Backend
proliferation risks
and issues

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Overview

- efficiency vs proliferation risk
- institutional / technical measures
- Pu recycle using LWR
  - MOX
  - PUREX
- Pu recycle using fast reactors
  - electro-processing
- Pu recycle without reprocessing
  - DUPIC
- fast reactors and GEN IV
- concluding comments
Efficiency vs Risk

- once through – inefficient
- reprocessing & use of MOX
- recycle & use of fast reactors
  - can increase the efficiency of resource usage
- BUT
  - risks associated with the spread of separated plutonium in the civilian sector.

Core of CROCUS, a research reactor, Switzerland.
Institutional vs Technical Measures

Institutional
- treaty level peaceful use commitments – NPT
- verification – IAEA safeguards
- national controls
- Nuclear Suppliers Group
- Additional measures
  - fuel assurances
  - multi-lateralise enrichment/reprocessing

Technical
- avoid production of weapons grade material
- ensure nuclear material is difficult to access
- avoid separation of plutonium
Plutonium – physical and chemical forms
Plutonium recycle using light water reactors

- Stockpiles of separated Pu - managed using recycle of MOX in existing power reactors
  - about 30 thermal reactors in Europe
  - over 25 years.
  - no major incident or problem of safeguards or security significance.
  - material accountancy, control and physical protection do require special attention.
- MOX not directly weapons usable
- Disadvantage
  - relatively simple to re-dissolve MOX and separate out plutonium.
- an ongoing concern
  - i. the risks in the civil use of a potentially weapons usable material
  - ii. the number of countries operating MOX fabrication facilities.
Schematic material flow for MOX cycle

Reprocessing

- Spent LEU fuel to reprocessing
- Spent LEU processed to separated Pu, U and fission products
- Separated Pu mixed with DU to form MOX
- Fission products stored as waste, recovered U stored as waste or re-enriched
- MOX fabricated into fuel assemblies

Reactor Pu balance

- Fresh LEU fuel to reactor, two thirds of core
- During irradiation Pu content of MOX drops Pu content of LEU rises
- Fresh MOX fuel to reactor, one third of core
- Spent LEU contains Pu, after starting with zero
- Spent MOX contains less Pu than fresh MOX
- Net change in Pu inventory approx zero

- Spent MOX contains less Pu than fresh MOX
PUREX pulse columns

- PUREX process well established and effective
  - but its spread among NNWS is undesirable
    - primarily designed to separate pure plutonium product
    - (incorporated into MOX)
- Re-design to ensure that plutonium is co-precipitated with uranium or a mix of minor actinides
  - but still possible to get pure plutonium with additional processing
  - product of this process has low radioactivity
    - remains a proliferation concern
    - requires intensive effort on the part of the IAEA to safeguard.
Plutonium recycle using fast reactors

- Electro-processing produces a product that retains substantial amounts of fission products.
- The fuel, suitable for use in fast reactors, is hotter and harder to handle than the equivalent PUREX product.
  - confers a significant degree of non-proliferation assurance.
  - however, this material still poses some proliferation risk.
    - PUREX processing could separate the Pu from the remaining fission products and actinides.
    - much less waste to process.
Plutonium recycle without reprocessing

- **DUPIC** process recovers some of the residual fissile value of PWR spent fuel by incorporating the spent fuel into CANDU fuel without reprocessing.

- A dry processing technology is being developed to remove only the volatile fission products from the spent PWR fuel mix.
  - After removal of the cladding, a thermal-mechanical process (crushing in an oxygen atmosphere) is used to reduce the spent fuel pellet to a powder, which is then sintered and pressed into CANDU-sized pellets.

- Simpler than conventional wet-chemistry techniques for reprocessing

- Significant non-proliferation benefit as radioactive fission products and fissile material are not separated.
Fast Reactors (i)

- do not have a moderator
  - utilise fast neutrons
- generate power from Pu
  - while making more of it from the U-238 in or around the fuel
- get more than 60 times as much energy from the original uranium
  - compared with normal reactors
- But
  - expensive

Monju
Fast Reactors (ii)

- Can be designed and operated in the following modes:
  - consume more Pu than they produce – termed a “burner” reactor;
  - produce same quantity of Pu as consumed – an equilibrium core; or
  - produce more Pu than they consume – termed a “breeder” reactor.
- Burning mode - to consume Pu, minor actinides and long lived fission products
- Breeder mode of direct proliferation concern if a fertile “blanket” used
  - Pu produced in fast breeder reactor blankets - very high proportion of the isotope Pu-239
  - producing weapons grade Pu + reprocessing
  - presents obvious proliferation concerns.

Fuel bundle for MONJU
Six reactor types have been selected for development under GIF –

- 3 are fast neutron reactors and one can be operated as a fast reactor
- the fast breeder design has been replaced by fast neutron reactors where there is no breeding blanket
  - Pu production in the core where burn-up levels very high
  - less attractive for explosive than Pu produced in LWR
- advanced spent fuel treatments (electro-processing) are being developed, to enable plutonium to be recycled without separation
Concluding Comments

- Once through – inefficient + potential future problems
- Current reprocessing technology gives a state the capability to separate Pu for military use, if it decides to abrogate peaceful use commitments.
- Plutonium recycle conducted without plutonium separation has non-proliferation advantages
  - fast reactors + advanced spent fuel treatments (eg electro-processing) could make current aqueous reprocessing technology obsolete in the future.
- There is no magic bullet to eliminate all proliferation risk – no nuclear fuel cycle is completely proliferation proof
  - but a combination of institutional and technical measures can provide a degree of non-proliferation assurance.