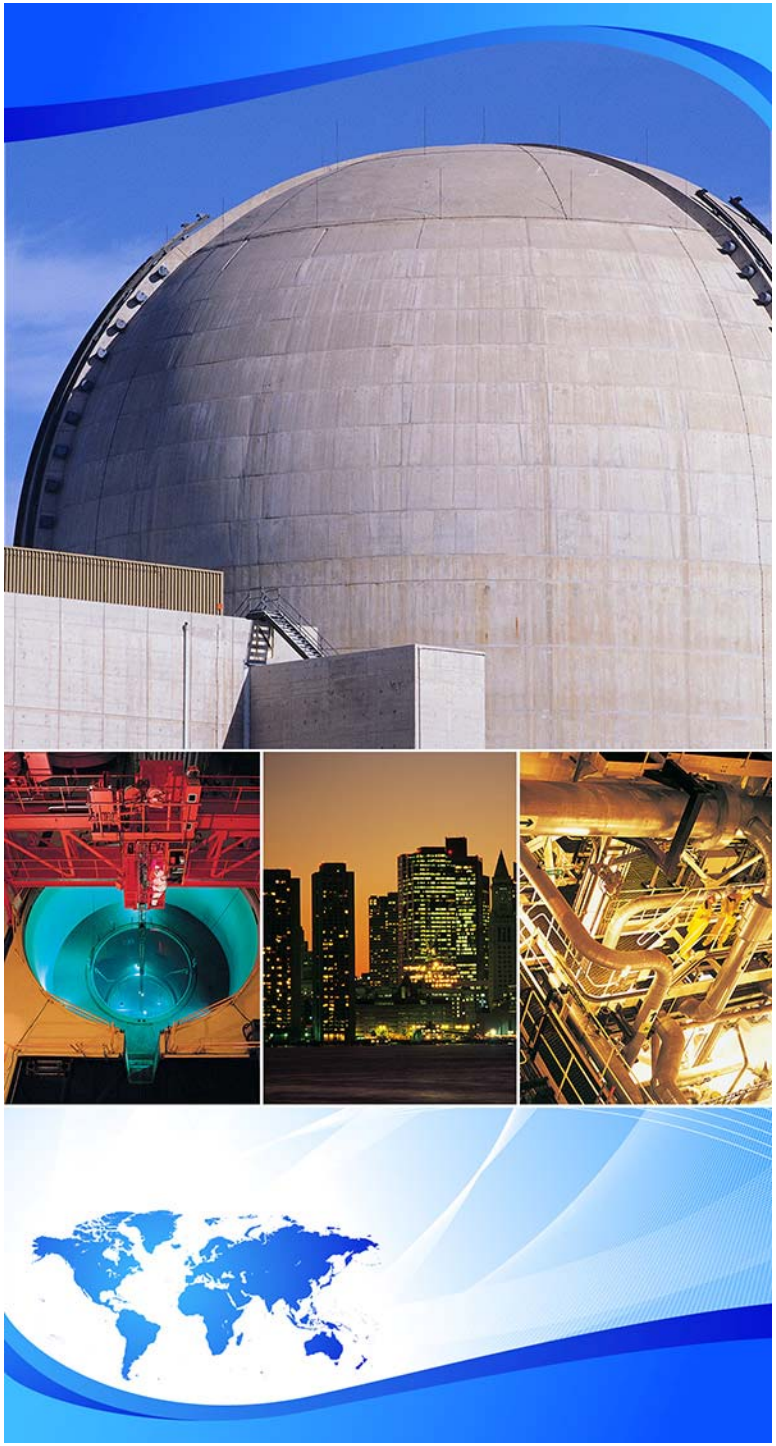

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Alternative Approaches

Fusion-Fission Workshop
September 30 – October 2, 2009
Gaithersburg, Maryland

Albert Machiels
Senior Technical Executive

Topics

- The Nuclear Fuel Cycle Simplified
  - Light-Water Reactor (LWR) Power Block
  - Managed Storage
  - Fast Breeder Reactor (FBR) Power Block
  - Geologic Disposal
- Conclusion/Discussion

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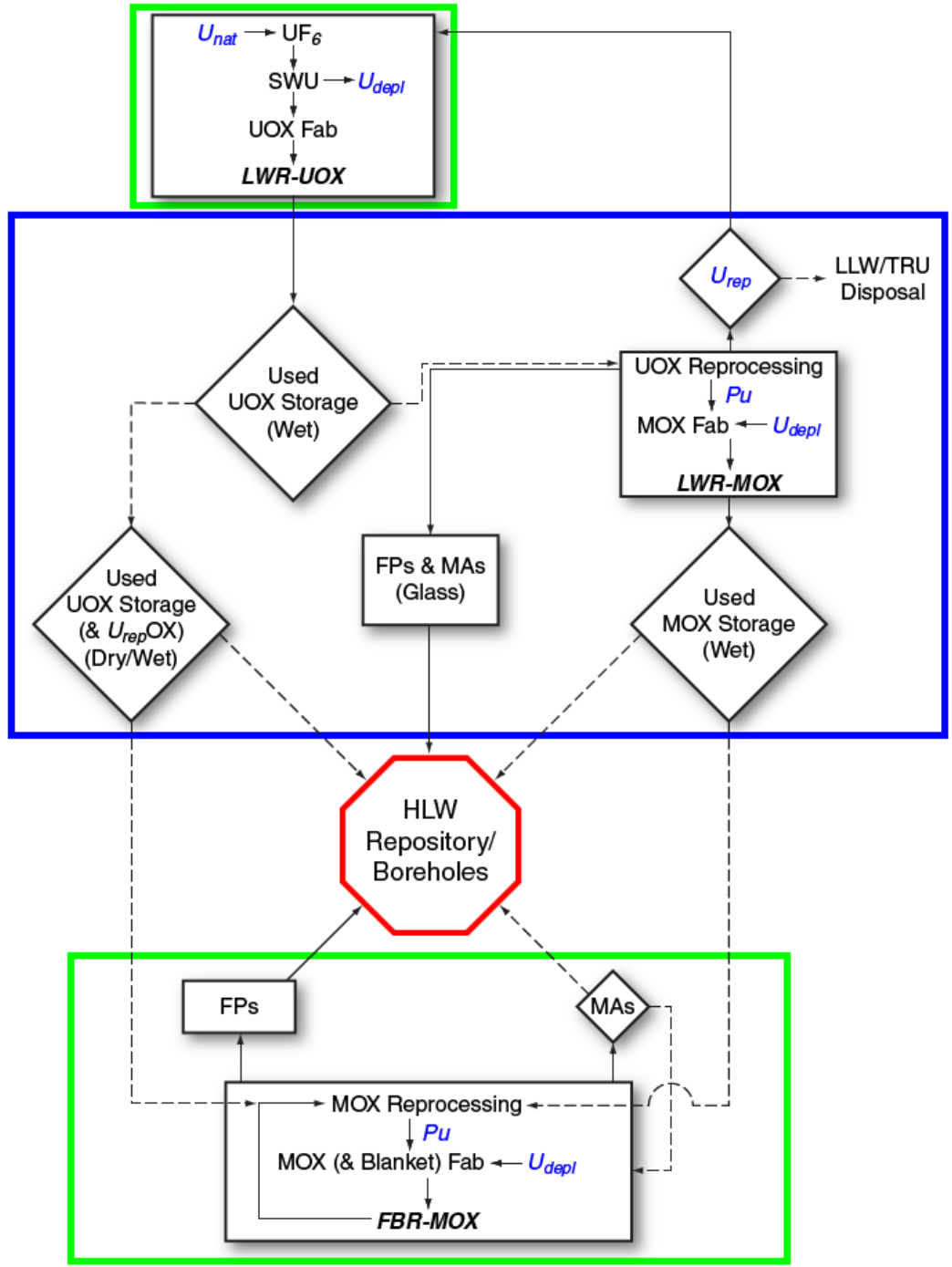

LWR Power Block

Managed Storage

Geologic Repository

FBR Power Block

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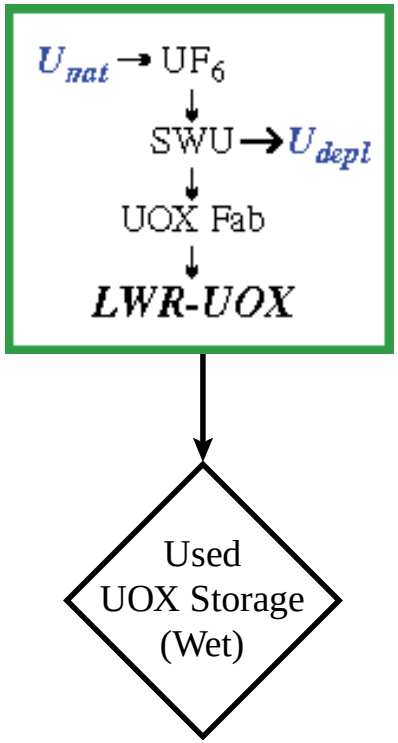
LWR Power Block: U-235 (0.711% of U_{nat}) Energy



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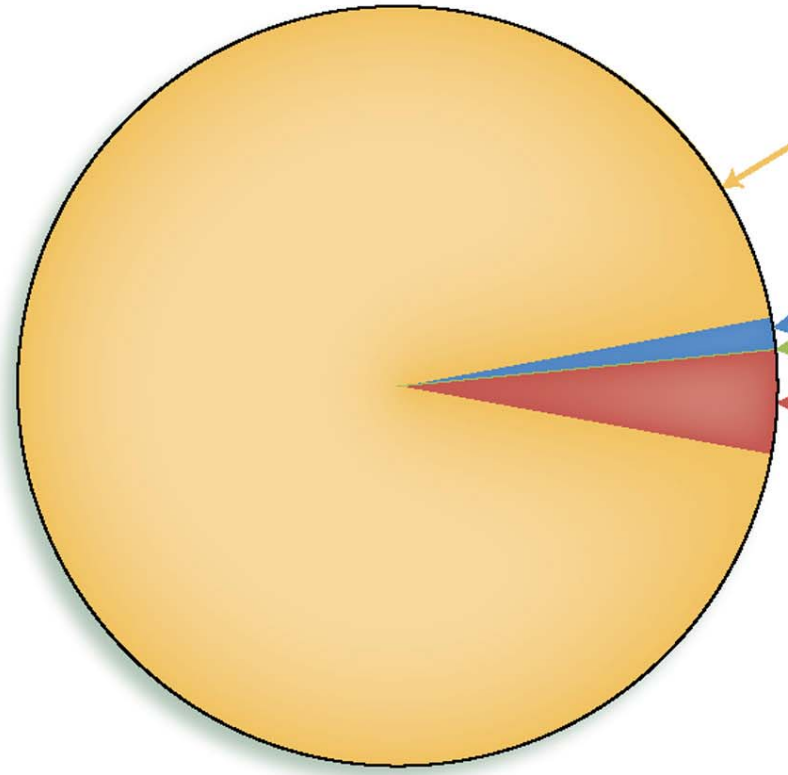
Used LWR Fuel – Waste or Resource?



Uranium ~94%

U-235	~0.7%
U-238	~93%

Plutonium ~1%

Pu-238	0.04%
Pu-239	0.7%
Pu-240	0.3%
Pu-241	0.2%
Pu-242	0.1%

Minor Actinides ~0.1%

Np-237	0.07%
Am-241	0.03%
Cm-244	0.01%

Fission Products ~4–5%

Sr-90	0.1%
Cs-137	0.2%
I-129	0.03%
Tc-99	0.1%

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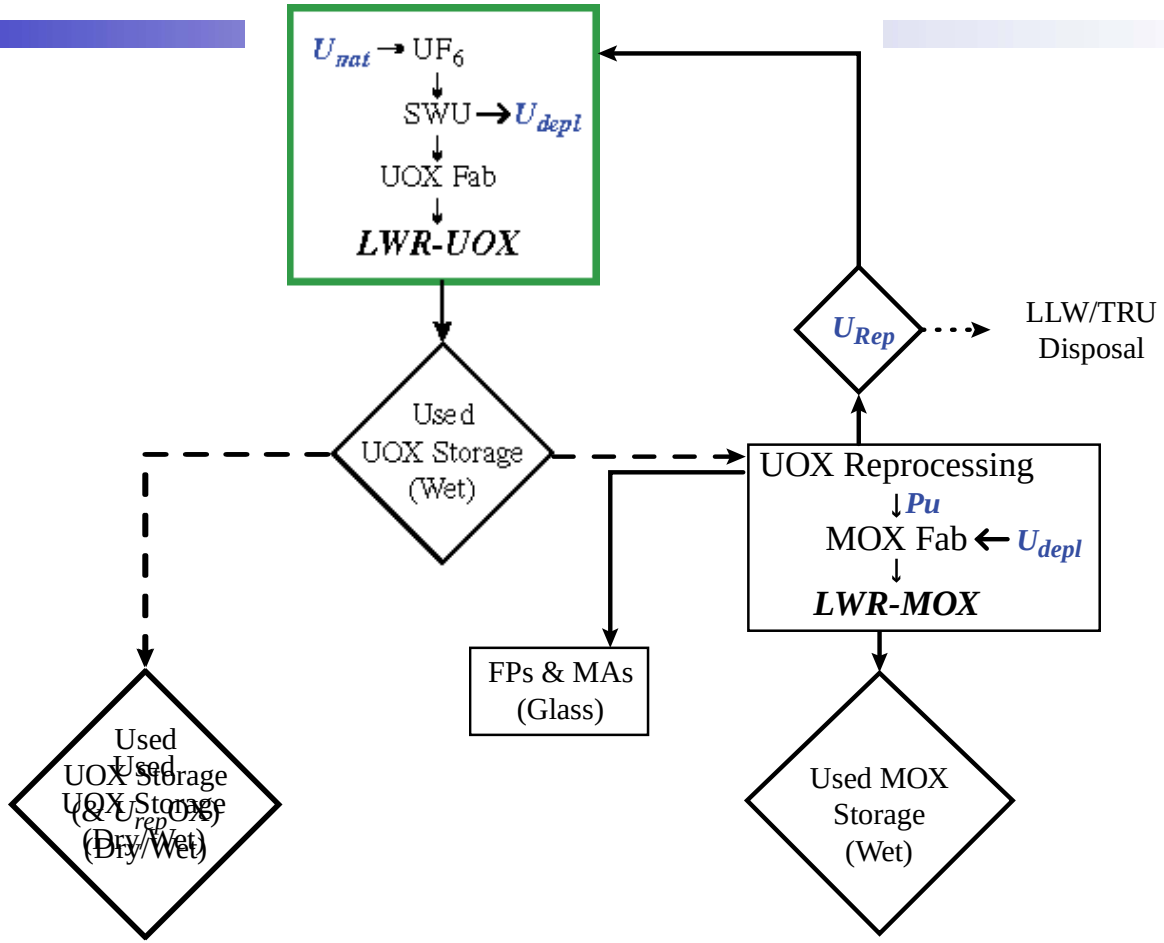
“Managed Storage”



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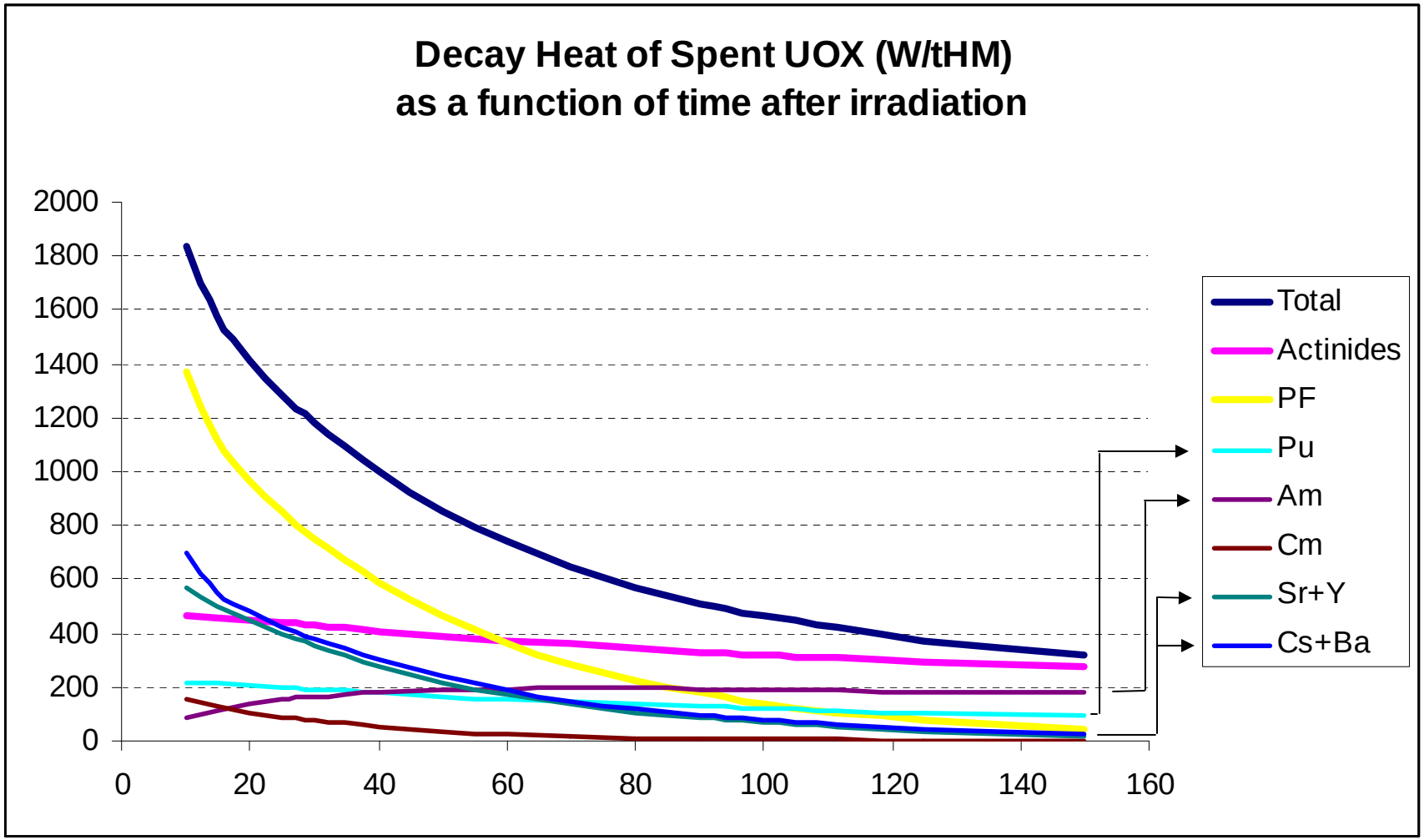
Decay Heat from Used UOX Assemblies



Source: EDF (July 2009)

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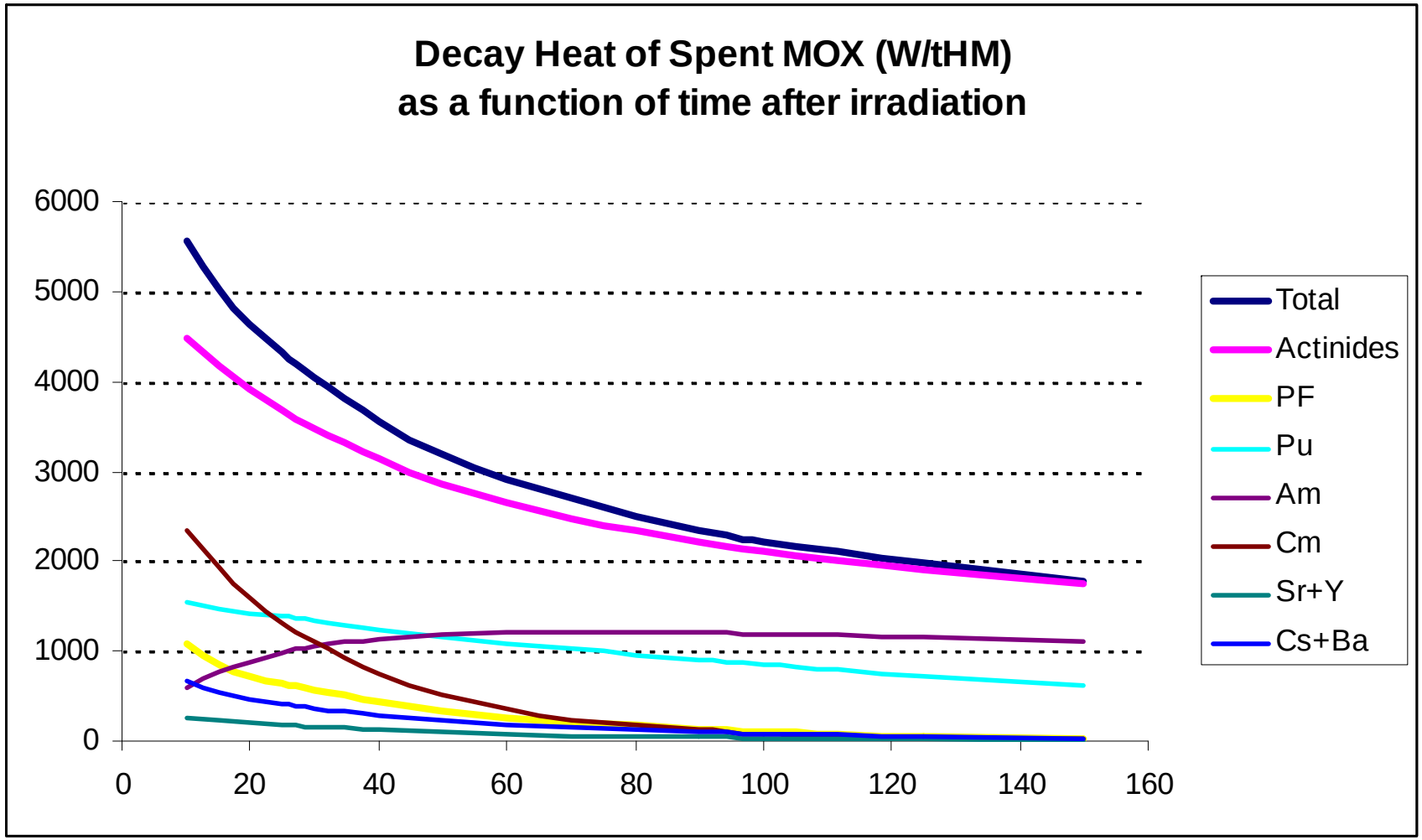
Decay Heat from Used MOX Assemblies



Source: EDF (July 2009)

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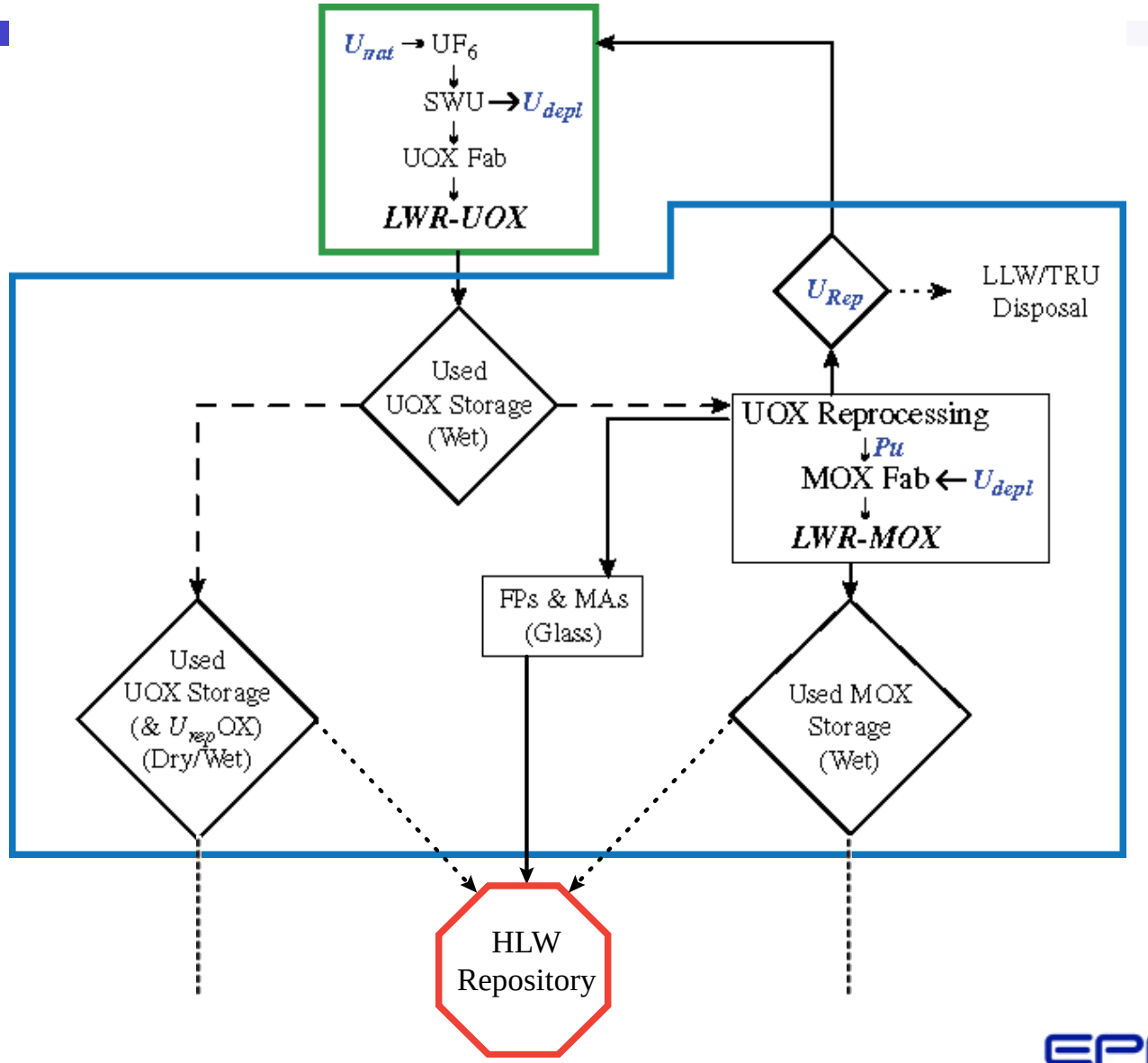
"Once-Through" Cycles



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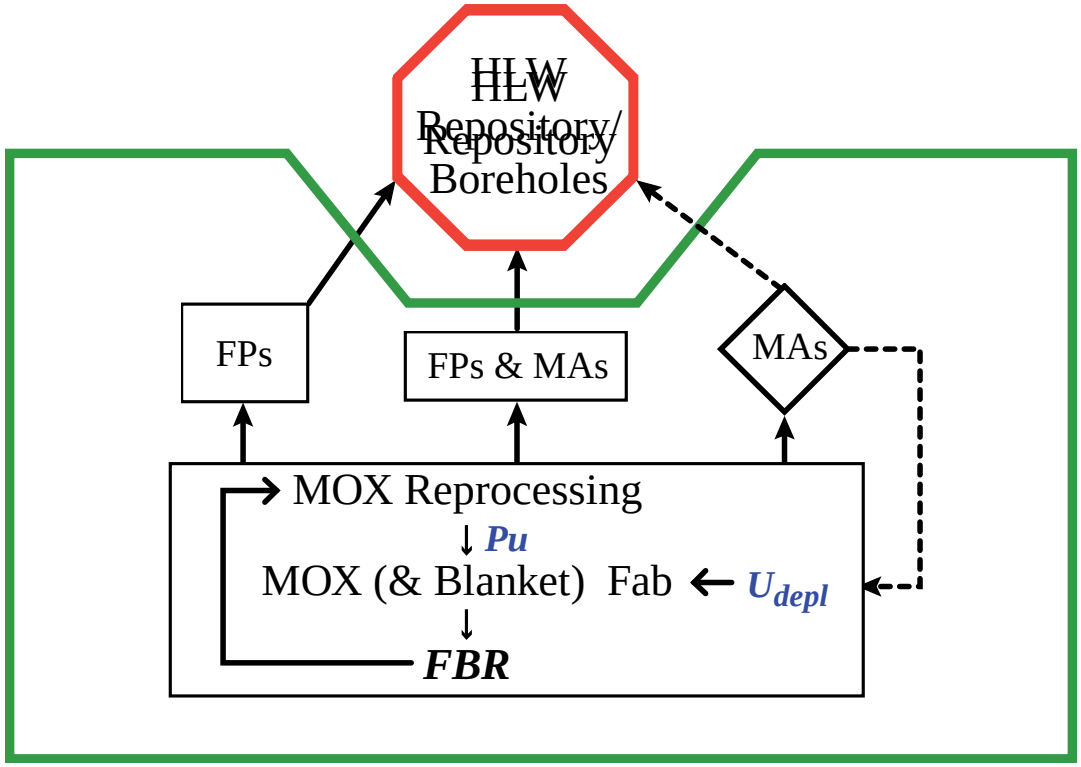
FBR Based Fuel Cycles "Burn" 238 (99.28% of U_{nat}) Energy



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International Developments

- Russian Federation
  - BN-600 [1470 MWth]: operating since April 1980
  - BN-800: under construction with planned start-up in 2016
- China
  - China Experimental Reactor (CEFR) [65 MWth]: first criticality planned in 2009
- Japan
  - Monju reactor: shutdown since 1995 following sodium leak
  - Expected to re-start by the end of March 2010
- India
  - 500-MWe Prototype Fast Breeder Reactor (PFBR): under construction at Kalpakkam
  - First criticality by the end of 2010

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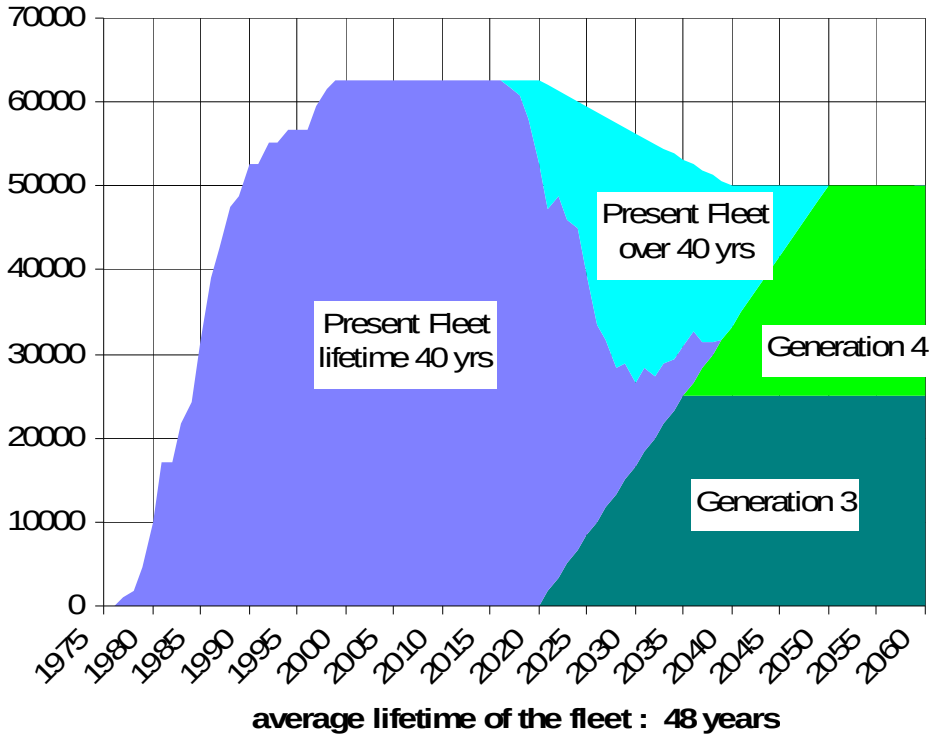
International Developments (continued)

- France
  - Two designs: Helium- & Sodium-cooled fast reactors
  - Progress report due Fall ’09
  - Preliminary design due in ‘12
  - Detailed design due in ‘15
  - Operating prototype in ‘20
  - Planned introduction of first unit in EDF fleet: during ’40-’50 decade



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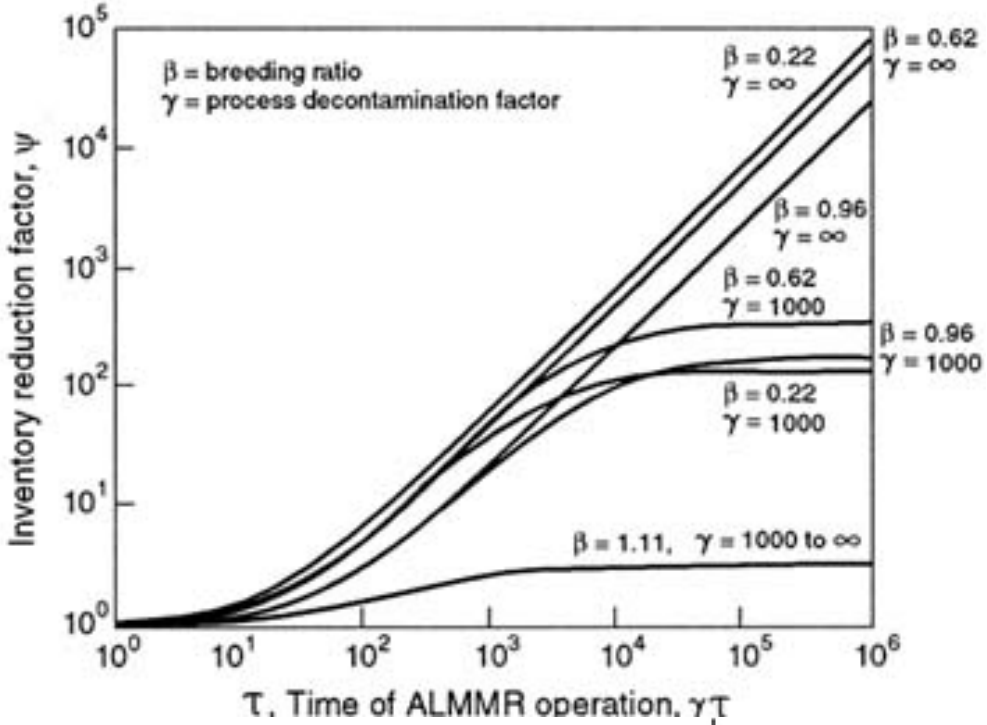
Geologic Disposal

- Visible progress: Finland, Sweden, and France
- Technical issues: not the dominating factors
  - Societal acceptability and political stability (continuity of decisions) dominate!
  - 1996 NAS Report: *"No evidence that applications of advanced S&T have sufficient benefit for the U.S. HLW program to delay the development of the first repository for commercial spent fuel"*



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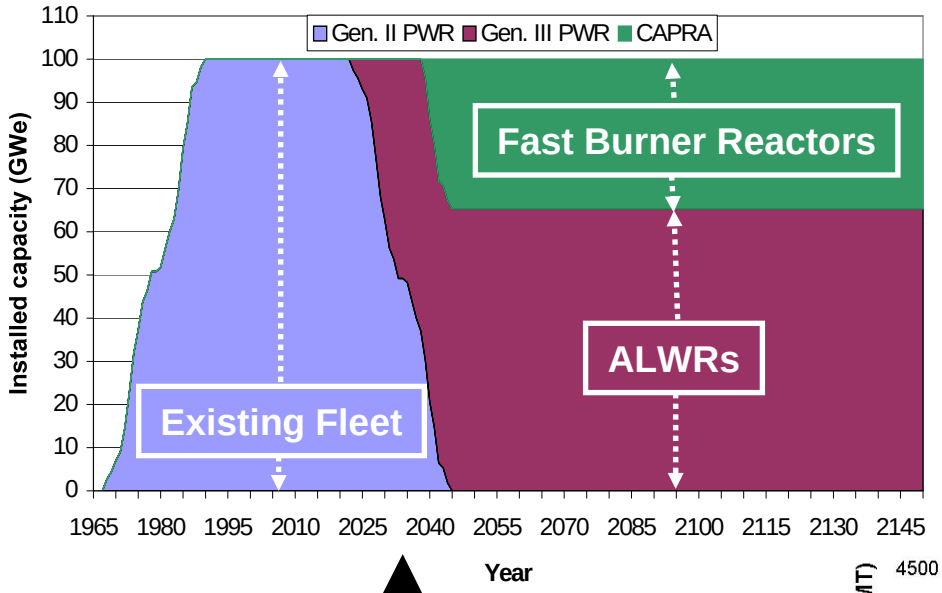
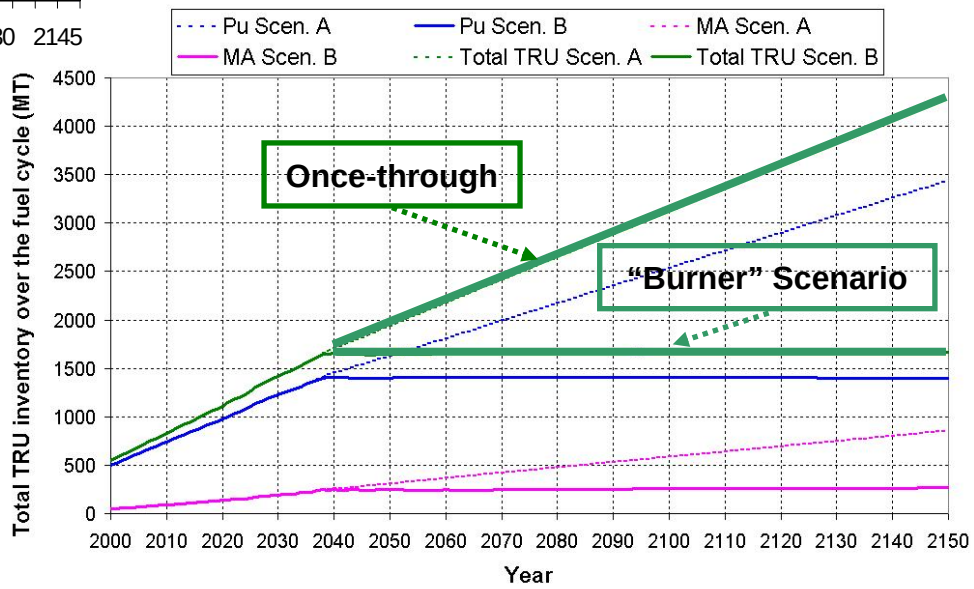
Cooperation with EDF R&D – Nuclear Fuel Cycle Simulation Tools



From ~2040 on:

- "Once-through" fuel cycle continues build-up of spent fuel (→ repository)
- "Burner" scenario results in a stabilization of the TRU inventory that is continuously recycled



"Burner" Scenario: Assume constant 100 GWe

- After 55 years of operation, existing reactors are first replaced by ALWRs
- When capacity of ALWRs reaches 65 GWe, existing reactors are then replaced by fast burners reactors with a conversion ratio of 0.5 (or CR = 0.5)

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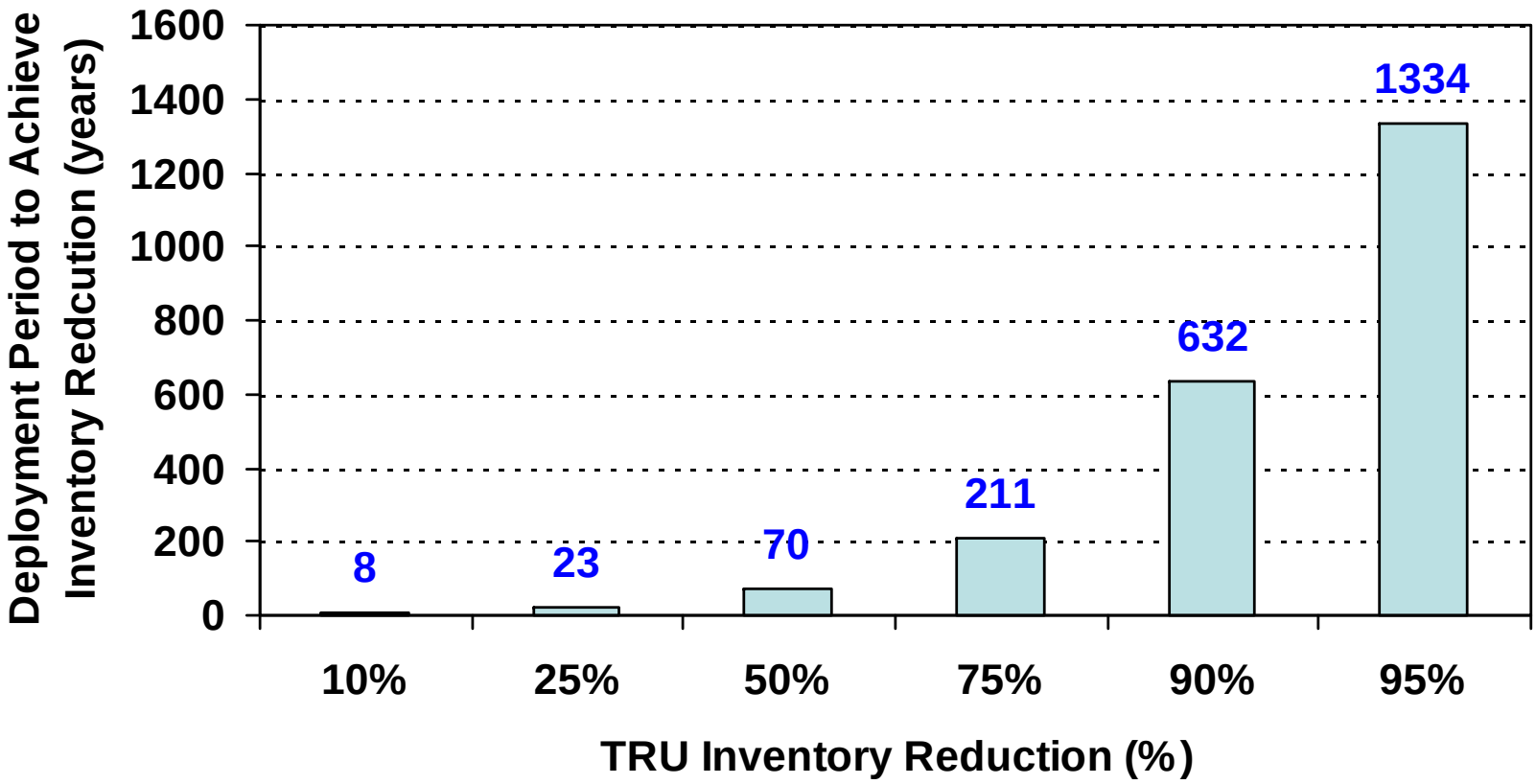
Time Required to Achieve TRU Inventory Reductions



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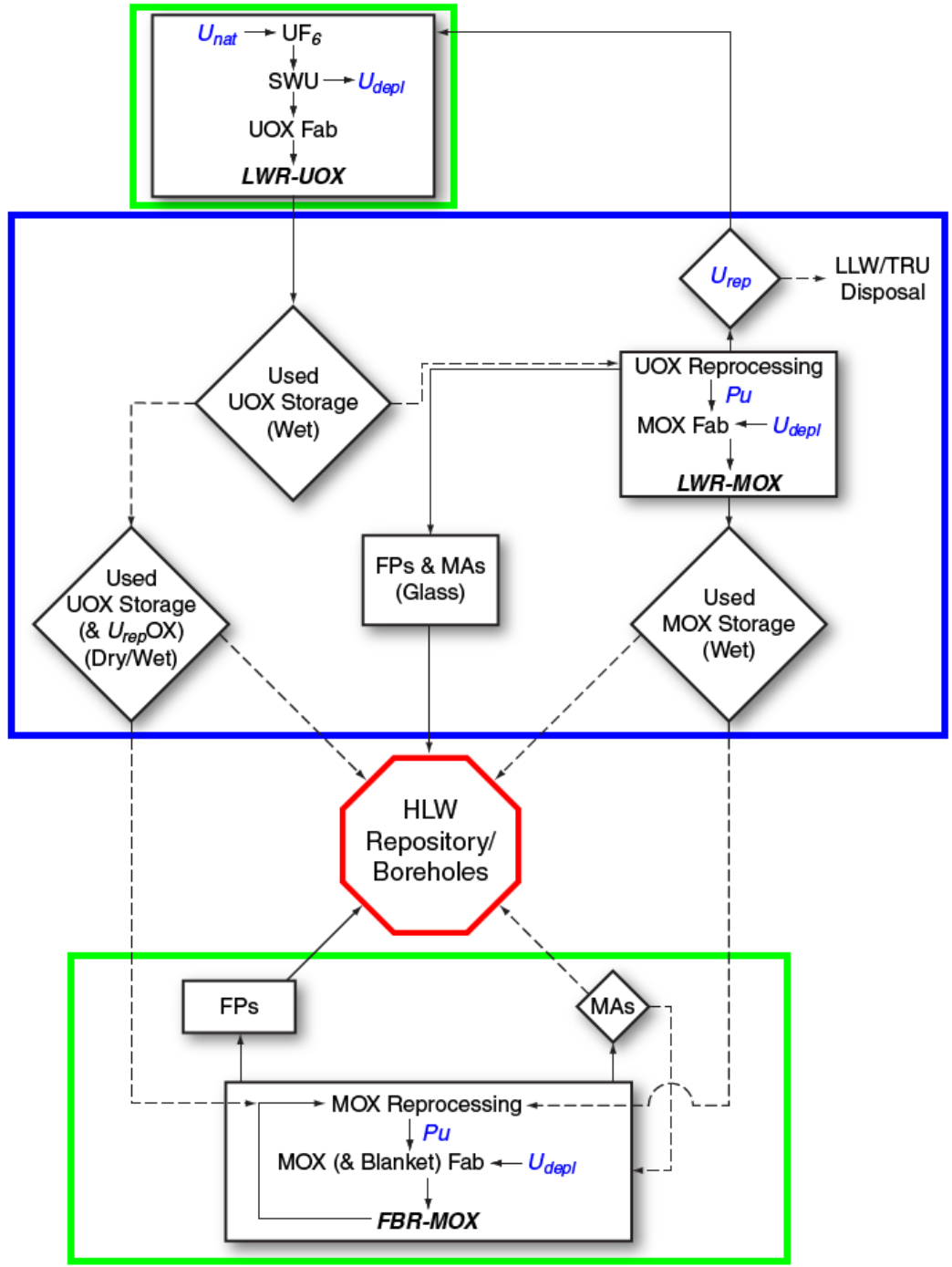

LWR Power Block

Managed Storage

Geologic Repository

FBR Power Block

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Conclusion/Discussion

- LWR Power Block
  - Commercial operation
- Managed Storage
  - Commercial operation
- Geologic Disposal
  - Visible progress: Finland (spent fuel), Sweden (spent fuel), and France (HLW glass canisters)

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Conclusion/Discussion (continued)

- Advanced Technologies ("FBR Power Block")
  - Fast Reactors
    - Some experience, but inconsistent performance
    - Key: economic competitiveness, assuming continuity in present, re-invigorated RD&D programs
  - Alternative: Accelerator-Driven Systems (ADS)
    - Key: demonstrate technical feasibility
  - Reprocessing: long technological maturation
    - Reference: PUREX
  - Manufacturing/Handling/Transportation
    - Costs and constraints associated with plutonium- and minor-actinide-bearing fuels

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Conclusion/Discussion (continued)

- The primary goal is production of electricity
  - Economics will remain the main driver
    - Cost of doing business includes safety and security
- Complete advanced fuel cycle (fast reactor, reprocessing, fuel fabrication) may be possible by mid-century
  - Issue: Industry engagement (French model)
- The true competition – Advanced Light Water Reactors
  - Proven reliability
  - Reduced concern about U availability
  - Probable success with implementation of spent fuel/HLW disposal in some countries
  - Accepted regime for ensuring low proliferation risks

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