yucca Mountain. With 100s of reactors there would be lots of waste going to Yucca -- including *process waste*

Total GNEP vision--pie in the sky