Tritium Supply Considerations

Scott Willms
Los Alamos National Laboratory

Fusion Development Paths Workshop
January 14, 2003

Credits

- Contributors
  - P. Rutherford, D.-K. Sze, J. Anderson, M. Abdou
- References

  - Rutherford, P., “The Tritium Window”, informal report (1999).
  - Bergeron, K. D., **Tritium on Ice**, MIT Press (2002).
  - Wittenberg, L. J., “Comparison of Tritium Production Reactors”, Fusion Tech., 19, 1040 (1991).
  - Snowmass 1999 report
  - Snowmass 2002 report
  - Personal Communication, Ontario Power Generation (2003).
  - Personal Communication, Atomic Energy Canada (2003).
  - Personal Communication, Accelerator Production of Tritium (1999).

Notional statement of committee’s charge

Find the design option(s) which minimize cost and risk, where:

$$\text{Cost} = \int_{0}^{35\,yr} f(design\ \ options,\ supporting\ \ facility\ \ options,\ resources,\ knowledge\ \ base, etc.)dt$$

Tritium constraint terms

Tritium used - tritium bred + tritium for next step < tritium available

- *Tritium used*: 55.8 Kg T/yr for 1000 MW_{fus} (includes alpha heat), 100% available
- *Tritium bred*: Fusion has never done this
- *Tritium for next step*:
  - ITER startup inventory estimated to be ~3 Kg
  - DEMO startup inventory likely to be between 4-10 Kg
- *Tritium available*: 18.5 Kg (2003)

Brief history of US tritium production

- 1953-1955 Tritium producing reactors online
- 1976-1988 Need for new tritium production method recognized, many false starts, controversy, no real progress
- 1979 Three Mile Island
- 1986 Chernobyl
- 1987 N and C reactors shutdown
- 1988 K, L and P shutdown
- 1989 Plan to refurbish/restart K

  New Production Reactor project start

  -MHTGH, HWR, LWR
- 1990 Ebasco HWR and MHTGR selected
- 1991 Arms reduction progress, only one option needed

  K Reactor leaks

Brief history of US tritium production (cont.)

1992 $1.5B spent on K reactor
$1.5B spent on NPR, program cancelled
1993 K reactor restart cancelled
1995 APT primary option and CLWR is backup
1997 TVA proposed sale of Bellefonte to DOE with Watts Bar/Sequoya service as backup
1998 "Interagency review" issued
Watts Bar service chosen

2011 Production restart date for START-II
2029 Von Hippel estimate for real restart date

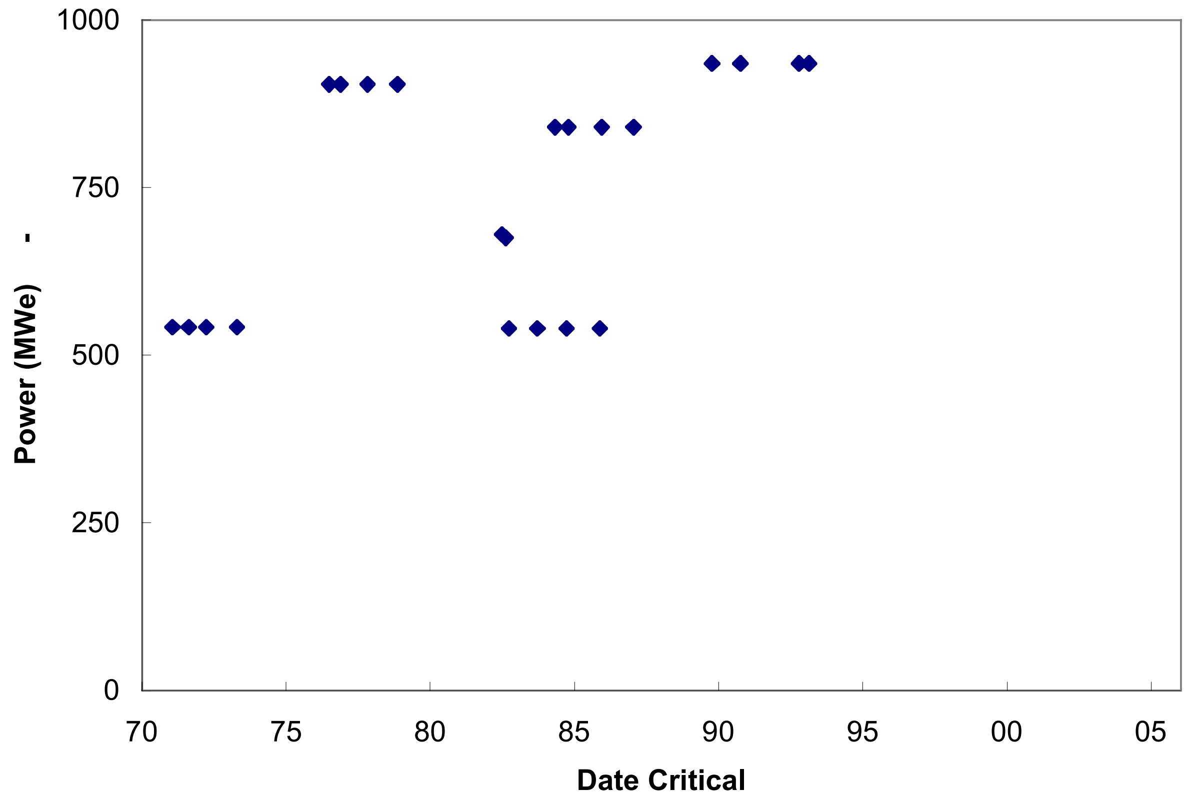
Cost of tritium

- Old DOE price was $10,000/gm
- Present Canada price is ~$30,000/gm
- Expected cost for future US production: $100,000 to $200,000/gm

- 4 kg startup cost at $30,000/gm: $120M
- 4 kg startup cost at $100,000/gm: $400M

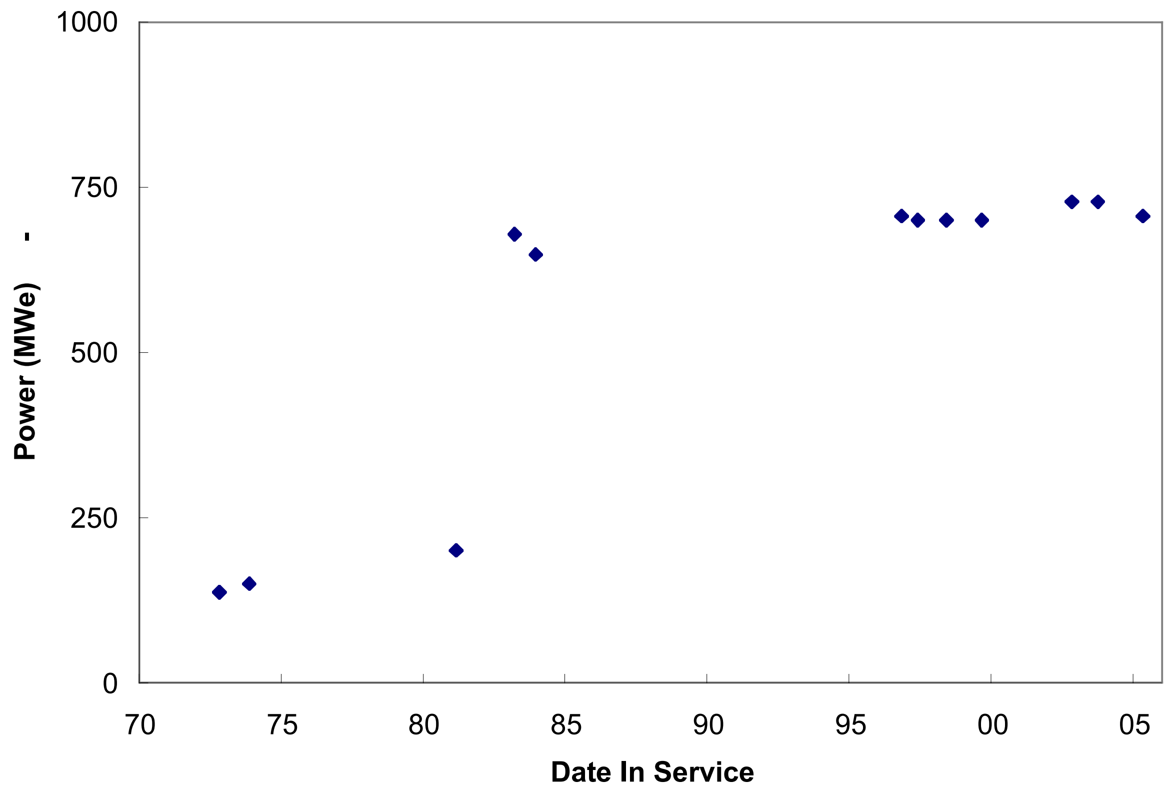
Canadian CANDU reactor summary

- 22 CANDU reactors in Canada
- 8 were taken out of service between 95 and 98
- 6 of these will be back in service by end of 2003
- Average age of reactors is 20.8 years



Non-Canadian CANDU reactor summary

- 12 reactors: Argentina (1), India (2), S. Korea (4), Pakistan (1), Romania (2), China (2)



Presently the only credible tritium for D-T fusion development is available from OPG

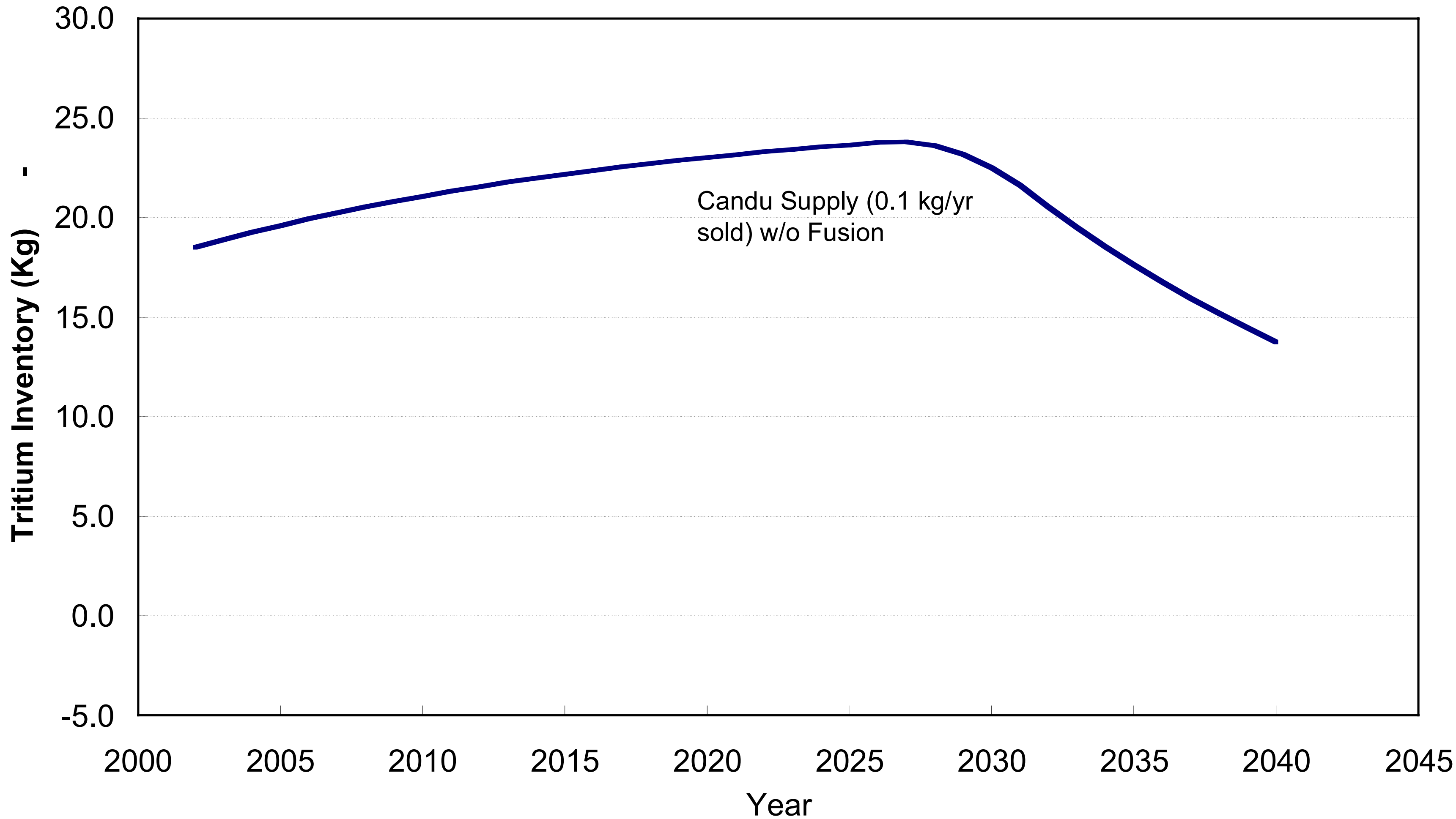
- At the end of this year there will be 20 operating Canadian CANDU reactors
- Reactors licensed for 40 years
- Tritium is recovered from these reactors at the Tritium Recovery Facility (Darlington)
- Presently about 18.5 Kg tritium on hand
- Tritium recovery rate was ~2.1 Kg/yr. Now it is ~1.5 Kg/yr.
- It is assumed that the tritium recovery rate will remain at this level until 2025. Thereafter the tritium recovery rate will decrease rapidly
- Tritium sales: About 0.1 Kg/yr

- Tritium decay rate: 5.47 %/yr

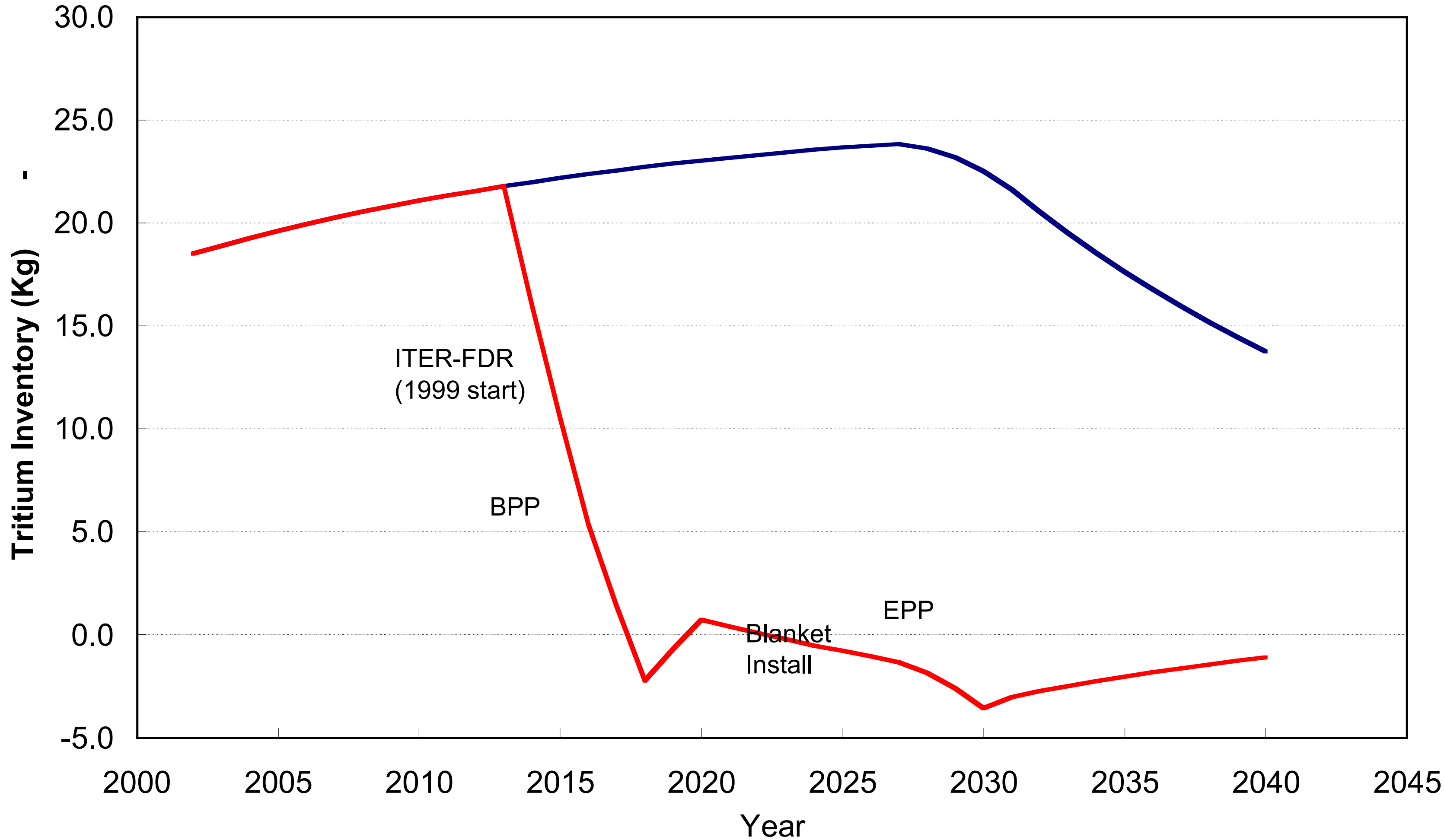
Assumptions

- Did not assume
  - CANDU lifetime extended from 40 to 70 years
  - More CANDU's built
  - Li targets irradiated in commercial reactors (including CANDU's) to specifically breed fusion tritium
  - Tritium procured from "nuclear superpowers"
- Also did not assume
  - Other major customers for Canadian tritium
  - CANDU's idled/decommissioned early
  - Canadian tritium unavailable for political reasons
  - Canadian tritium is not simply sent to waste
  - CANDU tritium production rate is lower than expected

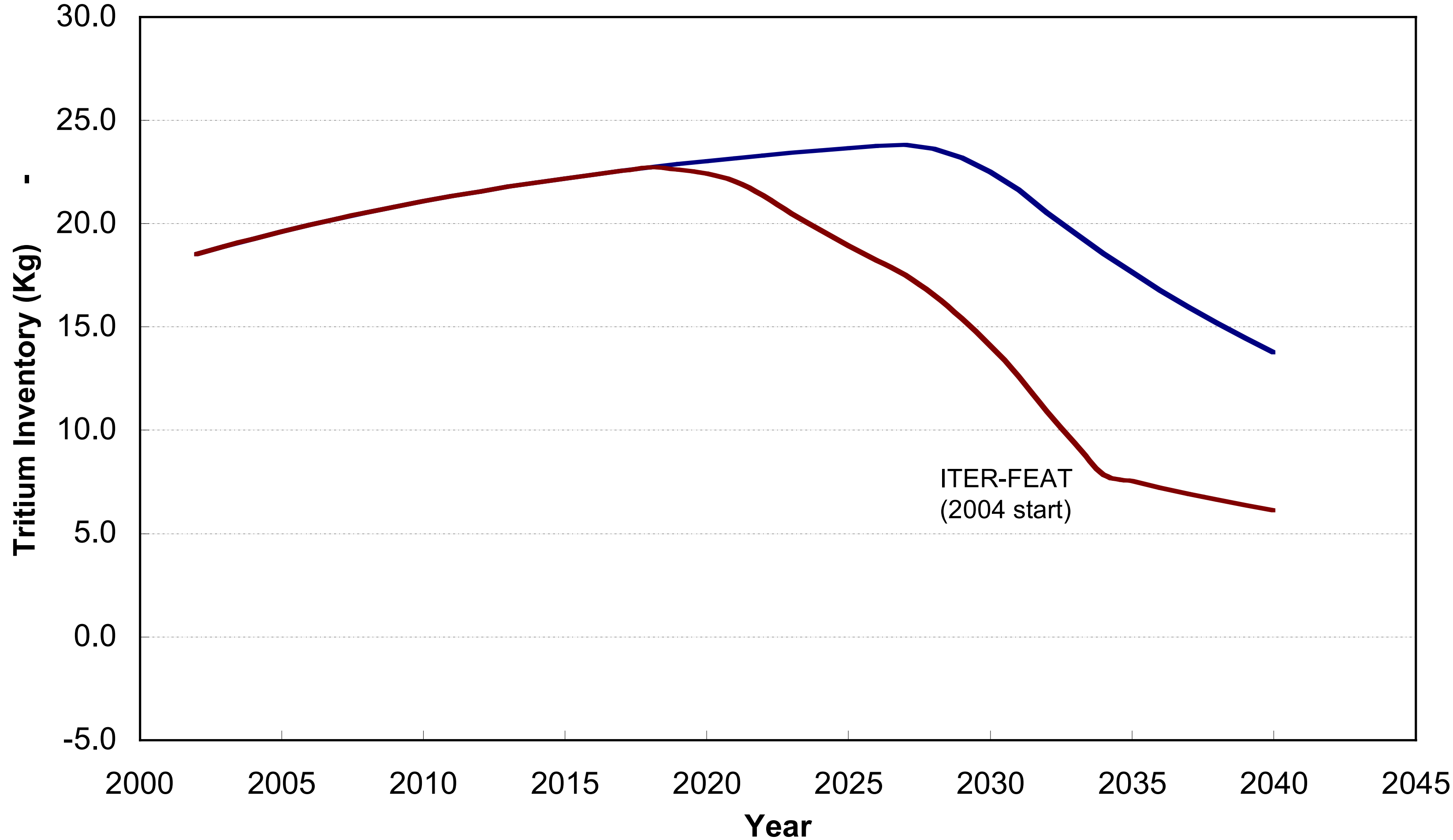
Projected Canadian tritium inventory without major impact from fusion. Curve assumes CANDU generation assumptions and 100 gm sold/yr.



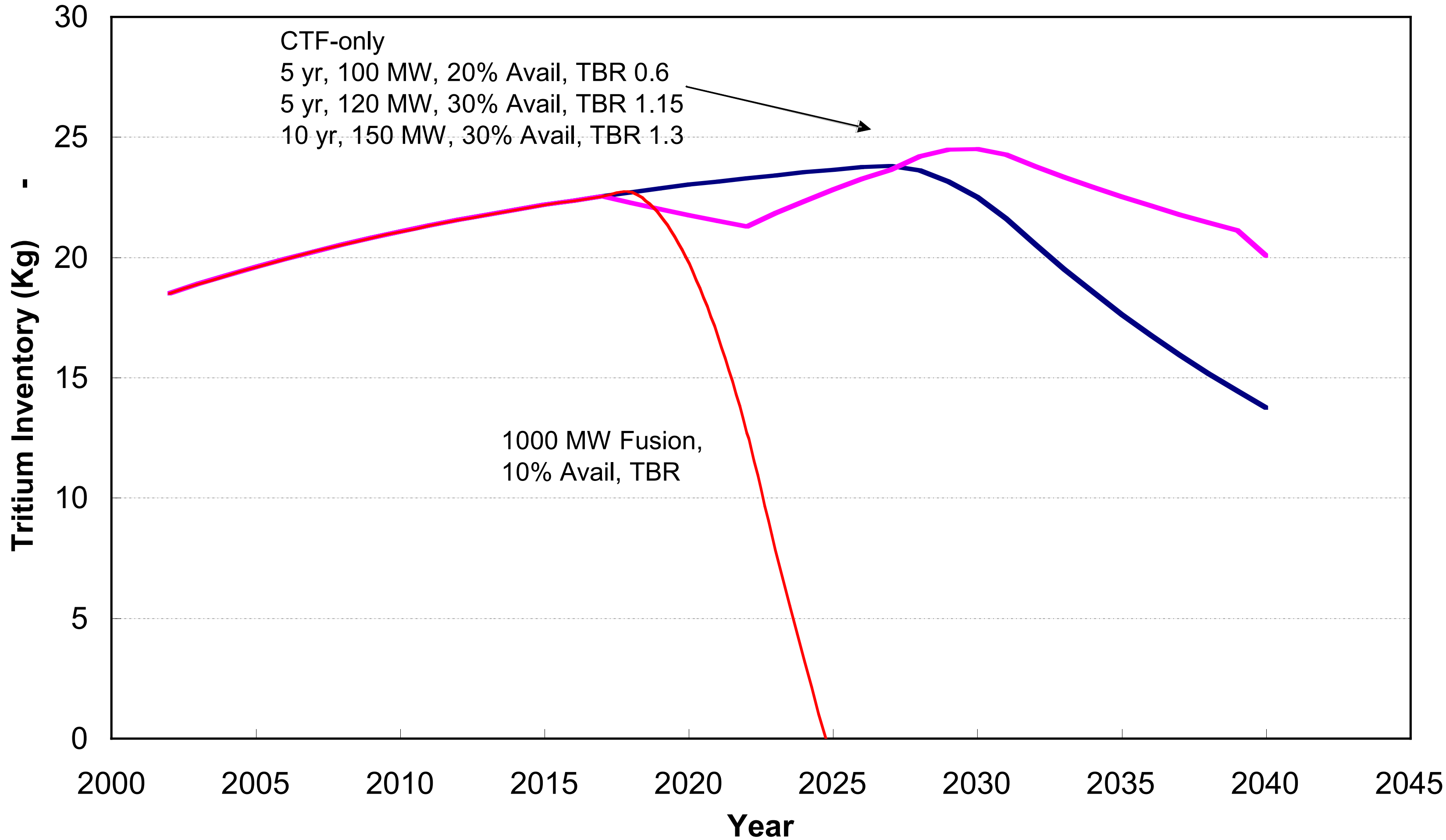
Baseline ITER Final Design Report experimental program would have consumed more than the available tritium



The reduced size and reduced mission machine, ITER-FEAT, will have a smaller impact on tritium supply



A wide range of fusion impacts on tritium supply can result for various scenarios



Conclusions

- Tritium available for fusion development will likely begin to diminish rapidly during the next 35 years
- Fusion should be developed expeditiously to take advantage of the unique opportunity
- Development of D-T fusion must be carefully planned world-wide taking into account available tritium
  - Experiments without breeding must be low power and/or low availability (ITER-FEAT appears okay. . .but barely so)
  - Sufficient tritium must be left for next steps
  - Significant losses of tritium must be carefully avoided
- Development and deployment of program components which breed significant quantities of tritium are needed soon