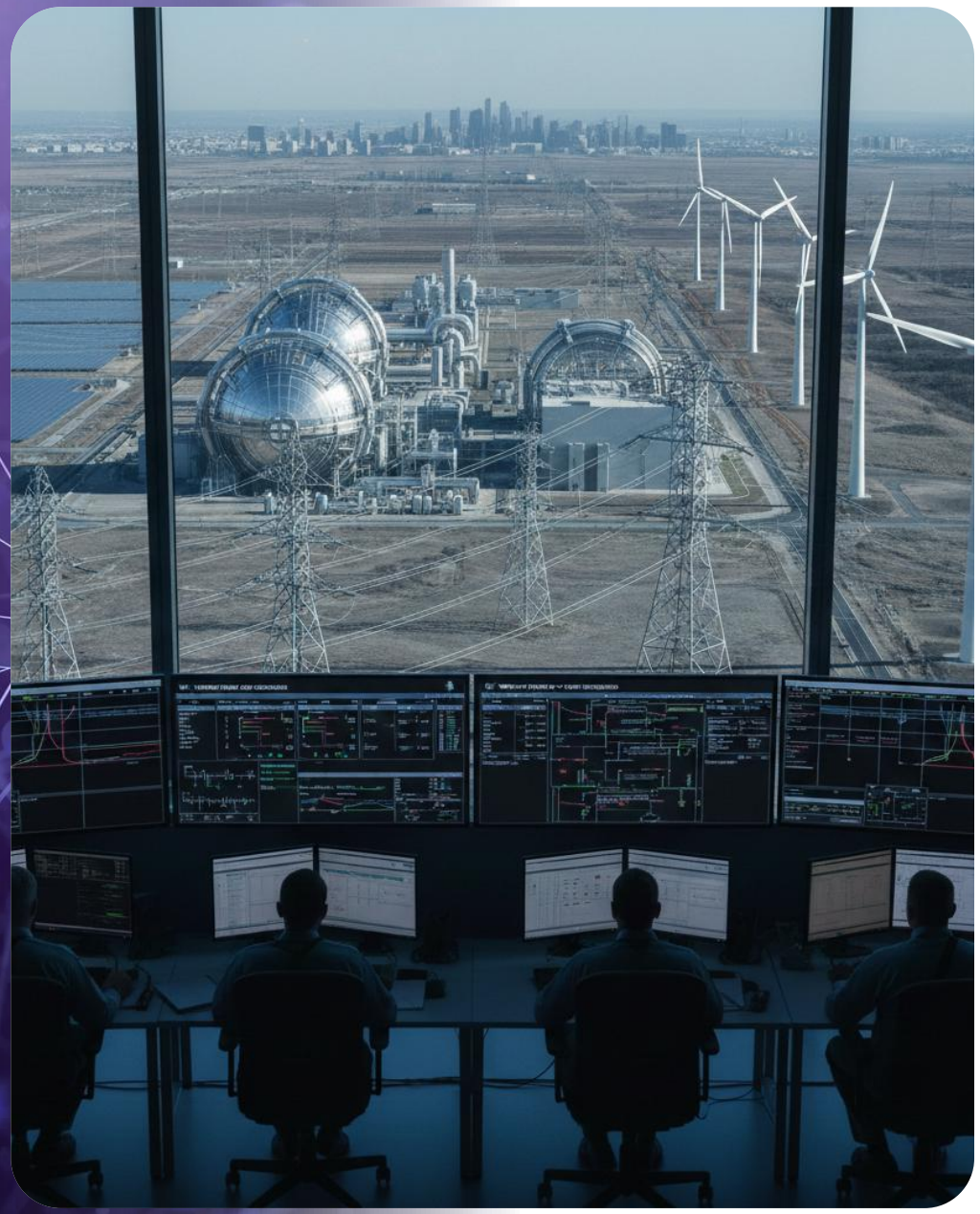


Part 1

Fusion as an Industry

Sergei Kniazev
MSc Physics | MBA MIT Sloan

Cofounder of Module12, an advisory firm specializing in fusion commercialization, techno-economic analysis, FOAK financing, and strategic planning for advanced energy ventures.
Holds an MSc. in Physics and an MBA from MIT Sloan School of Management.
18 years of experience across energy, finance, and advisory, including roles at KPMG and BP. Throughout his career, he has led and supported over 50 energy-sector projects globally, spanning asset valuation, corporate development, strategic planning, investment analysis, and capital allocation.
At Module12, his work focuses on commercialization strategy, project economics, investor readiness, and financing pathways for fusion companies

Key Stakeholders of a Fusion Power Plant

A comprehensive ecosystem across the full project lifecycle

1 GOVERNMENT & REGULATORS

- National government / Ministry of Energy
- Nuclear & fusion regulators
- Environmental regulators
- Grid regulator / electricity market operator
- Local authorities & permitting agencies
- Safety regulators
- Water-use regulators
- Export control & security agencies

2 PLANT OWNER / DEVELOPER

- Fusion plant developer / operator
- Independent Power Producer (IPP)
- Utility companies
- Industrial consortiums
- Infrastructure funds / private equity

3 FINANCING & INSURANCE

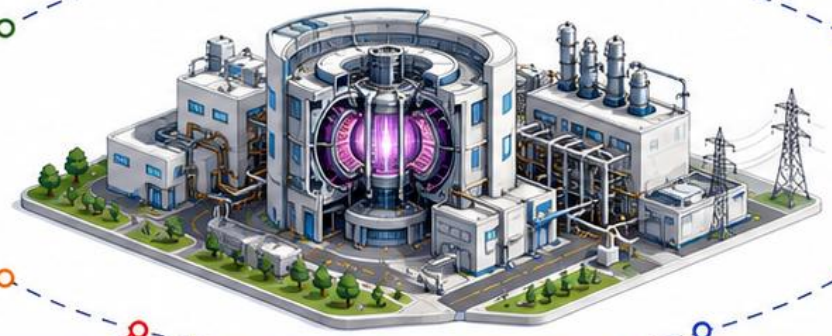
- Commercial banks
- Export Credit Agencies (ECAs)
- Multilateral institutions
- Institutional investors
- Sovereign wealth funds
- Insurance providers
- Reinsurance companies
- Rating agencies

4 ENGINEERING & CONSTRUCTION

- EPC contractors
- Magnet suppliers
- Turbine & balance-of-plant OEMs
- Cryogenic system suppliers
- Vacuum equipment suppliers
- Tritium/fuel-cycle system suppliers
- Civil construction companies

5 FUEL SUPPLY CHAIN

- Deuterium suppliers
- Lithium suppliers
- Tritium breeding/fuel-cycle operators
- Isotope processing companies
- Fuel storage operators
- Specialized logistics providers



6 GRID & OFFTAKE

- Transmission system operators (TSO)
- Distribution utilities
- Corporate PPAs / industrial buyers
- Electricity traders
- Capacity market operators

7 OPERATIONS & MAINTENANCE

- Plant operator
- O&M contractors
- Remote handling & robotics providers
- Digital/control system providers
- Workforce & unions
- Spare parts suppliers
- Inspection & maintenance firms

8 WASTE, SAFETY & DECOMMISSIONING

- Low-level radioactive waste handlers
- Materials recycling companies
- Decommissioning contractors
- Radiation monitoring providers
- Emergency response services

9 LOCAL & SOCIAL STAKEHOLDERS

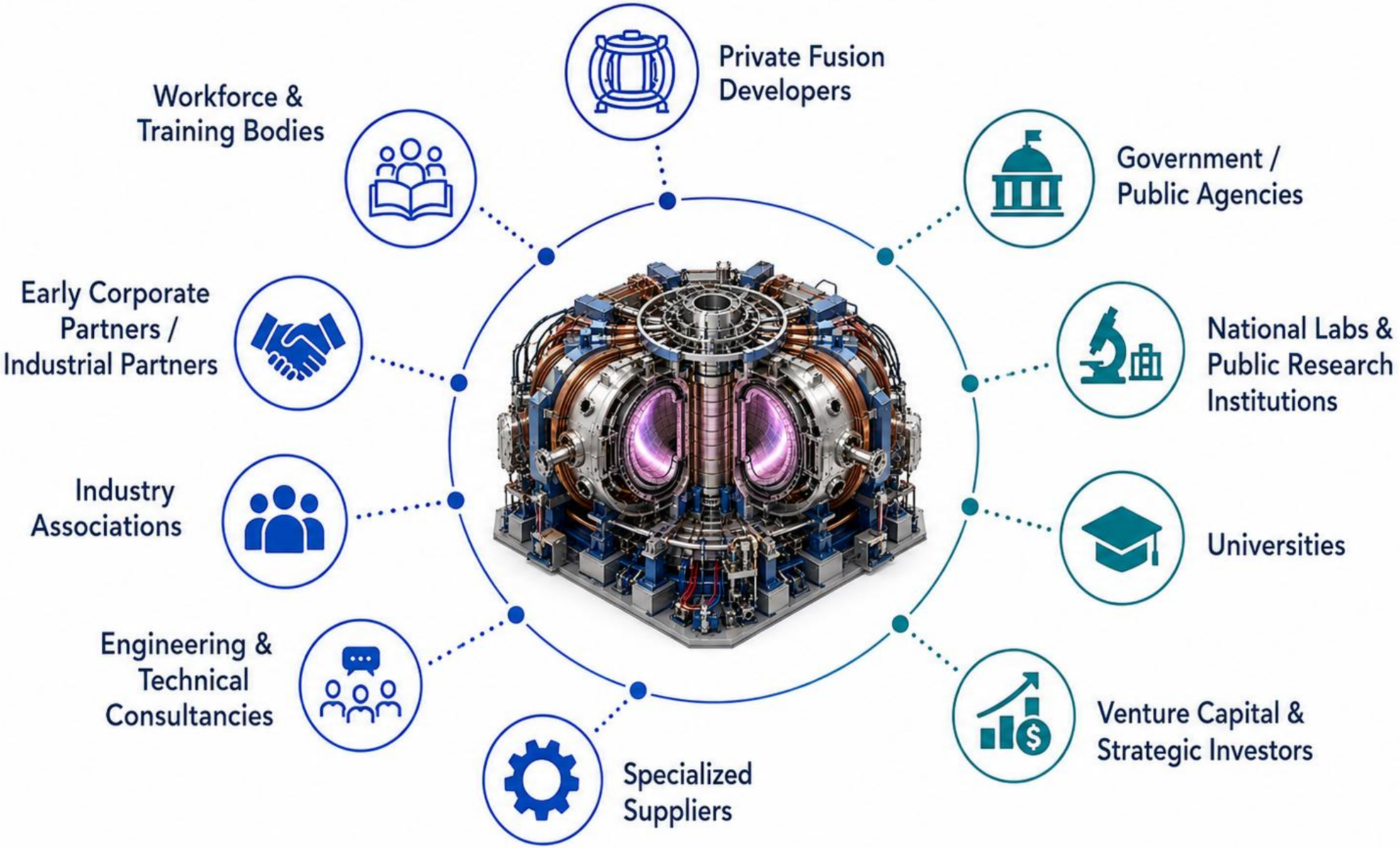
- Local communities
- Landowners
- Indigenous groups (where relevant)
- NGOs / environmental organizations
- Universities & workforce training institutions
- Local industrial ecosystem

10 RESEARCH & INNOVATION ECOSYSTEM

- National laboratories
- Universities
- Fusion research institutes
- Testing facilities
- Standards organizations
- Industry associations (e.g., FIA)

Collaboration Across All Stakeholders | Fusion success depends on aligned interests, transparent risk sharing, strong safety culture, and long-term public–private partnership.

Fusion ecosystem as of today



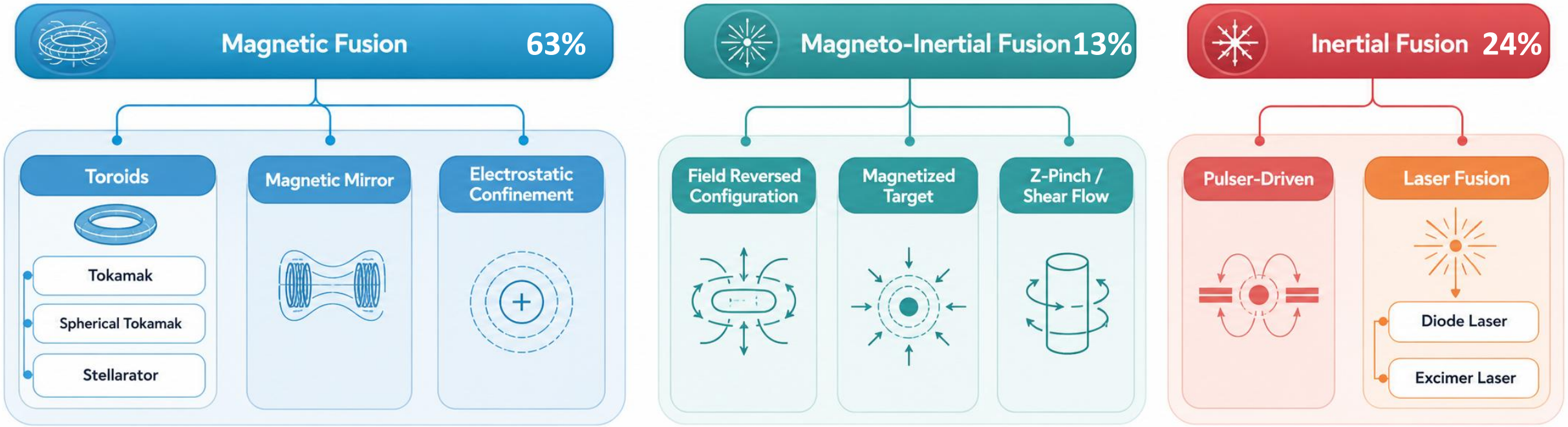
Fusion Ecosystem: Key Actors & Metrics for Shared Success

A diverse set of players advancing fusion from breakthroughs to commercial impact—each optimized on the metrics that drive their mission and success.

	1 Tech Developers & Supply Chain	2 Funding (Public & Private)	3 Research Organizations	4 Machine Developers	5 Non-Government Organizations
ACTORS	• **Component & subsystem makers** (magnets, blankets, power systems) • **Raw material suppliers** (superconductors, lithium, beryllium) • **Engineering & manufacturing services**	• **Funding** government (DOE budget, grants, programs) • **Private investors** (VC, growth equity, strategic) • **Offtake partners** (utilities, corporate buyers / PPAs)	• **National labs** (large, long-horizon programs) • **Universities** (targeted, academic projects)	• **Private fusion companies** building power-producing machines	• **Industry coordinators** (standards, roadmaps, supply chain) • **Energy advocates** (public awareness, policy support) • **Science & technology platforms** (knowledge sharing, partnerships)
KEY METRICS	• Cost per unit at scale • Guaranteed long-term supply contract • On-time delivery & yield • Lead time to scale production	• ROI • Private dollars leveraged per public dollar (government) • Guaranteed baseload power under contract (offtakers)	• Scientific gain (Q) • Progress to engineering breakeven • Peer-reviewed results • Talent trained into industry	• Net electricity to grid • Capacity factor & availability (uptime) • Projected LCOE • Operating life of key components	• Policy & legislation passed • Companies & supply-chain firms connected • Standards & roadmaps published • Public & political awareness

Different Missions. Shared Goal. Aligned success across the ecosystem is what will deliver safe, abundant, and affordable fusion energy.

FUSION PATHWAYS



https://www.scsp.ai/wp-content/uploads/2025/12/Fusion-Supply-Chain-Report.pdf

One Goal. Multiple Paths. Different Commercial Bets.

Different combinations of temperature, density, and confinement time can satisfy the Lawson criterion.

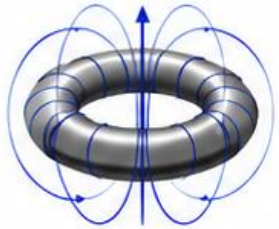
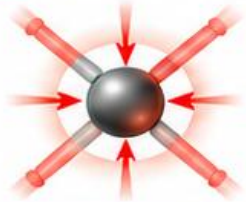
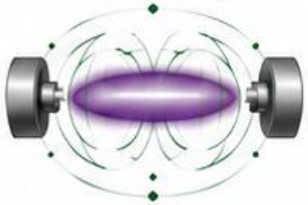
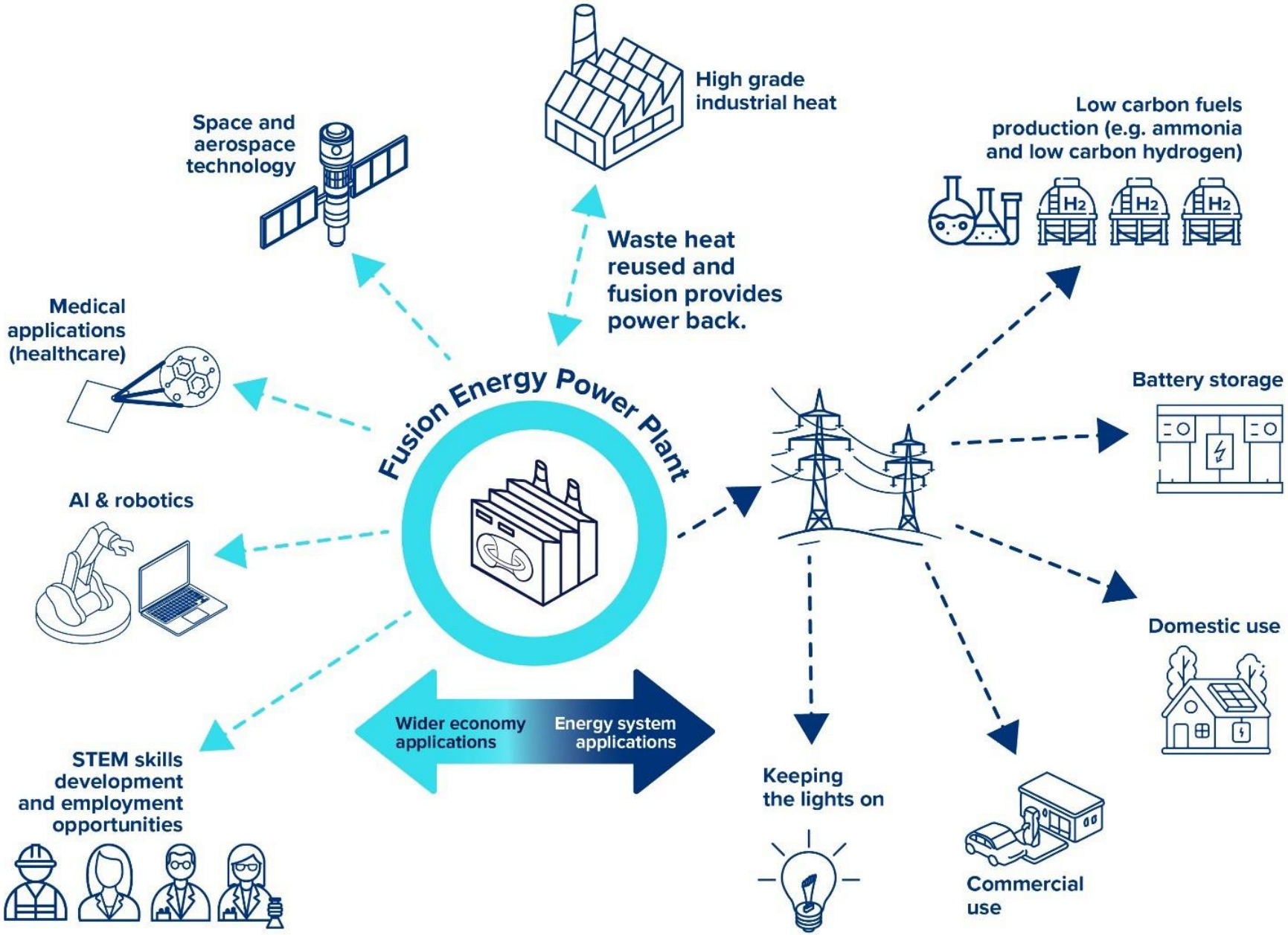
FUSION APPROACHES	PHYSICS ADVANTAGES	COMMERCIAL BETS
1 MAGNETIC FUSION Stellarators / Tokamaks  Uses strong magnetic fields to confine low-density plasma for seconds to minutes.	**Long confinement time** Plasma can be contained for seconds to minutes.	**Stellarators** Steady state operation **Tokamaks** Most technologically advanced approach
2 INERTIAL FUSION Laser or Pulsed-Power Compression  Uses lasers or pulsed power to compress fuel to very high density for nanoseconds.	**High density** Compression increases density by several orders of magnitude.	**Inertial Fusion** • Modular design • Steeper manufacturing curve Repetition rate and manufacturability drive cost-down potential.
3 MAGNETO–INERTIAL FUSION (M–I) FRC / Magnetized Target  Combines magnetic and inertial effects to achieve balanced performance.	**Balance between time and density** Provides a middle ground between magnetic and inertial approaches.	**Magneto–Inertial (M–I)** • Aneutronic path (e.g., TAE) • Direct electricity path (e.g., Helion) Potential for higher efficiency and simpler systems with fewer neutrons.

Table 2.1 Categorization of fusion companies by fuel and confinement method

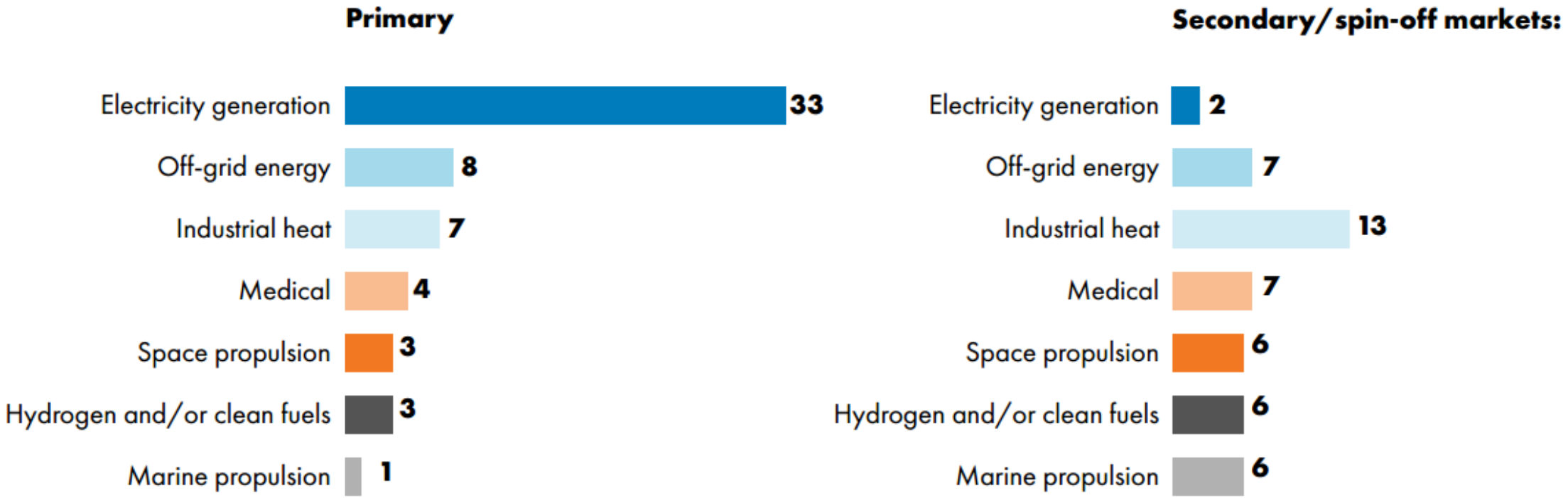
FUEL TYPE	CONFINEMENT		
	MAGNETIC	INERTIAL	MAGNETO-INERTIAL
Deuterium-tritium	Commonwealth Fusion Systems Realta Fusion Tokamak Energy Type One Energy	First Light Fusion Xcimer	General Fusion Zap Energy
Deuterium-deuterium			
Deuterium-helium3			Helion Energy
Proton-boron11	TAE Technologies	Marvel Energy	

Fusion as an enabling mechanism



UK's plan for delivering Fusion Energy

Target Markets



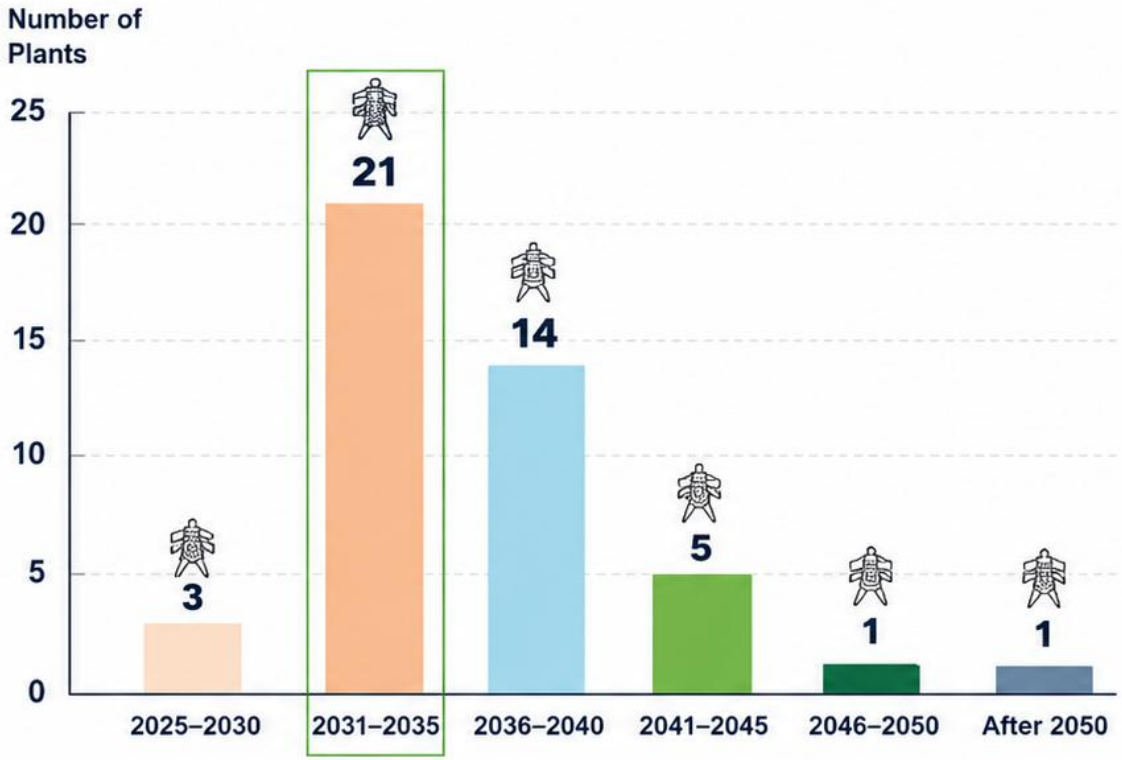
Other named markets included: materials research, lithium breeding, nuclear waste transmutation, laser driven imaging, neutron source, Radiation-as-a-Service (RaaS), hard rock tunneling and mining, diagnostic development, neutron imaging and radiation effects testing for advanced industrial inspection, tritium and radioisotope production.

Fusion Industry Association

WHEN?

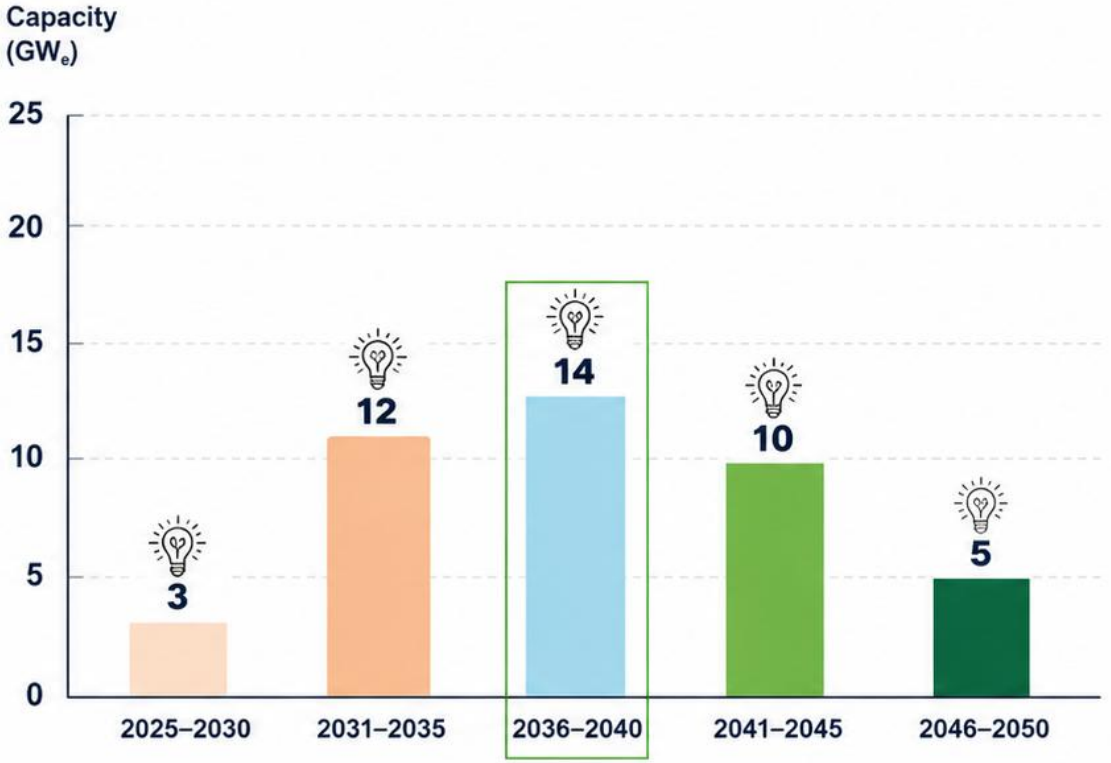
FUSION DEMONSTRATION POWER PLANTS (MW_e)

First grid-capable demonstration plants



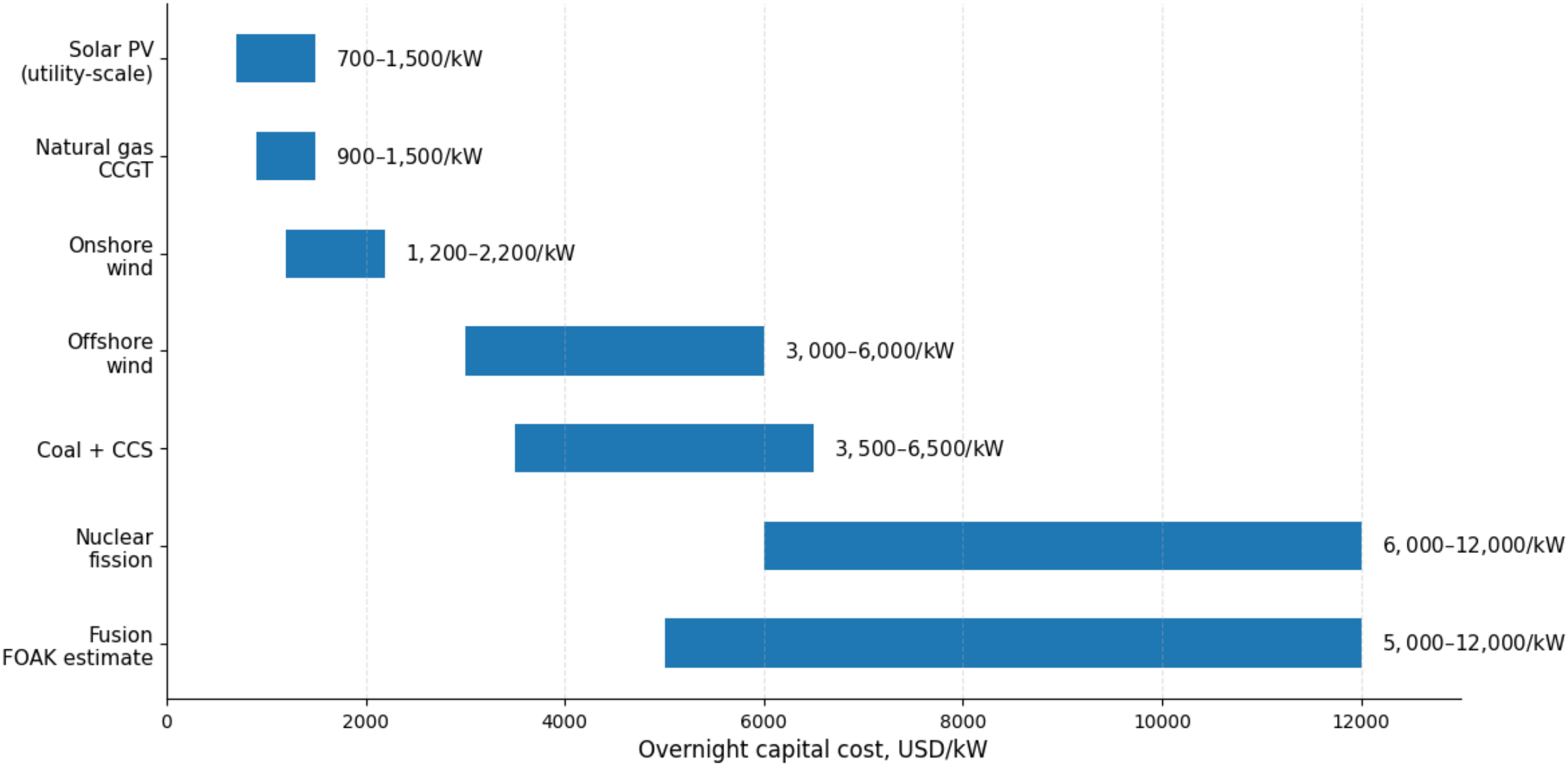
FUSION COMMERCIAL POWER PLANTS (GW_e)

Commercial-scale fusion capacity coming online



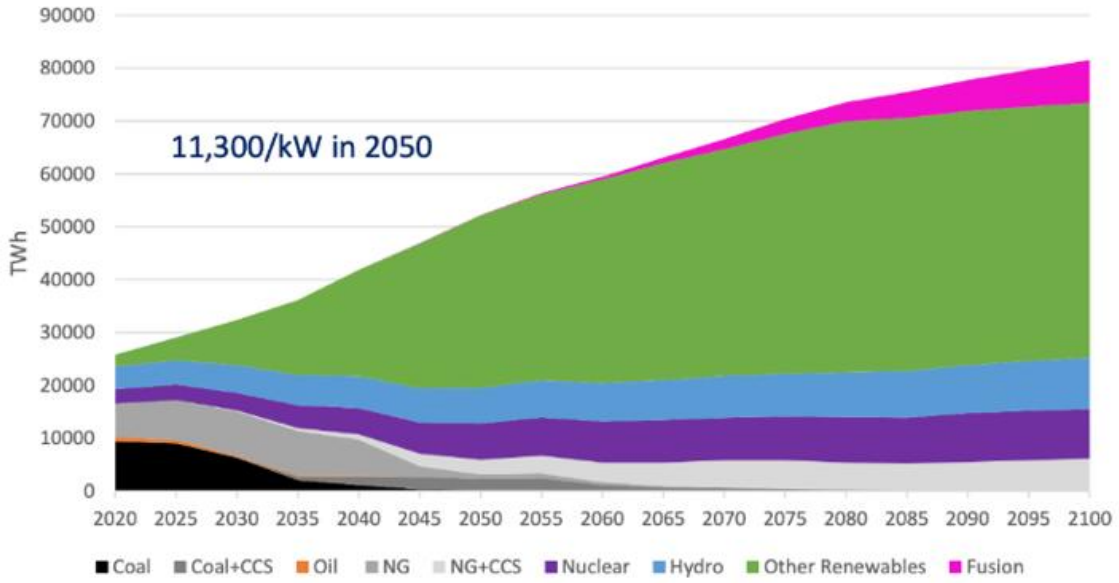
FIA report 2025

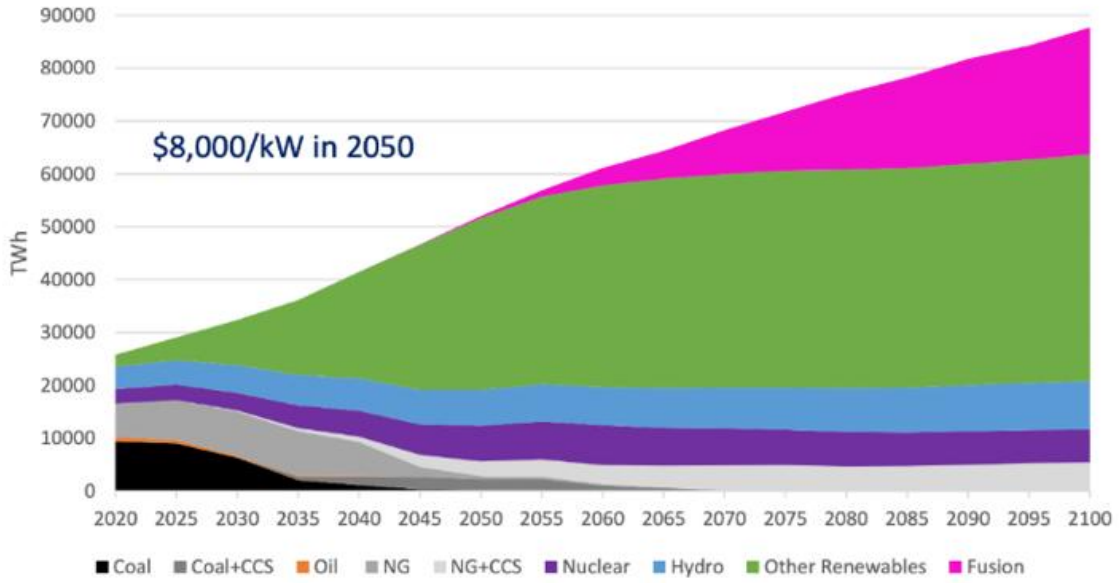
Overnight Capital Cost Ranges by Energy Technology

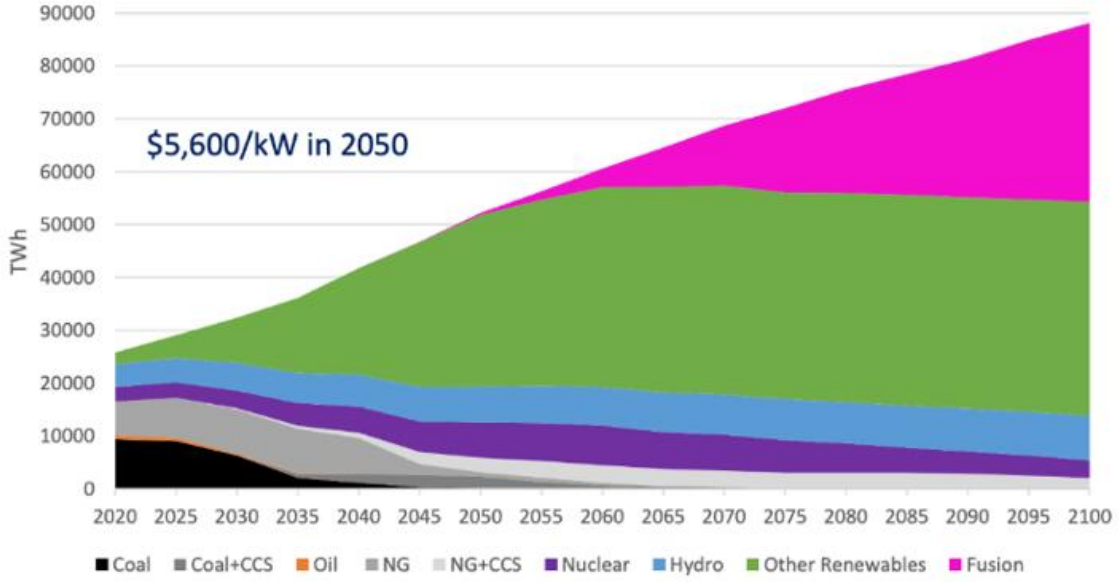


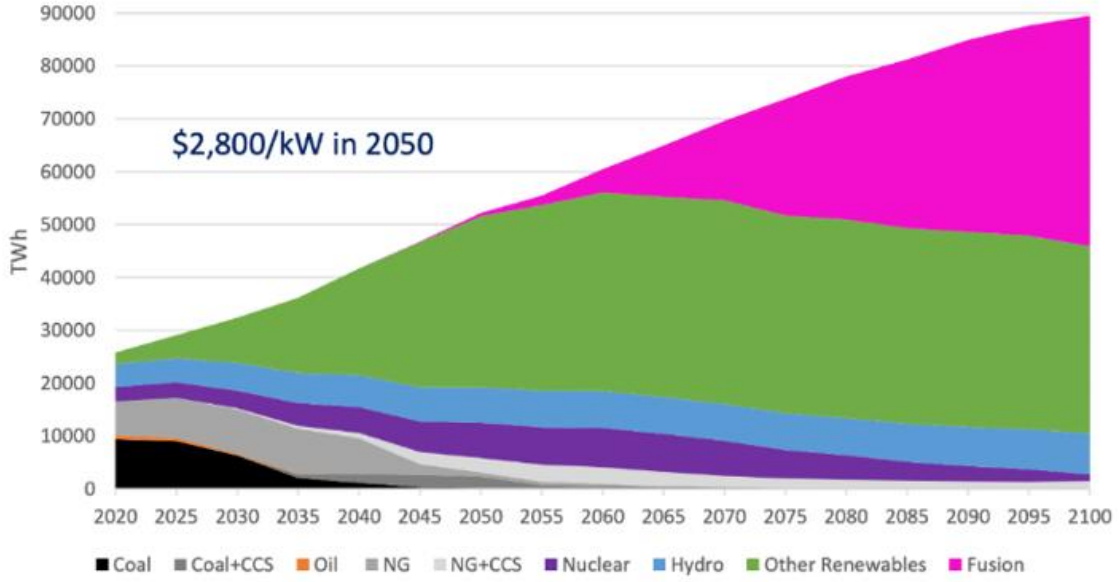
Indicative ranges for slide discussion; fusion range reflects uncertain FOAK estimates.

WHEN? Overnight capital costs and deployment scenarios









MITEI: The role of fusion energy in a decarbonized electricity system

Public Fusion Facilities by Design and Country

Number of Facilities by Design Type

Design	Country	Facility Configuration (Number of Facilities)				Total
		Altern. Concepts	Laser/Inertial	Stellarators/ Hellotrons	Tokamaks	
Exp	Japan	16	6	6	18	46
	United States	11	13	6	5	35
	Russia	12	4	3	9	28
	China	2	1	2	3	8
	Pakistan	0	0	0	5	5
	Italy	3	0	0	2	5
	India	0	0	0	5	5
	France	2	1	0	2	5
	Iran	0	1	1	2	4
	Germany	0	0	2	2	4
	Brazil	0	0	2	2	4
	Ukraine	1	0	1	1	3
	Switzerland	1	0	0	1	2
	Spain	1	0	1	0	2
	Republic of Korea	1	0	1	0	2
	Czech Republic	0	0	1	1	2
	Costa Rica	0	0	2	0	2
	United Kingdom	1	0	0	1	2
	Thailand	0	0	0	1	1
	Sweden	1	0	0	0	1
	Portugal	1	0	0	0	1
	Libya	0	0	0	1	1
	Kazakhstan	0	0	0	1	1
	European Union	0	1	0	0	1
	Egypt	0	0	1	0	1
	Denmark	0	0	0	1	1
	Canada	0	0	0	1	1
Plant	United Kingdom	0	0	0	1	1
	Russia	0	0	0	1	1
	Republic of Korea	0	0	0	1	1
	Japan	0	0	0	1	1
	European Union	0	0	0	1	1
	China	12	10	8	0	30
Total		50	30	30	62	142

Note: Facility counts are approximate and based on publicly available information.

Total Facilities
142
(Exp: 112 | Plant: 30)

Facility Configuration

Altern. Concepts
Alternative fusion approaches including pinch, Z-pinch, FRC, etc.

Laser/Inertial
Inertial confinement fusion using high-power lasers or particle beams.

Stellarators/Helotrons
Magnetic confinement using stellarator and heliotron designs.

Tokamaks
Magnetic confinement using tokamak designs.

Most Major Projects Come From Research Organizations and Govement Labs

Spin-Outs

Commonwealth Fusion Systems	⟷	MIT
tae	⟷	UCI
THEA ENERGY	⟷	PPPL
TYPE ONE ENERGY	⟷	WISCONSIN UNIVERSITY OF WISCONSIN-MADISON
REALTA FUSION	⟷	WISCONSIN UNIVERSITY OF WISCONSIN-MADISON
Proxima Fusion	⟷	MAX PLANCK GESELLSCHAFT
first light	⟷	UNIVERSITY OF OXFORD
Tokamak Energy	⟷	CCFE CULHAM CENTRE FUSION ENERGY
FOCUSED	⟷	TECHNISCHE UNIVERSITÄT DARMSTADT
ZAP ENERGY	⟷	UNIVERSITY of WASHINGTON

Close Collaborations

generalfusion	⟷	Canadian Nuclear Laboratories
PACIFIC FUSION	⟷	Lawrence Livermore National Laboratory
XCIMER	⟷	Lawrence Livermore National Laboratory
Marvel Fusion	⟷	Colorado State University

FUSION ECOSYSTEM

INDUSTRY COORDINATORS, ADVOCATES & ECOSYSTEM BUILDERS

A connected global ecosystem accelerating fusion energy commercialization

INDUSTRY ASSOCIATIONS & ECOSYSTEM BUILDERS

Supporting the fusion industry through advocacy, collaboration, investment and supply chain development.

Fusion Industry Association (FIA)
Global trade association advocating for a strong fusion industry and supportive policy frameworks.

FusionX Invest
Investor network and platform accelerating capital flow into fusion companies globally.

Fusion Cluster, UK
Grow the UK fusion supply chain and connect industry, academia and investors.

European Fusion Association
Representing the European fusion community and advocating for fusion at the EU level.

Fusion Power Associates (FPA)
Dedicated to commercial fusion energy and the development of a robust fusion supply chain.

https://usfusionenergy.org/
Broad coalition advancing fusion energy through policy engagement and public outreach in the United States.

INTERNATIONAL INSTITUTIONS & GOVERNMENT BODIES

Advancing research, setting standards, and enabling global collaboration.

International Atomic Energy Agency (IAEA)
Promoting peaceful use of nuclear science and technology, including fusion, worldwide.

Fusion Energy Sciences Advisory Committee
Independent advisory body to the U.S. Department of Energy on fusion energy sciences.

FUSION ECOSYSTEM

Office of Fusion Energy Sciences (FES)
Leading federal research to achieve transformative fusion energy.

EUROfusion
European research consortium driving fusion science and technology development across Europe.

NGOS, THINK TANKS & ADVOCACY ORGANIZATIONS

Advocating for clean energy solutions and informing policy for a sustainable future.

Clean Air Task Force (CATF)
Global nonprofit advocating for climate solutions, including fusion energy as a clean firm power source.

Good Energy Collective
Building public awareness and support for advanced energy technologies including fusion.

Energy for Growth Hub
Advancing energy solutions that power economic growth and human development.

Collaboration across industry, government, research, and advocacy organizations is essential to accelerate fusion energy from innovation to reality.

STRONGER TOGETHER | GLOBAL COLLABORATION | POLICY & STANDARDS | ACCELERATING COMMERCIALIZATION

FUSION STRATEGIES BY COUNTRY

Different strategies. Shared goal: Commercial fusion energy.

UNITED STATES

MAIN STRATEGY
Private-sector-led commercialization supported by public-private partnerships

GOVERNMENT COMMITTED FINANCING
415 mUSD to DOE milestone program through 2027;
135 mUSD from ARPA-E ever next 18 months

MAIN APPROACHES
- All scientifically proven fusion approaches

STRENGTHS
- Largest private fusion ecosystem
- Strong VC/deep-tech capital markets
- Leading startups and talent
- Flexible innovation environment

WEAKNESSES
- Fragmented national strategy
- Political/budget uncertainty
- Heavy dependence on private capital

UNITED KINGDOM

MAIN STRATEGY
Government-led fusion industrialization and ecosystem building

GOVERNMENT COMMITTED FINANCING
~£2.5B officially committed through 2030

MAIN APPROACHES
- Spherical tokamaks

STRENGTHS
- Clear national strategy
- Strong regulatory leadership
- Integrated fusion cluster at Culham
- Strong public coordination

WEAKNESSES
- Smaller private capital market
- Limited domestic industrial scale
- High dependence on government funding
- Bet on one approach

CHINA

MAIN STRATEGY
State-driven long-term strategic technology development

GOVERNMENT COMMITTED FINANCING
Estimated ~$7–10B+ public funding trajectory over next 5 years

MAIN APPROACHES
- Tokamaks
- Laser fusion

STRENGTHS
- Massive state resources
- Fast infrastructure buildout
- Strong manufacturing capability
- Long-term planning horizon

WEAKNESSES
- Slower entrepreneurial flexibility

GERMANY

MAIN STRATEGY
Research excellence transitioning toward commercialization

GOVERNMENT COMMITTED FINANCING
~€2.4B committed through ~2029

MAIN APPROACHES
- Stellarators
- Laser fusion

STRENGTHS
- World-class engineering
- Strong scientific base
- Leadership in stellarators
- Industrial manufacturing expertise

WEAKNESSES
- Smaller private funding scale
- Slower commercialization culture

Lessons from Nuclear:
Government progressively handed 14 functional roles to industry

From AEC running everything in test reactors to industry running everything by first commercial COD. The handoff was the program.