Alternative Energies

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Context for Today's Discussions

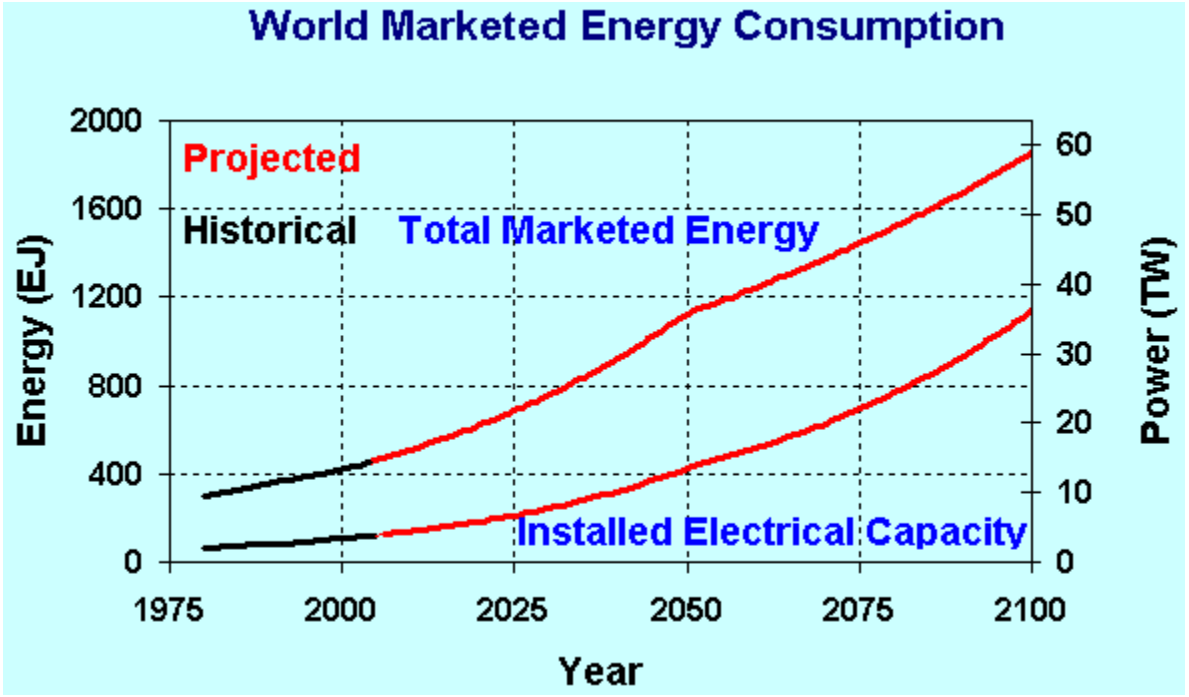
- Fusion energy will become important by mid-century (2050) **or sooner** (excepting Canada, much of the world is involved)

- De-carbonization is the change driver →fission/renewables → fusion/renewables (implications & opportunities for Canada)

- Fusion will generate new industries & large employment – in clean energy, technology spinoffs & applications in lasers, photonics, robotics, materials, sensors, computing, medicine

- Position Canada for future – energy, environment, economy (leverage global investment, world's first demo plant?)

Energy Demand – How to Satisfy?



- **Climate change – non-carbon energy sources**
- **Innovation and clean tech**
- **Creating new industries and next-gen jobs**

Alternative Energy Sources - Options

- **Increasingly, electricity is energy currency: (>40TW by 2100)**
- **Only 3 sustainable, non-carbon solutions for fueling central power plants – major economic impact**
  - fission (sustainable only with fuel breeding, leaves waste)
  - fusion (sustainable, primary energy source, electricity/heat/H_2)
  - renewables (sustainable, secondary energy source)
- **Fusion has highest energy density of all fuel sources**
- **Fusion has best energy payback ratio (EPR) & life cycle assessment (LCA) of all sources (solar, wind, fission)**

Renewable Energy – Solar & Wind

- Solar, both photovoltaic & concentrated solar thermal, has large potential but low energy density implies large collection space
  - – future energy needs could require up to 10% of all arable land space for solar (unacceptable)

- Wind has significant potential but also low energy density
  - – wind tower positioning has impact on other uses; also environmental impact

- **Fusion has the highest energy density of any source**
  - **– has the least environmental and land use impact**

Fission Energy

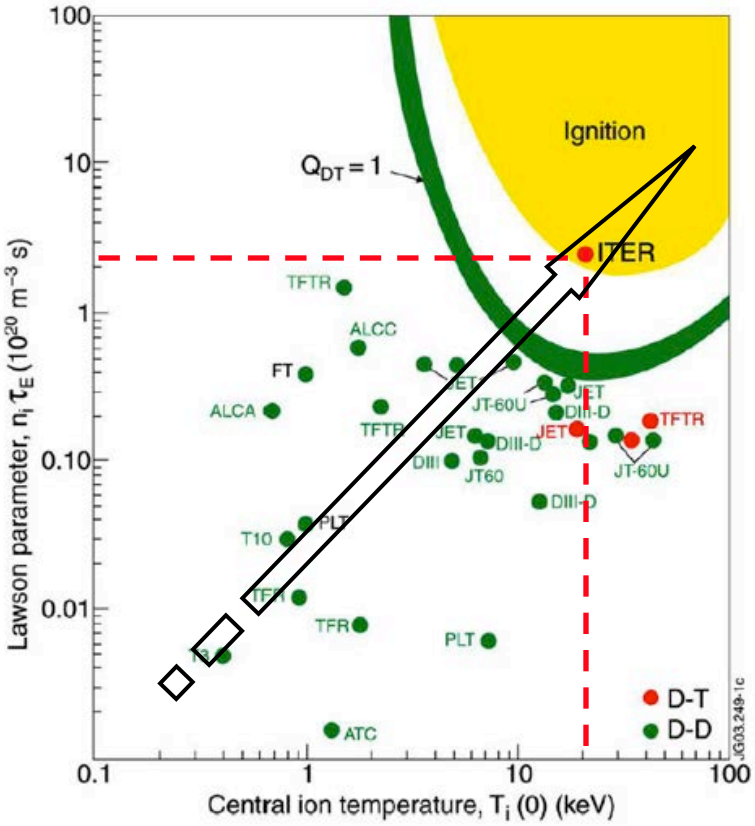
- Fission is a highly developed high energy density source but has limited fuel for current reactor cycle based on U235
- Future fission cycles will require fuel breeding; e.g., thorium cycle (Th+n → U233)
- Fission will be needed as transition energy source for base load electricity
- Energy evolution: carbon → fission & renewables → hybrid fusion/fission & renewables → fusion/renewables

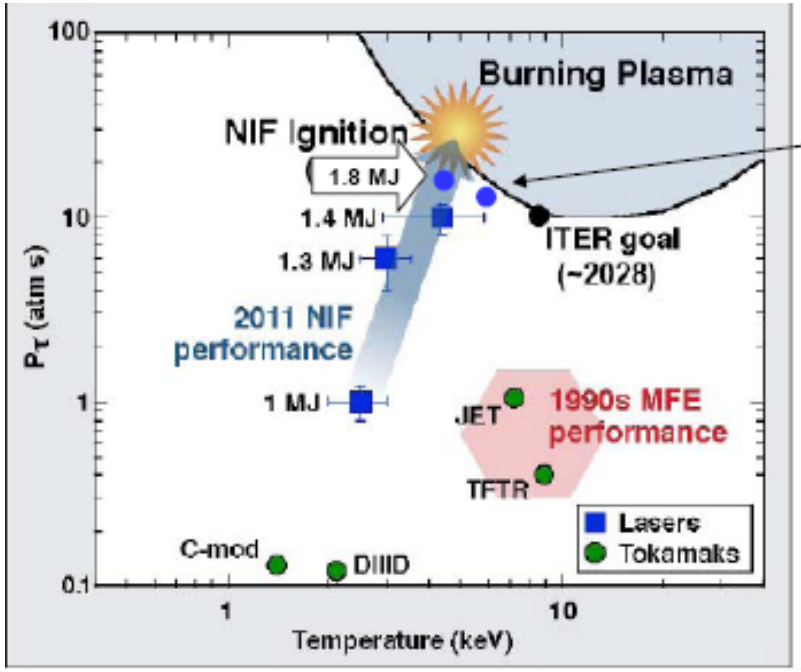
Why Fusion Energy?

- **Virtually inexhaustible fuel supply** (Deuterium in water and Lithium on land and sea to breed Tritium) – D+T → n + He + energy
- **No GHG or air pollution** (He^4 is the only "ash")
- **No long-lived radioactive products as for fission; no afterheat**
- **No risk of nuclear accident** (no public evacuation in vicinity of plant)
- **Fusion consumes less fuel mass per unit energy than any other source** (less resource investment, easy fuel deliverability)
- **Less environmental impact** (finding, producing, consuming)

Major Fusion Approaches – Progress

Magnetic (MFE) and Inertial (IFE) near to demonstrating ignition





1 keV ≈ 10,000,000 deg C

IFE Technology Opportunities

Inertial fusion R&D is a major driver of innovation

– Alberta could benefit economically from overarching technology driver

– knowledge economy reset; talent leading to prosperity

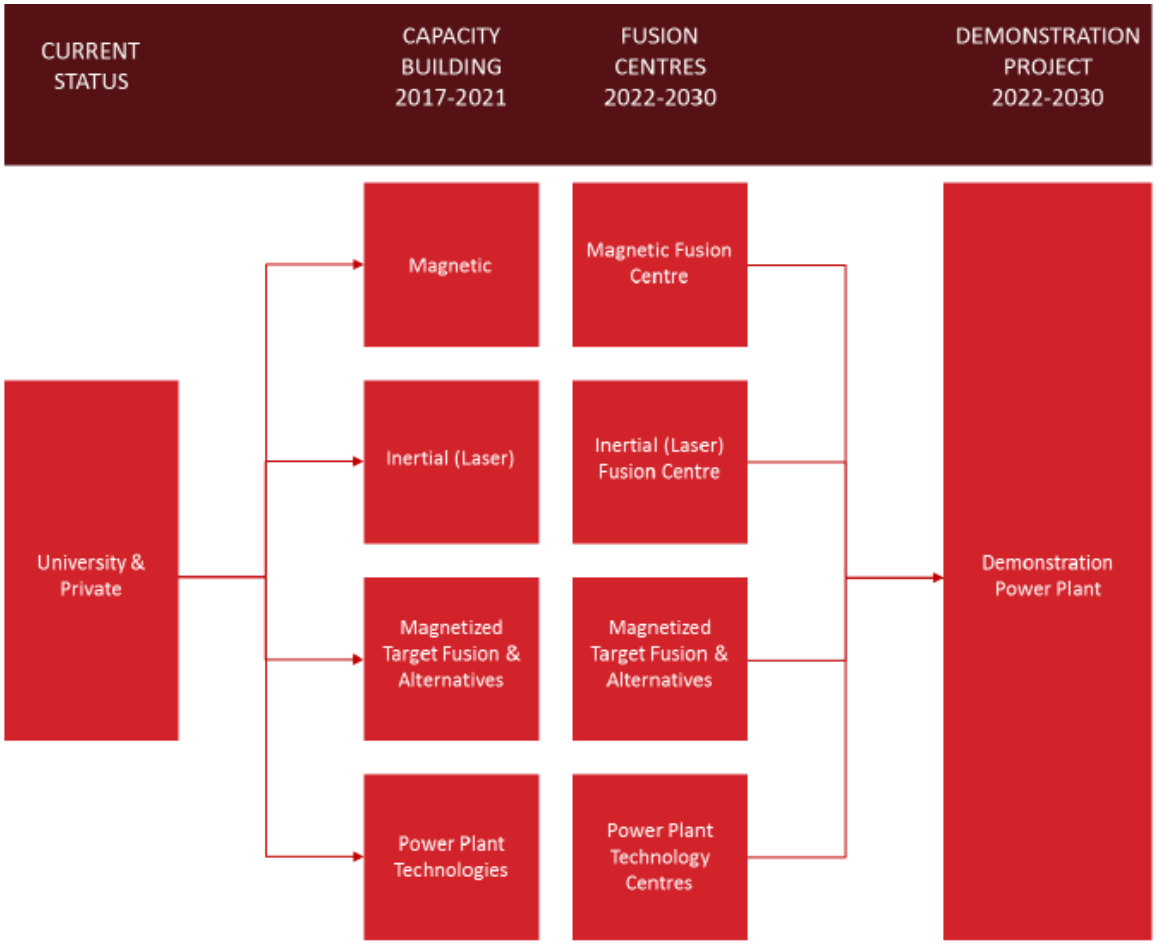
- **High power lasers** (diverse applications)
- **Precision optics** and opto-electronics
- **Photonics** (superseding electronics)
- **Sensors, instrumentation**
- **Robotics** (remote handling, line replacement modules)
- **Nanotechnology** (lasers, optics, targets, chamber materials)
- **Computer modeling** (control, data, analysis, etc)
- **Particle beam production & acceleration** (medical applications)
- **High energy density physics** (laboratory astrophysics)
- **Systems engineering** (design, construction, IP)
- **Additive manufacturing**

Alberta - Fusion Initiative

- Alberta engagement with international fusion effort
  - presently - university R&D; some small industry
- **Alberta/Canada Fusion Technology Alliance** established
  - to promote Alberta fusion involvement & outreach to postsecondary & industry institutions
- Proposal for “Capacity Building”
  - seeking funding from carbon tax to develop Alberta capacity
- Partner in National Fusion 2030 Roadmap
  - seeking to establish national fusion program

National - Fusion 2030 Initiative

Proposed to Federal Innovation Platforms



Fusion – On the Federal Radar

Alberta Well Positioned – University

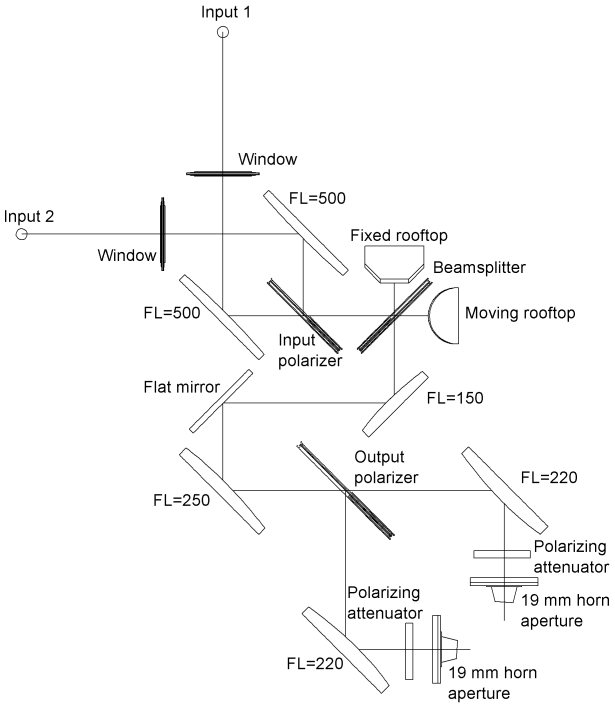
- Laser fusion approach is rapidly advancing together with rapidly advancing laser technology
- U of A has been a strong player in laser fusion for 4+ decades
  - laser systems, plasma science, advanced diagnostics (particle, x-ray, optical)
  - international linkages around the world
  - newly approved expansion in Faculty of Engineering

Alberta Well Positioned – Company Expertise

- Related Companies and Expertise in Alberta
  - Materials (NINT)
  - Nanotech (Micralyne, Norcada, Applied Nanotools, etc.)
  - Instrumentation (Blue Sky Spectroscopy)
  - Lasers (Boreal Lasers)
  - Big Computing
- Laser fusion will spawn spinoff technologies
  - industrial lasers, materials processing, medical radiation sources, radioisotope production, etc.

Blue Sky Spectroscopy & ITER

Far Infrared Spectroscopy – ITER diagnostic instrumentation



Blue Sky Spectroscopy Opportunity

- Opportunity to contribute to arguably the most transformative project on the global stage.

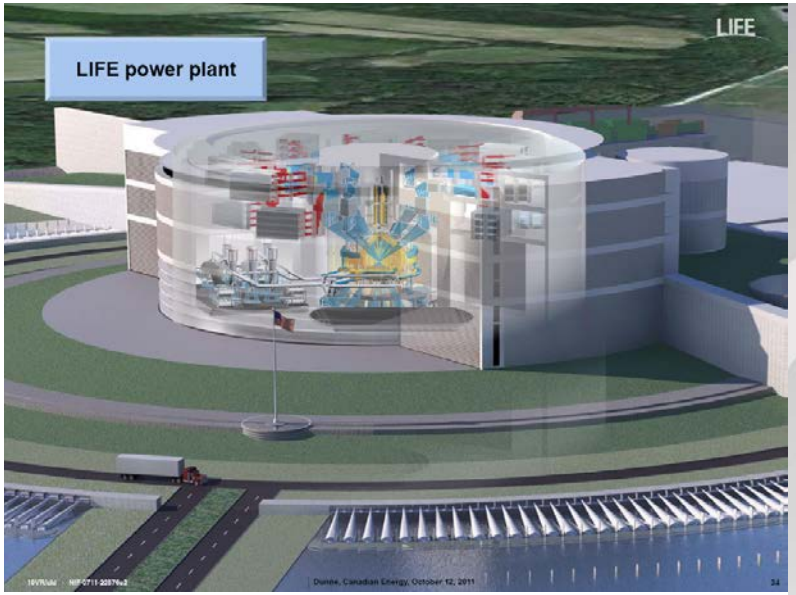
- Fusion reactors need diagnostic equipment for operation & control.

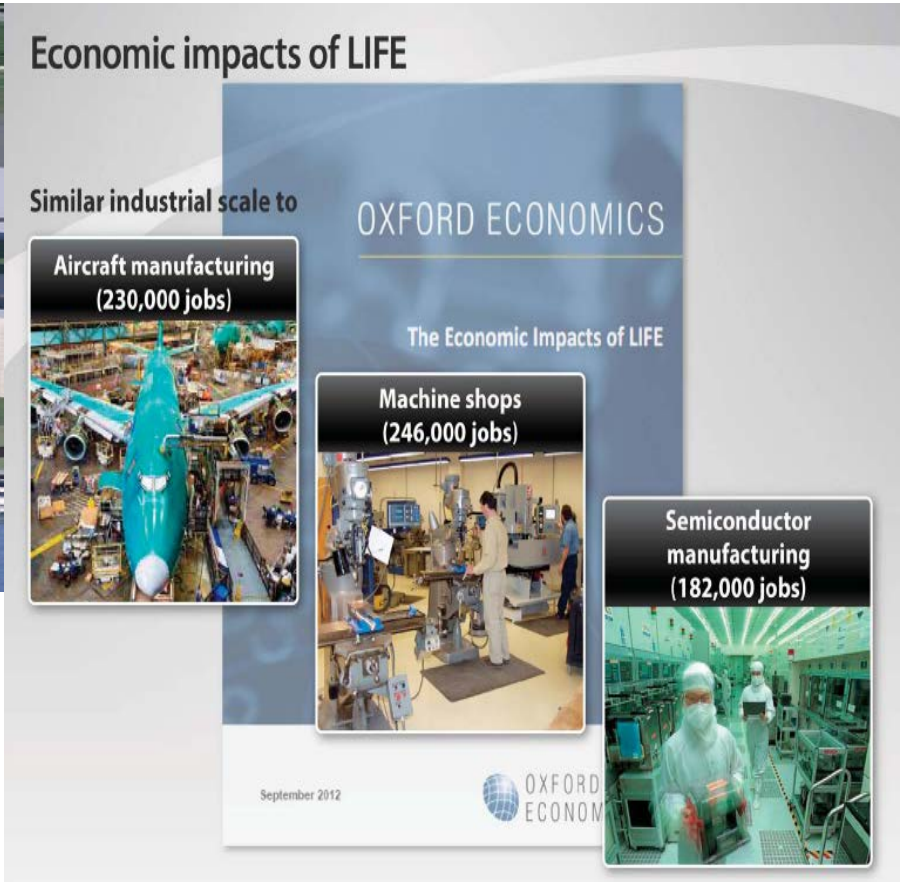
- For the last two years Blue Sky has been developing the first fast scanning far infrared diagnostic spectrometer for the fusion effort. Delivery is Dec 2016 – short term potential customers include existing fusion research facilities.

- The number of fusion reactors could exceed 10,000 by 2100; large market if half were ITER type, each requiring 2-3 spectrometers.

- **At a cost of ~$1M each this represents a significant, made in Alberta, commercial opportunity.**

Laser Inertial Fusion Energy - LIFE





Fusion energy impact - sustainable clean power; creating new industries

Summary

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Opportunity - Call to Action

- Fusion will be transformative – a global win in many ways!
- Fusion will be a great job creator – high value added
- Demonstration fusion power plant on the horizon
- Canada is the only OECD country without a fusion energy program
- Europe, Japan & the USA have opened their doors for us
- Alberta has an image opportunity as an innovation leader
- Come and join our fusion initiative – become a member

Alberta/Canada Fusion Technology Alliance