FUSION FOR ENERGY

Global Fusion Energy Trends

Report from the F4E Fusion Observatory

Funding • Performance • Research • Innovation

A comparative Analysis of China, EU, Japan, UK, and the USA

Foreword

Fusion — an energy for the future

Fusion is the process that powers the Sun and other stars. Reproducing it on Earth has the potential to provide safe, clean, and virtually limitless energy. The fuels required are widely available, with very small quantities capable of releasing large amounts of energy. Fusion produces no greenhouse gases or long-lived radioactive waste, and it is inherently safe. As a steady power supply, fusion can complement renewables and strengthen Europe's long-term energy security and autonomy.

Fusion for Energy

Fusion for Energy (F4E) is the European Union's organisation for the development of fusion energy. It is responsible for Europe's contribution to ITER — the largest international fusion experiment, amounting to nearly half of the project. In parallel, F4E is contributing to major fusion projects such as the JT-60SA tokamak as well as the IFMIF-EVEDA and IFMIF-DONES materials testing facilities. The knowledge and expertise acquired will feed into the construction of future fusion power plants.

Europe's investment in fusion generates business opportunities. F4E works with an impressive supply chain connecting large companies, SMEs and laboratories to manufacture complex components, deliver advanced technologies and provide infrastructure. Since 2007, F4E has signed more than 1400 contracts with over 2700 European companies and laboratories, injecting over €7 billion in the fusion supply chain. The skills, technology transfers, and business opportunities are paving the way for a European fusion industry that is competitive and resilient.

F4E Fusion Observatory

The F4E Fusion Observatory provides objective analysis and intelligence on worldwide and European fusion policies, R&D, technologies, investments and industrial activity for the benefit of European policymakers, the scientific community and other interested parties.

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Executive Summary

The pursuit of fusion energy has entered a more active and strategically important phase. Between 2022 and 2025, the five actors examined — China, the EU, Japan, the UK and the US — mobilised or formally committed approximately €20.35 billion in identified public funding and private capital raised. Behind this figure are different approaches by each of the actors to financing, research, industrialisation and regulation.

This report from the Fusion for Energy (F4E) Fusion Observatory compares the five actors across five quantitative dimensions — public funding, private capital raised, fusion activity, publications and patents — and reviews their regulatory frameworks. The actor profiles that follow bring these dimensions together to highlight the principal strengths, constraints and strategic choices within each fusion ecosystem.

The US combines the largest identified funding total with the deepest venture-capital base and the largest accumulated publication and citation record. The EU is anchored in ITER and a broad, distributed public research network, and leads publication output in the recent period examined. Japan combines a mature scientific base with a growing industrial-policy and private-sector push. The UK has the most centralised programme among the five actors, centred on UKAEA and STEP, and established an early and clearly defined non-fission regulatory pathway.

The following structural findings emerge:

1 US and China lead funding through different models

The US has the largest identified total for 2022–2025 at €7.38 billion, comprising €4.97 billion in public funding and €2.41 billion in private capital raised. China follows with €6.94 billion overall and has the largest estimated public total, at €5.45 billion. Approximately €3.73 billion of China's public funding is through support to state-controlled commercial entities. The EU accounts for €3.34 billion, including €2.12 billion in ITER in-kind procurement managed by F4E. The UK and Japan remain predominantly publicly financed. Across all five actors, public finance represents approximately 78% of identified funding and continues to carry most of the financial and technological risk.

2 The US dominates identified private fusion capital

US fusion companies raised €2.41 billion between 2022 and 2025 — 54% of the private capital identified across the five actors. China follows at approximately €1.50 billion, with the EU at €340 million, Japan at €138 million and the UK at €70 million. Power-purchase and offtake agreements involving Microsoft, Google, Helion and Commonwealth Fusion Systems (CFS) indicate early customer interest but remain conditional on developing facilities and technologies that have not yet delivered commercial fusion electricity. Outside the US, the private-capital base is thinner, creating a particular scale-up challenge for Europe.

3 The US has the broadest active device base, but no actor has yet demonstrated an integrated power-plant capability

The five actors have 83 operating, under-construction and planned fusion devices in their combined pipeline, of which 42 are active. The US leads with 14 active devices, followed by China with 9, the EU and Japan with 8 each, and the UK with 3. No device yet combines high fusion performance with the plant-relevant duration, repeatability and integrated technologies needed for practical electricity generation. The US National Ignition Facility, the EU-UK JET device and Japan's JT-60U all achieved high fusion performance but for short periods / low duty cycle. Four devices under construction: ITER, SPARC, BEST and JT-60SA, aim to address complementary parts of this challenge, while a wider group of public and private demonstrators is targeting the 2030s and early 2040s. Many of these dates are programme or developer targets rather than independently validated schedules.

4 The US and EU dominate scientific output, while the balance is shifting

The US and EU together account for approximately 65% of publications and 75% of citations in the five-actor full-record dataset of scientific publications. The US retains the largest accumulated totals, with around 50,300 publications and 42% of citations. The EU is close behind historically and leads over the last 20-year publication window, with a share of 34.2%. China has expanded rapidly to become the third-largest recent contributor. The institutional evidence also highlights contrasting research models. The top 20 publishing institutions include seven EU institutions, six from the US, three from China, two from Japan, UKAEA and the ITER Organization. EU output is distributed across a network of national laboratories, while Chinese activity is concentrated in a smaller number of leading institutions. The US combines major national laboratories, universities and large publicly supported research facilities.

5 China has by far the largest identified fusion patent portfolio

China accounts for 1,335 alive fusion patent families — approximately 60% of the five-actor total — with 13 of the top 20 patenting organisations located there. This is followed by the US with 438, Japan with 154, the EU with 143 and the UK with 140. Around 95% of the identified Chinese patent families had no published family member outside China at the cut-off. China leads numerically across most of the technology categories examined, while the US has a comparatively strong inertial-fusion portfolio and the UK, US and China have similar totals in superconducting devices. Outside China, patent leadership is concentrated in private fusion companies, with Tokamak Energy, CFS and Shine among the largest patent holders.

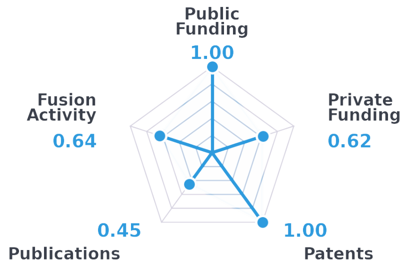
6 Regulatory principles are converging, but legal models remain different

The five actors increasingly favour graded, risk-informed and technology-neutral regulation, but they are not adopting a single institutional model. The UK and US have established pathways outside the licensing regimes used for fission reactors. China places fusion within its Atomic Energy Law while requiring specialised and graded supervision. Japan has adopted guiding safety principles and is developing detailed arrangements. The EU already has an operational foundation through national competent authorities and Euratom requirements; France's regulation of ITER demonstrates how an existing nuclear framework can be adapted to fusion-specific hazards. ENSREG is now examining where greater European coordination could improve consistency and predictability.

A Five-Dimensional Comparison

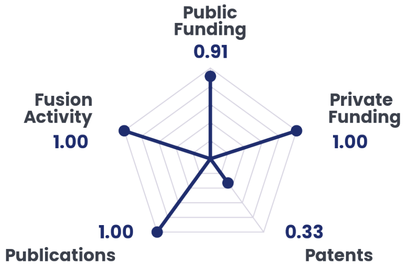
China

State-led industrial strategy



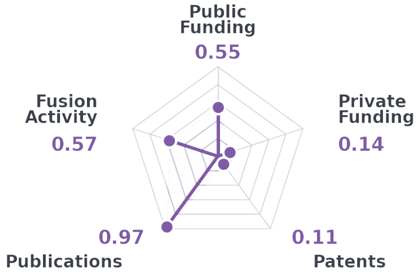
US

Private capital backed ecosystem



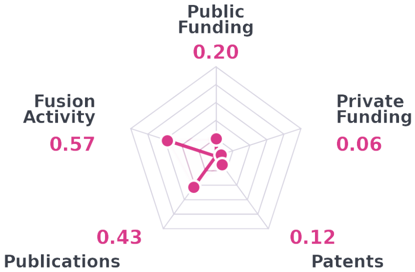
EU

ITER-anchored public research base



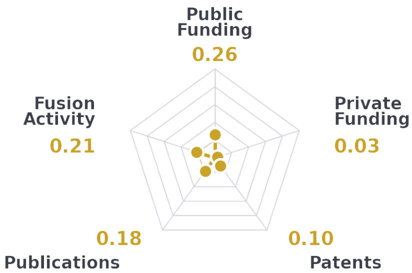
Japan

Public anchor, private pivot



UK

Centralised programme; clear non-fission regulatory pathway



READING THE RADARS

Public Funding — Public Funding incl. ITER in-kind

Private Funding — Inward private capital raised

Patents — Alive fusion patent families

Publications — Scientific output volume

Fusion Activity — Active device base

Index normalised to the group leader (1.0 = leader).

The indicators compare scale only; they do not measure quality, efficiency, technological performance or maturity.

China

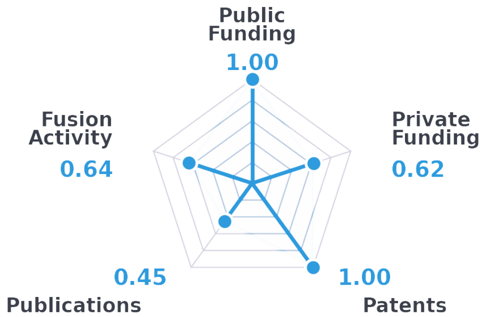
State-directed industrial pathway

China has the most state-directed fusion programme among the five actors, treating the technology as industrial policy and backing it with the largest identified public funding pool — €5.45 billion over 2022–2025, or 34% of the five-actor public total. A central feature is the channelling of approximately two-thirds of this funding into state-controlled commercialisation vehicles, creating a closely integrated public–commercial architecture. China also has the largest identified patent portfolio, with 1,335 alive families, or 60% of the five-actor total, although around 95% had no published foreign family member. Its EAST tokamak sustained a 1,066-second plasma in January 2025, shortly before WEST in France achieved 1,337 seconds. China's publication output is growing rapidly, but its younger portfolio has accumulated fewer citations per paper. With the Atomic Energy Law now in force, China combines scale and policy alignment with a detailed commercial licensing framework that is still evolving.

PUBLIC FUNDING	PRIVATE FUNDING	ALIVE PATENTS	PUBLICATIONS	ACTIVE DEVICES
€5.45B	**€1.5B**	**1,335**	**22,591**	**9**
34% of five actor public funding	*34% of five actor private funding*	*60% of five actor total*	*15% of five actor total*	*67% tokamaks*

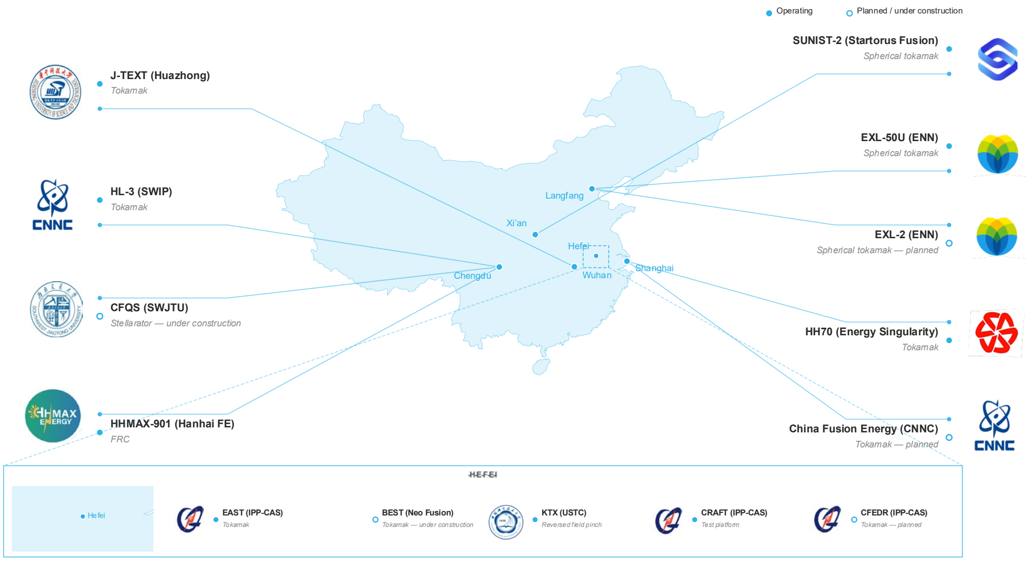
COMPETITIVENESS PROFILE

Normalised 0–1 · group leader = 1.00



FUSION DEVELOPERS & DEVICE SITES

IAEA FFDB · May 2026



CRAFT is enabling research infrastructure and is shown for context; it is not included in the fusion-device count

01 STRATEGIC POSTURE

China pursues fusion as state-led industrial policy, integrating central planning, state-backed commercialisation vehicles and a sequenced national roadmap into a coordinated programme anchored by China Fusion Energy Co. (CFEC), a CNNC-led consortium of 25 state enterprises, research institutes and universities. Fusion was designated a strategic frontier technology under the 14th Five-Year Plan and elevated to "Future Industry" status under the 15th (2026–2030). Implementation follows a sequential pathway: scientific breakeven via BEST around 2030, operation of the China Fusion Engineering Demonstration Reactor (CFEDR) from the 2030s, and commercial fusion power by 2050[7].

02 FUNDING & PRIVATE CAPITAL RAISED

→ Ch.2

Identified public funding mobilised or committed over 2022–2025 totals approximately €5.45 billion (incl. €431 million ITER in-kind). The defining feature is the public-to-private channel, capturing 68% of national outlays (€3.73 billion), capitalising state-backed vehicles: CFEC (€1.9 billion registered capital) and NEO Fusion (€1.85 billion, the BEST platform). Private capital-backed startups — Energy Singularity, ENN, Startorus Fusion — raised €1.5 billion.

03 DEVICES & PERFORMANCE

→ Ch.3

12 devices in pipeline; 9 active (7 operating, 2 under construction). Anchored by EAST (ASIPP, Hefei) and HL-3 (SWIP, Chengdu). Energy Singularity's HH70 became the world's first operational HTS tokamak in June 2024. BEST is under construction, with first plasma targeted for late 2027 or early 2028. Enabling infrastructure including the Comprehensive Research Facility for Fusion Technology (CRAFT) campus (ASIPP, Hefei).

04 INNOVATION OUTPUT

→ Ch.4-5

1,335 alive patent families — 60% of five actor total — combining 608 grants, 594 applications, 133 utility models. Leading applicants are HFIPS/CAS (317), NEO Fusion (209) and SWIP (198). Around 95% had no published foreign family member at the analysis cut-off. 22,591 publications place China third among the five actor total; citation share has nearly doubled since 2006, though per-paper impact remains lowest of the five actors.

05 GOVERNANCE & REGULATION

→ Ch.6

The Atomic Energy Law adopted September 2025, in force 15 January 2026 — a comprehensive atomic-energy statute that explicitly includes fusion and provides for graded supervision. NNSA (under MEE) leads regulation; CAEA promotes the sector. Detailed implementing and project-level licensing arrangements remain under development.

+ STRENGTHS	– CHALLENGES
• Largest state-directed public funding pool of five actor total; strong Five-Year-Plan alignment • Largest identified patent portfolio (60% of five-actor total), with public institutes, universities and commercial entities • Among world leaders in sustained-pulse operation through EAST (1,066 s), BEST tokamak operational in 2027 • Rapidly growing infrastructure - the Comprehensive Research Facility for Fusion Technology (CRAFT) campus	• Lowest per-paper citation impact of the five actors (~10 vs ~24 US/UK) • Around 95% had no published foreign family member at the analysis cut-off • Foundational law in force, implementing regulations still pending

China combines the largest identified public funding base of any actor with rapid growth in devices, enabling infrastructure — including the BEST device, due to operate in 2027 — a rising share of fusion publications, and world leadership in patents, albeit mostly filed domestically; its foundational fusion regulation is now in force.

European Union

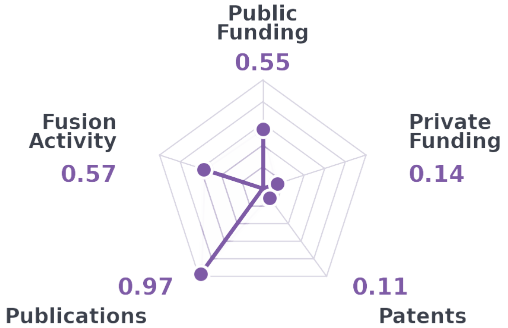
Scientific excellence and depth with ITER as cornerstone

The EU combines a deep scientific research base with its role as host and principal contributor to the ITER International Project, within a comparatively distributed architecture of Member State programmes and EU initiatives. Identified non-ITER public funding of €877 million rises to approximately €2.99 billion when ITER in-kind contributions managed by F4E are included. The EU has the second-largest accumulated publication total and the largest share in the 2006–May 2026 window, with seven institutions in the five-actor top 20. Its active device base is exclusively public and includes major tokamak and stellarator facilities: JET holds magnetic-fusion energy records, Wendelstein 7-X is the world's largest stellarator and WEST holds the tokamak plasma-duration record. The principal challenges are a modest patent footprint, a private-capital base well below the US level and the need to convert a distributed set of national and EU strengths into industrial scale.

PUBLIC FUNDING	PRIVATE FUNDING	ALIVE PATENTS	PUBLICATIONS	ACTIVE DEVICES
€3B	**€340M**	**143**	**48,820**	**8**
incl. ITER via F4E	*14% of US amount*	*6% of five actor total*	*32% of five actor total*	*dual tokamak/stellarator (excluding ITER)*

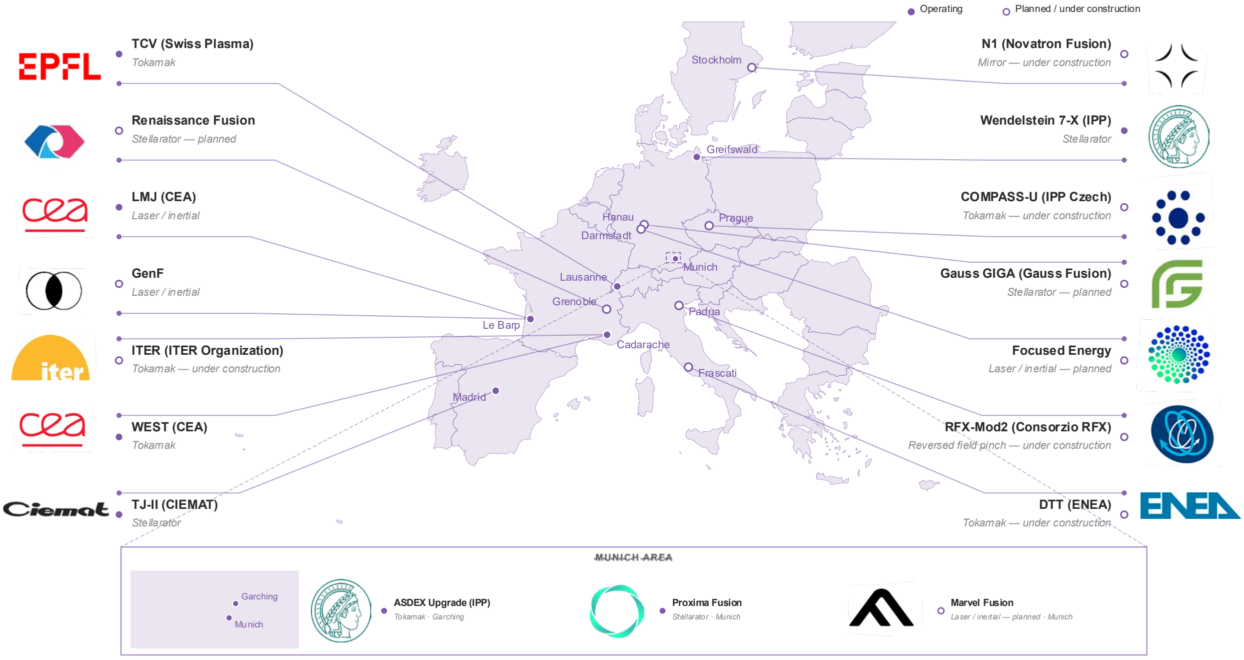
COMPETITIVENESS PROFILE

Normalised 0–1 · group leader = 1.00



FUSION DEVELOPERS & DEVICE SITES

IAEA FFDB · May 2026



01 STRATEGIC POSTURE

The EU combines deep scientific output and host of the ITER International Project with a comparatively distributed architecture of Member State programmes and EU initiatives. Over 2022–2025, national-level public funding of €877 million rises to €3 billion including ITER contributions. Germany's fusion strategy aims to make Germany a global fusion leader—and to host the world's first fusion power plant—by increasing research funding, strengthening industry–science partnerships and developing enabling infrastructure and regulation. An EU fusion strategy is anticipated in the second half of 2026.

02 FUNDING & PRIVATE CAPITAL RAISED

→ Ch.2

EU funding splits across public-to-public (83%, incl. the €2.12 billion ITER contributions and €641 million from EUROfusion), public-to-private (7%) and private (10%). National programmes complement this, notably Germany's €1.7 billion Fusion 2040. Private capital raised during the 2022-2025 period totalled €340 million, a private-capital base equal to approximately 14% of the US total. F4E's ITER procurement has placed €7.2 billion in contracts to supply chain companies and laboratories across EU Member States.

03 DEVICES & PERFORMANCE

→ Ch.3

22 devices in the pipeline, of which 8 are active — an exclusively public active base. Anchors are ASDEX Upgrade, Wendelstein 7-X (world's largest stellarator) and WEST (world tokamak plasma-duration record, 1,337 s, February 2025). DTT (Frascati, under construction) addresses power exhaust for DEMO. Preparations for JT-60SA's next operating phase are under way, with plasma operations targeted by the end of 2026. The mix is tokamaks (50%) with significant stellarator activity (25%).

04 INNOVATION OUTPUT

→ Ch.4-5

48,820 publications (32% of five-actor total) and ~928,000 citations on the full record; the largest publication share in the 2006–2026 window. The Max Planck Institute for Plasma Physics is the second-largest institution in the five-actor dataset; seven EU institutions sit in the five-actor total top 20. Patent output is modest at 143 alive families (6%), led by emerging firms — Proxima (9), Marvel (7), Renaissance (7) and Novatron (6).

05 GOVERNANCE & REGULATION

→ Ch.6

Fusion facilities are licensed by national competent authorities under national radiation-protection, environmental and, where applicable, nuclear legislation, within the Euratom legal baseline. France's regulation of ITER demonstrates how an existing nuclear framework can be adapted to fusion. Germany adopted a Fusion Action Plan in 2025, while Italy presented a draft enabling bill to Parliament. ENSREG is examining where greater European coordination could improve consistency and predictability.

+ STRENGTHS	– CHALLENGES
• Host of ITER project and largest contributor with €7.2 billion supply-chain of EU industry through F4E. • Fusion power records held by JET tokamak (EU-UK) albeit now being decommissioned. • Plasma-duration record (WEST, 1,337 s) and world's largest stellarator (W7-X). • Largest publisher in the 2006–2026 window (34.2%) with high impact	• Structural private-capital gap—the EU total is approximately 14% of the US total over 2022–2025 • Modest patent footprint (6% of five actor total) and low Public-to-Private mobilisation • No single EU licensing procedure; coordination across national frameworks is developing through ENSREG

The EU's strengths lie in scientific depth, ITER delivery, a broad public device portfolio and an established industrial supply chain. The central challenge is to convert these distributed assets into faster private-sector scale-up while improving coordination across Member State and EU initiatives.

Japan

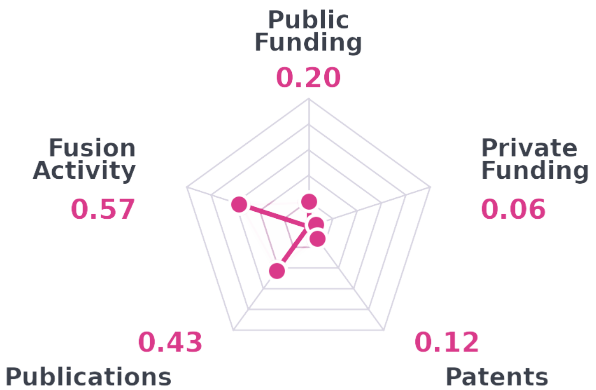
Scientific excellence pivoting to industrial policy

Japan combines a mature scientific and technological base with a clear pivot towards industrial policy. The revised Fusion Energy Innovation Strategy of June 2025 targets demonstration of fusion electricity in the 2030s and places industrialisation at the centre of national policy. QST leads tokamak research and ITER participation at Naka, while NIFS anchors the helical and stellarator programme at Toki; Japan also holds the historical peak magnetic-fusion triple-product record through JT-60U. Private activity is expanding rapidly, with the J-Fusion council growing from 21 to more than 90 members in 18 months and participation from major trading houses. Japan has the most diversified active configuration mix among the five actors and a substantial publication base. Its main constraints are the smallest overall identified funding total of the five actors, a modest international patent portfolio and detailed safety arrangements for future pilot plants that remain under development.

PUBLIC FUNDING	PRIVATE FUNDING	ALIVE PATENTS	PUBLICATIONS	ACTIVE DEVICES
€1.07B	€138M	154	21,389	8
incl. ITER	*3% of five actor total private*	*7% of five actor total*	*14.1% of five actor total*	*most diversified base*

COMPETITIVENESS PROFILE

Normalised 0–1 · group leader = 1.00



FUSION DEVELOPERS & DEVICE SITES

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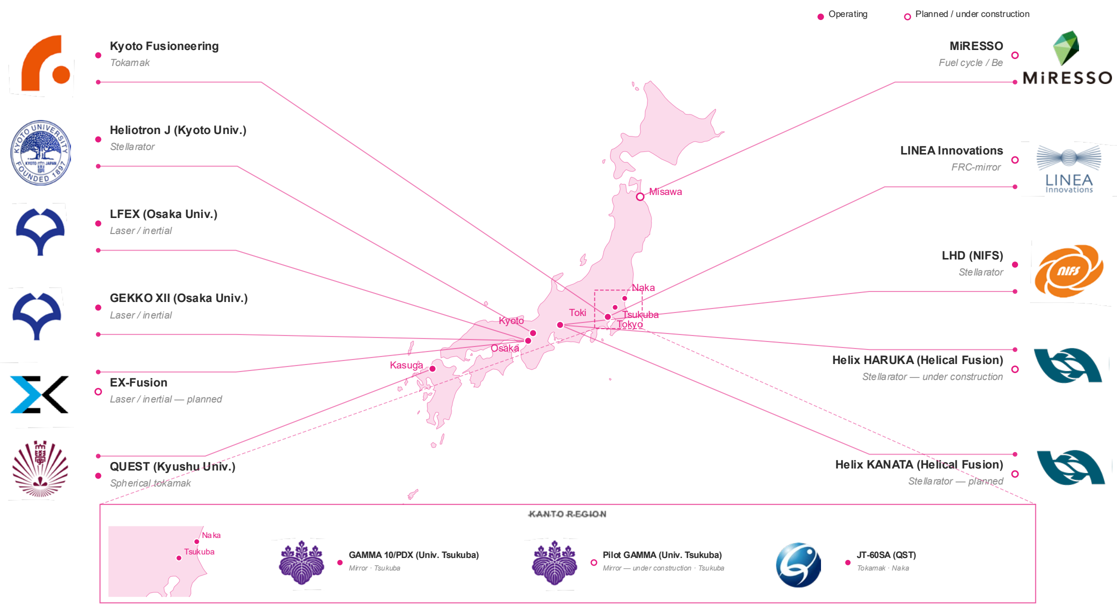


MiRESSO is shown as enabling infrastructure and is excluded from the active-device count.

01 STRATEGIC POSTURE

The revised Fusion Energy Innovation Strategy (June 2025[17]) explicitly targets demonstration of fusion electricity generation in the 2030s and frames fusion as industrial policy. It mandates a roadmap and is operationalised through a Cabinet Office Social Implementation Task Force (September 2025). QST leads ITER participation and tokamak research at Naka; NIFS runs the helical and stellarator programmes at Toki.

02 FUNDING & PRIVATE CAPITAL RAISED → Ch.2

Total identified funding over 2022–2025 is approximately €1.21 billion : €1.07 billion public (€609 million domestic plus €459 million QST ITER in-kind) and €138 million private. Newer instruments — Moonshot Goal 10 and SBIR Phase 3 — seed commercial activity. J-Fusion (est. March 2024) grew from 21 to over 90 members by mid-2025[20]; trading houses (Sumitomo, ITOCHU, Furukawa) extend reach globally.

03 DEVICES & PERFORMANCE → Ch.3

A mature base of 11 devices with 8 active. Principal facilities include the Large Helical Device, whose final experiment took place in December 2025, and JT-60SA, which achieved first plasma in 2023 and is preparing for its next operating phase, with plasma operations targeted by the end of 2026. Japan has the most evenly diversified active base in the dataset; it holds the historical peak triple-product record through JT-60U.

04 INNOVATION OUTPUT → Ch.4-5

154 alive patent families (7%) led by Toshiba (15), Kyoto Fusioneering (10), Kyoto University (7), with distinct strength in optical systems mirroring its laser-fusion heritage. Publications ~21,400 (14.1%) with ~260,000 citations (9.2%). NIFS (2,349) and JAEA (1,273) sit in the five actor total top 20. Japan's share of five-actor publications is lower in the 2006–2026 window than in the full historical record.

05 GOVERNANCE & REGULATION → Ch.6

Japan's 2025 Basic Approach establishes principles for graded and scientifically proportionate regulation and indicates that fusion facilities should not automatically be treated as fission reactors. Existing radiation-source and radiation-generating-equipment rules provide a starting point, while detailed project-level requirements and institutional responsibilities remain under development.

+ STRENGTHS	– CHALLENGES
• Most balanced configuration mix in the dataset (tokamak, stellarator, laser, alternatives) • Strong public-strategic alignment under the 2025 Innovation Strategy • Rapidly expanding private ecosystem (J-Fusion: 21 → 90+ in 18 months) • Deep domestic supply base and global reach via major trading houses	• Smallest overall identified funding total of the five actors • Modest international intellectual property scale • Detailed project-level regulatory requirements and institutional responsibilities remain under development • Lower recent-period publication share than in the full historical record

Japan combines a mature and technologically diverse research base with a strengthening industrial strategy. The main challenge is whether the new policy push and expanding private network can overcome a smaller funding base and translate scientific depth into demonstrator-scale delivery.

United Kingdom

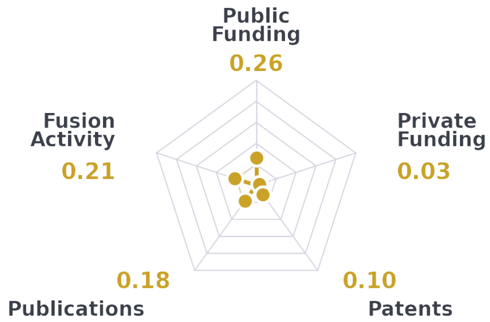
Centralised public programme — clear non-fission regulatory pathway

The UK has the most institutionally centralised programme among the five actors, centred on the UK Atomic Energy Authority and the STEP prototype power-plant programme. Over 2022–2025, around 90% of its €1.49 billion identified total flowed through public-to-public channels. Separately, the 2026 strategy, A New Energy Revolution, commits more than £2.5 billion over the five financial years to 2030. Private capital raised is the smallest of the five actors, at €70 million, but the UK has a comparatively strong specialist patent portfolio: Tokamak Energy holds 85 alive patent families, the largest identified non-Chinese applicant portfolio. Since JET ceased operations, the active device base has been small and strongly tokamak-weighted. The UK's distinctive strengths are institutional focus, STEP and an early, clearly defined regulatory pathway outside the fission-reactor licensing regime.

PUBLIC FUNDING	PRIVATE FUNDING	ALIVE PATENTS	PUBLICATIONS	ACTIVE DEVICES
€1.42B	€70M	140	9,027	3
90% of UK total	*smallest of the five*	*6% of five actor total*	*5.9% of five actor total*	*21% of US leader*

COMPETITIVENESS PROFILE

Normalised 0–1 · group leader = 1.00



FUSION DEVELOPERS & DEVICE SITES

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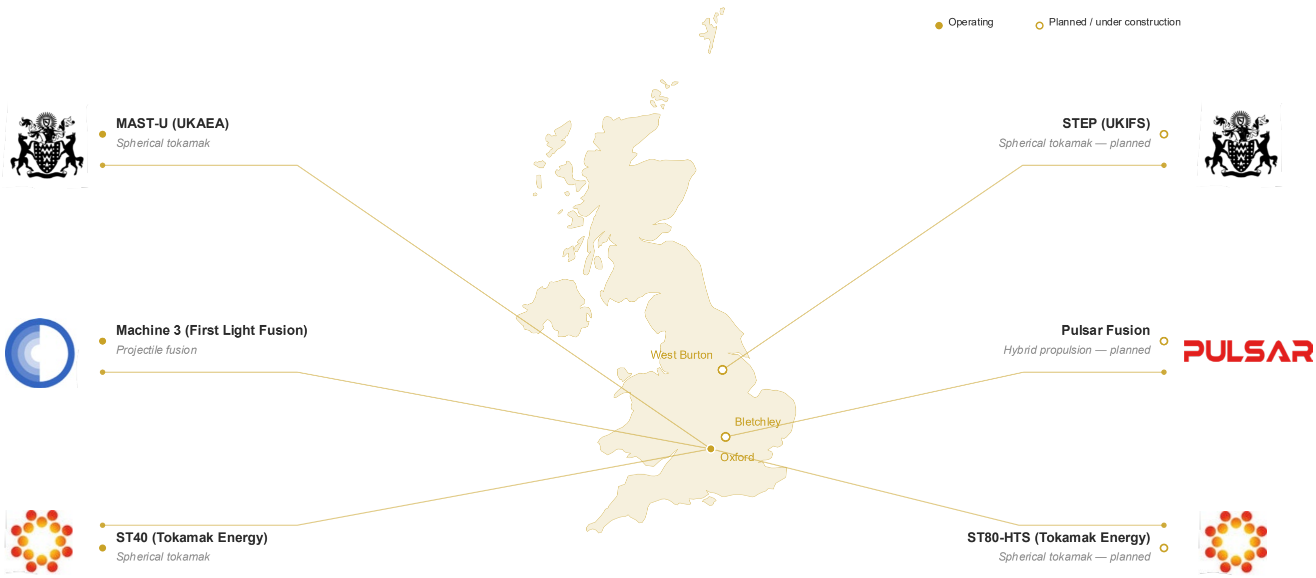


01 STRATEGIC POSTURE

The UK is the most institutionally centralised actor in the dataset: over 2022–2025, 90% of its €1.49 billion total flows through public-to-public channels, almost entirely via the UK Atomic Energy Authority (UKAEA). The 2026 strategy "A New Energy Revolution"[15] commits €2.9 billion over 2025–2030, building on the earlier Fusion Futures Programme.

02 FUNDING & PRIVATE CAPITAL RAISED

→ Ch.2

Identified public funding during the common 2022–2025 comparison window totals approximately €1.42 billion. Separately, the 2026 strategy commits more than £2.5 billion over the five financial years to 2030 for STEP and associated research, infrastructure and skills programmes. Private capital raised stands at €70 million — the lowest among the five actors — concentrated in Tokamak Energy and First Light Fusion.

03 DEVICES & PERFORMANCE

→ Ch.3

Following JET's closure in 2023, the pipeline contains 6 devices with 3 active (2 private, 1 public): Tokamak Energy's ST40 and First Light Fusion's Machine 3 alongside the public MAST Upgrade. The flagship STEP is the principal next-generation priority, with delivery of the prototype plant targeted around 2040. The active mix is heavily tokamak-weighted (67%).

04 INNOVATION OUTPUT

→ Ch.4-5

140 alive patent families (6% of five-actor total), punching above its weight in private-sector IP. Tokamak Energy holds 85 patent families, the largest identified non-Chinese applicant portfolio in the dataset — followed by First Light (14), UKAEA (9). Publications ~9,000 (5.9%) with ~218,000 citations (7.7%). UKAEA is effectively the sole UK institution in the five-actor top 20; per-paper intensity (~24) matches the US.

05 GOVERNANCE & REGULATION

→ Ch.6

The UK was among the first major actors to establish a clear regulatory pathway outside the fission nuclear-site licensing regime. A 2022 decision placed fusion under the Health and Safety Executive and the relevant environmental regulator— not the ONR — and the Energy Act 2023[51] distinguishes fusion facilities from fission. The draft National Policy Statement EN-8 was published in June 2026 and concerns planning and development consent rather than radiological safety licensing.

+ STRENGTHS	– CHALLENGES
• Early and clearly defined non-fission regulatory pathway • Tokamak Energy: largest identified non-Chinese applicant portfolio • Coherent single-mission strategy through UKAEA and STEP • The UK and US both average approximately 24 accumulated citations per publication	• Smallest private capital raised of the five actors (€70M) • Smallest active-device base in the comparison (3 devices, FAI = 0.21) • Limited publication scale

The UK's strengths are institutional focus, a clear regulatory route and strong private-sector patenting. Its constraints are a small active-device base and the lowest private-capital total, making successful delivery of STEP and associated supply-chain growth especially important.

United States

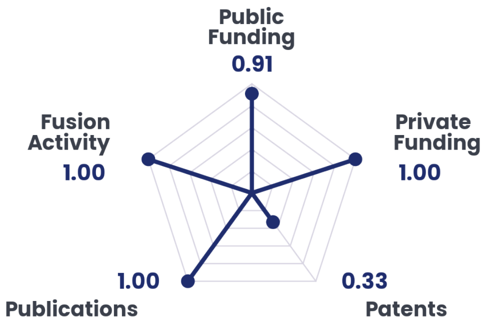
Market-driven commercialisation — private capital leader

The US has the largest and most market-driven fusion ecosystem among the five actors examined. Its 42 start-ups raised €2.41 billion over 2022–2025 — 54% of the private capital identified across the group — while federal policy is guided by the 2022 Bold Decadal Vision, the 2024 Fusion Energy Strategy and the 2025 Build–Innovate–Grow Roadmap. The US also has the broadest device pipeline, with 32 devices in total and 14 active, including the National Ignition Facility, which has achieved record inertial-fusion performance. It retains the largest accumulated publication total and one of the highest accumulated citation averages per publication among the five actors. Public funding remains concentrated in national laboratories and universities, with a comparatively small, targeted public-to-private channel. The US therefore combines scientific depth and private capital with a patent share that is substantial but smaller than its publication and citation weight.

PUBLIC FUNDING	PRIVATE FUNDING	ALIVE PATENTS	PUBLICATIONS	ACTIVE DEVICES
€4,969M	**€2,406M**	**438**	**50,300**	**14**
incl. ITER	*>50% of five actor total private*	*20% of five actor total*	*33.1% of five actor total*	*group leader*

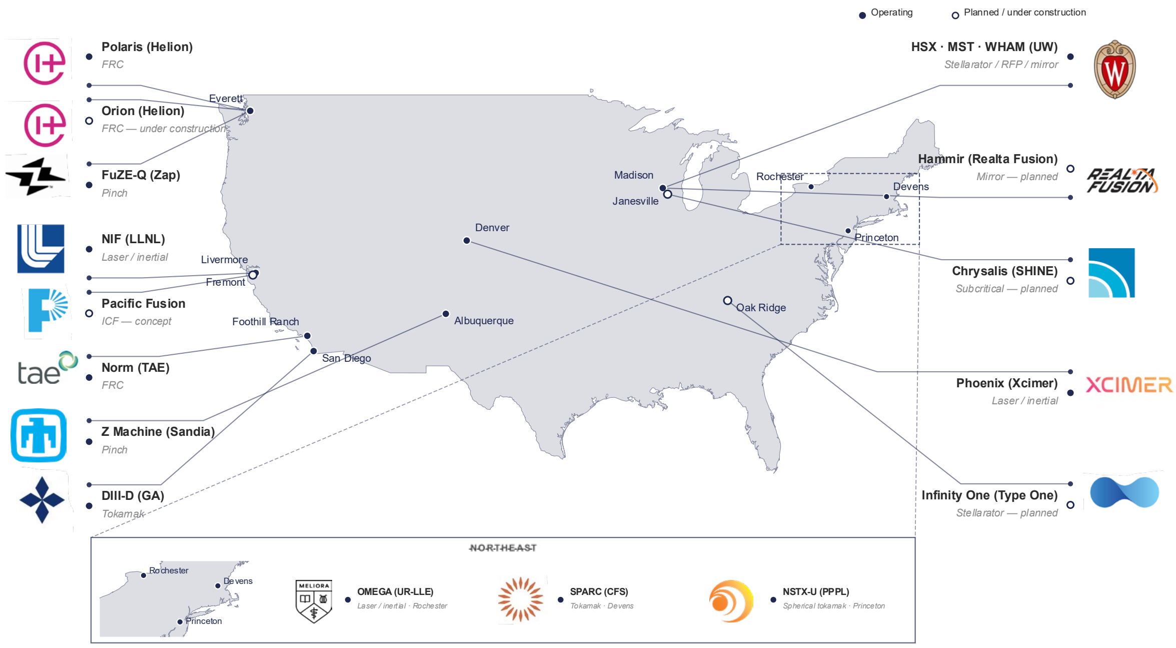
COMPETITIVENESS PROFILE

Normalised 0–1 · group leader = 1.00



FUSION DEVELOPERS & DEVICE SITES

IAEA FFDB · May 2026



01 STRATEGIC POSTURE

The US operates the world's largest private fusion ecosystem — 42 startups attracting €2.41 billion in 2022–2025, more than half of five actor total private capital. Federal posture is set by the 2022 White House Bold Decadal Vision[8], the DOE Fusion Energy Strategy 2024[9] and the 2025 Build-Innovate-Grow Roadmap[10], with public funding directed primarily to national laboratories and universities.

02 FUNDING & PRIVATE CAPITAL RAISED

→ Ch.2

Total commitment of €7.38 billion including ITER is split between public (€4.97 billion, of which €553 million is US ITER in-kind) and private (€2.41 billion) channels. The public-to-private allocation is relatively small (€120 million, ~2%) and intended to catalyse private-sector development. Early customer interest is reflected in conditional power-purchase and offtake agreements via PPAs: Microsoft has committed to 50 MW from Helion by 2028, Google has committed to 200 MW from Commonwealth Fusion Systems (CFS) by the early 2030s.

03 DEVICES & PERFORMANCE

→ Ch.3

Largest device pipeline among the five actors — 32 devices (11 operating, 3 UC, 18 planned); 14 active the largest active base of any actor. Alternative-concept devices account for half the active base. Public anchors are DIII-D and NSTX-U; flagship private machine is SPARC, for which CFS is targeting operation in 2027. US performance strengths span inertial fusion through NIF and magnetic-confinement research through facilities including DIII-D and the former TFTR.

04 INNOVATION OUTPUT

→ Ch.4-5

438 alive patent families (20% of the five-actor total) — second to China but stronger on citations and international filing; Leading applicants include CFS (41), Shine Technologies (39), MIT (36) and TAE Technologies (34). Scientific output is unrivalled: ~50,300 publications (33.1%) and ~1.19M citations (42.1%). Six US institutions appear in the five-actor top 20.

05 GOVERNANCE & REGULATION

→ Ch.6

In April 2023 the NRC voted to regulate fusion under the byproduct-material framework (10 CFR Part 30), distinct from the reactor framework. The ADVANCE Act of 2024[53] codified this and defined "fusion machine". The NRC's proposed Regulatory Framework for Fusion Machines[54] was published 26 February 2026, with the final rule targeted—not guaranteed—for October 2026.

+ STRENGTHS	– CHALLENGES
• Largest identified private-capital pool among the five actors; leading PPA momentum • Largest accumulated publication and citation record (~42% of five actor total) • Broadest device pipeline; SPARC paves the way for ARC and other concepts • Advanced, codified regulatory pathway via the ADVANCE Act	• Low Public-to-Private allocation (~2%) limits direct industrial-policy levers • Patent share (20%) modest relative to scientific output • Only 38% of devices currently operating; many remain pre-construction • Patent leadership concentrated in private firms rather than national labs

The US leads the five-actor comparison in total identified funding, private capital, active devices and accumulated citations. Its central challenge is converting a deep but fragmented pipeline—much of it still planned—into operating systems and durable industrial capability.

02

Fusion Funding Landscape

Between 2022 and 2025, the five actors examined mobilised or formally committed an estimated €20.35 billion in identified fusion funding, comprising domestic public funding, ITER in-kind contributions and private capital raised by fusion companies. A further €1.40 billion in ITER cash contributions is reported separately. Including these cash contributions would bring the source-based total to approximately €21.75 billion.

These figures should be interpreted as estimates of funding mobilised rather than as directly comparable cash funding. The underlying data combine public budgets and programme commitments, procurement expenditure, corporate capitalisation and private fundraising. The coverage and accounting basis also vary between actors, particularly where detailed public information is limited. The comparison therefore indicates the scale and structure of fusion financing, but not the efficiency, technological maturity or output of the programmes concerned.

As shown in Figure 2.1, the US accounts for the largest share of the €20.35 billion headline total, with €7.38 billion, followed closely by China with €6.94 billion. The EU accounts for €3.34 billion, the UK for €1.49 billion and Japan for €1.21 billion. Public funding represents approximately €15.90 billion—or 78%—of the total, while private capital raised represents approximately €4.45 billion, or 22%.

The similar headline totals for the US and China conceal markedly different funding architectures. The US total includes €2.41 billion in private capital raised, representing 54% of private capital raised across the five actors, while China has the largest estimated public funding total at approximately €5.45 billion. The EU, UK and Japanese totals are smaller, although the EU figure is strongly influenced by its contribution to ITER.

The US combines a large public research base with the deepest pool of independently raised private capital. China relies more heavily on state-backed corporate capital and commercialisation vehicles. The EU's profile is dominated by its contribution to ITER, while the UK and Japan remain principally dependent on nationally directed public programmes. These differences affect how financial risk, industrial capability and potential future ownership are distributed across the five fusion ecosystems.

To support the cross-actor comparison presented in pages 6-16, these funding totals are summarised in two normalised indicators: a Public Funding Index and a Private Funding Index. Each is constructed as the simple ratio of an actor's funding to that of the leading actor on that measure. Both indices inherit the limitations of the underlying figures: they weight each euro equally regardless of leverage or efficiency, they rest on best-available estimates of varying coverage — and, for China, on a midpoint between conservative and maximal scenarios — and they capture only the 2022–2025 window.

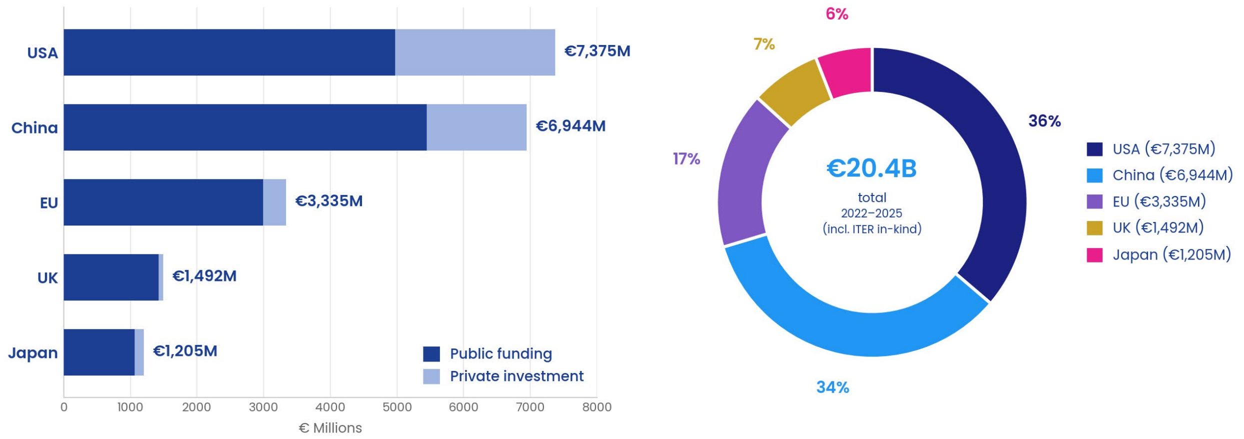


Figure 2.1 — Identified fusion funding by actor, 2022–2025. Left: public funding, including ITER in-kind contributions, and private capital raised. Right: each actor's share of the five-actor total.

Actor Level Funding Structures

Over the 2022–2025 period, total reported fusion funding varied substantially in both scale and composition across the five actors examined. Figure 2.2 disaggregates identified funding by channel and reveals substantial differences in funding architecture. The US combines the largest public-to-public research base with the largest independently raised private-capital component. China has the largest estimated public total, much of it classified as public support to state-backed commercial entities. The EU profile is dominated by ITER in-kind procurement, which accounts for close to two-thirds of its identified total. The UK and Japan remain predominantly publicly financed through national institutions. ITER cash contributions are shown separately and are led by the EU, further underlining the importance of ITER within the European funding profile.

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How to Read the Funding Figures

The figures in this chapter measure funding identified as mobilised or formally committed during 2022–2025. They do not represent expenditure compiled on a single accounting basis.

Public funding comprises financing provided by governments, public agencies and other state-controlled bodies. To show how this funding is directed, the chapter distinguishes three channels:

- **Public-to-public funding:** funding directed to public research organisations, universities, national laboratories and government agencies.
- **Public-to-private funding:** public grants, contracts, milestone payments, directed to commercial entities. This is a component of total public funding, not an additional source of finance.
- **ITER in-kind contributions:** public funding used by ITER Domestic Agencies to procure components and systems for ITER usually in their territories and hence attributed to the parties.

Private capital raised refers to inward financing secured by fusion companies from private investors based on disclosed funding rounds, announcements, and the sources described in the methodology annex.

ITER Cash Contributions are public funding but are reported separately as they are transferred directly to the ITER Organization to finance its centrally managed activities.

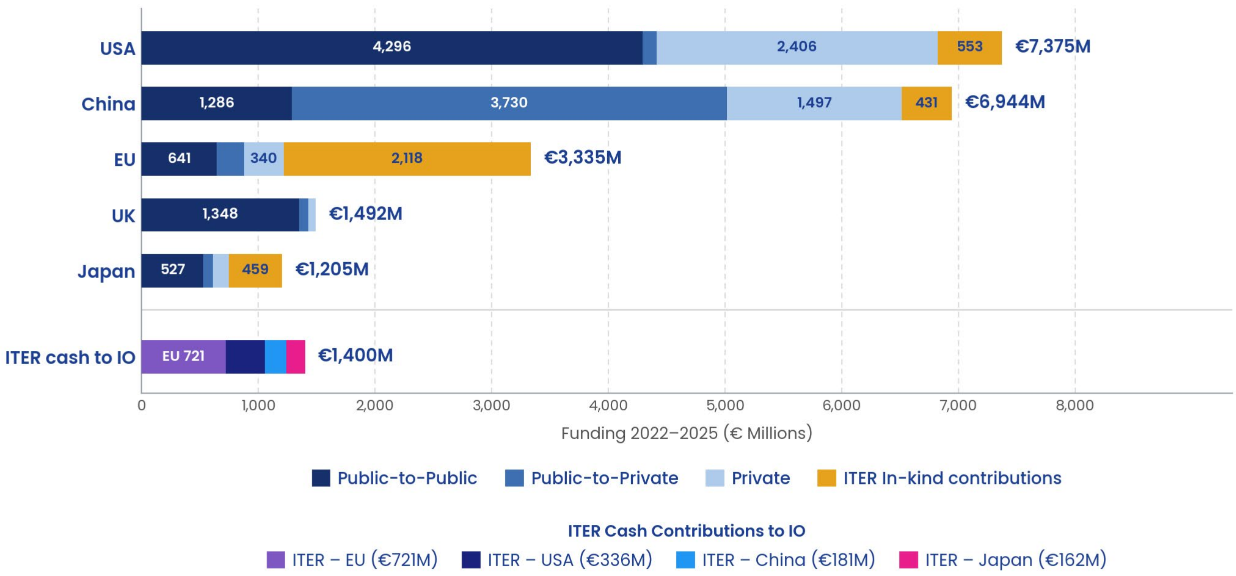


Figure 2.2 — Identified fusion funding by actor and channel, 2022–2025: domestic public research and institutions, public support to commercial entities, private capital raised and ITER in-kind contributions. ITER cash contributions to the ITER Organization are shown separately below the principal bars.

ITER-related public funding takes two principal forms, with different accounting and economic footprints. In-kind contributions consist of components, systems and services procured by each member's Domestic Agency from research organisations and industry usually in their territories. For the actors considered here, these responsibilities are managed by F4E for the EU, US ITER for the US, ITER China for China and QST for Japan[i]. Identified in-kind contributions over 2022–2025 amount to approximately €2.12 billion for the EU, €0.55 billion for the US, €0.46 billion for Japan and €0.43 billion for China.

Cash contributions are transferred directly to the ITER Organization to finance its centrally managed activities. Although some of this funding subsequently returns to companies and organisations in ITER member territories through contracts, its geographical distribution cannot be reliably reconstructed from publicly available information. ITER cash is therefore reported separately from the €20.35 billion headline total.

Actor Profiles

China

China has the largest estimated public fusion-funding total among the five actors and makes extensive use of state-backed commercialisation vehicles. Public funding is estimated at approximately €5.45 billion over 2022–2025, comprising around €5.02 billion in identified national funding and €0.43 billion in ITER in-kind contributions.

Approximately €3.73 billion—68% of the identified Chinese public total including ITER in-kind contributions, or approximately 74% of identified national public funding excluding ITER—is classified as public support to commercial entities, a share unmatched by any

[i] *Other ITER members are India, Republic of Korea and Russia, each with their own Domestic Agencies but not considered for the purpose of this study*

other actor. This funding flows principally to state-controlled commercial entities rather than to laboratories, reflecting a deliberate strategy to capitalise commercial vehicles for fusion industrialisation.

Two state-backed commercial vehicles account for most of this estimate: China Fusion Energy Co.[1], established in July 2025 as a CNNC subsidiary and NEO Fusion[2] backed by central state and Anhui provincial capital, each of which has been reported as having registered capital of approximately €1.9 billion. Registered capital does not necessarily represent capital paid in or funding deployed during 2022–2025. These amounts are therefore best interpreted as evidence of the intended scale of state-backed corporate capitalisation rather than directly comparable public funding. Public-to-public spending of €1.72 billion (including the CN-DA ITER stream) finances the institutes ASIPP and SWIP and the broader university and national-laboratory system. Private capital raised by China-based fusion companies of €1.5 billion — raised mainly by Energy Singularity, ENN and Startorus Fusion — completes the picture.

This is anchored in successive Five-Year Plans, with fusion a *strategic frontier technology* under the 14th Five-Year Plan (2021–2025)[3] and raised to "Future Industry" in the 15th (2026–2030)[4]. Implementation follows a long-term "three-step" nuclear roadmap of thermal fission, fast reactors, then fusion[5] with sequential engineering milestones: scientific breakeven through BEST by approximately 2030[6], operation of the China Fusion Engineering Demonstration Reactor (CFEDR) from the 2030s, and commercial plant operation by 2050[7].

European Union

The EU occupies a distinctive position whose comparative funding weight depends heavily on the treatment of ITER. Identified non-ITER public funding amounts to approximately €877 million over 2022–2025. Adding €2.12 billion in ITER in-kind procurement managed by F4E brings the identified EU public total to approximately €2.99 billion.

Public-to-public funding, including ITER in-kind contributions managed by F4E, accounts for around €2.76 billion, while public support to commercial entities amounts to approximately €236 million. EU-based fusion companies raised approximately €340 million in private capital during the period.

The identified non-ITER total includes €641 million of European Commission support to EUROfusion[8] and approximately €236 million in public-to-private support. It does not comprehensively capture all funding by Member States, whose programmes are financed through numerous institutions and budget lines. The EU total may therefore be more incomplete than the figures for actors with more centralised funding systems.

Looking beyond the comparison period of 2022-2025, Germany has announced a substantial national Fusion 2040 programme[9] and an ambition to host a future fusion power plant[10]. These future commitments demonstrate increasing national activity. France, Spain and Italy have also announced intentions to publish national strategies for fusion. EU-level coordination of fusion activities is distributed across Member State programmes, F4E, EUROfusion, the Fusion Expert Group (FEG) and more recently GO4FUSION and FUSIONNOW initiatives.

The strategic implication is twofold. First, among the five actors examined, the EU has the third-largest identified public total, behind China and the US, but is the largest contributor to ITER and the principal financier of the European in-kind contribution. Second, on a cumulative basis through September 2025, EU-based fusion companies had raised approximately €712 million—roughly 5% of global private fusion funding and around one-tenth of the corresponding US total[11]. This exposes a 'venture gap' reminiscent of other high-technology sectors where EU companies struggle to scale and to leverage public-sector R&D investments into commercial entities.

Proxima Fusion has proposed Alpha as a major public–private initiative. Proxima intends to finance approximately 20% of Alpha's estimated €2 billion cost privately, while Bavaria has indicated potential support of up to €400 million. The remaining financing—including prospective federal support—has yet to be secured[12]. The project illustrates growing European ambition but also the dependence of large-scale private demonstrators on public co-financing.

Japan

Japan combines a publicly anchored funding architecture with a growing private sector. Public funding amounts to €1.07 billion over 2022–2025 (€609 million national plus €459 million in ITER in-kind procurement). Public-to-public funding, including the separately identified ITER-related stream, amounts to approximately €986 million, or 92% of public funding, and is channelled principally through two organisations: the National Institutes for Quantum Science and Technology (QST), for ITER and Broader Approach participation alongside tokamak research, and the National Institute for Fusion Science (NIFS), which focuses on helical and stellarator systems. Public-to-private flows are modest at €81 million but rising, while Japan-based fusion companies raised approximately €138 million in private capital during the period.

Policy responsibility is distributed: the Cabinet Office sets overall direction, with science and industrial mandates shared between the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of Economy, Trade and Industry (METI), and operational delivery through the Japan Science and Technology Agency (JST) and NEDO. Strategic posture is defined in the *Fusion Energy Innovation Strategy* (2023, revised June 2025)[13], which puts fusion power at its core and targets "*demonstration of electricity generation with fusion energy in the 2030s*". Fusion is also embedded at the level of national science ambition through *Moonshot Goal 10* — JST's dedicated fusion track within the flagship 2050 programme, with an envelope of ~¥20 billion (~€120 million)[14] — complemented by MEXT's SBIR Phase 3 milestone-based grants[15].

United Kingdom

The UK has the highest public share of identified funding among the five actors. Total identified funding of approximately €1.49 billion over 2022–2025 comprises €1.42 billion in public funding and approximately €70 million in private capital raised. Public-to-public funding accounts for around €1.35 billion, while public support to commercial entities amounts to approximately €74 million. The UK is not included in the ITER contribution figures following its departure from Euratom.

Public funding is concentrated in the UK Atomic Energy Authority (UKAEA), which is the lead R&D agency and the sponsor of the flagship STEP prototype power plant. Fusion has been designated a strategic national priority, with the UK government committing €2.9 billion (£2.5 billion) for 2025/6–2029/30 with its 2026 strategy, "*A New Energy Revolution: The UK's Plan for Delivering Fusion Energy*"[16], including €1.5 billion (£1.3 billion) for STEP (major construction activity expected around the beginning of the 2030s) and investments in R&D infrastructure, fuel-cycle, AI supercomputing and skills. These commitments build on the earlier

Fusion Futures Programme (up to €747 million over 2023–2027)[17], which sought to strengthen domestic capabilities, expand industrial capacity, and cultivate the specialist workforce required for commercialisation. The UK's posture is therefore one of publicly directed industrialisation around a single national project, with private capital playing a lesser role and international collaboration through bilateral arrangements.

United States

The US has the largest identified fusion-funding total among the five actors and the deepest private-capital base. Public funding is estimated at €4.97 billion over 2022–2025, comprising approximately €4.42 billion in national funding and €0.55 billion in US ITER in-kind procurement. Of this public total, €4.85 billion is classified as public-to-public funding, including ITER in-kind contributions, and €120 million as public-to-private support.

Federal fusion activity is coordinated through the Department of Energy's Office of Fusion, while the Office of Science's Fusion Energy Sciences programme continues to oversee foundational science, enabling technologies and facilities — an arrangement underpinned by the 2022 'Bold Decadal Vision for Commercial Fusion Energy'[18], the DOE's Fusion Energy Strategy 2024[19] and the 2025 Fusion Science & Technology Roadmap: Build-Innovate-Grow[20].

The defining feature of the US model is what sits outside the public envelope: a private sector that raised €2.41 billion over 2022–2025 — 54% of all private capital across the five actors, and the largest single concentration of private capital-backed fusion activity in the world. The identified public-to-private channel (2%, €120 million) is small relative to the US private-capital base. Programmes such as the Milestone-Based Fusion Development Program, INFUSE and the FIRE Collaboratives are intended to reduce technical risk and provide private developers with access to public research capability. Published programme envelopes may extend beyond 2025 or remain subject to future appropriations and are therefore not directly comparable with expenditure identified within the four-year period.

Early power-purchase and offtake agreements—including agreements involving Microsoft (50 MW from Helion by 2028) and Google (200 MW from Commonwealth Fusion Systems) — provide evidence of potential customer demand and may support future project financing. However, they remain conditional on facilities and technologies that have not yet delivered commercial fusion electricity and should not be interpreted as evidence of established market pricing or commercial readiness.

Broader Supply Chain Footprint

Beyond research grants and corporate investment, a substantial share of fusion funding is delivered through procurement from industrial and research supply chains. The following examples use cumulative periods that differ from the main 2022–2025 comparison and are therefore presented as indicators of industrial reach rather than directly comparable funding totals.

Since its establishment in 2007, F4E has invested more than €7 billion through over 1,400 contracts supporting Europe's contribution to ITER and other international projects. These activities have involved at least 2,700 companies and 75 research and development organisations, building capability in fields including superconducting magnets, vacuum systems, nuclear buildings, fuel-cycle technologies and remote handling. This has built industrial capability while catalysing spillovers into adjacent sectors, driving innovation and creating jobs[21].

In the US, ITER in-kind contributions directed €1.6 billion ($1.7 billion)[22] into the domestic supply chain since 2007. This has mobilised more than 800 companies in 46 states, laboratories and universities, engaged in the manufacture of twelve ITER systems – including the central solenoid, superconducting cable and diagnostic systems. Comparable public information on the domestic supply-chain effect of ITER in China and Japan is more limited. Their reported in-kind contributions provide an indication of scale but should not be treated as a direct measure of contracts awarded to domestic companies.

As a more recent example beyond the 2022–2025 comparison period, the UK's STEP (Spherical Tokamak for Energy Production) programme is intended to anchor a domestic UK fusion supply chain. Backed by a €2.9B (£2.5B) government commitment over 2025–2030 — of which €1.5B (£1.3B) goes to STEP — UK Industrial Fusion Solutions has appointed the ILIOS consortium as construction partner under an initial €230M (£200M) contract[23] and as of January 2026, STEP had engaged 813 suppliers — approximately 84% of them UK-based — through 401 contracts, generating cumulative industry spend of €126M (£108.8M), of which €106M (£91.8M) was retained inside the UK economy. The programme is explicitly designed to catalyse a UK-based fusion industrial ecosystem.

Beyond ITER and publicly funded supply chains, private fusion companies are mobilising a rapidly growing supply chain. According to the Fusion Industry Association's (FIA) annual Supply Chain reports[24], its members who responded reported approximately $250 million in private-developer supply-chain investment in 2023, $434 million in 2024 and $538 million in 2025—a cumulative total of approximately $1.22 billion. Reported investment increased by 24% in 2025. Around half of the world's private fusion companies provided data, so the figures should be interpreted as reported minimums rather than as a complete total.

FIA does not publish a reliable geographical breakdown of this funding. Given the greater average capitalisation of US fusion companies, US-based developers may account for a substantial share, but the available data do not support a precise actor-level allocation or establish where the supplier funding occurs.

Conclusions

The five actors examined have mobilised substantial resources for fusion, but the headline totals conceal fundamentally different funding architectures. The US combines a large public research base with the deepest pool of independently raised private capital. China has mobilised a comparable overall amount through a more state-directed model, including substantial capitalisation of commercial entities. The EU's profile is strongly shaped by its contribution to ITER, while the UK and Japan remain predominantly dependent on nationally directed public programmes.

Public finance continues to underpin the sector, accounting for approximately 78% of identified funding. However, the boundary between public and private financing is becoming less distinct as governments increasingly use milestone programmes, co-investment, corporate capitalisation and public–private demonstrators to accelerate commercialisation. The different models distribute technological risk, financial exposure and potential future ownership in different ways; it is therefore too early to determine which architecture will prove most effective.

The funding totals should also be interpreted cautiously. They combine public budgets and commitments, procurement funding, corporate capitalisation and private capital raised, and the completeness of the underlying information varies between actors. They indicate the approximate scale and structure of financing, but do not provide a direct measure of expenditure, programme efficiency, technological maturity or the likelihood of commercial success.

The next phase will be defined less by the announcement of additional funding than by its conversion into operating facilities, validated technical milestones and durable industrial capacity. Growing supply-chain investment and early customer agreements provide evidence of commercial interest, but the decisive test will be whether public and private funding can deliver mature and integrated fusion technologies, credible project schedules and eventually a pathway towards economically viable fusion energy.

Key Takeaways
The Fusion Funding Landscape

- **Five actors mobilised over €20 billion between 2022 and 2025.** Identified fusion public funding, ITER in-kind contributions and private capital raised total approximately €20.35 billion (a further €1.40 billion in ITER cash contributions is reported separately).
- **Public finance remains the foundation of fusion development.** Public funding accounts for approximately €15.9 billion, or 78% of the total, compared with €4.45 billion in private capital raised. Governments therefore continue to carry most of the financial and technological risk.
- **The US and China lead in scale, but through different funding models.** The US has the largest total at €7.38 billion and largest private-capital base of €2.41 billion raised by fusion companies. China has the largest public total at €5.45 billion, with a substantial share through state-backed commercial entities.
- **The EU's funding profile is dominated by ITER.** ITER in-kind procurement managed by F4E amounts to €2.12 billion—close to two-thirds of the EU's identified funding total. This gives the EU a central role in international fusion infrastructure, while its private-capital base is smaller than the US.
- **The UK and Japan remain predominantly publicly financed**. Both actors rely mainly on nationally directed research institutions and strategic public programmes, although each is seeking to strengthen commercial participation, industrial capability and private capital raised.
- **Attention is shifting from raising capital to delivering capability.** Increasing public–private programmes, customer agreements and supply-chain investment indicate growing commercial interest. The next test will be whether announced funding is converted into completed facilities, validated technical milestones and durable industrial capacity.

€20.35B	78%	€7.38B	€4.45B	€5.45B
identified fusion funding across the five actors, 2022–2025	*of identified funding was public finance*	*US funding, the largest actor total*	*private capital raised by fusion companies*	*China's estimated public funding – the largest public total*

03

Fusion Devices: Capabilities, Performance, and the Next Generation

Fusion devices provide one of the clearest — although incomplete — indicators of an actor's fusion capability. This chapter compares the fusion-device landscapes of China, the EU, Japan, the UK and the US from three complementary perspectives: the number and diversity of devices currently active or in development; the experimental performance achieved by past and present facilities; and the objectives and schedules of the next generation of experiments, demonstrators and proposed pilot plants.

The comparison reveals important differences in both the scale and structure of the five fusion ecosystems. The US has the largest overall and active device base, but much of its pipeline consists of privately led projects that remain at the planning stage. Active capability is more evenly distributed, while the balance between public and private activity varies considerably: the EU's active devices are currently public-sector facilities, whereas the US, China and the UK have a more substantial private-sector presence. The actors also differ in their technological emphasis, ranging from predominantly tokamak-based programmes to more diversified portfolios of stellarators, inertial-fusion systems and alternative concepts.

Experimental results reveal a second distinction. The highest fusion-performance results and the longest-duration plasma discharges have generally been achieved in different machines and operating regimes. High triple-product or fusion-gain results have so far been obtained over comparatively short periods, while long-duration magnetic-confinement experiments have operated at lower plasma performance. Because energy-confinement time, discharge duration and the definitions of fusion gain differ between magnetic and inertial approaches, comparisons must be seen as complementary indicators rather than as a ranking.

The next generation of devices addresses different parts of this challenge. ITER is designed to demonstrate a burning plasma at high fusion gain for hundreds of seconds, while SPARC (US) and BEST (China) target high fusion gain in more compact, shorter-pulse machines and JT-60SA will explore long-duration, high-performance non-tritium plasmas. Alongside these public and private flagships, a wider pipeline of proposed pilot plants reflects considerable ambition but also substantial uncertainty in schedules and technical readiness.

Fusion Activity

An indication of fusion activity can be obtained by counting fusion devices that are operating, under construction or being upgraded. This measure is imperfect — it does not capture device size or performance but indicates the breadth of fusion ecosystems. For this analysis, a fusion "device" is an experimental facility, demonstrator or pilot plant designed to create and study fusion-relevant plasmas or fusion reactions. Test facilities devoted exclusively to individual fusion technologies—such as materials irradiation, magnets, tritium handling or component qualification—are currently excluded although they remain very important.

The analysis here uses an extract of the IAEA Fusion Facility Database (FFDB)[25], with each entry independently verified against device-developer communications and peer-reviewed literature as of May 2026. ITER is considered separately since it is an international project funded and governed by multiple parties; it is shown separately where relevant. The analysis is limited to the five selected actors and therefore excludes important facilities elsewhere, including KSTAR in the Republic of Korea. The classification distinguishes three status categories: operating (a device that has produced fusion-relevant plasma and is currently in or between research campaigns); under construction or upgrade (whose physical components are being assembled or upgraded); and planned (announced but for which physical construction has not yet begun).

The total device pipeline differs significantly across the actors. Figure 3.1 shows that the US has the largest and most diverse pipeline at 32 devices, albeit many planned facilities (18 of 32), reflecting the depth of its private-sector commercial pilot-projects. The EU has the next-largest pipeline at 22, including 14 planned devices, most of which are private-sector laser-fusion and stellarator startups. China, Japan and the UK have smaller and more concentrated pipelines (12, 11 and 6 devices respectively), with relatively few planned facilities.

Not all planned devices will proceed to construction; the rest of this section focuses on "active devices" — those operating and under construction or upgrade — as a more reliable measure of fusion capability. Figure 3.2 shows the differences between actors. The US has 14 active devices: 11 currently operating (CO) (7 public, 4 private) and 3 under construction (UC) or upgrade (1 public, 2 private). China has 9, with a notably balanced public–private profile (4 OP-public, 3 CO-private, 1 UC-public, 1 UC-private). The EU has 8 active devices, all public — the only actor whose active base is exclusively public-sector. Japan also has 8 active devices, of which 7 are public. The UK has 3 active devices with 2 of the 3 being private.

Different Approaches to Fusion[ii]

Magnetic Confinement Fusion (MCF): Uses magnetic fields to confine a hot plasma for long enough for fusion to occur. The best-known configurations are tokamaks and stellarators. Other MCF concepts include magnetic mirrors, field-reversed configurations, reversed-field pinches and spheromaks which differ in their magnetic geometry.

Inertial Confinement Fusion (ICF): Uses lasers, particle beams or pulsed electrical power to compress and heat a small fuel target to fusion conditions using its own inertia for an extremely short period. An energy-producing system would need to repeat the process at high frequency. ICF includes laser-driven, ion-beam-driven and pulsed-power-driven target-compression approaches.

Alternative Approaches: Covers concepts that do not fit wholly within conventional MCF or ICF, or that combine elements of both. These include magneto-inertial or magnetised-target fusion, in which a magnetised plasma is rapidly compressed by a liner, projectile or other driver, as well as inertial-electrostatic confinement, beam–target fusion and other emerging concepts.

[ii] *For consistency with the IAEA Fusion Facility Database, Figure 3.3 follows the database's configuration families. Some magnetically confined configurations described above—including field-reversed configurations, mirrors, reversed-field pinches and spheromaks—are therefore displayed under "alternative concepts"*

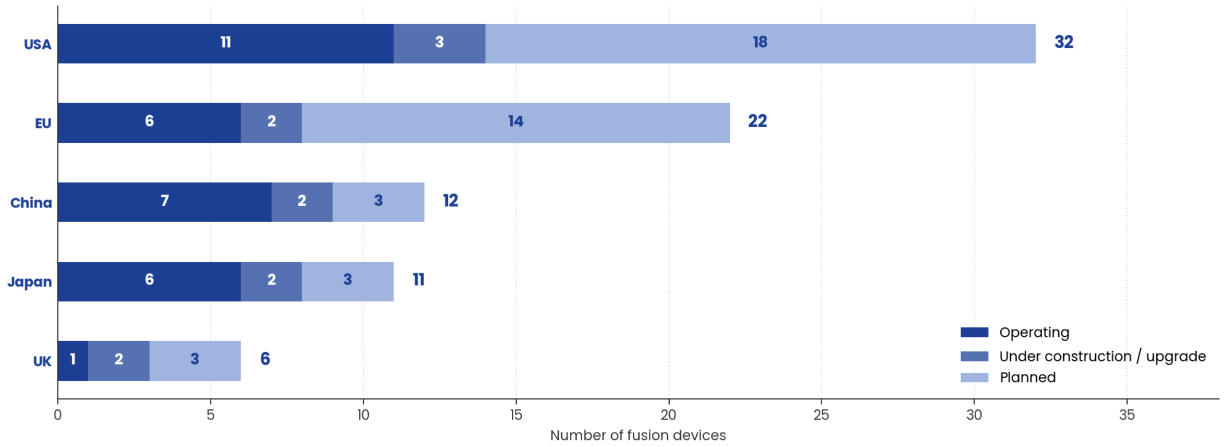


Figure 3.1 — Total fusion device pipeline split between operating, under construction / upgrade, and planned devices

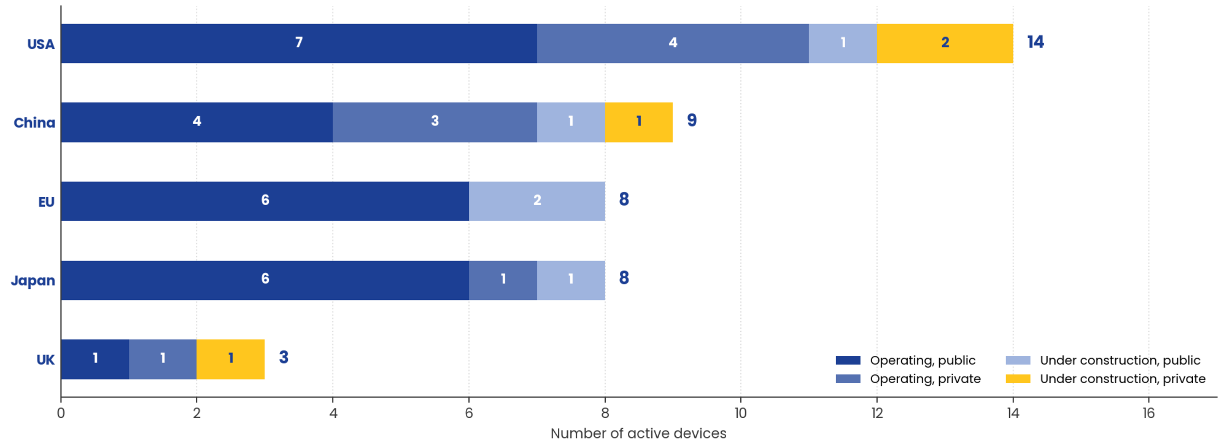


Figure 3.2 — Number of active fusion devices by actor, cross-tabulated by status (operating or under construction) and by ownership (public or private)

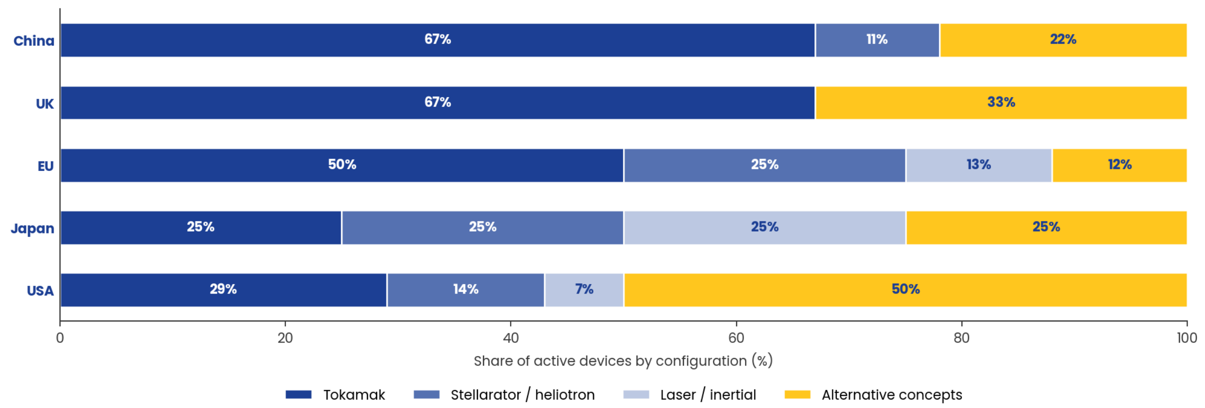


Figure 3.3 — Relative composition of active fusion devices by configuration family across actors with percentage split between MCF (tokamaks, stellarators / heliotrons), ICF (laser / inertial devices) and alternative concepts

Considering the different approaches to fusion in Figure 3.3, China and the UK are heavily tokamak-weighted (67% of active devices in each case). The EU combines tokamaks (50%) with significant stellarator activity (W7-X and TJ-II). Japan is the most evenly diversified actor, with active devices split roughly equally between tokamaks, stellarators / heliotrons, laser / inertial and alternative-concept families.

The US stands out for its concentration of alternative-concept devices, which account for half of its active base — driven by the private-sector pipeline of field-reversed-configuration and pulsed-power machines. To support the cross-actor comparison presented in the conclusions of this report, the active-device count is summarised in a simple normalised indicator: the Fusion Activity Index (FAI). The FAI is constructed as the simple ratio of each actor's active-device count to that of the leading actor. The US, with 14 active devices, defines the upper anchor at FAI = 1. On this basis, China scores 0.64, the EU and Japan tie at 0.57 and the UK at 0.21.

The FAI should be read alongside three caveats. First, it counts devices equally regardless of scale: a national flagship tokamak weighs the same as a private demonstrator. Second, it does not credit programmes for not-yet-built facilities; under this definition STEP in the UK, Proxima Alpha in Germany, ARC, Da Vinci and Infinity One/Two in the US are all excluded despite substantial funding commitments. Third, the Index reflects the state of the fusion landscape at the data cut-off (May 2026); both the device population and the public/private balance are evolving rapidly.

Fusion Performance

Fusion performance describes both how closely an experiment approaches the physical conditions required for useful fusion energy and how long—or how repeatedly—those conditions can be maintained. No single measure captures all aspects of performance. This chapter therefore considers three complementary indicators: the fusion triple product, the fusion gain factor (Q), and the duration of the high-performance phase. The distinctions between these measures are explained in the box below.

For comparisons across the international device landscape, this chapter uses the triple product as its principal measure of plasma performance. Unlike Q, it can be estimated for a broad range of experiments, including those that do not use deuterium–tritium fuel or produce substantial fusion energy. Only a small number of facilities—notably JET, TFTR and NIF—have produced significant D–T fusion yields, and the definition of gain used for inertial-confinement experiments such as NIF differs from the plasma gain (Q) used for magnetic-confinement devices. Gain values therefore cannot always be compared directly across fusion approaches.

The triple product must nevertheless be considered alongside duration. A future fusion power system must be able to maintain or reproduce high-performance conditions reliably. Magnetic-confinement devices generally aim to sustain the plasma for progressively longer periods, whereas inertial-confinement and other pulsed approaches produce extremely short fusion events that would need to be repeated at high frequency. The following analysis therefore examines plasma performance and duration as separate but complementary dimensions.

Measuring Fusion Performance

Fusion performance cannot be captured by a single measure. Three indicators are important: the fusion triple product, the fusion gain factor (Q) and the duration for which high-performance conditions can be maintained.

Fusion Triple Product ($nT\tau_E$): This combines plasma density (n), temperature (T) and energy-confinement time (τ_E), which indicates how effectively the plasma retains its heat. A higher triple product generally means that a plasma is closer to the conditions needed for substantial self-heating and fusion-energy production. Energy-confinement time should not be confused with pulse duration (see below).

Fusion gain (Q): Fusion gain is the ratio of the fusion power produced to the external heating power injected into the plasma. Q=1 means that fusion power equals external plasma-heating power, while Q=10 means that ten times as much fusion power is produced. This does not mean that the facility produces net electricity, because it excludes the power required to operate the plant. Fusion gain for ICF experiments can be defined differently.

Duration and Repeatability: A future fusion power plant must not only reach high performance but maintain or reproduce it reliably. MCF systems aim for long-pulse or continuous plasma operation. ICF and other pulsed systems instead aim to repeat extremely short fusion events at high frequency. Duration is therefore an important complement to the triple product and Q as highlighted in this chapter.

The analysis in this section uses only results available in the open literature. For magnetic-confinement fusion, it uses the IEA–IAEA CICLOP multi-machine database[26], which compiles published results from major tokamaks and stellarators. For pulsed fusion, it uses the published compilation by Wurzel and Hsu[27], which reports triple-products for inertial and magneto-inertial experiments. The comparison reflects openly reported performance only and does not capture unpublished or proprietary results from private fusion initiatives.

Figure 3.4 presents the experimental record for MCF alone from the CICLOP database. The long-standing trade-off between peak performance and pulse duration is immediately apparent. The historical peak-performance results are concentrated in the US (TFTR and DIII-D), the EU/UK (JET) and Japan (JT-60U), reflecting the dominance of these actors in high-performance campaigns in the 1990s and 2000s. It is worth noting that except for the US DIII-D device, these machines are decommissioned.

EAST (China), LHD (Japan) and WEST (France) (formerly Tore Supra) — have sustained plasma for thousands of seconds, but at lower triple products. The tokamak plasma-duration record is held by WEST, which sustained a hydrogen plasma for 1,337 seconds in February 2025. (not included in CICLOP data used for figure 3.4). Germany's W7-X stellarator sits in the middle: in May 2025, W7-X set a record for the triple product achieved in a long-duration plasma of 43 seconds. This result strengthens its position between the short-duration peak-performance machines and the longest-duration lower-performance discharges.

Figure 3.5 expands the picture by adding selected pulsed and ICF results from Wurzel–Hsu[27] (the duration shown for these points is the stagnation time). This includes the National Ignition Facility (NIF), which represents the most prominent US peak-performance achievement. The pulsed-fusion points occupy a very different region of the chart: their triple products can be very high — but the fusion occurs on timescales many orders of magnitude shorter than MCF devices. An ICF power plant would need a different operating model than MCF, with shots repeated frequently to provide steady power production.

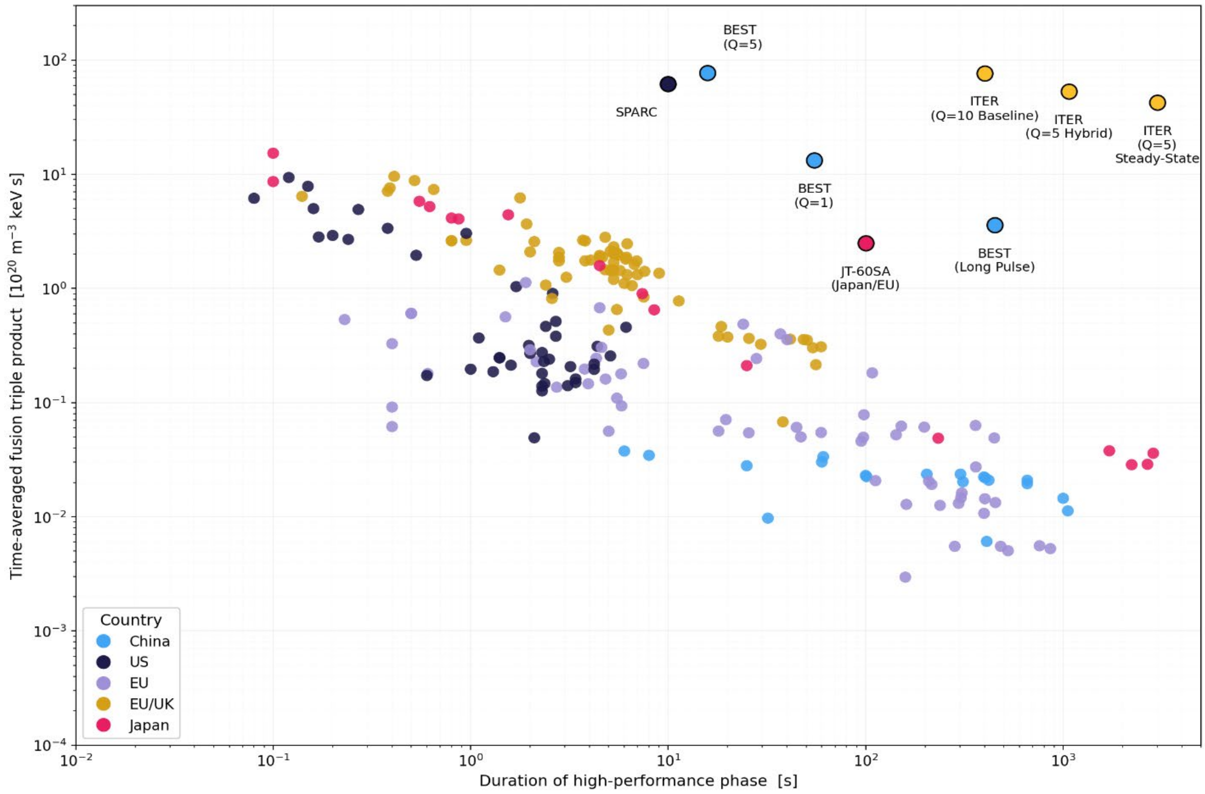


Figure 3.4 — Fusion triple product (nTτ) versus duration of the high-performance phase for magnetic-confinement devices in the CICLOP database [26]. Each filled point represents an openly reported tokamak or stellarator experiment, colour-coded by host actor. The outlined markers are design-point projections for the next-generation devices: ITER [28], BEST [29], SPARC [30] and JT-60SA [31]

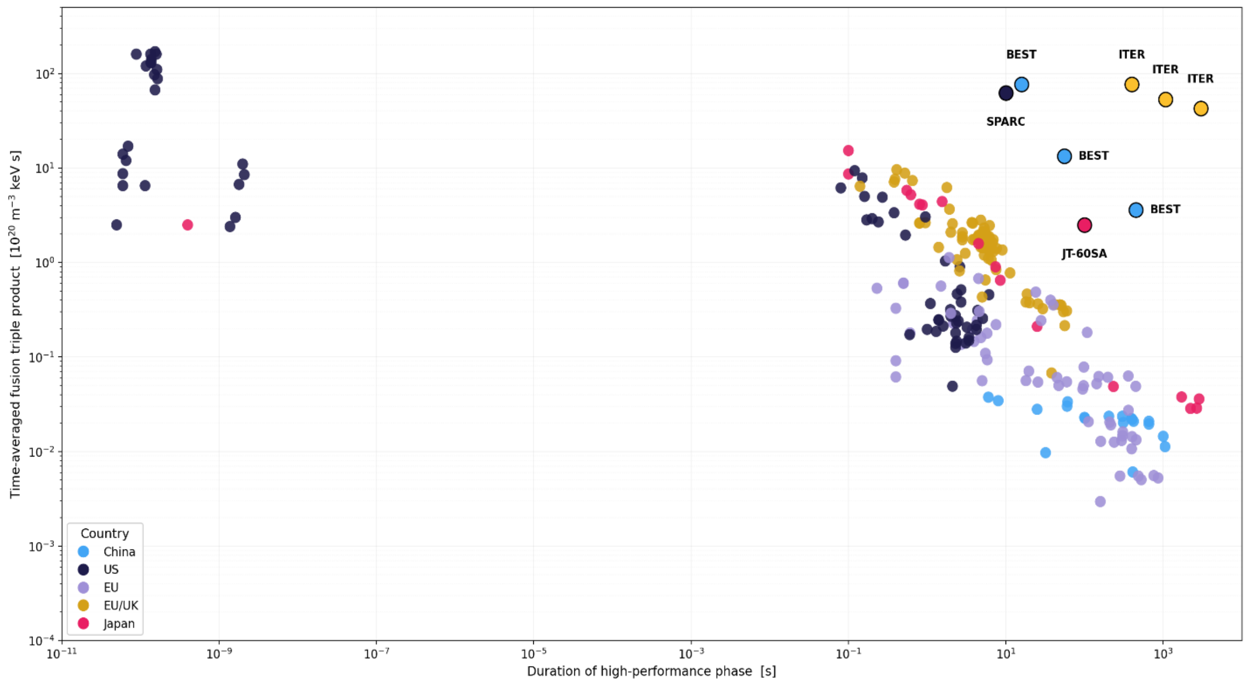


Figure 3.5 — Expanded fusion triple product (nTτ) versus duration plot including both magnetic-confinement results from CICLOP [26] and selected pulsed and inertial-confinement results from the Wurzel–Hsu compilation [27]. Note that the duration shown for the pulsed fusion experiments is the reported stagnation time τ_{stag}, and that the methodologies for triple product calculations may not be directly comparable across approaches.

To provide an alternative visualisation of the MCF results, Figure 3.6 shows a ladder view that makes the performance ranges and the central trade-off easier to read. Each device is represented by a single horizontal bar spanning the range of openly reported values between the open circles with shading applied. The gradient within each bar shows the distribution of reported values: one sees for a given device the darker shaded zones are near the high-performance end on the triple-product axis (upper panel) but fall at the shorter end of the duration axis (lower panel) reflecting the trade-off pointed out above.

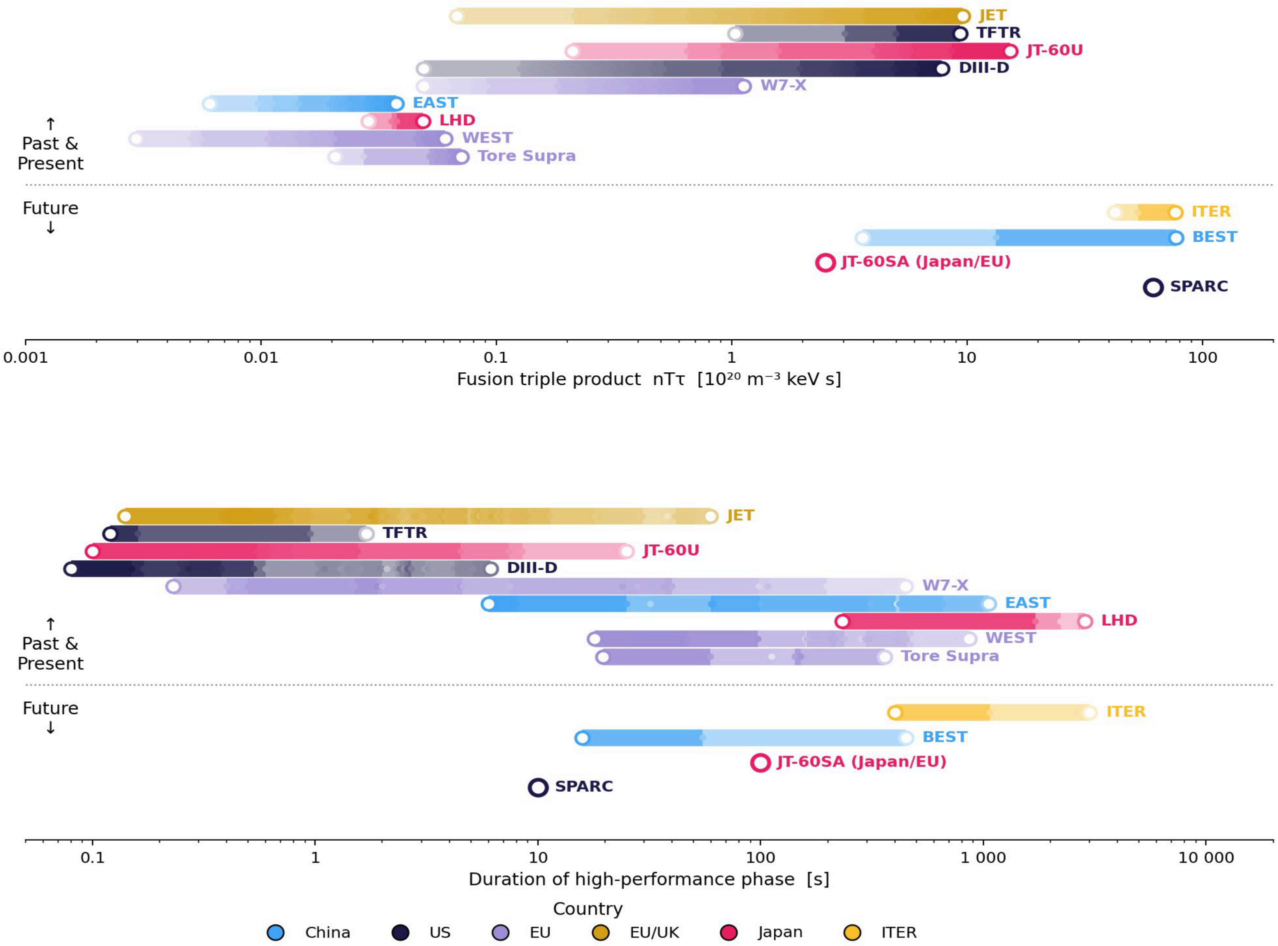


Figure 3.6 — Comparative ranges of fusion triple product (nTτ) (upper panel) and high-performance pulse duration (lower panel) for the major magnetic-confinement devices in the CICLOP database [26], with projections for the next-generation devices ITER, BEST, JT-60SA and SPARC shown below the dotted line

The Next Generation: Devices Under Construction or Planned

The next generation of fusion devices is intended to address a range of complementary challenges, including high fusion gain, long-pulse plasma control, burning-plasma physics and, in some projects, integrated power-plant operation. The portfolio includes publicly funded scientific facilities like ITER, privately led demonstrators and proposed commercial pilot plants pursuing magnetic, inertial and alternative fusion approaches.

Figure 3.7 provides a milestone view of the principal devices currently under construction or planned across the EU, the US, China, the UK and Japan, with ITER shown separately as an international project. The chart presents the announced start of construction and principal operational milestone for each project. These milestones are not fully equivalent: depending on the project, the operational milestone may refer to first plasma, a net-energy demonstration, the start of a research programme or the production of electricity. Starting operations does not necessarily mean achieving high performance, since experience from operating fusion devices is that moving to high performance regimes takes a long period of commissioning and scenario development. ITER, for example, aims to start high-performance operations in 2039, five years after initial operations[27]. The chart is not exhaustive: a device is included only when its developer has published a construction-start or operation-start year.

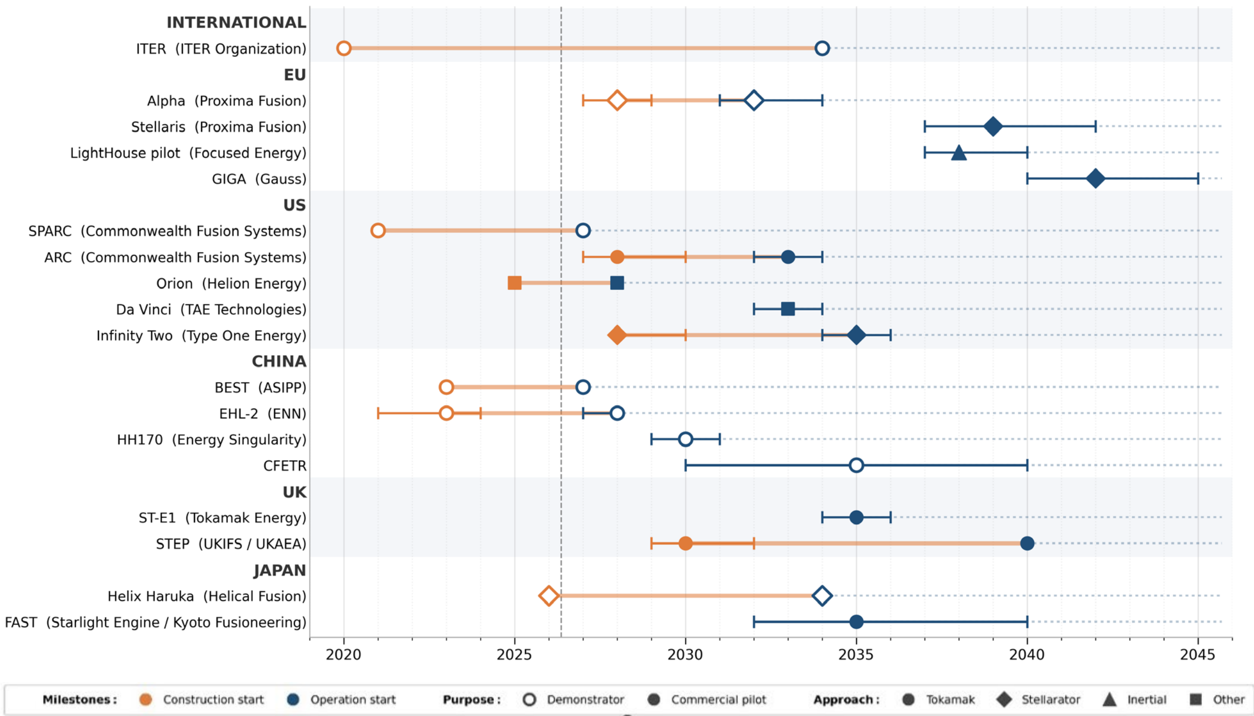


Figure 3.7 — Construction-start and operation-start milestones for next-generation fusion-performance and power-demonstration devices under construction or planned (data cut-off May 2026)

The chart shows a broad and increasingly diverse pipeline. Publicly funded flagships generally have longer construction and commissioning schedules, reflecting their scale, risk appetite, technical scope and governance requirements. Private-sector projects typically publish shorter schedules, concentrated in the late 2020s and 2030s, although many of these remain developer targets rather than independently validated project baselines. Figure 3.7 should therefore be interpreted as a combination of observed progress, announced intent and forecast, with differing levels of schedule confidence. Among the projects shown in Figure 3.7, four merit closer comparison because they represent the main near-term steps towards higher fusion performance and longer-duration operation: ITER, JT-60SA, SPARC and BEST.

ITER is the centrepiece of the international fusion programme, funded and governed by seven parties — the EU, China, India, Japan, South Korea, Russia and the US. JT-60SA, developed jointly by the EU and Japan, will investigate long-duration, high-performance non-tritium plasmas. SPARC is a compact, privately led US device intended to demonstrate high plasma fusion gain using high-temperature superconducting magnets. BEST, under construction in China, is intended to explore deuterium–tritium burning-plasma regimes across both high-gain and longer-pulse scenarios. The four projects pursue distinct scientific objectives and operate at different scales. Their design parameters are summarised in Table 3.1.

Parameter	ITER	JT-60SA	SPARC	BEST
Location	Cadarache, France	Naka, Japan	Devens, MA, US	Hefei, China
Programme	Intergov. (7 parties)	EU–Japan (BA)	Private (CFS/MIT)	China (ASIPP)
Machine type	Superconducting tokamak	Superconducting tokamak	Superconducting tokamak	Superconducting tokamak
Major radius R (m)	6.2	2.96	1.85	3.6
Minor radius a (m)	2.0	1.18	0.57	1.1
Current (MA)	15	5.5	8.7	3–7
Toroidal field (T)	5.3	2.25	12.2	6.15
Heating power (MW)	~100	41	25	50
Fusion Gain (Q)	10 (baseline) ≥5 (hybrid) 5 (steady state)	N/A (not D–T)	>2	≥1 (baseline) ≈5 (advanced)
Pulse length (s)	300-500 (Q=10) ≈1000 (Q≥5) ≈3000 (Q=5)	≈100	≈10	16 (Q≈5) 50 (Q≥1) 1000 (Q≈0.3)
Fusion power (MW)	500	N/A	140	10–200
Start of operations	~2034	2026 (restart)	~2027	~2027

Table 3.1 — Parameters of major fusion devices under construction or commissioning.

ITER differs from the other three projects in both scale and mission. It targets a baseline plasma fusion gain of (Q=10) for approximately 400 seconds, together with longer-pulse operating scenarios. Its purpose is to establish the scientific and technological basis for burning-plasma operation rather than to generate electricity[28].

JT-60SA achieved first plasma in 2023 and entered its second operational phase in 2026. Although it will not use deuterium–tritium fuel, it is designed to develop break-even-equivalent, high-temperature deuterium plasmas lasting around 100 seconds and to support the preparation of ITER and future demonstration power plants[30-31].

SPARC pursues a different route: a compact, high-field tokamak by Commonwealth Fusion Systems (CFS) in collaboration with MIT. Its mission is to demonstrate plasma fusion gain above (Q=2) in a comparatively short pulse, using high-temperature superconducting magnets to achieve strong magnetic fields in a smaller device. Nominal modelling predicts substantially higher gain, although (Q>2) remains the formal mission objective[32].

BEST, under construction by ASIPP in Hefei, is intended to investigate deuterium–tritium burning-plasma operation. Its research programme includes a principal target of (Q ≈ 1), more advanced scenarios approaching (Q ≈ 5), and longer-duration operation at lower gain. It therefore occupies an intermediate position between compact high-field experiments and the larger, longer-pulse ITER programme[33].

Beyond these flagships, Figure 3.7 shows a much broader set of devices in advanced planning or early construction. The EU pipeline includes private-sector stellarator and inertial-fusion plants planned by Proxima Fusion (Alpha and Stellaris in Germany)[34], Focused Energy (LightHouse pilot) and Gauss Fusion (GIGA). The US pipeline includes ARC[35], Helion Energy's Orion[36], TAE Technologies' Da Vinci, and Type One Energy's Infinity Two[37]. China has EHL-2 from ENN, HH170 from Energy Singularity, and CFETR[38]. The UK has STEP — a prototype power plant[39] — and Tokamak Energy's ST-E1[40]. Japan adds Helix HARUKA[41] and FAST (Kyoto Fusioneering's tokamak)[42].

Several patterns emerge from Figure 3.7. Private-projects generally publish shorter development schedules than the baselined programmes of major public facilities, with many targeting construction or initial operation in the late 2020s and early 2030s. These schedules are not, however, directly comparable. Many private-sector dates are developer targets rather than independently validated project baselines and reflect differences in project scope, technical maturity, regulatory requirements, financing assumptions and schedule risk. Announced commercial-pilot milestones are concentrated between approximately 2033 and 2040, although the associated date ranges are highly uncertain. Figure 3.7 should therefore be interpreted as a combined picture of construction already under way, established programme schedules and forward-looking developer ambitions, each carrying a different level of confidence.

Two large facilities currently under construction in China merit separate attention because of their apparent scale and rapid development. They are discussed here based on open-source reporting and satellite imagery rather than detailed official technical information. Unless otherwise stated, they are not included in the device totals presented earlier in this chapter.

The Xinghuo facility on Yaohu Science Island in Nanchang has been described in external reporting as a fusion–fission hybrid research facility intended to supply approximately 100 MW of electricity to the grid, with operation around 2030[43-44]. However, publicly available official information remains limited. The imagery shown in Figure 3.8 indicates that the site went from largely undeveloped land into an extensive construction complex over three years. The imagery provides evidence of the pace and scale of construction, but it cannot confirm the facility's internal equipment, technical configuration, operational readiness or eventual performance.

A second large facility near Mianyang in Sichuan has been identified by external analysts as a possible large-scale laser inertial-confinement-fusion facility. Its layout has been compared with that of the US NIF, and some analysts refer to it as the Shenguang-IV laser facility[45,46]. These identifications and comparisons have not been confirmed officially. Figure 3.9 shows the site going from cleared ground to a completed building complex within a few years. As with Xinghuo, the imagery shows rapid construction but does not establish the facility's specifications or its operational readiness.

Figure 3.8 — Open-source satellite imagery showing the three-year development of the site reported to be the Xinghuo fusion–fission hybrid facility on Yaohu Science Island, Nanchang, Jiangxi, China (28.69°N, 116.03°E). Uses modified Copernicus Sentinel-2 L2A true-colour imagery processed with Copernicus Browser. Site identification after D. Eveleth, CNA Corporation / James Martin Center for Nonproliferation Studies.

Figure 3.9 — Open-source satellite imagery showing the three-year development of a large facility near Mianyang, Sichuan, China (31.5433°N, 104.7395°E), identified by external analysts as a possible NIF-style laser inertial-confinement-fusion facility. Uses modified Copernicus Sentinel-2 L2A true-colour imagery processed with Copernicus Browser. Site identification after D. Eveleth, CNA Corporation / James Martin Center for Nonproliferation Studies.

The two sites illustrate the speed and scale of some recent Chinese investments in fusion-related infrastructure. They should nevertheless be interpreted cautiously: open-source imagery can reveal construction progress, but not whether the facilities will achieve their reported schedules, functions or performance objectives.

Conclusions

Taken together, the device counts, experimental results and construction timelines reveal a broad but uneven fusion landscape. The US has the largest overall and active device base, while China has developed a substantial mixed public–private ecosystem. The EU and Japan retain significant publicly funded experimental capability, and the UK has a smaller but increasingly private-sector-led portfolio. These differences extend beyond the number of devices to the balance of public and private activity and the range of fusion approaches being pursued.

Device counts nevertheless measure the breadth of activity rather than the maturity or performance of an ecosystem. Nearly half of the projects identified in the five-actor pipeline remain at the planning stage, and many announced private-sector schedules are developer targets rather than independently validated project baselines. The future pipeline therefore demonstrates considerable ambition, but not all planned projects will necessarily proceed on their currently stated schedules or reach their intended performance.

Experimental evidence shows that no operating facility yet combines reactor-relevant fusion performance with the duration—or, for pulsed approaches, the repetition rate and reliability—needed for practical energy production. The highest triple-product and fusion-gain results and the longest-duration plasma discharges have generally been achieved in different machines and operating regimes. ITER, SPARC, BEST and JT-60SA address complementary elements of this challenge rather than following identical objectives. The international project ITER comes closest to combining high plasma gain with long-pulse operation, with the objective of demonstrating the scientific feasibility of fusion on a reactor scale.

Progress towards commercial fusion will likely depend on a sequence of experiments, demonstrators and pilot plants rather than on any single device. It will also require advances in enabling technologies—including materials, tritium breeding and processing, heat exhaust, remote maintenance and power conversion. Many of the facilities needed to develop and qualify these technologies fall outside the device counts used in this chapter but will be essential to commercialisation. The central question for the next 10–15 years is therefore not only whether the next generation can achieve its plasma-performance objectives, but whether the wider pipeline can convert announced ambition into sustained, integrated and reproducible operating capability.

Key Takeaways

Fusion Device Landscape: Capabilities, Performance, and the Next Generation

- **The device pipeline is extensive, but its maturity varies.** The five actors have 83 operating, under-construction and planned devices between them. Of these, 42 are active, while 41 remain at the planning stage and may not all proceed on their announced schedules.
- **The US has the broadest active device base, but capability cannot be inferred from counts alone.** The US has 14 active devices, followed by China with 9, the EU and Japan with 8 each, and the UK with 3. These counts do not reflect device scale, performance, purpose or technological maturity.
- **Fusion ecosystems differ in structure and technological emphasis.** The EU and Japan remain mainly publicly led, while the US, China and the UK have a more substantial private-sector presence. Actors also pursue different combinations of tokamaks, stellarators, inertial-fusion systems and alternative concepts.
- **No operating facility yet combines high fusion performance with plant-relevant duration or repeatability.** Peak triple-product and the longest-duration plasma discharges have been achieved only in different machines rather than simultaneously in a single facility. ITER, SPARC, BEST and JT-60SA address complementary parts of this challenge.
- **Commercialisation requires more than plasma-performance devices.** Progress will also depend on advances in materials, tritium breeding and processing, heat-exhaust systems, remote maintenance, power conversion and other enabling technologies that are not captured in this chapter.

83	42	41	18	400 s
Devices in the five-actor pipeline	*Active devices (Operating or Under Construction/Upgrade)*	*Planned devices not yet under construction*	*next-generation projects with published milestones*	*ITER baseline high-gain pulse target at Q=10*

04

Scientific Output and Research Impact

Scientific publications provide an indication of the scale, depth and direction of a research base, while citations offer an indicative measure of its visibility and influence. This chapter examines publication volume, accumulated citations, growth trajectories, institutional structures and technology focus across China, the EU, Japan, the UK and the US.

The publication and citation record remains concentrated in the US and EU. However, the recent-period analysis shows a more dynamic landscape, with the EU leading publication volume since 2006 and China expanding rapidly. This sets the stage for one of the most striking structural features of the global fusion ecosystem: the actors who lead on scientific influence may not be the same as those who lead in translating that knowledge into protectable intellectual property, a tension explored in the chapter that follows on patenting.

The chapter highlights contrasting institutional models. EU output is distributed across a broad network of national laboratories and universities, while the US and China are more concentrated in a smaller number of major institutions. Commercial fusion companies contribute a comparatively modest share of openly published research, although publication data alone cannot fully capture their research or technological activity.

Publication Volume and Citation Impact

The five actors account for approximately 152,000 fractionally attributed publications[iii] and 2.83 million associated citations over the full record from 1950 to May 2026 (around 93% of the identified global corpus). Within the five-actor total, the US and EU lead on both publication volume and accumulated citations, jointly accounting for nearly two-thirds of publications and around three-quarters of citations; Japan, China, and the UK occupy smaller but distinct positions.

Within the five-actor full-record total, the US is the largest contributor, accounting for 33.1% of publications and 42.1% of accumulated citations. The EU follows closely on both metrics, with 32.1% of publications (48,820) and 32.8% of citations. Japan, China, and the UK form the second tier: Japan at 14.1% (21,389) and 9.2%, China at 14.9% (22,591) and 8.2%, and the UK at 5.9% (9,027) and 7.7%.

The relationship between publication and citation shares differs across the five actors. The US citation share is around nine percentage points above its publication share, while China's citation share is around seven points below its publication share. This partly reflects the different age profiles of their publication portfolios: the US has a large body of older research that has

[iii] *Actor-level totals use fractional counting: a paper co-authored by N institutions assigns 1/N of the credit to each. See the methodology annex.*

accumulated citations over several decades, whereas much of China's output is more recent. The UK and US have similar accumulated citation averages, at approximately 24 citations per publication. These figures are not normalised for publication year or research field and should therefore be interpreted as descriptive indicators rather than direct measures of research quality.

Within the 2006–May 2026 subset, the ranking by publication volume changes. The EU accounts for the largest share of the five-actor total, at 34.2%, followed by the US at 26.2%. China has become the third-largest contributor, with 21.5%, ahead of Japan at 12% and the UK at 6%. The EU also has the largest citation share within this recent subset, although the US retains a higher average number of accumulated citations per publication.

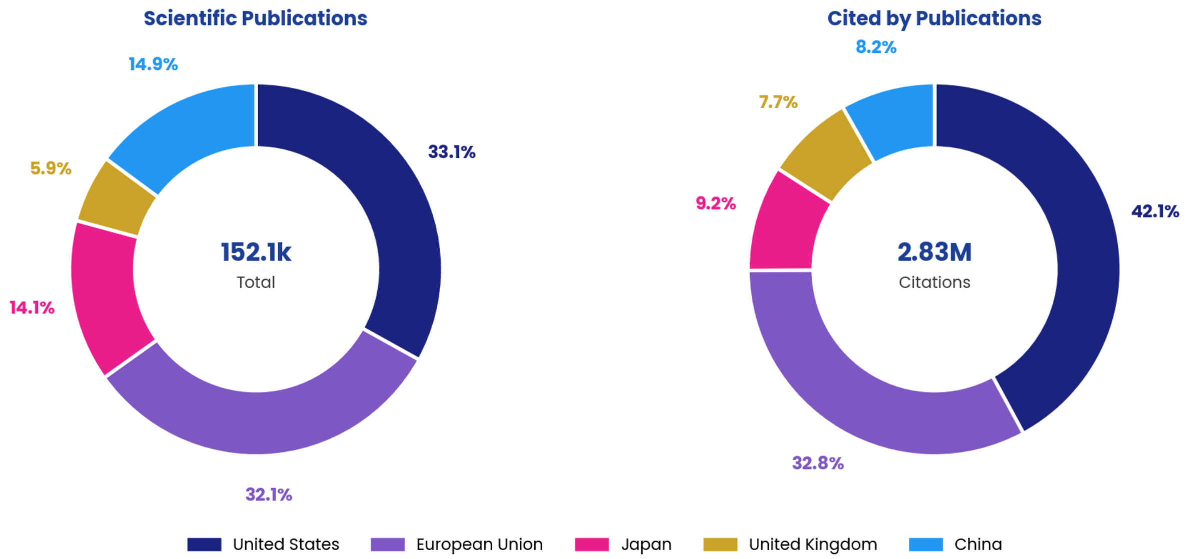


Figure 4.1 — Publication and citation shares among the five selected actors (1950–May 2026)

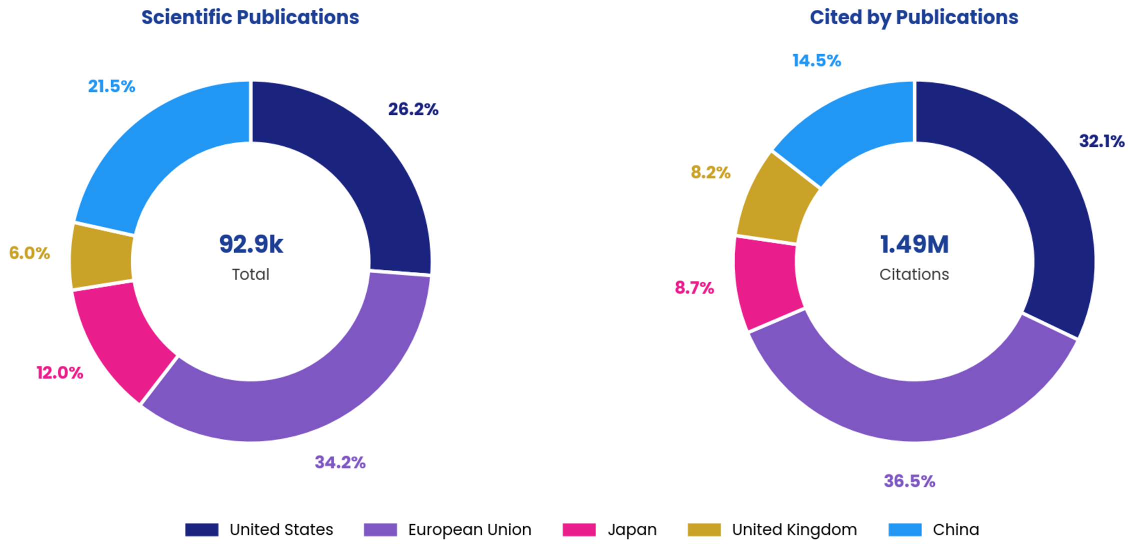


Figure 4.2 — Publication and citation shares among the five selected actors (2006–May 2026)

The contrast between the full record and the recent subset is particularly visible in the citation shares. The US accounts for 42.1% of accumulated citations across the full record, compared with 32.1% within the 2006–2026 subset. China's corresponding shares are 8.2% and 14.5%. The US remains a major contributor in absolute terms, but its share of the more recent five-actor publication total is lower than its share of the accumulated historical record, as output from the EU and China has expanded.

These shifts are consistent with the historical development of the major fusion programmes. The US held an early lead in fusion publishing, supported by major national laboratories including Princeton, Livermore and Oak Ridge. From the 1980s onwards, activity around TFTR in the US and JET in Europe contributed substantially to the scientific literature. The expansion of the coordinated European programme—including work associated with ASDEX and ASDEX Upgrade, Tore Supra and WEST, Wendelstein 7-X and, since 2014, EUROfusion—helped the EU progressively narrow the accumulated publication gap. In inertial-confinement fusion, the National Ignition Facility has been a major contributor to the US publication base.

China's growth is more recent and coincides with the commissioning of EAST in 2006 and the expansion of a broader university and laboratory network. Japan's lower share in the recent window follows a period of particularly strong publication activity around the late 1990s and early 2000s, associated in part with the start of Large Helical Device operations.

For use in the Actor Files, accumulated publication volume is also expressed as a normalised publication-volume score. Each actor's fractionally counted full-record publication total is divided by the total of the leading actor, giving the leader a value of 1. The score measures historical publication volume only: it does not incorporate citations, publication growth, research quality or technological impact.

Publication Growth

Figure 4.3 traces the cumulative publication trajectories of the five actors. The US entered 2006 with approximately 26,000 accumulated publications, compared with around 18,100 for the EU-27. The gap narrowed substantially over the following two decades as EU publication output grew more rapidly. By 2024 it had fallen to approximately 500 publications. At the May 2026 cut-off, however, the US remained ahead by approximately 1,400 publications, with totals of around 50,300 and 48,900 respectively. The latest figures therefore confirm a substantial long-term convergence, but do not establish that the remaining gap is continuing to narrow.

China's trajectory is markedly different. From a cumulative base of approximately 3,100 publications in 2006, its output accelerated during the 2010s and increased further from around 2017 onwards. This growth coincides with the continued operation of EAST, the development of the HL series and the expansion of the wider university and laboratory network engaged in fusion research. China overtook the UK in cumulative output around 2017 and reached a level like Japan in 2024–2025. By May 2026, China stood at approximately 22,500 accumulated publications, narrowly above Japan at approximately 21,300. Japan's accumulated output has continued to grow, but at a slower rate than China's and the EU's. UK growth has also remained steady but comparatively modest, reflecting its smaller research community.

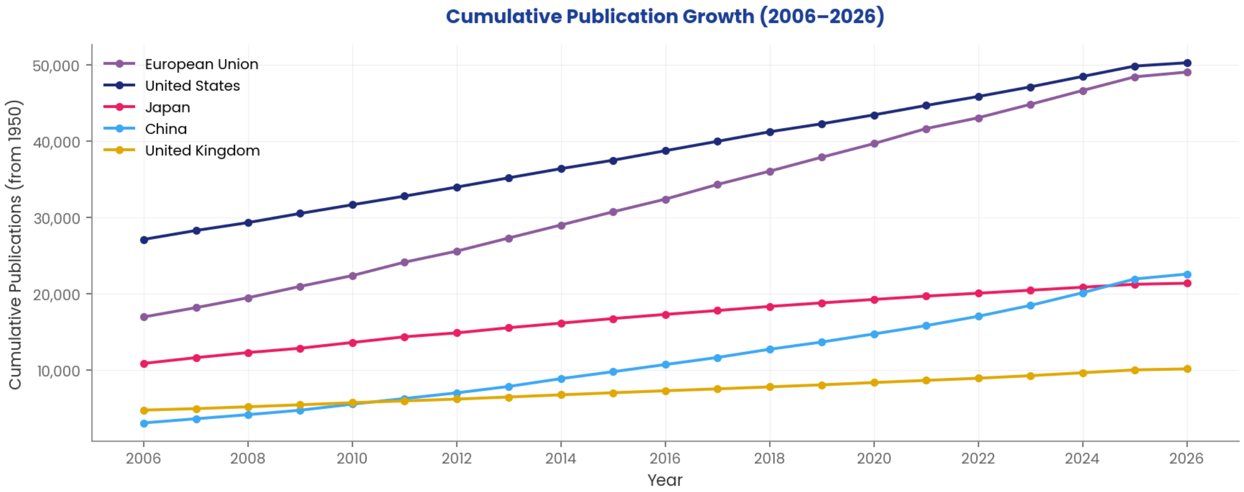


Figure 4.3 — Cumulative publication growth by actor (2006–May 2026)

Leading Publishing Institutions

Within the five-actor dataset, the 20 leading publishing institutions reveal different patterns of research organisation. Seven are EU entities (Max Planck IPP, ENEA, EUROfusion, CEA Cadarache, Czech Academy of Sciences IPP, Karlsruhe Institute of Technology, and Forschungszentrum Jülich), six are based in the US (PPPL, LLNL, General Atomics, the Laboratory for Laser Energetics at Rochester, LANL, and ORNL), three in China (ASIPP, SWIP and USTC), two in Japan (NIFS and JAEA) and one in the UK (UKAEA); the ITER Organization is shown separately as an international institution.

The Institute of Plasma Physics of the Chinese Academy of Sciences (ASIPP) places first with 4,133 publications, reflecting the continuous operation of EAST since 2006 and ASIPP's central role in both Chinese and international fusion collaboration. The Max Planck Institute for Plasma Physics – comprising IPP Garching (ASDEX Upgrade) and IPP Greifswald (Wendelstein 7-X) – follows in second place with 3,324, anchoring the EU's institutional base.

The next tier comprises Japan's National Institute for Fusion Science (2,349, LHD operation), Princeton Plasma Physics Laboratory (2,256, NSTX-U), Lawrence Livermore National Laboratory (1,912, anchored by NIF and ICF research). UKAEA is effectively the sole UK institution in the top tier, with 1,807 publications, making UKAEA by far the largest individual UK contributor. General Atomics (1,694), the principal US private-sector contributor, operates the DIII-D National Fusion Facility. The ITER Organization itself contributes 1,197 publications.

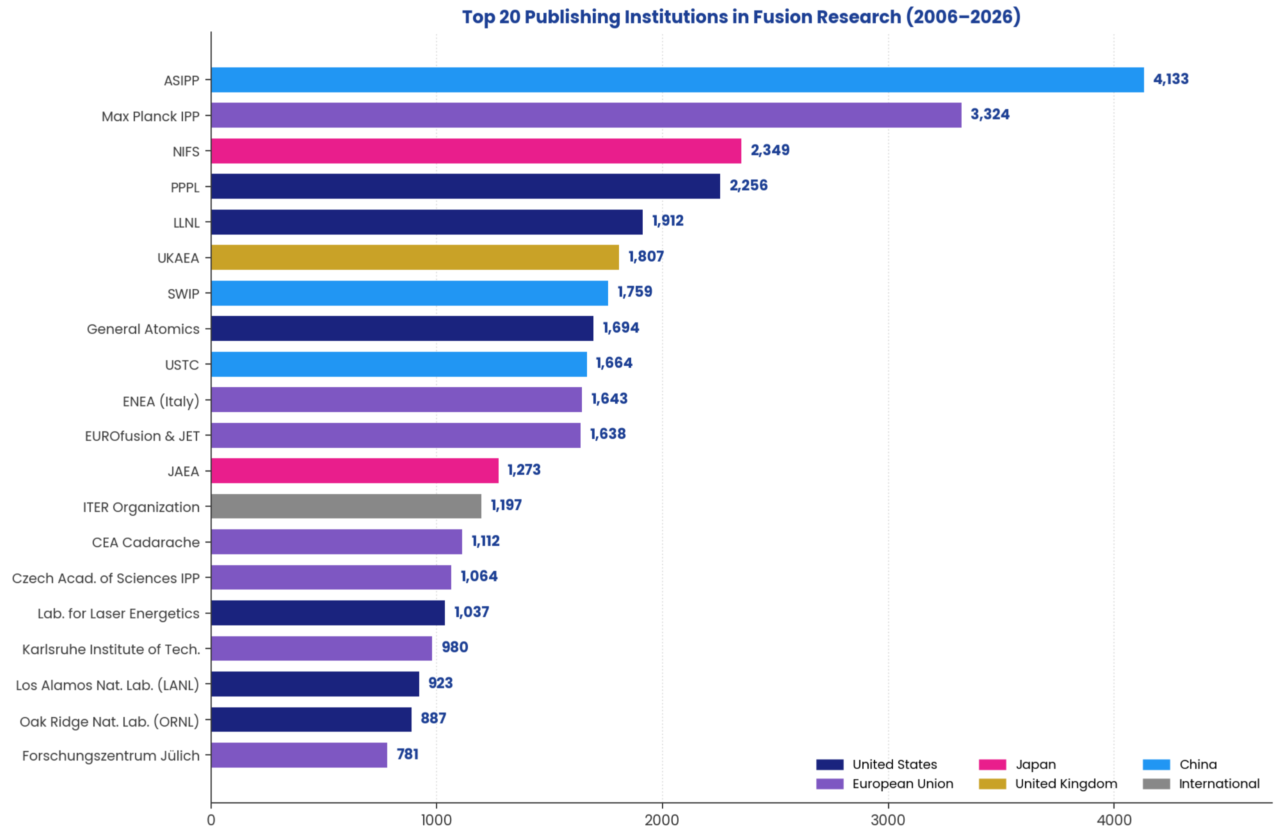


Figure 4.4 — Top 20 Publishing Institutions in Fusion Research (2006–May 2026)

Figure 4.5 breaks this top tier down by actor. China shows a high degree of institutional concentration (4,134 publications), with ASIPP producing more publications than the next four Chinese institutions combined. US output is distributed across several major laboratories and facilities (with its top five, PPPL, LLNL, General Atomics, LANL, and ORNL, all between 887 and 2,256 publications), reflecting the Department of Energy (DoE) national laboratory complex. The UK is anchored by a single institution, UKAEA (1,807), with a steep drop-off to Imperial College, Oxford, and York Universities.

EU output is distributed across a broad network of national laboratories, universities and associated organisations coordinated through EUROfusion. This creates a longer institutional tail than in the more concentrated US and Chinese systems. The Max Planck Institute for Plasma Physics (Germany) (3,324), four others – ENEA (Italy), EUROfusion & JET, CEA (France), and the Czech Academy of Sciences IPP – sit in the 1,064–1,643 range, mirroring the federated EUROfusion structure. Japan pairs two national-laboratory leaders (NIFS at 2,349 and JAEA at 1,273) with a substantial university contingent led by Kyushu and Kyoto.

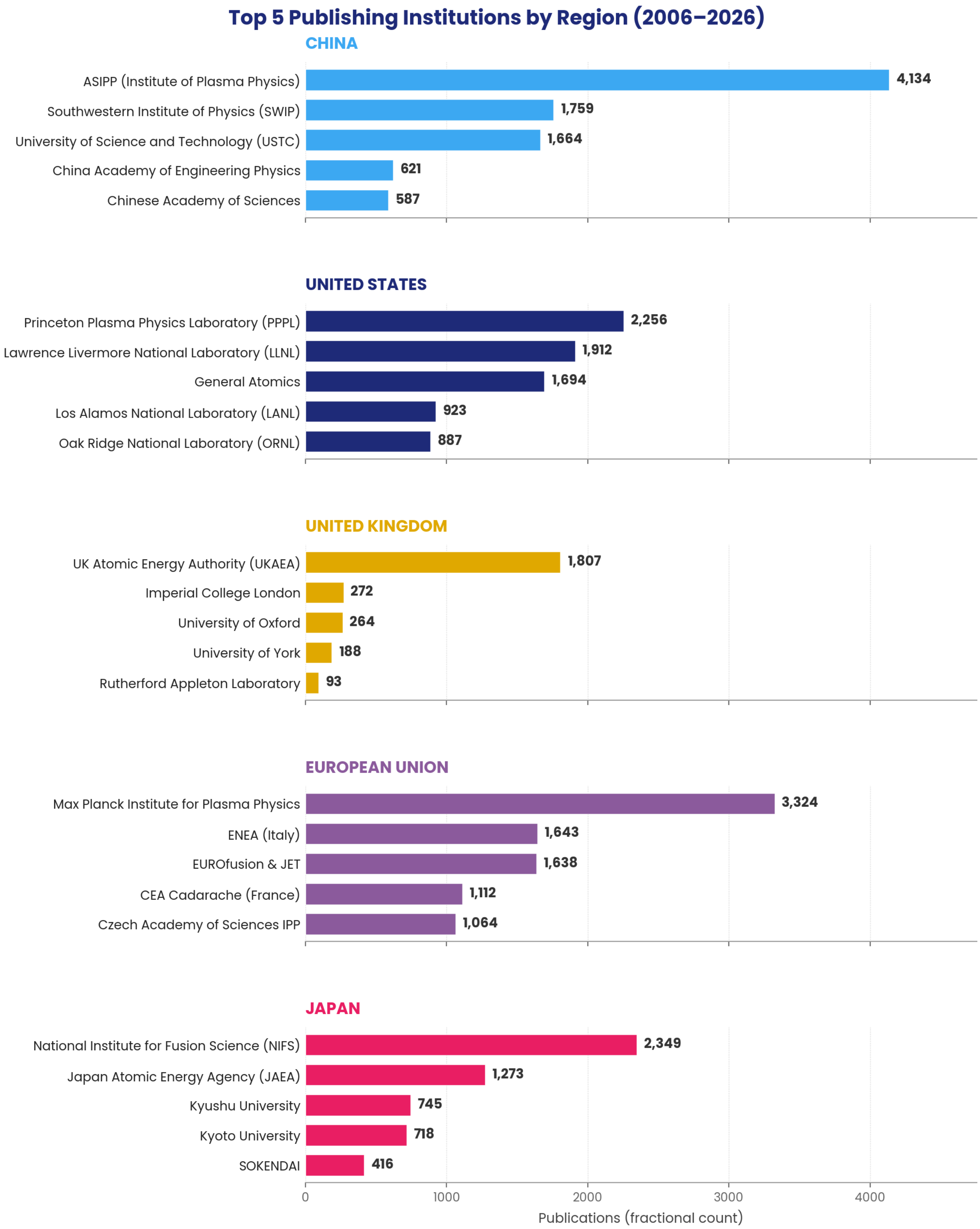


Figure 4.5 — Top 5 Publishing Institutions by actor (2006–2026)

The institutional pattern reveals different national models. EU output is distributed across all 27 Member States and coordinated through the federated EUROfusion consortium — some 4,800 researchers and staff across 30 member institutes — with a long tail of Member-State centres beyond those shown in figure 4.5 including Consorzio RFX (Italy), CIEMAT (Spain), KTH Royal Institute of Technology (Sweden), Instituto Superior Técnico (Portugal), Aix-Marseille

Université (France), and many others. The US, by contrast, concentrates its activity within the Department of Energy (DoE) national laboratory and major DoE-supported facilities / operators: PPPL, LLNL, General Atomics, the Laboratory for Laser Energetics, LANL, and ORNL together produce the bulk of US output. China's institutional pattern resembles the US in its concentration — ASIPP, SWIP, and USTC account for most national output — while Japan's output is distributed across QST, NIFS, JAEA, and the major universities.

Commercial Fusion Companies

Private-sector contributions to fusion publishing remain modest, with one important exception. General Atomics—founded in 1955 and operator of the publicly funded DIII-D National Fusion Facility—has a publication profile closer to that of a national laboratory or major research-facility operator than to that of a recent commercial fusion venture. General Atomics ranks among the world's largest fusion publishers over the whole-time window, with 8,567 publications[iv] and the highest citation impact in the top tier (35.3 citations per paper). It is therefore reported separately and excluded from the comparison of newer commercial fusion companies.

The commercial fusion sector — a mix of privately-funded firms established between the late 1990s and the early 2020s — produces relatively few peer-reviewed publications, which is understandable given their commercial focus. The leading private ventures are TAE Technologies (US, founded 1998, 356 publications, 11.4 average citations per paper), Tokamak Energy (UK, founded 2009, 262 publications, 14.6 average citations), Commonwealth Fusion Systems (US / MIT spin-out, founded 2018, 187 publications, 16.8 average citations), ENN (China, founded 2018, 124 publications, 6.8 average citations), and First Light Fusion (UK, founded 2011, 86 publications, 9.9 average citations). The next tier comprises Zap Energy, Focused Energy, Type One Energy, HyperJet Fusion, and Kyoto Fusioneering, each with between 30 and 60 publications. Using the whole-count, full-history measure applied in this section, the ten leading commercial ventures account for approximately 1,200 publications. This figure should not be compared directly with the fractionally counted, 2006–2026 institutional rankings above.

Citation impact varies widely across the private sector: Commonwealth Fusion Systems, founded in 2018, has already accumulated an average of 16.8 citations per publication — close to the average across the publication corpus and reflecting the high visibility of MIT-affiliated SPARC tokamak work — while younger ventures have not yet built comparable citation profiles.

The comparatively modest open-publication footprint of commercial fusion companies is likely to reflect several factors, including their younger age, smaller research workforces, product-focused development priorities and greater commercial confidentiality. Publication counts therefore provide only a partial view of private-sector research activity. The following chapter on patents offers a complementary perspective on the protection of commercially relevant technologies.

[iv] *Company-level statistics use whole-count attribution rather than fractional counting; each paper is credited once to each contributing company, irrespective of how many institutions co-authored it. This choice better reflects the absolute scale of each company's research engagement.*

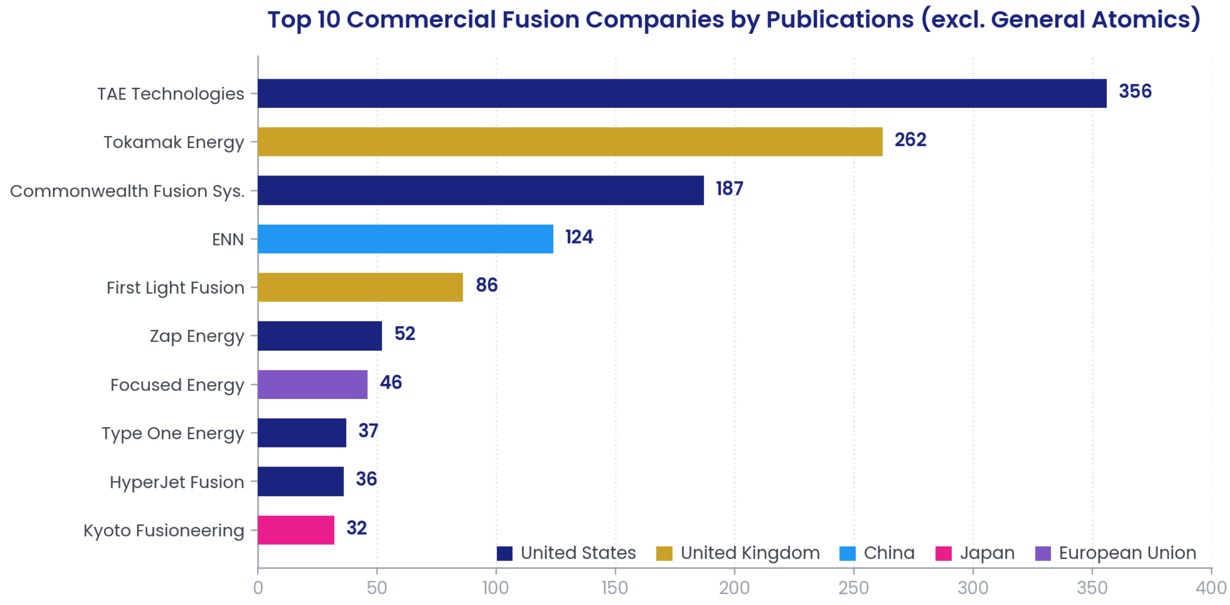


Figure 4.6 — Top 10 Commercial Fusion Companies by Publications (excluding General Atomics). Whole-count publications, full history (1950–May 2026)

Technology Focus Areas

The publication corpus also provides an indication of the fusion approaches most frequently addressed in the literature. Of the 100,987 publications identified in the 2006–May 2026 global corpus, 46,897—approximately 46%—could be assigned to a specific approach using the title, keyword and OpenAlex-topic classification described in the annex. The remaining publications either address cross-cutting subjects, such as plasma physics, diagnostics, materials and modelling, or could not be assigned reliably to a single approach.

For the purposes of this bibliometric analysis, publications are grouped into four families: Magnetic Confinement Fusion; Inertial Confinement Fusion; Magneto-Inertial and Pulsed Fusion; and Other Fusion Approaches. These categories reflect the structure of the keyword classification used in this chapter and do not correspond exactly to the broader conceptual taxonomy used in Chapter 3.

Among publications that could be assigned to an approach, figure 4.7 shows that MCF accounts for approximately 77%, ICF for around 19%, Magneto-Inertial and Pulsed Fusion for roughly 3%, and the remaining classified approaches for less than 1%. Within the classified corpus, tokamak-related publications account for approximately 44%, stellarator-related publications for around 7%, and the “other MCF” category—including spherical tokamaks and spheromaks under the bibliometric classification used here—for approximately 2%.

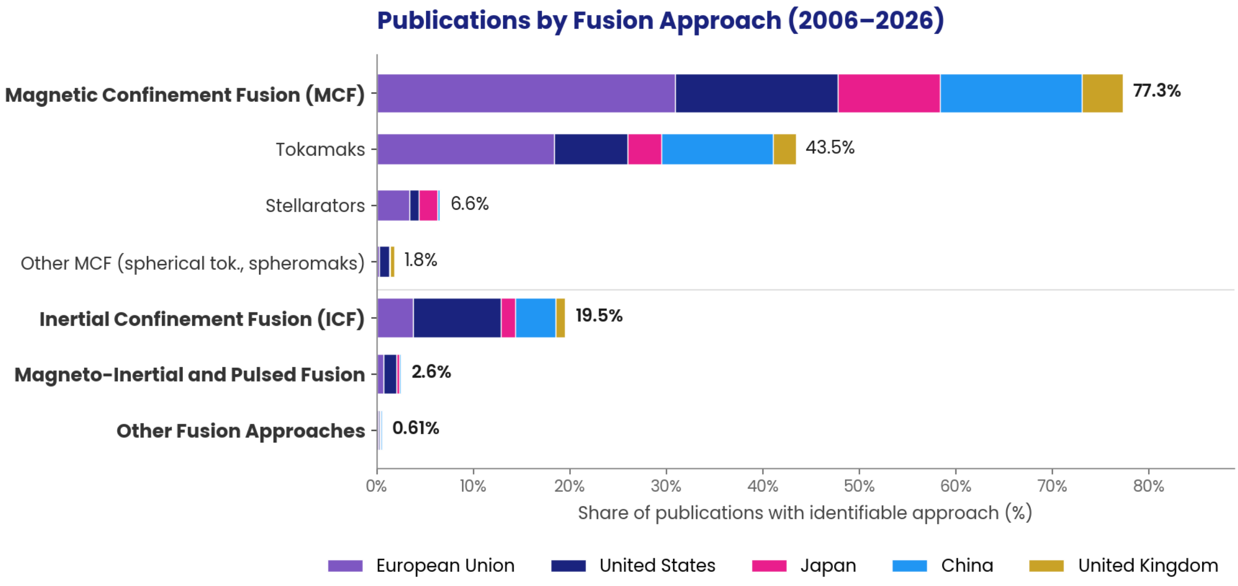


Figure 4.7 — Publications assigned to a fusion approach, 2006–May 2026. Shares are calculated within the 46,897 publications that could be classified by approach and are stacked by contribution from the five selected actors

The composition by actor tracks the structural patterns identified earlier in this chapter. MCF — and tokamaks specifically — is led by the EU, reflecting the EUROfusion effort across JET, W7-X, ASDEX-Upgrade, and ITER preparation, with substantial Chinese contributions anchored by EAST and the HL series. ICF is heavily US-dominated, anchored by NIF, OMEGA, and the broader DoE ICF programme. Stellarator publishing is concentrated in the EU (W7-X) and Japan (LHD), with limited engagement elsewhere. Magneto-Inertial and Pulsed Fusion, while a small share of total output, is comparatively diversified across actors — reflecting the recent expansion of private-sector ventures pursuing routes outside the mainstream MCF/ICF families.

Conclusions

The five actors examined dominate the identified fusion-research literature, but their positions differ according to the period and indicator considered. The US retains the largest accumulated publication and citation record, while the EU leads publication output in the 2006–2026 window. China has expanded its scientific output rapidly and now represents the third-largest recent contributor, although its younger publication portfolio has had less time to accumulate citations.

The institutional evidence points to different research models. The EU draws on a broad network of national laboratories, universities and coordinated programmes; the US combines national laboratories, universities and major publicly supported user facilities; and Chinese output is concentrated in a small number of leading institutions. Japan retains a substantial laboratory and university base, while UK output is anchored strongly by UKAEA.

These findings should be interpreted within the limitations of bibliometric analysis. Publication counts measure output rather than research quality, while raw citations are affected by publication age, research field, database coverage and a small number of highly cited papers. Commercial companies may also publish less because they are younger, smaller or more protective of proprietary research. Publications therefore provide one important indicator of scientific capability, but must be read alongside experimental performance, funding, patents, workforce and industrial capacity.

Key Takeaways
Scientific Output and Research Impact

- **The US and EU dominate the accumulated scientific record:** Together they account for approximately 65% of publications and 75% of citations within the five-actor full-record dataset. The US retains the largest accumulated citation share.
- **The recent publication landscape is more dynamic:** The EU has the largest publication share in the 2006–May 2026 window, while China has expanded rapidly to become the third-largest contributor and has overtaken Japan in cumulative publication volume.
- **Citation comparisons reflect both influence and publication age.** The US and UK average around 24 citations per publication, while China's younger and more rapidly expanding publication portfolio has had less time to accumulate citations. The figures are not normalised for year or subfield.
- **Research systems differ in their institutional structure.** EU output is distributed across a broad network of institutions, while US and Chinese activity is more concentrated in a smaller number of major laboratories and facilities.
- **Commercial fusion companies have a comparatively small open-publication footprint.** This reflects their younger age, smaller research workforces and potentially greater commercial confidentiality; patent data provide a complementary view of their innovation activity.

152,100	**2.83M**	**50,286**	**34.2%**	**21.5%**
publications attributed to the five actors, 1950–May 2026	*accumulated citations across the five-actor full record*	*US publications—the largest accumulated actor total*	*EU share of five-actor publications in 2006–May 2026—the largest recent share*	*China's share of five-actor publications (2006-May 2026)*

05

The Intellectual Property Landscape

Patents provide an indication of the technologies for which organisations are seeking legal protection and of how actors are building portfolios of fusion-related inventions. Patent families are therefore a useful proxy of the scale and geographical distribution of fusion patenting, although their number alone does not establish technological quality or commercial value.

This chapter examines the number and status of fusion patent families across the five actors; their development over time; the principal patenting applicants; and the technological areas in which protection is being sought. The analysis combines patents classified under the International Patent Classification category G21B with supplementary searches covering core commercial fusion companies whose inventions may be classified in adjacent technology fields.

The results reveal an uneven landscape. China accounts for approximately 60% of the identified alive patent families across the five actors and leads numerically in most of the technology categories examined. However, most Chinese families have only domestic filings, and the portfolio includes utility models that are not directly equivalent to invention patents. The US, UK, EU and Japanese portfolios are smaller but contain higher proportions of families seeking protection in more than one jurisdiction.

These differences point to contrasting intellectual-property systems and filing strategies. They should not be interpreted as a simple ranking of technological strength or future commercial value: patent counts do not account for claim scope, legal validity, geographic coverage, citation impact, licensing, implementation or economic significance.

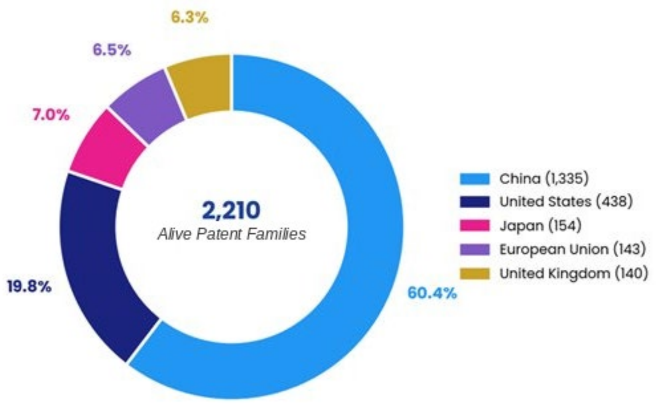
Patent Holdings and Composition

The dataset combines patent families containing at least one document classified under G21B ("Nuclear Fusion Reactors") with supplementary families identified through searches of core commercial fusion companies. Actor attribution is based, where possible, on the location of the applicant rather than on the jurisdiction in which protection was sought. Further details are provided in the methodology annex.

A subsequent global coverage check indicates that the families attributed to the five actors account for 87% of the worldwide fusion patent families. As of the February 2026 cut-off, 2,210 alive patent families were attributed to the five actors. As shown in figure 5.1, China accounts for 1,335 families, or 60% of the identified five-actor total, followed by the US with 438 (20%), Japan with 154 (7%), the EU with 143 (6%) and the UK with 140 (6%). These figures measure portfolio volume and do not weight families according to geographical coverage, legal strength, or commercial significance.

The qualitative composition of China's portfolio distinguishes it from all other actors. It comprises 608 granted patent families, 594 applications, and 133 utility models. Utility models offer a distinct and generally shorter form of protection and are not directly comparable with examined invention patents. Nevertheless, China would still account for approximately 58% of the five-actor invention-patent total if the identified utility models were excluded.

The distribution between granted patents, pending applications and utility models also differs among the actors. The UK, US, EU and Japanese portfolios are dominated by applications over granted patents. A higher proportion of pending applications may partly reflect more recent filing activity, but it can also reflect differences in examination procedures and processing times.



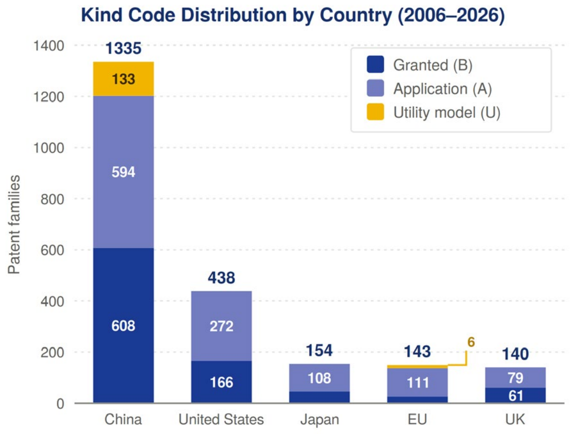


Figure 5.1 — Alive Fusion Patent Families by actor (left) and Kind Code Distribution by actor (right). 2006–2026

Key Terms in Patent Analysis

Patent: A legal right granted by a national or regional patent office that confers, for a limited period (typically 20 years), the exclusive right to prevent others from making, using, selling or importing the protected invention within the jurisdictions in which it has been granted.

Patent Family: A group of related patent applications and granted patents covering the same invention, derived from a common priority filing across one or more jurisdictions. Counting patent families rather than individual filings avoids multiple counting of the same invention when it has been filed in several countries.

Alive Patent Family: A patent family counted as active at the analysis cut-off because at least one member was recorded as a pending application or a granted right still in force.

WIPO Classification: The technology classification scheme maintained by the World Intellectual Property Organization, used in this report to group fusion patent families by technical focus area.

Utility model: A form of intellectual-property protection like a patent but with a shorter term (typically 6–10 years), faster and cheaper registration, and a lower inventive-step threshold.

Jurisdiction: The geographic territory — typically a country, or a regional bloc within which a patent or other IP right is legally enforceable.

Patent Cooperation Treaty (PCT): An international treaty administered by WIPO that allows an applicant to file a single "international application" which preserves, for a limited period of 30 months from the priority date, the right to seek patent protection in any of the contracting states.

Kind Code: A standardised one- or two-character suffix (defined by WIPO Standard ST.16) appended to a patent publication number to indicate the type and stage of the document. Common codes include A for a first-publication application, B for a granted patent, and U for a utility model.

For use in the Actor Files, patent-family volume is also expressed as a normalised patent-volume score. Each actor's number of identified alive families is divided by that of the leading actor, giving the leader a score of 1. The score measures volume only and does not incorporate patent quality, geographic coverage, legal status, commercial use or technological importance.

Patent Growth Trajectory

Figure 5.2 shows the cumulative number of identified patent families that remained alive at the February 2026 cut-off, arranged by their earliest priority year. It should not be interpreted as a historical count of the patents that were active in each individual year, because families that had already expired, lapsed or been withdrawn by the cut-off are excluded.

Within this currently alive portfolio, China's accumulation has accelerated markedly since the mid-2010s. The US also shows substantial growth, particularly from around 2019, while the EU, UK and Japanese portfolios have grown more gradually. The latest years should be interpreted cautiously because patent applications are normally published only after a delay and some recent filings will not yet have appeared in the databases.

China's trajectory forms part of a much broader rise in patenting by Chinese applicants. One important contextual factor has been the country's long-standing emphasis on intellectual-property creation within its innovation policy. From the late 2000s and especially in the early 2010s, the Chinese government adopted what it called an "innovation-driven development" model, making intellectual property creation a central pillar of economic policy. Patents became one of the primary metrics by which the state measured innovation performance, with universities, companies, and state research institutes all incentivised to file patents as a demonstration of scientific output.

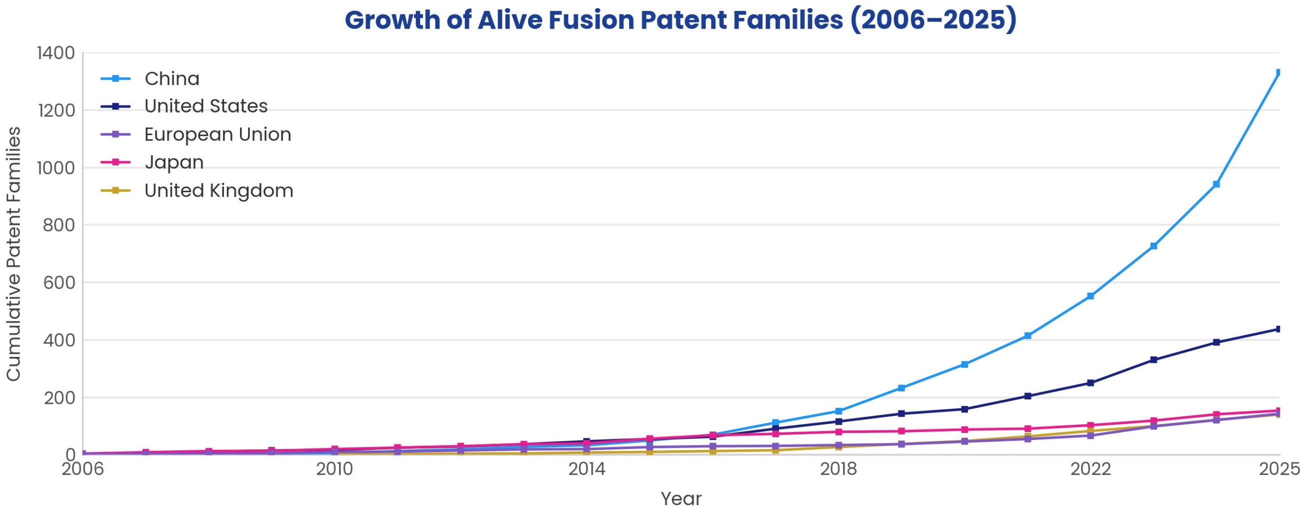


Figure 5.2 — Cumulative identified fusion patent families remaining alive at the February 2026 cut-off, by earliest priority year, 2006–2025. Recent years are incomplete because of the normal delay between filing and publication

Approximately 95% of the Chinese fusion families in the dataset have no published family member outside China. This indicates a much more domestically oriented filing pattern than the other four actors. It does not necessarily mean that every family is intended exclusively for the Chinese market: some recent applicants may still be within the period for filing internationally or entering national phases. Nor does international filing by itself demonstrate greater technical quality or commercial value. It does, however, indicate that the applicant is seeking protection across a broader geographical area and is prepared to incur the associated costs.

Leading Patenting Applicants

The institutional breakdown of fusion patent families reinforces the picture of Chinese dominance. Of the top 20 patenting applicants among the five actors shown in figure 5.3, 13 are Chinese – spanning state research institutes, universities, and a growing number of private-sector companies. The Hefei Institutes of Physical Science of the Chinese Academy of Sciences (CAS) leads with 317 patent families, followed by NEO Fusion with 209, and the Southwestern Institute of Physics (SWIP) with 198.

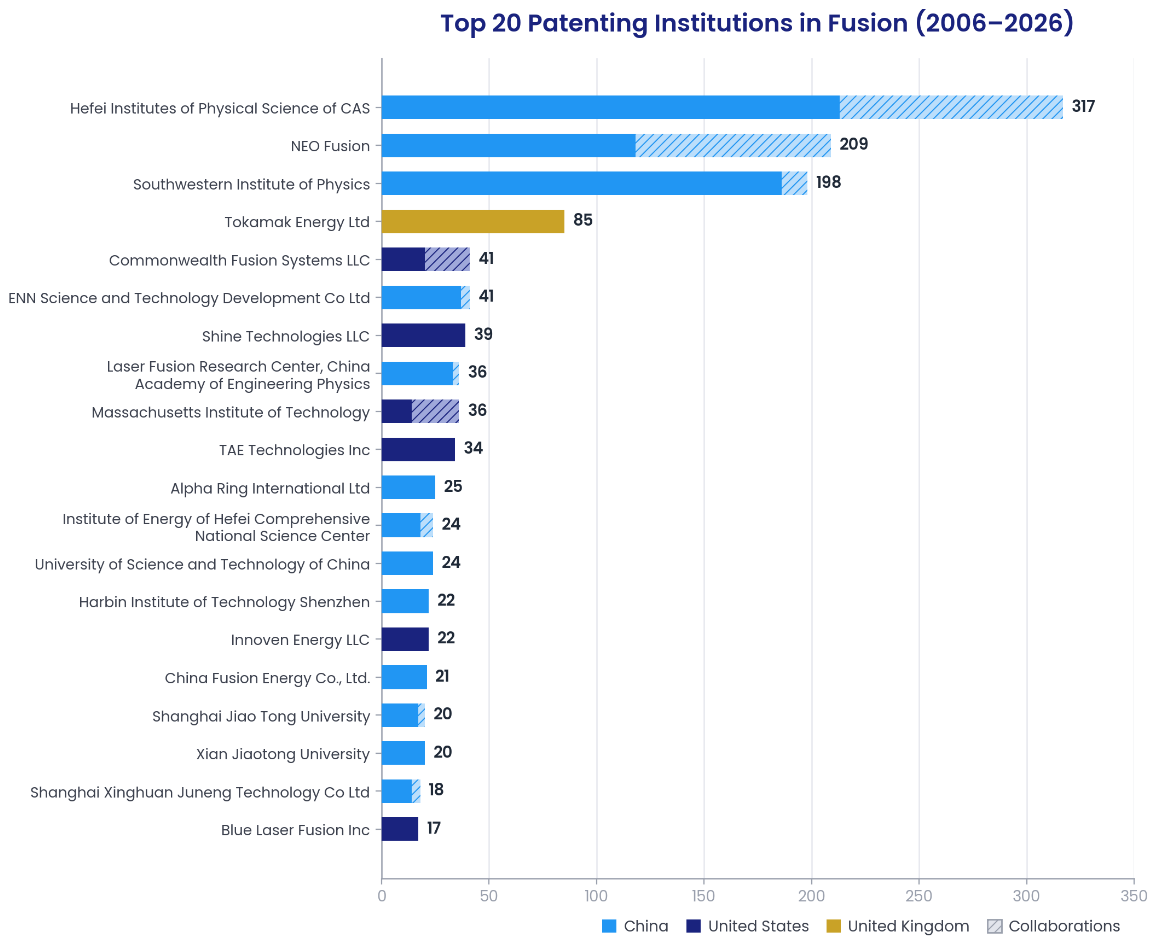


Figure 5.3 — Top 20 Patenting Applicants in Fusion (2006–2026), with collaboration share shown by hatched bars[v].

[v] *Institutional counts use whole-count attribution: for jointly-held patent families, each contributing institution is credited with one family, so the same patent can appear in the totals of more than one institution.*

Outside China, leading applicant portfolios are considerably smaller and are more frequently associated with private fusion companies. These include Tokamak Energy (UK), Commonwealth Fusion Systems (US), Shine Technologies (US), MIT (US), TAE Technologies (US), Alpha Ring International (US), Innoven Energy (US), and Blue Laser Fusion Inc. (US).

Figure 5.4 breaks down the top patenting applicants by actor, with the collaboration share again shown as hatched bar segments. In both figures 5.3 and 5.4, hatched bar segments indicate the share of each institution's portfolio held jointly with other organisations — i.e. patent families involving collaborations.

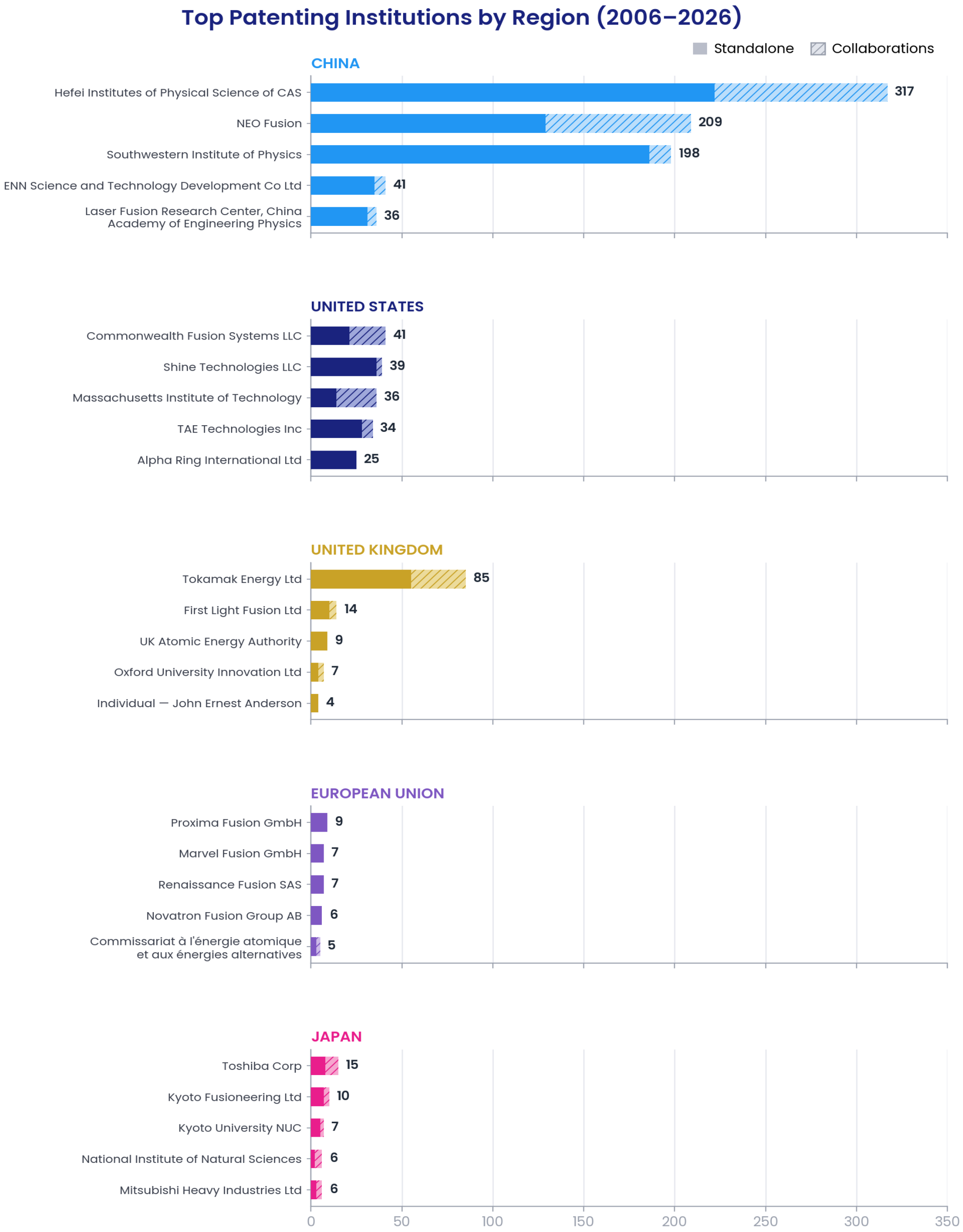


Figure 5.4 — Top Patenting applicants by actor (2006–2026) with collaborations shown as hatched

Technology Focus Areas

Patent families may be assigned to more than one technology category. The distribution of patent families by WIPO technology field[47] indicates the technical priorities of each actor in fusion. As shown in figure 5.5, the largest technology family category is "Magnetic or electric plasma confinement" — consistent with the continued dominance of MCF approaches — with China holding 436 families, the US 132, the UK 49, the EU 39, and Japan 17. In "Inertial plasma confinement", the US (42 families) nearly matches China (44), consistent with the long-standing scale of US activity in inertial-confinement fusion.

Read against the publication record, these distributions reveal a consistent pattern: China's portfolio is particularly concentrated in the magnetic/electric confinement category, while the US has a comparatively large share of inertial-confinement families. Japan's portfolio includes a notable presence in low-temperature-fusion. These patterns indicate different areas of patenting activity but do not, by themselves, measure technological leadership.

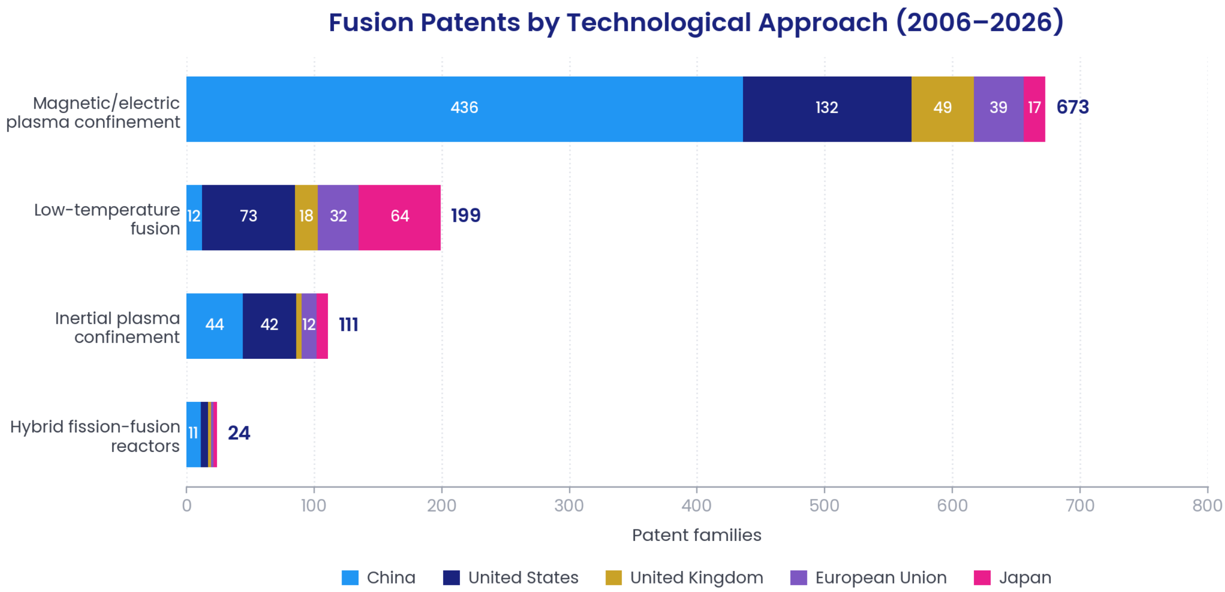


Figure 5.5 — Fusion Patents by Technological Approach (2006–2026)

Figure 5.6 then shows the breakdown by enabling technology — the reactor sub-systems and component categories that any fusion programme must master. The "Superconducting devices" category seems to be closely balanced, with the UK (40) narrowly leading the US (39) and China (36), reflecting the prominence of high-temperature superconducting (HTS) magnet development through companies such as Tokamak Energy and Commonwealth Fusion Systems. China leads across the core engineering categories: "First wall, Blanket, Divertor" (247 vs. US 32), "Maintenance and remote inspection" (195), "Optical systems" (148 vs. US 44), "Vacuum systems" (96 vs. US 35), and "Targets" (91 vs. US 53) — indicating that China's IP effort is not merely broad but shows broad numerical coverage across many reactor-system and enabling-technology categories. Japan's presence in optical systems mirrors its laser fusion expertise, while the US nevertheless has a substantial portfolio of target-related families, consistent with its long-standing activity in ICF research.

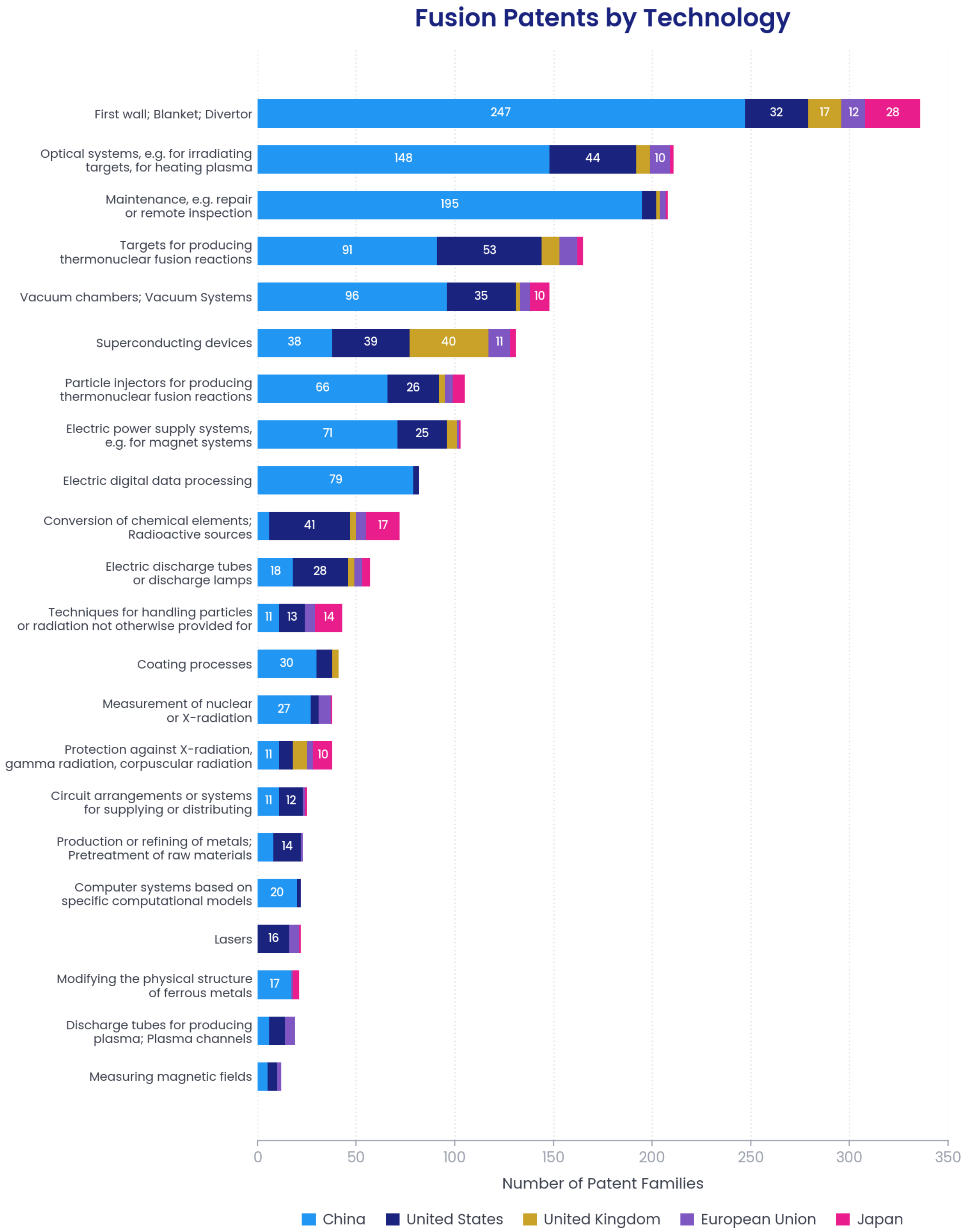


Figure 5.6 — Fusion Patents by Technology (2006–2026).

Conclusions

The patent landscape is considerably more concentrated than the publication landscape. China accounts for approximately 60% of the identified alive patent families across the five actors and has the largest numerical portfolio in most of the technology categories examined. Its leading applicants include public research institutions, universities, state-backed commercial entities and private companies, giving the Chinese portfolio both scale and institutional breadth.

The headline counts nevertheless require careful interpretation. The Chinese total includes utility models, and approximately 95% of its identified families had no published foreign family member at the February 2026 cut-off. By contrast, the smaller US, UK, EU and Japanese portfolios contain higher proportions of multi-jurisdiction families. These patterns indicate different filing systems and geographical protection strategies, but do not establish the quality, enforceability or commercial value of the portfolios.

Outside China, patenting is more strongly associated with specialist fusion companies. Tokamak Energy holds the largest identified non-Chinese portfolio, while Commonwealth Fusion Systems, Shine Technologies and TAE Technologies are among the leading US applicants. The EU portfolio remains comparatively small and is distributed among several young private ventures and public research organisations.

The technology analysis shows that Chinese applicants seek protection across a wide range of confinement, reactor-system and enabling technologies. However, patent-family volume is only one indicator of innovation capability. A fuller assessment would also require evidence on international coverage, claim scope, legal survival, citation, licensing, technology deployment and the ability to manufacture and operate the patented systems.

Key Takeaways
The Intellectual Property Landscape

- **China has the largest identified fusion patent portfolio:** It accounts for 1,335 alive patent families, or approximately 60% of the five-actor total, compared with 438 for the US, 154 for Japan, 143 for the EU and 140 for the UK.
- **Patent volume does not equate directly to portfolio value:** The counts treat all families equally and do not account for claim scope, legal strength, geographic coverage, licensing, implementation or economic significance. The Chinese total also includes 133 utility-model families.
- **Filing strategies differ markedly:** About 95% of the identified Chinese families had no published family member outside China, while higher proportions of the other actors' portfolios sought protection in multiple jurisdictions. Recent filings may not yet have completed their international filing cycle.
- **Leading applicant structures differ across actors:** Thirteen of the top 20 applicants are Chinese. Outside China, the largest portfolios are more frequently held by specialist commercial fusion companies, particularly Tokamak Energy, Commonwealth Fusion Systems and TAE Technologies.
- **China has broad numerical coverage across fusion technologies:** Chinese applicants lead most of the identified confinement and enabling-technology categories. The UK, US and China have similar totals in superconducting devices, while low-temperature-fusion patent counts should not be interpreted as evidence of scientific validation.

2,210	**60.4%**	**95%**	**317**	**85**
identified alive fusion patent families across five actors	*share attributed to Chinese applicants*	*Chinese families with no published foreign family member*	*families attributed to HFIPS/CAS, the leading applicant*	*families attributed to Tokamak Energy, the leading UK applicant*

06

The Fusion Regulatory Landscape

The regulatory environment in which fusion developers operate is becoming an important strategic variable. Across the five actors examined, a broad consensus is emerging that regulatory requirements should reflect fusion's specific hazards and should be applied through a graded, risk-informed and technology-neutral approach. There is less convergence, however, on the legal and institutional framework through which this should be achieved[48-51].

Two broad pathways are developing. In the UK, fusion facilities are regulated principally through the existing health, safety, environmental and radiation-protection framework and are expressly excluded from the nuclear-site licensing regime applicable to fission installations[52-53]. In the US, the Nuclear Regulatory Commission has chosen to regulate fusion machines through an adapted byproduct-material framework under 10 CFR Part 30, an approach subsequently reflected in the ADVANCE Act and the proposed fusion-machine rule[54-56].

Other jurisdictions apply or are developing approaches within broader nuclear or atomic-energy legislation. France's licensing and oversight of ITER as basic nuclear installation INB No. 174 provides the leading practical example of an established nuclear regulatory framework being applied to fusion while individual requirements are adapted to the facility's design and hazards[57-58]. China combines elements of both models by explicitly including fusion within its Atomic Energy Law while requiring the establishment of a specialised, graded supervisory framework[59-60].

Fusion differs fundamentally from fission in several respects. It does not involve a self-sustaining chain reaction or the possibility of a fission-core meltdown, and it does not generate spent nuclear fuel or fission products in the same manner as a fission reactor. Fusion facilities nevertheless present radiological and conventional hazards that require effective regulation, including tritium inventories, neutron activation of structural materials, activated dust and waste, and the significant magnetic, electrical, cryogenic, thermal and chemical energies associated with some designs.

Recent IAEA work identifies proportionality, a graded approach, technology neutrality and the preservation of established safety principles as common elements of an effective framework. It also recognises that these objectives may be delivered through different legal architectures, including existing nuclear-facility regulation and regulatory systems for radiation sources and industrial installations[48-51].

This chapter surveys the current position in China, the EU, Japan, the UK and the US. It examines the authorities and legislation currently applicable to fusion, the regulatory pathways under development and the principal milestones expected to influence the licensing of future experimental facilities and power plants.

Regulatory Frameworks

Table 6.1 summarises the current state of fusion regulation across the five major actors. It captures the principal authority, the current approach and the next significant milestone in the regulatory pipeline. The remainder of this chapter develops each actor profile in detail.

China

China has adopted a hybrid regulatory approach that places fusion within its broader atomic-energy legislation while requiring supervision specifically adapted to fusion's characteristics. The Atomic Energy Law, adopted on 12 September 2025 and in force since 15 January 2026, defines atomic energy as including energy released through fission, fusion and radioactive decay. It also expressly encourages research and technological development in controlled thermonuclear fusion. Most importantly, Article 39 requires the establishment of a supervisory and management system suited to the characteristics of controlled thermonuclear fusion and provides for the graded and classified management of fusion fuels and fusion devices or facilities[59].

An initial operational framework for radiation-safety regulation was already established before the law entered into force. In April 2025, the Ministry of Ecology and Environment issued its Notice on Matters Concerning the Radiation Safety Management of Fusion Devices. The Notice recognises that the radiation risks of fusion devices differ from those of conventional fission reactors and particle accelerators. It places fusion devices under the Ministry's radiation-safety supervision by reference to the framework used for nuclear-technology applications, requires radiation-safety licences and environmental-impact assessment, and introduces graded treatment according to the type and radiation risk of the facility[60].

Taken together, the Atomic Energy Law and the 2025 Notice show that China is not simply applying the conventional fission-reactor licensing regime to fusion. Instead, it combines a comprehensive atomic-energy legal foundation with a specialised, risk-differentiated regulatory pathway. The existing arrangements provide an operational basis for the supervision of experimental fusion devices, while Article 39 establishes the legal basis for the further development of requirements appropriate to larger experimental facilities and future fusion-energy applications[59-60].

The framework nevertheless remains under development. The published instruments do not yet set out a complete project-lifecycle regime covering all aspects of the siting, design approval, construction, commissioning, operation and decommissioning of future commercial fusion plants. Further implementing provisions and project-level regulatory practice will therefore be needed as Chinese fusion programmes progress towards larger deuterium–tritium experiments and energy-producing facilities. China's position is consequently best described as having a clear statutory and radiation-safety foundation, with the detailed commercial licensing framework still evolving.

Actor	Principal Authorities	Current Approach	Next Milestone
China	Ministry of Ecology and Environment / National Nuclear Safety Administration and other competent authorities	Atomic Energy Law explicitly includes fusion and requires specialised, graded oversight; the 2025 radiation-safety notice establishes the initial treatment of fusion devices	Detailed licensing, inspection and implementing rules
EU	National competent authorities; European Commission and ENSREG at EU level	Member State licensing under national radiation-protection, environmental, industrial-safety and, where relevant, nuclear law; common Euratom baseline; ITER licensed under the French nuclear-installation framework	ENSREG assessment and recommendations on application and coordination of existing frameworks
Japan	Cabinet Office coordination; NRA and other authorities under the applicable legislation	2025 Basic Approach establishes principles for graded and scientifically proportionate regulation, building on existing radiation-source and radiation-generating-equipment rules	Detailed legal responsibilities and project-level implementing requirements
UK	Health and Safety Executive (HSE) & Environment Agency	Existing health, safety and environmental regulation; Energy Act 2023 excludes fusion facilities from nuclear-site licensing	Consultation and eventual designation of NPS EN-8; further planning and market arrangements
US	US Nuclear Regulatory Commission (NRC) & Agreement State Regulators	Byproduct-material licensing under 10 CFR Part 30; fusion status codified by the ADVANCE Act; proposed fusion-machine rule and guidance	Final NRC rule and NUREG-1556 Volume 22 guidance

Table 6.1 — Comparison of Current Fusion Regulatory Approaches (status as of May 2026)

European Union

The EU's fusion regulatory architecture reflects the division of responsibilities established by the Euratom Treaty. Licensing and supervision of individual facilities are carried out by national competent authorities, while Euratom legislation establishes common requirements in areas including radiation protection. There is no single EU licensing procedure for fusion facilities, but this does not mean that fusion is unregulated at EU or Member State level. Facilities are licensed under the applicable national radiation-protection, environmental, industrial-safety and, where relevant, nuclear legislation, within the common baseline provided by EU law[60].

France provides the most developed practical example. ITER is licensed as French basic nuclear installation INB No. 174 and is supervised by the French Authority for Nuclear Safety and Radiation Protection, ASNR[57]. The French approach demonstrates that an established nuclear regulatory framework can be applied to a fusion facility while individual requirements are adapted in accordance with the facility's design and hazards.

In April 2026, ASNR excluded the ITER vacuum vessel from the specific regulatory regime applicable to nuclear pressure equipment[58]. This decision did not remove ITER or the vacuum vessel from nuclear safety oversight. Rather, it recognised that the vessel's principal design loads arise from electromagnetic and other fusion-specific effects rather than internal pressure. ASNR continues to require ITER Organization to define and justify appropriate technical requirements under the regulations applicable to basic nuclear installations.

At EU level, ENSREG decided to establish a Task Force on Fusion Energy, whose membership and terms of reference were endorsed in March 2026[62]. The Task Force is examining the applicability of existing European frameworks, the potential value and timing of additional EU action, and areas in which greater coordination among national regulators could improve consistency and regulatory effectiveness.

Several Member States are also developing national policy. Germany's 2025 Fusion Action Plan includes work towards an appropriate regulatory environment for future fusion facilities[63]. Italy is considering fusion as part of a broader draft enabling law on sustainable nuclear energy. The government bill, presented to Parliament in October 2025, would empower the government to develop a comprehensive framework covering both sustainable nuclear technologies and fusion, but has not yet been enacted[64].

The EU approach should therefore be understood as a combination of existing national licensing capability, binding Euratom requirements and developing regulatory coordination. The central question is not whether a framework exists, but how far greater convergence would improve predictability for developers while preserving Member State responsibilities and the ability to apply requirements proportionately to different fusion technologies.

Japan

Japan's Basic Approach to Ensuring Safety for the Realisation of Fusion Energy, adopted by a Cabinet Office-led process in March 2025, sets out the principles that should guide the development of future safety arrangements[65]. It calls for safety to remain the overriding priority, for requirements to be scientifically justified and proportionate to the risks of different fusion devices, and for early consideration of safety during technology development.

Under Japan's current legal structure, fusion is included within the broad concept of atomic energy but fusion devices do not fall within the statutory definition of a fission reactor. Existing experimental devices may instead be regulated as radiation-generating equipment under the RI Law. The Basic Approach identifies these existing arrangements as an important starting point while recognising that future pilot plants may require additional measures as their designs, tritium inventories and potential accident consequences become clearer.

Japan therefore shares the UK and US emphasis on avoiding automatic application of the fission-reactor licensing regime. However, detailed project-level requirements and the final allocation of responsibilities among the relevant authorities remain under development.

United Kingdom

The UK was among the first actors to clarify formally that fusion energy facilities would continue to be regulated through the existing health, safety, environmental and radiation-protection framework rather than through the nuclear-site licensing regime applicable to fission installations. The government confirmed this approach following its 2021–2022 consultation on fusion regulation[52]. Section 156 of the Energy Act 2023 subsequently placed the distinction in primary legislation by excluding fusion energy facilities from the nuclear-site licensing requirements of the Nuclear Installations Act 1965 and defining the term "fusion energy facility"[53].

Safety oversight rests principally with the Health and Safety Executive, while environmental permitting is undertaken by the relevant environmental regulator. Other requirements—including planning permission, safeguards and security arrangements for radioactive materials, and conventional industrial regulation—continue to apply through the competent authorities. The UK approach therefore does not remove fusion from regulation; rather, it applies existing regulatory systems according to the specific hazards and activities of the facility.

The UK Fusion Strategy published in March 2026 builds on this legal foundation and identifies several additional policy measures intended to support future deployment. These include engagement with the insurance sector on proportionate cover for fusion facilities and the development of arrangements through which fusion electricity could participate in the energy market. These measures remain under development and are distinct from the health, safety and environmental framework already in force[66].

The government published the draft National Policy Statement for Fusion Energy Generation, EN-8, in June 2026[67]. EN-8 concerns planning and development consent rather than radiological safety licensing. It is intended to provide a dedicated planning-policy framework for nationally significant fusion energy infrastructure in England and Wales and remains subject to public consultation, parliamentary scrutiny and final designation.

Under the current statutory thresholds, fusion energy infrastructure expected to generate more than 50 MW in England or 350 MW in Wales may qualify automatically as nationally significant infrastructure. Smaller facilities may proceed through other planning routes, while certain projects may be directed into the nationally significant infrastructure regime where appropriate. EN-8 consequently complements, rather than replaces, the existing safety and environmental regulatory framework.

United States

In April 2023, the US Nuclear Regulatory Commission approved a limited-scope rulemaking to establish a regulatory framework for fusion machines by augmenting its existing byproduct-material framework under 10 CFR Part 30. The Commission chose this route rather than applying the reactor-licensing regimes in 10 CFR Parts 50 and 52, reflecting its assessment that fusion machines should be regulated according to their particular radioactive-material hazards rather than automatically as fission reactors[54].

Congress subsequently reinforced this approach through section 205 of the ADVANCE Act of 2024. The Act introduced a statutory definition of "fusion machine" and amended the definition of byproduct material in the Atomic Energy Act to include radioactive material produced through the operation of a fusion machine[54]. This provides the legal basis for licensing the possession and use of fusion-machine-produced radioactive material through the national materials regulatory system.

On 26 February 2026, the NRC published its proposed rule, *Regulatory Framework for Fusion Machines*, together with draft programme-specific licensing guidance in NUREG-1556, Volume 22[56]. The proposed framework is intended to be technology-neutral and to accommodate different fusion configurations without prescribing a particular machine design. The accompanying guidance identifies the information expected from applicants seeking possession licences for fusion machines and explains how NRC reviewers would assess those applications. The rule and guidance remained in draft form at the chapter's cut-off and should not yet be described as final requirements.

Licensing responsibility may rest either with the NRC or with an Agreement State. Under section 274 of the Atomic Energy Act, the NRC may transfer authority over specified categories of radioactive material to states operating regulatory programmes that the NRC has found adequate and compatible. The proposed rule records that 38 of the 39 Agreement States have assumed authority over the category of byproduct material that includes fusion-machine-produced radioactive material. In those jurisdictions, the relevant state regulator would generally oversee the possession and use of that material, while the NRC would retain authority where it has not been transferred[68].

This arrangement is already relevant to commercial projects. Massachusetts regulates radioactive-material activities associated with Commonwealth Fusion Systems' SPARC facility, Tennessee is working with Type One Energy on the proposed Infinity facilities, and Washington State oversees relevant activities associated with Helion Energy. The Agreement State system is therefore not a new delegation created specifically for fusion, but an established federal–state structure through which the fusion framework will be implemented in many locations[68].

Once finalised, the NRC rule and associated guidance would provide a consolidated fusion-specific framework for licensing and oversight of byproduct material associated with fusion machines. They would not constitute a single licence covering every aspect of a project: environmental review, occupational safety, construction, electricity-market requirements and state or local land-use controls would continue to apply through the relevant authorities.

The Fusion Regulatory Timeline

Figure 6.1 summarises the principal milestones in the development of fusion regulation across the five actors between 2022 and 2027. The milestones are not directly equivalent. Some establish primary legal authority, such as the UK Energy Act, the US ADVANCE Act and China's Atomic Energy Law; others concern regulatory policy, implementing guidance, planning arrangements or coordination between competent authorities. The timeline should therefore be read as an overview of the development of the different national and regional frameworks, rather than as a ranking of regulatory maturity.

The period since 2022 has nevertheless seen a marked acceleration in activity. The UK confirmed its decision to regulate fusion through the existing health, safety, environmental and radiation-protection framework and placed the exclusion of fusion facilities from the nuclear-site licensing regime in primary legislation through the Energy Act 2023[52-53]. In the US, the Nuclear Regulatory Commission decided in 2023 to develop a fusion framework under its existing byproduct-material regime, an approach subsequently codified by the ADVANCE Act 2024. The NRC published its proposed fusion-machine rule and draft licensing guidance in February 2026, with finalisation expected following consultation and regulatory review[54-56].

China has followed a different institutional route. Its Atomic Energy Law, adopted in 2025 and in force since January 2026, explicitly includes controlled thermonuclear fusion and requires a supervisory system adapted to its characteristics[59]. This builds on the Ministry of Ecology and Environment's April 2025 notice establishing initial radiation-safety requirements for fusion devices[60]. Detailed implementing and project-lifecycle arrangements will continue to evolve as Chinese programmes progress towards larger experimental and energy-producing facilities.

Japan's March 2025 Basic Approach established the policy principles for a graded and scientifically proportionate fusion-safety framework[65]. Japan has not created a wholly separate fusion statute; instead, it is examining how existing rules for radioactive isotopes and radiation-generating equipment should apply to current facilities and what additional provisions may be required for future pilot plants. The Basic Approach is therefore an important policy milestone, while detailed project-level arrangements remain under development.

Europe's timeline reflects its multilevel regulatory structure. Fusion facilities are already subject to national regulatory systems and the common requirements established by Euratom legislation[61]. France's licensing and continuing supervision of ITER as basic nuclear installation INB No. 174 provides the most developed practical European example of applying an existing nuclear framework to fusion[57]. The April 2026 ASNR decision concerning the ITER vacuum vessel further demonstrates how individual technical requirements can be adapted where justified by fusion-specific design characteristics, without removing the facility from nuclear-safety oversight[58].

At EU level, ENSREG's decision to establish a Task Force on Fusion Energy, followed by the endorsement of its membership and terms of reference in March 2026, marks the beginning of a more coordinated examination of the existing European framework[62]. The Task Force is expected to assess where current national and EU arrangements are already adequate and where greater convergence, guidance or future EU-level action could improve regulatory consistency and predictability. This work builds on existing Member State competence and practical regulatory experience rather than starting from an absence of regulation.

The UK's draft National Policy Statement for Fusion Energy Generation, EN-8, published in June 2026, represents a further planning-policy milestone[67]. It should be distinguished from the UK's safety and environmental regulatory framework, which is already in force. Similarly, the NRC's proposed rule in the US concerns the licensing and oversight of fusion-machine-produced radioactive material and does not replace the other federal, state and local approvals applicable to a fusion project.

Taken together, the timeline shows convergence around common regulatory principles—proportionality, graded requirements, technology neutrality and protection of workers, the public and the environment—but continued diversity in legal architecture. The UK and US have established clear pathways outside the licensing regimes used for fission reactors; China combines comprehensive atomic-energy legislation with specialised fusion provisions; Japan is adapting its existing radiation framework; and the EU combines national licensing competence, Euratom requirements, practical experience through ITER and developing coordination through ENSREG.

The next phase will be less about establishing high-level policy positions and more about their practical implementation. Detailed licensing guidance, project-level regulatory engagement, internationally recognised codes and standards, and experience from the first commercial-scale facilities will determine how effectively the different frameworks support innovation while maintaining proportionate and robust safety oversight.

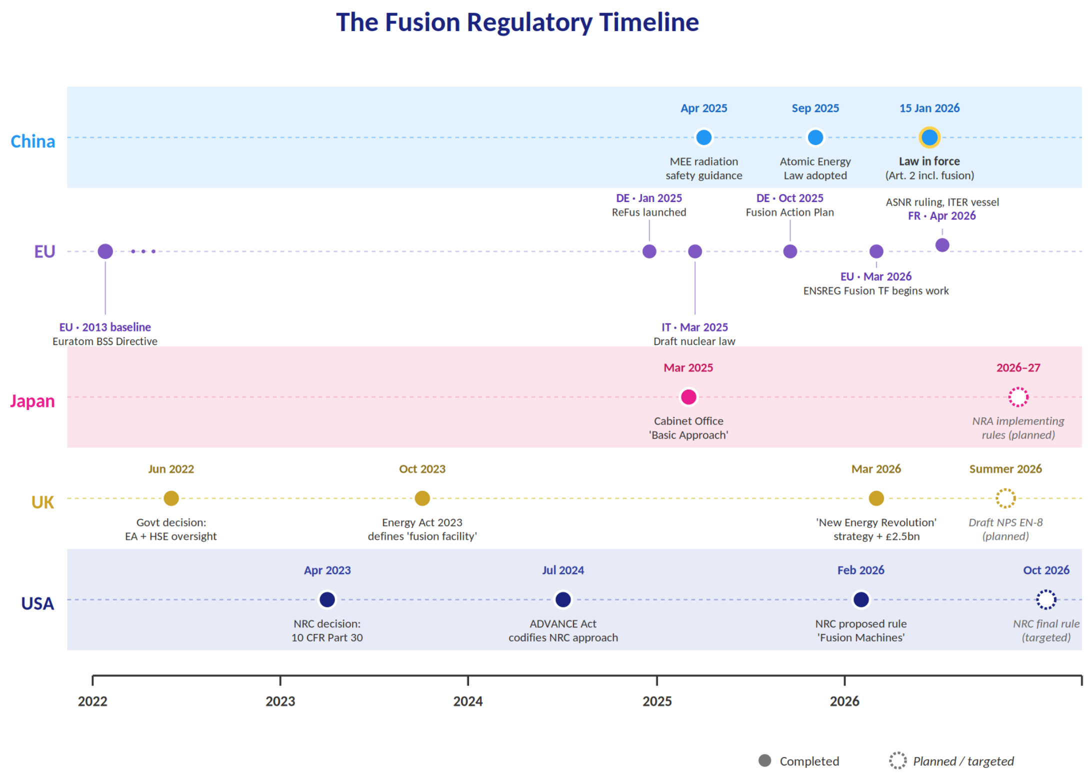


Figure 6.1 — Indicative timeline of selected fusion regulatory and policy milestones across the five actors from 2022–2027. Solid markers indicate completed milestones; outlined markers indicate planned or targeted milestones

Key Takeaways
The Fusion Regulatory Landscape

- **Convergence concerns regulatory principles, not a single legal model.** All five actors are moving towards graded and risk-proportionate treatment, but some use radiation or industrial frameworks while others adapt existing nuclear or atomic-energy legislation.
- **The EU already has an operational regulatory foundation.** Facilities are licensed by national authorities within the Euratom legal baseline. The absence of a central EU licensing authority should not be confused with an absence of regulation.
- **France demonstrates the adaptability of existing nuclear regulation.** ITER is licensed as a French basic nuclear installation, while ASNR has adjusted individual technical requirements when justified by fusion-specific design characteristics.
- **The UK and US have established clear non-fission pathways.** The UK relies on health, safety, environmental and radiation-protection regulation, while the US uses its byproduct-material framework through the NRC and Agreement States. Detailed planning and licensing guidance continues to evolve.
- **China and Japan have established important foundations, but implementation remains central.** China is developing detailed rules under its Atomic Energy Law, while Japan is translating its 2025 safety principles into practical regulatory arrangements.
- **International coordination will become increasingly important.** Common safety objectives, terminology, codes and regulatory expectations could reduce unnecessary divergence while allowing each jurisdiction to retain its chosen institutional architecture.

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Annex 1

Description of the Methodology Used in the Report

This report draws on data compiled by the F4E Fusion Observatory, covering the period 2022–2025 for funding analysis and cumulative records for patents, publications, and device inventories.

Actor Files

Each Actor File includes a comparative profile — a radar chart placing the five actors on a common 0–1 scale across the five quantitative dimensions compared throughout this report: Public Funding (state funding including ITER in-kind contributions), Private Funding (private capital raised), Publications (scientific output volume), Patents (alive fusion patent families) and Fusion Activity (the active-device base).

Each axis reproduces the index defined in the relevant chapter — the Public and Private Funding Indices (Chapter 2), the Publication Index (Chapter 4), the Patent Index (Chapter 5) and the Fusion Activity Index (Chapter 3). The normalisation is identical throughout and is applied in two equivalent steps: each actor's raw value is divided by the largest such proportion in the group. This yields a 0–1 scale on which 1 denotes the leader on that dimension, with other actors placed in proportion.

Funding (Chapter 2)

National public-funding totals include ITER in-kind contributions managed by each member's Domestic Agency. Readers should note that data coverage and definitional consistency vary across countries, and the figures presented should be treated as best available estimates rather than audited statistics.

Funding data cover the 2022–2025 period and are disaggregated into three channels:

- **Public to Public:** direct public institutional funding for national laboratories and state-controlled projects;
- **Public to Private:** public investment channelled into commercial fusion enterprises;
- **Private to Private:** privately raised capital invested in fusion companies.

Cash contributions paid by ITER members directly to the ITER Organization in Cadarache are reported as a separate stream. Even if a proportion of this funding returns to members via contracts placed by ITER the value of these is unknown. The data sources and reconstruction methods vary by actor and are described below.

All values are expressed in nominal euros. Non-euro figures are converted using annual average exchange rates from a single specified source. Fiscal-year data are attributed to the calendar year in which the fiscal year ends. No inflation adjustment is applied.

China

Funding estimates for China combine four distinct fiscal streams: (i) departmental budgets of the Hefei Institutes of Physical Science (HFIPS) of the Chinese Academy of Sciences, which fund ASIPP's domestic facilities (EAST, CRAFT CAS-channel share, CFETR R&D, high-field superconducting magnets, plasma programmes, and the Anhui provincial "Fusion Ignition" major S&T project)[69]; (ii) Annual Final Accounts of the China International Nuclear Fusion Energy Program Execution Center (CN-DA), a MOST-affiliated public institution managing China's ITER participation and the National MCF Energy Development Research Special Programme[70]; (iii) ITER Organization Financial Reports for cash contributions paid directly by the Ministry of Science and Technology to the ITER Organization, which do not pass through CN-DA's budget and are reported separately for cross-actor comparability[71]; and (iv) corporate registration filings and F4E Fusion Observatory previously elaborated data for commercial entities and private investors. Values reported in CNY were converted to EUR using annual average exchange rates.

Two scenarios were constructed to reflect uncertainty. The lower estimate represents a conservative, audit-anchored minimum based primarily on audited or ownership-confirmed figures. The upper estimate reflects maximum plausible public mobilisation when large strategic hybrid projects (CRAFT, Xinghuo) are treated at full reported scale. For cross-actor comparison, the report adopts a midpoint approach. This smooths the effect of uncertainty, avoids relying exclusively on either the most conservative audit baseline or the maximum strategic ceiling, and maintains transparency, as both bounding scenarios remain fully documented for sensitivity analysis.

Treatment of EAST. For 2022–2023, the budget function "Major Scientific Engineering" (code 2060205) does not explicitly name EAST. However, 2024–2025 documents explicitly identify this mechanism as EAST Operation and

Maintenance (O&M), and ASIPP operates no other comparable national engineering facility. Considering the continuity of programme structure and stability of funding levels, the 2022–2023 allocations are therefore attributed to EAST O&M.

Treatment of CRAFT. Two data streams exist: ASIPP annual budget lines (~€105 million cumulative, CAS-channel share) and the SCSP Commission on the Scaling of Fusion Energy estimate ($570 million, ~€481.7 million cumulative since 2023)[71]. The difference likely reflects multi-source funding that includes NDRC infrastructure allocations and provincial co-funding not visible in CAS departmental budgets. The lower estimate uses ASIPP auditable figures; the upper estimate incorporates the full external cumulative estimate, adjusting for overlap.

Treatment of Xinghuo. Total reported project value is approximately ¥20 billion (~€2.4 billion), reported as a 50/50 partnership between a state entity and a private partner[72]. This represents the total planned cost, not necessarily expenditure to date. The lower estimate applies a conservative approximation of the public share (~€500 million); the upper estimate applies the full public half (~€1.2 billion). The private share is mirrored in inward private funding totals.

Treatment of NEO Fusion. NEO Fusion's ownership structure reflects approximately 55% regional public backing (provincial SOEs and government investment arms from Anhui Province), approximately 40% national/central public capital (including CNPC Kunlun Capital and Hefei Science Island / CAS-affiliated public platforms), and approximately 5% private industrial capital (NIO and related investors, post-dilution). The public-to-private classification is adopted because most of the capital originates from public entities.

Treatment of China Fusion Energy Company (CFEC). CFEC was established in July 2025 as a wholly state-owned subsidiary under the China National Nuclear Corporation (CNNC), with ¥15B (~€1.9 billion) in registered capital assembling a consortium of central state-owned enterprises and provincial public investment vehicles. CFEC is included in the public-to-private channel as a state-owned commercial vehicle, consistent with the framework applied to NEO Fusion.

ITER contributions. China's overall ITER engagement comprises (i) in-kind contributions through ITER China, covering domestic procurement contracts placed with Chinese industry and institutions to manufacture ITER components (€431 million cumulative 2022–2025); and (ii) in-cash contributions paid directly by the responsible ministry (MOST / Ministry of Finance) to the ITER Organization (€181 million cumulative). The in-kind stream is included in the Public-to-Public bar in Figure 2.2 (incl. ITER, BA, DONES); the in-cash stream is reported separately in the dedicated ITER column.

Excluded streams. SWIP/CNNC operational budgets (HL-3 operations, non-ITER R&D, ~600 fusion staff) are excluded because CNNC, as a state-owned enterprise, does not publish disaggregated departmental budgets – a known and significant undercount. NSFC and MOST competitive grants outside the National MCF Special Programme are excluded. Provincial funding beyond Anhui (Sichuan, Shanghai) is not disaggregated in published sources.

EU

In the EU public funding for fusion is composed of Member State programmes (national and regional level) and EU-level funding provided via Euratom for Fusion for Energy (F4E) and the Euratom Research and Training Programme for EUROfusion. The estimates used for public funding in this report are calculated by taking the EU financial contribution provided by EUROfusion and adding the proportion of national co-funding provided by participating Member States.

It should be noted that these estimates are likely to represent a lower bound of total public fusion funding in the EU. In practice, Member State contributions included in this calculation generally correspond only to the co-funding required to match the EUROfusion EU programme contribution, rather than the full scope of national fusion investments. Evidence from countries such as Germany, France and Italy suggests that additional domestic funding exists beyond the amounts included in the EUROfusion co-funding mechanism. The figures used should therefore be interpreted as a conservative estimate of EU-level public fusion funding.

ITER, Broader Approach and DEMO. The EU's overall fusion engagement comprises (i) in-kind contributions implemented through F4E, covering procurement contracts, grants and other activities supporting ITER construction, the Broader Approach programme, DEMO-related activities and other fusion projects. These amounts were extracted from the F4E Financial Accounts (2022–2025) and are included in the Public-to-Public bar in Figure 2.2 (incl. ITER, BA, DONES); and (ii) in-cash contributions paid directly to the ITER Organization. The in-cash stream is reported separately in the dedicated ITER column.

Japan

Funding estimates for Japan are derived from four institutional fiscal streams covering FY2022–FY2025 (Japanese fiscal years run April 1 to March 31): (i) audited

Settlement Reports of the National Institutes for Quantum Science and Technology (QST), the MEXT-supervised national R&D agency that manages Japan's ITER Domestic Agency (JADA), operates the Broader Approach activities, and conducts domestic tokamak research at Naka and Rokkasho; (ii) audited segment disclosure of the National Institute for Fusion Science (NIFS) within the National Institutes of Natural Sciences (NINS) Financial Statements, covering helical/stellarator research and Large Helical Device operations; (iii) ITER Organization Financial Reports for cash contributions paid directly by MEXT to the ITER Organization, which do not pass through QST's budget and are reported separately for cross-actor comparability; and (iv) MEXT SBIR Phase 3 grant award announcements, corporate registration filings, and F4E Fusion Observatory data for public-to-private grants, direct equity rounds into Japanese fusion companies, and commercial sector activity. Values reported in yen were converted to euros using fiscal-year average exchange rates.

QST domestic fusion segment. Funding data for the fusion energy research was extracted from the audited Settlement Report of the National Institutes for Quantum Science and Technology (QST) for FY2022–FY2024 and from the approved budget for FY2025[73]. Three domestic public lines are included: Operating Business Expenses, Facility Development Subsidy, and Equipment Subsidy.

NIFS segment funding. Funding data for the National Institute for Fusion Science (NIFS) was sourced from the audited segment disclosure of the National Institutes of Natural Sciences (NINS) Financial Statements[74]. The FY2025 NIFS estimate uses the average of FY2023–FY2024 segment funding (¥7,794 million), with FY2022 excluded as it preceded the 2023 LHD mission transition.

ITER and Broader Approach. Japan's overall ITER engagement comprises (i) in-kind contributions through QST, covering two QST lines — the ITER R&D Subsidy (in-kind procurement contracts with Japanese industry such as Mitsubishi Heavy Industries, Canon Electron Tubes & Devices, and cable/superconductor manufacturers, plus JADA operational costs) and the Advanced Fusion R&D Subsidy (Broader Approach activities at JT-60SA Naka and IFMIF/LIPAc Rokkasho, originating from the 2005 ITER site agreement and classified alongside ITER for consistency with MEXT's own budget presentation), totalling €459 million cumulative 2022–2025; and (ii) in-cash contributions paid directly by MEXT to the ITER Organization without passing through QST (€162 million cumulative 2022–2025). Both QST in-kind streams and the MEXT cash stream are tracked separately from the domestic public-to-public total.

Treatment of additional public channels and exclusions. Several channels were identified but excluded from core auditable totals due to lack of annual drawdown data: Moonshot Goal 10 estimated disbursment[18]; partial SBIR Fusion Phase 3 awards[19]; FY2025 supplementary allocations to MEXT and METI (no material payments occurred within scope); university-based MCF research at Kyoto University, Tohoku University and elsewhere, where fusion-specific budget lines cannot be isolated from university operating grants; NEDO fusion-relevant programmes (no dedicated fusion line). These are documented for completeness but excluded from core totals. Aggregate documented undercount: approximately €45–65 million cumulative, representing a second-order correction relative to the core auditable total of approximately €747 million.

UK

The main sources used are the International Energy Agency (IEA) RD&D Budget Database[75] and the UK Atomic Energy Authority (UKAEA) Annual Report and Accounts 2024/25[76]. The values used for the UK are derived from an average of the figures reported in these two sources. The IEA data represent aggregated national public funding for fusion reported by the UK government on a policy-budget basis. These figures consolidate funding across relevant departments and programmes supporting fusion research and innovation.

The UKAEA Annual Report and Accounts provides institutional-level financial information related to the UK's national fusion programme and the operation of major national facilities. Together, these sources likely capture funding associated with: national fusion research and technology programmes delivered through UKAEA; the operation and development of major facilities such as Culham Centre for Fusion Energy; research and engineering activities supporting the STEP Programme; publicly funded fusion science carried out in collaboration with universities and research organisations; and technology development programmes related to plasma physics, materials, and fusion engineering. However, the available data do not provide full disaggregation between operational funding, capital investment, and project-specific funding. They also do not isolate budgets for individual facilities or programmes, nor do they systematically separate core fusion research from adjacent enabling research areas.

No official data for the UK are currently available for 2025; the 2025 value is therefore estimated as an average based on the three previous years. This estimate is used solely for trend and comparative analysis and does not represent an approved or executed national budget.

US

The main source used is the fusion budget dataset compiled by Fusion Power Associates[77], which tracks US federal appropriations for magnetic confinement fusion (MCF) and inertial confinement fusion (ICF) programmes. These figures represent federal public funding allocated to fusion primarily through the U.S. Department of Energy and its Office of Science, particularly the former Office of Fusion Energy Sciences, and through the National Nuclear Security Administration.

To ensure consistency and accuracy, the MCF figures have been cross-checked against the data presented in the Congressional Research Service report "ITER — An International Nuclear Fusion Research and Development Facility"[78], which also details the US financial contribution to ITER.

The resulting figures therefore likely include federal funding for: plasma physics and fusion science research programmes; operation and upgrades of national experimental facilities; fusion materials and enabling technology development; university-based fusion research supported through federal grants; and national laboratory research activities. The data do not provide detailed facility-level disaggregation, nor do they systematically separate operational, capital, and project-specific funding.

No finalized budget data was available for 2025 at the time this report was compiled; the 2025 value is therefore an estimate based on projections reported by Fusion Power Associates. This estimate is used solely for trend and comparative analysis and does not represent an approved or executed federal budget.

Devices: Capabilities, Performance and the Next Generation (Chapter 3)

Fusion Activity

The analysis is based on an extract of the IAEA Fusion Facility Database (FFDB)[25], which lists fusion facilities by organisation, facility name, configuration, device type, development status, design category and ownership. Each entry was independently verified against device-developer communications, peer-reviewed literature and national-laboratory announcements as of May 2026. In this section "EU" refers to the EU-27; Switzerland (TCV at the Swiss Plasma Center) is therefore not included in the EU count, although the Swiss programme is otherwise an integral part of the EUROfusion roadmap. ITER is excluded from the actor-level comparison because it is an international project that cannot meaningfully be attributed to a single actor.

Devices were allocated to actors manually using organisation name, facility name and known device location. Facility location was used where clear; host-institution location was used for public laboratories and universities; announced device location was used for private companies where this differed from company headquarters. Joint projects were attributed to the host country: JT-60SA to Japan (notwithstanding the EU–Japan Broader Approach contribution), CFQS to China (notwithstanding the joint China–Japan construction).

Device status was taken from FFDB and then re-verified, since the FFDB status field is not always current. Reclassifications applied in this analysis include: FTU (ENEA Frascati) moved from "operating" to "retired" (last fusion-plasma campaign late 2019); LHD (NIFS) moved from "operating" to "closed" (final experiment 25 December 2025); Helion Polaris moved from "planned" to "operating" (running since December 2024); Helion Orion moved from "planned" to "under construction" (site work since July 2025); Helix HARUKA moved from "planned" to "under construction" (Phase 1 components in manufacture); TAE Copernicus marked as "cancelled" (November 2025); First Light Fusion Machine 4 marked as "cancelled" (February 2025). The full device-by-device verification is provided in the supplementary classification spreadsheet.

Active devices are defined as the union of "operating" and "under construction or upgrade". Planned facilities are excluded from the active count even where funding has been committed, because the analysis counts physical infrastructure rather than capital commitments. Examples of devices excluded on this basis include STEP (UK), Proxima Alpha (EU), Pacific Fusion's Demonstration System (US), TAE's Da Vinci (US), Type One Energy's Infinity One and Infinity Two (US), Tokamak Energy's ST-E1 (UK), CFETR (China) and FAST (Japan). All such cases are flagged in the classification spreadsheet for future revisit.

Ownership was taken from FFDB and grouped into public and private categories. Configuration categories were also taken from the FFDB configuration field and grouped into four families: tokamaks (including spherical tokamaks), stellarators / heliotrons, laser / inertial devices, and alternative concepts (mirror machines, field-reversed configurations, reversed field pinches and pulsed-power systems).

The principal limitations of the analysis are that all devices are counted equally regardless of scale, performance, cost or strategic importance; that the results reflect the data cut-off of May 2026 and may not capture subsequent status changes; and that actor allocation required manual judgement in a small number of cases, particularly for private companies with international operations.

Fusion Performance

The analysis uses only openly available sources. Magnetic-confinement data are taken from the IEA-IAEA CICLOP (Coordination on International Challenges on Long duration OPeration) multi-machine database[26]. Pulsed-fusion data are taken from the compilation by Wurzel and Hsu[27]. The analysis does not include unpublished or proprietary results from private fusion initiatives unless those results are available through these open sources.

Figures 3.4, 3.5 and 3.6 all draw on the same CICLOP extract. The triple-product axis shows, for each device or experiment, openly reported time-averaged fusion triple-product values from CICLOP (column W, in units of 10^{20} m^{-3} keV s). The duration axis shows the corresponding high-performance pulse duration. In Figures 3.4 and 3.5 each point represents an individual experiment; in Figure 3.6 each device is represented by a horizontal bar spanning the minimum and maximum reported values, with the gradient within the bar reflecting the density of reported values across the range and an open circle marking the maximum. Actor allocation follows the device-host convention used elsewhere in the chapter: JET is treated as an EU/UK joint device; TFTR, DIII-D as US; JT-60U, LHD as Japan; W7-X as EU (Germany); EAST as China; WEST and Tore Supra as EU (France); JT-60SA as a Japan-EU joint device.

The triple-product and duration values shown for ITER, SPARC, BEST and JT-60SA below the dotted line in Figure 3.6, and as large, outlined markers in Figures 3.4 and 3.5, are projections from device design parameters published by the respective organisations — not openly reported experimental results. ITER is shown in three operating modes (Q = 10 baseline, Q = 5 hybrid, Q = 5 steady-state); BEST in three operating modes; SPARC and JT-60SA each as a single design point.

Pulsed and inertial-confinement results shown in Figure 3.5 are taken from the Wurzel–Hsu compilation. For these experiments the duration axis shows the reported stagnation time τ_{stag}, the brief interval during which the compressed fuel remains near peak conditions. The stagnation time is used as a plotting proxy to display ICF results on the same axes as magnetic-confinement pulse duration but is not directly comparable: it measures the brief peak-compression interval of an imploding target, not the sustained duration of a confined plasma.

The Next Generation: Devices Under Construction or Planned

Figure 3.7 covers fusion devices currently under construction or being planned in the five actors, with ITER shown separately as an international project. The data cut-off is May 2026. Primary sources include the IAEA World Fusion Outlook 2025[79], the ITER Organization Baseline 2024 endorsed by the ITER Council in November 2024[28], the Chinese magnetic confinement fusion roadmap presented by the Chinese Nuclear Society and the Ministry of Science and Technology in 2018[38], the Memorandum of Understanding signed in February 2026 between Proxima Fusion, the Bavarian State Government, RWE and the Max-Planck Institute for Plasma Physics regarding the Alpha demonstrator at Garching[34], Helical Fusion's announcement of the construction site for the Helix HARUKA integrated demonstrator at the National Institute for Fusion Science campus in Toki, Gifu (March 2022[41]), and the Conceptual Design Report for the FAST tokamak issued in November 2025 by Starlight Engine Ltd and Kyoto Fusioneering[42]. Where primary sources do not give a specific year or year range, this has been supplemented from the public communications of the individual device organisations. Industry press (World Nuclear News, Nuclear Engineering International, Xinhua, ANS, Fortune) has been used for corroboration.

Inclusion Criteria

A device is included only when publicly available schedule information exists. A construction-start milestone is shown either (i) when work is already under way (ITER[28], SPARC[32], BEST[33], EHL-2[80], Helix Haruka Phase 1[41], Orion[36]) or (ii) when the responsible organisation has publicly announced a specific construction year or year range (ARC[35], STEP[39], Alpha[34], Infinity Two[37]). An operation-start milestone is shown when the organisation has stated a target date for first plasma, first electricity to the grid, or net energy demonstration, as appropriate to the device's purpose.

Several devices appear only with their operation-start milestone because their organisations have not yet announced a specific construction-start year. This applies to Stellaris (Proxima Fusion)[34], LightHouse pilot (Focused Energy), GIGA (Gauss), Da Vinci (TAE Technologies), ST-E1 (Tokamak Energy)[40], HH170 (Energy Singularity), CFETR Phase I[38] and FAST[42].

Where date ranges are asymmetric around the point year, the point year reflects the organisation's current target and the surrounding range reflects the wider window over which the milestone has been publicly described as plausible. FAST is illustrative: a point year of 2034 with a 2032–2040 range reflects the developer's "demonstrate fusion electricity in the 2030s" framing combined with the "by 2040" backstop in the Conceptual Design Report[46].

Exclusions

Four categories of device are deliberately excluded from the chart.

- **Enabling facilities** that support future power plants but do not themselves aim to demonstrate fusion energy are not shown. The two most prominent omissions are IFMIF-DONES — the international materials-test neutron source for EU-DEMO, with groundbreaking in May 2025 near Granada, Spain[81] — and DTT, the Divertor Tokamak Test facility under construction at ENEA Frascati, dedicated to power-exhaust solutions for DEMO[82] albeit a fusion device according to the definition used in the chapter.
- **Technology-validation prototypes** whose primary role is to inform the design of a follow-on commercial device are also excluded. This applies to ST80-HTS (Tokamak Energy's spherical-tokamak magnet-integration prototype at UKAEA Culham, build completion 2026)[39] and Infinity One (Type One Energy's stellarator testbed at the TVA Bull Run site in Tennessee)[37].

Notes on specific entries

ITER. The construction-start year shown (2020) refers to the start of tokamak machine assembly, in line with the ITER Organization Baseline 2024. Civil construction at Cadarache started in 2010. The operation-start year shown (2034) corresponds to the Start of Research Operations phase (hydrogen / deuterium plasmas) under the 2024 baseline; full magnetic energy is scheduled for 2036 and first deuterium–tritium plasma for 2039[28].

Helix Haruka. The device is shown as a single integrated entry. Phase 1 magnet manufacturing started in early 2026 following Helical Fusion's site announcement at the NIFS campus in Toki, Gifu[41], with energization tests scheduled for 2027. The chart treats this as the construction-start milestone, while the operation-start milestone (2034) corresponds to the integrated fusion-demonstrator target as framed in the IAEA World Fusion Outlook 2025[79].

Private-sector dates. Dates from private-sector developers reflect company-stated targets and carry higher schedule risk than dates from publicly funded facilities. This is particularly relevant for ARC (CFS)[35], Orion (Helion)[36], Infinity Two (Type One Energy)[37] and ST-E1 (Tokamak Energy)[40], where permitting, site lease and grid-interconnection processes are still in progress.

Scientific Output and Research Impact (Chapter 4)

Scientific publications were retrieved from OpenAlex[83], an open-access scholarly database (consulted in May 2026), via the pyalex Python library[84] (consulted in May 2026). The process followed three phases: retrieval, cleaning, and aggregation.

Retrieval (1950–May 2026). The retrieval combined six complementary query strategies, each designed to capture a different segment of the fusion literature:

1. Tier-1 journals. All papers published in the primary plasma physics and fusion journals — Nuclear Fusion, Physics of Plasmas, Plasma Physics and Controlled Fusion, Fusion Engineering and Design, Fusion Science and Technology, and related titles.
2. Magnetic confinement fusion (MCF) keywords. References among the others to "nuclear fusion", "thermonuclear fusion", "tokamak", "stellarator", "ITER", "DEMO", and the names of major MCF devices (JET, EAST, KSTAR, ASDEX Upgrade, Wendelstein 7-X, and others).
3. Inertial confinement fusion (ICF) keywords. References to "inertial confinement fusion", "National Ignition Facility", "laser fusion", "hohlraum", "target physics", and related ICF terminology.
4. OpenAlex research topics. Papers tagged with fusion-relevant primary topics in OpenAlex's automated topic taxonomy (e.g., "Nuclear Fusion and Plasma Physics", "Magnetic Confinement Fusion", "Inertial Confinement Fusion").
5. Institutional authority list. Papers affiliated with an authoritative list of established fusion laboratories, university plasma physics departments, and international research consortia.
6. Commercial fusion ventures. Papers attributed to any of the 71 commercial fusion companies tracked by the F4E observatory's earlier report on the private fusion sector[11], ranging from established firms (General Atomics, TAE Technologies) to recent start-ups (Commonwealth Fusion Systems, Tokamak Energy, First Light Fusion).

The principal comparative dataset covers the EU-27, the UK, the US, China and Japan. A separate global retrieval check was subsequently undertaken to assess the share of the identified global corpus represented by these five actors.

Cleaning. The raw union of the six queries inevitably captured papers that mention fusion-related terms but address phenomena outside the scope of controlled fusion research. Two filtering steps were applied:

- **Topic exclusion list.** A curated list of 142 OpenAlex research topics was excluded as off-topic — for example, astrophysical plasmas, plasma surface treatment (industrial plasma coating processes), atmospheric discharges (lightning and ionospheric phenomena), and dusty plasma physics.
- **Manual review.** A final pass identified and removed false positives not caught by the topic filter (papers typically using "fusion" in unrelated contexts).

After filtering and quality control, the database comprises 163,010 unique publications and 3,054,914 citations.

Aggregation. Results are disaggregated using fractional counting: for a paper with N affiliated institutions, each institution (and its associated actor) receives 1/N of the credit. A paper co-authored by three institutions therefore counts as one-third of a publication for each. This avoids the over-counting of international collaborations that would arise under whole counting, where each contributor would receive full credit for the same shared paper. Totals are reported across five actors — the US, EU-27, Japan, China, and the UK — consistent with the scope of the analysis.

Fusion approach classification. Each paper was assigned to one of four approach families: Magnetic Confinement Fusion (MCF) — with three device sub-categories for tokamaks, stellarators, and other devices (spherical tokamaks, spheromaks); Inertial Confinement Fusion (ICF); Magneto-Inertial and Pulsed Fusion; and Other Fusion Approaches. Classification used a two-stage process combining title and keyword matching (approximately 125 patterns across six dictionaries) with OpenAlex primary-topic mapping as a fallback for papers whose titles did not name a specific device. Papers matching neither stage were left unclassified and excluded. Shares by actor use the same actor-level fractional counting described above. Of the 100,987 publications (2006–2026), 46,897 (46%) could be assigned to a specific approach; the remaining publications either addressed cross-cutting topics or could not be assigned reliably to a single approach using the classification rules.

The Intellectual Property Landscape (Chapter 5)

Data Sources

The dataset draws on two complementary sources. The primary source is Espacenet[85] (consulted in February 2026), from which all patent families classified under G21B ("Nuclear Fusion Reactors") in the International Patent Classification (IPC) were extracted. The secondary source is the Lens[86] database (consulted in April 2025), used to supplement coverage for a defined list of 33 patenting core private fusion companies tracked by the F4E Observatory — firms known to be active in fusion development but whose patents may not be fully captured under the G21B classification alone (for instance, companies filing in adjacent technology fields). Patent activity is measured at the level of patent families — groups of related filings across multiple jurisdictions protecting a single invention — to avoid double counting.

Geographical Coverage

The primary analysis was conducted for the five selected actors. A subsequent global search using the same general retrieval framework was used to estimate the share of identified worldwide fusion patent families represented by those actors. This coverage check indicated a share of approximately 87%; it was not used to alter the actor-level rankings or technology classifications.

Merge and Deduplication

To identify duplicates between the two databases, records were matched on shared priority application numbers, the most reliable indicator that two publications belong to the same patent family. Priority numbers were normalised prior to matching, as the two databases record them in different formats (e.g. with or without country-code prefixes, separators, and date components).

A secondary check based on publication numbers appearing in family member fields was applied where priority matching was inconclusive. Lens records matched to an existing Espacenet entry were discarded. Lens records with no match — patents from core fusion companies falling outside Espacenet's coverage — were added. For assignee attribution, Espacenet's classification was preserved in all cases of conflict.

Applicant Country

Standard patent databases commonly assign applicant country based on the first filing jurisdiction, which can be misleading: for instance, Tokamak Energy (UK) frequently files first in the US for strategic legal reasons. For patents sourced from Espacenet, a custom methodology was developed instead to identify the applicant country, applying the hierarchy: (1) applicant address where available; (2) inventor address otherwise; (3) first-filing country as a last resort. For patents filed by core fusion companies and sourced from Lens, applicant country was assigned based on the company's country of registration as recorded in the Lens database. To improve precision, the dataset underwent extensive manual review to correct residual misattributions.

Scope of Analysis

A family was classified as "alive" where at least one family member was recorded as a pending application or a granted right still in force at the cut-off. Families for which all known members had expired, lapsed, been withdrawn or been invalidated were excluded. Legal-status information may be incomplete or subject to reporting delays in some jurisdictions.

Technology Categories

Technology categories were derived from the IPC codes assigned to family members. A family could be counted in more than one technology category where multiple relevant codes were present; category totals are therefore non-exclusive.

Annex 2

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