Nuclear Energy and Security Risks

Is the Expansion of Nuclear Power Compatible with Global Peace and Security?

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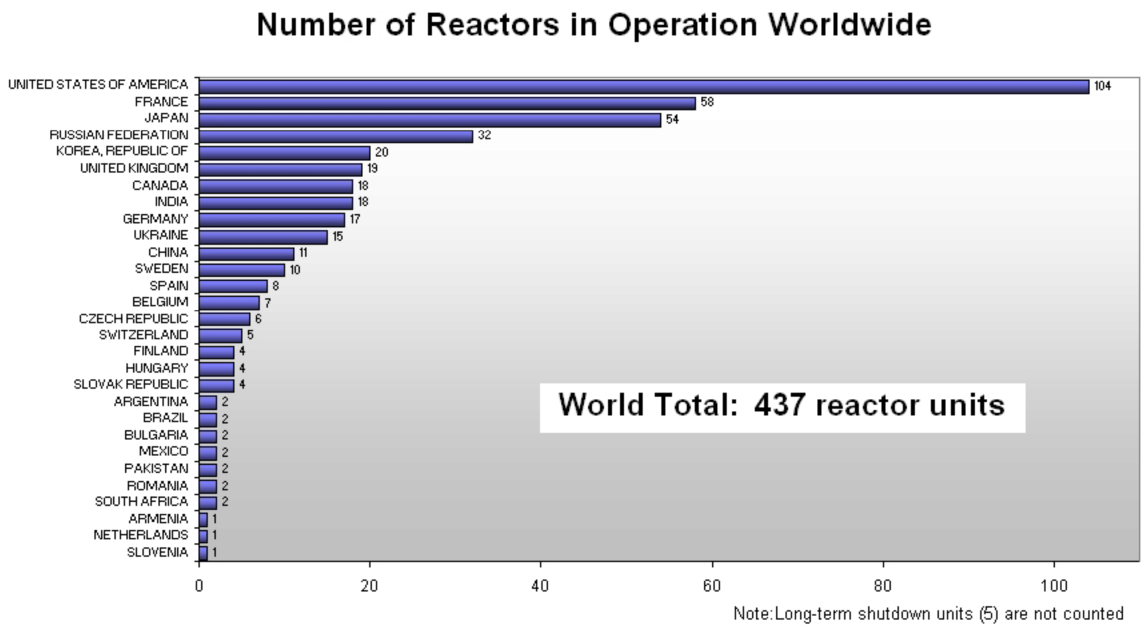
* Viewpoints expressed here are those of the author, and may or may not agree with those of his affiliations

Outline

- Current Status – Global nuclear capacity (2010)
- Why nuclear and why now?
- Key issues for nuclear power expansion
  - Nuclear Security
  - Non-proliferation
  - Spent fuel management
- “Business-as-usual” vs. A new approach
- Possible Outcome

Nuclear Capacity (2010) in the World*



104 in the US

59 in France

55 in Japan

- 437 nuclear power plants, net installed capacity of 371.5 GWe in 29 countries
- Top 3 countries (US, France, and Japan) account for half of total
- P-5 (nuclear-weapons countries) account for more than half of total
- 14 countries with 5 reactors or less (8% of total)

* Taken from Power Reactor Information system, IAEA

Why Nuclear and Why Now

- **Rising/Volatile Fossil-Fuel Prices**

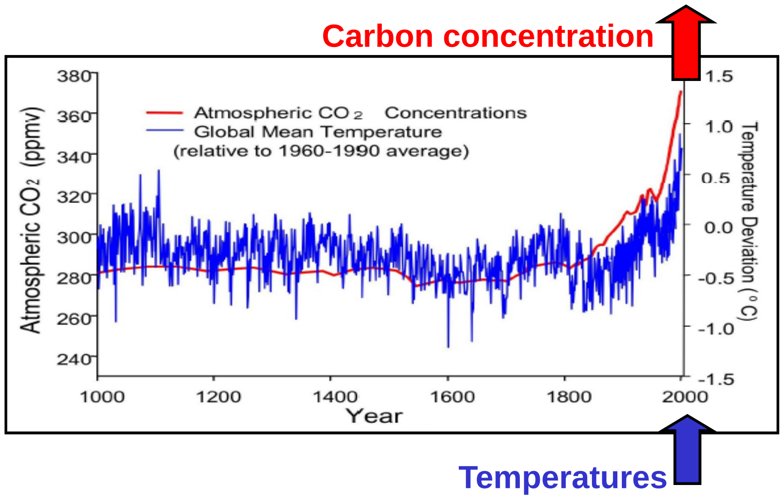
Oil Prices

Gas Prices

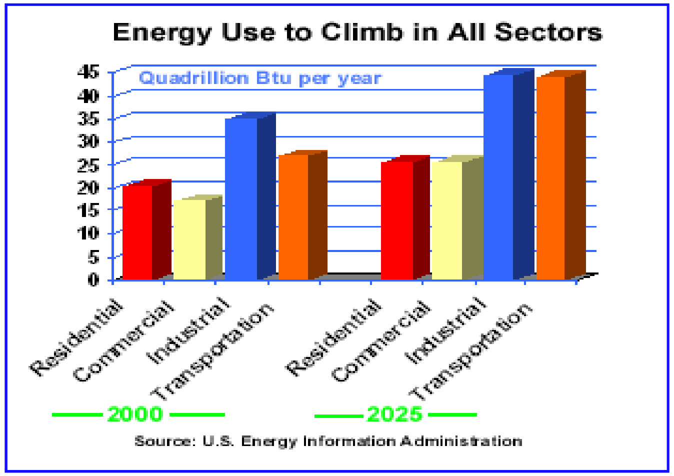
- **Energy Security**

Oil and gas supply disruptions
Infrastructural security
Shipping chokepoints

- **Environmental Concerns**

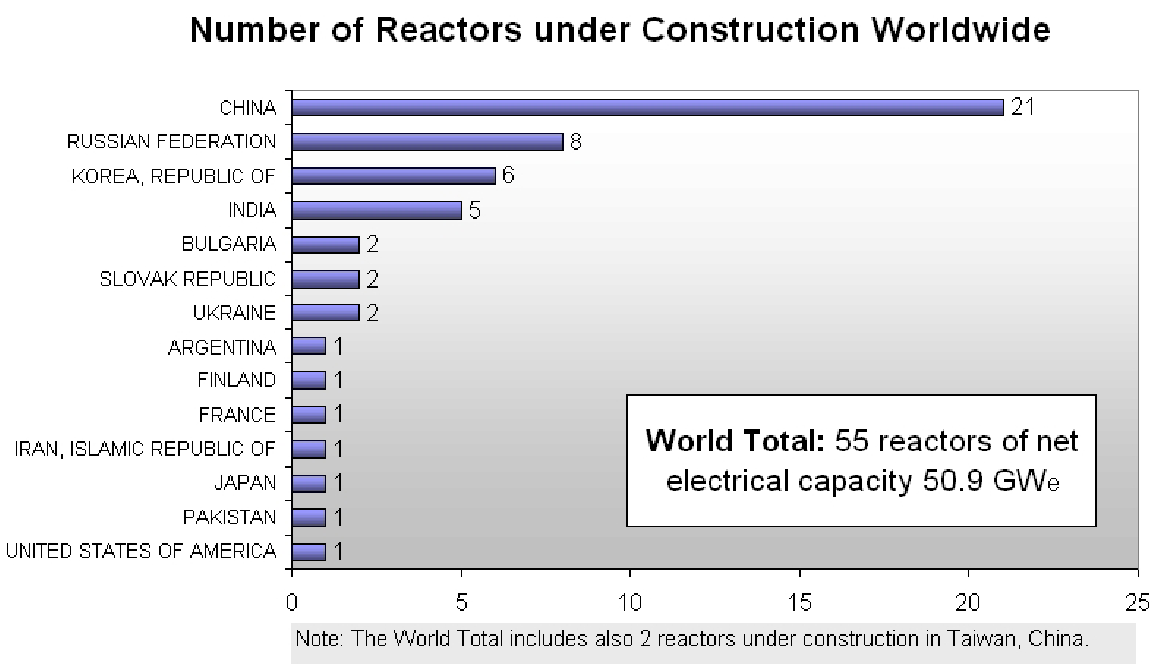


- **Increased Living Standard**



Why Nuclear and Why Now

- Nuclear energy contributes little greenhouse gas emissions
- Relative to other renewable (solar, wind, etc), nuclear energy is not affected by climate change
- Nuclear energy is proven. It can provide a large scale electricity generation base for lifting the standard of living in many countries
- Nuclear energy can help offset transportation emissions now by supporting hybrid and electric cars, and in the future, through production of hydrogen



Key Issues for Nuclear Power Expansion

- Costs/Financing
- Nuclear safety and reliability
- Human resource and infrastructural development

Generation III
Advanced LWRs

- CANDU 6
- System 80+
- AP600

Generation III+
Evolutionary

- ABWR/ESBWR
- ACR1000
- AP1000
- APWR
- EPR

- **Nuclear Security**
- **Nuclear non-proliferation**
- **Spent fuel management**

➤ Discussed in other sessions

The World has Changed

- Threat of terrorist WMD, possibly aid by rogue actors
- Global non-proliferation regime threatened by weak enforcement – withdrawal by DPRK
- Nuclear weapons capability could be acquired under the guise of peaceful uses and by covert means – e. g., Iran . . .
- Closed fuel cycle seen as “latent proliferation” concern

Issues

- Physical protection of nuclear facilities and transport of nuclear materials
- IAEA safeguards (CSA*, CSA+AP**)
- Spread of sensitive technologies (enrichment and reprocessing)
- Spent fuel management

* CSA = Comprehensive Safeguards Agreement
** AP = Additional Protocol

“Business-as-usual”

- Global separated civil plutonium stock > 250 tons in 2010, stored in a few countries
- Progress in disposition of 34 tons each of US/Russian weapons plutonium is slow
- Global highly enriched uranium (HEU) stock is ~1900 tons in 2010, resided primarily in nuclear weapons countries
- There are 250 research reactors (RRs), of which 75 once used or still use HEU as fuel
- Civil spent nuclear fuel is > 250,000 tons in 2010, resided in 30 countries, with ¼ in the US, or 87% in the top 10 countries
- Spent fuel with imbedded plutonium will be produced in newcomer countries, many located in less-stable region of the world

In-Country stocks of separated Pu and HEU*

Country	Plutonium (t) Military	Plutonium (t) Civil	HEU (t) Military	HEU (t) Civil
Belgium	0	3.5 (2.3)	0	0.3
China	4	0 (0)	21	1
France	5	78.6 (46)	29	1
Germany	0	12.5 (32)	0	1
India	0.4	1.5	0.5	0.01
Japan	0	5.4 (39)	0	2
Russia	95	88** (82)	1073	30
Switzerland	0	~1 (3)	0	0.01
UK	3.2	96.2 (69)	21.9	1.5
US	47	45 (45)	580	125
Others	~0.7 (Israel, Pakistan, DPRK)	<1 (3.2)	0	~13 (CIS, Canada, etc.)
Total	~155	332 (321)	1725	175

* Represents stocks held in a country, taken from ISIS database, ** Includes 50 tons from excess military stocks, (parenthesis) = (estimated country-owned plutonium stock, calculated based on infc549 & open sources)

HEU used in Research Reactors*
(Type, Power Level>5MW)

Country	Reactor	Type	Power MW	Enrich-ment %
Belgium	BR-2	H_2O	100	93
Canada	MNR	H_2O	5	93
China	HFETR	H_2O	125	90
	MJTR	H_2O	5	90
France	HFR	D_2O	58.3	93
	ORPHEE	H_2O	14	93
Germany	FRJ-2	H_2O	23	93
	BER-2	H_2O	10	93
Greece	GRR-1	H_2O	5	93
Israel	IRR-1	H_2O	5	93
Japan	KUR	H_2O	5	93
Kazakhstan	EWG 1	H_2O	60	90
Netherlands	HFR	H_2O	45	93

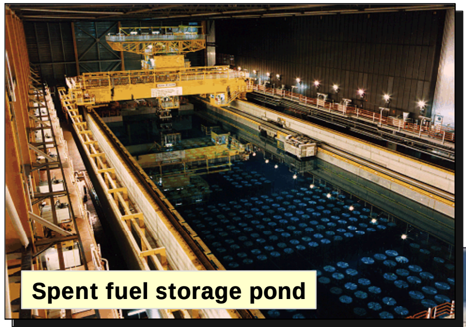
Romania	Triga-II	H_2O	14	93
Russia	IR-8	H_2O	8	90
	BR-10	FR*	8	90
	WWR-M	H_2O	18	90
	IVV-2	H_2O	15	90
	MIR-M1	H_2O	100	90
	IRT-T	H_2O	6	90
	SM-3	H_2O	100	90
	BOR-60	FR	60	90
United States	ATR	H_2O	250	93
	MIT R-II	H_2O	4.9	93
	NBSR	D_2O	20	93
	HFIR	H_2O	85	93
	U. M.	H_2O	10	93
	Fast Burst	FR*	10	93

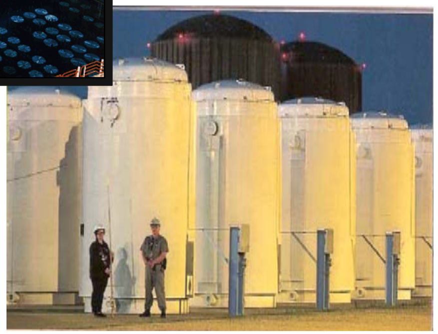
* FR – fast reactor

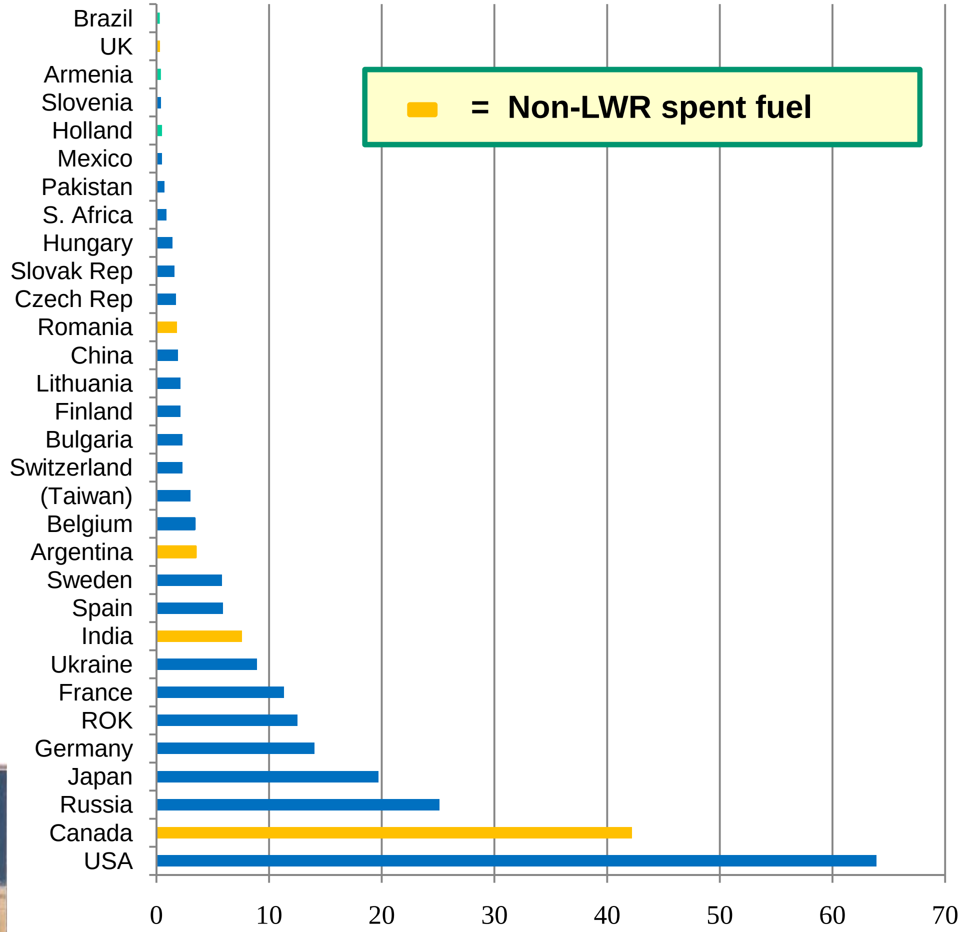
** UCRL-JC-151485, LLNL, May 2003.

Growing Spent Nuclear Fuel Inventories

- Worldwide: >250,000 tons in 2010, grows by ~10,000 MT/yr
- US: ~64,000 tons in 2010, grows by ~2,000 MT/yr
- Stored on-site or away-from-reactor, in wet storage pools or day casks


Spent fuel storage pond





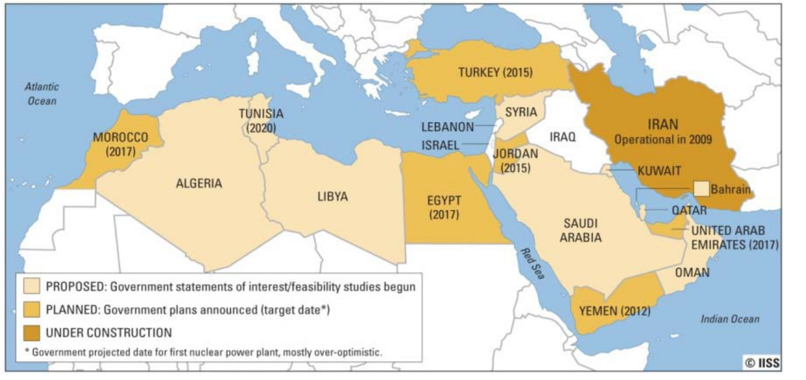
Estimated Global Spent Fuel Inventory (1000 tonHM) in 2010

Countries with small spent fuel inventory may need help in managing their spent fuel – Can multilateral/regional storage be a viable option?

Non-proliferation Implications

Spent fuel in newcomer countries

- Countries in less-stable region of the world are interested to build nuclear reactors
- Leverages on spent fuel produced in these reactors are limited*



Separating Plutonium

- Purex reprocessing is not as technically restrictive as enrichment. It takes 3 months to separate plutonium from spent fuel (could be shorter under some conditions)
- Process equipment/chemicals can be readily available, making export controls difficult

* The 123-agreement between UAE and the US stipulated that spent fuel could be shipped to Europe for storage and reprocessing with return of HLW (but not plutonium)

A New Approach

- Secure and draw down the excess weapons-usable materials
- Cooperate and coordinate on nuclear security (materials & facilities)
- Provide economically-competitive nuclear power with assurance of reliable fuel supply, and perhaps, spent-fuel take-back/take-away
- Reduce the “proliferation and spent-fuel ” burden for countries wanting only nuclear electricity generation
- R&D of advanced partitioning technologies to treat and dispose the long-life and problematic radionuclide in spent fuel

Secure and Reduce excess Pu and HEU

- The US and Russia signed on 8 April 2010 the new START to reduce their numbers of deployed nuclear weapons by 30%
- The US and Russia signed on 13 April 2010 to disposition 34 tons of WG-Pu each, starting in 2018
- The US and Russia signed a “Megaton-to-Megawatt” agreement in 1993 to down-blend 500 tons of Russian HEU to LEU for use in western reactors. The agreement will end in 2013
- The US started a “Reduced enrichment in research & test reactor (RERTR)” in 1978 to reduce the use of HEU in research reactors (RR)
- The US takes back spent HEU fuel from US-origin RR and continue to help repatriate HEU from less-secured sites to their points of origin
- 47 countries pledged in the Nuclear Security Summit on 13 April 2010 to secure, account for, and consolidate nuclear materials in their countries

International Cooperation on Nuclear Security

- Since 11 September 2001, the US nuclear industry has enhanced security at nuclear plants requiring extensive security measures in place to protect the facility from intruders

- IAEA Nuclear Security in Numbers*
  - Training: 400 workshops/courses provided to 120 States
  - Field visits: 200^{+} conducted at > 350 sites
  - Radioactive materials: 4700^{+} sources secured in > 35 States
  - Radioactive sources: 170^{+} repatriated to supplier States
  - Research reactor fuel repatriated: 1040^{+} kg
  - Physical protection upgrades: 100^{+} sites in 30 States
  - Detection equipment: 3000^{+} instruments to 55 States

- 47 countries attending the Nuclear Security Summit on 12-13 April 2010 have committed to maximize security for nuclear materials in 4 years, bringing all relevant conventions into force and continuing the peaceful use of nuclear energy

Ref.: www.iaea.org

Reliable Fresh Fuel Supply

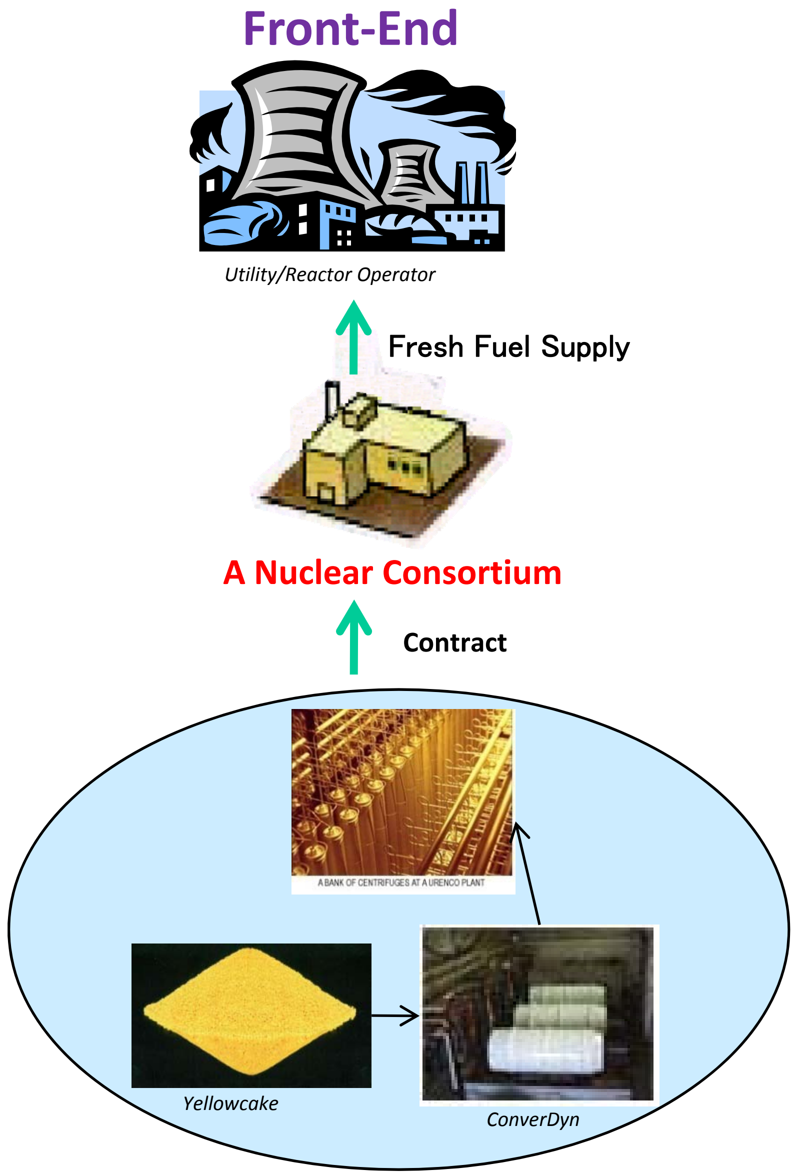
A packaged deal for front-end fuel-cycle services

- Becoming a norm:

  The customers (utilities) now prefer a packaged deal for front-end fuel services

- Driven by market demand:

  A joint venture to manufacture nuclear fuel from Kazakh uranium using Areva technology and sell it to the Asian market as an integrated product*

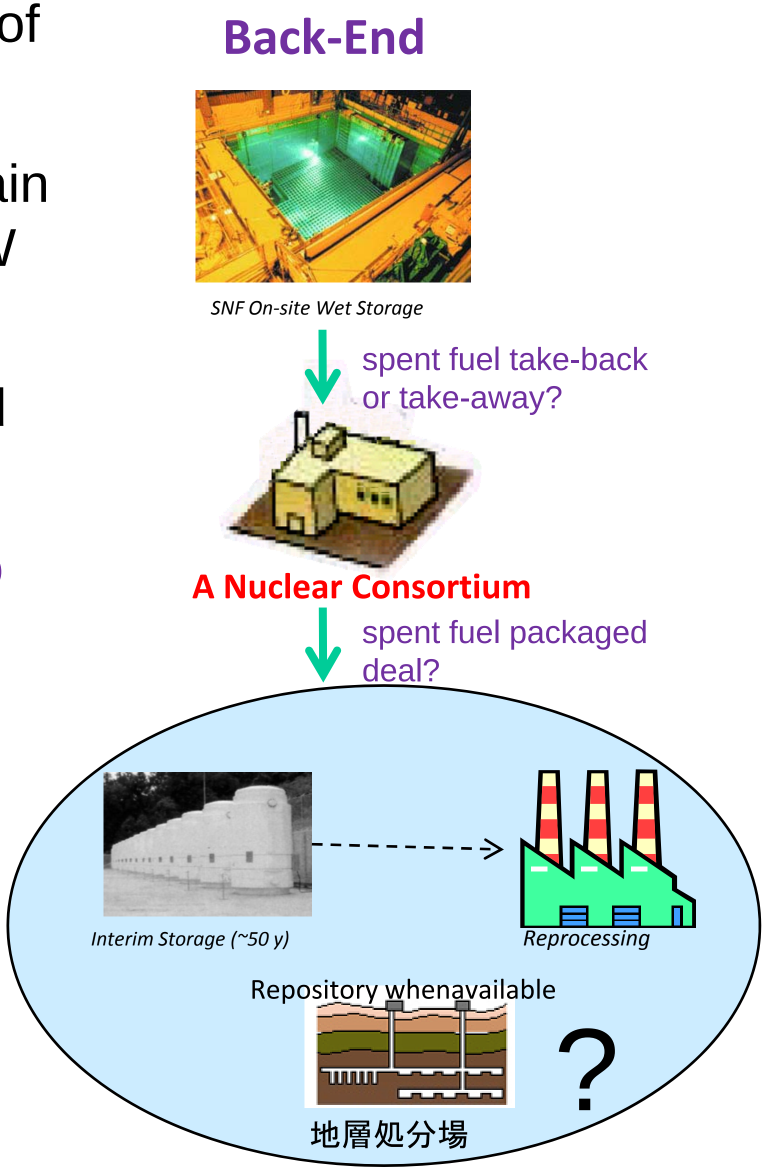


Reliable fuel supply by market mechanism can reduce/eliminate incentives for national enrichment

Ref.: "One-stop fuel shop coming for Asia", World Nuclear News, 10/6/09.

Spent Fuel Storage and Waste Management

- Geologic disposal is needed regardless of open or close fuel cycle
- The termination of the US Yucca Mountain has significant ramification for other HLW repository efforts around the world
- Sweden and Finland are moving forward on their repository programs
- Regional spent fuel storage is needed to allow for spent fuel take-back/take-away services
- Can nuclear weapons states help?
- Can major uranium producing countries help?



Environmental Burden and Sustainability

- PUREX was originally developed to recover plutonium for military purpose, not intended for reducing long-term environmental burden of spent fuel
- Advanced partitioning technologies should be developed to treat and dispose the problematic & long-life radionuclide

Reducing Environmental Burden

Item	Spent Fuel Content	Wt%	Possible Disposition Methods
1	Uranium	95.6	Reused in reactors or disposed of in uranium mines
2	Stable short-lived radionuclide	3.0	Pose no major disposal concern, disposed of as LLW
3	TRU (Np, Pu, Am, Cm)	1.0	Reused in reactors
4	Radioactive and heat producing radionuclide, e.g., cesium (Cs) and strontium (Sc)	**0.3**	Separated and decay away in 300 years, or disposed of in deep boreholes with long-life radionuclide (^{135}Cs and those in item 5)
5	Long-life radionuclide, e.g., ^{129}I, ^{99}Tc, ^{237}Np	**0.1**	Separated and disposed of in deep boreholes

Spent Fuel Treatment with Advanced Partitioning

- ^{129}I can be collected as silver iodine (AgI)
- ^{99}Tc can be separated
- Uranium can be separated and recycled
- TRU and cesium/strontium can be collected together, and the high radiation of Cs/Sr can provide self-protection
- At appropriate time (e.g., fast reactors are economically viable), TRU can be separated from Cs/Sr for recycled
- AgI, ^{99}Tc, and Cs/Sr can be encapsulated and disposed of in deep boreholes*

Foot-print of deep boreholes can be very small, could eliminate the NIMBY** problem for permanent disposal of long-life radio-nuclide – R&D is needed to study the deep-borehole concept

* An example of encapsulation is the a technology known as hot iso-static pressing (HIP) developed by ANISTO, Australia making the waste form small and long-lasting, like a Synroc. Also, the deep borehole concept was previously studied for disposition of weapons-grade plutonium by LLNL, USA.

** NIMBY – Not in my backyard

Possible Outcome

- Newcomer countries have access to nuclear power and reliable fuel supply at market prices
- Spent fuel from less-stable region of the world could be taken-back/ taken-away on a contractual and time basis
- Spread of enrichment/reprocessing technologies* minimized or eliminated
- Spent fuel treated by advanced partitioning process with the long-life and problematic radionuclide disposed of in deep boreholes
- Allow expanded use of nuclear energy with reduced proliferation/ security risks and lessened environmental/waste burden

* This is not a restriction to a country's own fuel cycle development.
- It is an option to reduce the proliferation, security and environmental risks.
- If a country decides to develop its own enrichment or reprocessing, it will have to deal with the proliferation and security issues and conform to international safeguards, safety, and security (3S) standards.