Synergistic Nuclear Fuel Cycles of the Future

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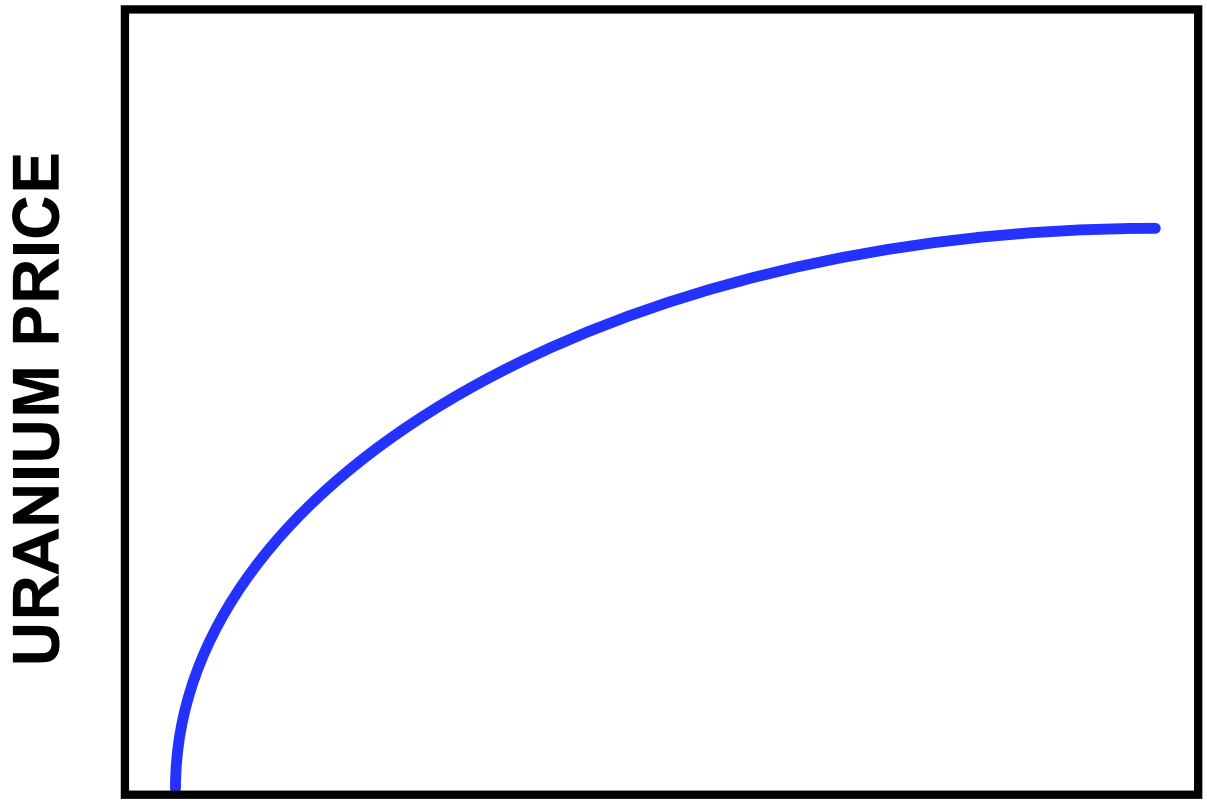
Objectives of this Study

- 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

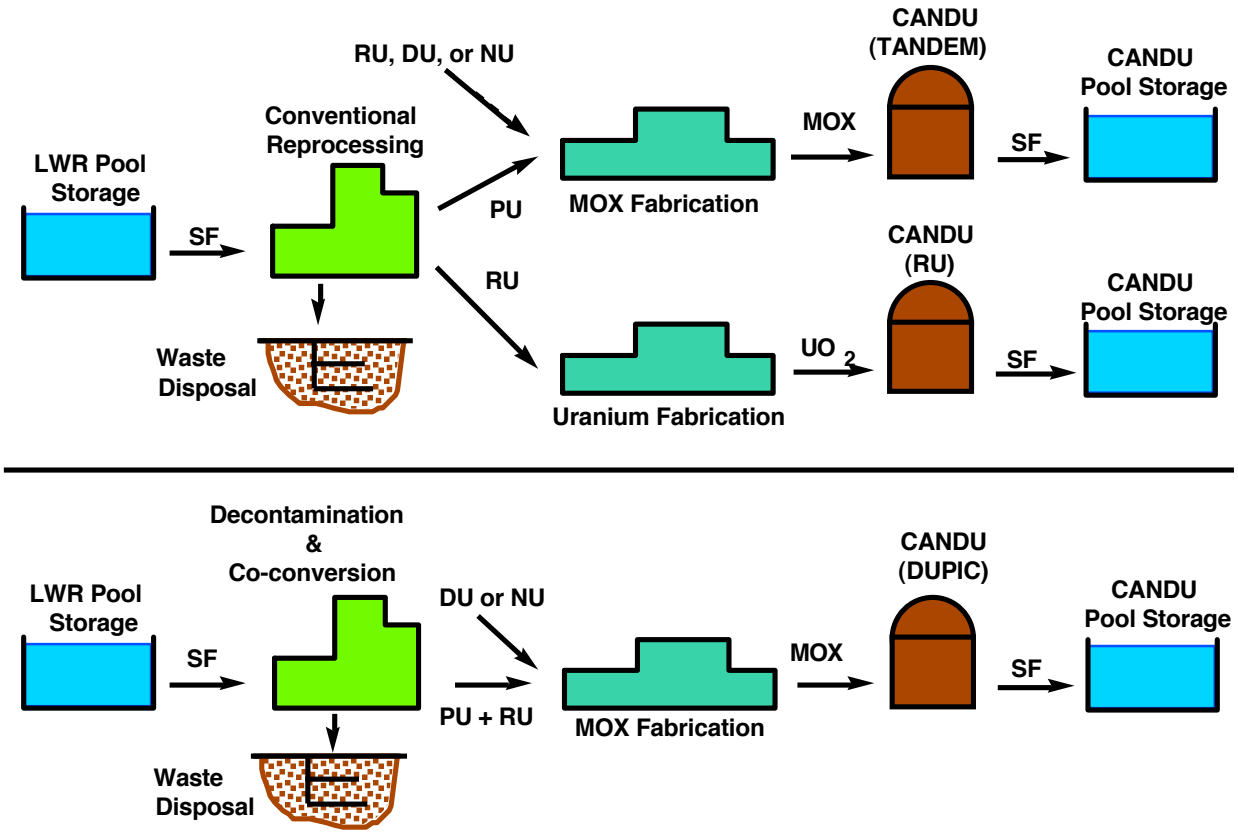
Development Needed for CANDU Advanced Fuels

- **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

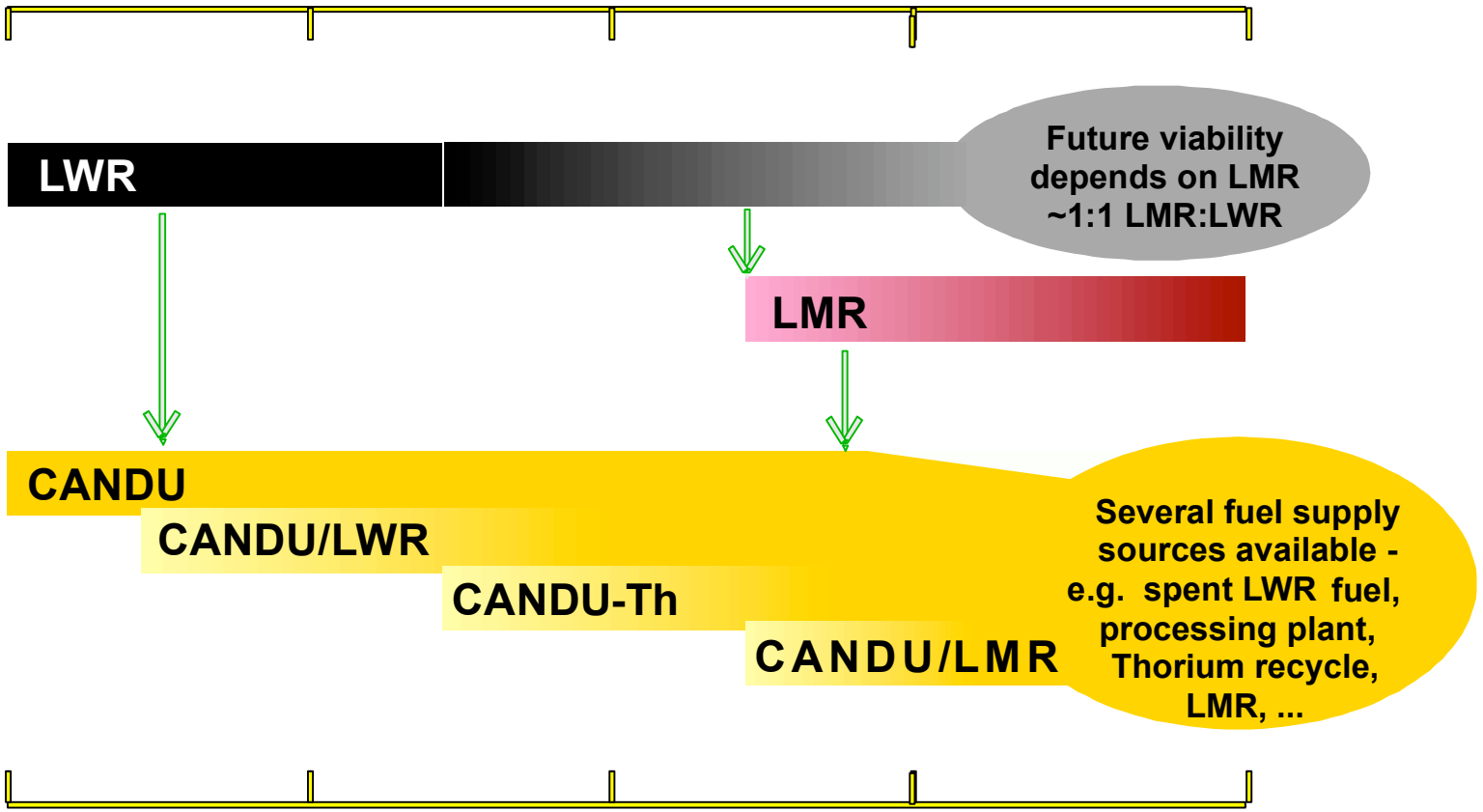
BRUCE ENERGY CENTRE TODAY

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