

FUSION



INDUSTRY ASSOCIATION

The Global Fusion Industry in 2023

Canadian Workshop on Fusion Energy Science and Technology
October 24, 2023

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Chief Executive Officer

Overview: The Private Fusion Industry Today

- 43 verified private fusion companies
- **\$6.2 billion in investment**
- 13 new fusion companies
- Increasing optimism on timescales
- Growing interest from governments in Public Private Partnerships
- Growing geographical diversity
- But – many challenges remain



FIA Membership



Commonwealth
Fusion Systems



HELION



tae



ZAP ENERGY

generalfusion®

TYPE ONE
ENERGY



GAUSS
FUSION



HB11
ENERGY
LASER BORON FUSION



AVALANCHE

Tokamak Energy



FOCUSED
ENERGY



KYOTO
FUSIONEERING

XCIMER

ENERGY
CORPORATION



first light



THEA ENERGY



EX-Fusion

MIFTi



RENAISSANCE
FUSION



Proxima
Fusion

fuse

HelicitySpace



ELECTRIC
FUSION
SYSTEMS

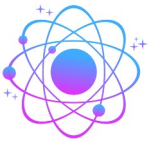
REALTA
FUSION



Helical Fusion



LONGVIEW FUSION
ENERGY SYSTEMS



BLUE LASER
FUSION

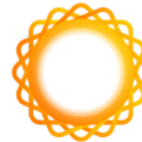
SHINE



MarvelFusion



STELLAREX



OPENSTAR
TECHNOLOGIES LTD



NOVATRON

nT-tao



LaserFusionX

HORNE
TECHNOLOGIES



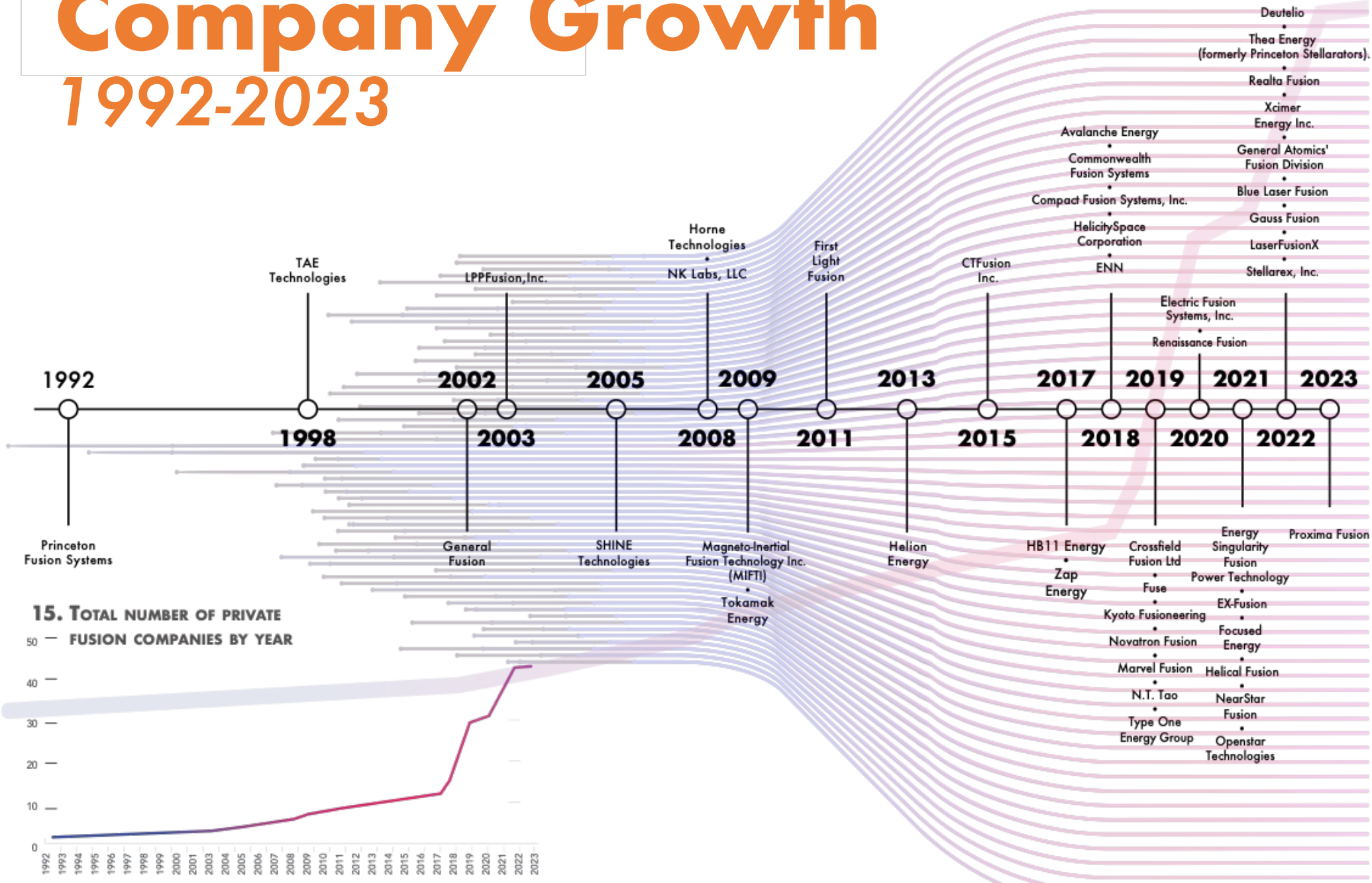
PrincetonSATELLITE
SYSTEMS

nearstar
FUSION

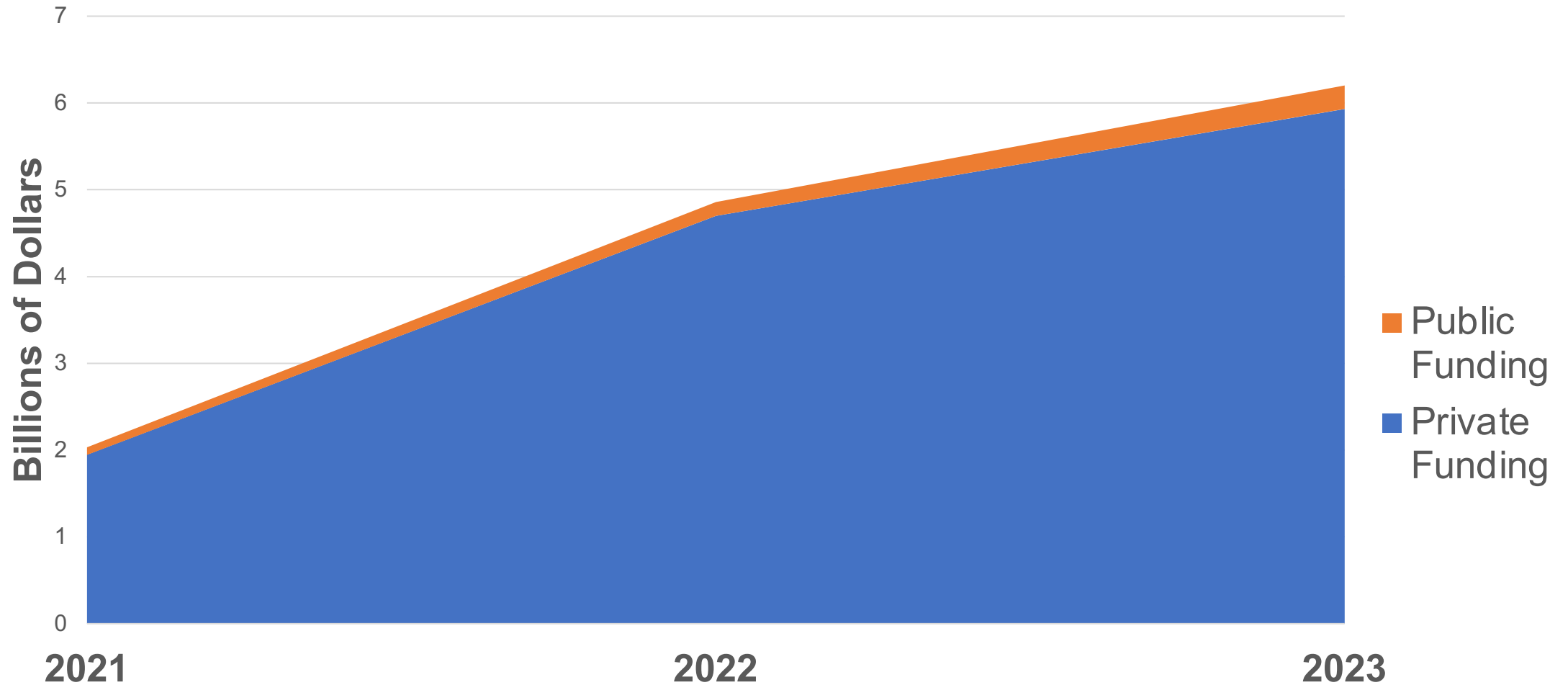


LPP FUSION

Company Growth 1992-2023



Private Funding Growth 2021-2023



A Global Industry *Led by American Companies*



- 25 American Fusion Companies
 - With > 80% of the investment
- Growing global diversity
 - 12 countries with at least one fusion company
- A global supply chain
- A global workforce
- Global scientific leadership



Variety of Approaches



- | | |
|--|---|
| ● 1 Dense Plasma Focus | ● 1 Muon-catalyzed fusion with high density fuel |
| ● 1 Direct laser-driven pB11 | ● 2 Magnetic-electrostatic confinement |
| ● 1 Epicyclotron: a hybrid beam background approach | ● 1 Magnetized Liner Inertial Fusion (MagLIF) |
| ● 1 Electro-centripetal confinement with magnetic plasmas not in thermodynamic equilibrium | ● 1 Plectonemic reconnection |
| ● 3 Field Reversed Configuration | ● 1 Poloidal magnetic confinement, e.g. Levitron, LDX, Intrap |
| ● 1 Hypervelocity Gradient Field Fusion | ● 1 Pulsed magneto-plasma pressurized confinement |
| ● 1 Laser-driven inertial confinement | ● 1 Shock-driven inertial confinement |
| ● 1 Laser-driven Direct Drive Inertial Confinement Fusion | ● 1 Spindle cusp, superconducting shielded-grid Inertial Electric Confinement |
| ● 1 Levitated Dipole | ● 6 Stellarator |
| ● 1 Magnetic mirror | ● 6 Tokamak/Spherical Tokamak/Advanced Tokamak |
| ● 1 Mirror machine | ● 2 Z-pinch |
| ● 1 Magnetized target fusion | ● 1 N/A |
| ● 1 Modified Stellarator | |

Notable investments since last survey



\$23_m
THEA
Energy

\$250_m
TAE

\$79_m
Kyoto
Fusioneering

\$55_m
Energy Singularity
Fusion Power
Technology

\$200_m
ENN

\$50_m
SHINE
Technologies

\$41_m
Avalanche

\$22_m
n-Tao

\$20_m
General
Atoms

\$67_m
Focused
Energy

Trends: Broad-Based Investment



- 27 announced capital raises
- Median raise: \$9,000,000

But...a difficult investment environment for large raises?

Why Now?



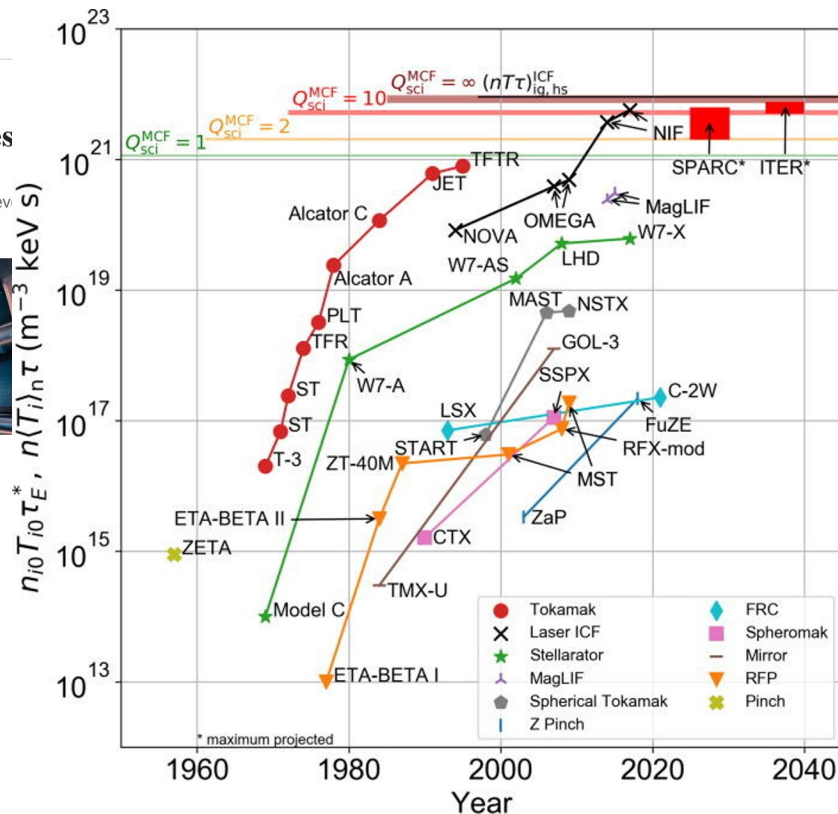
Fusion is READY + The world NEEDS fusion

WSJ

SCIENCE

Nuclear-Fusion Breakthrough Accelerates Quest to Unlock Limitless Energy Source

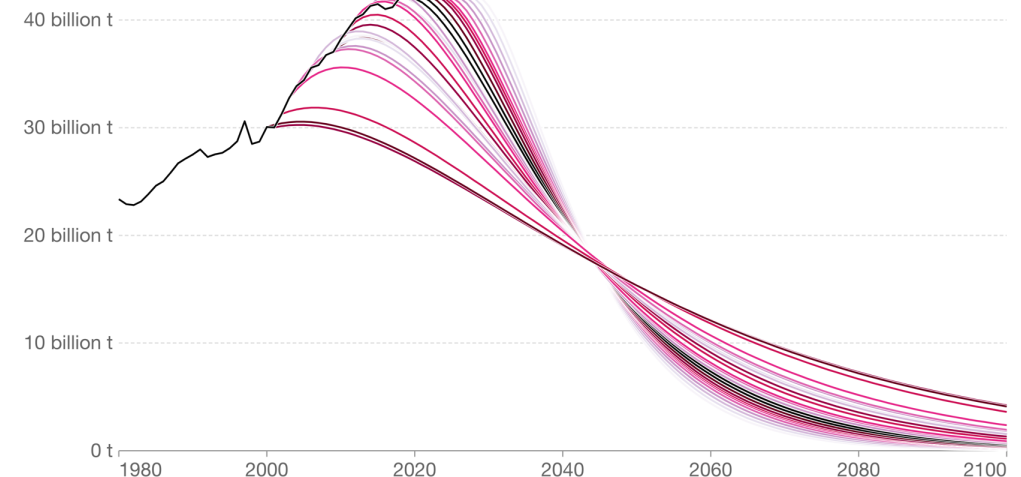
Experiment yields net-positive energy, a milestone in effort to dev nuclear fusion as a source of clean power



CO₂ reductions needed to keep global temperature rise below 2°C

Our World in Data

Annual emissions of carbon dioxide under various mitigation scenarios to keep global average temperature rise below 2°C. Scenarios are based on the CO₂ reductions necessary if mitigation had started – with global emissions peaking and quickly reducing – in the given year.



Source: Robbie Andrews (2019); based on Global Carbon Project & IPCC SR15

Note: Carbon budgets are based on a >66% chance of staying below 2°C from the IPCC's SR15 Report. OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

Why Now?

Fusion is *READY*



Today's Scientific and Technological Advances Enable Breakthroughs

New Materials

New materials, including High Temperature Superconductors, advanced lasers, new alloys, power management chips, and more enable smaller, cheaper machines.

High Speed Computing

Advances in computing power allow advanced modeling and the application of artificial intelligence to experiments.

Greater Scientific Understand of Plasmas

Breakthrough fusion experiments at NIF and elsewhere will bring greater fidelity to models and enable faster experimentation.

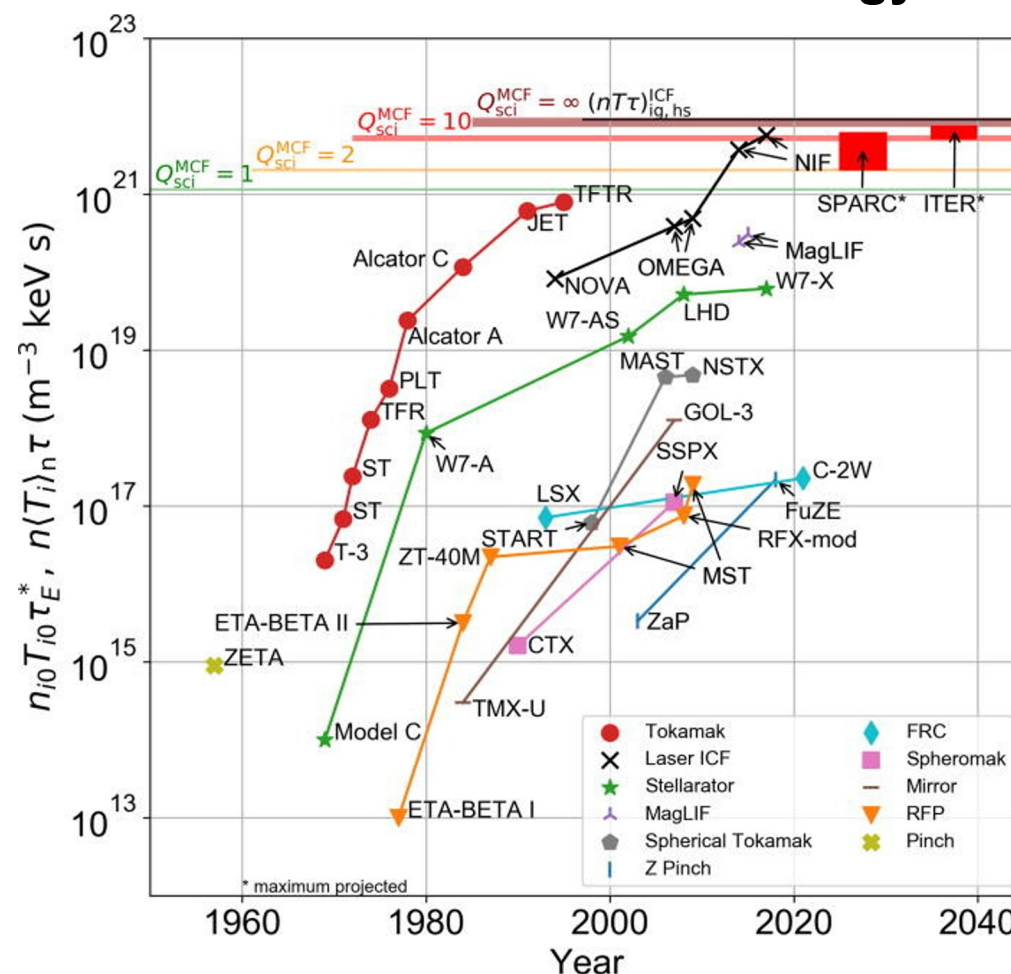
Advanced Manufacturing

Will allow quick and cheap production of components in complex shapes and with new materials.

Business Model Improvement

The application of the Silicon Valley-style venture capital has injected funding, urgency, and greater tolerance of risk.

Historical progress shows continuous advances towards fusion energy



Why Now?

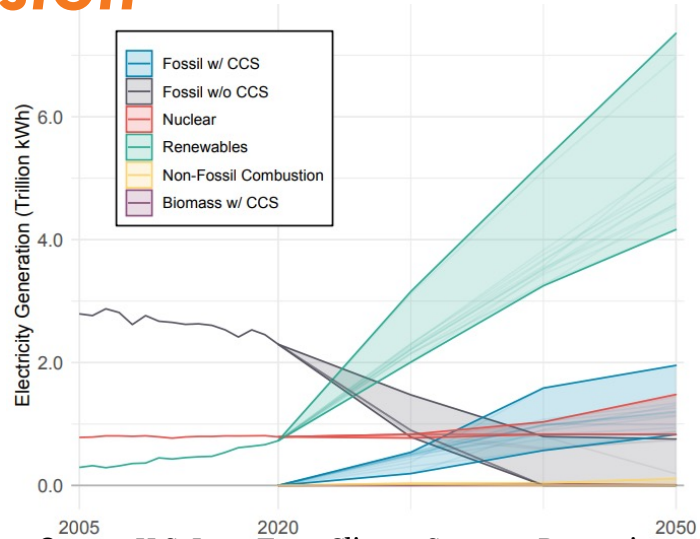
*The world **NEEDS** fusion*

Fusion is a Climate Solution

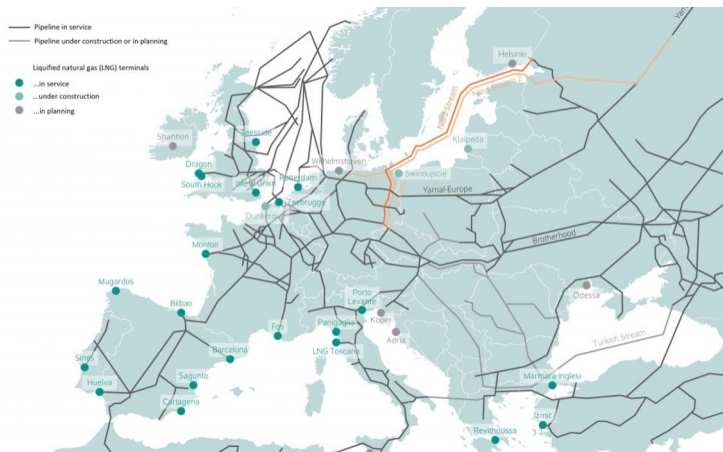
Meeting the world's climate goals are **almost impossible** without massive deployment of zero-emissions dispatchable power.

Fusion provides Energy Security

Fusion energy will **break the geopolitics of energy**, so that no dictator can control the price of energy. Fusion energy will be manufactured, not mined.



Source: U.S. Long Term Climate Strategy: Domestic Climate Policy Office and the State Department, 2021



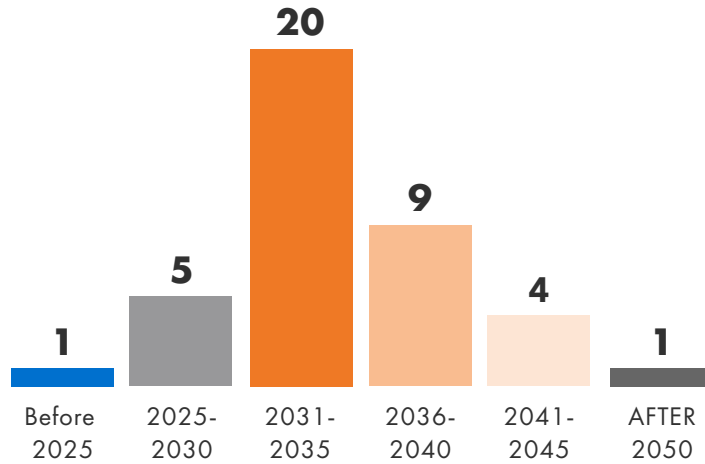
Fusion is a Business Opportunity

Bloomberg: fusion energy industry could be valued at **\$40 trillion**

McKinsey: fusion could be **“dominant”** source of energy in Europe by 2050

Fusion companies already are spending over \$500m per year

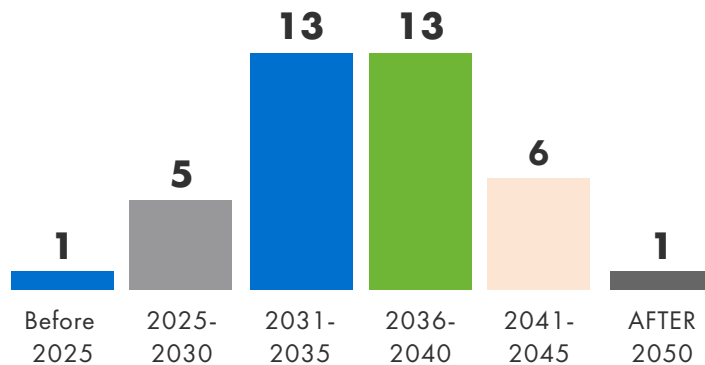
When will the first fusion plant deliver electricity to the grid? (40 responses)



Growing Confidence



When will the first fusion plant demonstrate a low enough cost/high enough efficiency (Q) to be considered commercially viable? (40 responses)



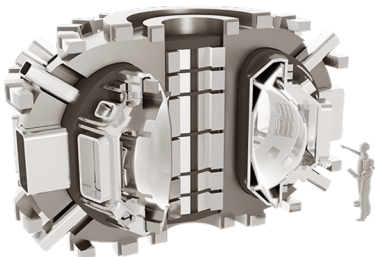
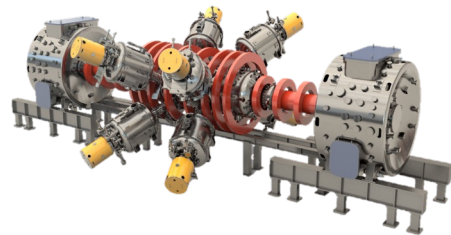
- 88% expect fusion power on the grid in the 2030s or before
- 84% expect commercial cost competitiveness on same schedule

Industry's Timeline



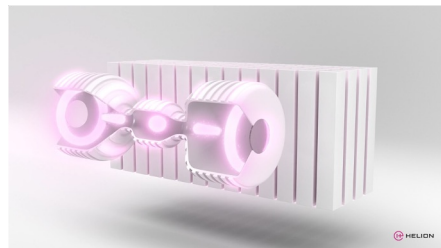
60 years
of
research

- Scientific basis for fusion energy



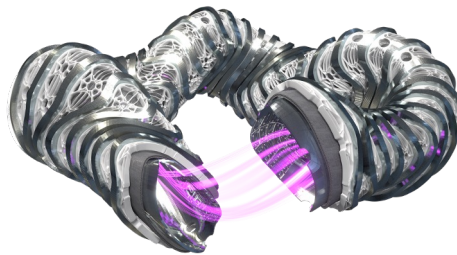
Mid 2020s

- Scientific Proof of Concept



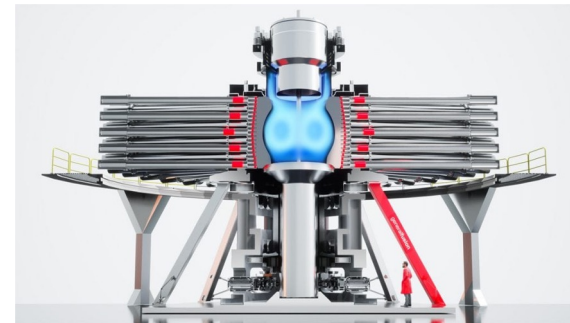
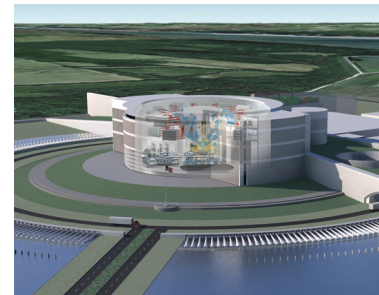
Late
2020s

- Design and build Pilot Plants



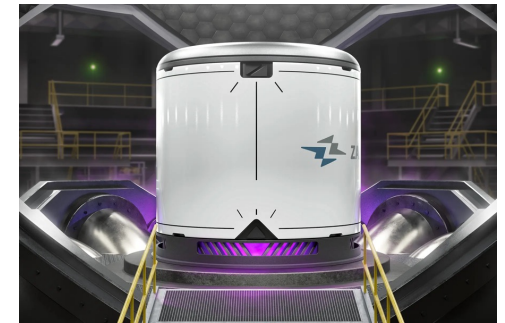
Early
2030s

- Operate Pilot Plants, first sales



Mid 2030s

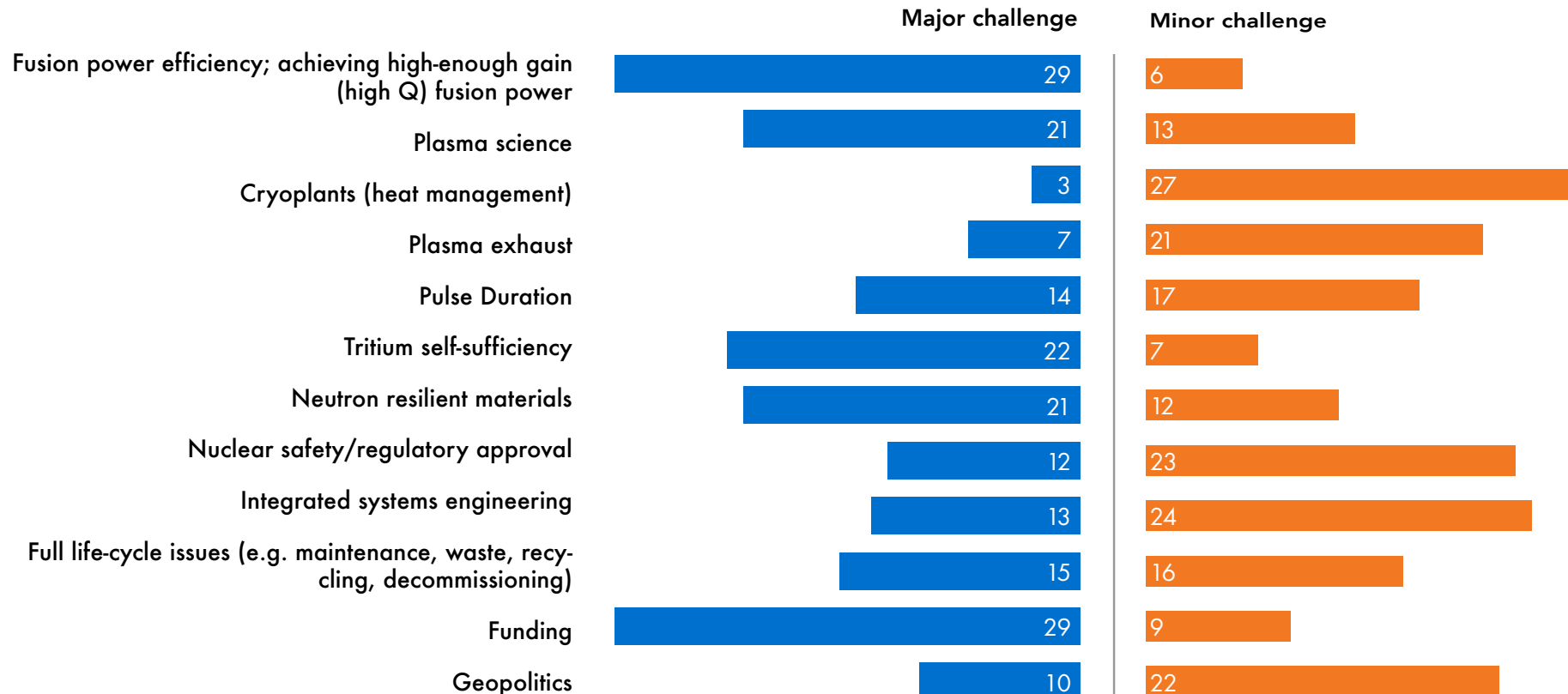
- Commercial Fusion, rapid scale-up to global deployment



Expecting Challenges



What do you see are the main challenges for fusion energy up to 2030?
(38 Responses, non-reported answers indicate not seen as a problem/don't know)



FIA Supply Chain Report: *Key Findings*



- Fusion developers spent **over \$500m** on their supply chain in 2022, and that will grow to over \$7bn per year by the time they build their “First of a Kind” power plant, and potentially trillions in a mature fusion industry (timescales for this range from 2035-2050).
- *Technological diversity in fusion*: there is not a fusion “supply chain” – there are fusion “supply chains”
- High value supply chain needs are primarily **specialized precision manufactured components**
 - Steady-state Magnetic = high-powered magnets + resilient materials
 - Pulsed power = power electronics and semiconductors
 - Laser IFE = specialized laser & optics components
 - Fusion Fuel Cycle = Lithium blanket
- Biggest challenge = balancing suppliers’ scale with business risk.
 - Fusion companies need suppliers to invest in scale ahead of demand, but suppliers are reluctant to do so without confirmed commitments or clear timelines.
 - Chicken vs Egg?

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The Fusion Industry Supply Chain:

Opportunities and challenges

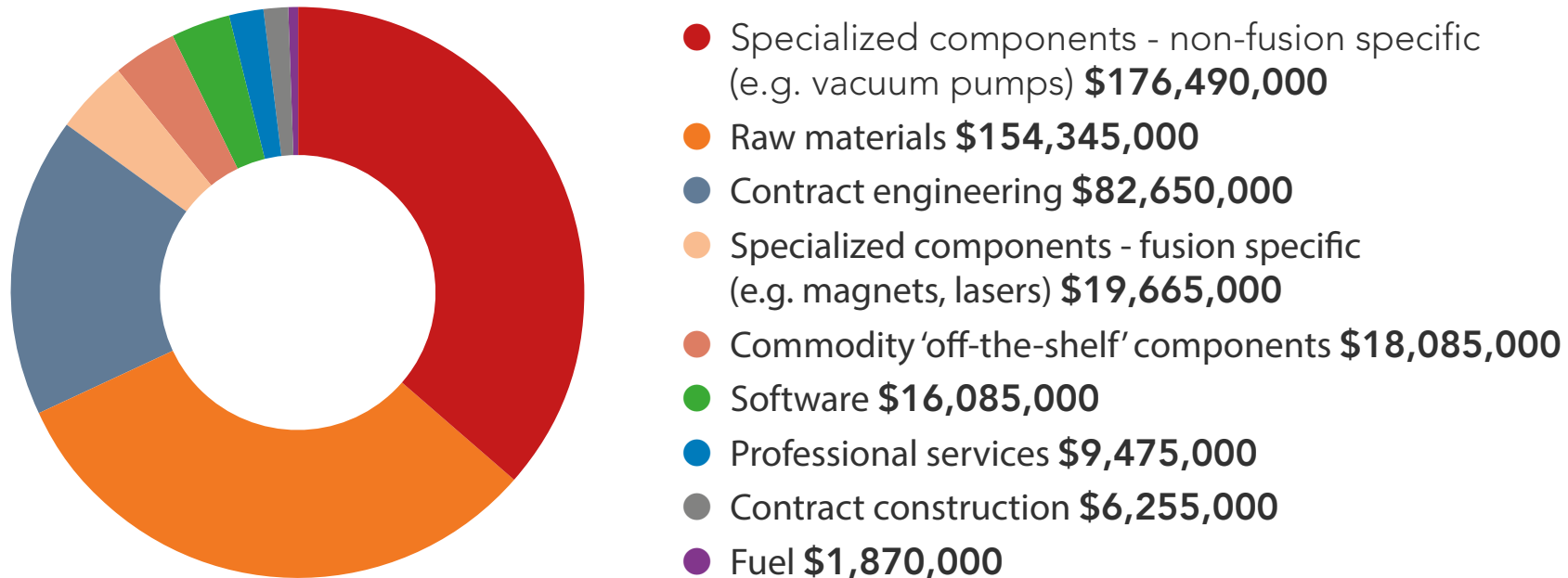


Industry Growth



- \$500 million per year industry today -> \$7 billion in a decade

Declared annual spending on supply chain by fusion companies



Supply Chain Needs Now



- Vacuum technology is (almost) the only shared technological need across the fusion technologies
- In a fusion energy facility, the walls exposed to the plasma will be bombarded by highly energetic neutrons.
- A solution is a composite wall consisting of a suitable coating on a substrate chosen for its strength and ease of fabrication. The techniques employed to deposit several of these candidate materials onto stainless steel substrates as thick coatings are described.

Current demands from the fusion supply chain (26 responses.
Answered 'critical' or 'important').

See Appendix 1 for expanded table.

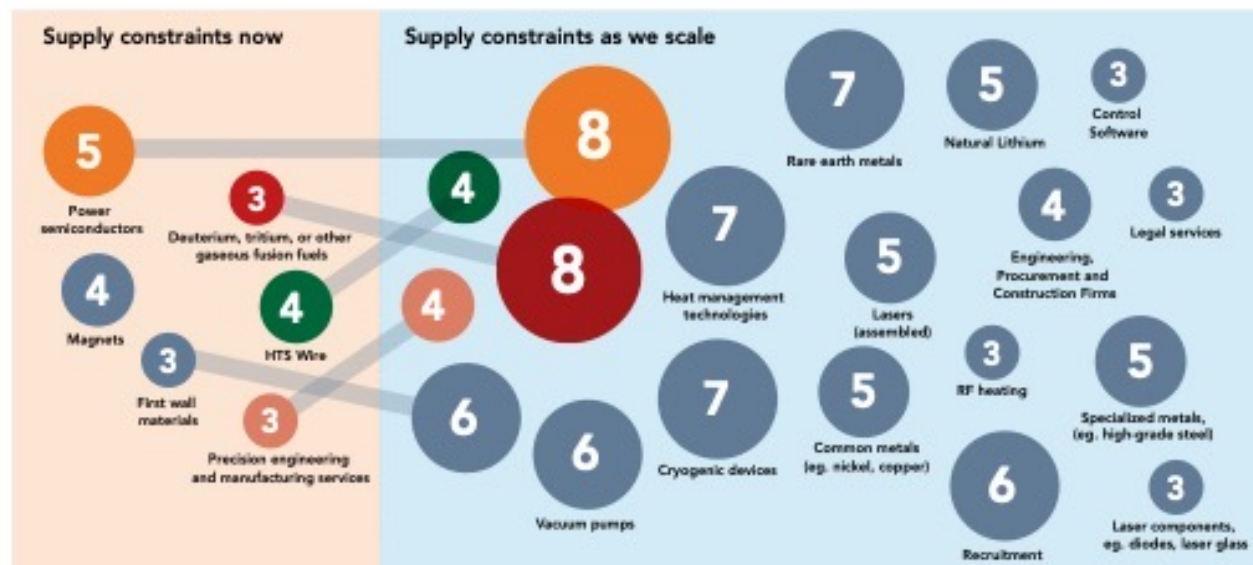
	Critical/important
Vacuum pumps	24
Precision engineering and manufacturing services	24
Control Software	21
Power semiconductors	20
Deuterium, tritium, or other gaseous fusion fuels	19
Recruitment	19
Specialized metals, e.g. high-grade steel	17
Common metals, e.g. nickel, copper	16
Engineering, Procurement and Construction Firms	16
Heat management technologies	14
Natural Lithium	14
First wall materials	14
Legal services	14
Cryogenic devices	13
Magnets	12
RF heating	10
Lithium (enriched)	10
High Temperature Superconducting (HTS) Tape	9
Lasers (assembled)	6
Rare earth metals	6
Laser components, eg. diodes, laser glass	5

Supply Chain Needs Will Grow



Number of companies expressing concerns about current and future supply constraints (only categories with 3+ responses included below).

See Appendix 1 for expanded data.



Demand increase for fusion components over next ten years (26 responses. Answered 'critical' or 'important').

See Appendix 1 for expanded table.

Order of magnitude/
significant increase

Vacuum pumps	14
Precision engineering and manufacturing services	14
Heat management technologies	13
Deuterium, tritium, or other gaseous fusion fuels	13
Engineering, Procurement and Construction Firms	13
Recruitment	13
Power semiconductors	12
Specialized metals, e.g. high-grade steel	12
Control Software	12
First wall materials	11
HTS Wire	10
Magnets	10
Cryogenic devices	10
Natural Lithium	10
Lithium (enriched)	8
Legal services	8
RF heating	7
Rare earth metals	7
Common metals, e.g. nickel, copper	6
Lasers (assembled)	5
Laser components, eg. diodes, laser glass	5



How FIA Accelerates Fusion



Public Private Partnerships

The private sector should have access to the scientific research that governments have pursued for decades. Public-Private Partnerships that include government support to private fusion companies can rapidly accelerate fusion development by driving new private financial support.

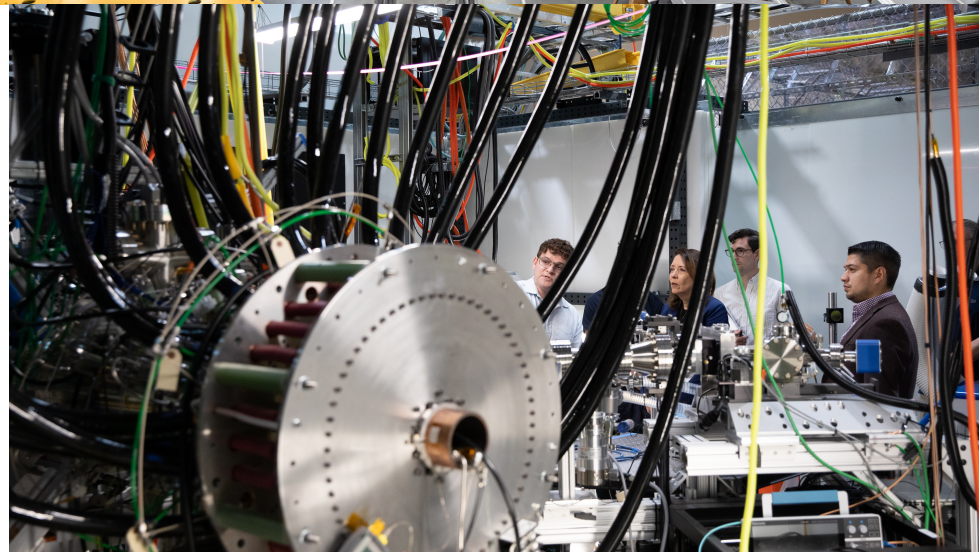
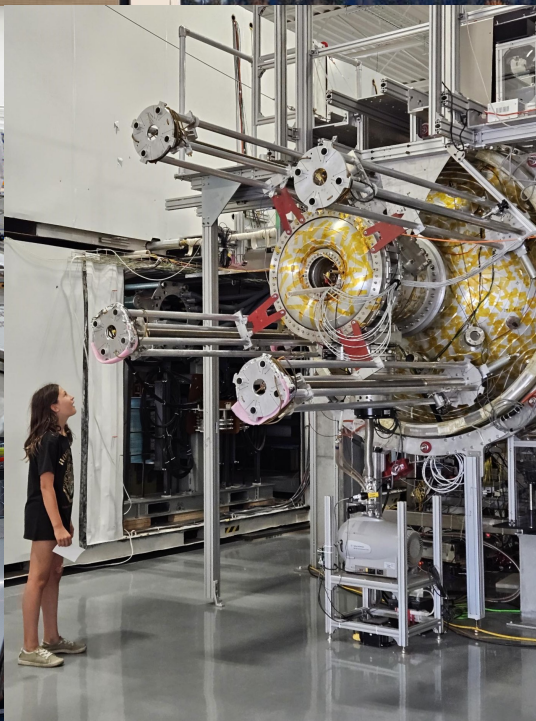
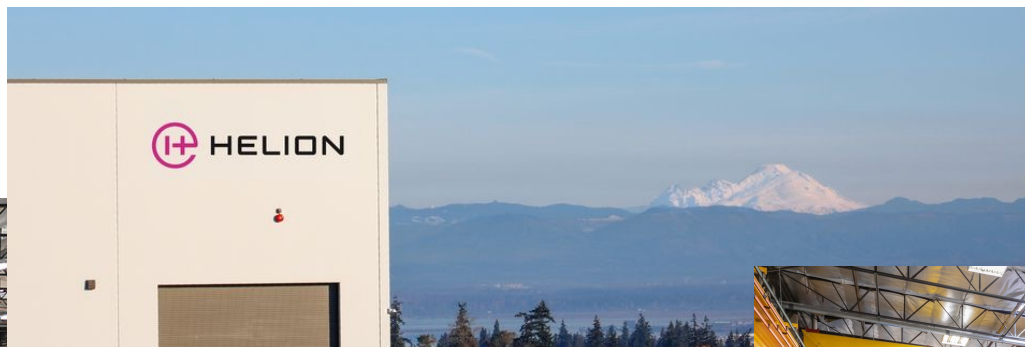
Ensuring Regulatory Certainty

The regulatory regime for fusion should be predictable, proportional to the risk, and supportive of innovation, while also giving confidence about ensuring public safety and security. Fusion energy regulation must be permanently separated from fission regulation and should not require lengthy permitting process for every facility.

Incentives to Build a Global Fusion Energy Industry

Fusion does not need special status or excessive subsidies but should have a level playing field as it grows into a new industry.

Progress



Why? Fusion will Change the Outlook for 2050 Net Zero



*Fusion is a source of nearly unlimited **clean, firm power***

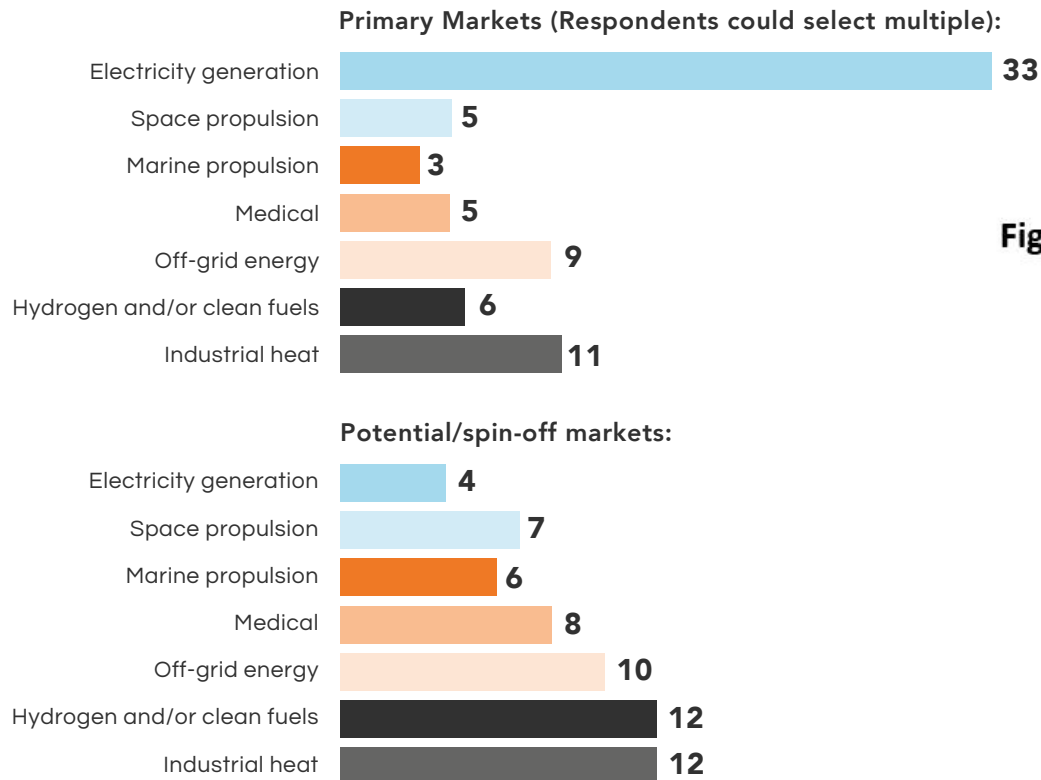
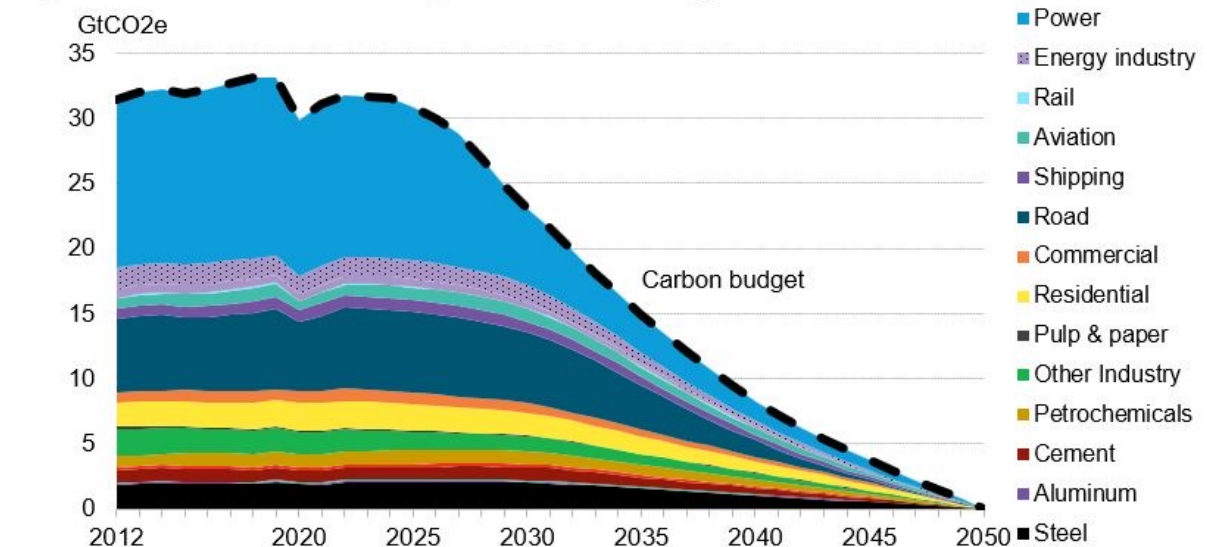
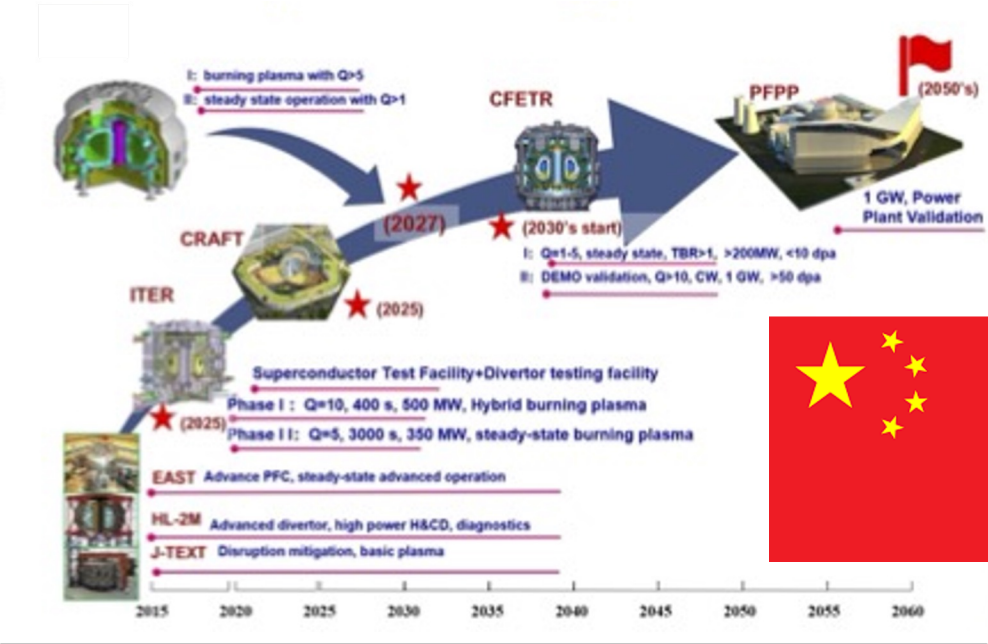


Figure 1: Total carbon budget for the energy sector

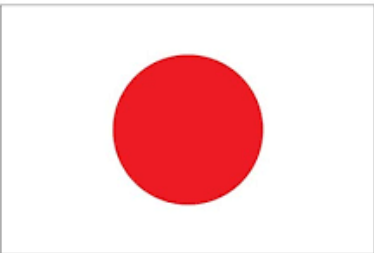
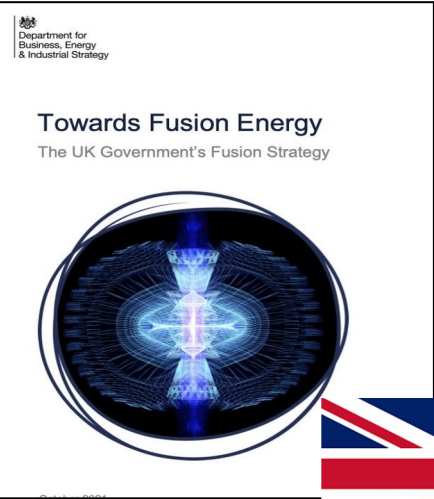


Source: BloombergNEF

Geopolitics of Fusion



Z-FFR 总体结构示意图



Results: FIA's Vision for the 2030's



- **Industry** builds multiple fusion pilot plants of different sizes, technologies, and fuel cycles, preparing to scale-up into a globally-leading export industry.
- **Fusion Supply Chain** grows to over \$7 billion per year industry (already over \$500 million today)
- **Governments** support fusion commercialization push with world-leading science, computing power, and test facilities - the **infrastructure** that enables a fusion industry.
- **Research Universities** form the backbone of the **fusion workforce** and train the next generation.





Thank You

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www.FusionIndustryAssociation.org*