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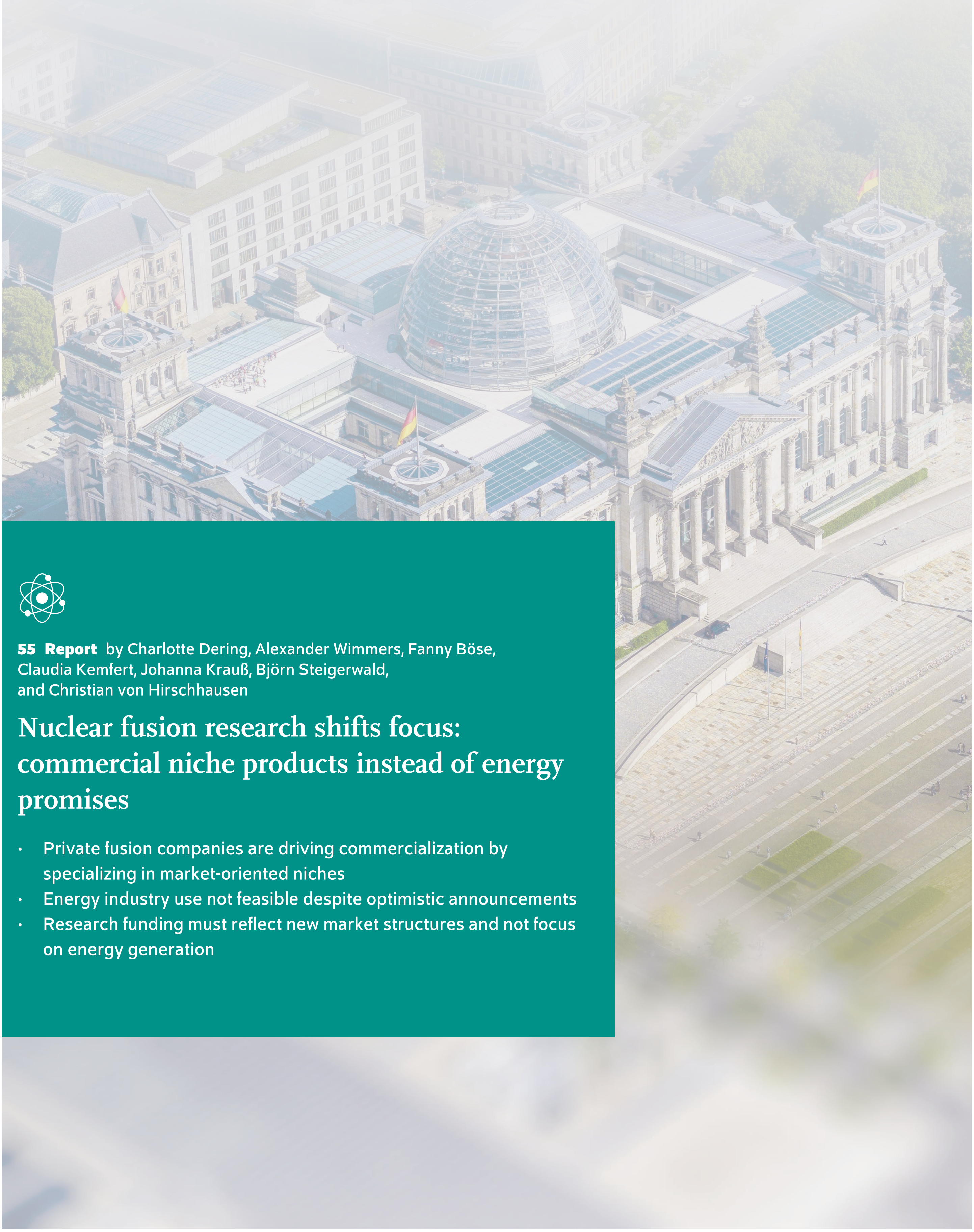

55 Report by Charlotte Dering, Alexander Wimmers, Fanny Böse, Claudia Kemfert, Johanna Krauß, Björn Steigerwald, and Christian von Hirschhausen

Nuclear fusion research shifts focus: commercial niche products instead of energy promises

- Private fusion companies are driving commercialization by specializing in market-oriented niches
- Energy industry use not feasible despite optimistic announcements
- Research funding must reflect new market structures and not focus on energy generation

LEGAL AND EDITORIAL DETAILS

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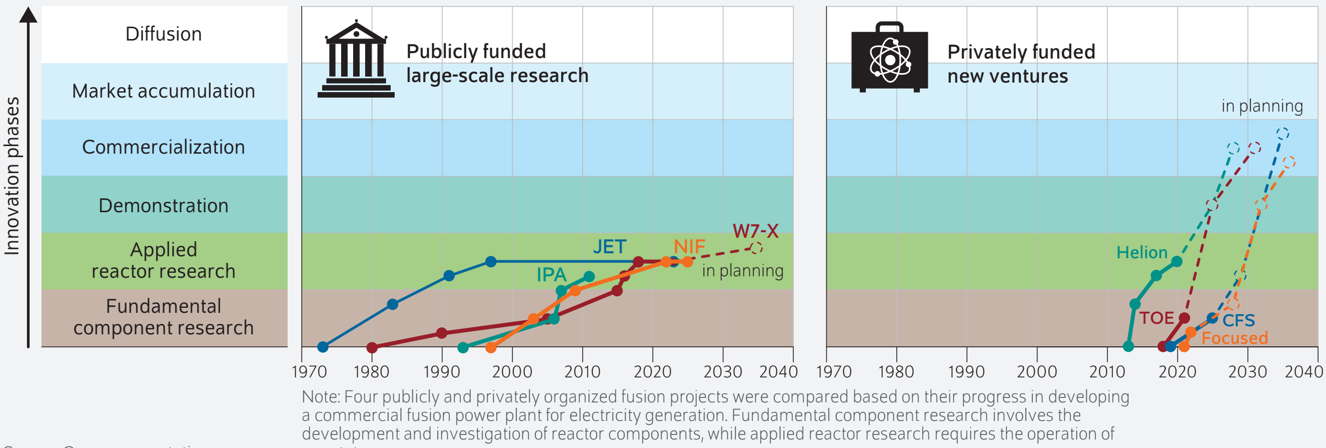
AT A GLANCE

Nuclear fusion research shifts focus: commercial niche products instead of energy promises

By Charlotte Dering, Alexander Wimmers, Fanny Böse, Claudia Kemfert, Johanna Krauß, Björn Steigerwald, and Christian von Hirschhausen

- Privately organized companies are on the rise, but there is also pressure to commercialize research results
- Specialization in market-oriented niches can be observed, for example in magnet development and laser technology
- Case studies on specific fusion projects reveal a significantly changed, application-oriented industrial development
- Despite optimistic announcements, concrete energy-related applications remain highly unlikely
- Research funding must adapt to new developments and should not focus on the use of nuclear fusion for energy generation

Private companies promise commercial fusion energy in a few years, although large-scale research projects remain in the realm of fundamental research



Source: Own representation.

Note: Four publicly and privately organized fusion projects were compared based on their progress in developing a commercial fusion power plant for electricity generation. Fundamental component research involves the development and investigation of reactor components, while applied reactor research requires the operation of a prototype.

FROM THE AUTHORS

"Nuclear fusion will not contribute to energy supply in the foreseeable future—for 70 years, it has been said that it will come 'in a few decades.' In reality, it is about competition for scarce research funds, even within fusion research. Given limited resources, we should set priorities, for example, in energy storage, which is now crucial for the energy transition." — ***Claudia Kemfert*** —

MEDIA

Audio Interview with Christian von Hirschhausen (in German)
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Nuclear fusion research shifts focus: commercial niche products instead of energy promises

By Charlotte Dering, Alexander Wimmers, Fanny Böse, Claudia Kemfert, Johanna Krauß, Björn Steigerwald, and Christian von Hirschhausen

ABSTRACT

Nuclear fusion research shifts focus: commercial niche products instead of energy generation. Nuclear fusion, in which atomic nuclei are fused, promises clean, safe, and virtually inexhaustible energy. Since the 1950s, this promise has justified extensive public investment in research, without any real progress being made toward commercial use in the energy sector. However, nuclear fusion research is currently undergoing significant change: while large public research institutions (big science) are unable to progress beyond basic research, private companies are increasingly focusing on subcomponents such as magnet development and laser technology. With the help of an evaluation scheme, the activities of very different private nuclear fusion companies can be compared and conclusions drawn for research and innovation policy. Four companies are examined in terms of their development status and potential. The comparison shows that private companies are increasingly focusing on components and subareas that could be commercially exploited in the short- and medium-terms. In contrast, the expectations for large-scale research extend far beyond the 2050s. Thus, German research policy should not stick to the goal of using nuclear fusion for energy generation, but rather focus on the innovative momentum of private actors while fundamentally evaluating the existing structures of publicly funded large-scale research.

Since the 1950s, nuclear fusion[1] has been envisioned as the energy source of the future. However, despite decades of research, billions in investment, and hopeful political statements—most recently by German Chancellor Friedrich Merz, who described wind energy as a transitional technology to nuclear fusion at the North Sea Summit in January 2026[2] —its use for energy generation remains a distant prospect.[3] For several years now, however, global research into nuclear fusion has been gaining momentum. The development of private companies ("new ventures") in segments of nuclear fusion is being fueled by increased financial investments and in the media, especially due to the involvement of AI companies. The hoped-for potential of nuclear fusion lies in the provision of energy for data centers and the use of AI approaches in reactor development itself.[4] The latest highlight is the announced merger of the company founded by US President Donald Trump, the Trump Media and Technology Group (TMTG), with a new venture from the nuclear fusion industry, TAE in California. At an estimated six billion US dollars, this merger would be three times larger than the largest private sector activity in the fusion industry to date.[5]

For decades, research and development in the field of nuclear fusion was almost entirely dominated by large-scale publicly funded research programs. Since the 1950s, the long-term prospect of using nuclear fusion for energy generation has

1 The fusion of light atomic nuclei into heavier ones releases large amounts of energy, which shall be used in reactors to generate heat and electricity. See Alexander Wimmers et al. (2025) Power Generation from Nuclear Fusion Not Expected in the Foreseeable Future: Applied Research Developing Dynamically. DIW Weekly Report No. 14/15, 89–95 (available online; accessed on February 5, 2026. This also applies to all other online sources in this report, unless otherwise noted).

2 See ntv (2026): Wind power from the North Sea to prevent new dependencies (in German; available online).

3 These hopes have existed for decades, cf. Lyman Spitzer (1958): The Stellarator Concept. The Physics of Fluids 1 (4). 253–64 (available online); Cesare Marchetti and Nebojsa Nakicenovic (1979): The Dynamics of Energy Systems and the Logistic Substitution Model. International Institute for Applied Systems Analysis (IIASA) (available online); and International Atomic Energy Agency (2024): IAEA World Fusion Outlook 2024. International Atomic Energy Agency (available online).

4 See IEA (2024): Energy and AI. International Energy Agency. Paris, France (available online).

5 Currently, the largest private sector activity in the fusion industry is held by Commonwealth Fusion (Massachusetts, USA) with approximately two billion US dollars in capital inflows, cf. Deborah Sophia and Timothy Gardner (2025): Trump Media bets on fusion energy with US-$6 billion TAE deal. Reuters. December 19, 2025 (available online), and Wimmers et al. (2025), ibid.

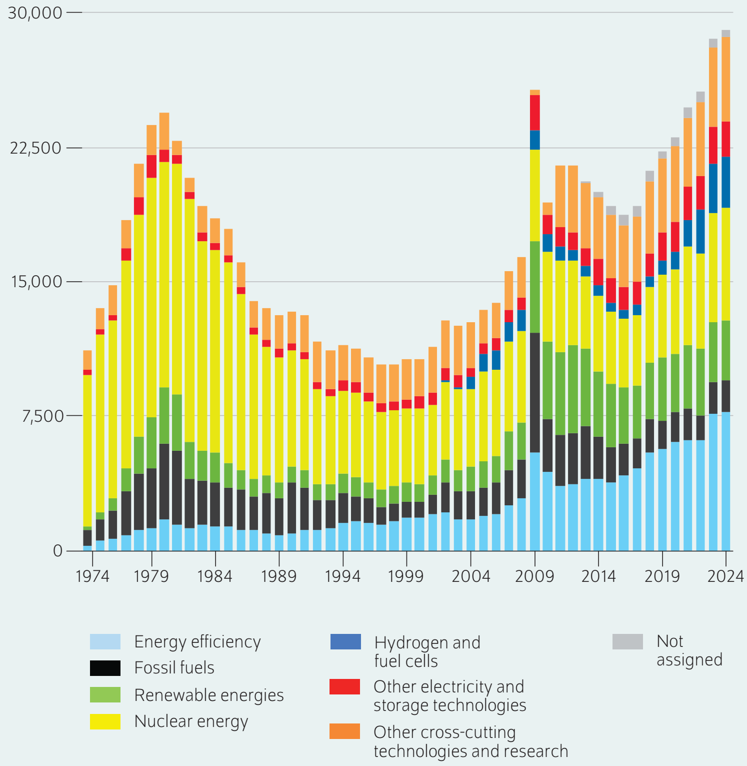
 DOI: https://doi.org/10.18723/diw_dwr:2026-7-1

been a key justification for extensive government investment. The nuclear fusion community's constant promise that cost-effective and infinitely available energy would be available in a few decades even entered the literature as the so-called "fusion constant."[6] For many decades, nuclear fusion (in conjunction with nuclear fission) received the highest level of funding within the energy sector, far ahead of fossil fuels, renewables, or the promotion of energy efficiency measures (Figure 1).

At the European level, major projects such as the Joint European Torus (JET) and, in particular, the ITER project currently under construction have been financed through the EURATOM and EUROfusion funding programs. The EU's 2021–2027 financial framework program earmarked €5.6 billion for ITER alone.[7] In Germany, nuclear fusion research activities will receive comprehensive funding of €2.7 billion over the next few years. This applies in particular to the establishment and long-term operation of large non-university research facilities, such as the Nuclear Research Center in Karlsruhe (now KIT) and the Research Center (FZ) Jülich, as well as the Max Planck Institute for Plasma Physics (IPP) in Garching near Munich. In addition, the German federal government has special programs, such as the "Fusion 2040 Funding Program" and the "Fusion Action Plan" as part of its High-Tech Agenda.[8]

Figure 1

Energy research funding in OECD countries
1974–2024, in millions of US dollars (2022)



Note: Despite the large sums involved, official statistics do not differentiate between nuclear fission and nuclear fusion. For 2014 to 2024, statistics from the International Energy Agency (IEA) based on reports from European-funded member countries show an average ratio of research expenditure on nuclear fusion to nuclear fission of approximately five to two.

Source: IEA Energy Technology RD&D Budgets Data Explorer.

Nuclear energy, including nuclear fusion, received by far the highest subsidies.

Dynamic rise of private-sector new ventures ...

While fusion research and development has long been concentrated in public research institutions, privately organized companies have been increasingly active in this field over the last 20 years. The rise in start-ups is also characterized by the fact that significantly more private capital has been invested in recent years. The funds invested in the private sector now amount to over eleven billion US dollars.[9] The number of privately funded companies in the sector now stands at over 80. This trend is likely to continue intensifying. Most companies included in the statistics come from OECD countries, with the vast majority from the US (Figure 2). The scene is also particularly active in the United Kingdom, Japan, and Germany. The situation in China is less well documented, but considerable research efforts are underway there, too.[10]

New ventures not only differ from large-scale public research in terms of organization but also pursue different development strategies. They formulate more ambitious timetables, rely on alternative fusion concepts, or focus specifically on individual technological components such as magnets or lasers. In contrast, they do not conduct basic research.

... but also exaggerated expectations for upcoming fusion power plants

The increase in private sector activity in the fusion sector in recent years has led to a shift in expectations regarding the commercialization of fusion energy and an increase in

6 According to the fusion constant, the energy breakthrough of nuclear fusion is always 20 to 40 years in the future, cf. Wimmers et al. (2025), ibid. Other prominent examples are Marchetti and Nakicenovic (1979), ibid, and Cesare Marchetti (1976): On Hydrogen and Energy Systems. International Journal of Hydrogen Energy 1 (1), 3–10 (available online) and, more recently, IAEA (2024), ibid.

7 European Commission (2021): Fusion Energy and ITER (available online).

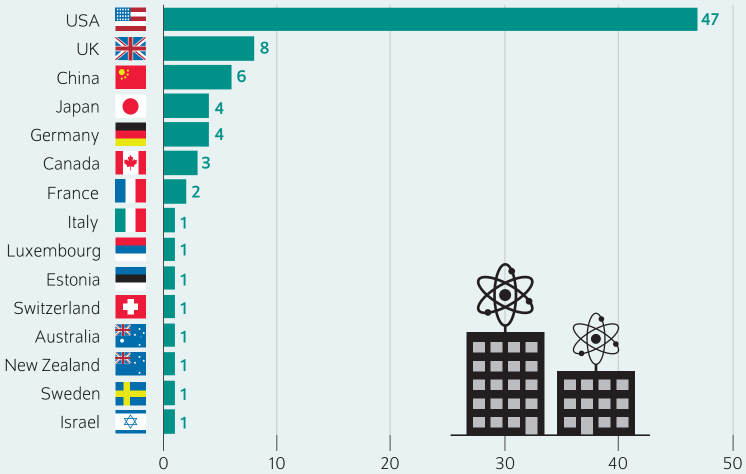
8 In 2023, KIT had a total budget of €1.147 billion, of which €154 million was allocated to nuclear fusion. In addition, there is FZ Jülich with a total budget of €973 million in 2024 and IPP with a budget of approximately €156 million in 2023. The "Fusion 2040 funding program" provides for €370 million, and the "Fusion Action Plan" was planned for the period 2025–2029 with €2 billion.

9 These investments correspond to a compound annual growth rate (CAGR) of approximately 20 percent since 2007. Updated total private investment since 2000, adjusted for inflation in US dollars based on Björn Steigerwald, Johanna Krauß, and Jens Weibezahn (2026): New Ventures in Fusion Energy: Analyzing a Dynamically Emerging Market. In Alexander Wimmers et al. (eds.): Nuclear Power: Technology, Geopolitics, and Economics. Studies in Energy, Resource and Environmental Economics. Springer Nature Switzerland, 395–408 (available online). Current data can be viewed on platforms for new ventures such as Crunchbase (available online).

10 Steigerwald, Krauß, and Weibezahn (2026), ibid.

Figure 2

Regional distribution of private companies ("new ventures") in the field of nuclear fusion
Number of companies



Source: Own research.

More than 80 private companies are working on nuclear fusion topics. The US is strongly dominant.

political responses. A veritable race for the first commercial application has emerged, leading to much hype.[11]

However, given the slow progress in nuclear fusion research in recent decades, these announcements seem irrational, which is why we can speak of a "nuclear fusion paradox."[12] Private companies with relatively little research of their own are announcing commercial power generation as early as the 2030s, whereas large research institutions are only planning for the second half of the century. After Helion Energy, which plans to start supplying electricity in 2028, TAE, has announced the second most ambitious target for commercial energy generation from nuclear fusion, together with TMTG: 2031.

In this dynamic environment, competition has arisen between several German federal states to achieve the "first fusion power plant" within their own borders—first Bavaria,[13] then Hesse,[14] and now also a party in the state parliament of North Rhine-Westphalia.[15] The states of Bavaria, Hamburg, Hesse, Mecklenburg-Western Pomerania, Saxony, and Schleswig-Holstein have now joined forces to form a "fusion alliance" with the aim of enabling a fusion power plant to be built in Germany.[16] By forming this alliance, the federal states hope to attract high-tech companies and expand existing research structures, thereby creating the political symbolism of an "innovative location."[17]

New ventures are to be specifically supported through skilled labor programs, innovation hubs, and suitable locations. This shifts the perceived role of new ventures from exploratory technology developers to supposed implementation actors for a major research policy project.

Although the new hype promises energy-efficient use in the near future, a number of unresolved technical and scientific challenges remain—including the development of heat-resistant materials, reliable fuel production and supply, as well as energy transfer within the potential power plant. This is also the consensus in the literature not directly associated with the fusion research community.[18]

New ventures focus on components

The fusion innovation framework (Box) can be used to compare and monitor large-scale public research projects with private-sector new ventures.[19] Four dominant technology lines in fusion research were identified for the selection of case studies: magnetic confinement fusion, either in the form of tokamak or stellarator concepts, laser fusion, and field reversed configurations (FRC).[20] For each of these approaches, one publicly funded and one private-sector project was selected to provide a comparative overview of the current fusion sector.[21]

The private companies selected are the leading companies in their respective technology line according to financial criteria:[22] Commonwealth Fusion Systems (CFS), Type One Energy (TOE), Focused Energy, and Helion Energy. The large-scale public research projects were selected based on

11 See Dan Drollette (2024): Introduction: Fusion, the next big thing—again? Bulletin of the Atomic Scientists 80, 343–344 (available online); and Jasha Bareis et al. (2023): Technology Hype: Dealing with Bold Expectations and Overpromising. TATuP – Journal for Technology Assessment in Theory and Practice 32 (3), 10–71 (available online).

12 See also the authors' work on the paradoxical role of nuclear energy in energy scenarios, for example in Christian von Hirschhausen et al. (2023): Energy and Climate Scenarios Paradoxically Assume Considerable Nuclear Energy Growth, DIW Weekly Report 45–49/2023, 293–301 (available online).

13 Rebekka Jakob and Christoph Frey (2026): The world's first fusion power plant is to be built in Gundremmingen. Augsburger Allgemeine, January 15 (in German; available online).

14 Timothy Gardner (2025): Fusion energy startup Focused signs agreement with RWE, German state. Reuters.com, March 24 (available online).

15 FDP parliamentary group in North Rhine-Westphalia (2025): The first fusion power plant is to be built in North Rhine-Westphalia – Setting the course now for the energy supply of the future (in German; available online).

16 Ministry of Science, Culture, Federal and European Affairs of Mecklenburg-Western Pomerania (2025): MV is part of the new fusion alliance (in German; available online).

17 Bavarian State Ministry of Science and the Arts (2023): Bavaria launches the nuclear fusion mission: Minister President Dr. Markus Söder and Science Minister Markus Blume present master plan (in German; available online).

18 See detailed explanations in Wimmers et al. (2025), ibid, which references further literature.

19 Charlotte Dering, Alexander Wimmers, and Christian von Hirschhausen (2026): Innovation Dynamics and Technological Maturity in the Fusion Sector: An Assessment of Fusion Projects. Accepted for publication in Energy Strategy Reviews. Preprint (available online).

20 For a classification of technologies, see Alexander Wimmers, Fanny Böse, and Christian von Hirschhausen (2026): Nuclear Physics and Reactor Technologies (Fission and Fusion). In Alexander Wimmers et al. (eds.), ibid., 11–54 (available online).

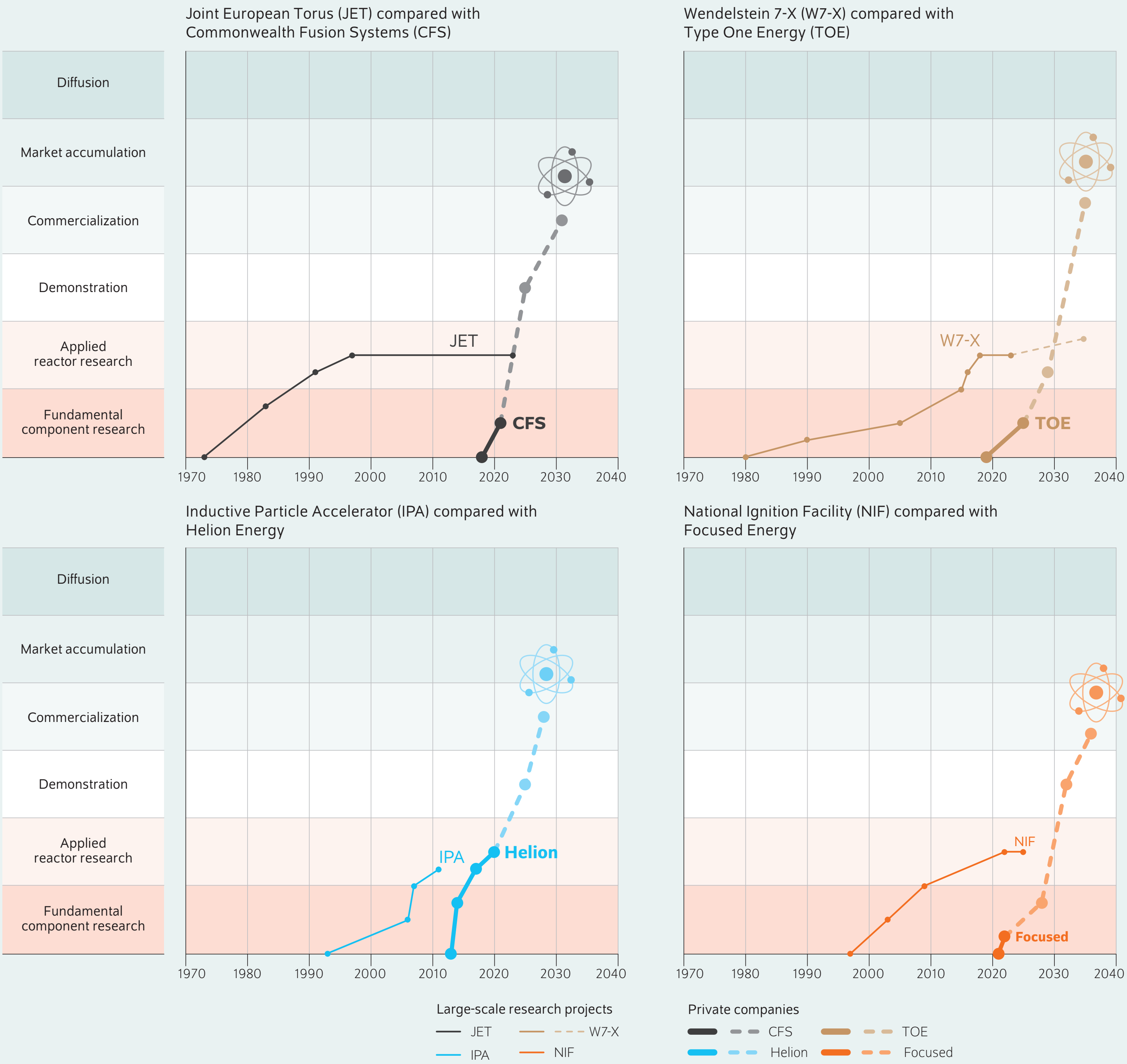
21 For the methodology and rationale behind the selection of case studies, see Dering et al. (2026), ibid.

22 The cumulative sums from venture financing rounds and grants awarded were compared.

Figure 3

Techno-economic classification of selected private-sector companies and large-scale research projects using our fusion innovation framework

The progress of large-scale research projects is compared with that of private-sector companies



Source: Own calculations.

Large-scale public research projects remain at a low level of research, while private companies promise swift commercialization of the energy use of nuclear fusion.

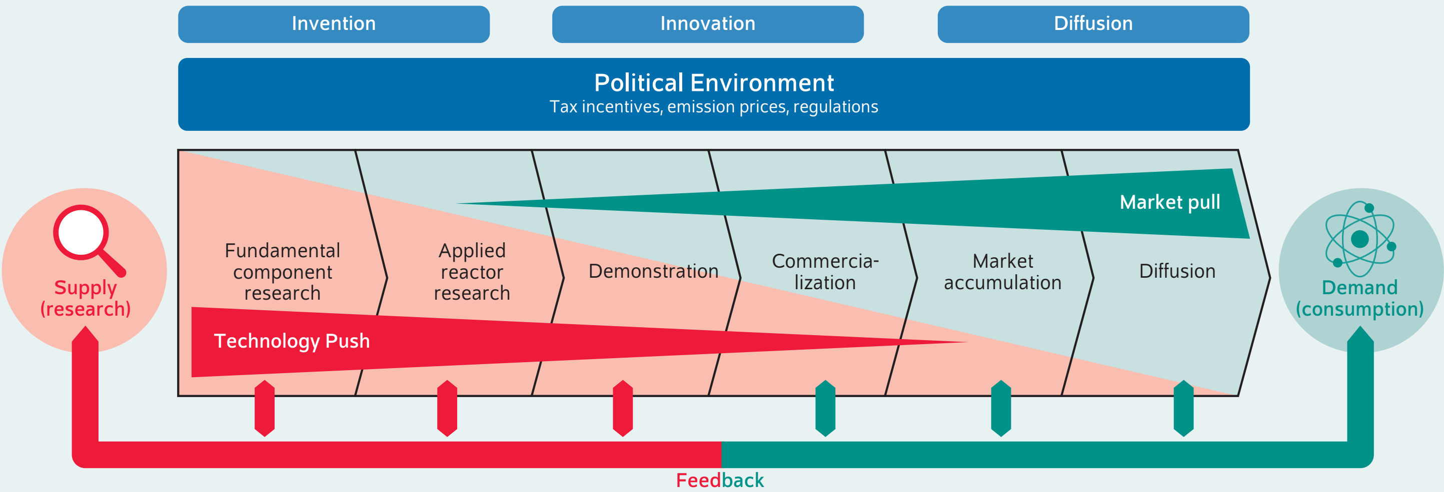
Box

An evaluation scheme for the techno-economic comparison of different nuclear fusion companies: the fusion innovation measure framework

Figure 1

Innovation chain between basic research and market introduction

Innovation theory based on Schumpeter (1939): Invention, Innovation, Diffusion



Source: Michael Grubb, Jean-Charles Hourcade, and Karsten Neuhoff (2014): Planetary Economics – Energy, Climate Change, and the Three Domains of Sustainable Development. London, UK: Routledge, 325.

Fundamental component research involves the development and testing of reactor components, while applied reactor research requires the operation of a prototype.

To compare the techno-economic developments of different nuclear fusion companies with many different subsystems, an approach that draws on the revised model of an innovation process is used.[1] After beginning with basic research and development, this takes on more concrete forms in relation to a product range (Figure 1).

Although nuclear fusion, unlike other products such as microchips or spacecraft, has so far only been in the research and development (R&D) phase, the scheme is suitable for comparing different reactor concepts. For this purpose, a distinction is made between six process stages along techno-economic subcriteria, which are

1 Joseph A. Schumpeter (1939): Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process. New York: McGraw-Hill, 2nd edition; Michael Grubb, Jean-Charles Hourcade, and Karsten Neuhoff (2014): Planetary Economics – Energy, Climate Change and the Three Domains of Sustainable Development. London, UK: Routledge.

the level of a technical performance parameter.[23] Since this report focuses on new ventures, only one public project is presented in detail as a reference point: the first large-scale European research project, the Joint European Torus (JET) (Box).

The new ventures under consideration pursue development strategies that differ significantly from those of large-scale public research (Figure 3). A characteristic feature of these companies is that they either rely on alternative fusion concepts and reactor configurations beyond the established laser- and magnet-based approaches, or, as spin-offs from a university context, build directly on the scientific results of so-called “big science.”[24] In doing so, they draw on a foundation of publicly funded knowledge and technology that has been built up over decades. On this basis, the new ventures have set themselves the goal of not only reproducing the performance indicators achieved to date, such as magnetic field strength and laser shot repetition, but also exceeding them by several orders of magnitude.

23 The triple product, i.e., the product of temperature, pressure, and confinement time of the plasma, was compared. It must exceed a certain threshold value for self-sustaining fusion ignition to occur, cf. Samuel E. Wurzel and Scott C. Hsu. (2022): Progress toward Fusion Energy Breakeven and Gain as Measured against the Lawson Criterion. Physics of Plasmas 29 (6), 062103 (available online).

24 On the subject of big science, see Richard Rhodes (1995): Dark Sun: The Making of the Hydrogen Bomb. New York, N.Y: Touchstone; and Alvin Martin Weinberg (1994): The First Nuclear Era: The Life and Times of a Technological Fixer. New York: AIP Press (Chapter 13: Moonlight Philosophy of Scientific Administration).

made comparable through a combination of quantitative and qualitative evaluation.

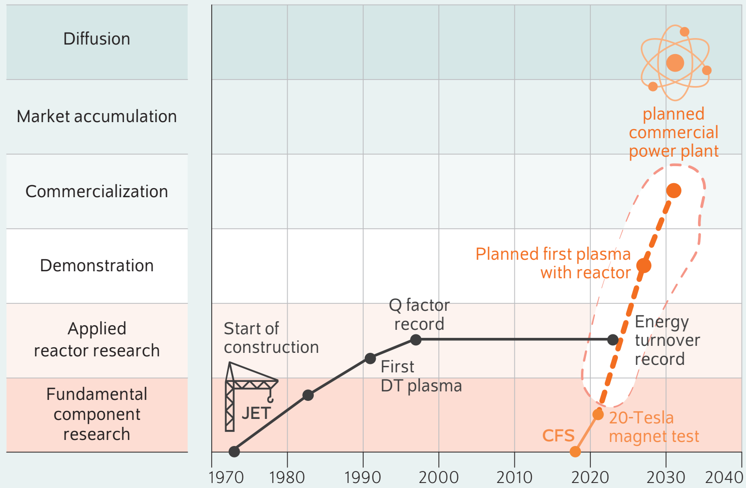
The innovation measure then comprises a combination of research type, technical milestones or technological readiness level (TRL),[2] and a measure of energy use. The TRL is assigned from one to two for basic research, three to four for applied research and development, five to six for the demonstration phase, and seven to eight for the commercialization phase. The measure of energy utilization accounts for the level of energy gain over energy consumption (called Q) that is customary in the nuclear fusion industry, which, in turn, is linked to a technical criterion from plasma physics, the triple product.

For magnetic fusion with tokamaks, which is considered the most promising technology line, research on the former large-scale project, the Joint European Torus (JET), has remained at the level of basic research since 1973 and remained so until its shutdown in 2024. Although milestones were achieved in 1983, 1991, 1997, and late 2023, some of which were published as "world records," the goal of feedthrough, i.e., a Q factor greater than one, was never achieved (Figure 2). The curve for the private spin-off, Commonwealth Fusion Systems (CFS), on the other hand, looks structurally different (Figure 2): From relatively low TRL values, reduced to magnet development outside a reactor (2021), very ambitious goals are being formulated. The plan is to build a first experimental reactor for system validation (called SPARC, initially in 2025, now in 2027), followed by a commercial reactor called ARC, which is expected to start generating electricity in the early 2030s. As a sign of the seriousness of the timeline, power purchase agreements worth over a billion US dollars have been signed with Google and Eni Energies (Italy).

Figure 2

Derivation of the techno-economic innovation framework for fusion companies

Using the example of Joint European Torus (JET) and Commonwealth Fusion Systems (CFS)



Source: Own calculations.

The stagnating development of basic research (JET) contrasts with CFS's ambitious plans for rapid commercialization.

2 The TRL was introduced by NASA to assess the state of technological development and was later standardized as an international standard (ISO 16290) that is used here.

This acceleration logic represents a break with the traditional, sequential development models of publicly funded fusion research. At the same time, it harbors technological and economic risks, as key assumptions about scalability, system integration, and long-term stability have not yet been empirically validated in many cases. Parallel to fusion research, a multitude of products are emerging that could serve as sources of revenue. These include technological subsystems, components, and sub-infrastructures. While the complex overall system of a fusion reactor often remains at a predominantly conceptual level, individual components—such as magnetic technologies, laser systems, and optical components—are often developed independently of each other and are already at advanced stages of development.[25]

Magnetic and laser technologies are particularly relevant, as they form the technological focus of new ventures' research and development work. These technologies already have industrial application potential and are reaching higher levels of technological maturity compared to the integrated reactor system. However, this is accompanied by a shift in the focus of research away from the originally intended energy

25 Stefania Böhnlein, Fanny Böse, and Alexander Wimmers (2026): The System Good Nuclear Fusion—Organizational Approaches and Two Case Studies on Magnetic Confinement Fusion. In: Wimmers et al. (eds.), ibid, 99–133 (available online); and William Nuttal et al. (2025): Commercializing Fusion Energy – How Small Businesses Are Transforming Big Science. Golden, CO: Whittles Publishing.

generation toward shorter-term commercial services that depend on market demand and could soon be viable without government funding.

Case study: Focused Energy: Strategic shift from energy use to laser development

The shift from energy use to commercializable intermediate products and components can be observed, for example, in the German-American new venture Focused Energy.[26] The company is pursuing a laser fusion approach. The concept is directly linked to the scientific principles of the National Ignition Facility (NIF), but aims at an alternative ignition strategy that, if successful, promises higher energy gains and better scalability. Technologically, this approach requires the use of extremely powerful laser systems that generate pulses with high temporal precision and repeatability. However, these laser systems are still in an early stage of development.[27]

Since 2022, Focused Energy has been building its own experimental laboratory infrastructure in Darmstadt, Germany. The focus is on reducing fundamental technical uncertainties.[28] In the medium term, the company initially planned a series of different test facilities with the aim of generating energy. However, this roadmap is no longer being pursued in its original form. Specifically, the explicit demonstration reactor as an integrated intermediate step has been removed from the plan. Instead, Focused Energy is now working on establishing a series of specialized development infrastructures, each addressing individual core technological components. This new prioritization clearly focuses on industrial laser systems as an independent technology and business segment. At the same time, individual reactor components are being developed in modular systems rather than in an overall system. Instead of the immediate demonstration of a closed fusion energy system, the focus is shifting to applications that can be exploited in the short term. For example, Focused Energy plans to build a high-power laser facility at the site of the former Biblis nuclear power plant, which will enable, among other things, the screening of radioactive waste and disposal containers for non-destructive content determination. In addition, mobile high-precision testing methods are planned that can be used outside the actual fusion context, for example in bridge testing procedures.[29] In contrast to Focused Energy, which is technologically in the first phase of the innovation chain, the activities of the comparable large-scale research project NIF can be classified as belonging to the second stage, applied research and development (R&D) (Figure 3).

Commonwealth Fusion Systems: Focus on magnet development

CFS was founded in 2018 as a spin-off from the Plasma Science and Fusion Center at the Massachusetts Institute of Technology (MIT). The company pursues a compact approach to magnetic fusion, in which technological advances are to be achieved by increasing the magnetic field strength instead of enlarging the facility. The goal is to realize a demonstration reactor in the early 2030s. Similar to TOE, however, the technological core of CFS lies in the development and application of reactor components, in particular high-temperature superconducting magnets (HTS). These are expected to enable magnetic field strengths of up to 20 Tesla. Compared to the most successful European tokamak to date,[30] the Joint European Torus (JET), this represents an increase of about a factor of five to six.[31] The successes of JET are attributable to basic research (Box). CFS has already demonstrated corresponding field strengths in isolated magnet tests.[32] Thus, the integration of these high-field magnets into a complete reactor system remains a key challenge.

Regardless of the actual reactor goal, the developed magnet technology has considerable potential for short-term commercial application. Current studies emphasize that HTS magnets in the range of approximately 15 to 25 Tesla represent an independent technological leap that can be used in numerous applications, such as nuclear magnetic resonance spectroscopy, materials research, and fundamental physics, regardless of the construction of a fusion reactor.[33]

Type One Energy also specializes in magnet development.

Unlike CFS, TOE is pursuing the development of an alternative magnet concept (called “stellarator”). Both companies are cooperating closely in magnet development. Technologically, TOE builds directly on the results of decades of public stellarator research, in particular on the findings from the operation of the Wendelstein 7-X at the Institute for Plasma Physics (IPP) in Greifswald, Germany, whose activities can be classified as applied research and development (Figure 3). The design, simulation, and optimization tools developed for this purpose, which are increasingly AI-based, are standalone products that can already be used independently of the fusion context in other areas, such as acceleration magnets, precision drives, and special electromagnetic systems. In addition, relevant niche products can be created in precision manufacturing and system integration. Stellarators require

26 The company was founded in 2021 as a spin-off from Darmstadt Technical University and National Energetics (Austin, USA), see Focused Energy website (available online).

27 See Todd Ditmire et al. (2023): "Focused Energy, A New Approach Towards Inertial Fusion Energy." Journal of Fusion Energy 42 (2), 27 (available online).

28 Focused Energy (2022): Focused Energy Celebrates One Year of Achieving Key Fusion Energy Milestones (available online).

29 Timothy Gardner (2025), ibid.

30 The term tokamak is an acronym derived from the Russian name for a toroidal chamber with magnetic coils, which describes the torus-shaped structure of these reactors. Tokamaks are considered the most advanced fusion reactor concept, cf. Wimmers et al. (2025), ibid.

31 Pablo Rodriguez-Fernandez et al. (2022): Overview of the SPARC Physics Basis towards the Exploration of Burning-Plasma Regimes in High-Field, Compact Tokamaks. Nuclear Fusion 62 (4), 042003 (available online).

32 Commonwealth Fusion Systems (2021): A record of progress and milestones of the HTS Magnet Demonstration through September 8, 2021 (available online).

33 Tim A. Coombs et al. (2024): High-Temperature Superconductors and Their Large-Scale Applications. Nature Reviews Electrical Engineering 1 (12), 788–801 (available online).

tight geometric tolerances in the submillimeter range.[34] The manufacturing and assembly processes developed in this context have spillover potential for other industries with comparable requirements, such as the aerospace and the semiconductor industries.

Helion Energy: A pioneer in energy industry ambitions

Helion Energy, the new venture with the most ambitious commercialization goals (2028), is an exception in that it is currently focused on energy generation. Helion Energy's organizational and technological orientation deviates from the pattern observed in other new ventures in that, since its founding in 2013, it has developed several prototypes based on the FRC concept that are intended to enable the step-by-step development process for a fusion power plant.[35] This approach follows a comparatively traditional, linear path of technological development, in which successive prototypes primarily serve to approximate a functional power plant design. This orientation is particularly evident in the company's ambitious time and performance targets. Helion planned to demonstrate net electricity generation with the Polaris reactor as early as 2024.[36] However, as of February 2026, there are no publicly available results that would confirm successful net electricity generation. Regardless, Helion Energy announced its intention to commission its first commercial fusion power plant by 2028 and to supply energy to Microsoft under a power purchase agreement (PPA).[37] Systematic commercialization plans for components have not yet been communicated. The technological maturity at the applied research and development stage is on par with the public comparison project, the "Inductive Particle Accelerator" (Figure 3).

34 Hans-Stephan Bosch et al. (2013): Technical Challenges in the Construction of Steady-State Stellarator Wendelstein 7-X. Nuclear Fusion 53, 126001 (available online).

35 See the Helion Energy website (available online).

36 See Helion Energy website (available online).

37 Justine Calma (2023): Microsoft just made a huge, far-from-certain bet on nuclear fusion. The Verge, May 10 (available online).

Conclusion: Funding should focus more on the innovative dynamism of private actors

Research into nuclear fusion is no longer primarily an energy policy issue, but rather a matter of research and innovation policy. Due to a multitude of unresolved scientific and engineering questions, the commercial use of nuclear fusion for energy purposes remains, as it has since the 1950s, "several decades" away and is not a focus for most private companies. In view of these structural shifts and the obvious difficulties of publicly funded basic research, the long-term research structure for nuclear fusion must be questioned and given a conservative and cautious reassessment. The fusion sector is increasingly developing into an innovation-driven field of technology whose economic attractiveness no longer depends on the realization of a marketable fusion power plant. It is instead focused on developing and promoting niche products and components in other sectors.

Against this backdrop, German research policy should not focus on the goal of building the "world's first fusion power plant." Instead, it makes sense to rely on the innovative momentum of private actors and to conduct a fundamental evaluation of the existing structures of publicly funded large-scale research. In view of declining public funding and the rise of other technologies with more urgent relevance for the energy transition, continuing with the status quo of the funding structure does not seem appropriate. Instead, focus should be placed on the commercial use of subcomponents. These products and other usable components, for example in the fields of magnet, laser, or material technologies, already have a higher degree of technological maturity and clearly identifiable industrial applications. Public funding in these areas should be independent of their potential for energy use.

The discrepancy between public basic research and new ventures is likely to further increase. The approach developed here allows for an assessment of the different dynamics in both market segments. In view of the extensive research funds planned for nuclear fusion, an objective analysis of the opportunities and risks of this funding is useful, which has been lacking in the discourse so far (with very few exceptions). An annual "fusion monitoring" would be a sensible first step in this direction.

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