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Joint ICTP-IAEA School of Nuclear Energy Management

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Proliferation Analysis of the Fuel Cycle

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Joint IAEA/ICTP School of Nuclear Energy Management

Proliferation Analysis of the Fuel Cycle

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SGCP Section for Safeguards Training

IAEA
International Atomic Energy Agency

Learning Objectives

- Define the nuclear fuel cycle
- Introduce key SG nuclear material definitions
- Summarize the main processes in the nuclear fuel cycle
- Understand principle nuclear material flow throughout the fuel cycle as it relates proliferation concerns
- Describe acquisition path analysis

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What is the Nuclear Fuel Cycle

- The nuclear fuel cycle consists of a series of industrial (and commercial) processes for the generation of electricity in nuclear reactors and the subsequent management of the spent fuel.

- It consists of obtaining, processing, utilizing and disposing of the fuel – the vital steps in generating electricity.

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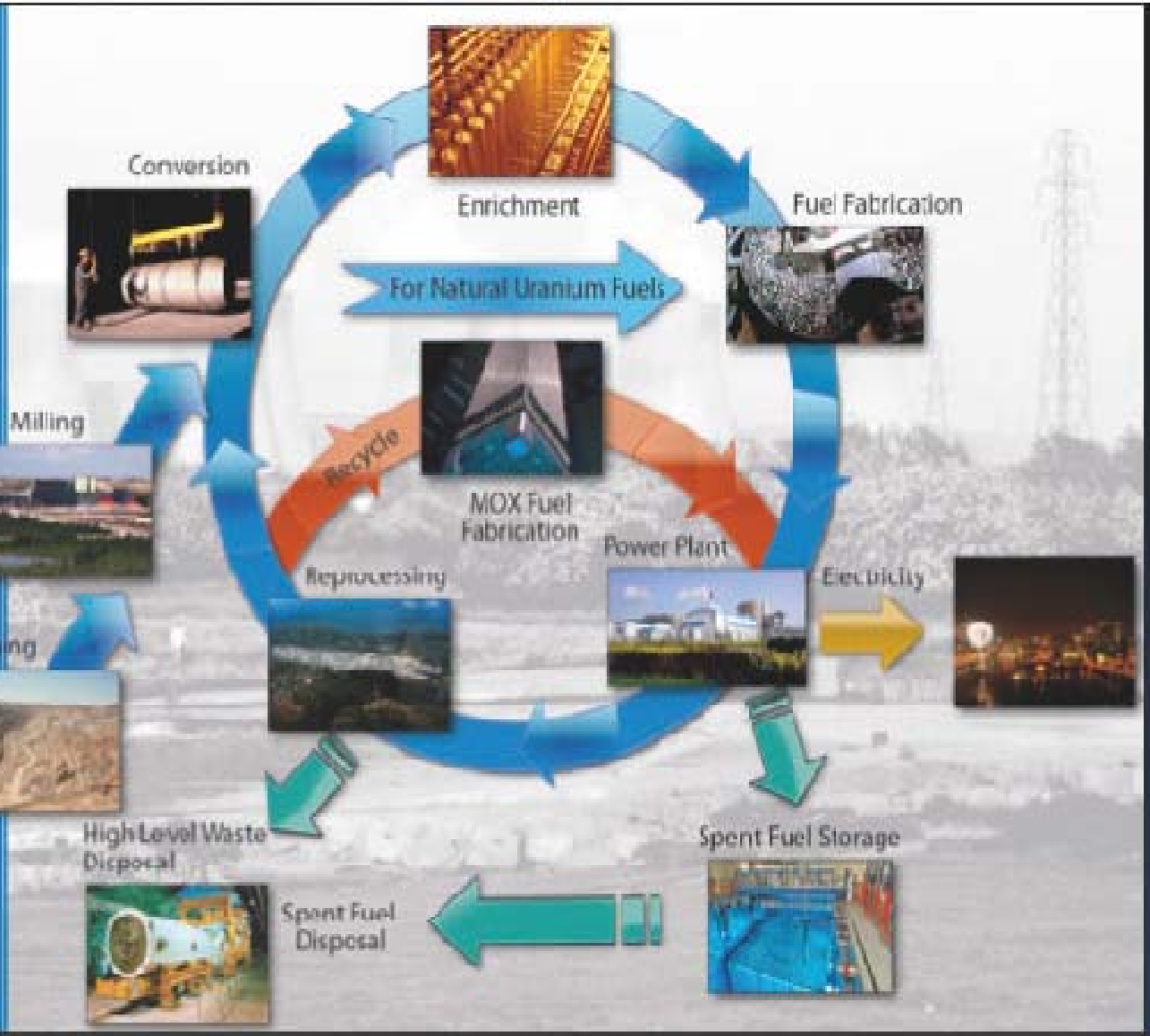
IAEA Introduction to the Nuclear Fuel Cycle

The Nuclear Fuel Cycle



The raw material for today's nuclear fuel is uranium. It must be processed through a series of steps to produce an efficient fuel for generating electricity. Used fuel also needs to be taken care of for reuse and disposal.

The nuclear fuel cycle includes the 'front end', i.e. preparation of the fuel, the 'service period' in which fuel is used during reactor operation to generate electricity, and the 'back end', i.e. the safe management of spent nuclear fuel including reprocessing and reuse and disposal.

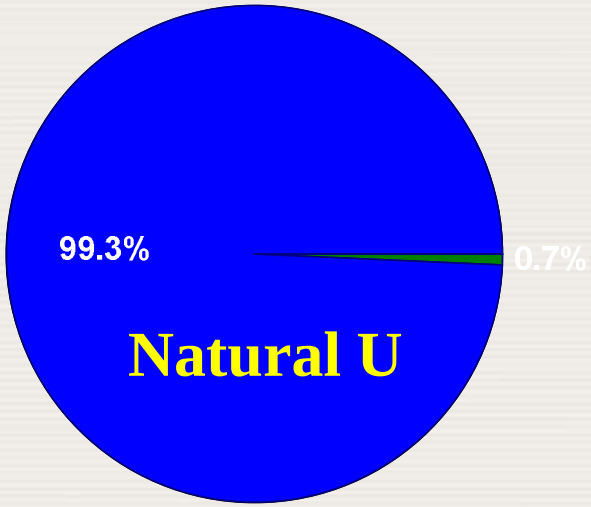
If spent fuel is not reprocessed, the fuel cycle is referred to as an 'open' or a 'once-through fuel cycle'; if spent fuel is reprocessed and partly reused, it is referred to as a 'closed fuel cycle'.

Definitions

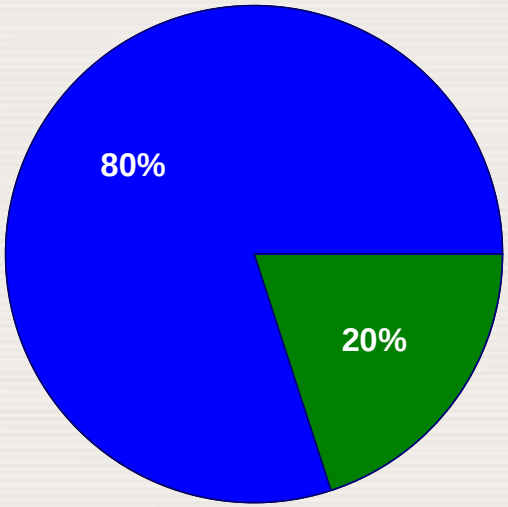
- Source material - natural uranium, uranium depleted in the isotope 235, thorium; any of the foregoing in the form of metal, alloy, chemical compound, or concentrate (IAEA Statute, Article XX.3)
- Special fissionable material - Pu-239; U-233; uranium enriched in the isotopes 235 or 233 (IAEA Statute, Article XX.1)
- Nuclear material – source material; special fissionable material (INFCIRC/153, para. 112)

Uranium

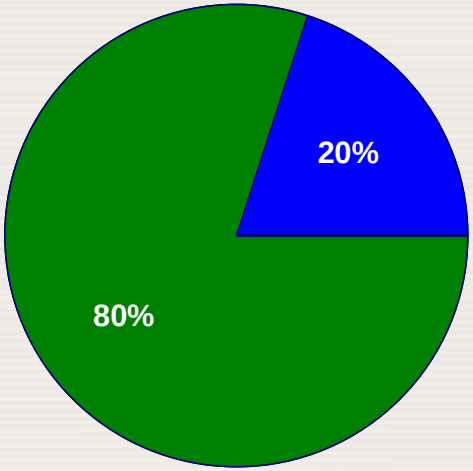
Primarily ^{238}U (99.3%)



LEU <20% ^{235}U



HEU >20% ^{235}U



- Natural U and LEU in reactors
- Only HEU is useful for weapons

Uranium is mined from the ground, processed and enriched in the isotope ^{235}U.

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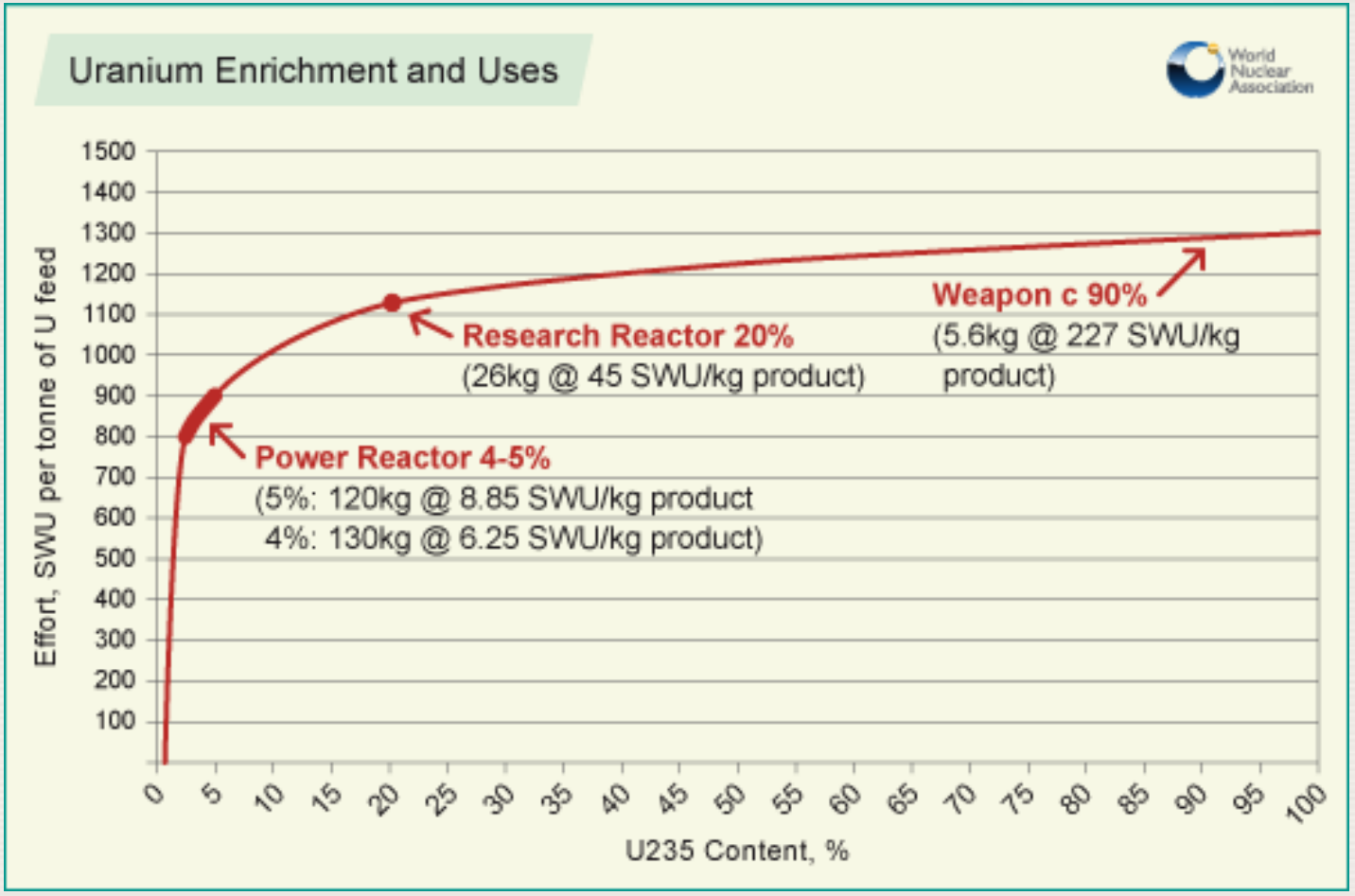
Uranium - Enrichment

Mining/Milling

Production reactor

Centrifuge R&D



<u>Concerns:</u> Undeclared Mining,
Clandestine enrichment (various technologies)

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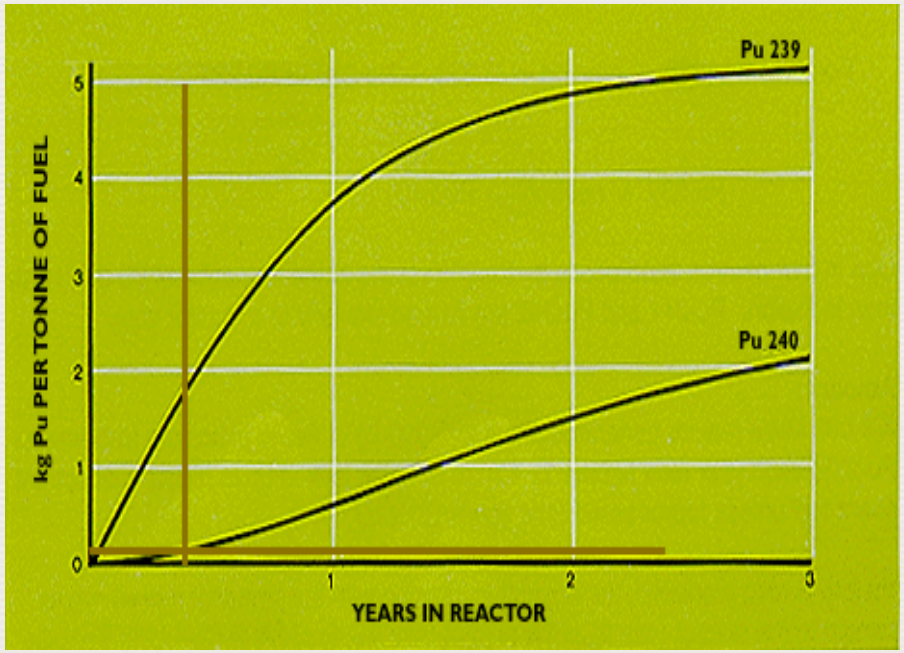
Pu: Isotopic Composition Range

Element number: 94
Chemical symbol: Pu
Half-lives: 14 yrs to 375,000 yrs

	Low Burnup		High Burnup	
^{238}Pu	0.02	0.3 →	0.8	1.6
^{239}Pu	93.5	82.5	73.3	57.3
^{240}Pu	6.2	13.8	18.3	25.0
^{241}Pu + ^{241}Am	0.3	3.8	6.6	11.7
^{242}Pu	0.04	0.8	2.1	5.6



Definitions:

- Weapons-Grade <7% ^{240}Pu or >93% ^{239}Pu

- Reactor-Grade >7% ^{240}Pu or <93% ^{239}Pu

Getting from here to there….

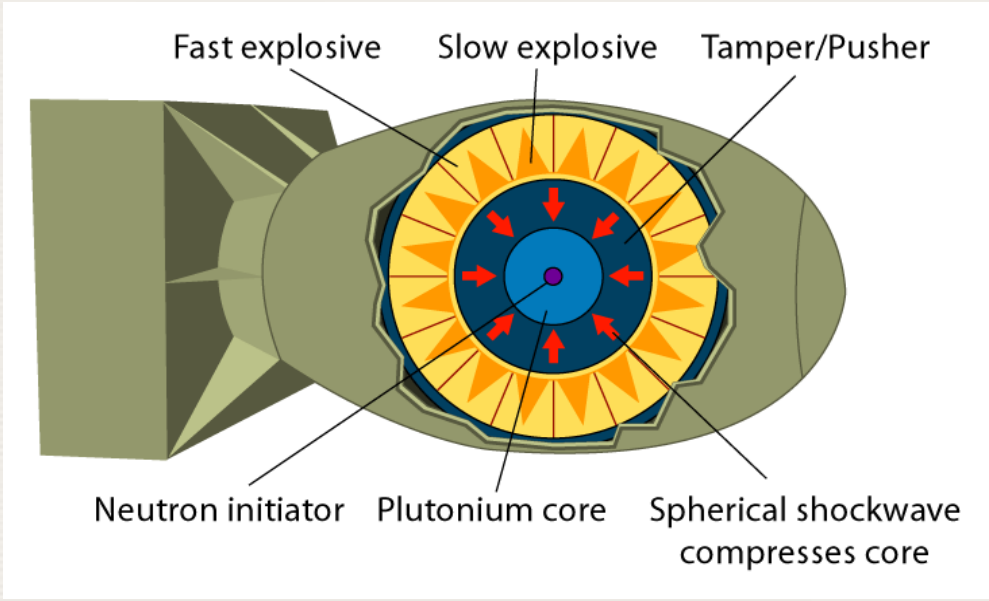
Indirect or direct use?

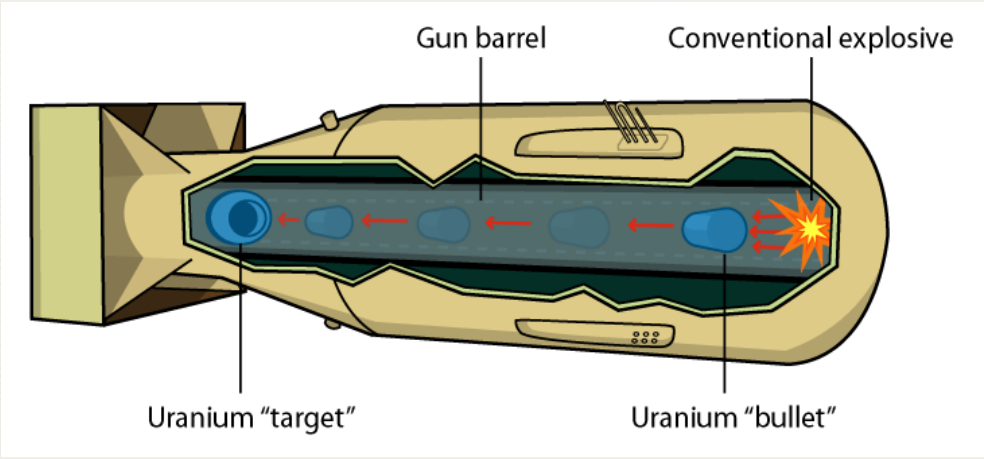
Weapons usable material

+ weaponization

+ expertise

+ technology





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Direct and indirect use

Mining/Milling

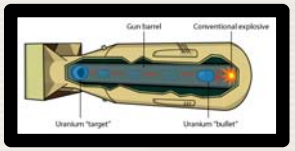
Oxides UO_2/UO_3 UF_4

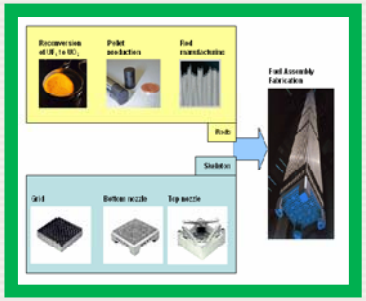
Conversion to UF6

Enrichment

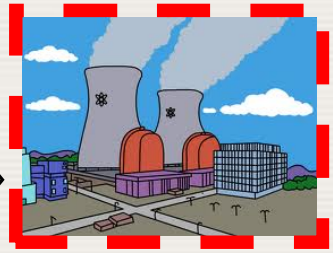
Clandestine HEU

Conversion to U Metal

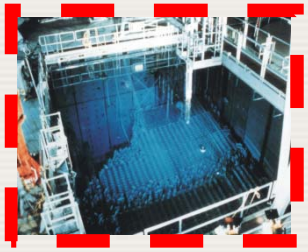




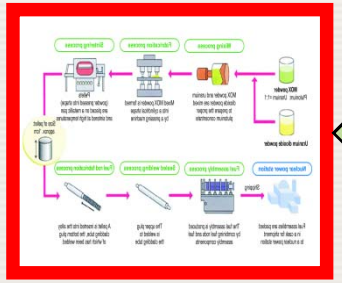
Fuel Fabrication



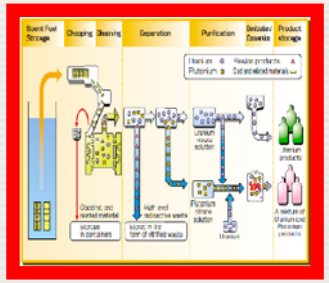
Reactor



SF Storage

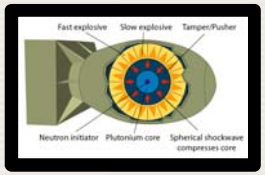


MOX Fuel Fabrication



Reprocessing/ storage of Pu & U

Conversion to Pu Metal



Indirect
Irradiated direct use
Unirradiated direct use
Diverted material

*U233

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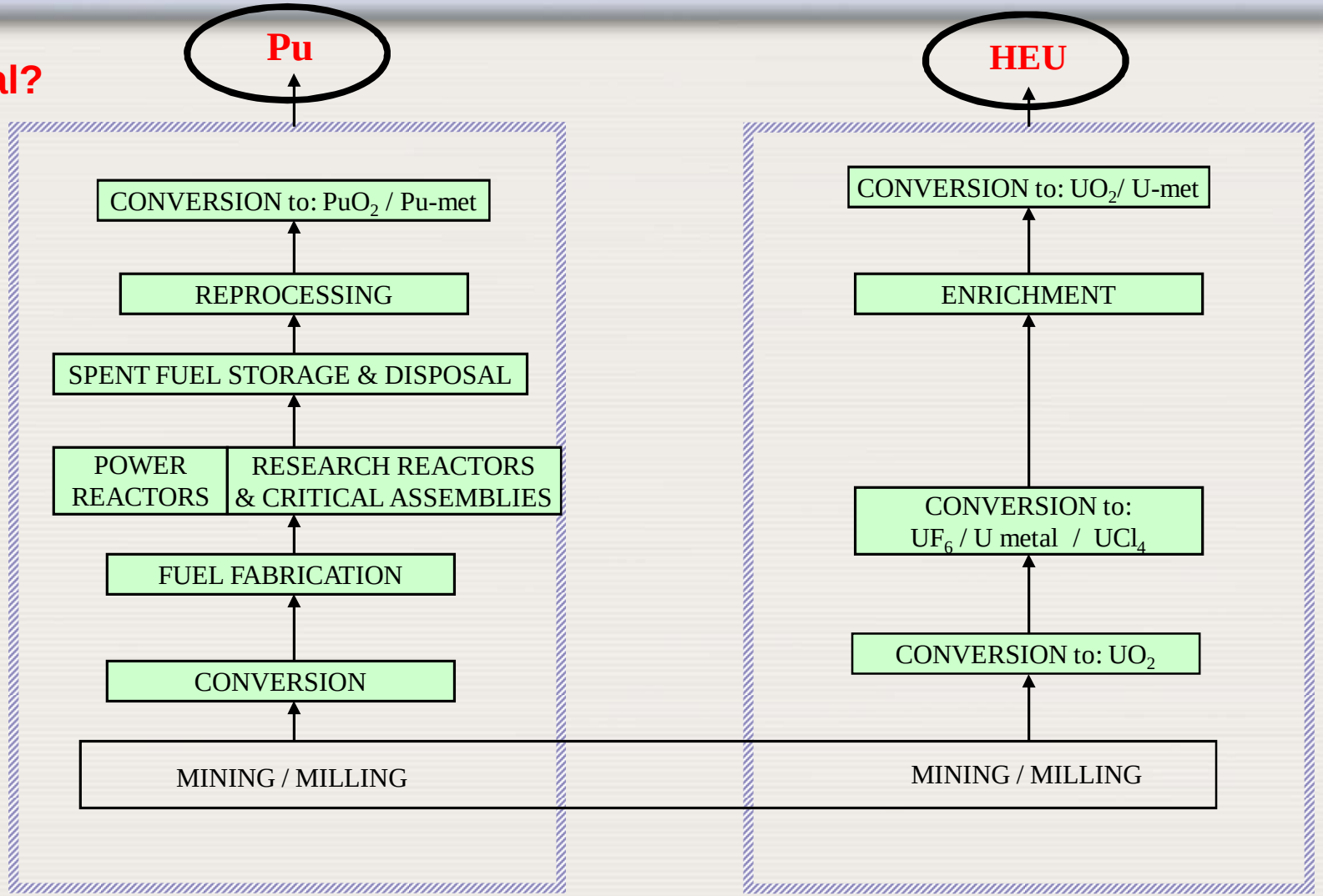
Acquisition Path Analysis

Commercial?
Lab scale?
Where?
Diversion?



Pu ROUTE

HEU ROUTE

Summary

- Nuclear fuel cycle is a set of industrial processes to create electricity
- Throughout the nuclear fuel cycle nuclear material is being processed in a variety of forms
- There are two main routes to acquire weapons usable material (HEU/Pu)
- Material of Safeguards concern: Indirect and Direct use material

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References

- Nuclear Energy Department
  - http://www.iaea.org/NuclearPower/
- Nuclear Energy Knowledge Resources
  - http://www.iaea.org/inisnkm/nkm/aws/index.html
- Country Nuclear Fuel Cycle Profiles
  - http://www-pub.iaea.org/MTCD/publications/PDF/TRS425_web.pdf

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