An overview of recent fusion developments

Tomas Lindén

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The number of companies developing fusion is continuing to increase and the funding to the field is growing. Fusion regulation is developing in several countries and some governments are including fusion in their energy strategies. The first fusion power plants are being planned or being built. The first plans for large scale fusion energy deployment have been published. But fusion energy breakeven and fusion gain needs to be demonstrated as well as cost competitiveness in order to demonstrate fusion as an energy source. In order for the fusion industry to develop further an even larger scale of funding is needed as well. Also topics related to fuel cycle, material physics, supply chain, and work force education needs to be further developed.

Contents

Growth of the fusion industry

The Fusion Industry Association (FIA) has surveyed the private fusion companies since 2021.

Table: The growth of the private fusion industry [1]

year	2021	2022	2023	2024	2025
companies	23	31	41	45	53
annual funding (GUSD)	1.9	2.9	1.4	0.9	2.6

The funding to private fusion companies exceeds **10 GUSD** in September 2025.
The median cost of funding a first FPP is **700 MUSD** according to FIA [1].

In 2025 12 companies have raised 200 MUSD or more (9 in 2024) [1, 2]:

- **CFS**[a] (USA, 2018) 2 923 M$
- **ENN** (China, 2006/2017) 550 M$
- **Focused Energy** (Germany, 2021) 200 M$
- **General Fusion** (Canada, 2002) 350 M$
- **Helion Energy** (USA, 2013) 1 000 M$
- **Marvel Fusion** (Germany, 2019) 440 M$
- **Pacific Fusion** (USA, 2023) 900 M$
- **Proxima Fusion** (Germany, 2023) 200 M$
- **Shine** (USA, 2010) 800 M$
- **TAE Technologies** (USA, 1998) 1 300 M$
- **Tokamak Energy** (UK, 2009) 335 M$
- **Zap Energy** (USA, 2017) 338 M$

[a] Commonwealth Fusion Systems

Growth of the fusion industry

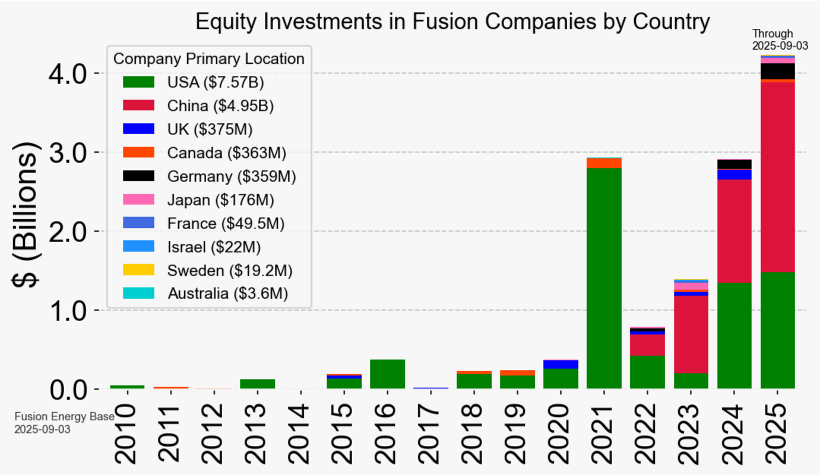


Figure: The equity funding 2010 – 2025-09-03 from the Fusion Energy Base [3].

- The Chinese fusion investments have been estimated to exceed **6.5 GUSD** since 2022 [4]
- A US proposal for a one time **10 GUSD** public fusion investment has been made [4]

Growth of the fusion industry

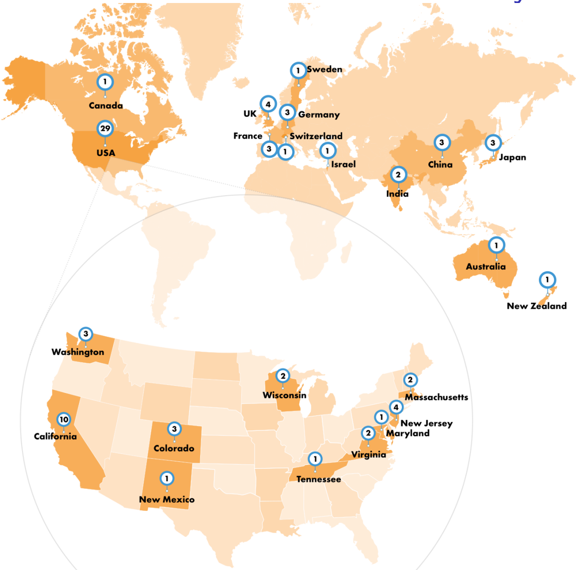


Figure: Locations of the FIA private fusion companies: America 30, Europe 12, Asia 9, Australia + New Zealand 2, from [1].

Growth of the fusion industry

European FIA member fusion companies

- **France**
  - GenF, Elancourt, laser driven ICF, 2024, 8 p
  - Renaissance Fusion, Grenoble, stellarator, 2020, 66 p
  - Undisclosed company in ”stealth mode”
- **Germany**
  - Focused Energy, Darmstadt (also US company), laser ICF, 2021, 90 p
  - Gauss Fusion, Munich, stellarator, 2022, 30 p
  - Marvel Fusion, Munich, laser driven ICF, 2019, 75 p
  - Proxima Fusion, Munich, stellarator, 2023, 100 p
- **Sweden**
  - Novatron Fusion Group, Stockholm, cusp ended mirror, 2019, 70 p
    - *Presented in plenary talk by K. Dunne and P. von Segebaden and parallel talk by M. Airila*
- **Switzerland**
  - Deutelio AG, Grono, magnetic confinement, 2022, 5 p
- **UK**
  - Astral Systems, Bristol, IEC, fission-fusion hybrid, 2021, 20 p
  - First Light Fusion, Oxford, shock-driven ICF, 2011, 80 p
  - Pulsar Fusion, Bletchley, space propulsion, 2011
  - Tokamak Energy, Oxford, spherical tokamak, 2009, 280 p

Growth of the fusion industry

Fusion acceptance in Europe

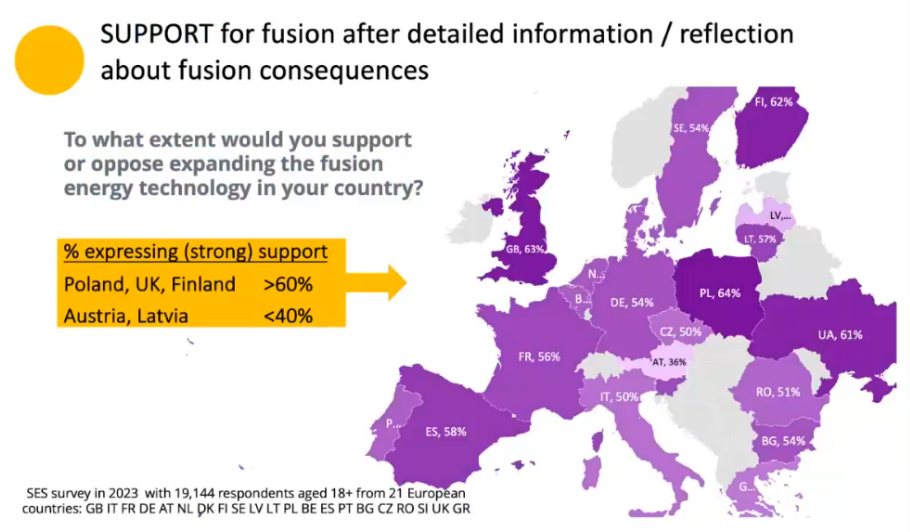


Figure: Fusion acceptance in Europe. Top acceptance: Poland 64 %, UK 63 %, Finland 62 %, Ukraine 61 % from [5].

Fusion regulation

An appropriate risk proportional and predictable fusion regulation is a necessary requirement for the development and deployment of fusion power plants (FPP) [6].

- The **UK** fusion regulators are the Environment Agency and the Health & Safety Executive according to the Energy Act 2023 which became law in October 2023
- The **US** regulator the Nuclear Regulatory Commission (NRC), suggested that fusion will be regulated under the byproducts materials framework and this became law with the Advance Act of 2024. NRC is developing the details of the framework needed for fusion and also for mass manufactured fusion systems [7].
- In the draft **Finnish** Nuclear Energy Act[1] fusion is proposed to be regulated under the Radiation Safety Act
- The **German** government published in October 2025 an Action Plan which states that fusion will be regulated under the Radiation Safety Act and not by the German Atomic Energy Act [8]
- The paper *Towards the EU Fusion Strategy* lists recommendations for fusion regulation as part of preparations for the **EU** fusion strategy [9].
- In **Japan** there is a proposal for fusion devices to fall under the purview of the Act on the Regulation of Radioisotopes and Related Substances [10].

[1] There are talks on Tuesday and Wednesday on the proposed Nuclear Energy Act.

National strategies for fusion energy

Fusion strategies are made in several countries [11]

- The **UK** will invest **2.5 GGBP** over 5 years in the STEP programme. The UK Industrial Strategy (2025) contains fusion energy as a central part [12]
- The **US** has published 2024 a Fusion Energy Strategy 2024 document, [13] and in October 2025 the DOE has published a new national fusion strategy Fusion Science & Technology Roadmap - Build Innovate Grow [14]
- **Japan** has published a strategy on Fusion energy in 2023 and updated it in 2025 [15]
- **Germany** has published the Action plan *Deutschland auf dem Weg zum Fusionskraftwerk* (2025) and will fund fusion research and development with more than **2.4 GEUR** [8]
- Fusion is mentioned in the draft **Finnish** energy and climate strategy document (2025)
- The **EU** is working towards an EU Fusion Strategy

Fusion developments

Fusion power plants sites

- In October 2022 it was announced that Spherical Tokamak for Energy Production (**STEP**) will be built on the West Burton power station site in North Nottinghamshire, UK targeting first operations in the early 2040s
- CFS announced in December 2024 that the first **ARC** high field tokamak 400 MW power plant will be built in Chesterfield County, Virginia, USA and ready in the early 2030s
- In March 2025 **Focused Energy** partnered in a consortium and signed agreement to repurpose a former fission plant into a fusion pilot plant
- Helion Energy announced in July 2025 the start of building its first 50 MW FRC powerplant **Orion** in Malaga, Chelan County, Washington, USA to be completed in 2028
- In September 2025 The Tennessee Valley Authority (TVA) announced that they have issued to Type One Energy a Letter of Intent to build one or more **Infinity Two** stellarator 350 MW fusion power plants at the Bull Run site near Knoxville, Tennessee, USA.

Fusion developments

Figure: A rendering of the ARC tokamak. Picture by CFS.

Fusion power purchase contracts and collaboration agreements

The first three contracts on selling future fusion power have been made:

- **Helion Energy** signed in May 2023 a contract with Microsoft on selling 50 MW of fusion power starting in 2028
- **CFS** signed a contract in June 2025 on selling 200 MW fusion power to Google from its first 400 MW ARC power plant in Chesterfield County, Virginia
- **CFS** signed a 1 GUSD contract in September 2025 on selling fusion power to Eni from its first 400 MW ARC power plant in Virginia in the 2030s

Helion Energy and Nucor Corporation announced in September 2023 an agreement to develop a 500 MWe fusion power plant at a Nucor steel manufacturing facility in the United States.

Large scale fusion energy deployment

The success of fusion energy will depend on developing economically competitive Fusion Power Plants (FPP) that can be mass produced and deployed on a large scale.

- Building a successful FPP needs much more in addition to optimizing the plasma physics performance of the device [16].
- The market penetration of fusion energy as a function of the cost of fusion energy has been studied by the MIT Energy Institute [17]. The same model has been run for a global scenario and included in the IAEA World Fusion Outlook 2025 [11].
- Helion Energy has published papers outlining the requirements to be able to deploy mass produced FPPs on a large scale [18, 19].
- A successful rapid rollout of fusion power requires resolving issues related to fuel cycles, material physics and a skilled workforce.
- The rate of deployment of fusion power will also depend on the supply chain and special materials as discussed in the FIA Supply Chain 2025 report [20].

Fusion triple product overview

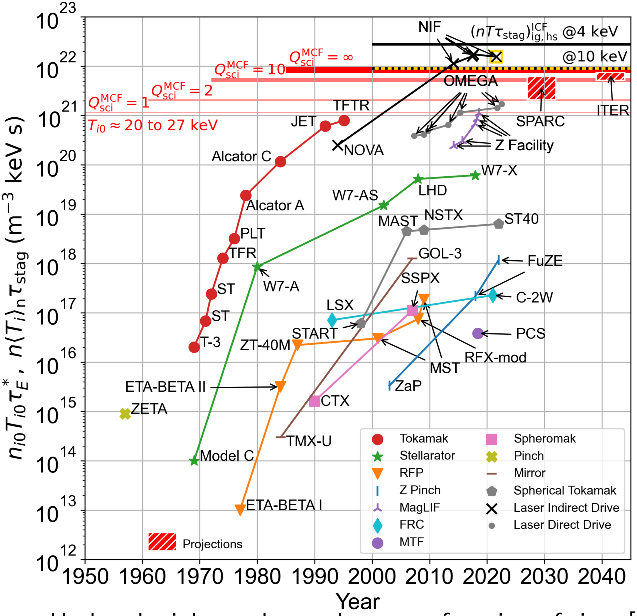


Figure: Updated triple product values as a function of time [21].

Fusion triple product overview

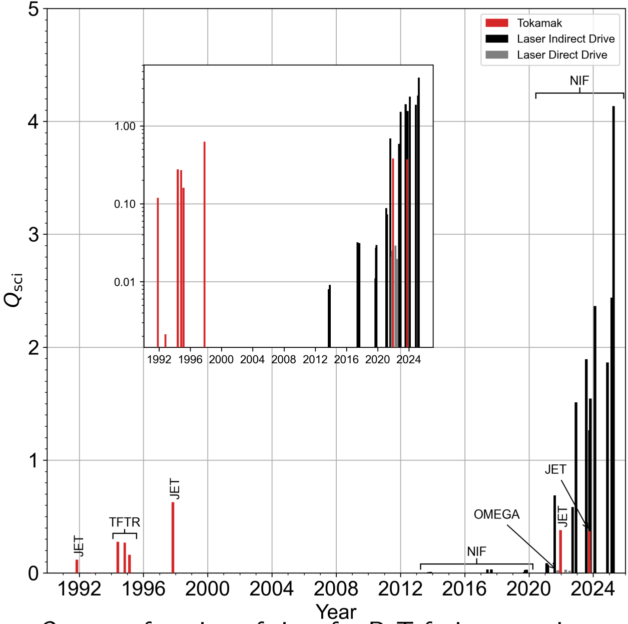


Figure: Q_{sci} as a function of time for D-T fusion experiments [21].

Scientific break even targeting devices

Table: Experiments built to achieve "near term" scientific break even (BE), Q$\geq$ 1. The planned schedules might change due to plasma physics, technological or financial reasons

Organization	**Experiment**	**Built**	**Concept**	**Projected BE year**
Helion Energy	Polaris	2024	FRC (D-^{3}He)	2025
General Fusion	LM26	2024	MTF	2026
CFS[2]	SPARC	2026	Tokamak	2027
Neo Fusion[3]	BEST	2027	Tokamak	2027 [4]
Zap Energy	FuZE-Q	2021	Z-pinch	by 2027
TAE Technologies	Copernicus	2027	FRC (p-^{11}B)	before 2030

[2] Commonwealth Fusion Systems

[3] Institute of Energy, Hefei Comprehensive National Science Center

Helion Energy

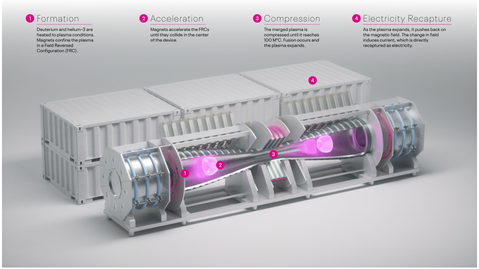


Figure: A schematic figure of a Helion Energy FPP. Picture Helion Energy.

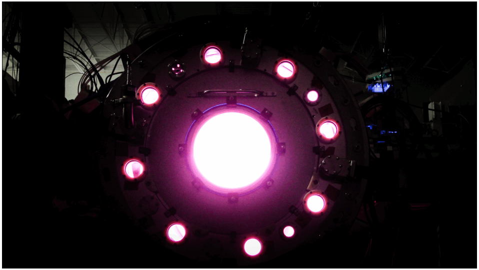


Figure: Endview of Polaris. Picture Helion Energy.

Helion Energy

- HE reported in 2020 for the previous device Trenta:**T_t=9 keV**, 7 T
- Polaris is a 50 MW FPP prototype with 3800 diagnostic channels
- First plasma in the 19 m long Polaris experiment was in 2024
- The Polaris goals are $f_{pulse} > 0.1$ Hz and a magnetic field >15 T to demonstrate electricity production with it
- D-D, D-T and D-^{3}He reactions will be studied with Polaris
- Helion Energy possesses more than 2 g of tritium
- The energy of the Polaris condensator banks energy is $\geq$ 50 MJ
- HE can produce some FPP parts like condensators
- HE got **425 MUSD** of new funding in January 2025
- Experiments with Polaris are being made
- Helion Energy has published a paper showing advantages of the D-^{3}He reaction in a high β FRC-reactor [22]
- There FRC-plasmas are studied and simple FRC-models are used to compare D-T- and D-^{3}He-reactions at low and high β-values
- Helion Energy has published on arXiv a paper on *Hybrid simulations of FRC merging and compression* [23]

General Fusion

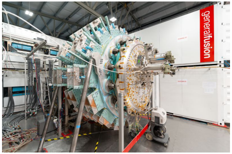


Figure: The Lawson Machine 26 (LM26) MTF demonstration machine. Figure General Fusion.

General Fusion uses a D-T MTF concept where hundreds of steam pistons compress a spherical tokamak inside a molten Li liquid .

- GF plans a $P = 150$ MW_e, $f \approx 1$ Hz reactor
- LM26 is meant for de-risking building the Fusion Demonstration Plant
- The LM26 temperature goals are 1 keV, 10 keV and ultimately Q=1 equivalent [24]
- LM26 consists of the PI3 plasma injector and magnets compressing a solid lithium ring compressing the plasma
- The first LM26 plasma compression shots have been made
- A Savannah River National Laboratory General Fusion INFUSE paper gives a TBR of 1.4 (LiPb) and 1.8 (Li) [25]
- The corresponding plant doubling times are 56 and 67 days
- The 2018 PCS-16 explosive compression test results have been published [26]
- GF got **22 MUSD** in August 2025 in their latest funding round

Commonwealth Fusion Systems

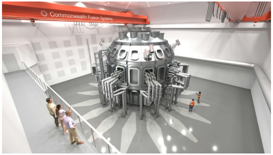


Figure: SPARC, picture by CFS.

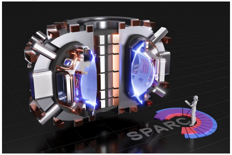


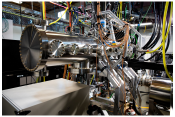
Figure: SPARC core, picture by CFS.

- CFS has built a HTS magnet factory in Devens
- CFS is building magnets also for WHAM compact mirror experiment by Realta Fusion and University of Wisconsin Madison and has a license agreement with Type One Energy on HTS magnet technology
- **SPARC** will be a strong field HTS demonstration tokamak for CFS
- SPARC 100 MW_{th}, to be completed in 2026, initially Q>2 [27, 28]
- CFS got **863 MUSD** new funding in August 2025 to complete SPARC and for building ARC
- Affordable, robust, compact (**ARC**), a strong field HTS tokamak
- ARC - commercialization, Q>10, $P_e \approx 400$ MW, early 2030s

Neo Fusion

Neo Fusion in connection with the Institute of Energy, Hefei Comprehensive National Science Center builds:

- Burning plasma Experiment Superconducting Tokamak (**BEST**)
- BEST is a strong field tokamak designed for Q=1–5 [4]
- Operations for the 1 GW device are planned to start in 2027



Zap Energy

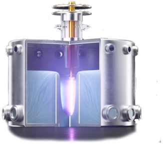


Figure: FuZE-Q, picture by ZE. Figure: SFS Z-pinch 4m high core, picture by ZE.

- ZE develops the sheared flow stabilized Z-pinch, $E_{fusion} \propto I^{11}$ ideally, [29, 30]
- No magnets, simple, low cost, DT fuel, f_{pulse} 10 Hz, 200 MW_{th}, β=1
- Q=1: pinch current 600–700 kA, a reactor would have 1.2–1.5 MA
- FuZE has reached a T_e of 2.25$\pm$0.8 keV [31]
- ZE measurements show isotropic neutron production, which suggests a thermal origin for the neutrons [32]
- Challenges: scaling to larger currents, electrode erosion
- ZE got in July 2024 **130 MUSD** used partly for Project Century for technology developing liquid metal walls, pulsed power and electrode durability [33]
- ZE is using *four different Z-pinches* to speed up research & development: **FuZE-Q**, **FuZE-3**, WEPL-02 (Century) & SIMPL with *a fifth Z-pinch being built*
- ZE has reached the first DoE Milestone-Based Fusion Development Program goal of producing $>$ 1000 at least 100 kA Z-pinch discharges for 3 hours without problems in a liquid metal walled container with a liquid metal wetted electrode ($\approx$ 0.1 Hz)

TAE Technologies

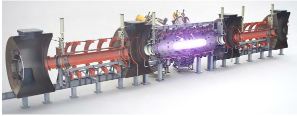


Figure: **C-2W** (Norman), 2017 length 30 m. Picture by TAE.

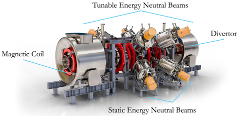


Figure: C-2W (Norm), picture by TAE.

- TAE uses a beam stabilized FRC configuration aiming for $\mathrm{p}^{11}\mathrm{B}$
- D-T, D-^{3}He and D-D reactions could also be used
- Two 500 km/s colliding FRCs produce a FRC
- The FRC is maintained by neutral beams and electromagnetic fields
- C-2W FRC lifetime **40+ ms**, power supply limited
- T_{tot} **6+ keV**, $T_e \leq 1$ keV, density 1–5*10^{19}m^{-3}, B$\leq$ 0.3 T [34]
- In their latest funding round TAE obtained **150 MUSD**
- TAE Technologies has developed a new NBI only FRC creation method simplifying their devices and reducing costs [35, 36]
- C-2W (Norman) has been shortened and reconfigured into Norm
- FRC plasmas in C-2W (Norm) have also been sustained for 40 ms
- **Copernicus** breakeven demonstration, goal T_i 10+ keV hydrogen, 2-3 s pulses
- **Da Vinci** $\mathrm{p}^{11}\mathrm{B}$, prototype FPP, 2030s

Summary

- NIF scientific breakeven has spurred fusion development and especially ICF
- The good W7X results have paved the way for several stellarator projects
- The number of tokamak projects is large due to their good performance
- The Z-machine and MagLIF results have inspired pulsed power concepts
- The increased funding results in several new fusion projects each year
- Several devices built for scientific breakeven are operational or are built
- Some fusion companies can mass produce components and parts for fusion
- Fusion regulation is worked on in several countries and several countries plan to regulate fusion power plants according to Radiation Safety Acts and not according to Nuclear Energy Acts
- To enable fast deployment of mass produced fusion devices licensing models similar to airplanes or medical radiation equipment would be needed
- Fusion is developing fast as states and organizations publish fusion strategies
- It can be anticipated that the development will continue and speed up
- But a lot of work remains in terms of fuel cycles, material research, supply chain and work force education

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