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Regulatory Horizons Council

Report on Fusion Energy

31st May 2021

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Note on report versions

The main report was published 31st May 2021 and consists of the forewords, chapters one to seven, and appendixes A-C.

The Commercial Fusion Supplement was added on 6th August 2021 and consists of chapter eight plus appendix D. The rationale for this supplement is explained in chapter eight.

Contents

Forewords

Cathryn Ross

Chair of the Regulatory Horizons Council

I am delighted to be writing the foreword to this, the Regulatory Horizons Council's first 'deep dive' report.

The Council exists to promote regulatory change that is needed to ensure the UK gets best value from technological innovation. That value could be in terms of productivity and global competitiveness; it could be in terms of environmental sustainability or social inclusion. But no technological innovation will deliver value unless it is able to make the – often difficult – journey through from concept to start up and from start up to scale. Regulation plays a critical role in this journey and may even be the deciding factor in the success, or otherwise, of a particular innovation.

Regulation can impede innovation in many different ways. It may be designed and implemented in ways that suit existing technologies and established firms, but are inimical to disruptive technologies or business models. It can be hard for those who are not practised in and resourced for discussions with regulators and policymakers to navigate. It may simply be unclear, creating risk that undermines investment cases. It may create processes that take too long to implement, adding cost and slowing down the vital process of iteration, learning and refinement.

But the answer is not always as simple as 'deregulation'. Regulation often fulfils a need to address public concerns. Regulation helps to keep us safe, ensure we are not ripped off, protects and promotes healthy, competitive markets. If technological innovations are to deliver benefits, they must be taken up and trusted by society, and regulation plays a critical role in securing that trust.

So the answer must lie in getting the right regulatory frameworks. By doing this, we will enable innovation to happen *and* foster the trust that is needed for it to achieve maximum impact.

And we can do this. The UK has a long track record in leading edge thinking and best practice on regulation. We have dedicated, expert, passionate regulators who are already pushing the boundaries of regulatory technology to deliver benefits from innovation. We have a vibrant community of inventors, innovators and entrepreneurs with myriad ideas about new and better ways of doing things. We also have a wide variety of highly engaged and articulate civil society groups, providing clarity both on issues of potential concern and possible solutions.

By listening to, understanding, and working with others, the Regulatory Horizons Council hopes to achieve real impact by advocating regulatory approaches that will enable innovation to flourish and deliver value across our economy and society. This report on fusion energy exemplifies our approach. Our recommendations are grounded in an understanding of the relevant technologies, a desire for simplicity and clarity, and they are eminently practicable. I commend them to you.

Dr Tim Stone CBE

Chair of the Nuclear Industry Association

Fusion energy has been for many years, and is still today, the most promising long-term solution for the world's need for energy without CO_2 pollution. With many potential technologies – from tokamaks to stellarators to modern inertial confinement techniques such as First Light Fusion and General Fusion – the promise of fusion as a net energy generator is now tantalisingly near.

The work of the team at the Culham Centre for Fusion Energy with the JET tokamak has already produced the world's longest continuous burst of fusion and the outstanding work of that team has led to the design of the world's first net-energy fusion device – ITER – which is due to create its first plasma in 2025. ITER is, however, primarily a research design and has not been created to be a production reactor. Meanwhile, the Culham team have devised a much smaller and neater tokamak concept – STEP (Spherical Tokamak for Energy Production) which is now moving towards construction of a practical reactor.

So far, the safety regulation of fusion has been on the basis of scientific experimentation and the time is ripe to consider, carefully, how practical fusion reactors should be regulated during actual construction and operation.

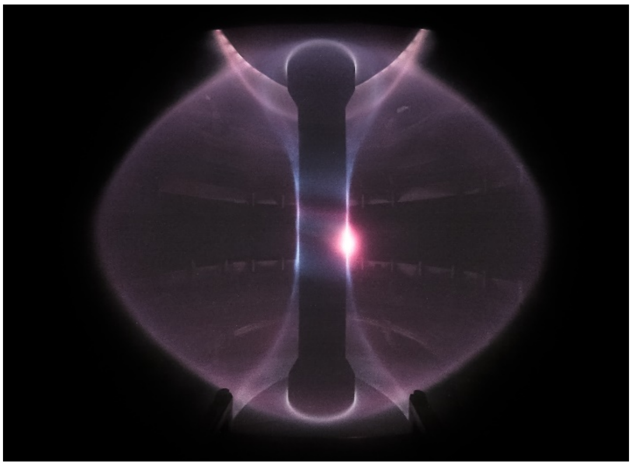
Regulation of commercial nuclear energy devices in the UK has so far only been for fission reactors of which those currently operating provide around 17% of the UK's electricity at the time of writing. The UK's nuclear regulation for fission is currently provided by the Office for Nuclear Regulation and the Radioactive Substances and Installations unit of the Environment Agency. Importantly, nuclear safety regulation in the UK has always been based on principles and outcomes and as such the ONR and EA are highly regarded, globally, for the quality of their regulatory supervision and pragmatism as well as high levels of safety.

As fusion moves towards practical reality, it is time to examine the basis on which fusion regulation should be implemented. The consequences of safety regulation will materially affect both public and investor confidence and it is vital that both are considered carefully in the development of fusion safety regulation. The public and investors in low-carbon energy both need to have robust confidence in the safety regulation of fusion.

This report and the approach taken by the Regulatory Horizons Council is a very valuable step towards a sensible and pragmatic approach to safety regulation of fusion. The UK needs to continue to be the world leader in all aspects of fusion and I look forward to seeing the results of the consultation and the application of wisdom in the ultimate decisions.

1. Executive Summary

Fusion energy has the potential to provide a virtually limitless source of zero-carbon electricity.



Plasma in the MAST spherical tokamak device - https://ccfe.ukaea.uk/wp-content/uploads/2019/10/Plasma-in-the-MAST-spherical-tokamak-device.jpg

The UK is widely recognised as a world-leader in the most promising fusion energy technologies. The UK Atomic Energy Authority (UKAEA) is building the Spherical Tokamak for Energy Production (STEP), a prototype fusion power plant. The first phase of this (the concept design) will be completed by 2024 and a siting competition to find a location has already been launched with an expected announcement in 2022. Private industry is also developing concepts and securing commercial investment.

The UK must now show it has the appropriate regulatory environment to capitalise commercially by providing a clear direction in early 2021. The full regulatory framework may take longer to develop and is likely to evolve as more fusion technologies come to market, but uncertainty around these issues is a key part of embracing innovation and must not be used as a reason to delay providing clear leadership on the overall approach.

In this report, the Regulatory Horizons Council (RHC) focuses on the regulatory approach and regulators for STEP. It engaged with key stakeholders and reports, and developed criteria to produce its recommendations. It currently plans to conduct a follow-up report, building on this one, that looks at the broader regulatory framework for commercial fusion.

Fusion energy does present some hazards, as is the case with other industrial processes and conventional power generation technologies. However, the hazards are significantly lower than those associated with nuclear fission. As the International Atomic Energy Agency (IAEA) notes, it is impossible for fusion to cause a nuclear accident and STEP will not produce any high-level radioactive waste.

Fusion in the UK is currently regulated by the Health and Safety Executive (HSE) and the Environment Agency (EA), or their equivalents in devolved administrations.[1] This is within a framework appropriate for various complex and hazardous industrial processes and the RHC has found that they regulated fusion in a proportionate way. In many other countries the nuclear fission regulator covers all radiological hazards and therefore covers fusion. In the UK, the nuclear fission safety regulator is the Office for Nuclear Regulation (ONR).

The RHC recommends that the UK champions the way for a non-fission approach, by setting out and consulting on a bold, forward-looking vision of how HSE and EA[2] could lead and evolve the regulatory approach for STEP. The RHC found that although changes, potentially including legislation, will be needed, STEP does not require a different regulatory approach to that which has worked well for fusion to date. The EA and HSE provide the proportionate framework for regulation of STEP commensurate with the hazards presented by the technology. This approach will help enable the rapid and safe commercialisation of fusion energy and contribute to backing its contribution to long-term growth in the UK.

Significant changes to the current approach, in particular the adoption of a fission-based regulatory approach to fusion, risk being disproportionate, creating uncertainty and substantially increasing costs. Importantly, the perception of a more fission-based approach, could also risk falsely alarming the public and discouraging private investment.

The RHC also found that more could be done to clarify, both to the industry and the public, what this regulatory approach is, how it will be enforced and how it could be applied to future fusion projects. **It recommends that a joint guidance document is produced to cover this by EA[3], HSE and BEIS.** The guidance should also be developed in consultation with the UKAEA as appropriate. This could also help to provide reassurance that there are no gaps in the regulatory approach.

The RHC also recommends that the government takes the following actions:

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[1] SEPA (Scottish Environment Protection Agency), NRW (Natural Resources Wales) and NIEA (Northern Ireland Environment Agency) HSENI (Health and Safety Executive Northern Ireland). Currently there are no fusion devices in Scotland, Wales, so it is only the EA that regulates fusion in the UK at this time. However, should fusion come to other parts of the UK, then SEPA, NRW and NIEA would regulate respectively under a similar framework to the EA.

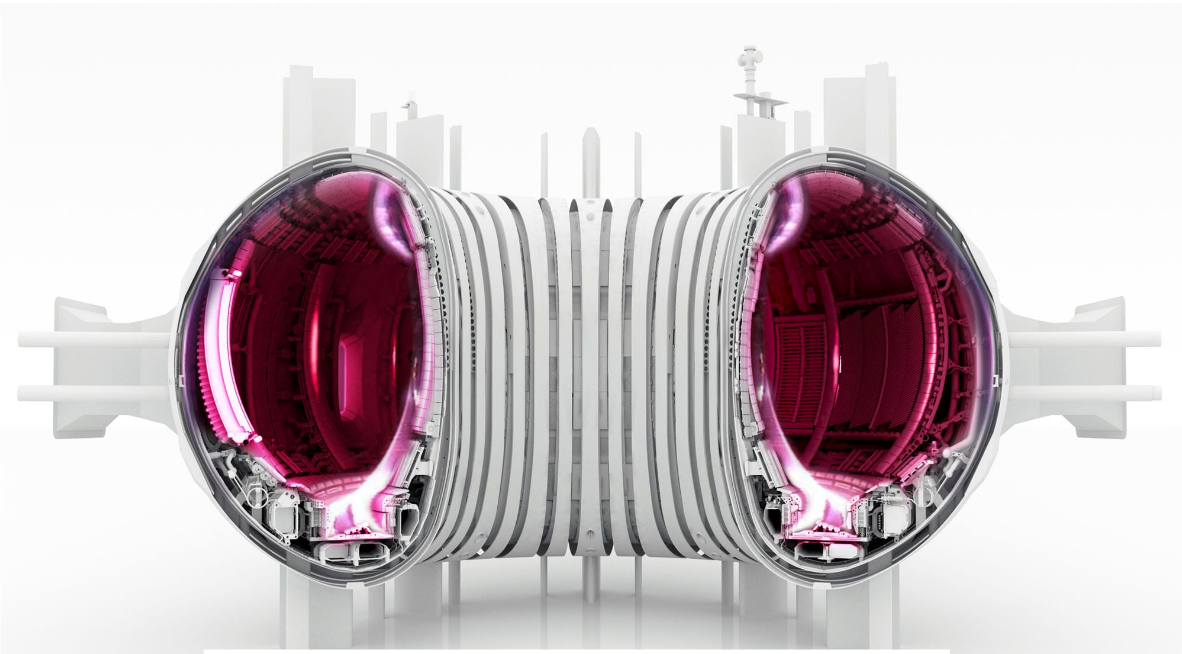
[2] and devolved equivalents

[3] and devolved equivalents

- Consult as soon as possible, and by Summer 2021 at the latest, on the above main recommendation to provide urgent regulatory clarity. The consultation should also act as the start of a wider public engagement programme to help public understanding of fusion in general as well as the regulatory approach.

  The consultation should also contain a call for evidence on consequential changes, such as changes to legislation, that may be required for this approach. If ONR's current policy definition of a 'bulk quantity' of radioactive material, based on quantities specified in the Radiation (Emergency Preparedness and Public Information) Regulations 2001 ('REPPIR') are updated based on values specified in the 2019 version of those regulations, as proposed in the recent ONR consultation, a commercial-scale fusion reactor could be considered a prescribed nuclear installation under the relevant legislation, bringing it into ONR vires at the start of the fusion process and thereby increasing regulatory burdens. We note that ONR are actively seeking to define their interpretation of bulk quantities to avoid the inadvertent capture of fusion.

- Work with HSE, EA and UKAEA to consider and take action on potential upskilling that may be needed as STEP and other fusion projects develop further; and how best to cooperate with other regulators internationally.



Cutaway illustration of JET - https://ccfe.ukaea.uk/wp-content/uploads/2019/10/Cutaway-illustration-of-JET-2.jpg

2. Introduction and background

The Regulatory Horizons Council (RHC) is an independent expert committee that identifies the implications of technological innovation, and provides government with impartial, expert advice on the regulatory reform required to support its rapid and safe introduction. It conducted horizon scanning and prioritisation exercises to first get to a shortlist of priority areas, and then selected four initial areas to focus on: fusion energy, genetic technologies, unmanned aircraft and medical devices.

This report represents views from across the RHC and was led by Parag Vyas with particular support from Alastair Denniston (Council members).[4]

What is fusion energy?

Fusion energy[5] aims to replicate the process which powers the sun. When light atomic nuclei, such as hydrogen, fuse together to form heavier ones, such as helium, a large amount of energy is released. To do this, fuel is heated to very high temperatures forming a plasma in which fusion reactions take place. A commercial power station will use the energy produced by fusion reactions to generate electricity. This process is fundamentally different from nuclear fission – the reaction that is used in today's nuclear power stations – in which energy is released when a nucleus splits apart to form smaller nuclei. Further background is available here on fusion science from the International Atomic Energy Agency

2.1 Why fusion and why now?

Fusion energy has the potential to provide a virtually limitless source of zero-carbon electricity. Fusion is part of the Prime Minister's ten point plan for a green industrial

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[4] RHC membership details are here: https://www.gov.uk/government/groups/regulatory-horizons-council-rhc#membership

[5] We choose to use the term 'fusion energy' rather than 'nuclear fusion'. This is to avoid confusion with nuclear fission, which is often called "nuclear power". This is also to emphasize that Fusion Energy is inherently less hazardous than fission. Furthermore, we are aware that the term 'nuclear' has negative connotations for the perception of the technology. For example, in the medical sector, Magnetic Resonance Imaging (MRI) is now commonly used instead of Nuclear Magnetic Resonance (NMR) to address concerns from the public.

revolution and its success will help the government priorities of backing long-term growth, delivering on net zero, and unleashing innovation.

The UK is globally recognised as a leading centre for fusion technology[6] and the Joint European Torus (JET) experiment in Oxfordshire has demonstrated the viability of a magnetic confinement approach. The UK's research capabilities across the technical challenges of fusion mean that the UK is a strong place to promote the commercialisation of this technology.

Economic Benefits
The economic consultancy London Economics have estimated that for every £1 invested in UKAEA, approximately £4 is generated in return through the creation of employment, contracts and materials spend in the UK as well as commercial benefits to UK industry helped by UKAEA's world-leading knowledge in fusion.[7] In addition, the Fusion Industry Association (FIA) estimated that over $1 billion in private capital has been invested in new start-up companies with transformative approaches to fusion and the JET facility underpins over 1,000 jobs in Oxfordshire, including 600 highly skilled scientists and engineers.[8]

Environmental Benefits
The Engineering and Physical Sciences Research Council states that 'fusion as an energy source has the potential to radically change the world's energy supply providing low-carbon and safe energy for thousands of years'.[9] This is partly due to the fact that fusion draws on abundant and widespread fuel resources (the raw materials are found in seawater and the earth's crust), and the quantities needed are relatively small.[10]

International co-operation benefits
The UK has recently reached an agreement with the EU and Euratom to participate in the Euratom Research and Training Programme Fusion for Energy and the ITER project, as a Fusion for Energy member from 1 January 2021. Fusion projects bring

[6] https://epsrc.ukri.org/newsevents/pubs/indrevfissionfusion
[7] The impact of the UK's public investments in UKAEA fusion research
[8] Fusion Industry Association Announces Launch
[9] https://epsrc.ukri.org/newsevents/pubs/fusion20yearvision/
[10] https://ccfe.ukaea.uk/all-systems-go-for-uks-55m-fusion-energy-experiment/

many countries together for mutual scientific cooperation to help deliver a net zero power source.

Safety
Fusion energy does present some hazards, as do many other industrial processes and conventional power generation technologies. However, the radiological overall hazard of the fusion process is intrinsically lower than those associated with nuclear fission.

Unleashing Innovation Benefits
Research into Fusion Energy helps advance "adjacent" technologies through technology transfer. These include advancements in robotics, developments of new materials and contributions to computing and artificial intelligence. Future applications are expected in other fields, such as space exploration, mining and healthcare, and transport.

Differences between fusion and nuclear fission[11]

- Both are nuclear processes in that they involve changes to the nucleus of atoms, but fission splits heavy elements whereas fusion joins two light elements. **In common parlance though, the term 'nuclear power' refers to *nuclear fission* not fusion energy.**
- **Fusion *cannot* cause a nuclear runaway reaction accident** because it is not based on a chain reaction.
- Unlike nuclear fission powerplants, **fusion does not create any significant long-lived radioactive nuclear waste.**
- **Fusion reactors are considered inherently safe.** There is no risk of fuel meltdown and they cannot be used to produce weapons.

Providing a clear regulatory approach now to maximise UK future benefits from investment
The UK Atomic Energy Authority (UKAEA) is building the Spherical Tokamak for Energy Production (STEP), an innovative plan for a prototype fusion power plant. The

[11] Textbox information taken from https://www.iter.org/sci/Fusion and https://www.iaea.org/topics/energy/fusion/faqs

UKAEA is a non-departmental public body under the Department for Business, Energy and Industrial Strategy (BEIS), established under the Atomic Energy Act 1954. The first phase (the concept design) will be complete by 2024. The siting competition has been launched and a site is expected to be announced by the end of 2022. Detailed design and construction will lead to a functioning prototype power station by 2040. Private industry is also developing concepts and securing commercial investment.

The UK must now set out an appropriate regulatory environment for STEP by providing a clear direction in early 2021. A key part of this is providing clarity on how commercial fusion projects will be regulated and by whom.

Fusion must not be regulated in the same way as nuclear fission. It would lead to unnecessary burdens, substantial cost increases and could also deter innovation by reducing flexibility in design. It has been suggested by some fusion stakeholders that this has been experienced with the ITER fusion project in France, which has taken a nuclear fission approach to regulation. Adopting a fission approach is likely to severely undermine private sector fusion development and would send the public a disproportionate indication of the actual risk fusion in fact poses.

Fusion in England is currently regulated by the Environment Agency (EA) and Health and Safety Executive (HSE).[12] In most other countries the fission regulator has jurisdiction over fusion. This includes the USA, although the Nuclear Regulatory Commission there is currently consulting on its approach.[13] In the UK, fission is regulated by the Office for Nuclear Regulation (ONR) and the relevant environment agency.

The UKAEA, the government research organisation responsible for the development of fusion, has taken a leading role in operating fusion experiments in the UK since the 1950s. The bulk of the work has taken place at a single site, Culham in Oxfordshire. With new devices about to be constructed, including STEP which is currently determining its site location, and private sector developers taking forward concepts, there is a need for certainty about the long-term framework for regulation. Doing this

[12] There are Environment Agency equivalents for each of the UK devolved nations: Natural Resource Wales (NRW), The Scottish Environment Protection Agency (SEPA), The Northern Ireland Environment Agency (NIEA)

[13] https://www.fusionindustryassociation.org/post/doe-nrc-fia-public-forum-on-a-regulatory-framework-for-fusion

will encourage more private finance and will mean the UK enjoys a firmer footing for effective regulation at home and for influencing international fusion regulation.

2.2 Report Scope

Key questions

The RHC takes a multidisciplinary and agile approach to developing its recommendations. It conducted its investigations according to the following planned questions:

Overarching question: "How can the UK continue to move towards an innovation-friendly, long-term regulatory framework to support the rapid and safe introduction of fusion energy?". This should play a critical 'enabling' role: increasing market confidence and certainty through regulatory clarity, and so supporting private investment into promising fusion technology. It should also ensure that fusion is regulated in an appropriate bespoke manner and thereby avoids unnecessary burdens and costs.

First deliverable: This initial report with recommendations on the regulators and regulatory approach for STEP.

Second deliverable: A look at the regulatory framework for commercial fusion and to build on the work from this first report. This deliverable has been completed and is the chapter 8 supplement of this report.

Public engagement

Although the RHC decided that public engagement on fusion in general (as opposed to specifically on regulation) was not in scope, it noted the importance of public confidence for the regulatory approach. In particular, the process of selecting a regulatory framework needs to be transparent, evidence based, account for diverse opinions and well communicated. In addition, it will be critical to ensure that public stakeholders do not conflate fusion energy with nuclear fission and fully appreciate the lower level of risk of fusion energy.

Focusing initially on STEP

STEP launched its siting process in December 2020 and a decision is expected by the end of 2022. The concept design is to be completed by the end of 2024. Regulatory clarity is needed as soon as possible to facilitate investment later in the 2020s. A preliminary decision on the regulators for fusion, which can be included as part of a consultation, would help to start informing the regulatory environment. This should help provide clarity to nominees who wish to bid to site STEP and the regulator(s) who wish to know the regulatory process and their responsibilities. For example, it is important to know whether government will mandate that STEP must be on a nuclear-licensed site before the site selection is made.

The urgency created with the STEP-siting process is why this initial report focuses primarily, although not exclusively, on the regulatory approach for STEP. Considering the most pressing question first reflects the RHC's agile approach. **The RHC intends to focus more on the broader regulatory framework after this initial report.**

3. Methodology

The RHC used the following process to arrive at its recommendations:

1. Consulted the Department for Business, Energy and Industrial Strategy (BEIS) fusion policy team to discuss their **objectives for a regulatory framework** and reflected on these to formulate **key questions to explore**.

2. Conducted **stakeholder engagement** with relevant regulators and key parts of industry to investigate how to achieve these objectives[14]. This was supplemented by reviewing several key reports.

3. Used key sources on innovation-friendly regulation to help develop five **key criteria for a fusion regulatory framework** that can meet the required objectives. These were iterated following input from stakeholders.

4. Applied the collated evidence to the criteria to provide **recommendations** for what the regulatory approach should be for STEP. This process also included identifying common challenges and differences between STEP and other fusion projects, reviewing the risks to determine if a different type of regulatory approach to UK fusion research was needed, and whether any changes to the regulatory approach would require changes to the current regulators.

3.1 Fusion Objectives

BEIS provided and agreed with the RHC on the main objectives below for what a fusion regulatory framework should achieve. They are represented in Venn diagram form because the objectives are interconnected and all critical for establishing a successful framework. For example, maintaining human and environmental protections in a proportionate way that acknowledges the risks can help to provide assurances to the public. Similarly, if there is limited public acceptability for the technology, this can potentially act as a significant deterrent for facilitating the UK as

[14] The RHC can claim some expertise in innovation, regulation and, importantly, how regulation can stimulate innovation. However, the Council does not always have in-house expertise on the specific technologies that it examines, so stakeholder input is a key part of RHC work. The RHC brings a multidisciplinary approach drawing upon expertise from various sectors. As such it brings an outside view to the question.

an enabling environment for appropriate investment opportunities and commercialisation of the technology.

On the objective to ‘provide appropriate assurances to the public’, the RHC would particularly emphasise the need for a two-way dialogue which allows the public opportunities to pose questions and express views, thus ensuring public confidence in the safe and rapid adoption of fusion energy technology. We are conscious that the current framing of this objective largely suggests a ‘deficit’ model of engagement i.e. a one-way flow of information from experts to a largely passive public. While many members of the public are unlikely to appreciate the important distinction between fusion and fission, and increasing knowledge will be critical, there is no guarantee that this will automatically lead to increased acceptability or trust.

3.2 Stakeholder engagement and acknowledgement

As part of its ongoing investigations, the RHC has engaged with the below stakeholders to obtain their views on fusion regulation. This included their views on the type of regulatory approach, type of regulators, and their views on the key criteria we developed. The RHC intends to conduct additional engagement with regulators and other stakeholders in future.

Regulators

- Environment Agency (EA)
- Health and Safety Executive (HSE)
- Office for Nuclear Regulation (ONR)
- Natural Resources Wales (NRW)
- Northern Ireland Environment Agency (NIEA)
- Scottish Environment Protection Agency (SEPA)

Industry and projects

- UK Atomic Energy Authority (UKAEA)
- Fusion Industry Association (FIA)
- Tokamak Energy Ltd
- First Light Fusion Limited
- International Thermonuclear Experimental Reactor (ITER)
- Tokamak Fusion Test Reactor (TFTR)

Others

- The Domestic Fusion Policy Team within BEIS
- Tim Stone CBE, Chairman of the Nuclear Industry Association

The above stakeholders cover some of the key voices in the fusion sector, although further RHC work aims to engage more widely, including beyond those with direct interests in fusion. We are very grateful to the time and views provided by the stakeholders, including follow-up work on many occasions.

The main views from these stakeholders are captured in section six of this report. However, the following key themes came from a majority:

1. The current regulatory approach is broadly working well.

2. Increased intensity of regulation, appropriate for nuclear fission plants, would seriously harm private sector development in the UK and could deter future investment.

3. As important as the above point, if not more so, is the type of approach that the regulator takes in practice and whether they are more innately risk adverse, which can lead to disproportionate requirements.

4. Public and investor perception of fusion is key. In particular, its regulatory framework needs to be, *and be clearly seen to be*, distinct from that of nuclear fission.

4. Key Criteria

This section looks at the key criteria the RHC arrived at for the fusion regulatory framework for STEP and sets out how these criteria were arrived at.

The documents below were used as sources on innovation-friendly regulation to help develop the criteria. The specifics of how key points from these documents align with the criteria are in Annex A.

The Regulators' code
In addition to these sources, the RHC also reviewed the Regulators' Code, the 2014 framework for how regulators should engage with those they regulate. This provided a useful reference point to develop some elements of the RHC criteria. However, the RHC criteria below seek to be more tailored towards innovation-friendly regulation and for fusion regulation specifically.

4.1 Key sources on innovation-friendly regulation

2019 BEIS White Paper on Regulation for the fourth industrial revolution[15] – identified six challenges that need to be addressed, e.g. "*ensure that our regulatory system is sufficiently flexible and outcomes-focused to enable innovation to thrive*"

2020 BEIS Research on Regulatory approaches to facilitate, support and enable innovation[16] – Reviewed broad types of innovation-friendly approaches, e.g. "*supporting experimentation and testing of innovations using 'sandboxes' and 'testbeds'*"

2020 World Economic Forum Toolkit for Regulators on Agile Regulation for the Fourth Industrial Revolution[17] – Identified key tools for good regulatory practice, e.g. foundations such as "openness, proportionality and fairness"

[15] https://www.gov.uk/government/publications/regulation-for-the-fourth-industrial-revolution
[16] https://www.gov.uk/government/publications/regulator-approaches-to-facilitate-support-and-enable-innovation
[17] https://www.weforum.org/about/agile-regulation-for-the-fourth-industrial-revolution-a-toolkit-for-regulators/

4.2 Key criteria

The RHC then tested the criteria and corresponding descriptions with stakeholders to further develop them. The headline criteria stayed the same through this process, but the descriptions were improved. The criteria the RHC used for this report are as follows:

1. Proportionate and agile
Includes championing risk-based regulation, being adaptive and flexible, being outcomes- and goal-focused, and streamlining regulatory approvals. Will the risks be managed and assessed appropriately, and tailored to reflect substantive risk whilst minimising regulatory burdens but balancing safety and innovation, to ensure that the UK is the best place in the world for commercialising fusion energy?

2. Perception and trust
Includes providing sufficient assurance, inspiring confidence in the regulator's capability, acting openly, fairly and transparently, and providing sufficient certainty of approach. The regulator is clear over its expectations for the management of fusion activities and maintains a clear line of sight to legislative requirements. It also means that the public, industry and investors trust that the regulator and regulatory framework is best placed to deliver a proportionate and agile approach.

3. Lessons learnt and understanding
The regulator(s) have experience of the sector or if the regulator has less experience, their approach and regulatory framework can build on what has gone before (including internationally). Can the regulator be expected to have adequate experience and reach an appropriate standard by the time fusion becomes operational? Is there continuity of best practice as has been established on existing experimental devices in the UK and globally?

4. Experimentation and forward-looking
Innovations should be able to be tested and trialled under the regulatory framework. Is it proactive in identifying and embracing innovations and new ways to achieve compliance? Has adequate consideration been given to the different regulatory needs of test devices compared to long-run operational devices, in terms of balancing risk and innovation?

5. Support and collaboration

Includes the regulator holding themselves accountable and enabling the sector while also challenging it to continually improve and evolve - providing guidance and making it easy for industry and innovators to navigate the framework. The regulator and regulatory approach should help build partnerships and trade opportunities, and keep informed by developments, both domestically and internationally.

5. Options for regulatory approaches

5.1 Options

Fusion R&D in Great Britain is currently regulated by the Environment Agency (EA) and the Health and Safety Executive (HSE), covering the health and safety and environmental aspects of fusion activity and is broadly recognised to be fit for purpose. However, there is no regulation specifically for fusion in several other areas (e.g. licensing designs, export). Utilising the regulatory framework and approach for fission would not be appropriate given the differences in underlying risk and technology maturity.

In most other countries, the nuclear fission regulator covers fusion as well. This is the case in Canada, China, France, Germany, Italy, Japan, South Korea, and the US. The reason for this approach is often because that regulator covers all other radiological hazards (such as sources used in industry or research and x-ray generators in hospitals). This is not the case in the UK and helps to explain why the UK has not used the fission safety regulator for fusion.

For the purposes of this report, the RHC worked on the basis of the three broad options below for the regulatory framework for STEP. The options focus on who leads the regulatory approach, but the regulators may still benefit from working with other regulators, for example to assist with sharing knowledge, best practice and skillsets.

Option A – Evolution and continuation of current regulatory approach with HSE regulating on safety and EA on Environment
See overview of regulators section below.

Option B – Adaptation to ONR regulating safety (with EA still regulating on Environment)
See overview of regulators section below.

Option C – A new fusion-specific regulatory approach by a new regulator
It could be proportionate, given the size of potential gains from fusion, to create a new regulator. This option considers the creation of a fusion-specific regulatory approach led by a new regulator – one that either only regulates fusion or also

regulates other areas. It could be formed partly from existing expertise, such as from existing regulators and UKAEA.

5.2 Overview of UK Regulators

Relevant points about regulators in UK and abroad

The Environment Agency (EA)
The EA is the environmental regulator for England, responsible for implementing legislation and policies set by government. The Culham Centre for Fusion Energy (CCFE) operated by the UKAEA is regulated by the EA as a non-nuclear radioactive substances activity under the Environmental Permitting Regulations (EPR16). CCFE is regulated by the EA's Nuclear Regulation Group, the group who also regulate nuclear licensed sites, although the regulatory requirements and expectations are the same as for other comparable non-nuclear sites.

On non-nuclear sites, the EA regulates the storage and use of radioactive material and accumulation and disposal of radioactive waste to ensure proper protection of people and the environment. The EA is also the security regulator for specified sources held at non-nuclear sites.[18]

Regulatory engagement with complex or high-risk non-nuclear sites often starts prior to a permit being issued, in the form of pre-application discussions. Pre-application advice to prospective fusion operators is already built into EA's environmental regulatory model, discussing items relating to risk assessment preparation, complex modelling, monitoring requirements which would attract a time and materials charge to the operator.

The Control of Major Accident Hazards Regulations 2015 (COMAH) prevent and mitigate the effects on people and the environment of major accidents involving dangerous substances. COMAH 2015 is jointly regulated by the HSE and the EA, together acting as the competent authority. On nuclear licensed sites which are subject to COMAH, ONR and the relevant environment agency act as the joint competent authority.

[18] Some of the Environment Agency's requirements are legally dis-applied when a nuclear site licence (NSL) is in effect and in this case the Environment Agency only regulates radioactive disposals, including the discharge of gaseous and aqueous radioactive wastes.

The Environment Agency has established memorandum of understanding and mature relationships with both HSE and ONR. This ensures effective co-ordination of regulation, minimises duplication of regulatory effort, and avoids placing conflicting demands on businesses and others as a consequence of regulation.

The Health and Safety Executive (HSE)
HSE is the policy lead for occupational health and safety in Great Britain. HSE is the regulator in Great Britain for the risks to workers and others, including the health and safety from work with fusion technologies. The legislative framework for the control of risks associated with fusion technologies is well-established and includes primary and secondary legislation.

Fusion is not a prescribed activity under the 1971 Nuclear Installations Regulations, therefore HSE, rather than ONR, regulates safety matters under the Health and Safety at Work Act 1974 and regulations made under that act such as the Control of Artificial Optical Radiation at Work Regulations 2010, the Control of Electromagnetic Fields at Work Regulations 2016, the Ionising Radiations Regulations (IRR17) and the Radiation (Emergency Preparedness and Public Information) Regulations 2019 (REPPIR19).

Joint inspection visits between EA and HSE occur when there is a clear purpose for doing so and where there are demonstrable benefits to all parties, both regulators and the operator, in having a co-ordinated approach. For existing non-nuclear facilities there are also regular discussions and interactions between the two regulators to ensure sharing of knowledge and any issues identified, including potential enforcement action. A memorandum of understanding exists between EA and HSE which covers working together practices.

The Office for Nuclear Regulation (ONR)
The ONR is a statutory body created by the Energy Act 2013 with extensive legal powers to regulate the nuclear industry in Great Britain. ONR supports and intervenes as necessary with UK duty holders and/or Euratom and the International Atomic Energy Agency (IAEA). ONR also enforces the relevant statutory provisions of the Health and Safety at Work Act 1974 at GB nuclear licensed sites.

The ONR describes its regulatory philosophy as enabling and goal setting.[19] The enabling approach means it takes a constructive approach with duty holders and

[19] http://www.onr.org.uk/documents/2020/onr-innovation-report-2020.pdf

other relevant stakeholders to enable effective delivery against clear and prioritised safety and security outcomes. Taking into account the magnitude of the hazard and risk is one of the key principles of ONR's enforcement policy (the 'targeting' principle). Duty holders need to consider both the magnitude of the hazard and the frequency of the hazard or fault in demonstrating that the risk has been reduced to ALARP ('as low as reasonably practicable').

6. Reviewing and applying the evidence

This stage applied the collated evidence to the criteria to provide **recommendations** for what the regulatory approach should be for STEP. It also included comparing STEP to other fusion projects and reviewing the risks, to determine which type of regulatory approach to UK fusion is needed.

6.1 Lessons learnt from other projects

The RHC reviewed reports on various relevant projects and discussed these projects and similar situations with stakeholders. STEP, JET, ITER and TFTR are all tokamaks – a type of fusion device, so there is a continuity between them and international collaboration and learning. The summaries of the projects and any points that are particularly relevant to STEP are as follows:

JET

- Located in the UK and operated by Culham Centre for Fusion Energy, the Joint European Torus (JET) is the focal point of the European fusion research programme. JET was designed to study fusion in conditions approaching those needed for a power plant. It is currently the only experiment that can operate with a deuterium-tritium fuel mix.[20]
- Its success has led to the construction of the first commercial-scale fusion machine, ITER, and has increased confidence in the tokamak as a design for future fusion power plants.[21]
- The current UK approach to regulating JET, led by HSE and EA, is understood to have broadly worked well.

[20] https://ccfe.ukaea.uk/research/joint-european-torus/#:~:text=JET%20was%20designed%20to%20study,science%20and%20engineering%20of%20fusion.

[21] https://ccfe.ukaea.uk/research/joint-european-torus/#:~:text=JET%20was%20designed%20to%20study,science%20and%20engineering%20of%20fusion.

- STEP will present significantly larger hazards than JET due to much larger quantities of tritium, which is radioactive. It is therefore more comparable to ITER (see below).

ITER

- Currently under construction in the South of France, ITER (International Thermonuclear Experimental Reactor) is a large-scale scientific experiment intended to prove the viability of fusion as an energy source.[22]
- It is located on an existing nuclear licenced research site, and within the French regulatory framework, it is regulated by ASN (Autorité de Sûreté Nucléaire), the French nuclear regulator.
- The RHC engaged with stakeholders directly involved in the project who highlighted the perception of the inflexibility of the process for ITER. For example, it is unable to take a proportionate approach to consequences of risks and instead needs to fully mitigate risks, such as building much larger walls for the facilities, even if the consequences of the risks would be very small. This leads to very expensive unnecessary mitigation.
- One observation on the ITER approval process concerns its over-emphasis on radiological protection compared to other hazards, such as chemical toxicity hazards posed by beryllium. This indicates the different priorities and emphases when taking a more fission-based approach to fusion.

TFTR

- The Tokamak Fusion Test Reactor (TFTR) was an experimental tokamak built at Princeton Plasma Physics Laboratory (PPPL), USA. It operated from 1982 to 1997. It achieved all of its hardware design goals, and reached temperatures well beyond the 100 million degrees required for commercial fusion, thus making substantial contributions in many areas of fusion technology development.[23]
- Those involved with the project informed the RHC that public engagement was key to its success. This included presentations to the local community and making information available through the use of public libraries.
- Relationships and mutual understanding between the TFTR team and the regulator and other stakeholders were also vital to the project's success.

[22] https://www.iter.org/proj/inafewlines
[23] https://www.pppl.gov/Tokamak%20Fusion%20Test%20Reactor
https://www.pppl.gov/Tokamak%20Fusion%20Test%20Reactor

6.2 Reviewing the risks

Environmental and safety risks

Potential risks to people and the environment have been well established, based on decades of research, through experience with the JET experiment in the UK, TFTR in the USA, and the ongoing design and construction of ITER in France. The main hazards from fusion reactors are the inventories of tritium and other chemicals that are stored on site, and contaminated and activated structural components and materials resulting from operation of the reactor.

The combined tritium inventory for the JET facility is less than 100g and risk assessments show that the individual risk of death per annum is around or below the level that is deemed to be broadly acceptable (as defined in HSE Publication "Reducing Risks, Protecting People). However, it is expected that STEP, as with ITER, will have an overall tritium inventory of a few kilograms of tritium. Fusion power plants will operate almost continuously at high neutron fluxes over decades, rather than sporadically as with JET. The question arises as to whether this poses an increased hazard.

A report by the Society for Plant and Reactor Safety (Gesellschaft für Anlagen- und Reaktorsicherheit gGmbH, known as "GRS" - a German-based non-profit organisation) speculates that future larger fusion reactors could pose a greater hazard due to the inventories of tritium involved that could potentially result in significant off-site consequences if not adequately controlled[24]. However, the report emphasises that such a worst-case scenario is purely hypothetical. It also states that the doses are several orders of magnitude lower than those for hypothetical worst-case scenarios of nuclear fission power plants. The hypothetical scenario is analogous to simply releasing tritium in an open field, but in reality there are various confinements that would prevent such a hypothetical situation from happening in a reasonable worst case scenario.

The ARCS (United States Nuclear Regulatory Commission Advisory Committee on Reactor Safeguards), in a published letter to the NRC, also identifies the larger hazards due to the quantities of tritium involved in fusion power plants. The context

[24] Review of the safety concept for fusion reactor concepts and transferability of the nuclear fission regulation to potential fusion power plants: https://www.grs.de/en/node/2676

of the letter is the broader reform of fission involving SMR and other advanced fission technologies. The ARCS letter identifies issues, rather than distinguishing or providing analysis of hazard levels. However, it is clear from both the GRS report and the ARCS letter that there is a significant hazard and need for appropriate regulation of fusion arising from the quantities of tritium required for STEP-like devices.

Fusion power plants are expected to operate almost continuously with high neutron flux densities. This means that fusion structural components will become activated (radioactive) as they are bombarded with neutrons. There is also an expectation of some adsorption of tritium into other reactor materials. For STEP, this will mean that significant quantities of Intermediate Level Waste and Low Level Waste will be generated during operations and from decommissioning. However, no High Level Waste, such as that from spent fuel rods in nuclear fission plants, will be generated. The waste hazard posed by fusion will be orders of magnitude lower than fission.

The experience of ITER has also brought into focus the hazards arising from the use of beryllium.[25] Beryllium is a chemical element used in structural components in fusion power plants for its mechanical and thermal properties. It is also used in aerospace applications. However, it is toxic, and exposure to beryllium dust presents a risk of chronic lung disease. Its use therefore requires appropriate industrial measures and regulation.

Non-ionising radiation risks due to the use of high-power electromagnets and lasers present hazards, particularly to onsite staff.

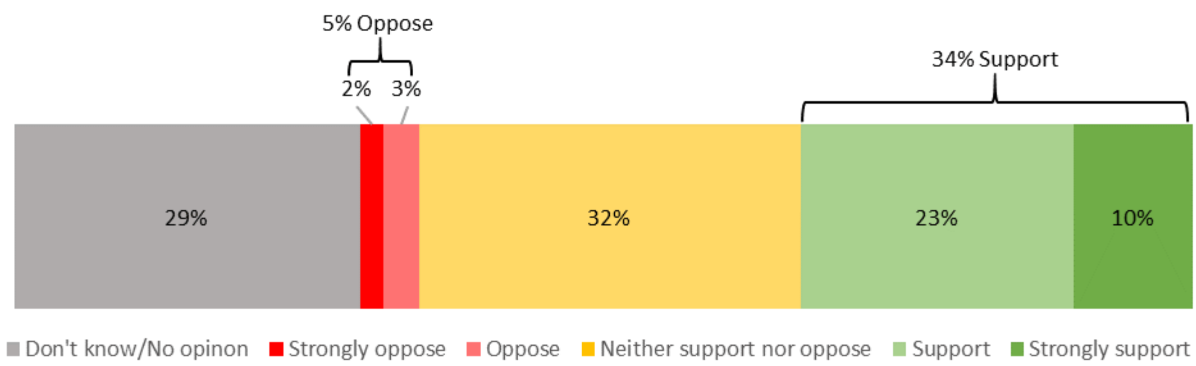
The US National Academies of Science report, Bringing Fusion to the U.S. Grid, states that “tritium releases may be kept within allowable limits via design and choice of materials”[26]. This is echoed by the FIA (Fusion Industry Association) who state that “By employing reasonable design, construction, and operations procedures, fusion energy generating facilities would not create a credible safety risk to the general public…”[27]. The experience of the ITER design and ongoing construction phase is found to support this analysis, and this is widely accepted by UKAEA and within the industry.

25 https://www.iter.org/newsline/-/2386
26 https://doi.org/10.17226/25991
27 https://www.nrc.gov/docs/ML2100/ML21006A238.pdf

Future Risks and Public Perception
There is also a potential risk that the public sees fusion as being akin to nuclear fission, which could lead to unwarranted reactions, such as safety fears. A 2020 attitudes tracker suggested that 34% of respondents supported the UK developing the technology compared to 5% opposing it.[28] When asked whether they support or oppose fusion energy, the majority (61%) of respondents neither supported nor opposed fusion energy or did not know whether they supported it.

This indicates that a significant proportion of the public have yet to form views either way on the technology and therefore public dialogue from government, the industry and the regulators will be essential for building public confidence, and trust.

Survey of support for fusion energy, September 2020[29]



6.3 Reviewing approaches against criteria

The information that the RHC collected was considered and then used to assess each of the three regulatory approach options against the key criteria.

[28] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/934647/BEIS_PAT_W35_-_Key_findings.pdf
[29] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/934647/BEIS_PAT_W35_-_Key_findings.pdf

6.3.1 Proportionate and agile

Option A – Evolution and continuation of current regulatory approach with HSE regulating on safety and EA on Environment

- The HSE and EA both have commitments to proportionate, non-prescriptive, goal-setting and outcomes-focused regulation set out in publications or legislation.[30,31]
- The HSE and EA have regulated the Culham Centre for Fusion Energy since its inception and the RHC's stakeholder engagement exercise indicated that Fusion industry stakeholders broadly view this approach as proportionate and agile. One fusion industry stakeholder emphasised that the EA had exceeded their expectations with their speed of response and ability to listen to their bespoke needs.

Option B – Adaptation to ONR regulating safety and EA on Environment

- ONR also have a commitment to proportionate regulations and describe their approach as enabling and goal setting, referencing publications such as their Guide to Enabling Regulation and 2020 Innovation Report.
- ONR also cite their Enforcement Policy Statement, Safety Assessment Principles and the UK's National Report on compliance with European Council Directive (2011/70/EURATOM) as evidence of a proportionate approach.
- The ONR have also committed to building upon efforts to be more enabling and innovation-friendly, as outlined in their 2020 Approach to Regulating Innovation.
- However, during the RHC's engagement with the fusion industry and its stakeholders, there was a consistent concern that regulation by the ONR would represent a less proportionate, agile and innovation-friendly regulatory approach.
- A prominent stakeholder was of the view that there could be a potential loss of expertise if ONR were to replace the EA/HSE as lead regulators, as well as the temptation for the ONR to be actively looking for issues requiring regulation and to increase regulatory burdens without due cause. They also raised concerns that ONR have a fundamental approach that is based on

30 Regulating for People, the Environment and Growth
31 The Health and Safety Work Act

nuclear fission, that might be difficult to overcome, as well as a risk-averse approach which may discourage investors.

- Another suggestion from the Fusion industry was that ONR may be predisposed to focus primarily on radiological risk, due to their prior experience focussed on nuclear fission, rather than taking a more holistic view of all the most relevant risks.
- However, the ONR have a different view, stating they have the necessary expertise in technical disciplines including fault studies, structural integrity, materials science, radiation protection and dispersion modelling – all of which could be relevant in the regulation of fusion. Similarly, they commented that their enforcement record does not show a predisposition to overfocus on radiological risk.

Option C – A new fusion-specific regulatory approach by a new regulator

- There may be a governance and agility advantage, in that a single lead regulator would not have to coordinate its efforts across two distinct bodies, as is currently required with the EA/ HSE combined approach.
- It is also possible that this option could be more proportionate and agile due to it not having any burdensome legacy approaches and ways of working.
- However, there is the opposing risk, that a new body could be motivated to over-regulate in order to swiftly justify its new position and remit.
- The process of setting up an entirely new body would likely be very resource intensive requiring a significant amount of initial set-up and governance work, which could reduce agility initially, as well as prolonging a period of regulatory uncertainty that is likely to discourage private investment.

6.3.2 Perception and trust

Option A – Evolution and continuation of current regulatory approach with HSE regulating on safety and EA on Environment

- The EA supports openness and transparency in the regulatory process and is also required to undertake comprehensive public consultation for new major facilities and significant variation to existing sites.[32]

[32] The EA have published the following guide on applications they have decided to consult on and how they will consult.

- Similarly, the HSE applies the following principles when conducting their enforcement activities to promote public trust:
  - Proportionality in how they apply the law and secure compliance;
  - Targeting of their enforcement action;
  - Consistency of their approach;
  - Transparency about how they operate and what an employer can expect
  - Accountability for their actions.[33]
- One member of the Fusion Industry Association stated strongly that: 'The existing arrangements for fusion regulation through Health and Safety Executive and Environment Agency have worked well for many years. The fact that these agencies have experience of regulating a wide range of different industries is a major strength that should inspire public confidence'

Option B – Adaptation to ONR regulating safety and EA on Environment

- The ONR highlight their Stakeholder Engagement Strategy 2020-25 as testimony that stakeholder confidence remains at the core of their 2025 ambitions.
- ONR have considerable experience of large projects and operational expertise. They also emphasise government recognition of their track record in the following publications: the Integrated Regulatory Review Service (IRRS): 2019 mission report, setting up of a new domestic safeguards regime.
- ONR's State System of Accountancy for and Control of Nuclear Material (SSAC) Project was nominated for Public Sector Project of the Year in the 2020 UK Project Management Institute Awards.
- Their 2020 Approach to Regulating Innovation document commits to take action over the next five years following dialogue with society and industry on how technological innovation should be regulated.
- However, there is a notable risk that, should ONR be selected as the regulator, investors and the general public will infer that the risks associated with fusion energy are equivalent to nuclear fission, given the word 'nuclear' in its title. It could also be seen to suggest that risks of fusion are predominantly around radioactivity, rather than the handling of toxic materials.
- One of the industry stakeholders that is not supportive of the regulator being ONR explained their view as being partly about investor perception. Even though ONR are technically competent, investors may perceive ONR will

[33] From the HSE Enforcement Policy Statement

create additional regulatory burdens and see ONR regulation as a sign that fusion energy and nuclear fission risks are equivalent.

Option C – A new fusion-specific regulatory approach by a new regulator

- This option may struggle to achieve trust quickly due to the fact it would be a novel body and would not have a track-record to demonstrate credibility.
- A dedicated regulator could also suffer from regulatory capture, whereby it would become symbiotically dependent on the fusion industry, including for staff or funding, which could harm its objectivity and perception of trust.
- One key fusion industry stakeholder commented that they were unsure why a new regulator was even an option at all and strongly questioned the value this would bring.

6.3.3 Lessons learnt and understanding

Option A – Evolution and continuation of current regulatory approach with HSE regulating on safety and EA on Environment

- Fusion industry stakeholders consistently emphasised that the EA and HSE have the necessary experience and a good track record thus far on fusion. HSE is the safety regulator for the JET facility and operational specialist radiation inspectors have inspected the facility many times over the years. The EA has regulated the JET facility at the Culham Centre for Fusion Energy since it started, working closely with the HSE. Maintaining this already well-functioning approach promotes continuity and allows the regulators to further build on their expertise.
- HSE have found that the current legislative framework for the control of risks associated with fusion technologies provides a comprehensive framework for controlling the risks associated with ionising radiation (see Appendix B for an overview of this legislative landscape). Key risks for fusion including handling toxic materials, which HSE and EA are very well placed to regulate.
- The EA's position is that the existing legislative framework, Environmental Permitting Regulations (EPR16)[34] is appropriate for regulating current and future fusion technology and no changes are needed to protect people and the environment. However, EA have identified the need to build their

[34] Environmental Permitting Regulations 2016 (as amended) (EPR16) Schedule 23 for Radioactive Substances Activities. The regulation of current and future fusion technology is solely in regards to EPR16

capability for regulation of a future large-scale fusion power plant (e.g. through staff training).

- In addition to radioactive substances regulation under the EPR16, the Environment Agency has experience in regulating a number of other high hazard, high complexity sectors under EPR16 alongside the HSE who regulate safety. For example, the EA regulates a number of inorganic chemical installation and the big four oil refineries in England (see Appendix B).
- HSE is the regulator for almost all workplace hazards and risk and already successfully regulate in areas with higher risks than fusion (see Appendix B)

Option B – Adaptation to ONR regulating safety and EA on Environment

- Through its Strategic Framework for International Engagement, which has been recognised as exemplary in the recent OECD UK IRC review, the ONR and environment agencies manages an extensive programme of international engagement in order to build on understanding and lessons learnt.
- Historically, ONR and its predecessors, alongside the relevant environment agency, have regulated a wide range of experimental reactors, and they currently regulate the Rolls-Royce Neptune facility, an experimental facility for the testing of fuel assemblies for future deployment on the UK strategic nuclear deterrent submarines.
- The ONR suggest that regulating future fusion would create continuity in terms of building on the relevant experience from fission operations and would be consistent with the majority of international regulators who regulate fusion alongside fission.
- However, there is the risk that the implied desire for building on fission experience in practice means that the distinct technology of fusion is considered closely related to, and regulated in a similar manner to, nuclear fission.
- ONR has had no direct experience of regulating fusion.

Option C – A new fusion-specific regulatory approach by a new regulator

- This option is much less appealing judged on the criteria of lessons learnt and understanding, as there is a high risk of a loss of the expertise the EA/ HSE have already built up in fusion regulation if there is a move to an entirely new regulator.

6.3.4 Experimentation and forward-looking

Option A – Evolution and continuation of current regulatory approach with HSE regulating on safety and EA on Environment

- The EA has both a Future Regulation Team that reviews their regulatory approach to improve and streamline how they permit and assess compliance, and a Horizon scanning team within the Research, Evidence and Analysis function.
- The EA, with ONR, developed the Generic Design Assessment (GDA) process for reviewing prospective fission reactor designs. This is aimed to allow the regulators to get involved with designers at the earliest stage, where they can have most influence. Government recognition of this process can be found in the foreword to the GDA Entry Process Guidance.
- The EA and ONR periodically review the GDA process, most recently to ensure it could be applied to Small Modular (fission) Reactors. There may be scope to develop a similar type of approach for fusion facilities, if there was a demand from the fusion industry.
- Since the Health and Safety at Work Act (HSWA) was introduced in 1974, major and sometimes rapid changes in the work environment have been considered and controlled by HSE using the same general approach: goals to be achieved rather than absolute standards to be met. This has allowed innovations like biotechnology; robotics; and sustainable energy technology to be enabled and facilitated by the general framework. The HSE confidently maintain that the HSWA can be similarly flexibly applied to the innovation of fusion.
- A specialist Foresight capability sits in HSE's Science Division. This function uses horizon-scanning, knowledge-sharing and a range of foresight and futures activities to help HSE and the broader health and safety system anticipate, and keep pace with, change.

Option B – Adaptation to ONR regulating safety and EA on Environment

- As above, the ONR, with EA, developed the Generic Design Assessment (GDA) process for reviewing prospective fission reactor designs. The ONR and EA periodically review the GDA process, most recently to ensure it could be applied to Small Modular (fission) Reactors. There may be scope to develop a similar type of approach for fusion facilities.

- The EA and ONR jointly developed a review process to support the BEIS Advanced Modular Reactor (AMR) competition which included one fusion design. This process was used to discuss regulatory expectations and overview of the vendor's designs. This early engagement in both design and construction seeks to assist vendors in better understanding regulatory expectations in the UK so as to inform the design process and de-risk any future development and deployment of these designs.
- In the ONR's recently published Guide to Enabling Regulation they commit to building upon their adaptive and forward-looking stance. This includes the deployment of innovation cells, sandboxes and safe spaces to examine innovative ideas.
- However, there is the risk that the ONR will be institutionally more inclined to work backwards from the current regulatory approach surrounding nuclear fission (of which they have vast experience), as opposed to evaluating the needs of fusion energy as a distinct issue with its own requirements.

Option C – A new fusion-specific regulatory approach by a new regulator

- It is possible that a new regulator, free from embedded ways of working, could be quite well placed to be forward-looking and adaptive over the long-term.

6.3.5 Support and collaboration

Option A – Evolution and continuation of current regulatory approach with HSE regulating on safety and EA on Environment

- Industry stakeholders have reported a positive working relationship with the EA and HSE and have remarked on the speed and collaboration of the relationship.
- Stakeholder and public confidence may be boosted by the certainty that the overall approach will not change; in fact, EA reports that a number of private fusion organisations have already engaged with the EA under 'business as usual' pre-permitting advice.
- In terms of collaboration, the EA work closely with other regulators through Memoranda of Understanding and Working Together Agreements. Their Corporate Plan EA2025 Creating a Better Place emphasises the importance of working together with local, national and global partners.
- The requirement to formally consult on some proposals – new regulations and statutory guidance - is established in the Health and Safety at Work Act.

HSE's policy approach to defining good practice requires that it be agreed as such through consensus.

Option B – Adaptation to ONR regulating safety and EA on Environment

- For compliant duty holders, the ONR takes a collaborative approach to enable effective delivery against clear and prioritised safety and security outcomes.
- However, fusion industry stakeholders frequently emphasised that they wanted a regulator to be 'engaging' and 'enabling' and they noted that ONR has previously not always been the most engaging organisation, although they recognised the ONR are making efforts to rectify this.
- The ONR offered a different view, pointing to evidence such as their case studies of their enabling approach and exceptionally positive feedback on their stakeholder engagement, which are reflected in their published stakeholder survey results.

Option C – A new fusion-specific regulatory approach by a new regulator

- Due to the fusion-specific approach of this option, it could mean a strong focus on these criteria, as the new regulator would need to work with the fusion industry closely, possibly to the detriment of both.
- Creating a new regulator risks creating doubt and ambiguity, with one member of the Fusion Industry Association (FIA) stating unequivocally that the RHC 'should avoid the risk, delay and uncertainty of creating a new regulator'.

7. Recommendations

Main recommendation

The RHC recommends that the UK champions the way for a non-fission approach, by setting out and consulting on a bold, forward-looking vision of how HSE and EA[35] could lead and evolve the regulatory approach for STEP. The RHC found that although changes, potentially including legislation, will be needed, STEP does not require a different regulatory approach from that which has worked well for fusion in the UK to date. The EA and HSE provide the proportionate framework for regulation of STEP commensurate with the hazards presented by the technology.

This approach will help enable the rapid and safe commercialisation of fusion energy, which has the potential to contribute to net zero UK carbon emissions over the long term and aligns with the PM's Ten Point Plan for a Green Industrial Revolution. Moreover, as other countries have given limited public statements on how they plan to regulate fusion, there is the opportunity for the UK to lead internationally in demonstrating a clear regulatory pathway for the sector. This is particularly relevant within the context of COP26, where the UK has the opportunity to communicate this bold, forward-looking approach on fusion. It could also be of relevance around the world, including the USA, where the RHC notes that their Nuclear Regulatory Commission is currently consulting on its approach to fusion.[36]

Significant changes to the current approach, in particular any that align more closely with nuclear fission regulation, risk being disproportionate, creating uncertainty and substantially increasing costs relative to the risks entailed. Importantly, the perception of a more fission-based approach, could also risk falsely alarming the public and discouraging investors.

The UK must now show it has the appropriate regulatory environment to capitalise commercially on fusion energy by providing a clear direction in early 2021. The full

[35] And devolved equivalents
[36] https://www.fusionindustryassociation.org/post/doe-nrc-fia-public-forum-on-a-regulatory-framework-for-fusion

regulatory framework may take longer to develop and is likely to evolve as more fusion technologies come to market, but uncertainty around these issues is a key part of embracing innovation and must not be used as a reason to delay providing clear leadership on the overall approach.

Based on the RHC's work to date, **the main recommendation for the regulatory approach for STEP is Option A – evolution and continuation of the current regulatory approach led by EA and HSE.** This is because the RHC judges that this option most closely aligns with the five key criteria which the RHC tested with fusion stakeholders. It finds the following points to be particularly convincing:

1. The majority of stakeholders, including industry, were satisfied with the existing HSE and EA led approach. The regulators have demonstrated a proportionate approach to fusion to date. In contrast, there was some concern from stakeholders that ONR would be more likely to embrace a fission-type approach in practice.

2. HSE and EA possess a track record and expertise in regulating fusion, in accordance with the RHC's five criteria. Whilst the RHC recognises there is a change in levels of hazard from JET to STEP, it did not find strong arguments to change the regulatory arrangements for STEP. This is due to the fact that the overall risk is still orders of magnitude lower than the risk associated with nuclear fission.

3. Given the significant differences between fusion energy and nuclear fission, and the extensive experience and success of the HSE and the EA in regulating fusion energy so far, there is no strong rationale to suggest a move to a different regulatory system for fusion energy. In contrast to nuclear fission, fusion energy is not uniquely hazardous and the evidence suggests that a version of the current regulatory approach, tailored to the needs of larger scale facilities, is sufficient to control future hazards, satisfy any public concerns, and enable future investment in the technology.

4. Changing to another regulator would risk losing some of the institutional knowledge about both fusion and chemical and other non-ionising radiation hazards that HSE and EA cover.

5. Changing regulator could also cause considerable unnecessary disruption and uncertainty at a key moment for commercial decisions around STEP. There

would likely be substantial cost implications to carry out the process of changing from the current regulators to another option. The RHC did not find reasons that would justify the value for money case that would need to be made for such a change. There would also be disruption to established ways of working. The RHC heard from the US TFTR fusion project that consistency is very important for timely success.

The RHC found that an ONR-led approach (Option B) would have some benefits. In particular, it would align with the general international approach of using the same regulator to cover both fission and fusion. This approach has been taken where a single regulator covers all radiological hazards and therefore covers fusion. However, the RHC also notes that this lack of alignment has not prevented the UK being widely recognised as a world-leader in safely developing the most promising fusion energy technologies. International approaches could also change, as is currently being discussed in the US. The proposed regulatory approach, Option A, could help the UK establish a precedent for fusion regulation worldwide.

Having the approach led by a single regulator could make it simpler to determine who is responsible for any regulatory issues, particularly if new issues arise. However, nuclear fission is already regulated by both ONR and the relevant environment agency to protect people and the environment, and this would be true for fusion as well.

The RHC considers Option C, a new fusion-dedicated regulator for STEP, to be the least attractive option. This is because it would bring the least regulatory clarity to the fusion industry and would mean the new regulator would need to upskill quickly due to its limited knowledge of the sector. A dedicated regulator could also suffer from regulatory capture, whereby it would become symbiotically dependent on the fusion industry, including for staff, which could harm its objectivity. Potential benefits, such as possibly being more agile and proportionate, would be hypothetical. This option would be more attractive if there were more fundamental issues with the technology that could not be covered by current potential regulators.

Second recommendation

Guidance on the EA and HSE regulatory approach to fusion should be produced to explain to stakeholders and the public how this works in practice. The guidance would help provide both clarity and reassurance concerning the UK's regulatory approach for STEP. It should cover which regulations apply and how they will be enforced. It could also include a schedule for STEP approval and regulation. BEIS should determine who is best placed to lead this guidance, but the RHC recommends that it has input from EA, HSE and ONR. The guidance should also be developed in consultation with the UKAEA as appropriate. It should also be reviewed by relevant stakeholders to help ensure it provides the necessary information. The process of creating the guidance could also help identify any potential regulatory issues either for STEP or other fusion projects.

Other recommendations

The RHC also recommends that government takes the following actions:

- Consults as soon as possible, and by Summer 2021 at the latest, on the above main recommendation to provide urgent regulatory clarity. The consultation should also act as the start of a wider public engagement programme to help public understanding of fusion in general as well as the regulatory approach. The consultation should also contain a call for evidence on consequential changes, such as changes to legislation, that may be required for this approach. For example, our understanding of the changes proposed to ONR's policy definition of a 'bulk quantity' of radioactive material, based on updating the quantities specified in line with the Radiation (Emergency Preparedness and Public Information) Regulations 2019 ('REPPIR'), means that a commercial-scale fusion reactor would be classed as a nuclear installation in legislation, bringing it into ONR vires at the start of the fusion process. This situation should be resolved to avoid having additional regulator oversight in the process, without due cause, that would unnecessarily increase complexity.
- Plans and works with HSE, EA and UKAEA to consider and take action on potential upskilling that may be needed as STEP and other fusion projects develop further; and how to cooperate with other regulators internationally.

8. Commercial Fusion Supplement

8.1 Introduction and Methodology

The RHC conducted additional work to consider whether its recommendations for STEP also applied to the commercial fusion sector. By commercial fusion this supplement is referring to the growing number of commercial vendors looking for a route towards viable fusion energy, such as Tokamak Energy and First Light Fusion in the UK. Whilst no developer has a mature technology for electrical power production ready for commercial development currently, many have ambitious future plans. Private investment has also been secured by a number of small companies, primarily in North America and also two in the UK. The right regulatory framework will be important to encourage further investment.

The RHC first opted to focus on the regulation of STEP, due to this being a more defined question which the RHC could provide timely thinking on, particularly in the context of the STEP siting competition being launched in December 2020. The RHC then began work on this additional commercial fusion supplement in March, once it had completed the majority of work on the STEP report. The RHC also conducted a stakeholder survey on fusion energy and its regulation which can be found in Appendix D.

The timing of this supplement is particularly notable given that the EA are now consulting until September 2021 on views to introduce a new specified radioactive substances activity (S-RSA) to enable the organisation to use appropriate specialists to do the necessary regulatory work at sites carrying out fusion activities and recover costs in line with other similar scale S-RSAs. We note however that this does not have direct implications for the regulatory framework for fusion in England and is only in relation to how the EA applies charging.

The work for this supplement drew upon previous stakeholder interactions completed for the STEP report whilst also requiring some supplementary engagements outlined below:

- BEIS' Chief Nuclear Advisor

- General Fusion [37]
- Jacobs Engineering Group
- Kinetrics
- National Grid
- Nuclear Decommissioning Authority (NDA)
- Ofgem
- SHINE
- The Nuclear Innovation and Research Office (NIRO)
- The ONR sponsorship Team within BEIS
- Nuclear Free Local Authorities (NFLA)

For this commercial fusion supplement, the RHC utilised the same key criteria outlined in Chapter 4 to assess the relative merits of different regulatory approaches to commercial fusion.

[37] The Canadian company General Fusion was viewed as a particularly timely and relevant stakeholder to engage with, due to its recent plans to build its fusion demonstration plant at UKAEA's Culham Campus: https://www.gov.uk/government/news/general-fusion-to-build-its-fusion-demonstration-plant-at-ukaeas-culham-campus

8.2 Reviewing and Applying the Evidence

This supplement outlines two options for a regulatory approach to commercial fusion:

- Option A – Evolution and continuation of current regulatory approach with HSE regulating on safety and EA on environment
- Option B – Adaptation to ONR regulating safety and EA on the environment

As with the main report regarding STEP, the RHC notes that the proposed regulator is the EA for sites in England, but that in other parts of the UK it will be the relevant environmental regulator.[38]

The RHC also notes that for this chapter it considered option C, that of a new fusion-specific regulatory approach by a new regulator, as it did in previous chapters on STEP. However, we refer to the findings of the above STEP report for commentary on this option, as no additional significant evidence was found for this approach.

Proportionate and agile

Option A – Evolution and continuation of the current regulatory approach with HSE regulating on safety and EA on environment

- One international stakeholder highlighted a risk of trying to regulate fusion in the same way as fission in that a fission approach could overburden fusion at a very nascent stage in its commercialisation.
- The stakeholder further noted that for the near-term future most commercial fusion devices would be small in nature and that these devices present hazards that are magnitudes of order lower than ITER in France and also have much less tritium than envisaged for ITER. Consequently, the current EA and HSE regulatory approach was deemed appropriate for these devices.

38 SEPA (Scottish Environment Protection Agency), NRW (Natural Resources Wales) and NIEA (Northern Ireland Environment Agency) HSENI (Health and Safety Executive Northern Ireland). Currently there are no fusion devices in Scotland, Wales, so it is only the EA that regulates fusion in the UK at this time. However, should fusion come to other parts of the UK, then SEPA, NRW and NIEA would regulate respectively under a similar framework to the EA.

- Another stakeholder noted that in the decommissioning process the de-license criteria is 'no danger' and took the view that this makes it very challenging for nuclear regulations to be removed once applied. It was argued that this may present the challenge that, should fusion be placed under nuclear fission regulations, it could be very difficult to then revert to other regulations even if the level of hazard that eventually materialises at commercialisation stage is deemed low.
- The stakeholder also thought that fission regulations are focused primarily on hazard, not likelihood – which could lead to disproportionate regulation if then applied to other technologies. There was a concern that 'as low as reasonably practicable' (ALARP) can in practice become 'as low as is reasonably possible' which in turn produces disproportionate regulation. However, the ONR took a different view, citing their Enforcement Policy Statement, Safety Assessment Principles and the UK's National Report on compliance with European Council Directive (2011/70/EURATOM) as evidence of a proportionate approach. They also emphasise government recognition of their track record in the Integrated Regulatory Review Service (IRRS): 2019 mission report.
- Another leading expert commented that tritium, which can be produced during fusion reactions, has a half-life of 12.3 years, which is very small in comparison with half-lives of nuclear fission fuels.
- In a similar vein, another stakeholder who is also very experienced in the field suggested that the main radiation hazard from fusion primarily comes from tritium. However, they suggested that tritium's negative reputation is undeserved, as a great deal of the radiation it produces is not absorbable by the body and as a gas it has a short biological half-life. They also maintained that some of the negative perceptions of tritium have been exacerbated by the anti-nuclear industry.
- Commercial developers for fusion seek to significantly accelerate historical trends on development timescales as compared to fission energy and there was a strong consensus from stakeholder engagement that having operators regulated by a separate entity to fission offers a means to best facilitate these accelerated timescales and support the increasingly urgent need to combat climate change. Although the ONR maintains a different view, highlighting the decommissioning and hazard reduction being driven at Sellafield, whilst also regulating operating reactors and new build, as evidence of being able to adopt a more accelerated approach suitable to the urgency of climate change.

- Overall, nothing was discovered in the evidence gathering for this report to indicate that hazards for commercial fusion would be greater than other industrial processes that are currently regulated by EA and HSE, such as ammonia plants and oil and gas refineries.

Option B – Adaptation to ONR regulating safety and EA on environment

- In the RHC's fusion survey (see Appendix D), 6 respondents agreed that the UK approach to the regulation of nuclear fission would be appropriate for fusion energy compared with 6 who disagreed. This seemed to imply some support for a fission-based approach for fusion. However, when provided with a direct choice between the approach taken to regulate JET, which was EA and HSE led, and an approach based on current nuclear fission regulation there was a much clearer majority: 9 respondents within the sample indicated that a regulatory approach that is broadly similar to what has been used for JET would be more appropriate than an approach based on current nuclear fission regulation.
- One stakeholder did highlight the goal-seeking approach of ONR as a positive factor in how a fission regulatory method could be applied to fusion. They noted that this approach may be particularly apt in regulating the wide range of routes to commercial fusion, the diversity of which necessitates regulatory flexibility. However, the RHC notes that EA and HSE also take this goal-seeking approach to regulation.
- There is the possibility of fission-fusion hybrid reactors in the commercial sector which will necessitate a fission regulation approach. With this in mind, it could be argued it is more consistent and simpler for all fusion devices to be regulated under the nuclear fission regulator. However, the RHC maintains that this possible advantage of consistency would be significantly outweighed by the negative impacts on proportionality of approach.

Perception and trust

Option A – Evolution and continuation of current regulatory approach with HSE regulating on safety and EA on Environment

- There was a broad consensus from the RHC's stakeholder interviews that commercial fusion having the same regulatory approach to the current framework that UKAEA and commercial vendors are working within offers greater clarity, consistency and confidence to both investors and the public.

- In the RHC's fusion survey only one respondent disagreed that the current UK regulatory approach is appropriate for fusion energy, with 7 respondents agreeing it was.
- One survey participant notably commented that the current approach to fusion regulation 'works well at JET and from a public perception point of view means it is regulated in the same way as hospitals, university and other non-nuclear operators which is proportionate to the risk from fusion and likely to make it more acceptable to the public.'
- Another survey participant maintained that 'the current EA/HSE approach should be entirely satisfactory given all we now know about the hazards of fusion'.
- One stakeholder suggested that a fusion plant would present a similar or lower level of hazard than an ammonia plant or an oil and gas refinery, which EA and HSE currently regulate.

Option B – Adaptation to ONR regulating safety and EA on Environment

- One international stakeholder highlighted that a possible advantage of being regulated by a fission regulator is that the perception of them being stringent provides robust reassurances to the public. They suggested this has the advantage of allowing the commercial provider more capacity to focus on their primary task of creating fusion energy rather than being required to expend time and resources on providing public assurance themselves. However, the RHC maintains that this possible advantage comes with too a high risk of implying to the public that fusion and fission risks are equivalent.
- One participant in the RHC survey commented that 'an approach based on nuclear fission is proven, so may be attractive to investors'. However, this should be weighed against their admission that a fission approach 'may be more costly than the approach used for JET'.

Lessons learnt and understanding

Option A – Evolution and continuation of current regulatory approach with HSE regulating on safety and EA on Environment

- One stakeholder interviewed highlighted that the majority of commercial fusion entities are much closer in nature to what is currently regulated by the HSE, such as university research facilities. Another stakeholder commented in the RHC's survey that 'regulations should be in line with particle accelerators not fission nuclear'.
- Where there are gaps in understanding of new commercial fusion vendors, regulators can reach out to universities or other experts should they need to upskill on a particular area of expertise and evidence suggests that the HSE/ EA have appropriate experience in doing this. For example, HSE notes that, in the rare event that they do not have the necessary expertise, they can 'procure research and advice from external organisations that is considered by HSE regulatory specialists who will then come to an independent decision. In addition to procuring research and advice from external organisations, Public Health England is able to advise HSE on radiological protection matters.'[39]
- There is international precedent for non-fission entities regulating fusion. For example, commercial fusion developers in the US using Department of Energy (DOE) facilities are regulated by the DOE and the Fusion Industry Association has noted that 'The DOE has created a framework for safe construction and operation of experimental fusion energy devices that has worked well for decades'. The RHC also notes the importance though of having a regulator that is independent of government.

Option B – Adaptation to ONR regulating safety and EA on Environment

- A stakeholder highlighted that EA and HSE could do the upskilling needed to understand how to regulate commercial fusion, but they are perhaps not as accustomed to undertaking this type of learning process as the ONR. They suggested that the ONR may have a much more structured set of interventions around how to gather this knowledge and expertise. It is noted that EA is already upskilling in relation to commercial fusion through their work with

[39] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/899129/irrs-report-2020-to-uk.pdf

Tokamak Energy as part of the BEIS Advanced Modular Reactor (AMR) Feasibility and Development Project.

- ONR is accustomed to putting a significant amount of work to the private sector, through framework contracts and other mechanisms. Examples of external organizations working with ONR include: Jacobs, Global Research for Safety (GRS) in Germany, and various universities. This ability to utilise private sector knowledge could be beneficial in helping to understand and regulate the wide range of potential commercial fusion devices.
- It was also suggested by one stakeholder that the HSE may have to upskill to do more pre-authorisation of higher hazard risks with a distinct focus on industrial levels of hazard. However, in response to this comment, the RHC notes that the HSE do in fact already have experience of regulating other industrial level hazards effectively, such as ammonia plants and oil and gas refineries.

Experimentation and forward-looking

Option A – Evolution and continuation of current regulatory approach with HSE regulating on safety and EA on Environment

- There was a strong suggestion in the RHC survey that the current approach to fusion is sufficiently adaptive and forward-looking. The vast majority of respondents agreed that the UK is both moving quickly to make decisions about the regulatory approach for fusion energy (12 respondents) and that its current pace of decision-making is appropriate (10 respondents).
- There was a strong consensus amongst stakeholders interviewed that it would be challenging to be adaptive and look forward to the bespoke requirements of fusion should the starting point be the way in which nuclear fission is regulated. However, ONR would highlight their published Guide to Enabling Regulation as evidence of their commitment to an adaptive and forward-looking approach. This includes the deployment of innovation cells, sandboxes and safe spaces to examine innovative ideas.
- With the growing concerns around climate change, the RHC notes that accelerating the introduction of carbon free power generation will be ever more critical. There was a broad consensus amongst stakeholders that the continuation of an EA and HSE approach would best allow for a regulatory approach that can enable fusion to more rapidly attain commercialisation and in turn aid efforts to counter climate change.

Option B – Adaptation to ONR regulating safety and EA on Environment

- One stakeholder suggested that the fission framework has a good degree of adaptability and can be used to map onto any technology.
- They also highlighted that innovators may have a different regulatory framework in laboratories, but there will be a change once reaching a certain level of maturity and before a full regulatory framework. This could suggest that the EA/ HSE approach, which currently functions effectively, may be less fit for purpose after scale-up occurs. However, the RHC notes that the timescales for commercial fusion to become viable permit the EA and HSE sufficient time to adapt their approach appropriately as the sector develops.

Support and collaboration

Option A – Evolution and continuation of current regulatory approach with HSE regulating on safety and EA on Environment

- 9 respondents in the RHC survey believed that a regulatory approach similar to JET would have a positive financial impact on UK businesses, with 8 of the same respondents also having indicated that an approach based on current nuclear fission regulation would have a negative financial impact on UK businesses. However, the RHC notes that reasons were not provided in the survey as to why stakeholders thought this would be the case.
- The commercial fusion industry in the UK has already had early engagement with the HSE and EA. Moving to a different regulator will require fresh partnerships to be made with the potential loss of time, experience, and established engagement channels.

Option B – Adaptation to ONR regulating safety and EA on Environment

- The evidence found for an ONR approach based around this criterion of support and collaboration was found to be the same as that in the main STEP report and no significant additional evidence was highlighted. Please refer to section 6.3 for previous findings in relation to this criterion.

8.3 Recommendations

Main Recommendation

The Council maintains that its recommendations for the STEP fusion project also hold for commercial fusion: the evolution and continuation of the current regulatory approach with HSE regulating on safety and EA on the environment. The RHC judged that proportionality was a particularly key factor in reaching its conclusion, particularly given that all of its survey respondents ranked proportionality to the hazards as the most important principle for fusion energy regulation. This emphasis reflects the amount of commentary provided for the proportionality criteria.

The Council found the arguments below to be particularly compelling in supporting its conclusion:

- Most of the smaller fusion devices, which are generally the commercial devices of private sector companies, are magnitudes of hazard lower than ITER in France and are of similar, or lower, hazard than numerous other processes currently regulated by the EA and HSE, such as chemical installations and the big four oil refineries.
- At present commercial fusion devices are at lab and prototype scale in a similar manner to the Joint European Torus (JET), which relevant stakeholders broadly agreed has been effectively and appropriately regulated by the EA and HSE to date.
- The majority of expert fusion stakeholders surveyed clearly supported the current approach used for JET, that of EA and HSE acting as safety regulators.
- Commercial fusion being regulated differently to the JET programme would risk causing unnecessary public alarm should it imply that commercial fusion ventures constitute a higher order level of risk than JET.
- Stakeholder engagement also suggested that commercial fusion vendors having the same regulatory approach as is currently taken with the JET programme at Culham would offer best overall clarity, consistency and confidence for investors.
- Finally, with the increasingly present threat of climate change, there is a need to adopt a regulatory framework that can best ensure the rapid and safe commercialisation of fusion technology. The RHC maintains that the UK is

well placed to lead the way with its fusion regulatory framework and has notable opportunities such as COP26 to demonstrate its approach.

The notable exception to the RHC's recommendation that EA and HSE should regulate would be for fusion fission hybrid concepts. These concepts were considered out of scope for this supplement, due to their more speculative nature, and the RHC's working assumption would be that these concepts would fall under normal fission regulations.

The Council also notes the very diverse range of commercial fusion devices currently being progressed and the varying levels of technical maturities for each of these devices. It therefore suggests that EA and HSE internally assess for any gaps in their own skill set to manage these differing technologies and upskill in turn as appropriate. However, the Council maintains that the timescales of commercial fusion realisation provide sufficient opportunity for the EA and HSE to build any of this additional capacity required, particularly through engagement with the UKAEA, consultants, universities, and international partners. R&D funding may also need to be made available so that regulators can reach out to appropriate bodies to upskill. There may also be some scope for collaboration between regulators, with HSE/ EA being the lead safety regulator but drawing on specific expertise from the ONR where needed via approaches such as memorandums of understanding which are already in place.

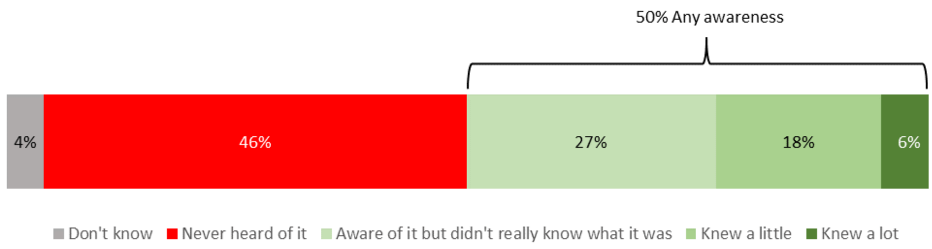
It was also highlighted in the RHC's stakeholder engagement that commercial fusion start-ups are unlikely to have a great deal of experience in working with regulators. It was felt that a fusion developer needs to understand the regulations themselves but also how to engage the regulator effectively and meet the specific requirements asked of them. **The RHC therefore suggests that guidance to developers on engaging with regulators is appropriately scaled up as commercial fusion moves closer to realisation**. In this regard, support may also need to be provided to commercial fusion companies from independent consultants who understand the regulatory processes and can assist fusion companies in navigating them. In particular, guidance on the goal-seeking nature of UK regulations would be helpful in this space, as it was highlighted by stakeholders that whilst goal-seeking regulatory approaches provide additional flexibility, some commercial fusion entities may be expecting a more prescriptive regulatory approach which outlines exact requirements they must then be met. It will therefore require time and support for all commercial vendors to become accustomed with a more flexible, goal-seeking approach.

8.4 Additional Findings of Interest

The RHC found certain additional points of interest during its stakeholder engagement which did not link specifically to the recommendations outlined above but had broader relevance for fusion regulation. Firstly, there was interesting commentary from some stakeholders on the UK's goal-seeking regulatory approach. Whilst overall it was seen as a positive, one drawback highlighted was that it is not always clear what is required of developers, unlike a more prescriptive checklist. It was also suggested that sometimes goal-setting is less attractive for investors on a more experimental technology, such as fusion, as there is a less clarity on exactly what regulatory burdens will be necessitated, and this could be a challenge particularly for non-UK companies less familiar with goal-seeking approaches.

However, these points were balanced with the recognition that whilst goal-seeking may provide less clarity for vendors upfront it can be quicker and more enabling in practice when it is carried out. It also has the benefit of additional flexibility to meet the variety of different routes to commercial fusion. What is required though is more time for commercial providers to become familiar with a goal-seeking process and how to navigate it. This is particularly true for providers coming from overseas from countries accustomed to a more prescriptive regulatory approach, whereas the UK based supply chain will likely be familiar with goal-seeking regulatory methods. In addition, there was a specific point made on the Generic Design Assessment (GDA) used by ONR and EA to identify any potential regulatory design or technical issues early and ask the reactor designer to address them. It was noted by one commercial stakeholder that there was a wide sentiment among investors that a great deal of time and cost was spent on the Generic Design Assessment (GDA) experience without sufficient benefit. However, the ONR take a very different view here, highlighting that the GDA is a voluntary risk reduction exercise and maintaining that this gives confidence to investors that the reactor design is viable ahead of starting construction, thereby saving significant costs during later phases.

Finally, there was a broad consensus from stakeholders that public engagement is critical with regards to fusion and that currently there is a lack of public understanding of what fusion entails. Indeed, one stakeholder survey notably commented: 'the nationwide search for a venue for STEP has surfaced an alarming lack of understanding from some elements of the public about the differences between fusion and fission.' This view is supported by the September 2020 BEIS Public Attitudes Tracker, as shown below, which questioned participants on how much they knew about fusion and found that 46% of participants had never heard of it.[40] However, the data from the public attitudes tracker also notably indicates that those who had greater knowledge of fusion energy were more likely to support it than oppose it. The RHC therefore maintains that building further understanding of fusion as the technology develops will be critical in generating greater public acceptance and in turn ensuring the technology is regulated proportionately. This view is supported by the RHC's own survey evidence where all fusion stakeholders agreed that the public needs to have at least a limited understanding of fusion, with the majority (10 respondents) stating that they should have a moderate understanding.



Q230. Before today, how much did you know about fusion energy?

[40] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/934647/BEIS_PAT_W35_-_Key_findings.pdf

Appendix

A. Sources for each of the key criteria[41,42,43]

1. Proportionate and agile

- 2019 Regulation White Paper challenge – 'We need to ensure that our regulatory system is sufficiently flexible and outcomes-focused to enable innovation to thrive'
- 2020 WEF Toolkit for regulators – Foundation of good regulatory practice: Proportionality
- 2020 WEF Toolkit for regulators – Outcome-focused regulation
- 2020 WEF Toolkit for regulators – Self- and co-regulation

2. Perception and trust

- 2019 Regulation White Paper challenge – 'We need to build dialogue with society and industry on how technological innovation should be regulated'
- 2020 WEF Toolkit for regulators – Foundation of good regulatory practice: Openness and Fairness
- 2020 WEF Toolkit for regulators – Self- and co-regulation

3. Lessons learnt and understanding

- 2020 Research on innovation-friendly regulatory approaches - Streamlining regulatory approvals for innovators
- 2020 WEF Toolkit for regulators – Data-driven regulation
- 2020 WEF Toolkit for regulators – Self- and co-regulation

4. Experimentation and forward-looking

- 2019 Regulation White Paper challenge – 'We need to be on the front foot in reforming regulation in response to technological innovation'
- 2019 Regulation White Paper challenge – 'We need to enable greater experimentation, testing and trialling of innovations under regulatory supervision'

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41 https://www.gov.uk/government/publications/regulation-for-the-fourth-industrial-revolution

42 https://www.gov.uk/government/publications/regulator-approaches-to-facilitate-support-and-enable-innovation

43 https://www.weforum.org/about/agile-regulation-for-the-fourth-industrial-revolution-a-toolkit-for-regulators/

- 2020 Research on innovation-friendly regulator approaches - Supporting experimentation and testing of innovations using 'sandboxes' and 'testbeds'
- 2020 Research on innovation-friendly regulator approaches - Setting regulatory challenges to boost innovation
- 2020 WEF Toolkit for regulators – Anticipatory regulation
- 2020 WEF Toolkit for regulators – Experimental regulation

5. Support and collaboration

- 2019 Regulation White Paper challenge – 'We need to support innovators to navigate the regulatory landscape and comply with regulation'
- 2019 Regulation White Paper challenge – 'We need to work with partners across the globe to reduce regulatory barriers to trade in innovative products and services'
- 2020 Research on innovation-friendly regulator approaches - Providing regulatory advice to innovators to help them navigate the regulatory system
- 2020 Research on innovation-friendly regulator approaches - Collaborating internationally on innovation to reduce the burden on innovators trying to sell their product or service in different jurisdictions
- 2020 WEF Toolkit for regulators – Self- and co-regulation
- 2020 WEF Toolkit for regulators – Joined-up regulation
- 2020 WEF Toolkit for regulators – International regulatory co-operation

B. Further background

Key safety legislation for fusion

Primary legislation

The Health and Safety at Work etc. Act 1974 (HSWA) establishes general duties for controlling workplace risks so far is reasonably practicable.

These general duties are supplemented by secondary legislation made under HSWA.

Secondary legislation

General

The Management of Health and Safety at Work Regulations 1999 (Management Regs) – require a risk assessment to ensure risks are reduced as low as is reasonably practicable

Radiation Safety - Non-ionising radiation

The Control of Artificial Optical Radiation at Work Regulations 2010 - controls the risks associated with the use of lasers for fusion purposes

The Control of Electromagnetic Fields at Work Regulations 2016 - controls the risks associated with the high magnetic fields in and around a fusion reactor

Radiation Safety - Ionising radiation

The Ionising Radiations Regulations 2017 - relevant because of the use of tritium, a radioactive form of hydrogen, and the possible production of radioactive activation products

The Radiation (Emergency Preparedness and Public Information) Regulations 2019 - relevant because of the storage of tritium on site

This secondary legislation is supported by statutory and non-statutory guidance to assist employers with developing their approach to compliance

Industrial Processes with significant hazards currently regulated by the EA and HSE

Inorganic chemicals: The Environment Agency regulates a number of inorganic chemical installations, including the Runcorn Membrane Chlorine Plant (MCP). The MCP has been designed to produce circa 500,000 tonnes of chlorine per year. Chlorine, together with the other hazardous products (caustic soda, sodium hypochlorite and hydrogen) from the process are used in the water industry and for other industrial processes. EA regulation addresses significant issues associated with protecting people and the environment, including air quality (e.g. chlorine, hydrogen); protection of soil and groundwater; water quality (e.g. brine, available chlorine, bisulphite) and waste management. This also covers the management of elemental mercury and mercury containing wastes arising from the decommissioning/demolition of the redundant chlor-alkali process on-site.

Refineries: The Environment Agency regulates the big four oil refineries in England (Philips 66 – Humberside; Total SA – Lindsey; Essar – Stanlow; Esso – Fawley). Together these complex and physically extensive installations produce around 50 million tonnes of petroleum products each year. EA regulation addresses significant environmental and safety issues including air quality (e.g. SO_2, NO_x, VOCs); soil and groundwater (e.g. hydrocarbons and metals); water quality (e.g. metals) and waste management.

Preparing for the hydrogen economy: EA technical support contractors are developing the UK Best Available Techniques (BAT) Guidance for large scale hydrogen production from methane with carbon capture and storage (CCS), and they expect a permit application this year for the Stanlow Refinery which is receiving phased BEIS funding as part of the HyNet decarbonisation cluster project competition. They are also supporting other UK industrial clusters, including Humber, Tees Valley, and South Wales where they have plans for hydrogen production at similar scale as part of their Net Zero ambitions.

These particular examples are also within the Control of Major Accident Hazards Regulations (COMAH) regime which aims to prevent and limit the consequences of major accidents at approximately 1000 establishments which use or store significant quantities of dangerous substances, such as oil products, natural gas, chemicals or explosives. The EA are the joint Competent Authority on these non-nuclear sites with HSE.

C. RHC Approach to the Fusion Report

How did the RHC arrive at Fusion as a Deep Dive Area?

The RHC conducted a rigorous horizon scanning exercise over a 6-week period and generated a list of 544 distinct innovations. Innovations were then mapped into broader groupings before being prioritised through three primary criteria: economic impact, societal benefits and scope for regulatory change. From this information and refined list, council members then applied their judgement and expertise to select their first tranche of priority areas to conduct deep dive reports into: fusion energy; genetic technologies; unmanned aircraft and medical devices.

How did the RHC identify and refine its scope and key question for the report?

The RHC began by consulting the BEIS Fusion Policy team to better understand the landscape of fusion regulation. It drafted and refined its exam question for fusion by testing it with key stakeholders. The RHC then arrived at the overarching question of: 'How can the UK continue to move towards an innovation-friendly, long-term regulatory framework to support the rapid and safe introduction of fusion energy'. Key amendments that went into the construction of the above question included:

- Incorporating the addition of 'continue to move towards', recognising from stakeholder input that the UK was already in the process of building an innovation-friendly framework for fusion.
- Ensuring the RHC also emphasised the importance of maintaining high safety standards in its exam question with the inclusion of 'and safe'.

How did the RHC Engage Fusion Stakeholders?

Given that the RHC's fusion deep dive was conducted during the COVID-19 pandemic, all the RHC's engagement was via email, Microsoft Teams, Zoom, or phone call. Whilst this virtual engagement provided certain challenges, it allowed the RHC to reach a wide range of fusion stakeholders more quickly than via traditional in-person engagement.

The RHC considered the use of more workshops in its engagement but found that bilateral meetings were effective for this particular deep dive, as it was able to canvass a wider range of opinion and elicit very open feedback from stakeholders in more in-depth conversations. Bilateral meetings also proved logistically achievable given the relatively small number of fusion stakeholders with direct views on regulation, as compared to the RHC's other deep dive topics.

What could the RHC have done differently in retrospect?

As can be expected, more time and more resources would have allowed for increased stakeholder engagement and a more in-depth report. However, this approach was balanced against the importance of moving quickly in order to help early decision making about this emerging technology. The RHC's view is that this approach still allowed for a robust report that identified and provided advice on the crux of the matter in scope.

The RHC engaged devolved regulators on fusion regulation for this report. However, it could have been more beneficial to do have done this at an earlier stage in the process. There were also delays to engagement with SEPA due to the significant cyber-attack they faced.[44]

The RHC engaged with a wide range of stakeholders, most of whom were unfamiliar with the council due to it being a new body. On occasions the RHC could have provided additional clarity to stakeholders from the outset about its remit, processes and approach.

The RHC completed a survey (Appendix D) to assist with the second deliverable on fusion regulation (the Chapter 8 supplement focusing on commercial fusion). There could have been benefits of using this approach nearer the start of this first report on STEP.

What Worked Well in the Approach

It was critical to understand quickly what value the RHC could add to the issue of fusion regulation, particularly given the relatively tight time constraints of the work (circa 6 months).

The RHC worked closely with the policy team for fusion allowed the RHC to consider where it could add value, how it could make its recommendations land, and how they would fit into other fusion timelines and considerations.

The RHC's position of independence and neutrality on the specific issue of fusion allowed it to engage with a wide range of stakeholders as a disinterested party and thereby perhaps elicit fuller, more comprehensive feedback on the issue.

The approach of engaging at a high-level on the principles which should inform a fusion regulatory framework, rather than going into the whole range of technical details on fusion, was effective and proportionate for this report and its aims.

[44] https://www.sepa.org.uk/about-us/cyber-attack/

The approach of focussing on the high-level criteria for what fusion regulation might look like helped clarify the process of reviewing the merits of different regulatory approaches.

Focussing on STEP (The Spherical Tokamak for Energy Production) helped to contain the scope at an early stage and appropriately reflected the RHC ambitions to promote more agile ways of policy working.

Finally, the RHC report was well timed given that the launch for STEP siting has taken place, creating a greater desire for regulatory clarity for fusion. Similarly, increasing investment in the fusion industry over recent years, as well as renewed government commitments to net zero, also made the report a timely and relevant one.

D. Findings from the Fusion Energy Survey

Executive Summary for the Fusion Energy Survey

- The Regulatory Horizons Council (RHC) recently published a report into fusion energy, providing recommendations for regulatory reform to help promote innovation, and the rapid and safe introduction of fusion energy technology.
- To support this ongoing work, the RHC conducted a survey and collected data from 13[45] organisations, consisting of regulators, businesses, specialist fusion energy laboratories, and a trade association.
- The vast majority of respondents agreed that the UK is both moving quickly to make decisions about the regulatory approach for fusion energy (12 respondents) and that its current pace of decision-making is appropriate (10 respondents).
- Respondents re-emphasised the work needing to be done to improve public awareness. 11 respondents believe that the public currently has a limited to non-existent understanding about fusion energy and its regulation, with the remaining two respondents being unsure. All respondents, however, agreed that the public needs to have at least a limited understanding, with the majority (10 respondents) stating that they should have a moderate understanding.
- 9 of the 13 surveyed believe that an approach that is broadly similar to what has been used for JET would be most appropriate for the rapid and safe introduction of commercial fusion energy.
- The same 9 respondents also believe that a regulatory approach similar to JET would have a positive financial impact on UK businesses, with 8 of the same respondents also having indicated that an approach based on current nuclear fission regulation would have a negative financial impact.

[45] Due to the small sample size of the survey, responses will not be reported in percentage terms and instead, reported in terms of the raw number of respondents.

- On average, 11 of the 13 respondents agreed that fusion energy will provide significant technological contributions for central adjacent technologies[46] and deemed these technologies as either extremely, or very important for the success of fusion energy.

[46] Adjacent technologies included in this survey are: magnetic technology; scientific measurement and instrumentation; artificial intelligence and computing; robotics and autonomous systems; materials research.

Methodology

The main aim of this research is to deliver supporting findings for the existing deep dive exploration that has been conducted into fusion energy and its regulation. There are four main research questions that were identified in the scoping of this project:

1. **What are the gaps in the fusion energy report, and can we strengthen the evidence-base in these parts?**

2. **What do organisations think the impact on/from adjacent technologies will be, as well as the commercial impact from fusion energy?**

3. What do organisations think of different regulatory scenarios and the possible impact this could have on them?

4. What are organisations' views of fission-based regulatory approaches vs a fusion-specific approach?

This research needed to be delivered at pace to align with further publications from the RHC for fusion energy. Consequently, it was important that the research design not be burdensome for staff and participants, and the scope of the project be focused. Points 3 and 4 above were covered in some depth within the fusion energy report, so it was decided that it would be most beneficial to predominantly focus on research questions 1 and 2.

With these considerations in mind, it was determined that the most efficient way to gather this data was through a targeted survey with expert stakeholders in the field of fusion energy and its regulation. Critically, it is noted that the data collected from this survey is not exhaustive and acts as a supplementary source of information to be used to triangulate the findings gathered through the RHC's other stakeholder engagements.

To collect the sample for this survey, an opportunistic approach was employed. Since fusion energy is a niche field of science with a small population, it would have been inappropriate (and most likely, ineffective) to attempt to obtain a representative sample through systematic sampling, particularly within the timeframe of this research. Instead, it was determined that the most effective route would be to utilise the pre-existing connections that the RHC has developed through its stakeholder engagement for the fusion energy deep dive report.

The opportunistic sampling approach that was employed provided a list of 21 possible respondents – 13 of these responded to the survey and form the sample for this analysis. Due to this sample size, results are referred to in raw numbers, rather than percentages. Additionally, due to the small sample size of the survey, factors such as statistical significance cannot be examined. Findings within this report are descriptive, with some bivariate analysis incorporated. The survey was completed online and was deployed using Microsoft Forms.

It is important to recognise the limitations of this exercise and its findings. While an opportunistic sampling approach was most appropriate for the scope of this research, it is noted that this limits the ability to make any inferences about the wider population within the field of fusion energy and/or its regulation. This report shall only present insight and analysis that refers to the sample surveyed and will not comment beyond this group. The purpose of this report is to act as supplementary evidence to the existing research and stakeholder engagement that has been completed as part of the fusion energy deep dive and its related publications.

Results

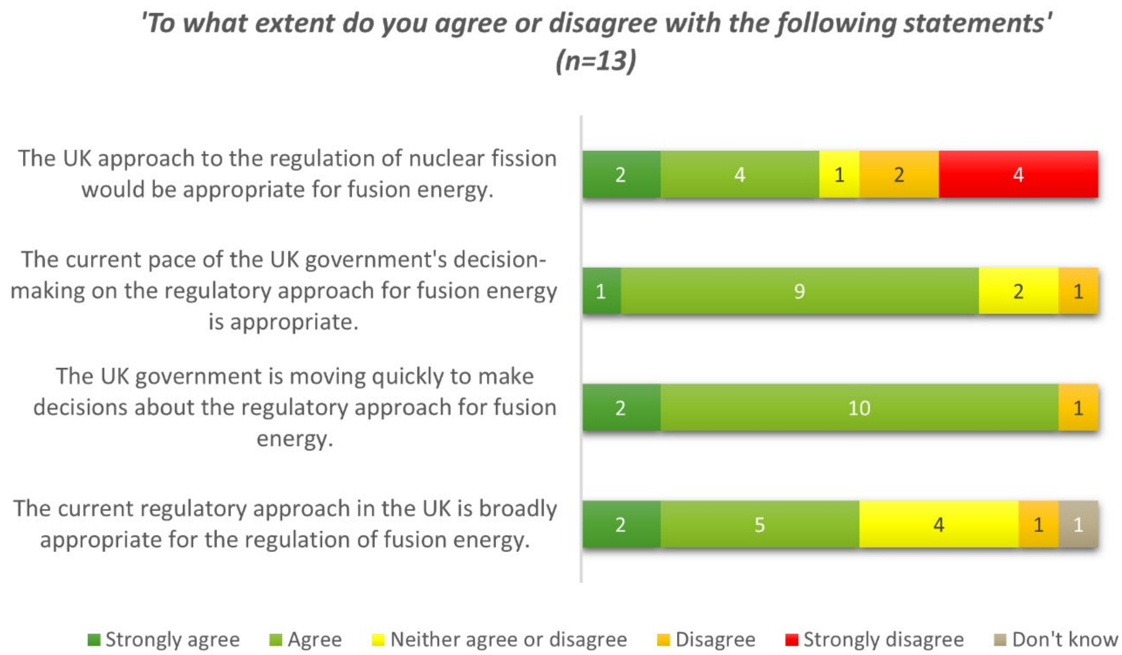
The subsequent discussion goes through each question of the survey and discusses the relevant findings, as well as providing tables and graphs with the result.

Question 1: Demographic data

The survey received 13 responses from the following organisations:

Organisation	Category
First Light Fusion Limited	Business
General Fusion Inc.	Business
SHINE Medical	Business
Tokamak Energy Ltd	Business
Nuclear Risk Insurers	Insurer
International Thermonuclear Experimental Reactor (ITER)	Laboratory
Princeton Plasma Physics Laboratory	Laboratory
Natural Resources Wales	Regulator
Office for Nuclear Regulation	Regulator
Ofgem	Regulator
Scottish Environment Protection Agency	Regulator
UK Atomic Energy Authority	Research organisation
Fusion Industry Association	Trade association

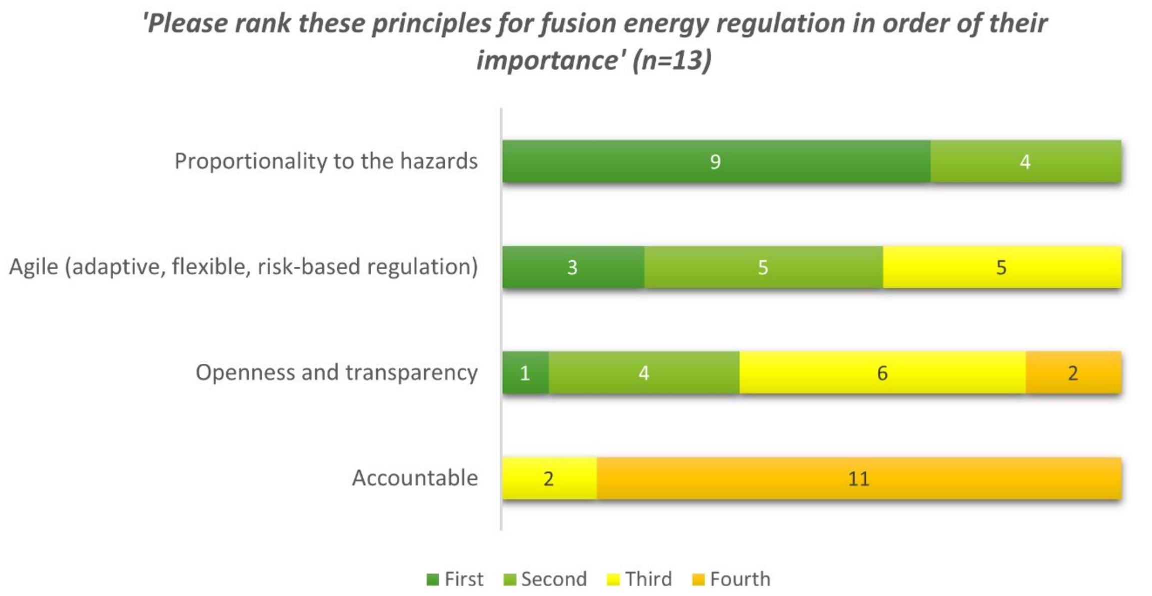
Question 2: UK approach to fusion energy regulation



The majority of respondents agreed that the UK government is moving quickly to make decisions about the regulatory approach to fusion energy (12 respondents) and that this current pace of decision-making is appropriate (10 respondents).

Opinions about whether the current approach towards the regulation of nuclear fission is appropriate for fusion energy were equally split, with 6 respondents agreeing that it would be appropriate, and 6 disagreeing. There was, however, a little bit more certainty as to whether the current UK regulatory approach is appropriate for fusion energy, with 7 respondents agreeing it was appropriate and one disagreeing.

Question 3: Principles for fusion energy regulation



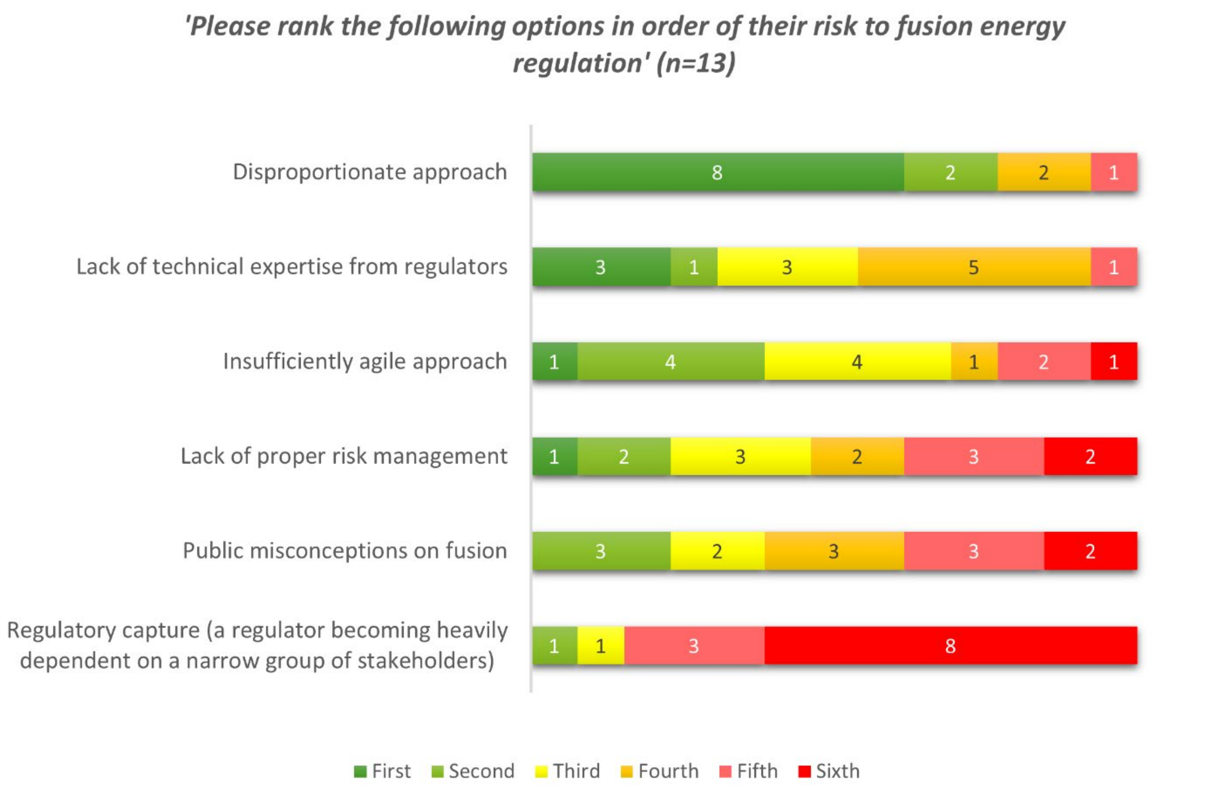
The results show that, of the principles tested, the sample ranked 'Proportionality to hazards' as the most important. This finding also came through in other sections of the survey where respondents were given the opportunity to provide open-ended answers (Question 12), reinforcing the notion that the respondents place the consideration of hazards as a high priority for fusion energy regulation.

It is unclear why accountability was placed as the fourth choice so often. This does not indicate that it is not a valuable principle, but that – out of those that were tested – it was deemed to be the least important for fusion energy regulation. If one were to speculate, it could be that respondents saw this as a given for this type of regulation, however, it is not possible to know without further exploration.

Question 4: Further principles for fusion energy regulation

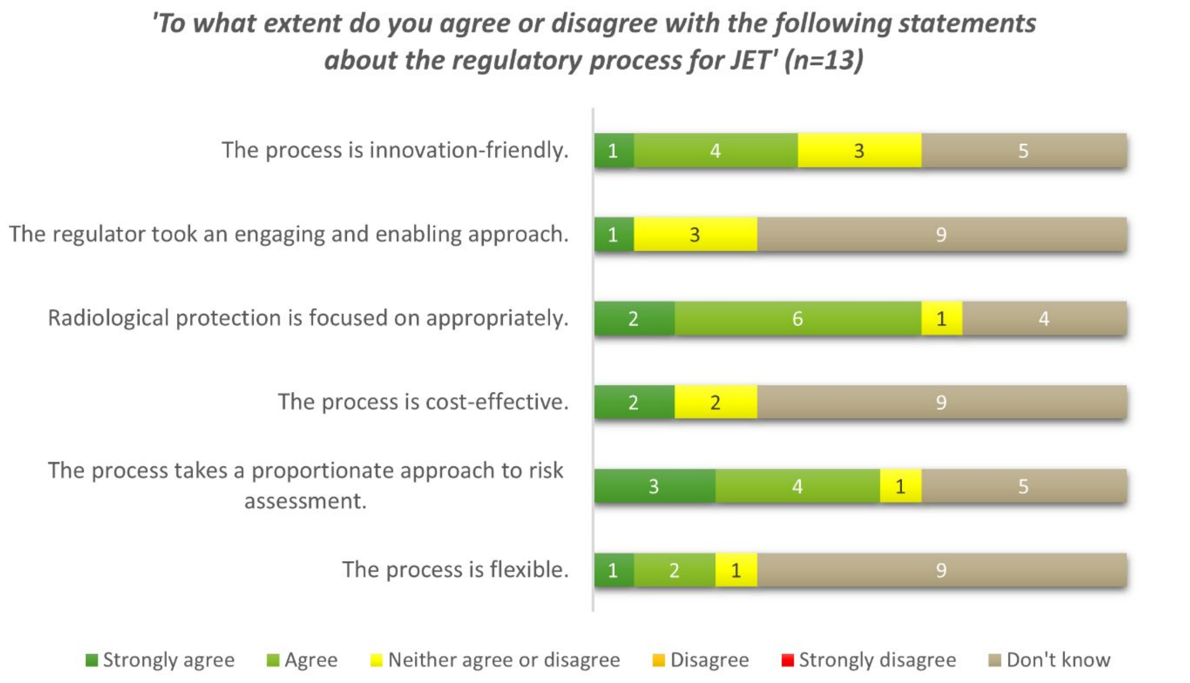
11 respondents provided detail of other principles that they thought were important for the regulation of fusion energy. Across the responses, the common themes that emerged were the need for the approach to be specific to fusion (3 respondents) and the need for international harmonisation in the approach (2 respondents). The full responses can be found in Annex A.

Question 5: Risks to fusion energy regulation



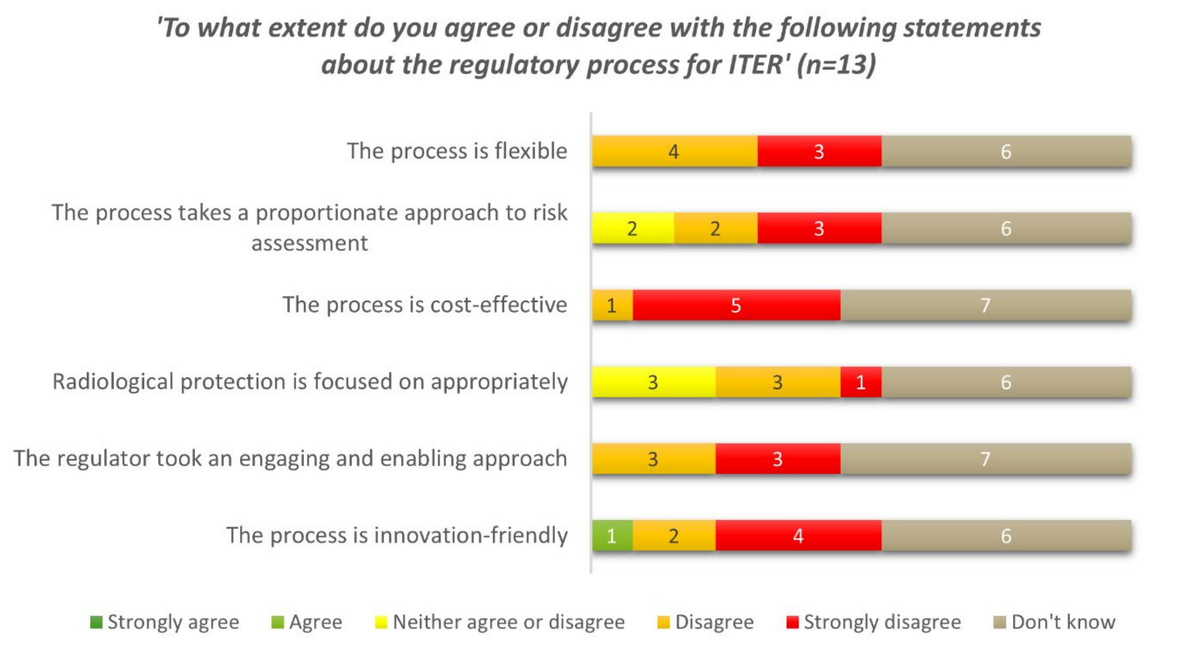
8 respondents ranked a disproportionate approach as the biggest risk to fusion energy regulation, which aligns with the findings from Question 3 and reinforces the narrative that – for the sample tested – proportionality is a central concern for the regulation of fusion energy. The majority of respondents (8 respondents) deemed regulatory capture to be the smallest risk out of those tested. This finding may demonstrate some slight bias in the sample, since regulators are one of the two most heavily represented groups (4 respondents – same as businesses) and may be more inclined to think that they would not be susceptible to regulatory capture. Again, this is difficult to determine without further exploration.

Question 6: Regulatory process of JET



Unfortunately, for half of the statements tested in relation to JET, the majority of respondents did not have the knowledge to be able to indicate their level of agreement or disagreement. Reassuringly, the responses that were obtained were mostly positive, indicating agreement with the statements. However, respondents' uncertainty around the nature of JET limits the utility of the results from this question.

Question 7: Regulatory process of ITER



When asked about the regulatory process for ITER, there was a similar level of uncertainty towards the statement, with only roughly half of respondents being able to indicate whether or not they agreed with each statement. Unlike the findings from Question 6, the respondents that did indicate a level of agreement/disagreement here, indicated disagreement with the statements in relation to ITER. Only one respondent indicated agreement with the statement that the regulatory process for ITER is innovation friendly.

The findings from both Question 6 and Question 7 largely align with the findings that were drawn out through the stakeholder engagements of the fusion deep dive report, however, should be heavily caveated, due to the large proportion of respondents who indicated that they could not provide an answer for each of the statements.

Questions 8 & 9: Public understanding about fusion energy and its regulation

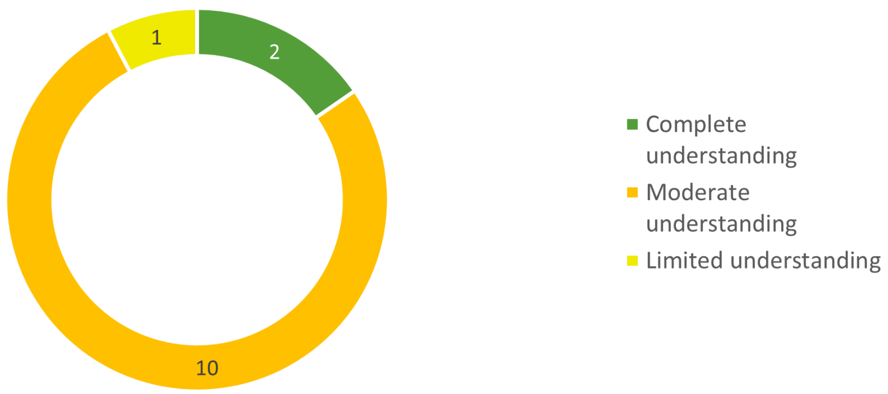
Question 8

'What level of understanding do you think the public has about fusion energy and its regulation?' (n=13)

11 respondents in the sample indicated that the current level of public understanding of fusion energy and its regulation was either limited (7 respondents) or non-existent (4 respondents).

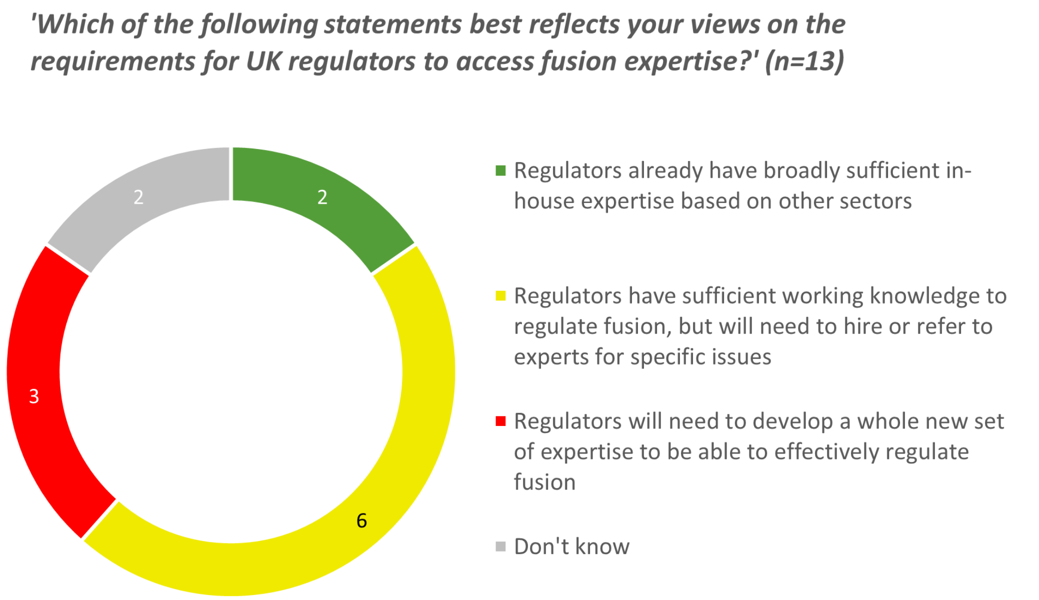
Question 9

'What level of understanding do you think the public needs to have about fusion energy and its regulation?' (n=13)



All 13 respondents indicated that the public should have, at minimum, a limited understanding of fusion energy and its regulation. Of those 11 respondents that previously indicated in Question 8 that the current level of public understanding was either limited or non-existent, 10 of them believed that the public should have a moderate to complete understanding. The two respondents in Question 8 that were unsure of the current level of public understanding both believe that there still should be a moderate understanding of fusion energy and its regulation.

Question 10: Fusion expertise for UK regulators

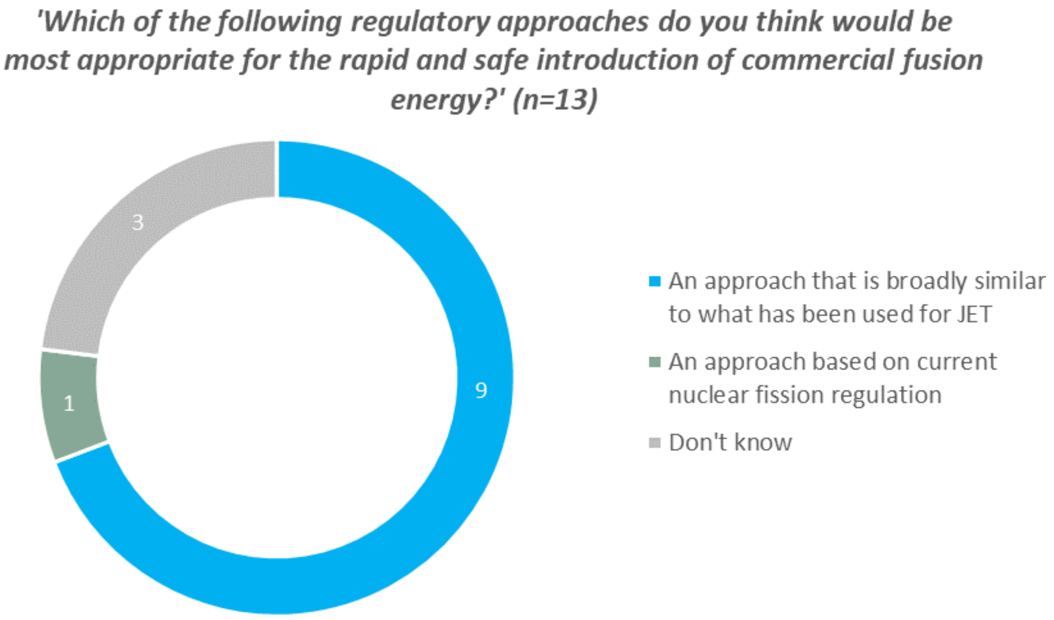


Views around the level of fusion expertise required for UK regulators were somewhat split. The most common view among the sample (6 respondents), however, is that UK regulators have sufficient knowledge to regulate fusion but will need to hire or refer to experts for specific issues.

It is worth highlighting that one respondent highlighted later on in the survey (Question 16) that they found this question difficult to answer since:

'[…] as worded as we weren't sure which regulator it was asking about.'

Question 11: Regulatory approaches for fusion energy



9 respondents within the sample indicated that a regulatory approach that is broadly similar to what has been used for JET would be more appropriate than an approach based on current nuclear fission regulation – these findings are consistent with those of the fusion energy report.

Question 12: Explanation of regulatory approach chosen

All 13 respondents provided further explanation of their choice of the regulatory approach in Question 11. Of the 9 respondents who said that an approach similar to JET would be most appropriate, the most common theme was the different hazards that fission and fusion present. One respondent commented:

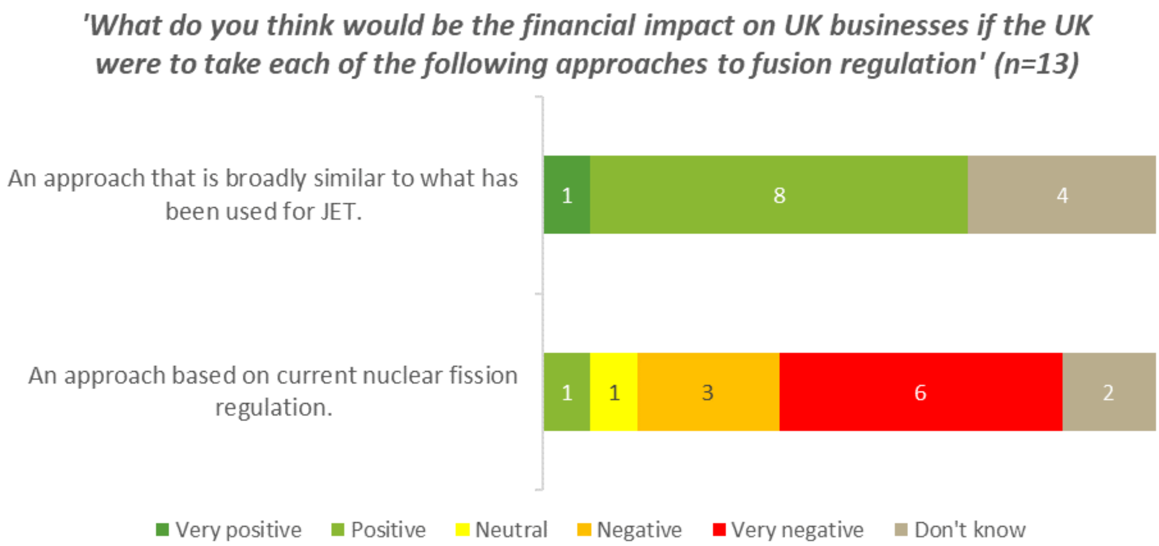
> **'The hazard and risk for fusion is significantly less than that of fission and therefore the approach to regulation needs to be proportionate. […]'**

Another respondent highlighted similar issues, along with the need for proportionality:

> **'The fundamental hazards are massively different to fission. Safety regulation must be proportionate, outcome-focused and agile as the research moves towards production.'**

Again, these findings are consistent with the stakeholder engagements of the fusion deep dive report. For the one respondent who indicated that an approach based on current nuclear fission regulation would be the most appropriate, they indicated that this regulatory approach has already been applied to fusion and demonstrated to be successful. All responses can be found in Annex B.

Question 13: Financial impact of regulatory approaches

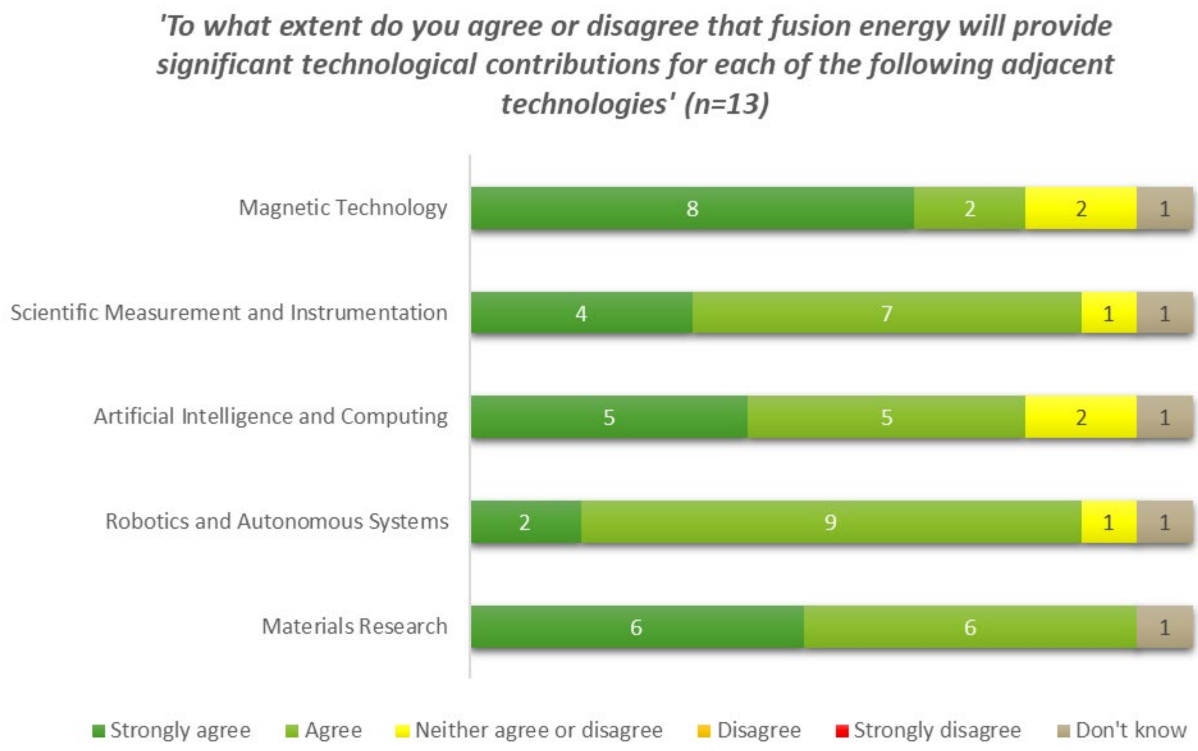


When respondents were asked to indicate the financial impact of different regulatory approaches, there were clear commonalities. Of those that were able to provide an answer in respect of each approach, the majority (9 respondents) indicated that an approach similar to JET would have a positive financial impact on UK businesses and that there would be a negative impact from an approach based on current nuclear fission regulation.

Unsurprisingly, the one respondent who indicated that an approach based on current nuclear fission regulation would have a positive financial impact, is the same respondent who selected it as the more appropriate regulatory approach in Question 11.

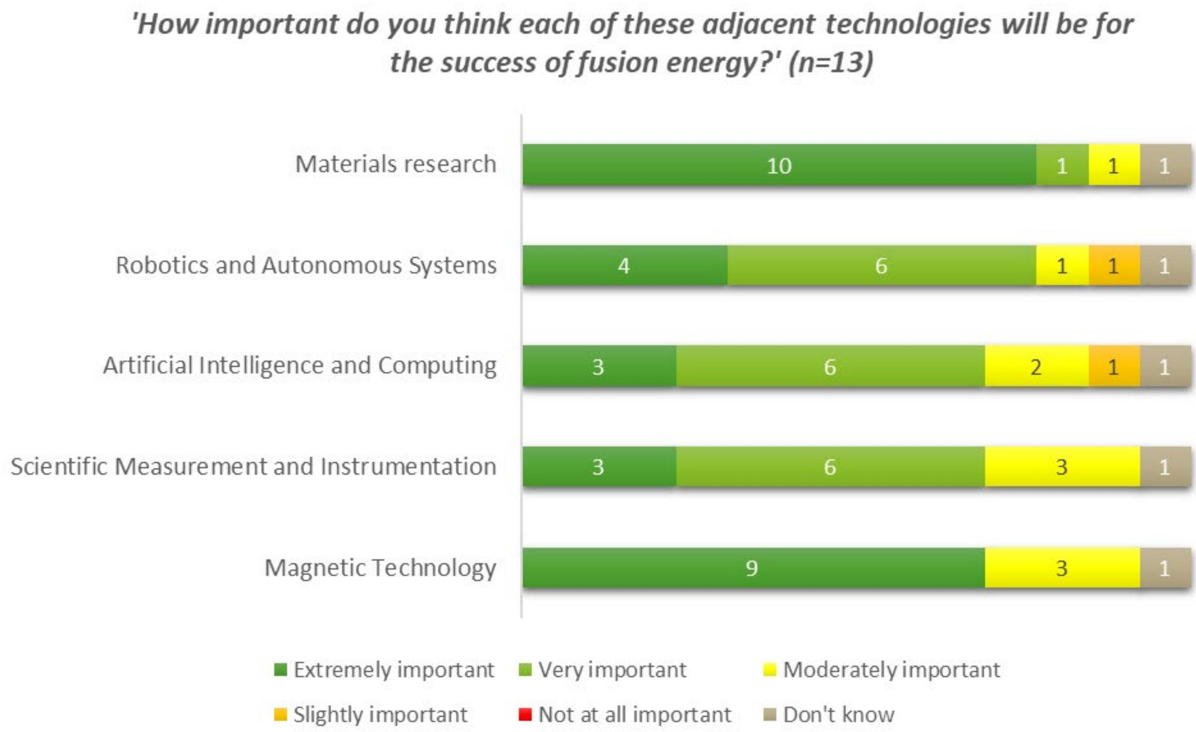
Question 14 & 15: Adjacent technologies

Question 14



Across each of the five adjacent technologies tested in the survey, there was generally strong agreement that fusion energy will provide significant technological contributions. Notably, no respondents disagreed that there would be significant technological contributions for any of the technologies included in the survey. Respondents most strongly agreed (8 respondents) that fusion technology would provide significant technological contributions for magnetic technology. Overall agreement, however, was strongest for materials research (12 respondents).

Question 15



On average, respondents considered all the technologies included in the survey to be either extremely important, or very important for the success of fusion. Respondents considered materials research to have the greatest importance for the success of fusion energy out of the adjacent technologies included in the survey, with 10 respondents deeming it extremely important. No respondents considered any of the technologies to not be important at all for the success of fusion energy.

Question 16: Further information from respondents

7 respondents provided further information about the regulatory approach for fusion energy. The only common theme across the responses was the need for the approach to be adaptable/flexible – this is reflective of the findings in the fusion energy report, which stresses these values within the 'Proportionate and agile' criteria. The full open-ended responses can be seen in Annex C.

Annexes

Annex A: Question 4 – Complete responses

'Please provide detail of any other principles you think are important for regulating fusion energy'

Open-ended responses
'Accessibility to the public'
'International harmonisation'
'Entirely focused on outcomes - slightly different to the first principle above but an elaboration'
'Supporting innovation; Enabling commercialisation; Incorporating rapid learning; International harmonization'
'We would have prioritised proportionality to risk rather than proportionality to hazard if it were available, followed by other key regulatory principles such as targeted and consistent.'
'Looking at ways to ensure any plant has multiple benefits to society and the environment in line with principles of sustainable management of natural resources'
'Fusion energy should represent Value for Money for future consumers, and that includes delivering power to the grid that is useful to consumers (i.e. available in useful quantities when consumers need it, as well as low carbon and affordable).'
'Developing regulatory requirements that have some specificity to unique aspects of fusion.'

‘1 mSv/year max for probable accidents (e.g.: 10^-1 to 10^-2) and 10 mSv/y for (10^-3 to 10^-4) unlikely accidents should be safe enough and shall not lead to public confinement or evacuation.’

‘Regulations should be in line with particle accelerators not fission nuclear’

‘The proportionality to the hazards needs to take into account also the differences between fusion technology. There shouldn't be a "one size fits all" approach for all fusion’

Annex B: Question 12 – Complete responses

'Please can you provide further explanation why you think this approach will be most appropriate'

Open-ended responses
'There is no basis in science or in risk to regulate fusion power plants like fission plants. The UK government must permanently and completely separate fusion regulation from fission regulation.'
'The hazard and risk for fusion is significantly less than that of fission and therefore the approach to regulation needs to be proportionate. The approach currently used for JET seems to meet this requirement and has been effective for the last few decades.'
'The fundamental hazards are massively different to fission. Safety regulation must be proportionate, outcome-focused and agile as the research moves towards production. We must avoid adding regulation for regulation's sake.'
'We need to differentiate from fission, to encourage investment in fusion. However .... we recognise that the current framework will need evolution for a fusion power reactors (eg. consideration of formalising the safety case approach, early engagement with regulators).'
'Not familiar with the approaches taken.'
'It works well at JET and from a public perception point of view means it is regulated in the same way as hospitals, university and other non-nuclear operators which is proportionate to the risk from fusion and likely to make it more acceptable to the public.'
'This depends on which approach turns out to deliver best Value for Money for consumers. The approach based on nuclear fission is proven, so may be attractive to investors; however, it may be more costly than the approach

used for JET. The costs saved by a more proportionate regime should not be negated by costs incurred due to increased financing costs associated with a novel regime.'

'The regulatory approach for fusion should be based on the technical aspects of fusion technology and risks, not another technology such as fission.'

'An integrated fusion Safety regulator (or knowledgeable counter) dealing with the protection of the environment, the workers and the public along with security and safeguards aspects (non-proliferation) would help gain time in the licensing process. Certification would also help embarking on fusion power programmes.'

'Fusion has no similarities to the risks of fission nuclear that current regulations are based on (i.e. interruption of reactor cooling, meltdown potential, reactor fire, heavy isotopes, proliferation, large inventories of fissile materials, off site dose etc).'

'Fusion hazards are significantly smaller than fission's. No meltdown, no weapons material. Some technologies can substantially reduce the already lower amount and grade of waste. HSE, EA and ad hoc expertise could suffice to provide a flexible and effective regulatory framework.'

'Fusion systems have widely varying risk, and so should be assessed proportional to the hazard with each approach'

Annex C: Question 16 – Complete responses

'Please provide any further information that you would like to add about the regulatory approach for fusion energy'

Open-ended responses
'The government should undertake a program of public education on fusion safety, risk and regulation to accompany its efforts to support the growth of fusion energy. The nationwide search for a venue for STEP has surfaced an alarming lack of understanding from some elements of the public about the differences between fusion and fission. Industry can support such a campaign, but the government is best-placed to lead it.'
'Keep it simple, based on the hazards. To the extent they change during development and construction, adapt. The current EA/HSE approach should be entirely satisfactory given all we now know about the hazards of fusion. If things change, so should the approach in an entirely proportionate manner.'
'Need to keep up the pace with the development of the regulatory framework (eg. some certainty for the business case for STEP Tranche 2). Encourage pragmatism (e.g. in safety case assessment methodologies, application of codes & standards). Note, we have not responses to the question on ITER, as we only have "hearsay" on the effectiveness of regulation.'
'In terms of the required regulatory expertise we found it difficult to answer the question in the survey as worded as we weren't sure which regulator it was asking about. [Redacted for confidentiality] We interpreted the survey's reference to the approach to UK fission regulation as being [a] proportionate approach to risk rather than the same level of scrutiny a full-scale fission reactor would require.'
' [Redacted for confidentiality], we are keen to ensure that the plant that is procured represents Value for Money for consumers. This means that it

should deliver power that is useful (i.e. available when consumers need it and likely flexible), low carbon, and affordable. It is our understanding that the hazards associated with fusion are several orders of magnitude lower than those associated with fission. Therefore, a disproportionate approach by safety regulators would risk pushing the cost of fusion power up unnecessarily; however, we are not qualified to judge what the 'appropriate' level of safety regulation would be. Thorough regulation by an internationally respected safety regulator would likely be seen by potential investors as increasing the credibility of the project, meaning that it could access more sources of capital at preferential rates; this would help to deliver better Value for money for consumers.

The proposals as we understand them would use a steam turbine to connect to the grid, so grid code compliance shouldn't be a significant regulatory barrier for these plants. [Redacted for confidentiality], the precedents we set with [Redacted for confidentiality] appear to be appropriate for fusion; however, the short construction schedule and highly novel nature of the project mean that some adaptations would likely be necessary.

Expertise, and the ability to access a wide pool of stakeholders could probably be developed at an international and domestic level over the next c.15 years to satisfy our needs.'

'As opposed to the fission world we may establish dose limits for accidents (1 mSv/y for probable accident scenarios and 10 mSv of dose intake for low probability accident scenarios). Those numbers should be driving the design in a reasonable manner.'

'Must be flexible absolutely based on the specific real risks based on the specific fusion technology. There are a wide variety of approaches to fusion therefore there needs to be a wide variety on how it is regulated based on each technologies real risk to the worker and public. A clean slate approach conducted by fusion savvy experts is required.'