

Laser Inertial Fusion: Pathway to Clean Energy

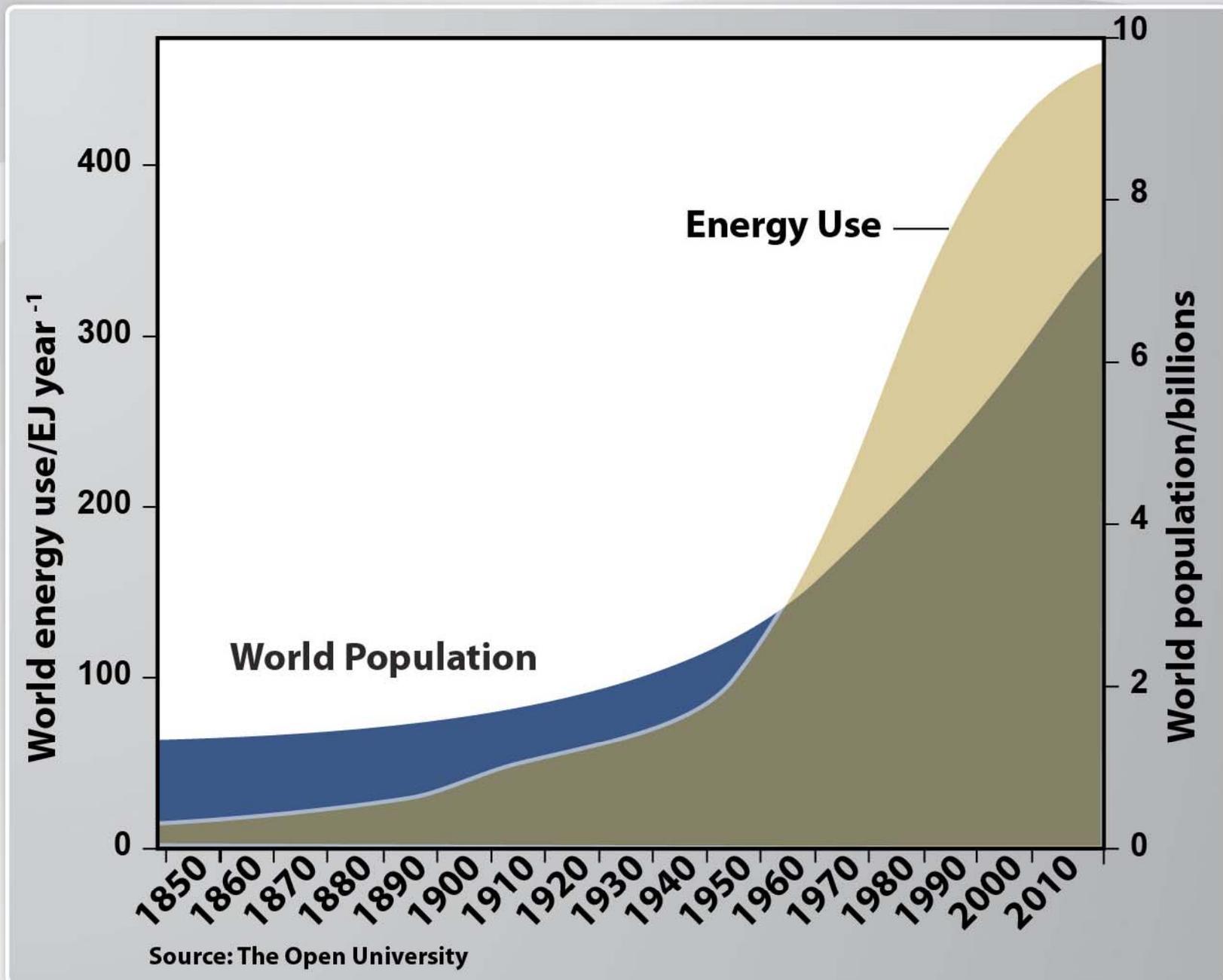


Bob Deri

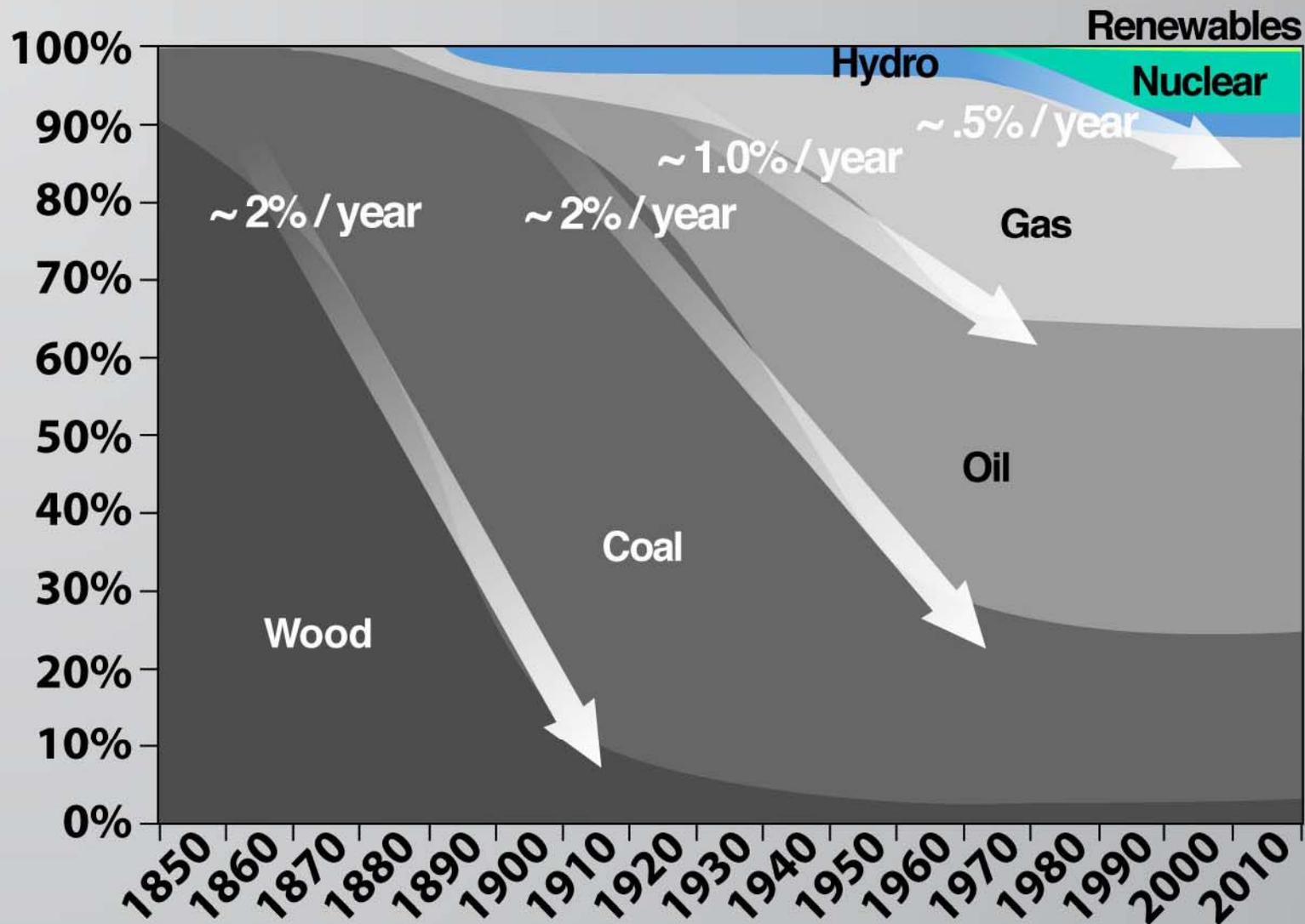
LLNL-PRES-476291-Draft

**Presentation to OSA-Rochester Section Annual Dinner
April 19, 2011**

International energy consumption



US energy modalities since 1850 have changed slowly



Source: Steven Koonin, Under Secretary of the Department of Energy

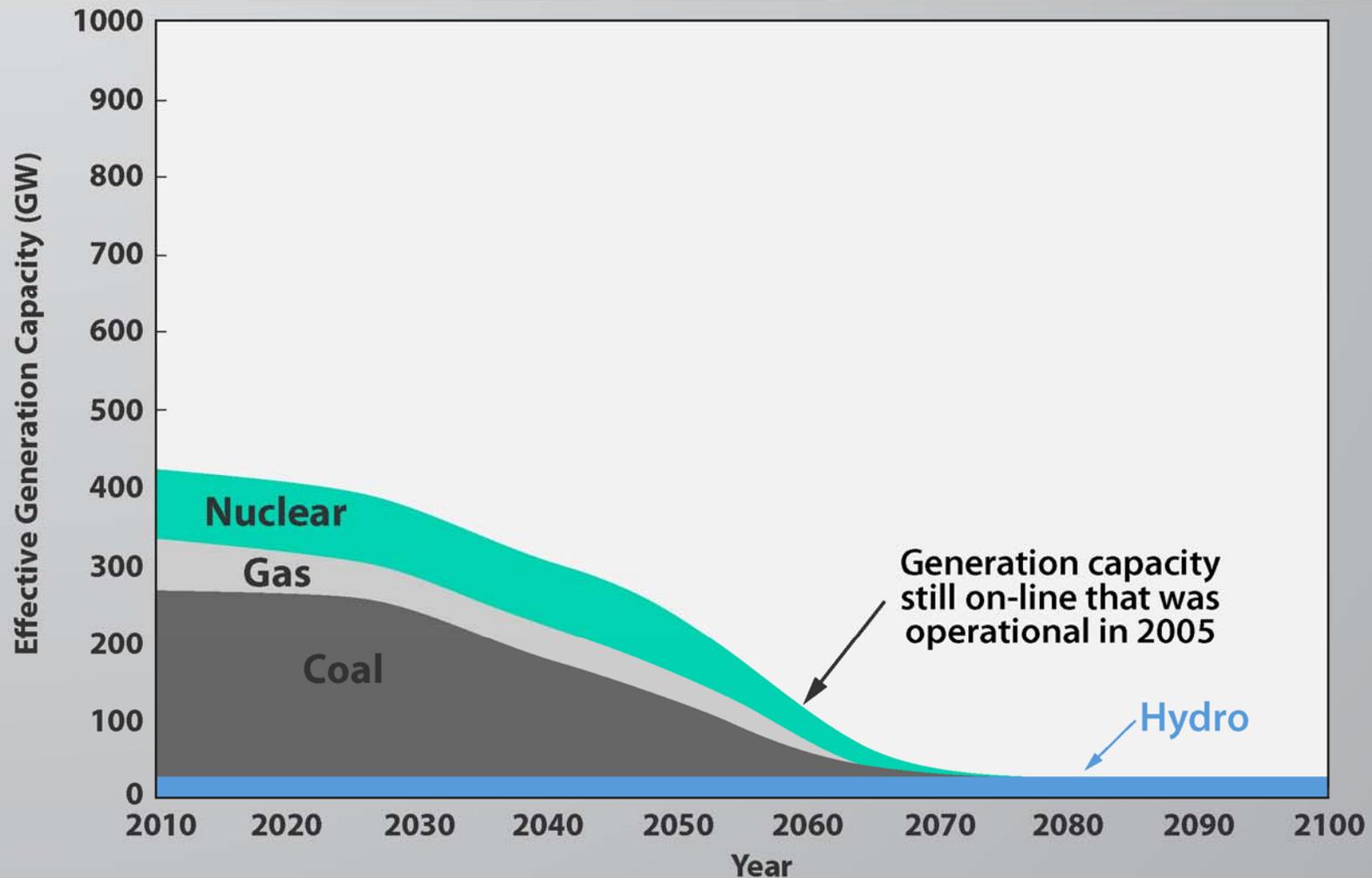


We are burning up to 10 million years of fossil carbon fuel every year

It's not going to last forever

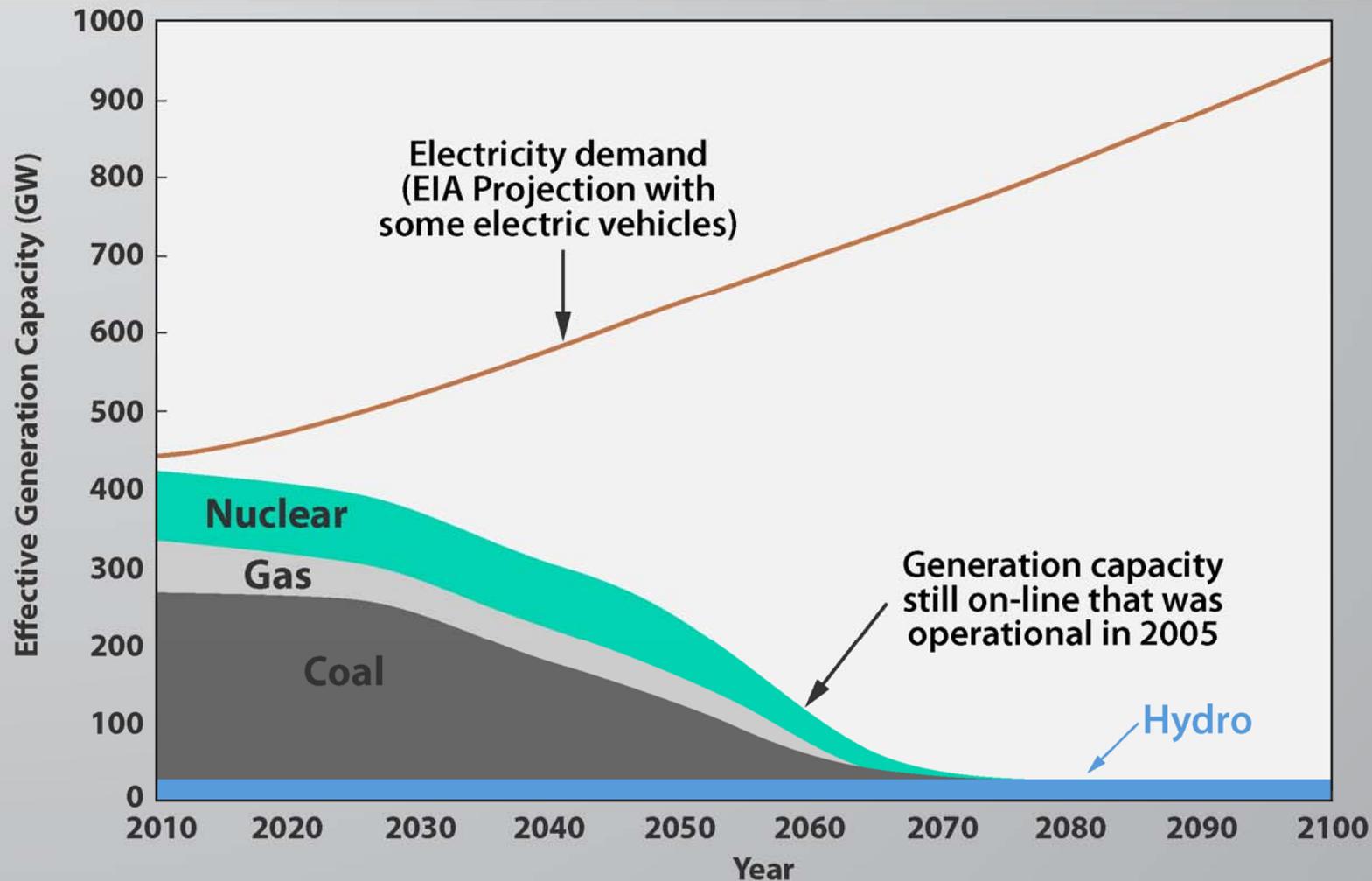
New-build electrical generation is required to fill the "generation gap"

Based on U.S. Energy Information Agency's Annual Energy Outlook (2009), Retirement of Plants



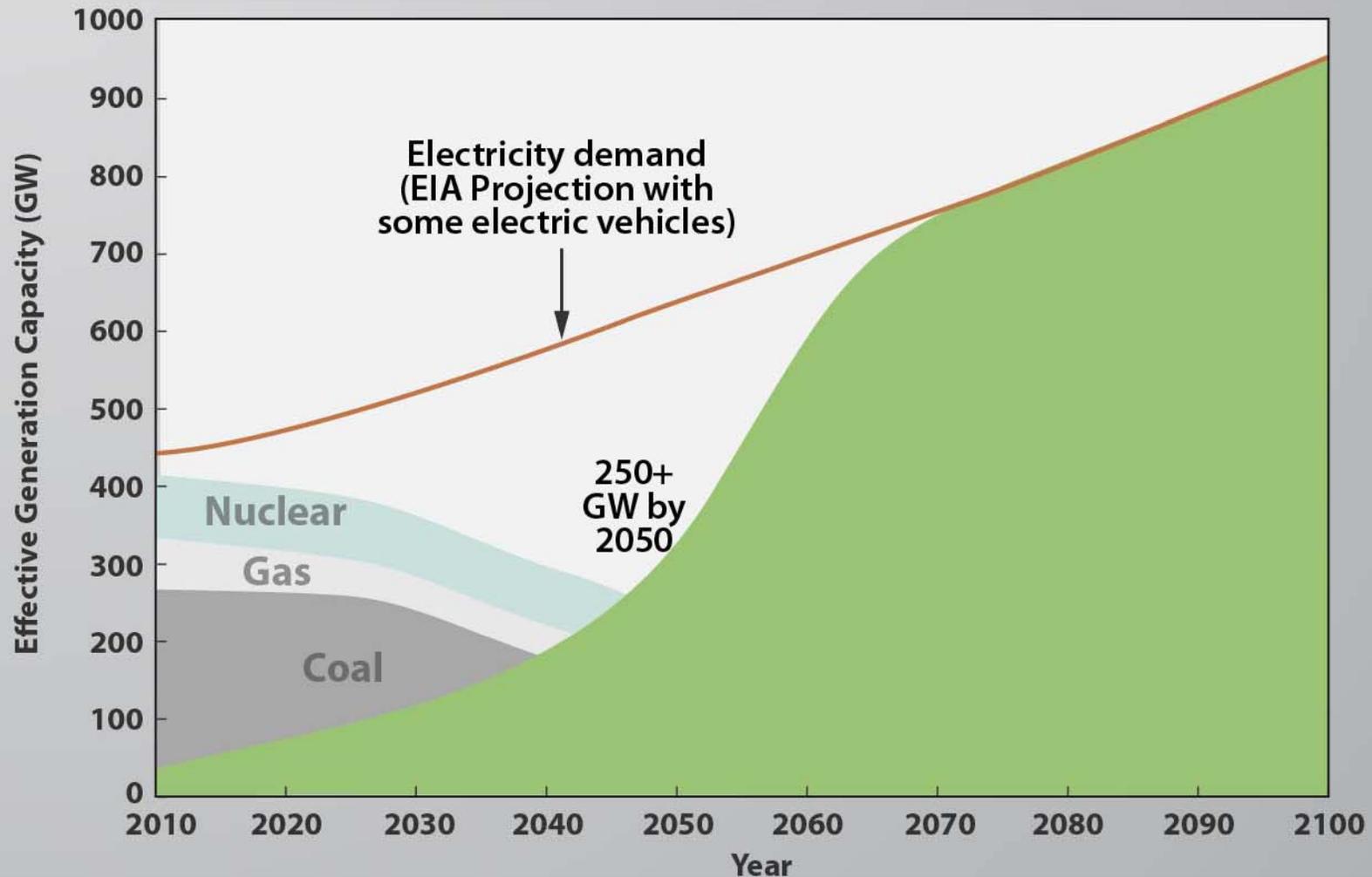
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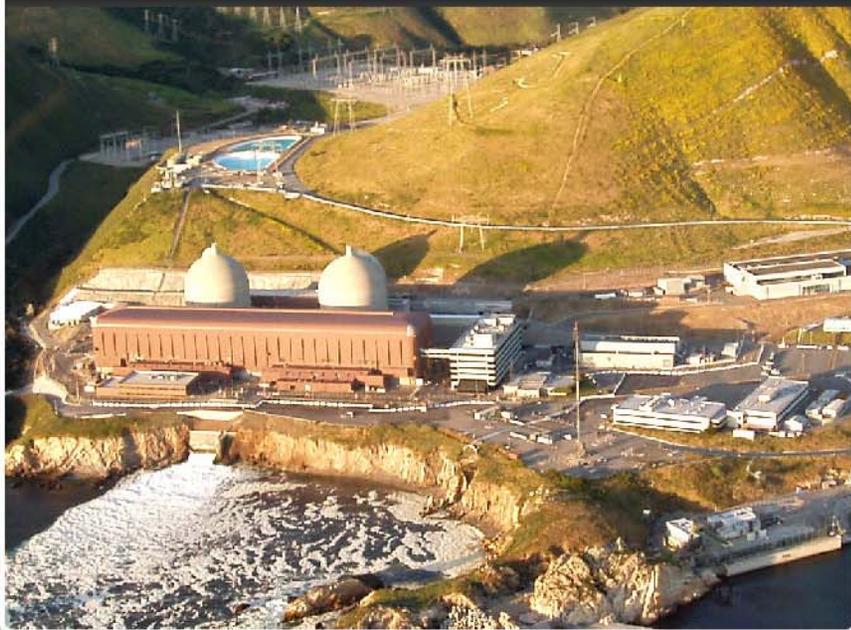
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How much energy does the U.S. need to provide/replace in the next 50 years?

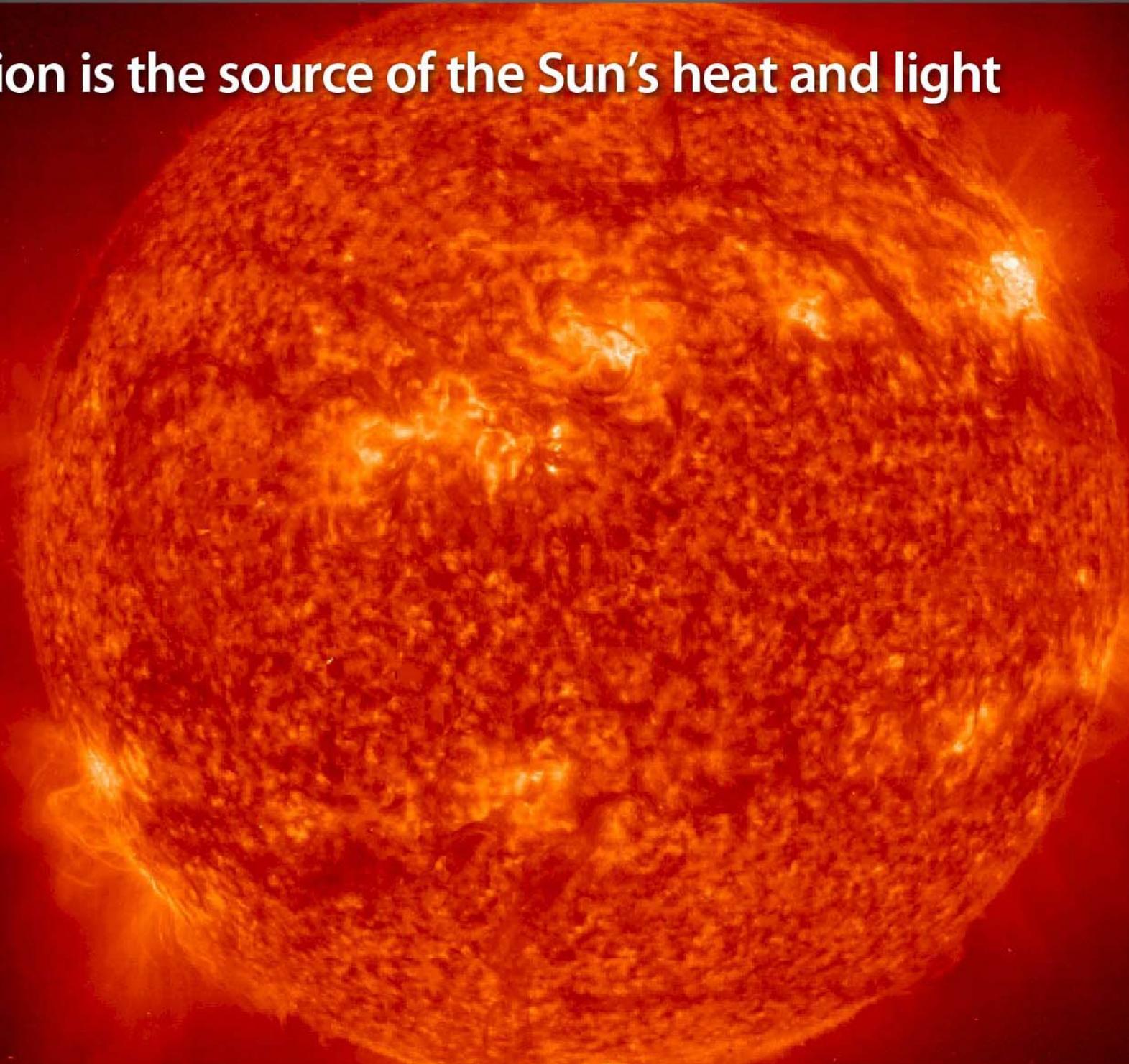
250 Diablo Canyon



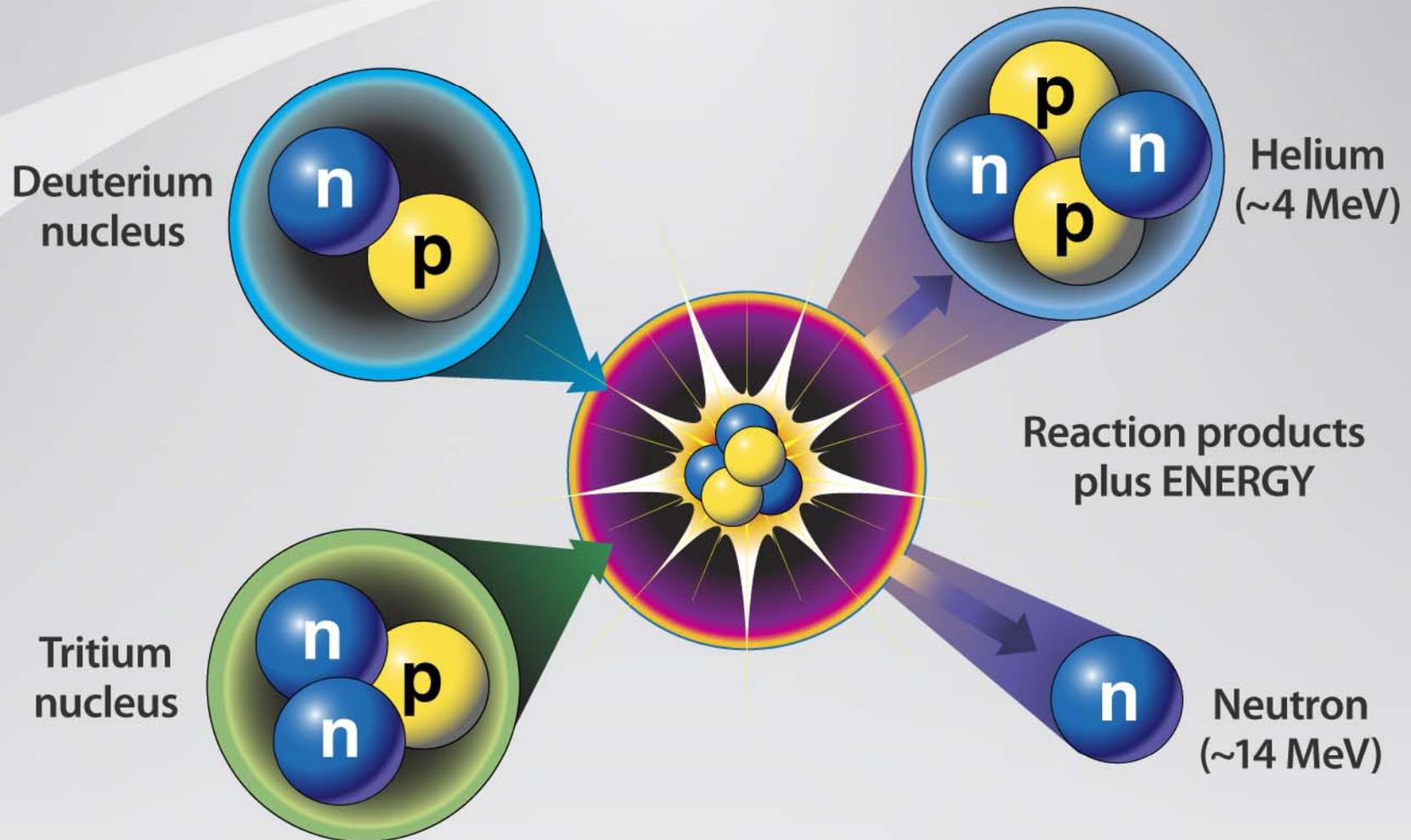
1000 Moss Landing Power Plants



Fusion is the source of the Sun's heat and light



Fusion Reaction



This is "Exothermic" — More energy out than in

**Fusion Energy:
35 liters of Heavy Water
Carbon Free**



**Chemical Energy:
Super Tanker Full of Oil
Carbon Dioxide Rich**





Could we build a miniature sun on earth?

... to provide significant
carbon-free energy
for humankind.

Recipe for fusion on earth

NIF

Ingredients

Hydrogen from water

Directions

1. Filter out heavy water
2. Place in oven and heat to 200M °F
3. Bake for few billionths of a second
4. Convert mass to copious amounts of clean energy

NO CARBON, NO WASTE!

Lawrence Livermore National Laboratory

LLNL

National Ignition Facility

NIF is the culmination of a long line of glass laser systems developed at LLNL

Janus, 1973



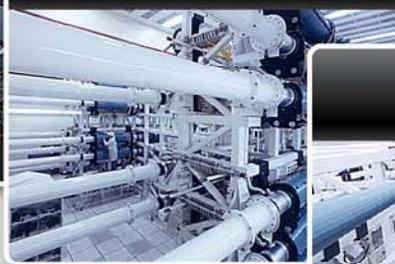
100J IR

Argus, 1976



1kJ IR

Shiva, 1977



10kJ IR

Nova, 1984



30kJ UV

NIF, 2009



1.8MJ UV

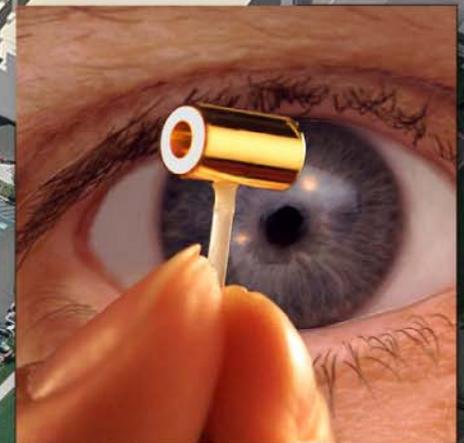
NIF Laser System

- 192 Beams
- Frequency tripled Nd glass
- Energy 1.8 MJ
- Power 500 TW
- Wavelength 351 nm

NIF is 50 times more energetic than any previous laser

NIF concentrates all 192 laser beam energy
in a football stadium-sized facility into a mm^3

Matter
Temperature $>10^8 \text{ K}$
Radiation
Temperature $>3.5 \times 10^6 \text{ K}$
Densities $>10^3 \text{ g/cm}^3$
Pressures $>10^{11} \text{ atm}$





Target Chamber June 1999



NIF is a Low Hazard Rad Facility



- Introduction of Tritium
- Neutron yield experiments

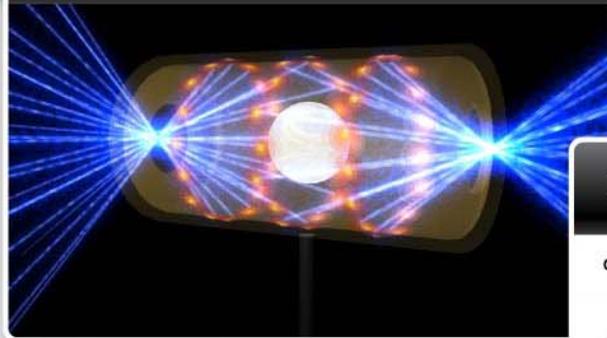
Four steps to ignition

Commission laser

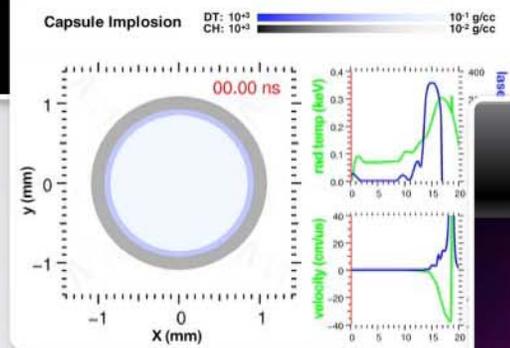


We are taking a systematic approach to learning and improving our engineering design to achieve ignition

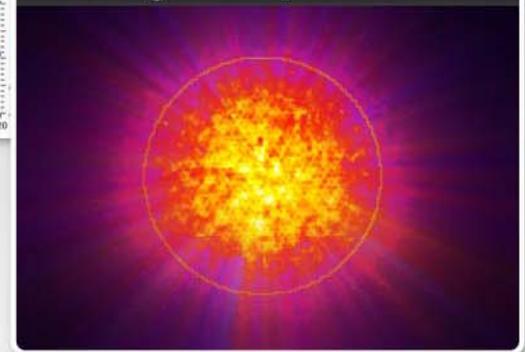
Commission hohlraum



Commission capsule



Commission layered target implosions



U.S Partners in NIF Enterprise:



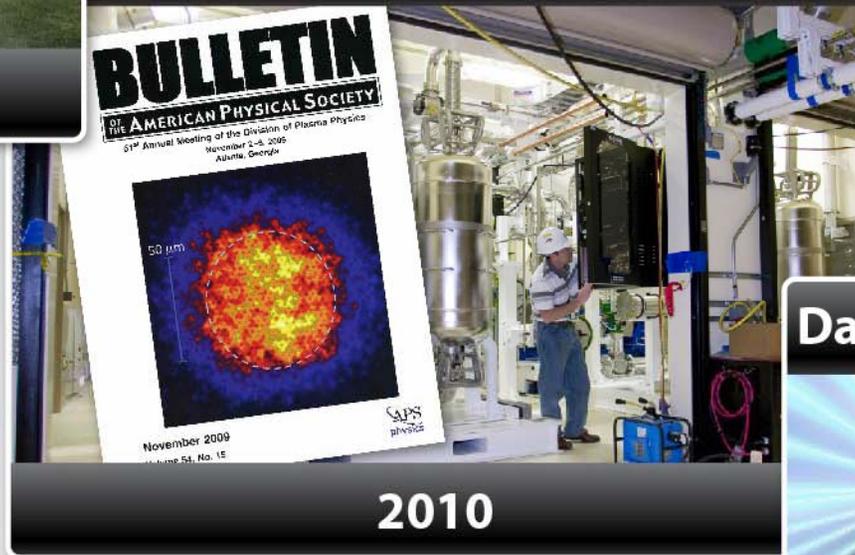
NIF/NIC Strategy: Ignition preparation period

Completed NIF Project



2009

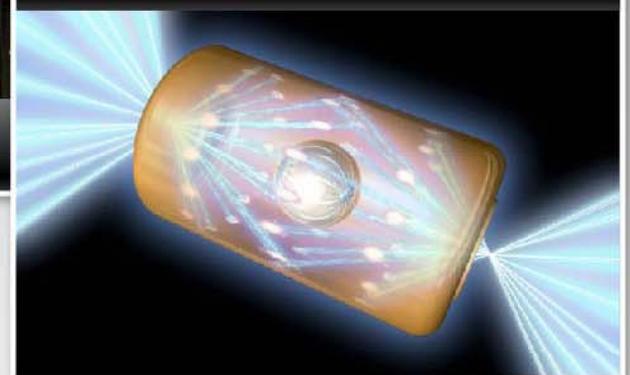
Preparation for Ignition



2010

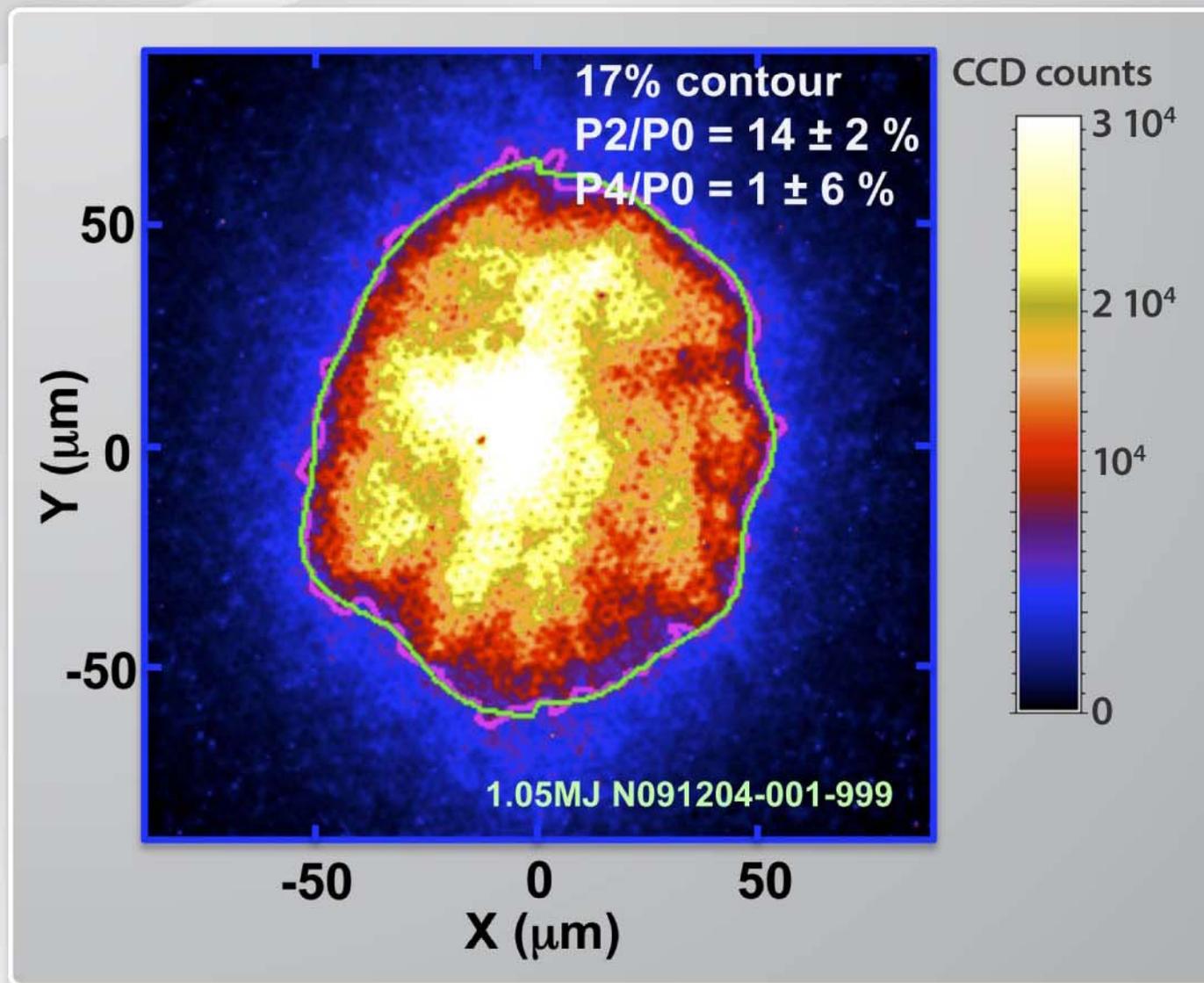


Data, Data, Data, Ignition

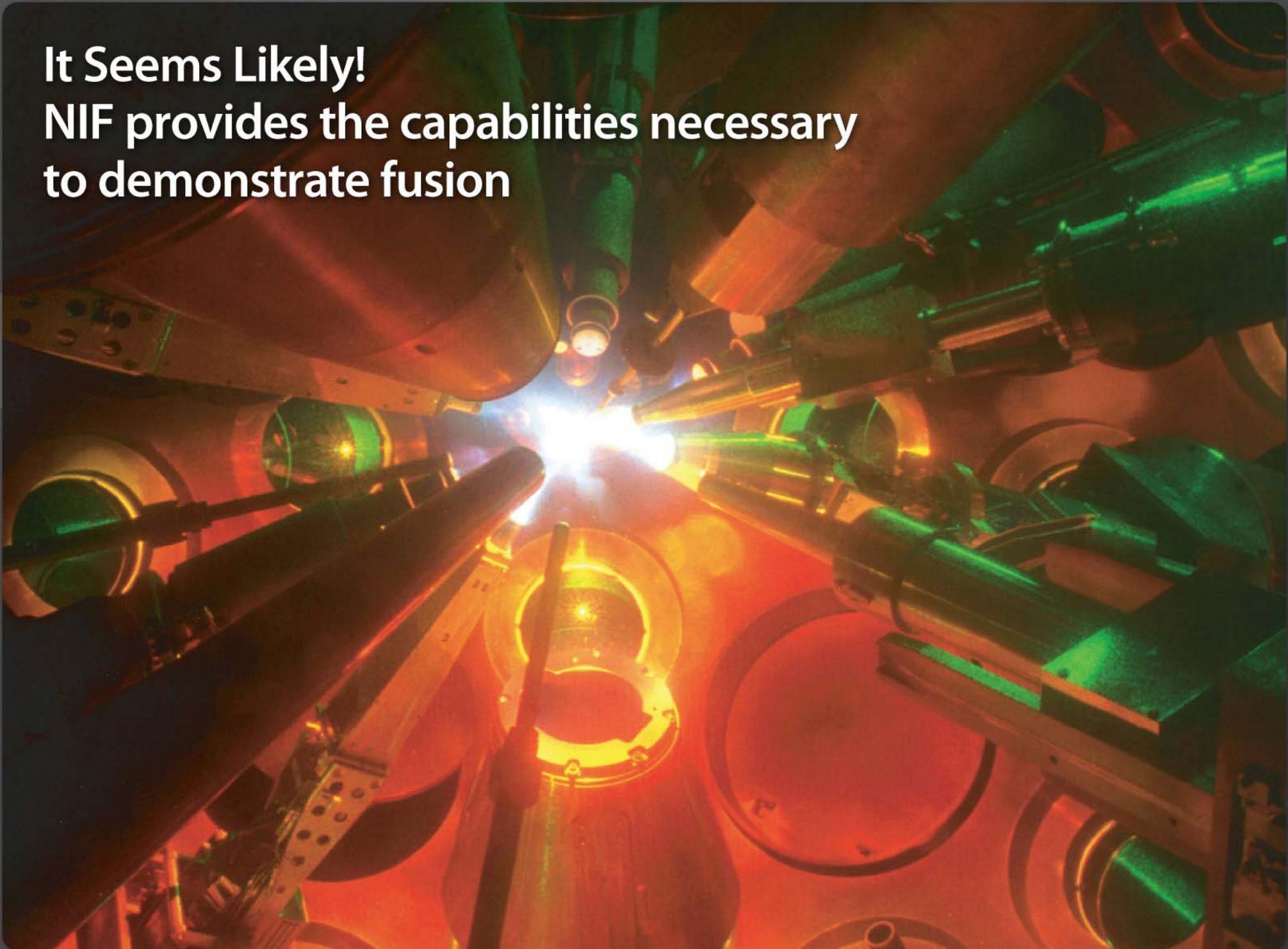


2011-2012

Capsule implosions in 1 MJ cryogenic gas-filled hohlraum have shown good symmetry at 284 eV



**It Seems Likely!
NIF provides the capabilities necessary
to demonstrate fusion**



The way forward to clean energy

“The National Ignition Facility is a marvel, and while the Laboratory will achieve ignition, we need to think about what we should be doing in a year or two from today.

... DOE should assume ignition success in that planning, and not wait for NIF ignition to start such planning.”

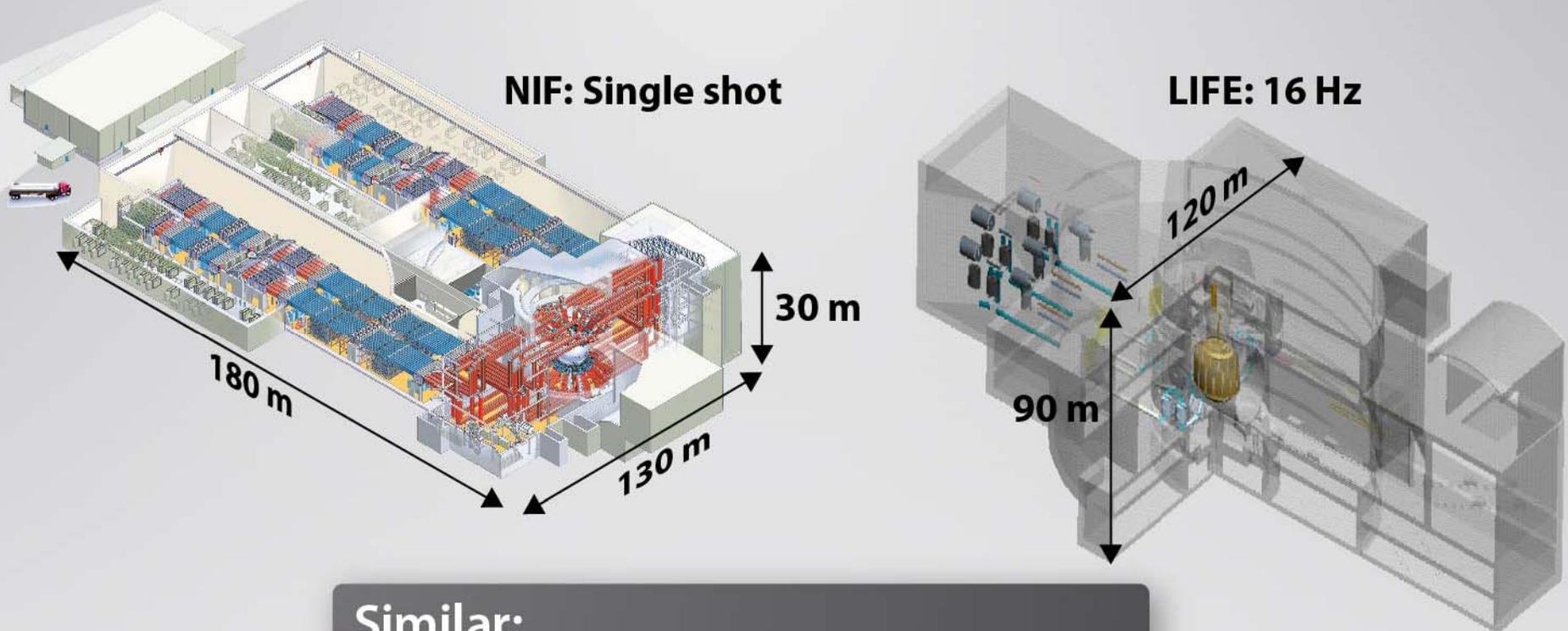
— Steven Chu U.S. Secretary of Energy

**Our plan is for LIFE:
Laser Inertial Fusion Energy**

**Energy Secretary
Steven Chu**



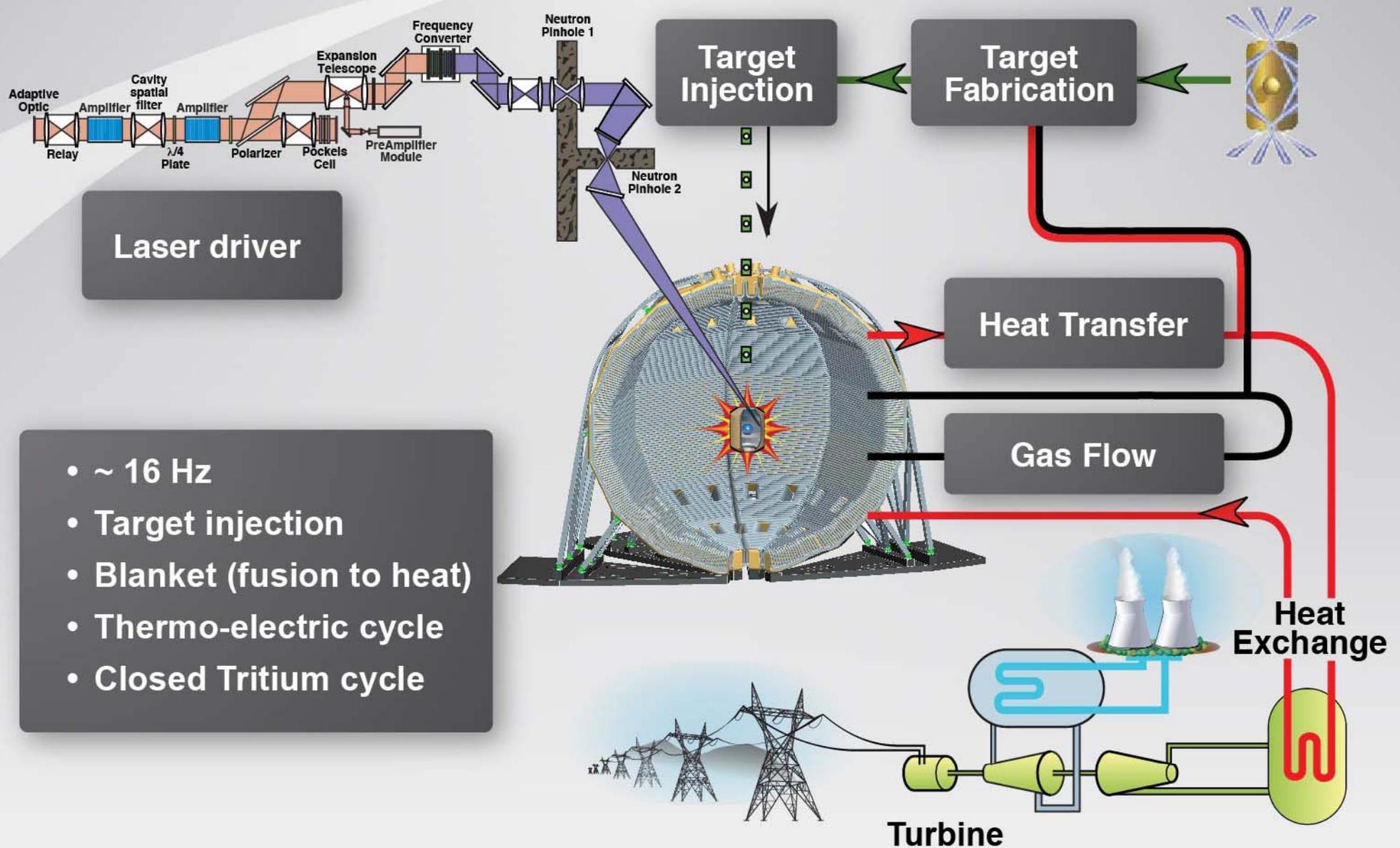
Experience with NIF & evidence from the ignition campaign are defining the path forward for LIFE



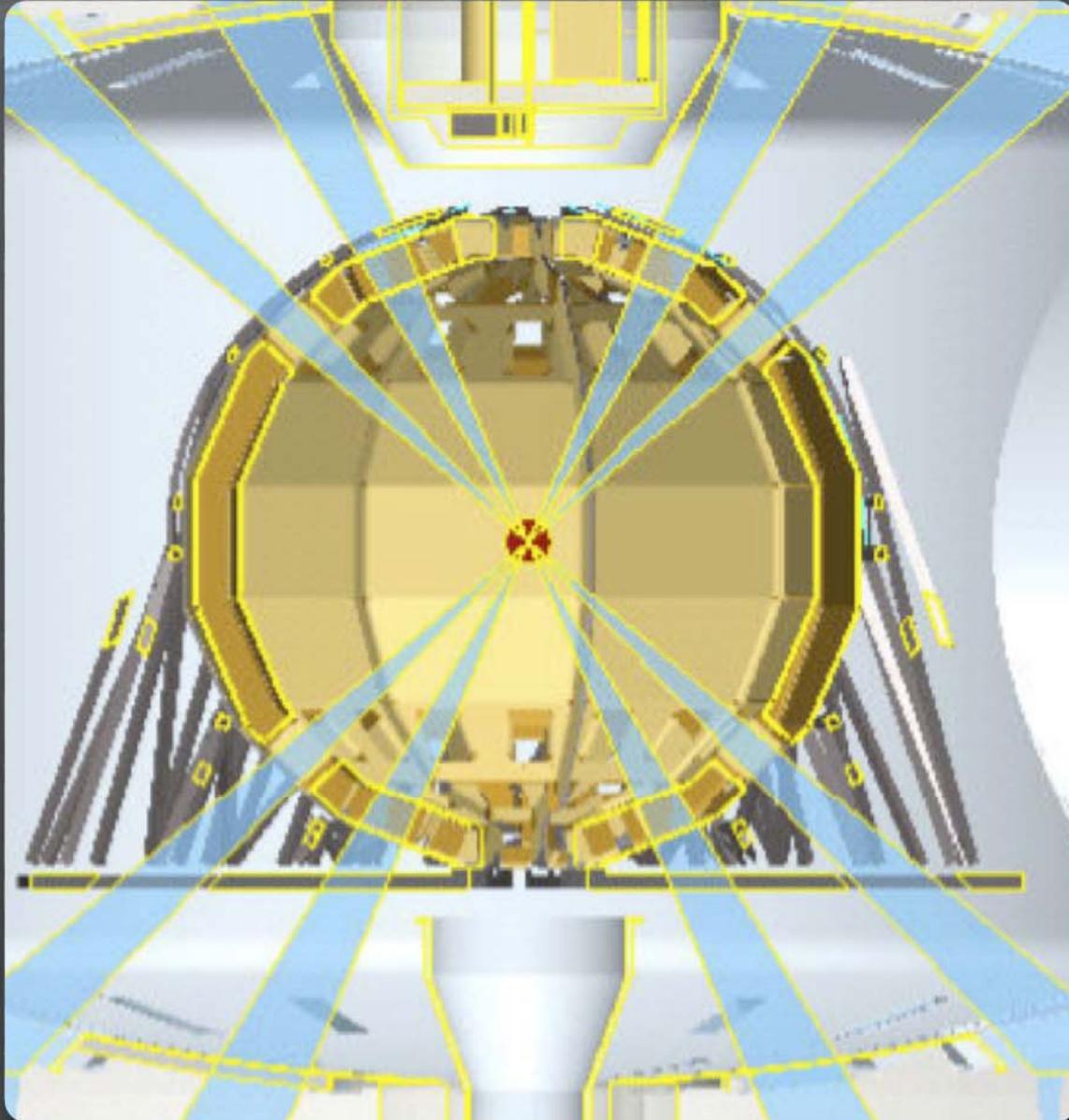
Similar:

- Physical size
- Laser energy
- Target performance
- Concept of operations (LRUs, ...)

LIFE combines the “single shot” capability of NIF with the ~16 Hz requirements for power plant operations

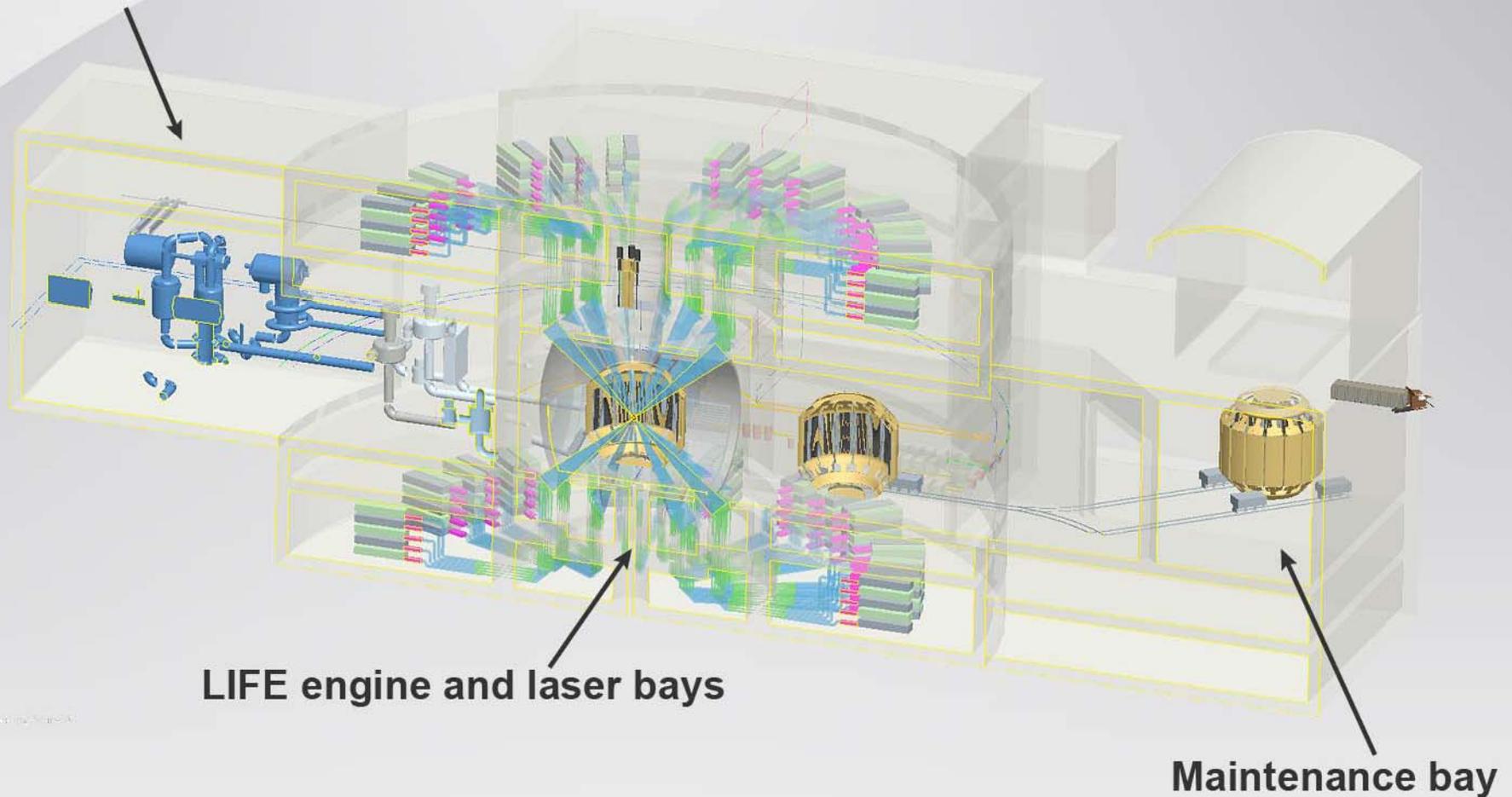


NIF Beam geometry and chamber size will be used for LIFE



An integrated design for LIFE power plants has been developed

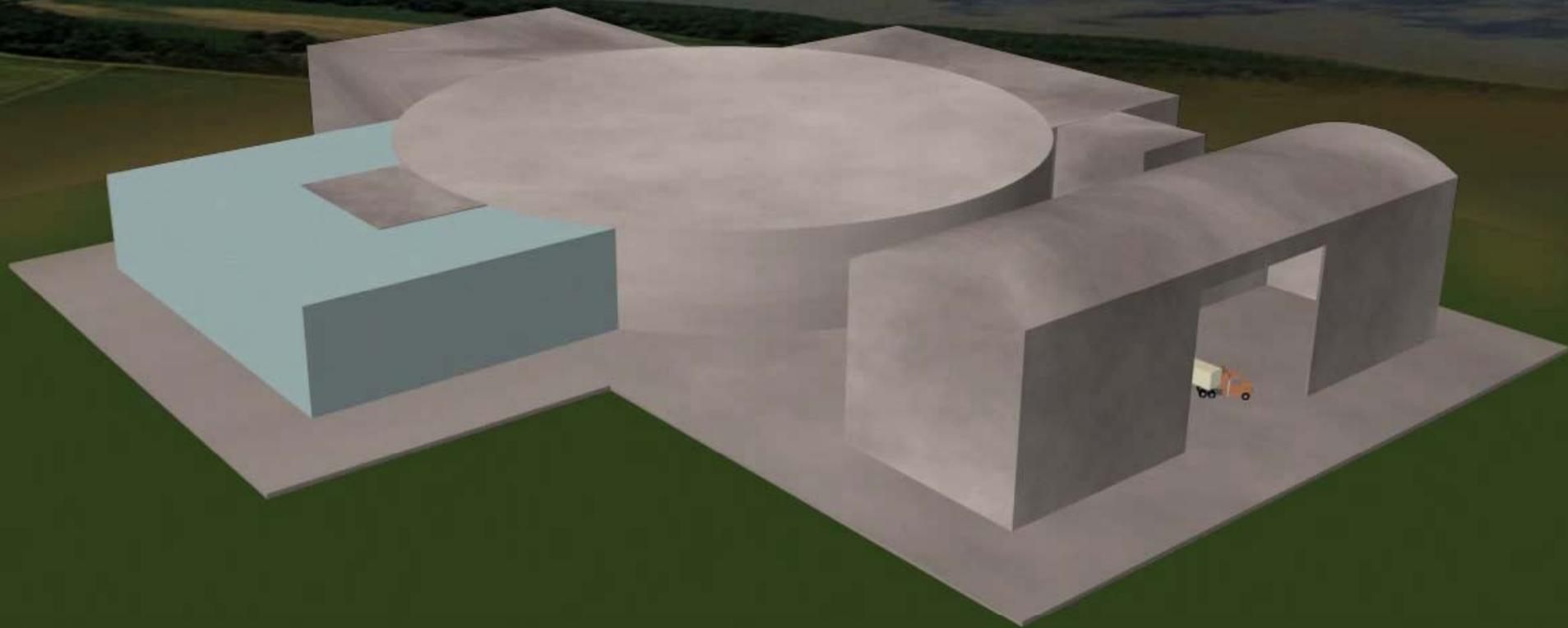
Turbines building



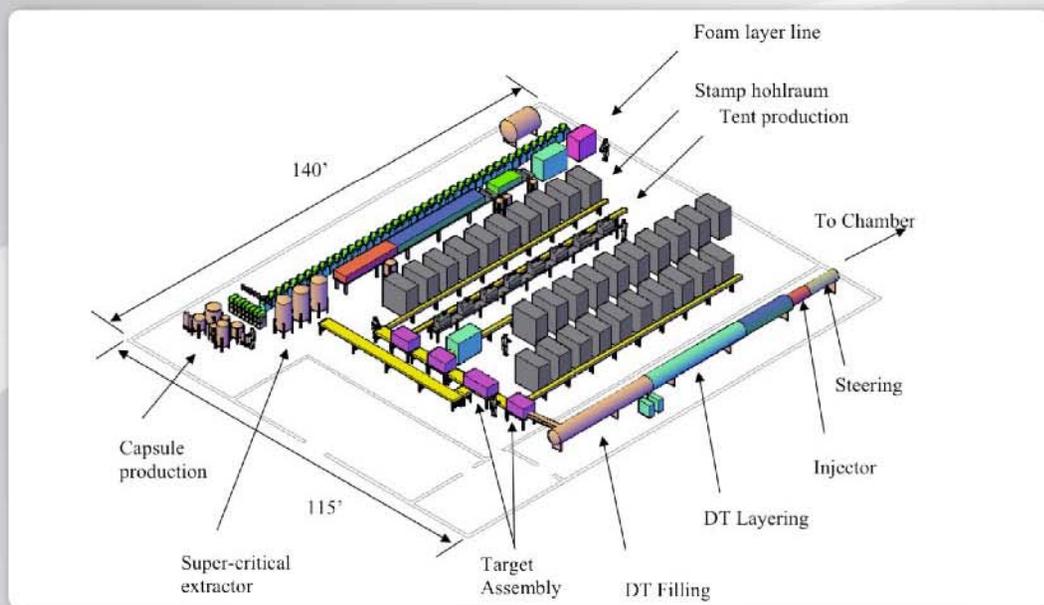
LIFE engine and laser bays

Maintenance bay

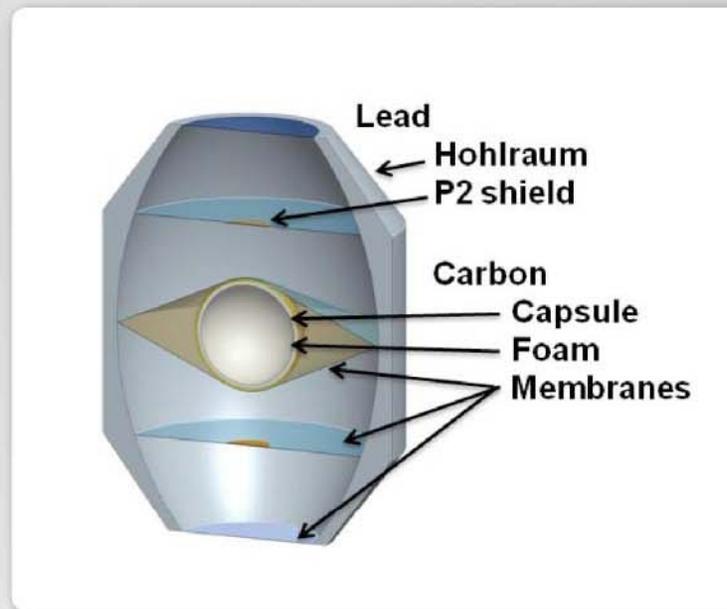
Energy production in a LIFE system



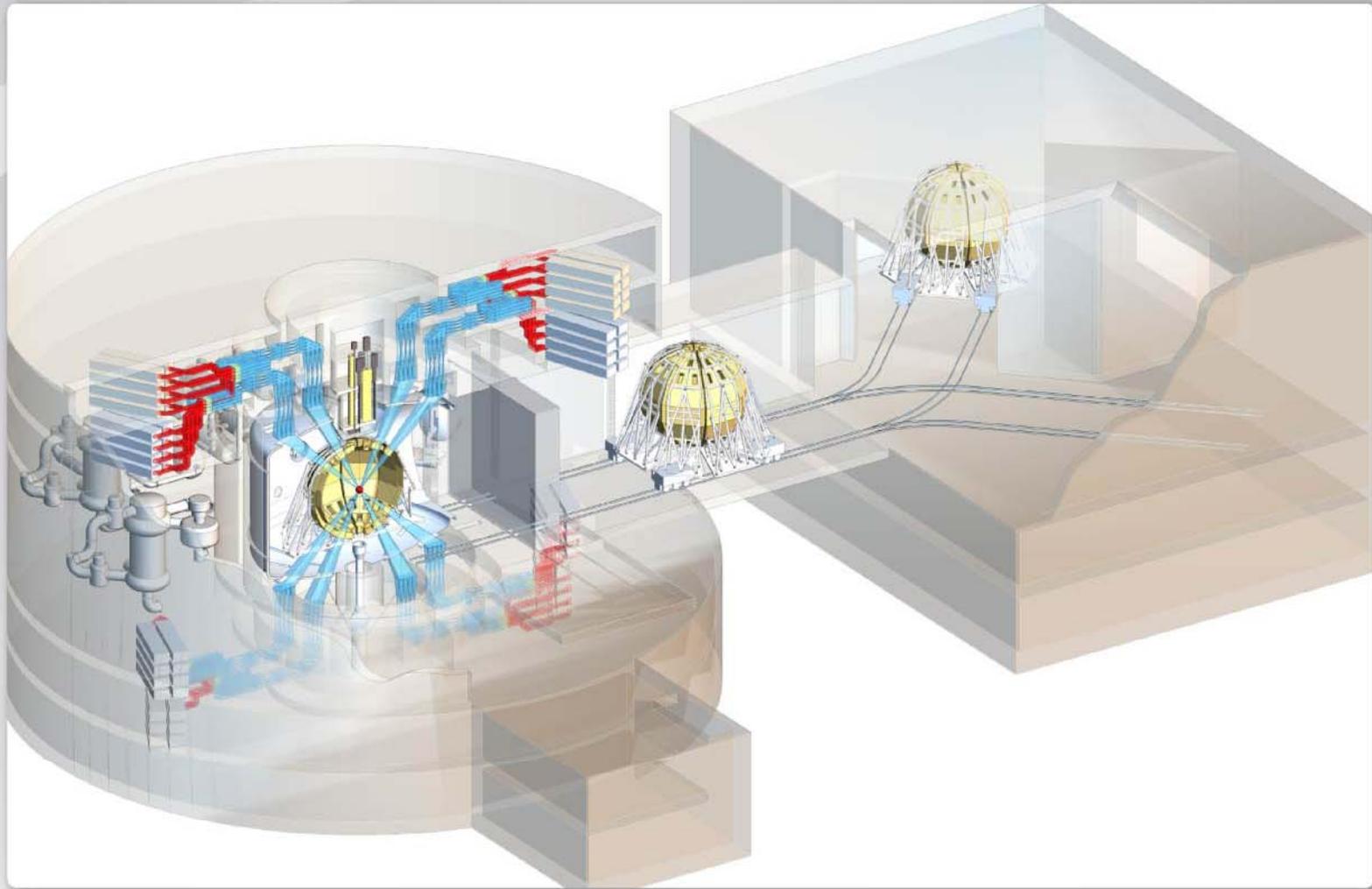
Targets are designed for ease of mass manufacture



- Use known high-throughput, low-cost manufacture techniques such as injection molding, plating
- Use large batch size for chemical processes
- Completely automated production line
- Statistical process control
- Approach based on consultation with potential industrial suppliers



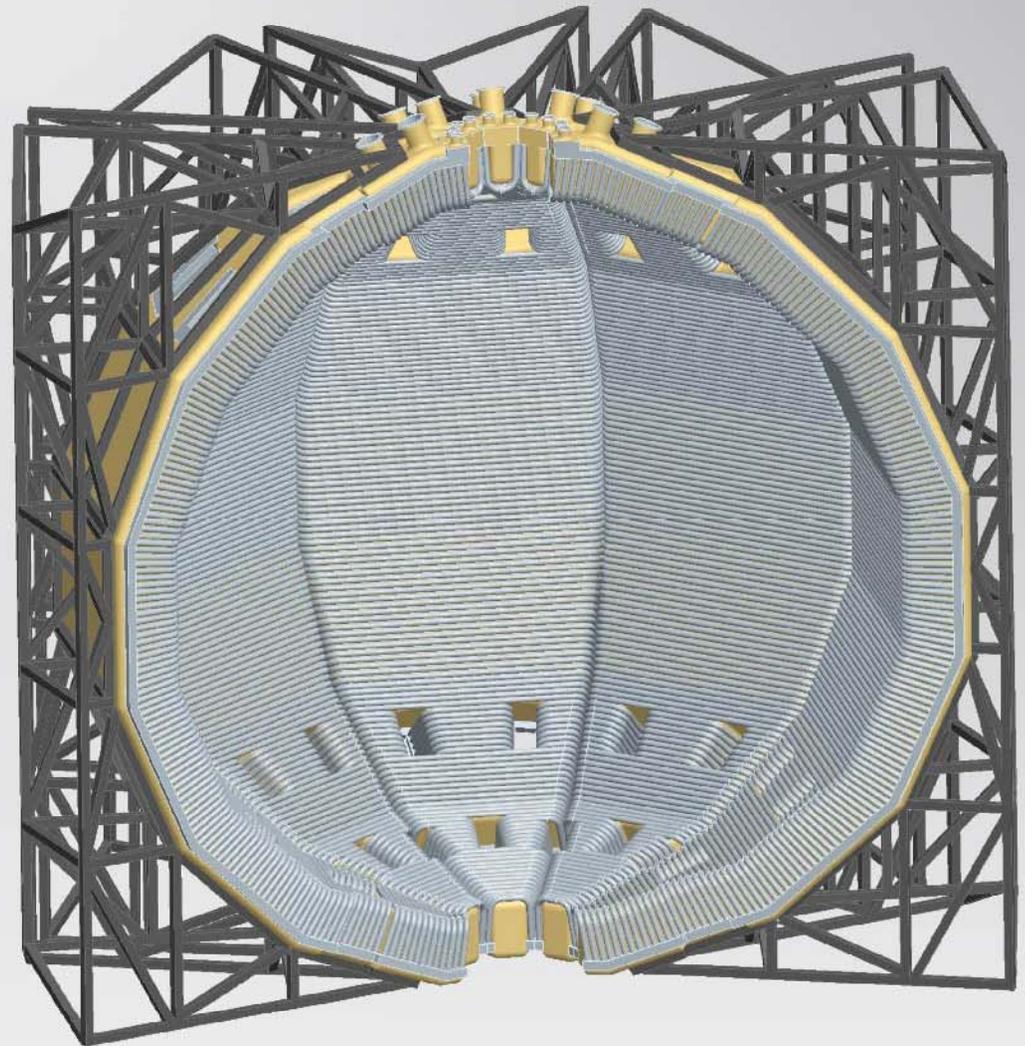
Material performance uncertainties will be mitigated by a modular, replaceable chamber



Unsealed chamber, separate from the vacuum and optical systems

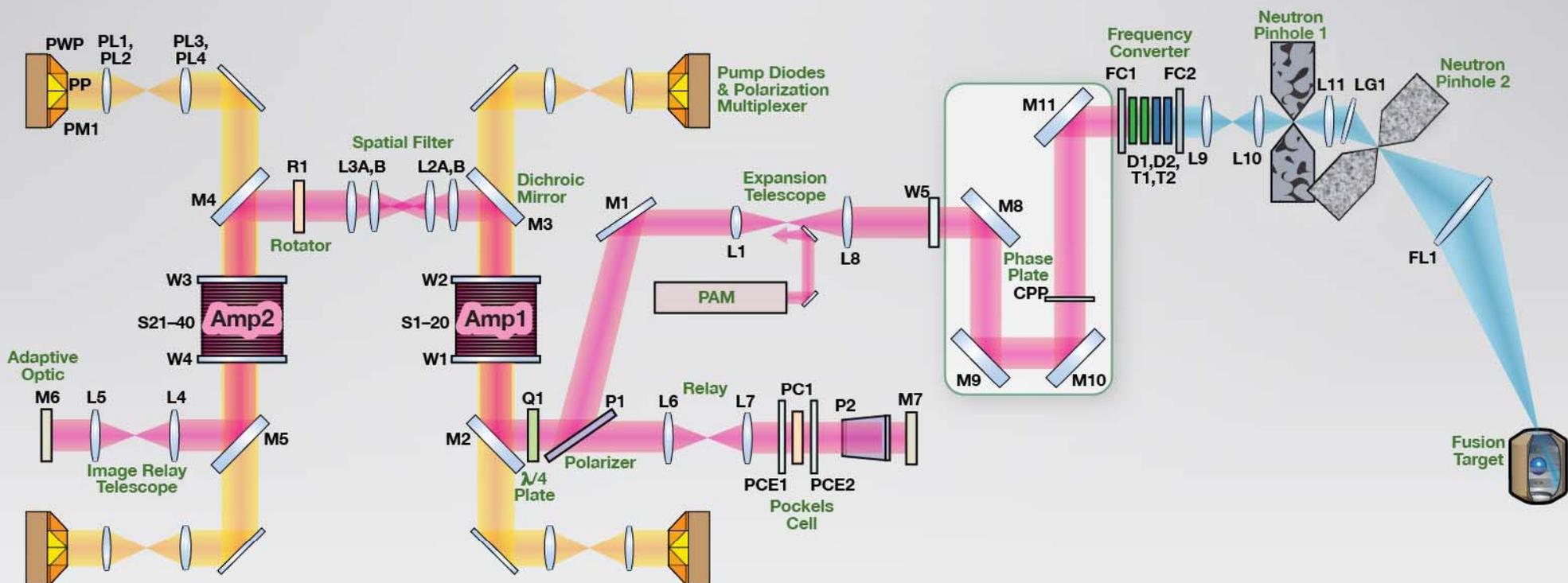
The LIFE “chamber” is a network of tubes, protected by Xenon gas. It is modular and NIF scale

- Tubes balance hydrostatic pressure, neutron heating and conduction terms
- Ions stopped in ~10cm gas
- X-ray heating mitigated (to ~800C)
- Wall lifetime of 2-4 years
- Laser propagation OK

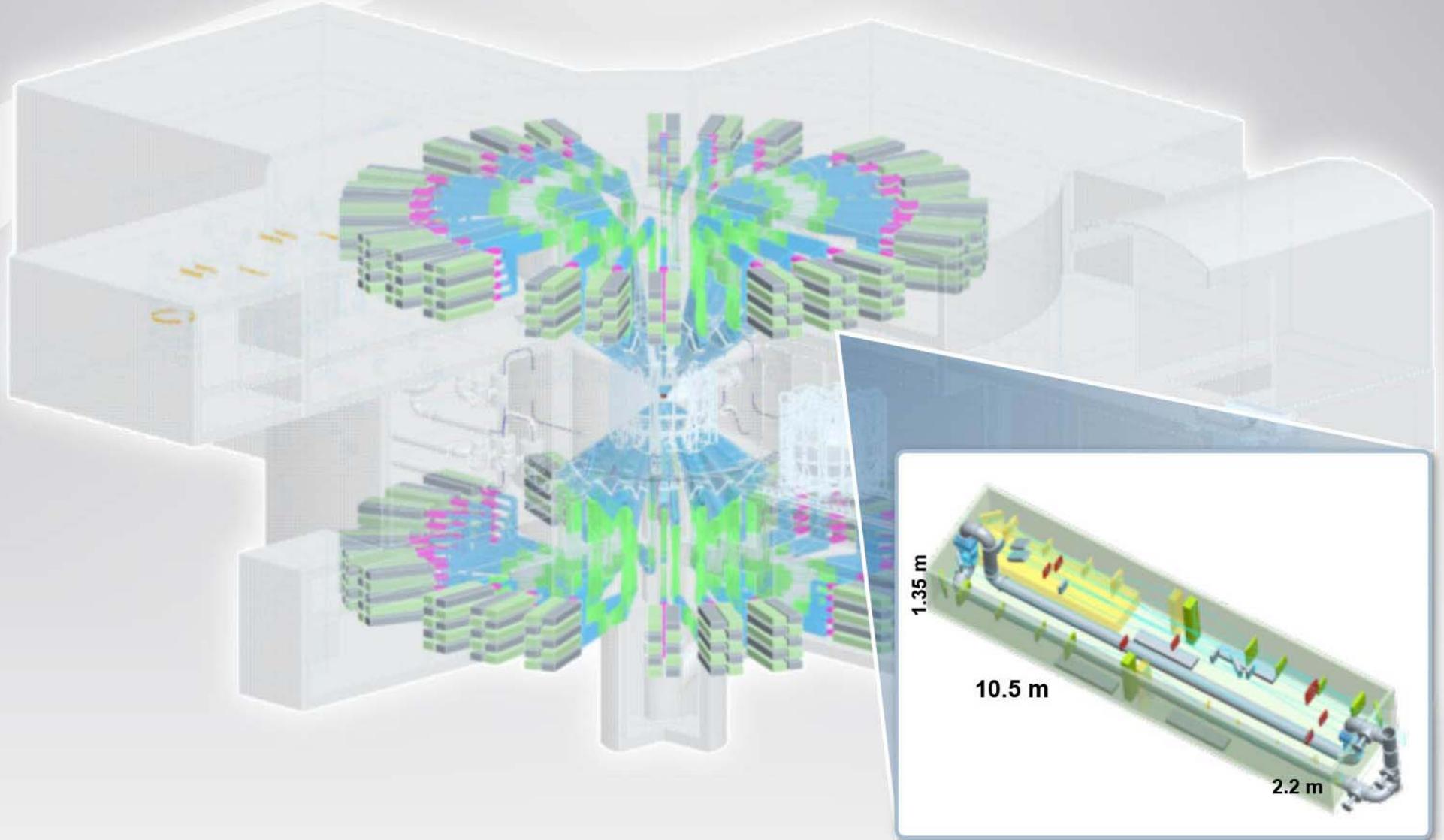


LIFE laser design has been developed to balance commercial and technical requirements

Time to market	Conventional glass technology
Reliability	3w fluence = 1/3 NIF
Availability	LRU beam box <12m long
Maintainability	Factory build and repair
Performance specification	Set by NIF demonstrations



The point design uses a modular laser system, removing the need for a NIF-style switchyard



Feedback from industry has been used to determine component availability, performance and cost

- **30+ major vendors engaged from the semiconductor, optics, laser, construction, controls, nuclear, project delivery and regulatory industries**
 - white papers produced detailing technology readiness and cost
 - market assessments and industrial advice have driven the LIFE design
- **Example output:**
 - Semiconductor/laser diode industry
 - Optics industry: e.g.; glass production readiness (Schott APG-1)
 - Manufacturing industry: e.g. production of low activation HT-9 tubes
 - Construction / Engineering: facility design, commissioning and operations
 - Many of the key LIFE manufacturing processes are already in place

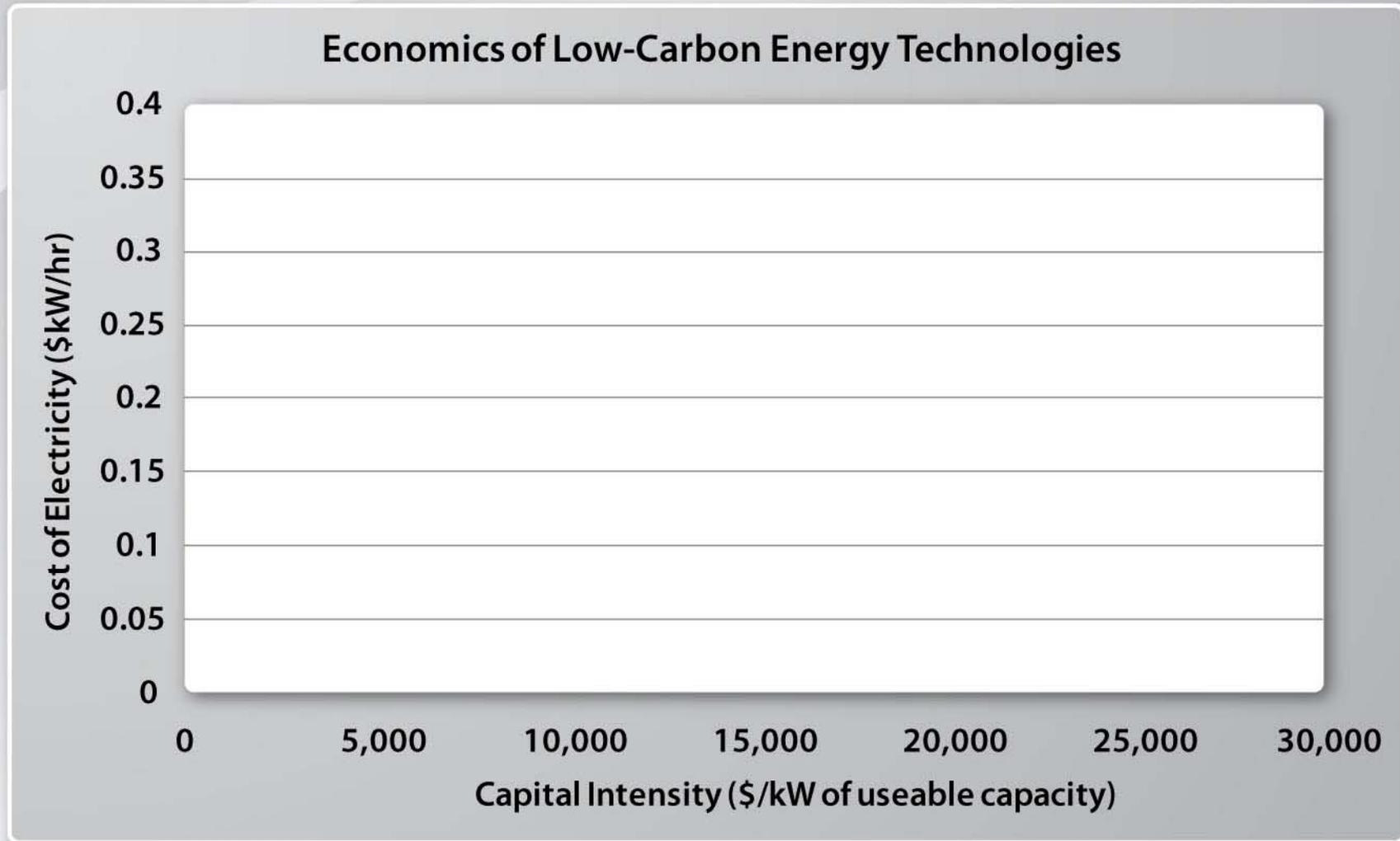
Polishing



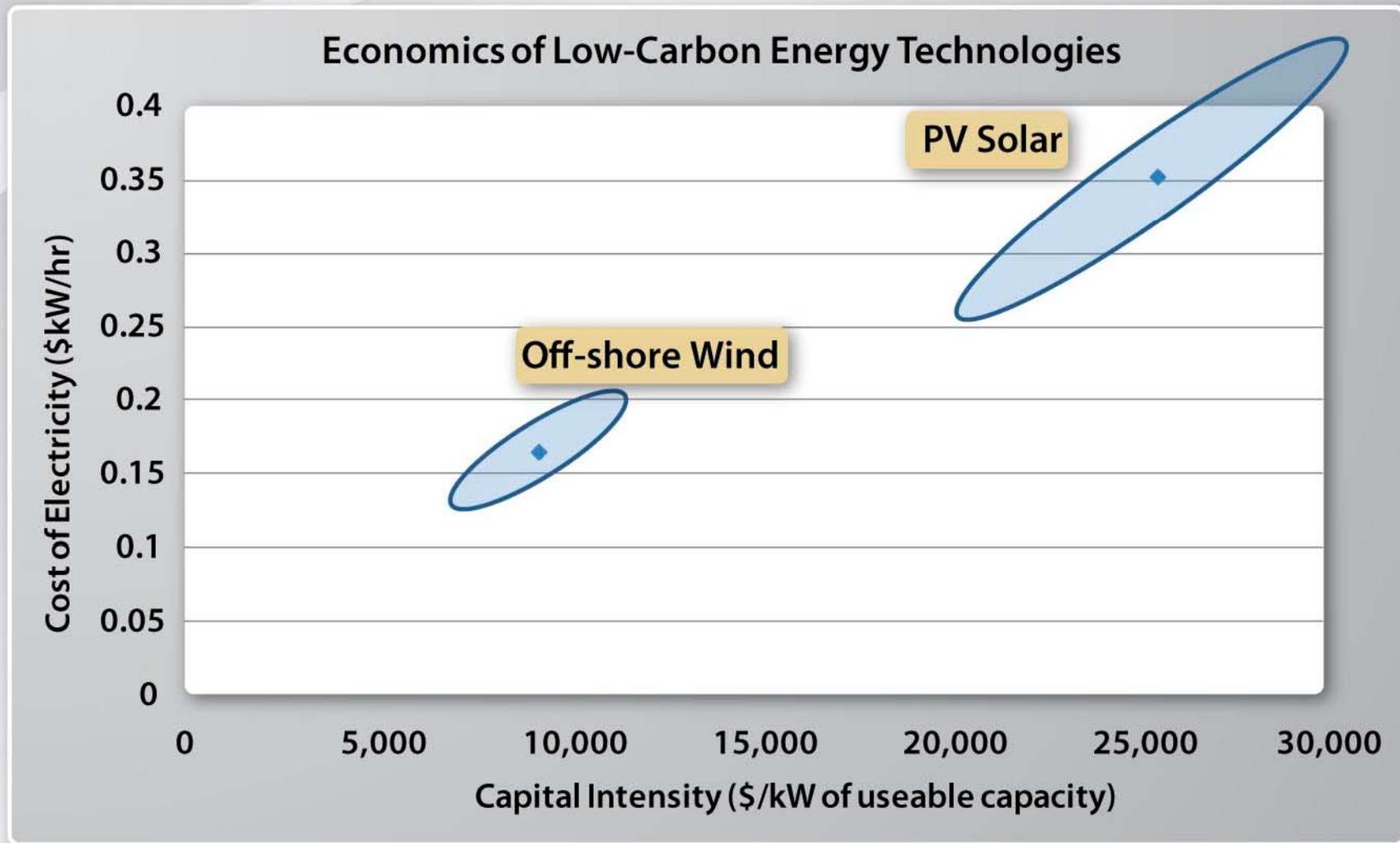
Coating



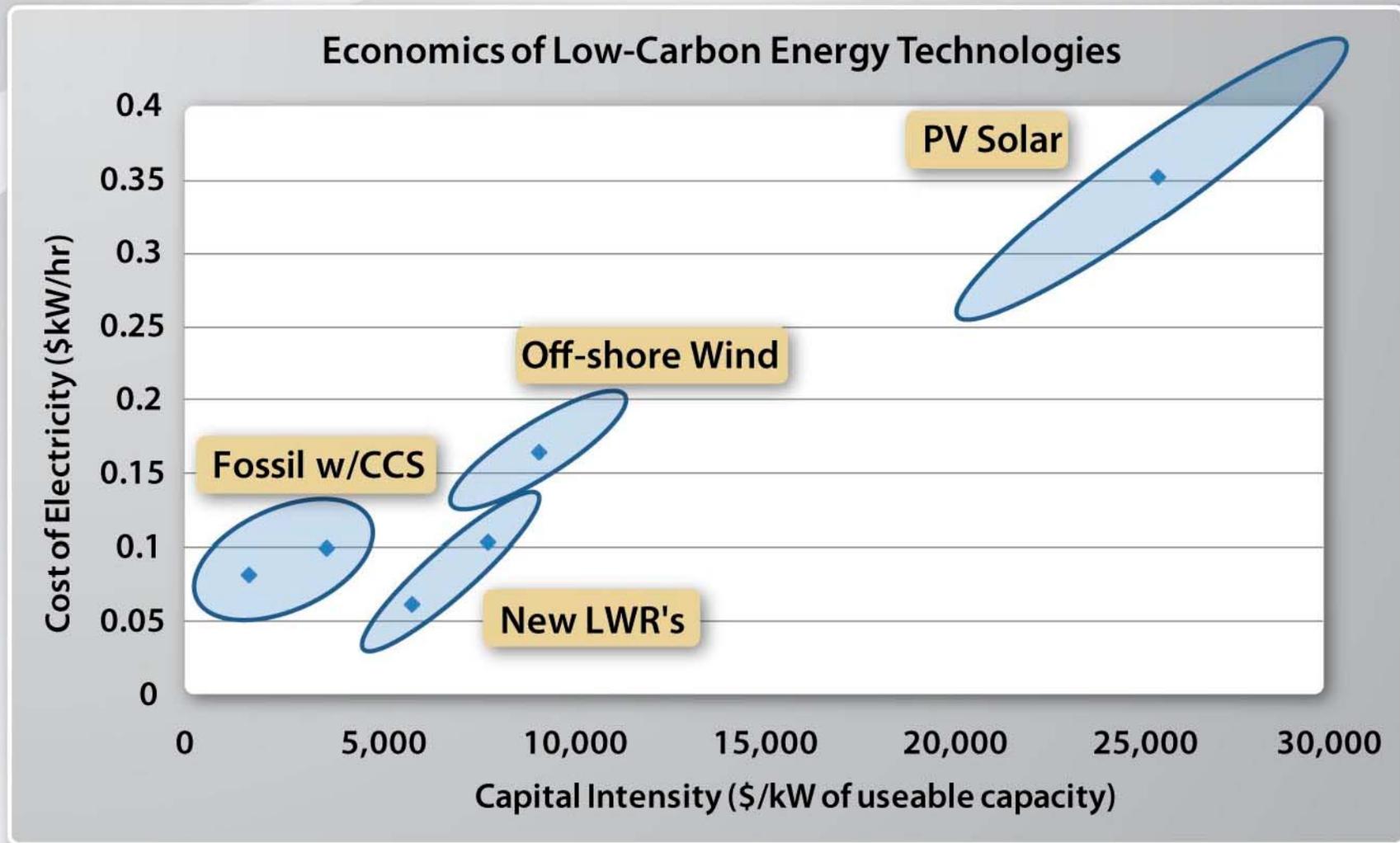
Economics of Low-Carbon Energy Technologies



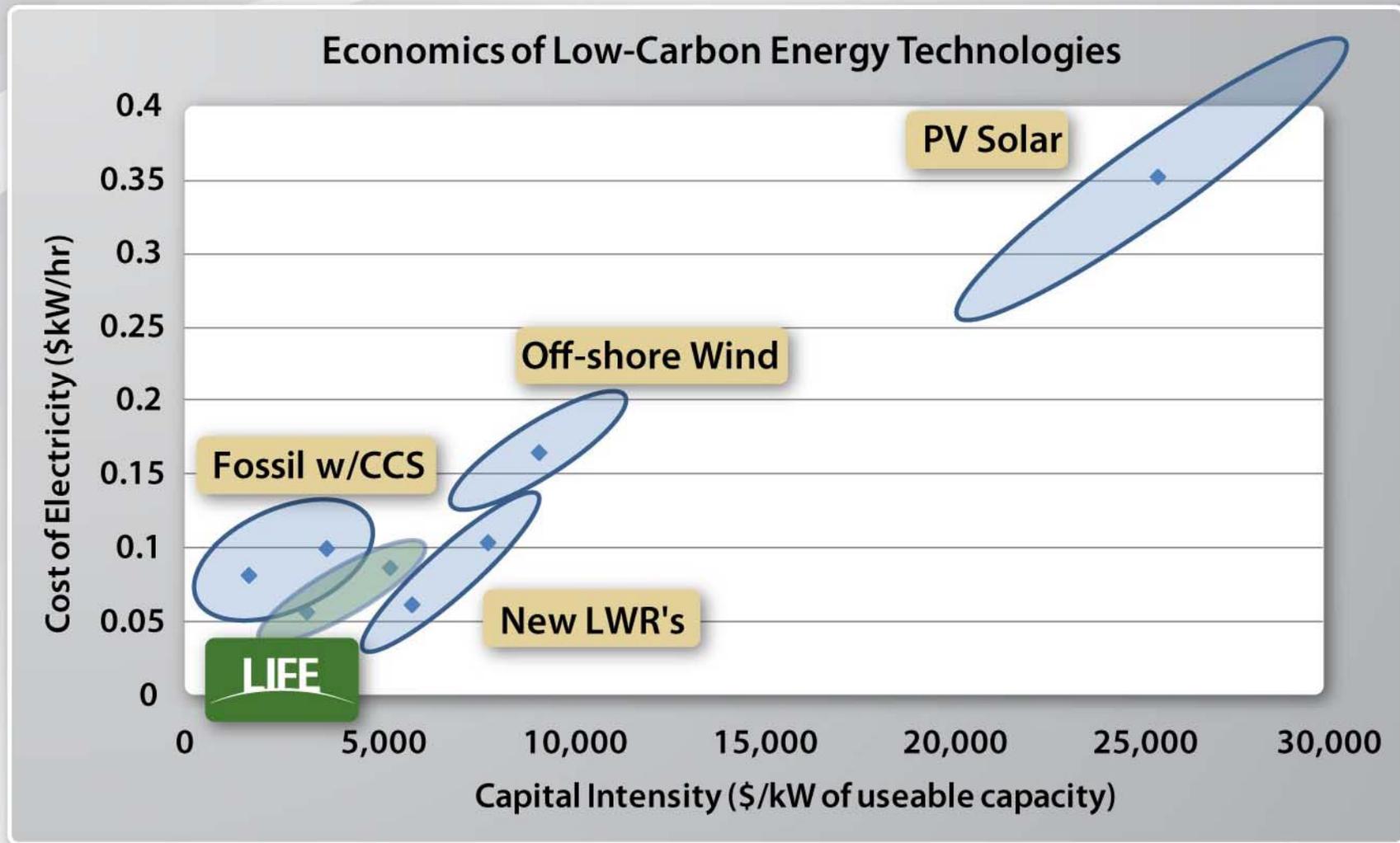
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Economics of Low-Carbon Energy Technologies

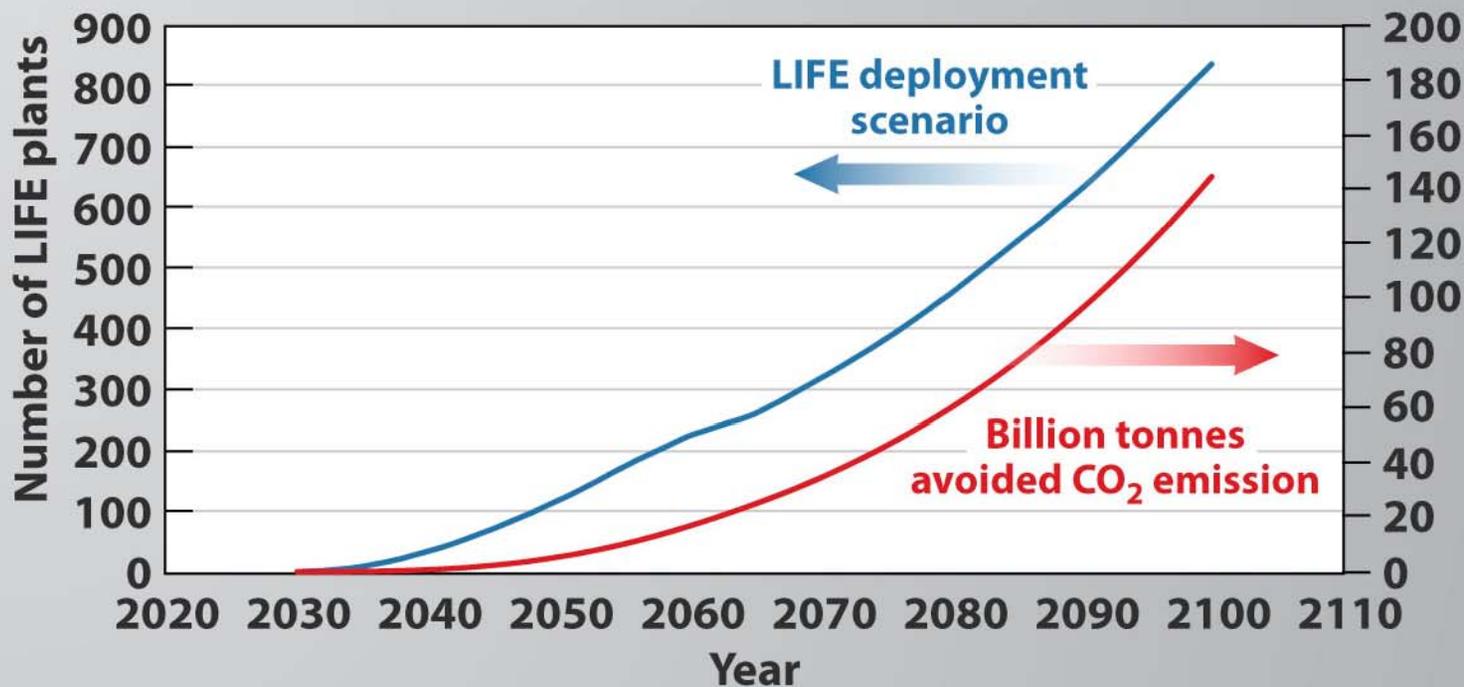


Economics of Low-Carbon Energy Technologies



US LIFE deployment would reduce CO₂ emissions by more than 140 billion tons (5 wedges) compared to coal

Carbon Emission Avoidance from Deployment of LIFE

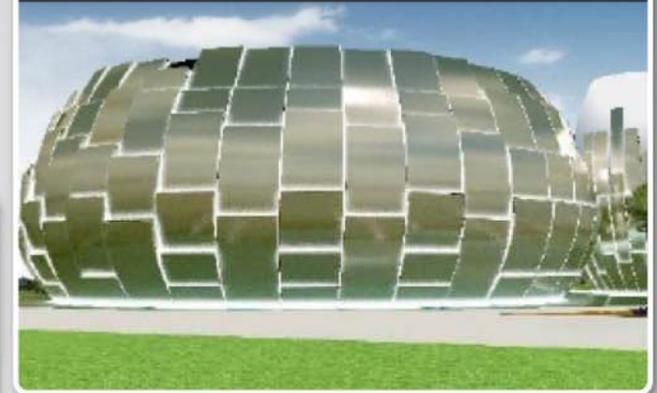


Assumes 0.84 kg CO₂ avoided/kWhr; typical for coal fired electricity generation

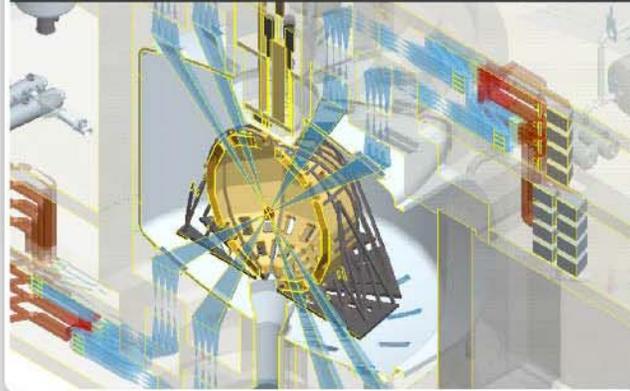
The cost of carbon is expected to be \geq \$100/ton

LIFE delivery – pilot power plant in mid 2020's

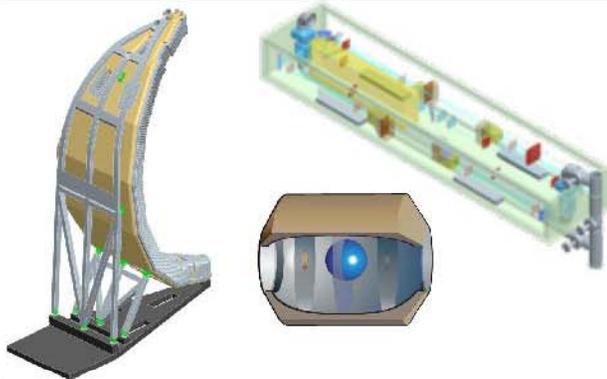
**Mature Technology, Global
Market Penetration**



**Pilot Plant, transition to
commercial power to the Grid**

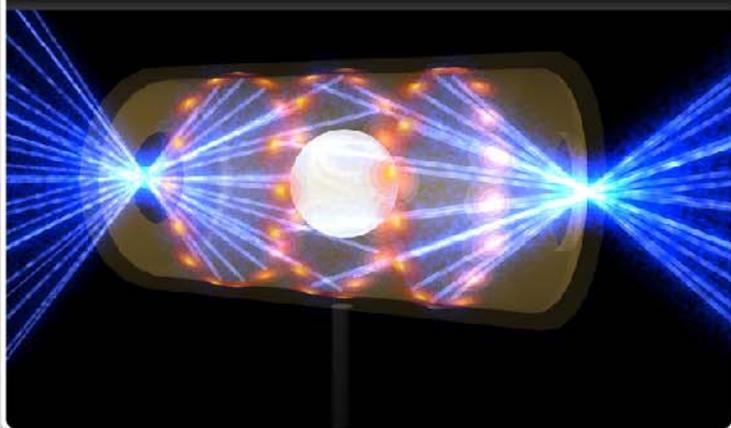


**Component and Subsystem
Level Demonstrations**

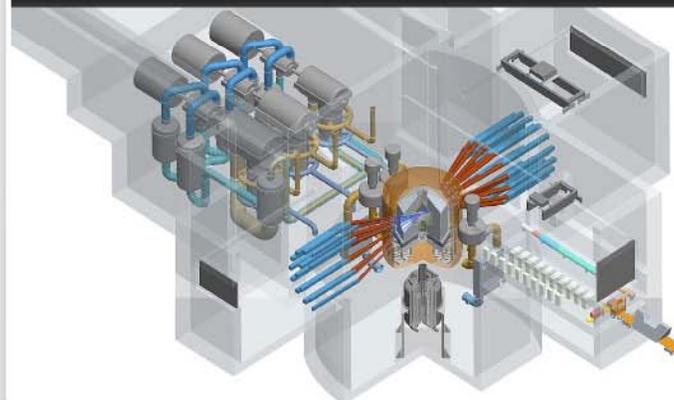


Fusion energy soon enough to make a difference

2009 NIF; ~ 2012 ignition



~ 2020 LIFE.1



**2020 LIFE demo;
2030 LIFE commercial**



~ 2050 fleet incorporated





