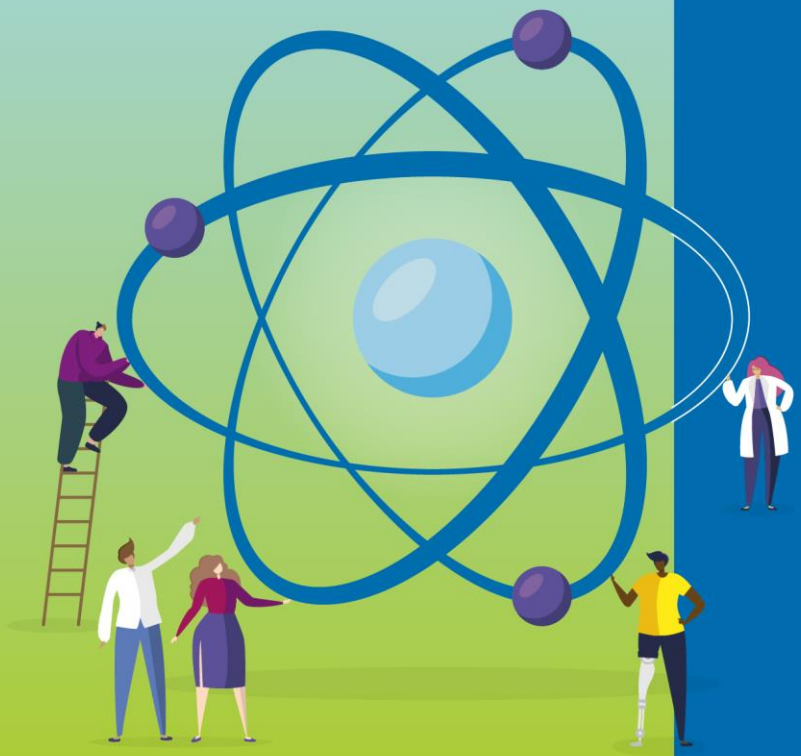
European Commission

Fostering Fusion Innovation: High-Level European Roundtable



Research and Innovation

Fostering Fusion Innovation: High-Level European Roundtable

European Commission
Directorate-General for Research and Innovation
Directorate C — Clean Planet
Unit C.4 — Euratom Research
Contact Elena Righi, Domenico Rossetti di Valdalbero, Fabio Belloni, Lorenzo Capisani
Email Elena.Righi-Steele@ec.europa.eu
Domenico.Rossetti-Di-Valdalbero@ec.europa.eu
Fabio.Belloni@ec.europa.eu
Lorenzo.Capisani@ec.europa.eu
RTD-FUSION@*ec.europa.eu*
RTD-PUBLICATIONS@ec.europa.eu
European Commission
B-1049 Brussels

Manuscript completed in April 2024
1st edition

PDF	ISBN 978-92-68-14418-3	doi: 10.2777/621539	KI-05-24-270-EN-N

Luxembourg: Publications Office of the European Union, 2024

EUROPEAN COMMISSION

Fostering Fusion Innovation:

High-Level European Roundtable

Edited by Lorenzo Capisani, Claire Camus and Maria Papadopoulou

2024

Directorate-General for Research and Innovation
Euratom Research and Training Programme

Table of contents

FOREWORD

The European Union has set the goal to become the first carbon-neutral continent of the planet by 2050 with ambitious intermediary targets of greenhouse gas emissions by 2030 and 2040. The European Green Deal and the EU Climate Law triggered European efforts to achieve structural changes across different sectors – such as energy, industry, residential and transportation – transforming the EU into a clean, resource-efficient, and competitive economy.

Today, the European Commission under the Net Zero Industry Act (NZIA) - one of the key legislative initiatives of the Green Deal Industrial Plan - aims to scale up the manufacturing of green technologies. Fusion innovation is indicated as a relevant opportunity by the European Commission, while nuclear has been listed among the net-zero technologies.

On 14 March 2024, I hosted the first High-Level European Roundtable on Fostering Fusion Innovation. It has been organised in a context of increasing investments from the private sector in fusion research, and of its transition from fundamental science to applied engineering. This event has seen the participation and the support of MEP Cristian Bușoi, Chair of the ITRE Committee on Industry, Research and Energy in the European Parliament, and key high-level fusion industrial and innovation stakeholders from all Europe.

The Roundtable is part of the stakeholder consultation that should lead to the development of a coordinated fusion strategy at EU level, which should encompass an agile and ambitious Research & Innovation policy framework. The establishment of an EU fusion strategy will foster coordinated efforts between research organisations and industry for a timely delivery of fusion energy. Stakeholders from the large industry, startups and academia have given their converging points of view and shared ideas for concrete actions to move forward to achieving fusion energy.

The focus of the discussion has been on policy tools that could inform the European R&I policy on fusion energy, nurturing interactions between public and private initiatives, and driving European competitiveness in an emerging global fusion energy market. The delivery of fusion energy should provide an abundant, low-carbon energy source with significant potential for industry, economic growth and job creation in the Union.

Fusion technology should become a viable source of decarbonised electricity as fast and safely as possible. In this R&I has a key role to play, and both public and private actors need to join their forces.

Synergies among the Euratom Research and Training Programme, EU national programmes and emerging private investments are crucial to foster innovation in the field of fusion energy. Exploring opportunities for increasing the impact of R&I investments will attract private investments and accelerate the demonstration of fusion electricity generation. The focus on R&I policy tools will empower the sharing of knowledge, skills, and competencies between the public and private sectors to match the technological changes and the demand for workforce in the coming years.

A critical goal is the establishment of a harmonised regulatory framework for future fusion facilities, supporting the best standards and considering the distinctive traits of fusion

energy. With an innovation-conducive, agile regulatory framework, Europe will send a clear message that the EU is a stable environment that incentivises investments by the private actors, thus fostering an environment for growth.

In the critical decades to come, only ambitious and collective actions can lead to a prosperous future for Europe, supported by a sustainable and unlimited source of energy from fusion.

Iliana Ivanova
European Commissioner for Innovation, Research, Culture, Education and Youth

INTRODUCTORY STATEMENT BY ILIANA IVANOVA

European Commissioner for Innovation, Research, Culture, Education and Youth

Dear Mr Bușoi,
Dear Dr Siegler,
Dear Speakers, Participants, Colleagues,

It is with great honour and pleasure that I open this High-Level European Roundtable on Fostering Fusion Innovation.

I thank all speakers for accepting our invitation and welcome our audience online.

I will begin immediately with raising a few important questions, on which I hope to hear the views of our speakers today:

- How can we unlock the disruptive innovation potential in the EU private sector and accelerate the demonstration of fusion electricity generation?

- What are the steps to move fusion energy from a LAB to a FAB phase?

- What research and innovation policy initiatives can be put in place to achieve this?

Answering these questions is not an easy task – but I trust today's roundtable to be a timely opportunity to address them.

Responding to climate change and ensuring our energy security are top priorities for the European Union.

Fusion energy offers a glimmer of hope as an abundant, low-carbon energy source with significant potential for industry, economic growth, job creation and innovation in the Union.

We can be proud that the European Union is at the forefront of fusion energy research:

- It is home to the ITER tokamak, the cornerstone of the European fusion programme, to which the EU is the main contributor.

- It has also funded the construction and operation of the Joint European Torus, a facility that has set world records in fusion energy research.

- Complementing ITER, the Euratom Research and Training Programme is investing over half a billion Euros from 2021 to 2025 into fusion energy research.

We are also rewarding outstanding fusion innovation through prizes, as well as strengthening our international collaboration with the United States, South Korea and Japan.

In this regard, I very much welcome the EU-Japan joint research facility, which has been inaugurated last December by my colleague, Commissioner for Energy, Kadri Simson.

The fusion energy landscape has dramatically changed in recent years with increased private sector interest and investments alongside public funding. New startups have emerged, including in Europe.

This is why we have initiated, in the European Commission, a reflection on the development of a possible EU Fusion Strategy.

It will aim at fostering active participation of private industry, in particular through a Public-Private Partnership. Our goal is to bridge the technological gaps to accelerate the construction of the first prototype fusion power plant.

We are also about to establish a Fusion Expert Group with EU Members States. The objective of this Expert Group will be to advise the European Commission on fusion energy policy, considering synergies with national policies.

The experience and guidance of such a group will be essential for us and the first meeting should take place before summer this year. Today's Roundtable is the first contribution to a wider stakeholder consultation process leading to this EU Fusion strategy, so hearing your views today is very important to us.

As we transition from fundamental research to applied engineering, I am delighted to see at our Roundtable representatives of both fusion industry, including startups, and fusion energy research.

Fostering collaboration between public and private entities, national, European, and international programmes, is crucial.

- Firstly, to consolidate and develop further the fusion industrial supply chain already established with the construction of ITER, and thus create a flourishing R&I ecosystem that would attract investments in Europe in this potentially transformational area,

- Secondly, to develop predictable regulatory frameworks,

- And lastly, to ensure European competitiveness in the long-term global fusion energy market.

Ladies and Gentlemen,

In the European Commission, we are strongly committed to support fusion research and industry in the EU, preserving our technological edge, and positioning the European Union as a leader in fusion energy.

I am looking forward to hearing your innovative ideas and I am sure that we will have a successful and forward-looking roundtable.

Thank you.

PARLIAMENT PERSPECTIVE BY CHRISTIAN BUŞOI

Member of the European Parliament,
Chair of the Committee on Industry, Research and Energy

Dear Ms Ivanova,
Dear Speakers, Colleagues, Invitees,

I would like to express the commitment of the ITRE committee – the Committee of Industries, Research and Energy that I am chairing in the European Parliament – to support the research and development of a fusion energy.

We in the European Parliament understand the need to introduce fusion electricity in the energy mix.

As regards the high demand that is expected in terms of resources, we really believe that Europe needs viable sources of decarbonised electricity to achieve our strategic goals in 2050 and the goals of the package "Fit for 55" in 2030. We expect an increase in the demand for electricity and in the deployment of electrification, which is part of our efforts to head towards the European Green Deal.

Fusion energy could provide a reliable and carbon-free source of electricity in future decades. However, we are talking about the medium and long terms. We need more research and engagement towards projects that investigate fusion science and engineering: research and innovation need to continue until it becomes a mature technology.

Clearly, we need very innovative solutions, and fusion energy could solve a lot of the issues in the next decades. We need to continue to invest in research, as Commissioner Ivanova said, and the European Commission is supporting this choice. The political support in the European Parliament, as I said, is very clear.

Additionally, we need more public and private engagements towards projects that study fusion energy. Of course, commercial feasibility is extremely important. In particular, ITER has made remarkable progress towards addressing the issues related to fusion energy already during its construction. Fusion research needs to continue and progress to its maturity – when we explain better what the challenges are, and what we still should do in order to have fusion in place as an energy source. Our job is to provide support and promote fusion energy among the decision-makers in the EU institutions and the member state level.

When we are successful – and I am sure we will be successful – this will significantly change the energy paradigm.

Once again, thank you for the invitation.

STAKEHOLDER STATEMENTS

Andrew Holland

Chief Executive Officer of the Fusion Industry Association

The 37 member companies of Fusion Innovation Association are dedicated to building the energy system of tomorrow, on a timescale that is relevant to today's energy challenges.

The truth is that today's energy systems are failing us. That's because existing energy sources are either environmentally unsustainable, economically inequitable or create national security vulnerabilities.

Fusion energy is the solution: it will unleash the power of a star in a controlled manner on earth. Fusion is clean, safe, an always-available power for a growing world.

Today, the global race to fusion energy has begun. As fusion energy research transitions from the laboratory to the commercial marketplace, nations are rushing to set the policies and incentives that will incubate a commercial fusion energy industry.

For decades, European scientists have led the way in the breakthroughs that have brought us to this transitional moment. All the commercial fusion energy companies chart their course based on the maps laid by government-funded scientists over the last decades.

The recent announcements of record energy production from JET, the Joint European Torus, is an example of this long-term investment paying off. Because of JET, we know that we can make a fusion machine that works.

Even so, in some ways, the fusion industry in the EU is behind in the global race to commercial fusion. Of the 43 start-up fusion companies the FIA has identified around the world, the EU is home to only six of them. The total amount invested in those companies is more than an order of magnitude less than the over USD 5 billion dollars invested in American firms.

However, thanks to the decades of government investment into devices like JET and ITER, the EU is home to a constellation of supplier companies eager and able to scale up to meet the needs of commercial fusion energy. Many of them, like SIMIC of Italy, Bilfinger Noell of Germany, Thales of France, or Cosylab of Slovenia are Affiliate Members of the FIA.

To build on this base and ensure that the EU can meaningfully enter the race for fusion, the EU needs to enact policies in three clear areas. First, the EU must encourage the public-private partnerships between national labs and companies that will unlock commercial deployment. Second, it needs to ensure that fusion energy receives the same incentives that other clean energy technologies get. Third, we need a regulatory regime that will protect public safety while also encouraging innovation. That means EU States must finally confirm that nuclear fusion is regulated separately from nuclear fission.

Let me close by saying that the opportunity for leadership is here, if the EU can grasp it. With public leadership on science and infrastructure paired with innovation from private

companies and a regulatory environment that is clear and fit-for-purpose, Europe can establish itself as a key region for fusion energy development. I look forward to your questions.

Thomas Mull

Chairman of the Fusion Industry Innovation Forum,
Scientific Advisor at Framatome

Already back in 2010, the European Commission had asked through the Fusion Industry Innovation Forum (FIIF) that the private sector play a more active role in the development of fusion technology, in terms of the definition of a reactor technology program and participation in plant design activities beyond ITER. It was clear already then that the development of fusion technology needs a reliable Private Public Partnership.

As we now look ahead, full innovative potential should unfold with effective collaboration between industry and research centres. It is necessary to establish an industrial project structure and clear industrial processes throughout the European DEMO project. Industrial engagement will be increased not only by the participation of the private sector to partnerships, but also by advantages coming along with protection of Intellectual Property, containing a certain promise of revenue tomorrow.

In this context, the FIIF has three missions:

- To contribute to the industrialisation of fusion technology and the design and specification of a first of a kind fusion power plant. Today it is crucial to accelerate DEMO with significant industry involvement and with the introduction of industrial processes that have clear breakdowns of the working activity, delegation of responsibilities and technical objectives.

- To forward the development of innovations in various technologies with secondary applications outside fusion. Technology transfer between research centres and industry is a crucial aspect that may stimulate a virtuous circle, allowing industry to become more interested and more engaged. This endeavour should be based on a comprehensive development programme of fusion power plant technology and the construction of ITER.

- To contribute to the development of skills to place European industry and the energy market in a competitive position. Qualified personnel will be what makes possible any future fusion power plant commercialisation.

For more than 60 years, Framatome has been involved in designing nuclear power plants. Its 14,000 employees are committed every day to helping customers supply ever cleaner, safer, and economical low-carbon energy. Safety is Framatome's fundamental value. Design and construction of nuclear power plants is its globally recognized expertise.

Framatome has also been working in nuclear fusion for more than 30 years. In EFET-EWIV (the European Fusion Engineering and Technology - European Economic Interest Grouping), Framatome has made large contributions to the ITER Engineering Design. Today, we are working for ITER and EUROfusion.

With the need for more and more electricity, and for decarbonisation at the same time, Framatome is convinced that fusion electricity will be a future key technology.

María Teresa Domínguez Bautista

Director of Advanced Projects at Empresarios Agrupados

Allow me to thank the European Commissioner for organising this event. As Executive Director of Advanced Projects and R&D at Empresarios Agrupados, a Spanish company very active in the energy and environment sectors, I have had the pleasure of being a first-hand witness and player in the long history of fusion in Europe.

A lot has happened since the Geneva Joint Soviet-United States Summit Meeting in 1985, when it was agreed that fusion energy was an "inexhaustible" source of energy to be developed for "the benefit of mankind". Today, Europe is very well equipped to rise to the challenge of transitioning fusion energy from fundamental research to commercialisation.

Throughout this period, the industry has been working to integrate the most innovative tools and methods in complex nuclear project management, risk assessments and mitigation, engineering, design, 3D modelling, calculation, qualification, instrumentation & control, electrical and radiological protection.

We can be proud of the success achieved thanks to the EU's support of fusion research. The EU is home to ITER, the largest fusion experiment, with extensive industrial participation. In addition, great work is done through the EUROfusion co-funded partnership in the framework of its Roadmap to develop DEMO and the JT-60SA-based approach.

What comes next? As part of its innovation strategy, EAG is a committed partner in fusion energy in Europe. We are working with Fusion for Energy, the ITER Organization and EUROfusion, gathering the support of Spanish stakeholders such as CIEMAT (Spanish research centre), CDTI (Spanish organisation promoting innovation in the industry) and universities.

With more than 30 contracts and an average of EUR 10 million per year over the last 15 years, EAG has in-house expertise in all the engineering disciplines relating to fusion technology, as well as in the manufacturing of components for ITER, DONES and JT-60SA.

Together with EAG's partners ENGAGE, Assystem, Egis, and Atkins under the ITER building contract with Fusion for Energy awarded in 2010, we have designed and built its extraordinary Tokamak Complex: a footprint of 120 meters by 80 meter weighing 475 000 tonnes supported by 473 seismic bearings. It is a fantastic piece of engineering.

The involvement of the EU industry in fusion is evident. The question is rather how to encourage the private sector to take the lead in fusion energy development and how to attract investors. The following are key elements in this respect, from our perspective:

- An appropriate regulatory framework;
- Awareness that Europe is investing in fusion in the long term;
- Incentives from the EU and Member States;
- Market opportunities and synergies with other sectors;
- Access to existing knowledge.

None of the above would be possible without continued support to ITER, the development of a sound strategy for DEMO, and a long-term strategy for fusion supported by the EU.

Francesca Ferrazza

Head of the Magnetic Fusion Initiatives at Eni

Thank you for this opportunity to participate to this remarkable panel, which is going to highlight important aspects for the fusion energy path in Europe and globally.

Fusion is a breakthrough technology for Eni, which was among the first energy companies to believe and invest in this field. Eni is committed to a strong decarbonization path by 2050 and actively supports the development of game-changing technologies for the energy transition.

At Eni we believe that fusion energy can bring clean, decarbonised, safe energy to the world and to Europe.

Eni participates to the ENEA's DTT (Divertor Tokamak Test facility) project, contributing to the engineering and construction of a tokamak machine. DTT, Italy's largest and one of Europe's leading fusion experiments, is a test facility with the aim of studying the contribution of heat extraction in a fusion system. The latter aligns with the EUROfusion roadmap and stands as a significant scientific experiment in Italy, showcasing a successful public-private partnership.

It is probably the first cooperation of this type in Europe, and it might pave the way for future collaborations. I think the other members of this panel and of the audience agree that we need the contribution of both the research world and industry.

Eni is already collaborating with several academies and universities not only on research but also on education, which is another important element needed for the creation of new jobs and skills that we need in fusion energy.

At the international level, Eni made its first investment into Commonwealth Fusion Systems (CFS) in 2018 and is a strategic investor of the fusion compqny. CFS aims to realise the first commercial fusion plant by the early 2030s. Moreover, Eni engages in collaborations with leading research centres, universities, and international entities like the Massachusetts Institute of Technology and the UK Atomic Energy Authority.

Europe has played a pioneering role in fusion research. Decades of dedicated effort on our continent have laid the groundwork for these significant advancements.

We emphasise the importance of innovation, collaborations, and synergies in driving the industrialization of fusion energy.

No one can do this on their own. We need synergies and cooperation, and we believe that a substantial acceleration in the development of the technology is key to its deployment.

Ambrogio Fasoli

Programme Manager of the European Partnership EUROfusion

Ten years ago, fusion research bodies from European Union Member States and Switzerland signed an agreement to cement European collaboration on fusion energy research: EUROfusion, the European Consortium for the Development of Fusion Energy, was born.

Presently EUROfusion supports and coordinates fusion energy research activities on behalf of the European Commission's Euratom programme within 26 EU member states, while Switzerland, Norway and the United Kingdom participate in the activities with their national fusion budgets.

The EUROfusion Consortium has 167 affiliated entities, including many universities but also a certain number of industrial partners. It is a consortium of many institutions, but more importantly of many human beings, with a wide and deep spectrum of competencies, and is the structure in which education and training of the new generation of scientists, engineers and operators are undertaken.

This is the lifeblood of the trans-generational fusion effort both for research and industrial development. Interest in fusion has grown enormously thanks also to our R&D successes (one for all, the fusion energy records at JET), and to the realization that baseload electricity power plants are essential for energy transition and security.

EUROfusion's R&D efforts are prioritised to address the most urgent science and technology gaps that remain open, using a variety of plasma and technology facilities, and state-of-the-art numerical simulations as well as their integration. Such integration is crucial and the worldwide unique feature of our programme.

The worldwide community is now assembling ITER, which will prove the scientific and technological feasibility of fusion; unique, invaluable lessons are being learned from every stage of the ITER project.

In addition to contributing to ITER activities, our Consortium is preparing the steps towards the prototype of a fusion power plant, now called DEMO, by working on the conceptual design of the machine.

DEMO will produce hundreds of MW of electrical power, with a self-sufficient fuel cycle. It will take fusion out of the laboratories and into the economic world, demonstrating the performance and integration of key technologies in view of the deployment of power plants.

All of us recognize that DEMO will be designed and built within a fully industrial framework. It is thus essential to combine industrial and entrepreneurial approaches with the extensive know-how, and the ambitious yet realistic vision of a public-funded European fusion program.

We need a collaborative approach involving joint leadership between research institutions and industrial partners, a combination of public and private IP, agile procurement processes, and strategic alliances. That is, we need Public-Private-Partnerships.

Innovation, industrial view and strategic partnerships, therefore PPPs and all possible mechanisms combining research and industrial developments, are also urgently needed to address technological gaps prior to DEMO design.

These include breeding blankets, that is the systems to generate the fuel and extract heat to make electricity, structural materials that resist unprecedented mechanical and thermal loads, and superconducting magnets that generate large magnetic fields in very large volumes – just to name a few examples.

These PPPs would also be the vehicle to develop capability and capacity in supply chains for DEMO and fusion power-plant deployment, especially in areas that are not stimulated by the ITER procurement.

The synergy between research institutions and industries is a must for the successful development of fusion power plants, an important building block for a sustainable future for our planet.

Maria Faury

Director of International Affairs and Large Research Infrastructures at CEA Saclay
Vice-chair of the Governing Board of Fusion for Energy (F4E),
Chair of F4E Industrial Policy WG

CEA is a mission-oriented research and technology organization. Its motto is “from science to industry”. It has a long-standing record in fusion research with many technological platforms like the WEST Tokamak.

As mentioned by the other speakers, the fusion landscape has been evolving rapidly in recent years, with renewed interest in fusion and its promise of an abundant and decarbonized energy source and massive private investments in startups.

I see the political will to accelerate development programmes towards commercial reactors in many countries, especially in Asia and the USA.

So, what are the challenges for Europe?

- Maintaining EU Involvement for the success of ITER (industry and labs) as a high priority and organize the knowledge management;

- The necessity to prepare for the future and secure the EU commercial leadership.

There is a risk in having relevant intellectual property (IP) developed for ITER “open” to the whole world, while significant PPP investments elsewhere may be generating other IP that belongs to non-EU private companies.

To date, F4E has mainly focused on the delivery of the EU in-kind contributions to ITER but has not yet sufficiently addressed other objectives of its industrial policy – i.e., to broaden the European industrial base for the long-term development of fusion energy.

Consequently, the F4E Governing Board has recently adopted an action plan identifying tools, such as the inclusion of a technological development program, and the implementation of the existing innovation partnership instrument that has not been exploited so far.

There are gaps in EU support for industrial innovation in the field of fusion, with existing instruments either dedicated mainly to ITER activities or scientific research. It is time to address the technological gaps needed for the development of a fusion power plant by involving European industry not as providers but as partners, together with the labs.

CEA therefore support the EU’s coming initiatives to work together with both industry and the laboratories in tackling these technology gaps and aiming to accelerate solutions.

The key to success is aligning and implementing a common EU-integrated roadmap encompassing all the stakeholders: the European Commission, the Members States, industry, F4E and EUROfusion. Fusion energy will only be possible if the Commission takes the initiative to align everyone around a European strategy.

I am therefore encouraging the Commission to establish a Fusion Expert Group with the Member States, to achieve such an integrated governance.

Markus Roth

Founder and Chief Science Officer of Focused Energy

I am honoured to address the esteemed members of the fusion community gathered here today by the European Commission.

As we embark on this journey toward realising the immense potential of fusion energy, I want to underscore the crucial role that startups play in driving innovation and progress in this dynamic field.

There are two primary approaches for generating fusion energy:

- *Magnetic Confinement Fusion*. This method involves using powerful magnetic fields to confine plasma in a controlled chamber. Notable projects, such as ITER, aim to achieve sustained fusion reactions through this approach.

- *Inertial Confinement Fusion*. In this technique, intense lasers rapidly compress tiny fuel capsules, creating the extreme conditions necessary for fusion. The goal is to achieve fusion at very high plasma densities.

While most of the efforts in the EU have been so far focused on magnetically confined fusion, initiatives in inertial (laser) fusion (such as Focused Energy) are gaining ground. Both approaches share some common challenges and opportunities for startups. Today, we stand at the cusp of a new era in fusion energy, one marked by unprecedented opportunities for startups to lead the charge in technological advancements and breakthroughs.

Startups bring to the table a spirit of agility, creativity, and entrepreneurial drive that is essential for pushing the boundaries of what is possible in fusion research and development.

It is heartening to witness the ambitious timelines set forth by these startups, ranging from the development of initial prototypes to the establishment of full-scale fusion power plants. Their bold vision and unwavering determination serve as a beacon of inspiration for the entire fusion community.

As we navigate the complexities of fusion research and development, it is imperative that startups are given the support, resources, and opportunities they need to thrive. This means fostering an innovation-friendly ecosystem that encourages collaboration, investment, and risk-taking. While startups may face challenges and uncertainties along the way, it is important to rally around them and provide the support they need to succeed.

By aligning public initiatives with the goals and aspirations of startups, it will become possible to create a synergistic partnership that accelerates progress and drives us closer to achieving our shared vision of harnessing the power of fusion energy.

In closing, I am confident that by championing startups and nurturing a culture of innovation and collaboration, we can unlock the full potential of fusion energy and usher in a new era of sustainable and abundant power for generations to come.

Thank you for your attention, and I look forward to working hand in hand with all of you.

HOW TO ACCELERATE FUSION ELECTRICITY?

1. How to unlock the disruptive innovation potential in the EU private sector to accelerate the demonstration of fusion electricity generation?

1.1. How have global investments in fusion R&D changed in the last five years? Which fusion approaches are the most attractive for investors?

Today, over USD 6 billion has been invested into private fusion energy – four billion of which has come in the last three years alone – more than has been spent by the U.S. government on fusion research in that time frame.

This investment is transforming fusion as the industry hires: there are more than 3,000 people working in fusion companies today, with nearly the same amount of jobs supported by suppliers. Over USD 500 million per year is being spent by the private fusion industry.

The technologies that investors are pouring into are extremely diverse, ranging from the more traditional like magnetically confined tokamaks, to newer investments into stellarators and laser inertial fusion, driven by recent breakthroughs, to a full range of magneto-inertial pulsed-power approaches that are more unique to the private sector.

Andrew Holland

1.2. Are the timeline expectations of private fusion companies realistic and complementary to major public initiatives?

The timelines of private fusion companies vary, but on average most of the companies aim for a prototype towards the middle or the end of the 2030s. Given the current research efforts in the public sector, this is significantly faster than the public approach. While private companies are willing to take a higher risk by advancing the timeline, it is fair to say that some could get to at least a prototype in this range.

The final quest will likely not be to get fusion to work but to develop materials and concepts, which will allow long-term operation and energy production. As the public efforts in materials testing facilities (such as IFMIF-DONES) are on a slower timeline, companies will probably choose not to wait until testing of critical materials is completed.

Given the will to take risks and having a reduced amount of bureaucratic drag a timeline towards the end of the ’2030s for a first proof of principle demonstration of power production by fusion seems possible. This first-of-a-kind power plant, capable of operating continuously will likely take a few more years, depending on regulation and available capital investments.

Markus Roth

1.3. How could the EC support the private sector to help unlock its disruptive innovation potential in fusion?

Innovations can be achieved 'by accident', but the probability for innovations should be larger in the case of comprehensive works which have some well-defined objectives − and this opinion is based on the industry's experience with innovations. Of course, innovations will not always be identical to the working objectives.

From an industry point-of-view, comprehensive contributions are the easier the larger the resulting benefit within a foreseeable time horizon.

Hence the EC should try to enable modes of collaboration, which are offering to industry a perspective of such benefits. They can be of quite different nature:

- Either the industrial efforts are compensated (as it would be the case in development contracts)
- Or other benefits can be secured. This could be for example an advantage in the face of competitors on a certain market and it would probably come along with a certain protection of Intellectual Property.

Supplementary motivation for industry will be provided by any significant success in ongoing fusion projects (for example achievement of some major objectives of the ITER project). Hence any support given to the ITER project will contribute to the good direction.

Finally − and even if I am repeating what I have said earlier at different occasions − it seems recommendable and motivating to include key industries in the DEMO project management, thereby following the requirements of the original Roadmap.

Thomas Mull

1.4. What is the estimated capital needed to move from research machines to prototype fusion power plants? Where is the cost-saving opportunities?

We are observing significant advancements in fusion energy development, with international projects transitioning from the design phase into tangible realities. At the same time, private fusion industry is experiencing rapid growth, accompanied by the development of innovative technological solutions.

We are seeing a new public and private funding flowing into the industry that underscores the need for efficient allocation of capital in order to:

:

- Investigate the different paths to fusion;
- Develop technologies aimed at addressing its challenges.

With this respect, collaboration between the public and private sectors is essential towards the commercialization of fusion energy. While private companies could play a crucial role in risk-taking and innovating, it remains shared technological challenges, such as materials or fuel cycle that will require joints effort. We believe that sharing of knowledge and expertise on a global scale, facilitated by collaborations between public and privates, not only will accelerate the pace of advancements but also will ensure a more efficient and de-risked approach.

It can be stated that realizing the first prototypes demands investments on the order of billions of dollars. However, we believe that that long-term costs will be competitive. This approach stems from several factors: the development of the supply chain, the standardization of components, the economies of scale, and expected technological advancements that will further improve efficiency. Additionally, its firm and dispatchable nature will be a winning factor in the future energy market.

Francesca Ferrazza

1.5. In a rapidly changing fusion landscape, how could R&I policy promote an innovation-friendly ecosystem for companies and businesses?

R&I policy can do many things in this direction, for instance:

Providing peer-reviewed funding by supplying grants, subsidies, and financial incentives to bolster R&D efforts in fusion technologies. This financial support enables companies to invest in groundbreaking solutions.

Encouraging risk-taking by creating a supportive environment that incentivises companies to pursue ambitious innovation projects and encourage the exploration of new ideas and technologies, including offering incentives like tax breaks or innovation grants.

Facilitating collaboration by encouraging partnerships between public research institutions, private firms, and startups. Collaboration harnesses diverse expertise and resources, expediting technological advancements, transfer of knowledge and technology, and market adoption.

Investing in essential infrastructure and research facilities for fusion research and technology testing. and ensuring access to cutting-edge facilities, thus lowering barriers for companies and fostering a collaborative innovation environment.

Markus Roth

HOW TO MOVE FROM LAB TO FAB?

2. What are the necessary steps that the EU could take to move fusion energy from a LAB to FAB phase, fostering the active involvement of industry?

2.1. How can we accelerate the development of the European fusion pilot plant in close partnership with the research community, private industry, and other important stakeholders?

In my view, the DEMO Programme managed by EUROfusion, which is being developed with a close collaboration between the industry and the research community, is a good starting point. The main questions are the scope, the objectives of the DEMO Programme and how to accelerate it.
The solution, in my view, is already in place. The 2023 Addendum of EUROfusion Roadmap, presently under consideration, proposes a way forward with the parallelisation of three (3) pillars: the construction of ITER, the DEMO programme and private sector initiatives.

The DEMO programme needs to identify the technology gaps that need to be overcome, taking stock of experienced gained during the construction of ITER. It should develop solutions that can service the needs of ITER as well as other machines, including those being developed by the private sector. The DEMO Programme should be flexible, integrated and servicing to ITER, DONES and other private or public-private fusion initiatives.

To accelerate the industry involvement, major changes should include how to implement the procurement contracts with the industry under the DEMO Programme. New mechanisms should be sought to incentivise industry participation. Progress has been made in Europe, notably through Fusion for Energy. However, more initiatives are needed on the points I outlined in my introductory statement (long-term Fusion Strategy, an innovation-conducive regulatory framework for fusion, amongst others).

I am looking forward to hearing more about the initiatives the European Commission is considering in this instance.

María Teresa Domínguez Bautista

2.2. Moving from fusion research to deployment, how will the demand for skills change?

As the fusion community progresses towards commercialization, the balance in research is shifting from a more academic and fundamental direction to a more technology and industry-driven orientation. I.e., there is a shift from basic research to applied research to technical development and industrial application.

Hence with respect to the range of required skills, the focus will gradually move from scientists/physicists to broadly educated physics engineers and engineers from other disciplines (e.g.: mechanical, electrical, civil, etc.), with nuclear awareness.

That does not mean that today we need people of the first kind and in 30 years we will need people of the last kind, but the percentual composition of the staff needed will evolve in the indicated direction.

Thomas Mull

2.3. How can we optimise the transfer of knowledge and experience between academia and industry?

The best way is developing and implementing common projects where everything is shared, from the contractual aspects to the very detailed engineering solutions. In the projects of Empresarios Agrupados, we have included universities; we have worked with CIEMAT, with labs for certification and pre-qualification, and with small and medium enterprises. In this collaboration, there is already a lot of knowledge transfer taking place.

Mechanisms and incentives that promote the execution, by multiple partners, of common projects are very effective in our experience. But once again, the focus should not be limited to technical aspects but also to contractual aspects. For example, you cannot transfer a back-to-back contract to one small-sized or medium-sized company.

When dealing with contracts involving public institutions, research centres, industry, SMEs, one needs to think through questions of liabilities, payment schedules, credits, taxes, etc., to make this collaboration feasible.

These very practical aspects can also de-incentivise the industry's participation. I trust these questions can be tackled in future initiatives that the Commission is considering accelerating the commercialisation of fusion energy.

María Teresa Domínguez Bautista

2.4. In the light of the latest breakthroughs in fusion, what are the challenges ahead that could impact fusion energy moving from a LAB to FAB phase by 2035-2040?

Recent breakthroughs in fusion technology have opened a door to a near future powered by clean energy. To seize this opportunity, we must prepare to scale up a whole new industry. This requires focusing on all the enabling factors crucial for large-scale fusion production.At Eni, we are committed to actively contributing to the successful transition of fusion energy from laboratory to the fabrication phase by addressing critical challenges ahead.

We have identified some key priorities on this topic, based on our expertise in the energy production., but more should be addressed and deepened:

- People. Workforce development will be pivotal for the successful transition to large-scale fusion energy production. Investing in training and education

programs to build expertise in fusion technology and related fields is essential for addressing the future possible shortage of qualified professionals. Eni is at the forefront of addressing the potential skills gap by actively collaborating on workforce development initiatives.

- Manufacturing and supply chain: Europe holds a leadership position in the fusion manufacturing and supply chain. However, the existing supplier model is based on one-time projects. A strategic approach is needed to develop and strengthen EU leadership and prepare the field for large-scale production of fusion machines.

- Regulation: Governments and policymakers will play a crucial role in creating a stable and predictable environment for businesses and investors during the commercialization of fusion energy . Some countries are already defining regulatory frameworks, tailored to the specific risks of the technology. Along this path, Europe risks falling behind without clarity on an enabling regulatory framework.Additional challenges such as public acceptance, digitalization, innovative maintenance, and plant efficiency should also be addressed.

As Eni, we remain committed to actively engaging in addressing these multifaceted challenges to contribute to the realization of fusion energy as a clean and sustainable energy source.

Francesca Ferrazza

WHAT R&I POLICY INITIATIVES?

3. What R&I policy initiatives could the EU put in place to achieve the above in the shortest possible time?

3.1. What R&I actions are needed to capitalise on the return of investment from ITER in parallel with accelerating fusion research and developing the European fusion pilot plant?

You mentioned a very important word: capitalise. It's important to capitalise on the lessons learned during the construction of ITER and on the ones that will be learned during its operation in the future.

In addition to this, several key Research and Innovation actions are essential. I would mention five domains. One is fusion plasma physics. It is crucial to continue improving confinement, modelling, simulation, stability of the plasma, and exhaustion with advanced diagnostics.

The second field is the self-sustained production of tritium, which is the fuel required for fusion energy. It is essential to invest in and develop all the relevant technologies in order to master the tritium breeding cycle.

Regarding power plants, efforts must be made to optimise their design, their engineering, and their system integration including innovative cooling systems, remote maintenance techniques, and advanced control systems. The EU will be thus able to maximize the benefits of its investment in ITER, accelerate fusion research, and advance the development of a European fusion pilot plant.

A key aspect is also advanced materials. Investments are needed to produce materials that can withstand the extreme conditions inside a fusion power plant in terms of high temperatures and intense neutron fluxes.

Finally, it's important to develop the next generation of magnetic technologies to increase fusion power output. Advancements in this field, including high-temperature superconductors, will be decisive to the economic success of future power plants.

Maria Faury

3.2. Is the European fusion roadmap sufficiently flexible to cope with these changes in a timely manner?

Absolutely! The roadmap has been conceived to be the reference for EUROfusion R&D efforts, and the focus of our activities. But it has always been a dynamic guide, evolving according to the changes in the surrounding ecosystems, and the changing needs.

In particular, EUROfusion has recently revised this approach, collectively and in full cohesion across all of our members, in view of the increased awareness of fusion needs, the realization that it is possible to learn lessons from all the steps of the

ITER project, and the identification of the most crucial gaps that need to be filled by research and development.

The EUROfusion Consortium has recently completed a facilities review, with the help of an external panel, to understand which facilities, as of today, are essential to advance the roadmap, and is taking the necessary steps to develop these and exploit them jointly and in the most effective way.

The consortium of course also recognizes that both the resolution of the remaining technological gaps and the development of the DEMO step to demonstrate the commercial feasibility of fusion on Earth, necessitate a full partnership between the public research and academic sector and industries.

Dynamic evolution also implies an increased openness to innovation, in science and in fusion-enabling technologies, embracing state-of-the-art approaches such as Artificial Intelligence, or additive manufacturing.

Such an open approach naturally calls for another kind of openness, namely with respect to the workforce that we educate and train. We must attract and train high-quality and diverse individuals – diverse in all senses of the word – as the new generation that starts today in fusion will be the one that, by operating in the context of public-private partnerships, will lead to our ultimate goal, fusion power plants.

Ambrogio Fasoli

3.3. What key elements of regulatory frameworks are needed to foster fusion energy innovation?

Building a regulatory regime for fusion that is appropriate to the level of risk and is separate from the regulation of today's nuclear fission power plants is necessary to unlock new investments into commercial fusion.

The UK and the US have confirmed fusion regulatory regimes that will separate fusion from nuclear fission.

Where possible, governments should use current risk-informed regulations, building on decades of experience at fusion experiments like JET and at other similar machines, like particle accelerators.

Only with regulatory certainty of this nature will investment-backed firms feel comfortable in siting and building new fusion pilot plants in any country.

Andrew Holland

WRAP UP SESSION AND KEY MESSAGES

András Siegler

Senior Advisor of the National Research Development and Innovation Office of Hungary

Let me try to wrap up this rich Roundtable.

Andrew Holland from the Fusion Industry Association has given us the figures about the investments of private companies. Worldwide, we speak of around EUR 5.5 billion (USD 6 billion) of investments have been directed towards fusion firms. This commitment demonstrates the interest of industry in technologies and components for fusion reactors. Still, fusion industry in the EU is lagging behind in the global race for commercial fusion. On the other hand, the EU is home to a number of supplier companies which, under favourable conditions, can meet the needs of commercial fusion energy, thanks to decades of public investment into devices like JET and ITER. There is an opportunity to maintain the European leadership, if the existing excellence of the EU in public-funded science and infrastructure is combined with innovation by the private industry and placed in an enhanced regulatory environment that is fit for purpose.

Francesca Ferrazza presented the commitment of ENI, the largest Italian energy company that is investing in fusion energy. ENI participates in the Divertor Tokamak Test facility project in Frascati, Italy. At the same time, it invests in the US-based Commonwealth Fusion Systems that has ambitious plan to realize a commercial fusion plant. It shows that research and deployment, public and private investments, long and short-term goals must and can go hand in hand.

As regards the extant challenges in fusion research, public funding is also needed. Maria Faury highlighted several examples of research topics that will require public investment. She mentioned the renewed worldwide interest in fusion and its promises of abundant and decarbonized energy source. She also emphasized the recent massive private investments in fusion startups. She highlighted the political will to accelerate development programmes towards commercial reactors, which is happening in some European countries, in Asia and in the US. Designing and building a fusion reactor is a highly complex task and needs strong central leadership combining the knowledge of the research laboratories, the experience of the large companies and the agility of the start-ups.

Thomas Mull, on behalf of Framatome and the Fusion Industry Innovation Forum (FIIF) underlined the need to establish lasting industry-academia partnerships for the specification and design of a first-of-a-kind fusion power plant. Framatome and the FIIF are convinced that fusion electricity will be a future key energy technology. He drew the attention of the panel to the FIIF's efforts to implement an effective collaboration between private industry and public research centres. The "roadmap to fusion electricity" is meant to give the industry a long-term vision of fusion development with technology transfer between research centres and industry.

Maria Teresa Dominguez clearly showed the size and the learning process at ITER. Be it planning, engineering, 3D modelling, calculation, qualification, civil engineering, ITER is a reference for future fusion plants. Bottlenecks are now clearer. After a first-of-a-kind machine is built, lessons can be drawn and methods, materials and technologies improved.

Ambrogio Fasoli underlined that interest in fusion energy has grown enormously thanks also to EUROFusion's R&D successes like the energy records at JET and thanks to the consideration that power plants providing baseload electricity are essential for energy transition and energy security. EUROfusion is also looking at the conceptual design of a prototype fusion power plant which is aimed to produce hundreds of MWs of electric power whilst being self-sufficient by producing its own fuel. It is meant to demonstrate the commercial feasibility of fusion. However, this requires a collaborative approach involving joint leadership between research organisations and industrial partners. This prototype fusion power plant needs to be designed and built within a fully industrial framework, and to succeed we must attract and train high-quality and diverse individuals – professionally but not only, fostering an inclusive and diverse environment that will engender creativity and innovation – a unique new generation that today starts being engaged in research and will work within the new private-public framework, leading to our ultimate goal, to commercially viable fusion power plants.

Markus Roth emphasised the role of startups to lead the change in technological advancements and breakthroughs. In fact, startups bring agility, creativity, and entrepreneurial spirit that is essential for pushing the boundaries of what is possible in fusion research and development. He highlighted the importance of fostering an innovation-friendly ecosystem that encourages collaboration, investment, and risk-taking.

It is difficult to predict what the future of fusion energy will look like. Probably, a set-up of networked public labs for certain research-intensive tasks, of large and experienced firms for the construction phase, and a panoply of startups and SMEs for producing first-of-a-kind components and delivering breakthroughs.

One thing is sure: The best way to propagate knowledge from laboratories to industry is to promote partnerships between public research entities and private industry, large and small. That is the common thread of this Roundtable.

To make fusion energy a success, we need the discoveries of the most talented scientists, and the pragmatism and engineering capabilities of the industrial actors. Hence, the education and training of the next generation of fusion scientists and engineers is also fundamental.

RECOMMENDATIONS AND NEXT STEPS

Harnessing the Sun's power on Earth to provide mankind with a nearly limitless source of clean energy is a monumental task requiring collaboration and coordination across the board.

During this Roundtable we have heard from high level stakeholders from both the public and private sectors, from large industrial consortia to small enterprises and startups, how this task could be tackled, building on the EU's technological and scientific leadership and harnessing the EU's growing industrial capacity developed through the construction of ITER.

While Europe has made significant achievements in fusion research, there is a pressing need to capitalise on our progress, establishing an agile research and innovation framework. We need to foster a stronger collaboration between industry and academia.

Today, I witnessed a genuine interest from both industry and academia to work together and improve their collaboration. However, challenges persist in mobilising industry efforts for fusion research, and call for sustained public support at both EU and national level.

That's why, to enhance the links between fusion research and industry, including the startups, we are exploring the opportunities of two powerful instruments:

- the creation of a Public-Private Partnership on fusion;
- the establishment of an Innovation Pillar to support bottom-up research on fusion.

Both are expected to be launched under the Euratom Research and Training Programme.

A Call for proposal for a Coordinated and Support Action will be published at the end of May 2024 in the frame of the Euratom Work Programme 2023–25. This action will lay the groundwork for the future Public-Private Partnership. As a first step, we aim at the creation of a European Fusion Industry Platform.

Additionally, we will continue collaborating with our colleagues Commissioners, Ms Kadri Simson and Mr Thierry Breton on the development of a possible future EU fusion strategy with further stakeholder consultations planned in the coming weeks and months.

All messages of this Roundtable will be made accessible to the public.

I extend once again my gratitude to MEP Buşoi for offering the European Parliament's perspective, and all our speakers for their innovative and constructive ideas.

Iliana Ivanova
European Commissioner for Innovation, Research, Culture, Education and Youth

Attendees to the High-Level European Roundtable

Giampiero Lapenna, Ansaldo Nucleare - Marco Palmero, Ansaldo Nucleare - Bernard Blanc, Assystem - Miguel Carrera, AVS - Michael Gehring, Bilfinger Noell GmbH - Ana Belén del Cerro Gordo, CDTI - Bertrand Bouchet, CEA - Thierry Pussieux , CEA - Jennifer Ganten, CFS - Angel Ibarra, CIEMAT - David Rapisarda, CIEMAT - Arto Timperi, COMATEC Group LTD - Hojka Jarc, Cosylab - Elio Filippo, Deutelio - Francesco Romanelli, DTT - Eric Boom, EB Consultancy - Al Mazouzi Abderrahim, EDF - Paola Batistoni, ENEA - Alessandro Dodaro, ENEA - Edoardo Fiorentini, Eni - Eliana De Marchi, ENI - Sofia De Paolis, Eni - Günter Kraft, Focused Energy - Ulli Kraft, Forum Fusion Deutschland - Manuel Pellissetti, Framatome GmbH - Karen Amram, French Research Ministry – Peter Schroth, German Federal Ministry of Education and Research - Stéphane Grandjean, French Research Ministry - Jean Philippe Gouy, French Secretariat for European Affairs - Cyrille Mai Thanh, Fusion Industry Association - Milena Roveda, Gauss Fusion - Moisés Weber, IFMIF DONES - José Manuel Perlado, Instituto de Fusión Nuclear (Universidad Politécnica de Madrid) - Stuart Codling, Jacobs - Heike Freund, Marvel Fusion - Moritz von der Linden, Marvel Fusion - Michal Kazda, MIFRE Energy - Peter Roos, Novitron Fusion - Jose Manuel Perlado, Polytechnic University of Madrid - Lucio Milanese, Proxima Fusion - Francesco Sciortino, Proxima Fusion - Francesco Volpe, Renaissance Fusion - Christian Schoenfelder, Schoenfelder Training - Marianna Ginola, SIMIC S.P.A. - María Ángeles Martín Prats, Skylife - Guido Van Oost, University of Ghent

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

Europe Direct is a service that answers your questions about the European Union.
You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),
- at the following standard number: +32 22999696,
- via the following form: european-union.europa.eu/contact-eu/write-us_en.

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

EU open data

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

The European High-Level Roundtable on Fostering Innovation for Fusion energy in Europe gathered leading public and private stakeholders in the field of fusion energy research and technology. Participants discussed how to accelerate the demonstration of fusion electricity generation, and involve bigger industrial stakeholders, as well as startups, in the transition from LAB to FAB. The participants also considered potential R&I policy initiatives to unlock the disruptive potential of EU innovation.

Research and Innovation policy

Publications Office
of the European Union