



Synergistic Nuclear Fuel Cycles of the Future

by

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Objectives of this Study

- **Discuss long-term future fuel cycle options**
- **Give guidance to short-term development**
- **Examine the role of the CANDU PHWR**
- **Provide framework for CANDU development**

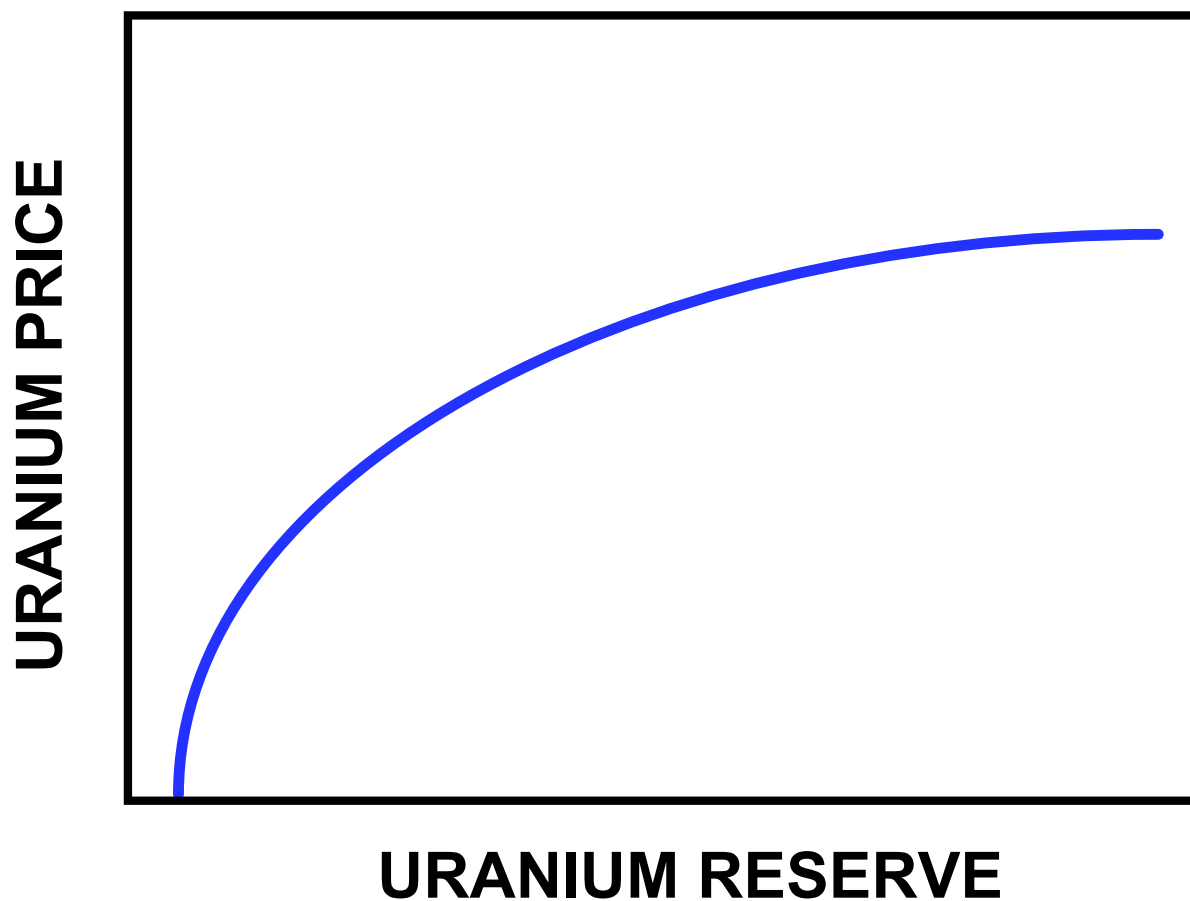


World Nuclear Fuel Inventory

- **Large absolute fuel supplies - uranium and thorium**
- **Limited economic supply at today's utilization level**
- **Higher fuel utilization greatly increases economic supply**
- **Power reactor types chosen today may determine future utilization options**



AFFORDABLE RESERVES OF NUCLEAR FUEL





The Case for High-Conversion Thermal Reactors

- They are in commercial use today - CANDU-PHWR
- Synergistic cycles can utilize RepU and Pu in LWR spent fuel
- They adapt easily to burning ex-weapon materials
- Th-U and Th-Pu cycles for new long-term fuel resource
- They are efficient minor actinide burners
- Bred plutonium from LMR can be used efficiently



Development Needed for CANDU Advanced Fuels

- **Proof-testing of RU and MOX fuel in a power reactor**
- **Pilot- and full-scale testing of DUPIC dry reprocessing**
- **Development of neutral-matrix carrier fuel**
- **Proof testing of Th-U and Th-Pu fuels in a power reactor**

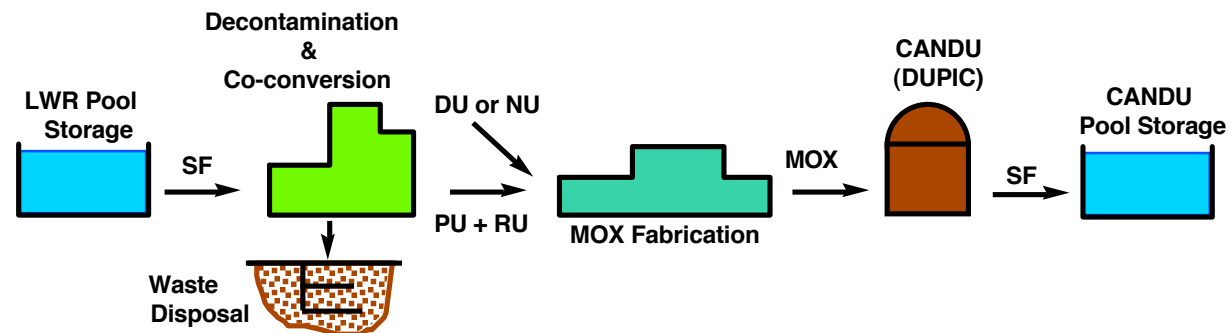
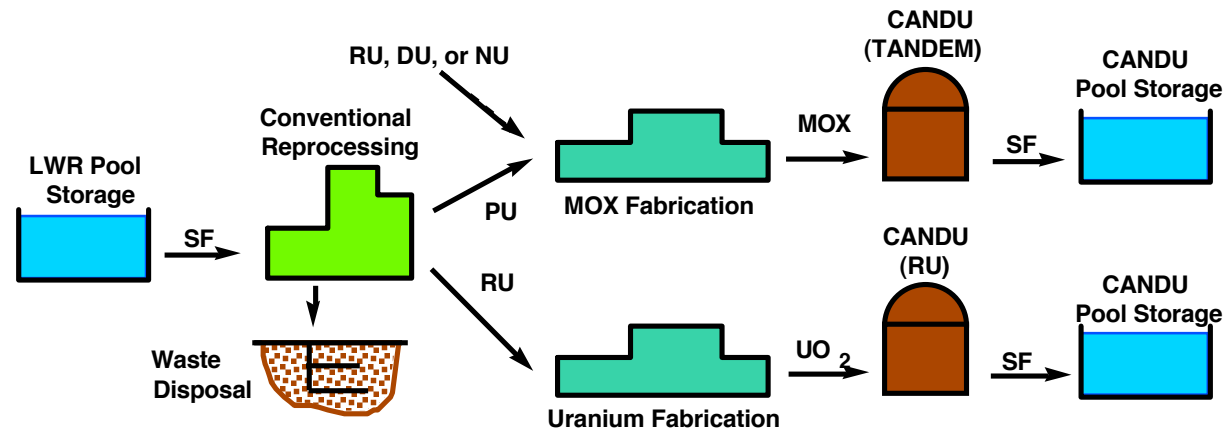


Power-Reactor Proof Testing in CANDU

- **Begins with carrier bundles containing test elements**
- **Selected channels are loaded with one or more bundles**
- **Power of test fuel is increased progressively**
- **Number of bundles of test fuel in core are increased**
- **Full loading of test fuel - conversion complete**
- **Process is fully reversible at any stage**



LWR-CANDU Synergistic Fuel Cycles





Fuel Cycle Characteristics of LWR and CANDU

	Specific Natural Uranium Usage Mg/GWy(e)	Specific Fuel Disposal Mass Mg/GWy(e)
● Enriched Uranium in LWR	217	33.2
● LWR-plutonium recycled in LWR	185	29.2
● LWR-Pu + re-enriched LWR-U recycled in LWR	157	24.7
● Natural Uranium in CANDU	157	157.0
● Slightly-enriched U in CANDU (1.2 w/o U235)	114	49.8



LWR-CANDU Synergistic Fuel Cycle Characteristics

	Specific Natural Uranium Usage Mg/GWy(e)	Specific Fuel Disposal Mass Mg/GWy(e)
● LWR-Pu recycled in LWR, recovered LWR-U in CANDU	151	23.8
● Re-clad LWR spent fuel recycled in CANDU (DUPIC)	125	19.7
● LWR-Pu and LWR-U recycled in CANDU	119	18.8
● Re-clad LWR spent fuel recycled in CANDU/Th-U233 converter	98	17.4
● Transuranics from LWR spent fuel annihilated in CANDU	0	1.2



Energy From LWR-CANDU Synergistic Fuel Cycles (Assuming 35 MWd/kg burnup in LWR Stage)

	MWd/kg of LWR Fuel - Total	Percent Increase over LWR Cycle
● LWR-Pu recycled in LWR, recovered LWR-U in CANDU	47	35
● Re-clad LWR spent fuel recycled in CANDU	53	51
● LWR-Pu and LWR-U recycled in CANDU	60	72
● Re-clad LWR spent fuel recycled in CANDU/Th-U233 converter	64	82
● Transuranics from LWR spent fuel annihilated in CANDU	37	5



Burning FBR Plutonium in CANDU (Once Through)

	Specific Plutonium Requirement Mg/GWy(e)	Specific Fuel Disposal Mass Mg/GWy(e)
● Uranium/Plutonium MOX in CANDU	0.73	61
● Thorium/Plutonium MOX in CANDU	0.31	20
● Uranium/Plutonium MOX in LWR	1.00	29



BRUCE ENERGY CENTRE TODAY



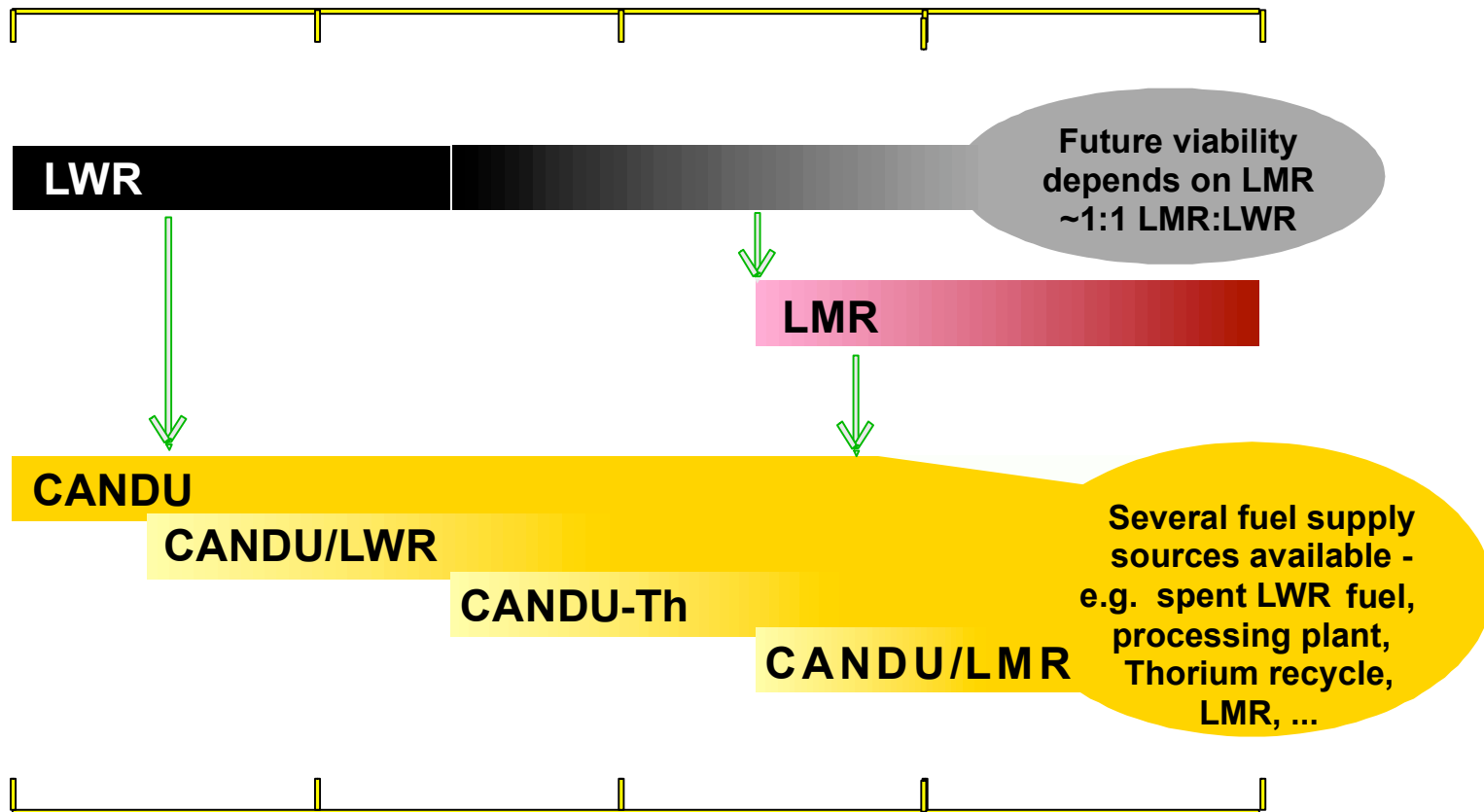


Possible Development of Bruce Energy Centre

- **“Vertical” Development -- Electricity Production, Fuel Systems**
 - Fuel dry storage systems
 - Additional CANDU generation capacity
 - Long-term: LMR with pyro-processing of fuel
- **“Horizontal” Development - Toward a Sustainable System**
 - Steam for alcohol prod’n, farm feed processing, greenhouse
 - Electrolytic hydrogen, methanol synthesis
 - Other agro-industrial uses for electricity and steam



Long-Term Fuel Supply Strategies





SUMMARY

- **There is no hurry -- economics will decide the time of introduction**
- **Current technology is sufficient for good fuel utilization**
- **Combination of high-gain breeder and high-conversion thermal reactor gives excellent fuel utilization in the long term**
- **Thorium once-through cycles in CANDU utilize present fuel resources and provide fuel legacy for the long term**
- **CANDU is a good actinide burner (for long-term waste management)**



Today's Products *CANDU 3, CANDU 6, and CANDU 9*

