FUSION

INDUSTRY ASSOCIATION

The Global Fusion Industry

Andrew Holland

Chief Executive Officer

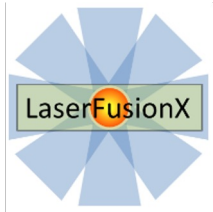
Overview: The Private Fusion Industry Today

- 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 Mission

*The Fusion Industry Association is the **voice** of the growing fusion industry. It is a membership organization that supports efforts to **accelerate commercial fusion energy** through **advocacy** and **education***

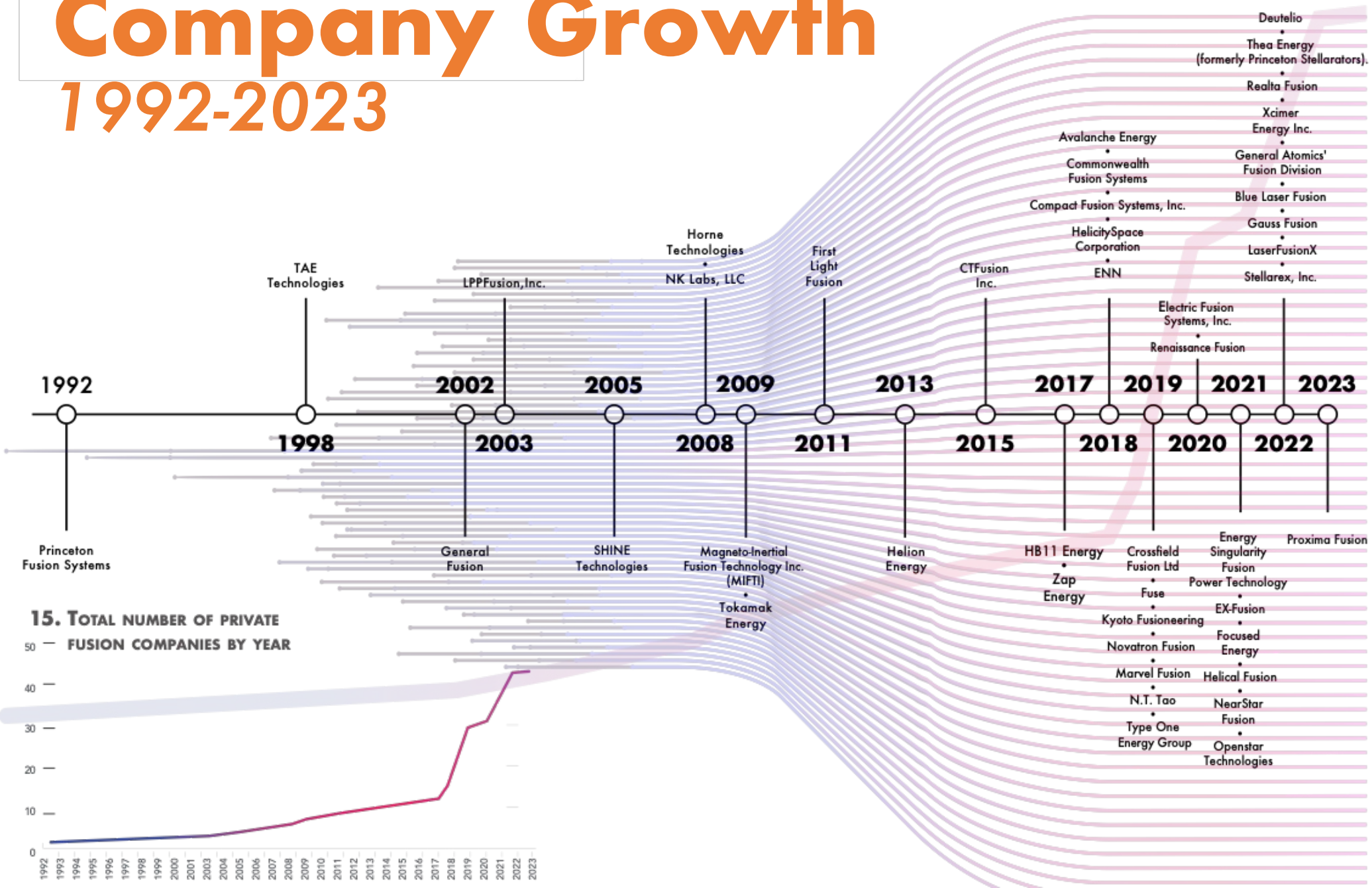
FIA Membership




Affiliate Members
BAYFUSION
Kansai Electric Power
power with heart
SIMIC
since 1975
A PASSION FOR CHALLENGES
Google
OPTICA
Advancing Optics and Photonics Worldwide
Formerly OSA
BUTTING
1777
THALES
AMPLEON
Mitsubishi Corporation
CleanTech Alliance™
TWI
TVA
KIND
Sumitomo Corporation of Americas
Enriching lives and the world
COHERENT
EXO FUSION
equinor
eni
Southern Company
Roland Berger
framatome
BILFINGER
BILFINGER NOELL GMBH
FLUOR
NEXT STEP FUSION
METOX™
ALSYMEX
ALCEN
radiasoft
SVC
SOCIETY of VACUUM COATERS
IF JAPAN
FARADAY FACTORY
CDE
ENERGIZING IDEAS
a division of Knowles Corporation
CORNELL DUBILIER
BRUKEP
Sapientαl
digiLab
peak
SCHOTT
STELLAR
ENERGY FOUNDATION
ENERGY for the COMMON GOOD
Soon enough to make a difference
LEONARDO
ONTARIO POWER GENERATION
Cryoelectra
RF Technology for Particle Accelerators
CLEARPATH ACTION
HTS
HIGH TEMPERATURE SUPERCONDUCTORS
OAK RIDGE CHAMBER OF COMMERCE
IN BUSINESS FOR BUSINESS
CURTISS-WRIGHT
Morgan Lewis
KINECTRICS
DIVERSIFIED TECHNOLOGIES, INC.
KTC
EST. 1918
We manufacture the future.
Keller Technology Corporation
PFEIFFER VACUUM
TERRA PRAXIS
WOODRUFF • SCIENTIFIC
ARNOLD MAGNETIC TECHNOLOGIES
COSYLAB
American Conservation Coalition
AMPEGON
pillsbury
AIR LIQUIDE
STRONG ATOMICS
research instruments
ASG SUPERCONDUCTORS
AEROSPACE
INTERLOCK ENERGY
EPRI
NEW LIGHT FUSION CONSULTANTS
TRUMPF
FRAZER-NASH CONSULTANCY
A KBR COMPANY
IDOM
ETEC
EAST TENNESSEE ECONOMIC COUNCIL
FUSION ENERGY INSIGHTS
K&L GATES
ENERCON
tecnatom
TELEDYNE BROWN ENGINEERING
ATDG
TRIANGLE DESIGN GROUP LLC
OXFORD SIGMA
OCEM
POWER ELECTRONICS

Company Growth

1992-2023



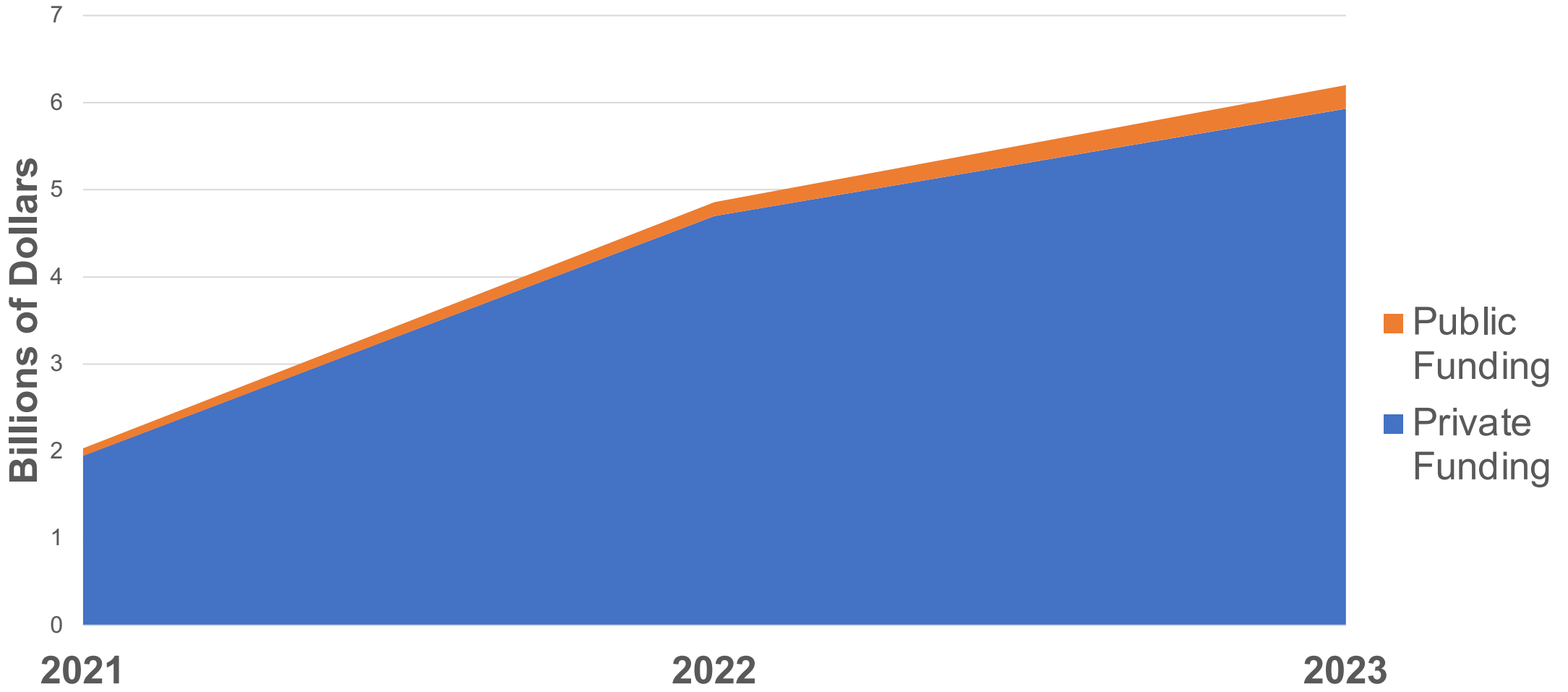
A Global Industry
Led by American Companies

- 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 Direct laser-driven p811
- 1 Epicyclotron: a hybrid beam background approach
- 1 Electro-centripetal confinement with magnetic plasmas not in thermodynamic equilibrium
- 3 Field Reversed Configuration
- 1 Hypervelocity Gradient Field Fusion
- 1 Laser-driven inertial confinement
- 1 Laser-driven Direct Drive Inertial Confinement Fusion
- 1 Levitated Dipole
- 1 Magnetic mirror
- 1 Mirror machine
- 1 Magnetized target fusion
- 1 Modified Stellarator
- 1 Muon-catalyzed fusion with high density fuel
- 2 Magnetic-electrostatic confinement
- 1 Magnetized Liner Inertial Fusion (MagLIF)
- 1 Plectonemic reconnection
- 1 Poloidal magnetic confinement, e.g. Levitron, LDX, Intrap
- 1 Pulsed magneto-plasma pressurized confinement
- 1 Shock-driven inertial confinement
- 1 Spindle cusp, superconducting shielded-grid Inertial Electric Confinement
- 6 Stellarator
- 6 Tokamak/Spherical Tokamak/Advanced Tokamak
- 2 Z-pinch
- 1 N/A

Private Funding Growth
2021-2023



Notable investments since last survey

$23m
THEA Energy

$250m
TAE

$79m
Kyoto Fusioneering

$55m
Energy Singularity Fusion Power Technology

$200m
ENN

$50m
SHINE Technologies

$41m
Avalanche

$22m
n-Tao

$20m
General Atomics

$67m
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?

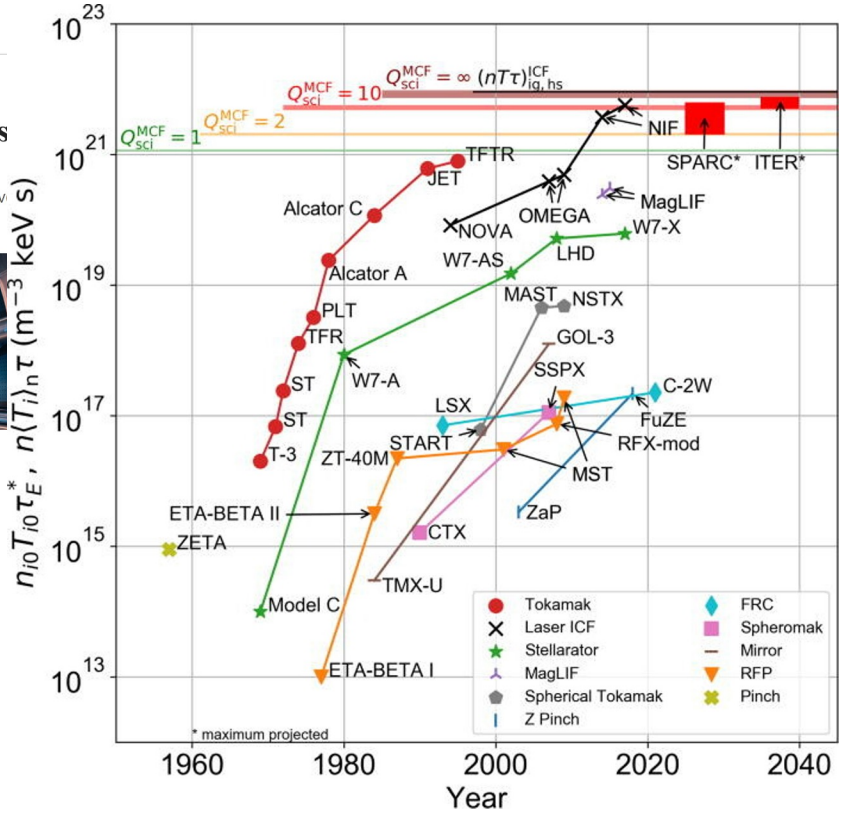
Fusion is READY + *The world NEEDS fusion*

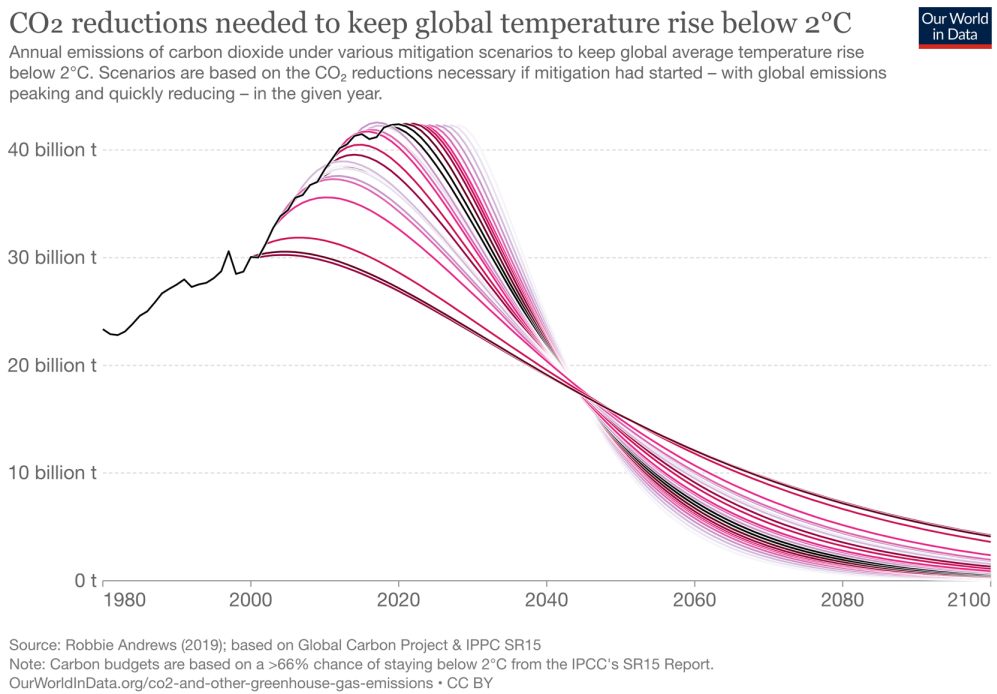
WSJ

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





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.

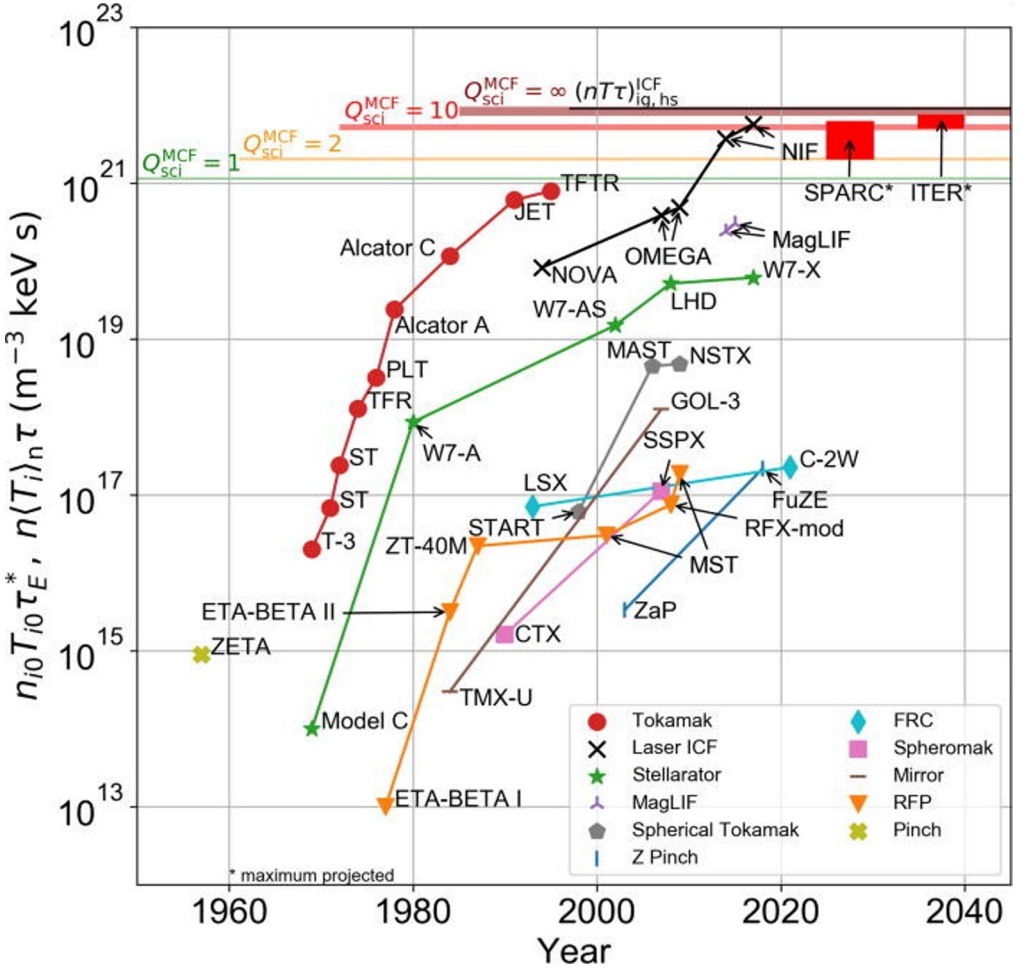
High Speed Computing
Advances in computing power allow advanced modeling and the application of artificial intelligence to experiments.

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

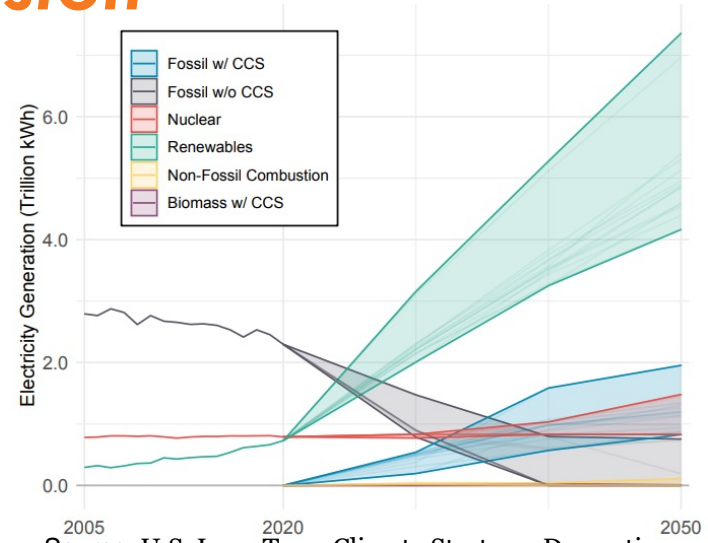


Why Now?

The world NEEDS fusion

Fusion is a Climate Solution

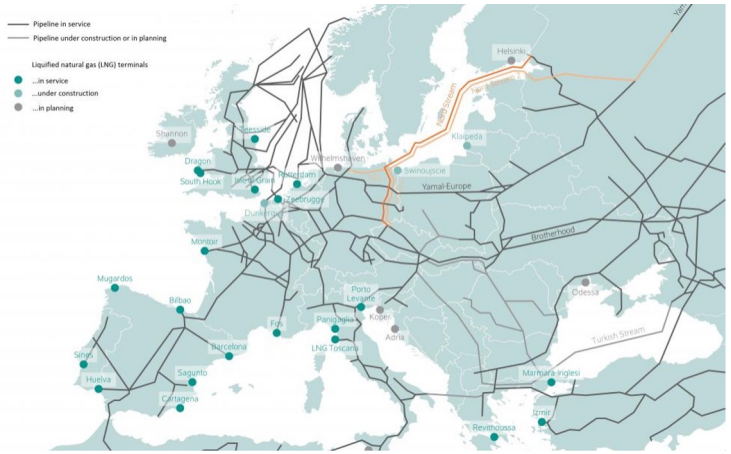
Meeting the world's climate goals are **almost impossible** without massive deployment of zero-emissions dispatchable power.



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

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.



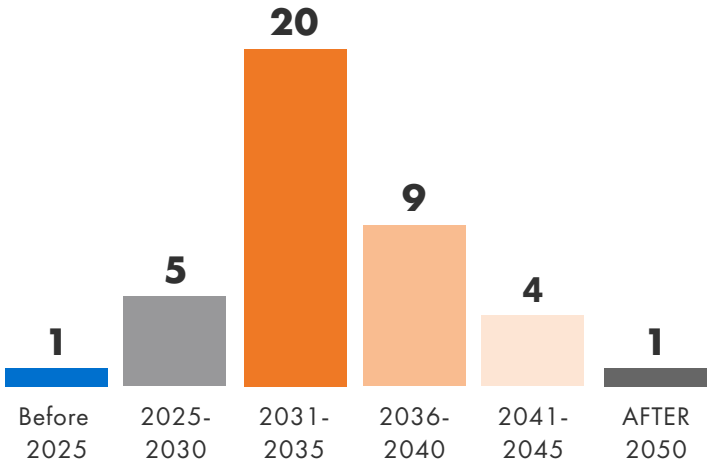
Fusion is a Business Opportunity

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

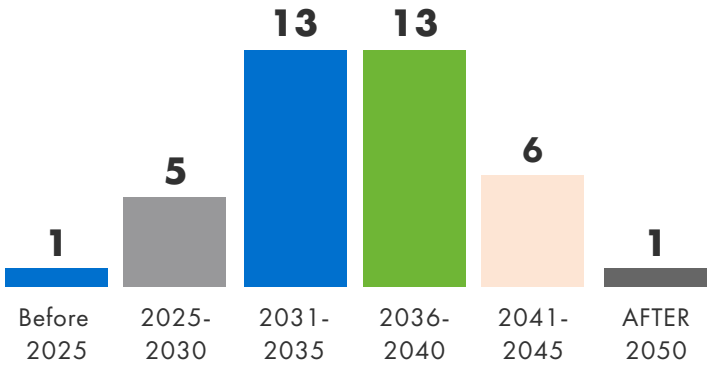
McKinsey: fusion could be "***dominant***" source of energy in Europe by 2050

Fusion companies already are spending over $500m per year

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



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

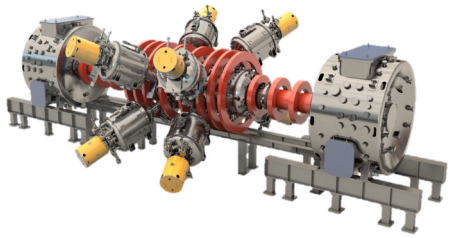


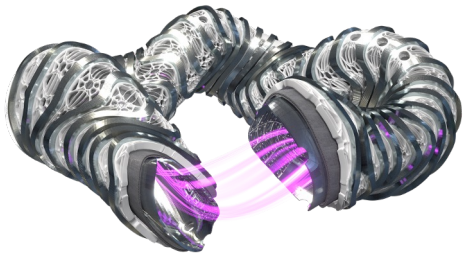
Growing Confidence

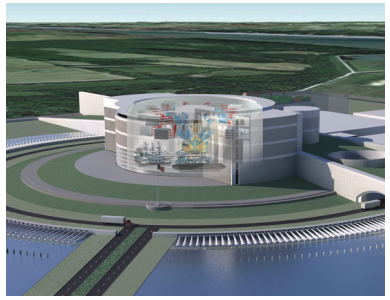
- 88% expect fusion power on the grid in the 2030s or before
- 84% expect commercial cost competitiveness on same schedule

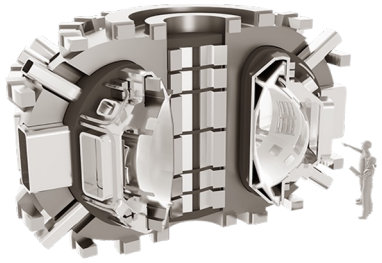
Industry's Timeline

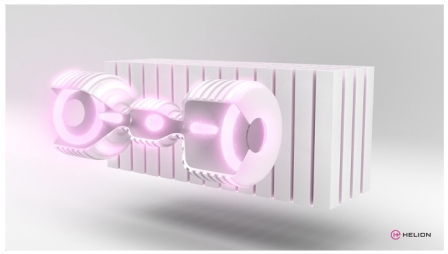
60 years of research	Mid 2020s	Late 2020s	Early 2030s	Mid 2030s
• Scientific basis for fusion energy	• Scientific Proof of Concept	• Design and build Pilot Plants	• Operate Pilot Plants, first sales	• Commercial Fusion, rapid scale-up to global deployment

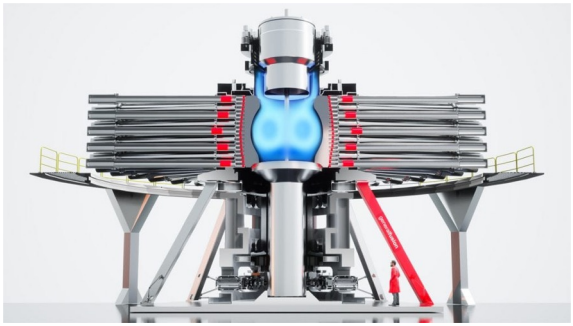






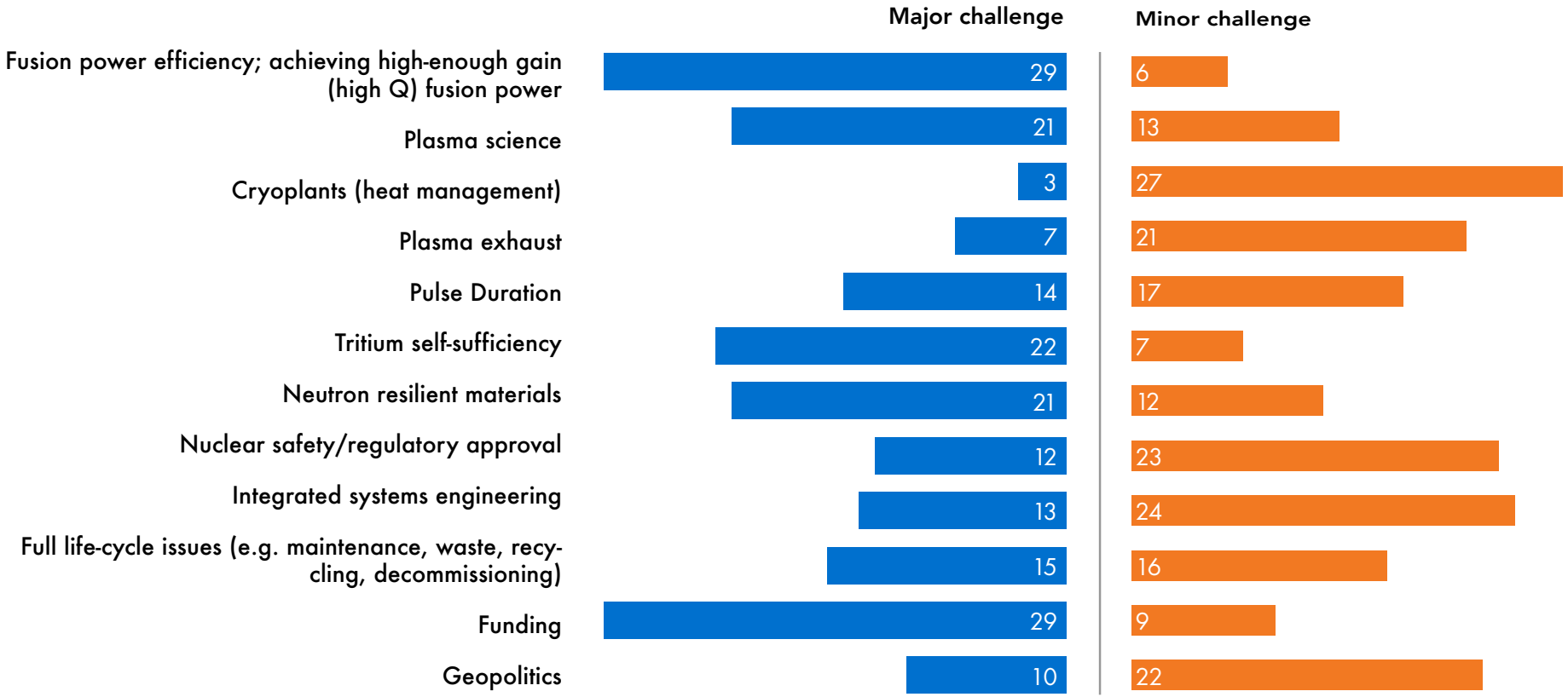






Expecting Challenges

What do you see are the main challenges for fusion energy up to 2030?
(38 Reponses, 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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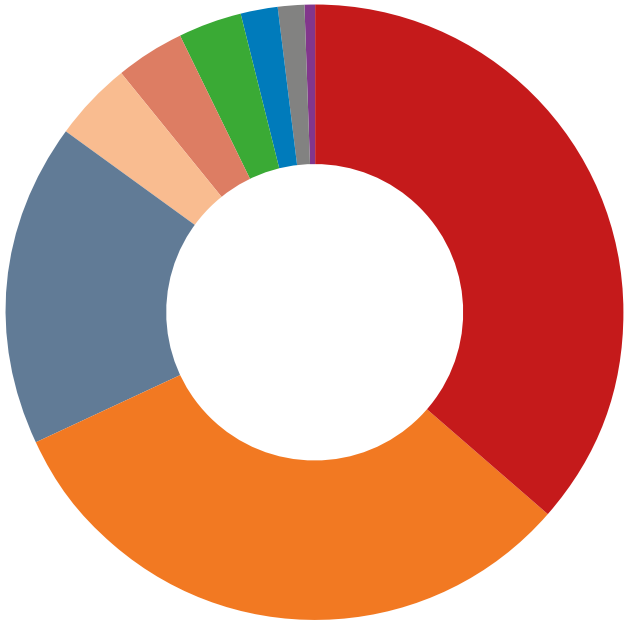
The Fusion Industry Supply Chain:

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



- Specialized components - non-fusion specific (e.g. vacuum pumps) **$176,490,000**
- Raw materials **$154,345,000**
- Contract engineering **$82,650,000**
- Specialized components - fusion specific (e.g. magnets, lasers) **$19,665,000**
- Commodity 'off-the-shelf' components **$18,085,000**
- Software **$16,085,000**
- Professional services **$9,475,000**
- Contract construction **$6,255,000**
- Fuel **$1,870,000**

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').

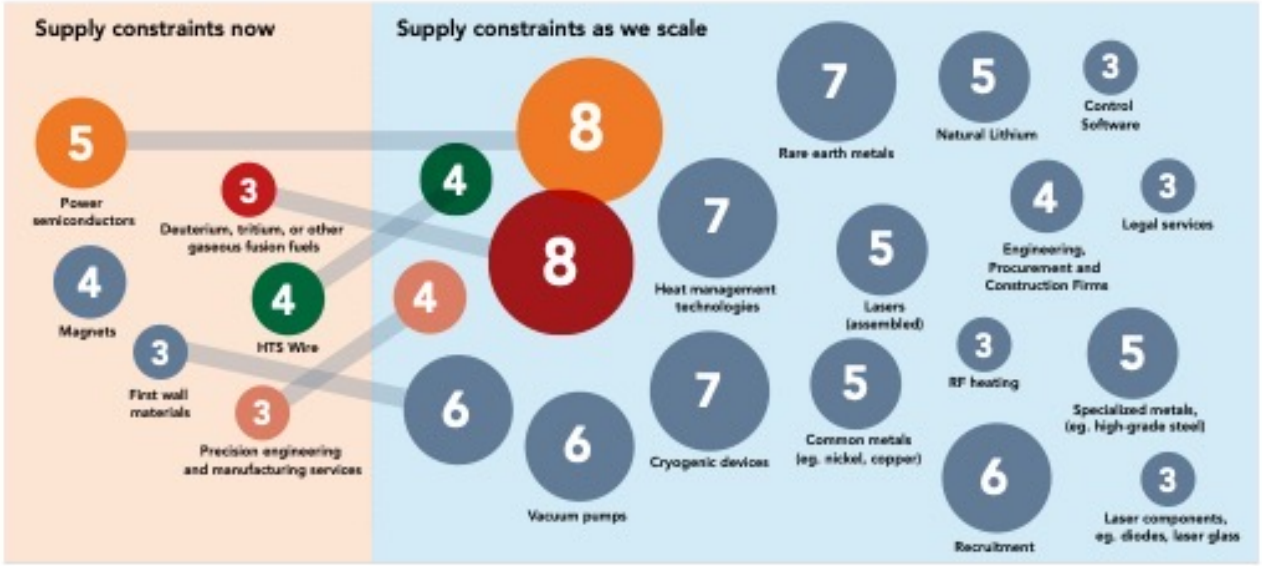
See Appendix 1 for expanded table.

	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

Affiliate Members

FIA's Principles for Accelerating 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.

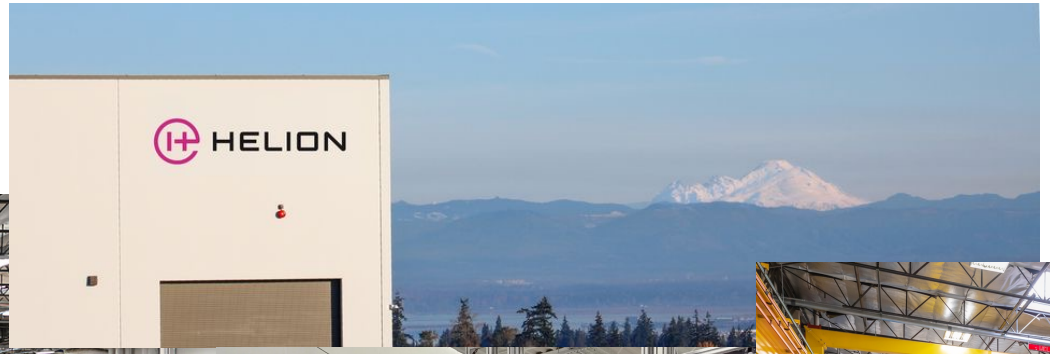
Ensuring Regulatory Certainty

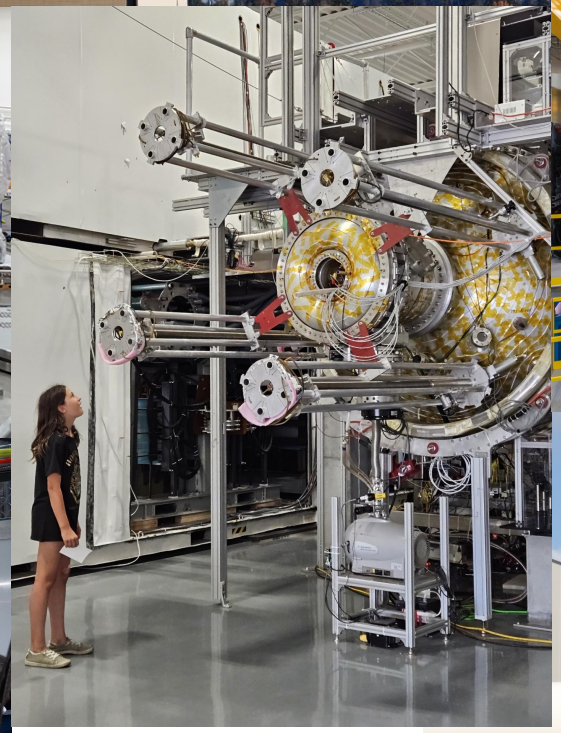
The regulatory regime for fusion should be predictable, proportional to the risk, and supportive of innovation, while also giving confidence about ensuring public safety and security. Fusion energy regulation must be permanently separated from fission regulation and should not require lengthy permitting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

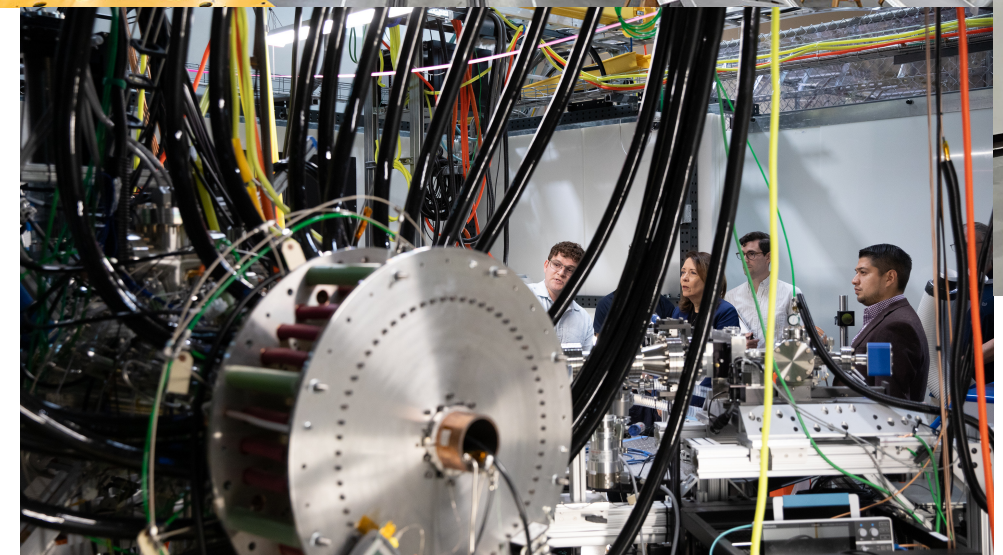
Incentives to Build a Global Fusion Energy Industry

The FIA supports efforts across the private, public, and philanthropic sectors to accelerate tomorrow's fusion power economy. 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***

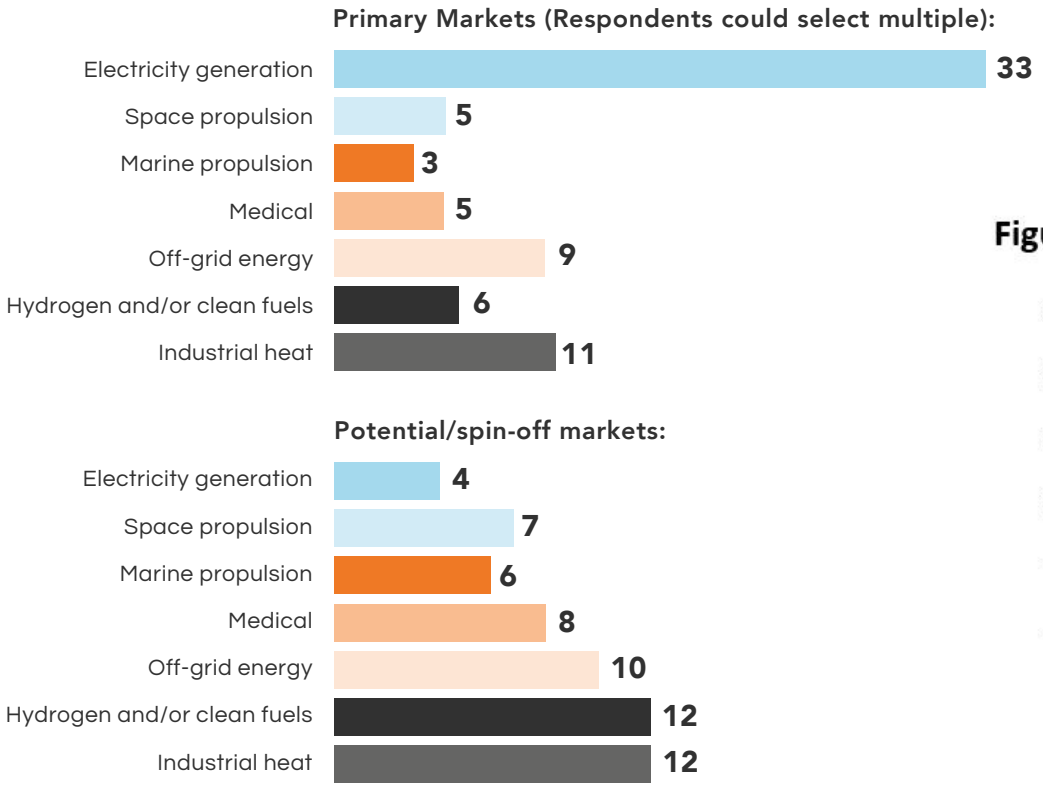
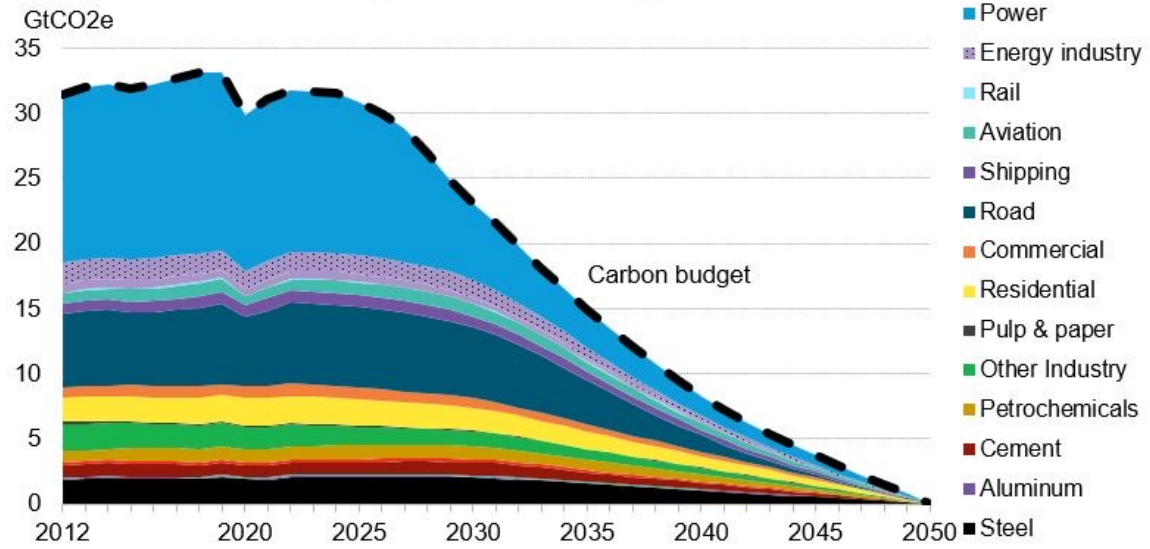
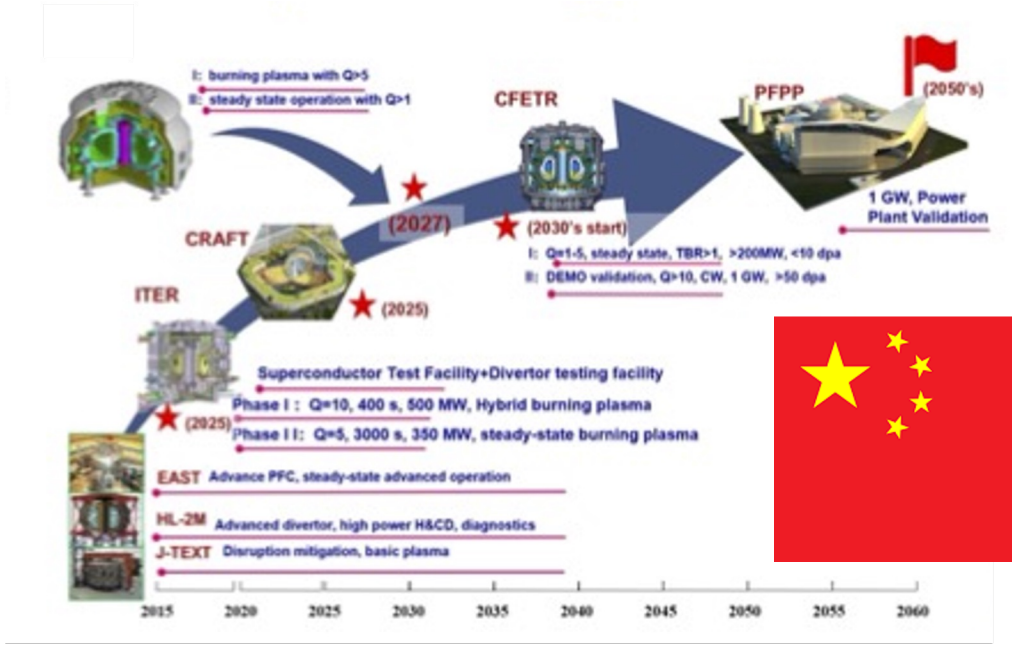


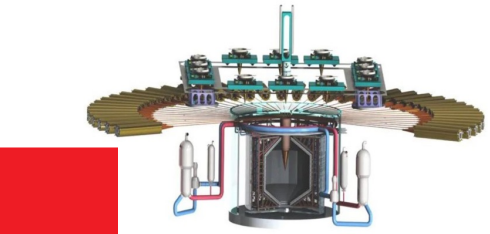
Figure 1: Total carbon budget for the energy sector



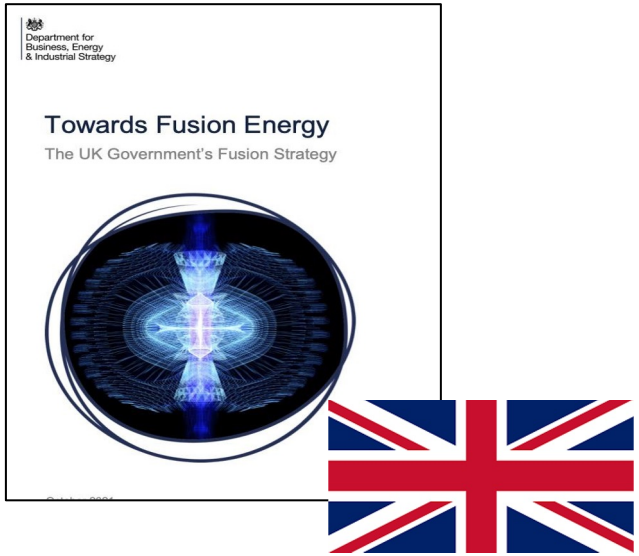
Source: BloombergNEF

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

For more information, contact Andrew Holland, FIA CEO:
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www.FusionIndustryAssociation.org