Power Plant Technologies / Generic and Supporting Technologies for Fusion Energy Development

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Introduction

- **Fusion Power Plant Technologies.**
- **Generic / Supporting Technologies.**
  - **Applicable to many or most fusion reactor concepts / designs.**
    - ***Mainstream (such as Tokamak, Laser-ICF, and Stellarators)***
    - ***Alternatives:***
      - **Magnetized Target Fusion, Reversed Field Pinch,**
      - **Field-Reversed Configurations, Magnetic Mirrors,**
      - **Spheromaks, Z-Pinches, etc.**
- **International Context**
  - **What are the issues?**
- **Canadian Context**
  - **Past / Current Experience**
  - **Proposed Canadian Program / Future Efforts**
    - **What can be done in the near and intermediate future.**

International Context (1/3)

- **Interaction between the fusion plasma and first wall of the surrounding structural components**
  - **Erosion of materials; contamination of plasma.**
  - **Generation of secondary X-rays.**

- **Modeling and assessment of radiation transport**
  - **High-energy neutrons (2.45-MeV, 14.1-MeV).**
  - **Photons (gamma rays, X-Rays).**
  - **Interactions outside the fusion plasma region.**
  - **Interactions with various materials and components**
  - **Interactions with coolants, breeding materials, shielding, support structures, field magnets, and others.**
  - **Damage, activation, breeding.**

International Context (2/3)

- **Performance of structural materials and components**
  - **High radiation environments (neutron, gamma, X-rays).**
  - **Cycling of thermal heat, stress, and mechanical force loads**
  - **Fatigue and damage issues. Engineering testing needed.**
- **Production, handling and storage of fusion fuels**
  - **Deuterium (D) and tritium (T)**
  - **Interactions of D, T with various materials.**
  - **Lithium-based blanket materials for producing tritium.**
- **Behavior of fertile and fissile nuclear materials**
  - **Fertile: U-238, Th-232; Fissile: Pu-239, U-233**
  - **If fusion reactor used as a neutron source to drive a sub-critical fission reactor blanket.**
    - ***Strong interest in this option in China, to complement fully-fusion systems.***
    - ***Only require a low performance fusion reactor (Q~1) to generate net power.***
    - ***Alternative to using fast breeder reactors*.**

International Context (3/3)

- **Balance-of-Plant**
  - Design and operation of the balance-of-plant, which is used to convert the heat from the fusion plasma into electricity.
- **Safety & Licensing Analyses**
  - Large magnetic, electromagnetic fields.
  - Radiofrequency EM waves.
  - Cyclic forces for pulsed systems. Thermal cycling.
  - High temperatures; chemically reactive materials (some cases).
  - High-pressure, high-temp. coolants (liquids, gases).
- **Environmental Assessments**
  - High radiation fields while in operation.
    - ***High-energy neutrons, X-rays, and gamma rays.***
  - Activation of materials by radiation fields.
  - Addressing risks of chemical/tritium leaks/contamination.

Canadian Context (1/2)

- **Historically, Canada involved at a small scale in carrying out supporting research**
  - **Mainstream and alternative fusion reactor concepts.**
    - ***Tokamak, Laser ICF, Magnetic Cusps***

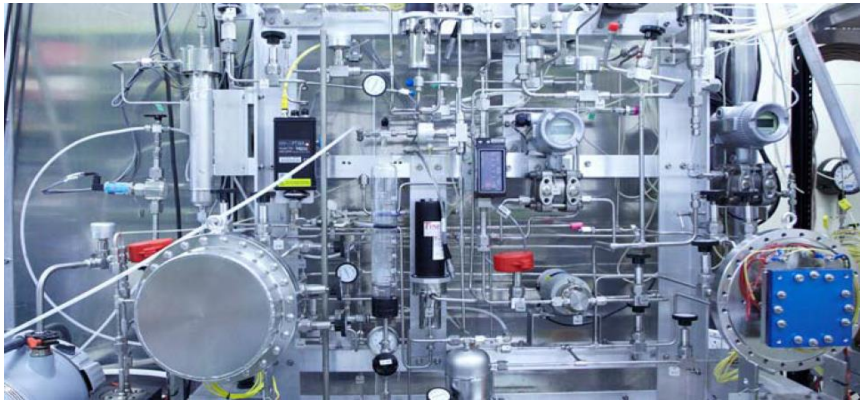
- **Since the early 1970s until 1997, researchers across Canada were contributing to broad-purpose fusion energy science and technology development through:**
  - **Canadian National Fusion Program**
    - ***Support halted in 1997 (part of GoC effort to eliminate deficit)***
  - **Canadian Fusion Fuels Technology Project (CFFTP).**
    - ***Cooperation between Ontario Hydro and AECL.***

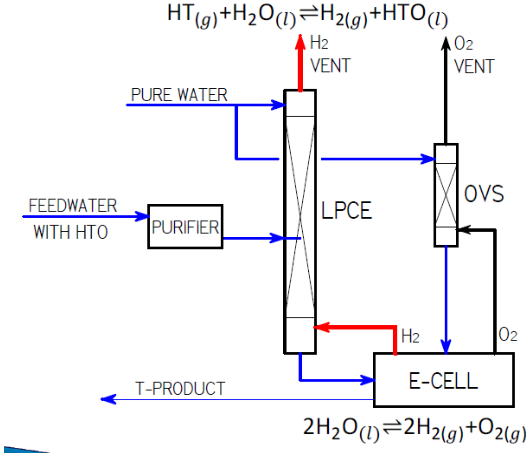
Canadian Context (2/2)

- **Technologies for the production, handling and storage of deuterium and tritium**
  - Evaluating tritium breeder blankets.
  - Materials/compounds containing Li-6, Li-7.
- **Understanding how D, T interact with materials.**
  - Chemical reactions, diffusion, crystal structures.
- **Separating D, T from water (D_2O, DTO).**
  - Methods of storage (metal hydrides).
- **Current activity focused on deuterium production and tritium handling.**
  - Ties in with Canadian nuclear industry with pressure tube heavy water reactors (such as CANDU) .

Future Canadian Efforts (1/4)

- **New contributions, build upon current expertise.**
  - **Make use of existing facilities. Experts in research and industry.**
- **Key areas:**
  - **Licensed facilities for handing T, DTO, T_2O.**
  - **D, T production, extraction, storage, handling.**
    - ***Builds upon experience with CANDU reactor technology.***
    - ***New technologies have been developed in Canada.***
    - ***No current formal linkages to ITER project.***
    - ***Access to potentially large market limited right now....***
    - ***Opportunity for Canada to re-assume leadership role.***





Future Canadian Efforts (2/4)

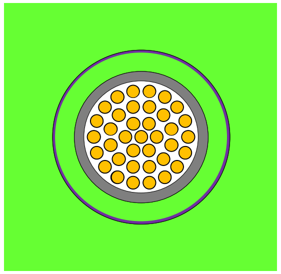
- **Key Area: Plasma-material interactions**
  - **Plasma bombardment, radiation damage of materials.**
  - **Testing of materials and components.**
  - **Use of neutron sources, proposed plasma sources, and high-energy particle sources (from accelerators) at various research and university facilities.**
    - ***Plasmionique in Quebec, U. Sask., U. Alberta, TRIUMF, NINT.***

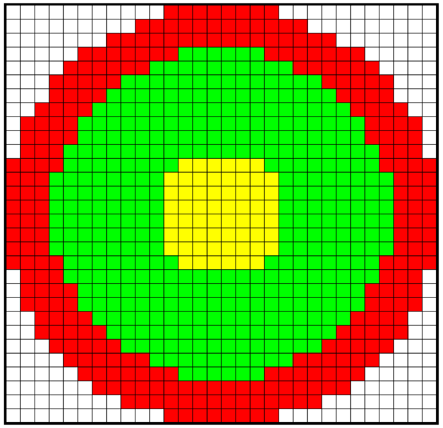
Future Canadian Efforts (3/4)

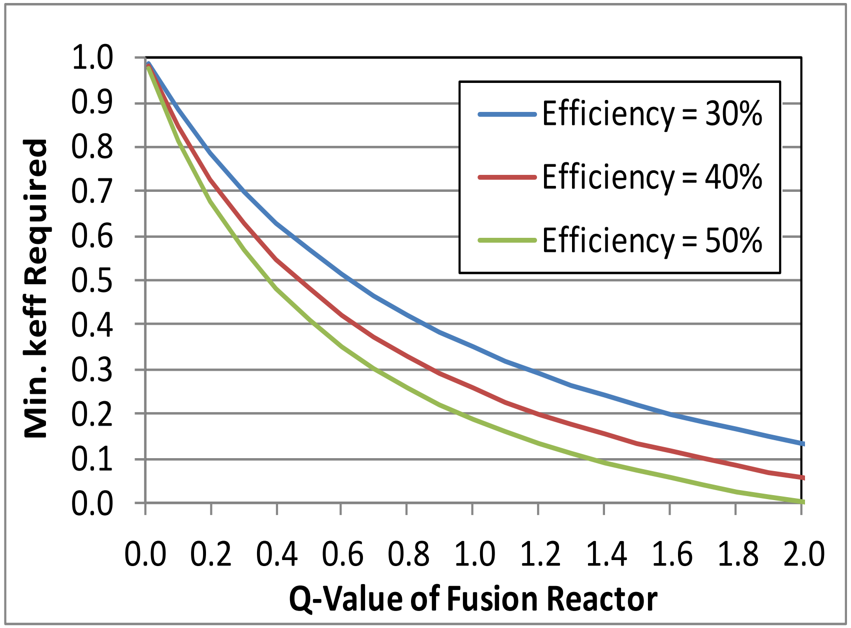
- **Key areas:**
  - **Licensed facilities for fusion blanket technology.**
    - ***Materials and components (lithium-based).***
    - ***Fabrication and testing.***
  - **Computational neutronics and radiation transport modeling.**
    - ***Evaluate materials damage, breeding in blankets.***
    - ***Design of shielding.***
  - **Thermal-hydraulics**
    - ***Fluid flow and heat transfer in fusion reactor components.***
    - ***Water, and alternative coolants (gas, liquid metals, molten salts).***
    - ***Computational and experimental.***

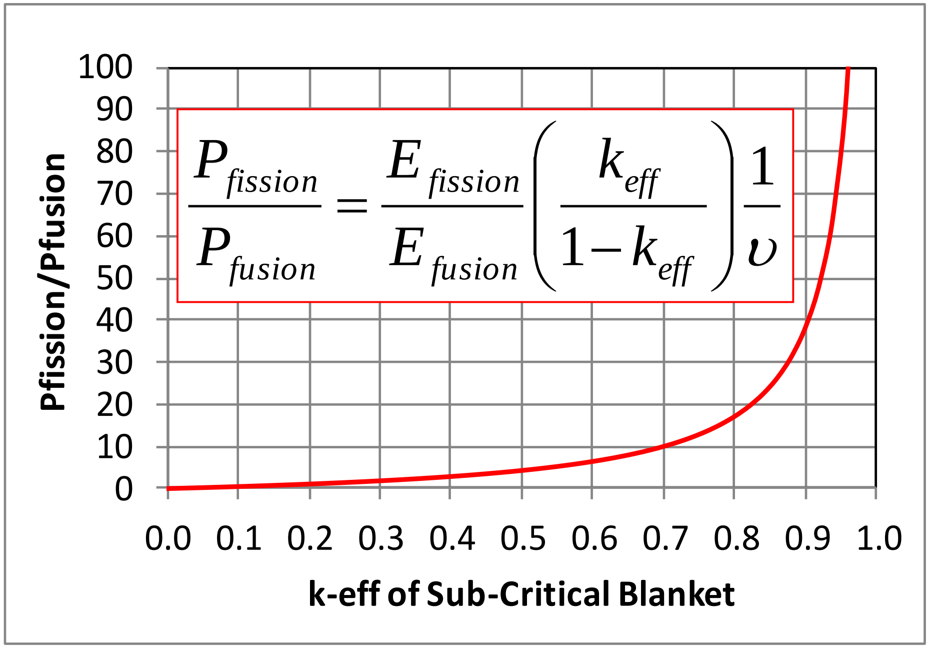
Future Canadian Efforts (4/4)

- **Hybrid fusion-fission reactor technology**
  - **Blankets made of Th-232 / U-238**
  - **Breeding U-233 and Pu-239.**
  - **Early application of fusion.**
  - **Q~1.0 fusion reactor sufficient.**
  - **Complements / supports fission reactor technology.**









Summary

- **Opportunity for Canada to develop fusion power plant technologies, and generic and supporting technologies for fusion energy development.**
- **Canada has experience, expertise and facilities.**
- **Key areas for Canada to take leading contributing role:**
  - **Deuterium, tritium production, storage, handling.**
    - ***Build upon expertise in Canadian nuclear industry with heavy water reactors.***
  - **Plasma-material interactions.**
  - **Fusion blanket technology**
    - ***Build upon past efforts with CFFTP.***
  - **Neutronics/radiation transport modeling.**
  - **Thermal-hydraulics / heat transfer modeling and experiments.**
  - **Hybrid fusion-fission reactor technology.**

END