THE FUSION CLUSTER

GROWING THE FUSION WORKFORCE

CHALLENGES AND OPPORTUNITIES FOR THE FUTURE

FOREWORD

Delivering fusion energy will require expertise from a wide range of people and industries. This report by The Fusion Cluster is a first-of-a-kind, designed to start conversations that will evolve as fusion moves from the research era to delivering power plants. It does not proclaim to have all the answers – these will emerge with more focused work.

Instead, this report outlines some of the challenges the fusion energy industry faces, as it seeks to expand its workforce in existing areas and augment it with new skills, and point ways forward. It was compiled from evidence provided at a roundtable workshop attended by fusion energy companies, suppliers, recruiters, and training providers that are part of The Fusion Cluster in the UK.

Its findings will help to realise the UK government's plan to invest £56 million in a fusion skills programme as part of Fusion Futures, the UK's alternative to the Euratom Research & Training programme.

Acknowledgements: we extend our thanks to the representatives from UKAEA, Tokamak Energy, First Light Fusion, Focused Energy, General Fusion, Commonwealth Fusion Systems, The University of York/Fusion Centre for Doctoral Training, Atkins, Jacobs, Assystem, Oxford Sigma, Kyoto Fusioneering, and Bond Global for their contributions, and a dedicated workshop at Culham in March 2023.

EXECUTIVE SUMMARY

- The fusion workforce requirements are inextricably linked with technological progress and investment, making it difficult to predict exactly how many roles are required and when;
- The nature of the workforce challenge evolves over the short-, medium- and long-term;
- Shifting the focus to skills rather than job roles, will allow fusion to draw from a wider range of potential recruits in other sectors;
- A targeted communication plan is essential to entice potential recruits, highlighting the rapid progress that is being made, routes into fusion and structured career pathways;
- Apprenticeship programmes are crucial for ushering in a new generation of people into fusion, but must be timed to ensure that there is sufficient work available at the end of the programme;
- The lack of diversity in fusion represents a missed opportunity;
- To make faster progress, the fusion sector should seek to learn from other STEM industries that face the same challenges.

INTRODUCTION

The UK has a distinguished history of pioneering fusion energy, beginning with the establishment of the UK Atomic Energy Authority (UKAEA) in the 1950s.

Today, Oxfordshire is a thriving centre of innovation and collaboration, where some of the brightest minds from around the world come together to tackle the complex challenges of achieving sustained fusion power.

The region is also home to two of the world's most exciting and innovative fusion energy companies, Tokamak Energy and First Light Fusion, who have attracted more than £280 million in investment according to the Fusion Industry Association.

With a solid foundation of skills laid down by the UKAEA, the UK is presented with a remarkable chance to capitalise on its achievements and ascend as a world leader in fusion.

However, having the correct breadth and depth of skills is crucial for UK-based organisations to make progress, and a talented workforce will attract inward investment from overseas fusion companies looking to advance their missions.

This report highlights challenges and makes suggestions to ensure that careful consideration is given to the talent needed to sustain a growing and highly technical workforce.

FUSION WORKFORCE OVERVIEW

...within the next decade fusion will need to draw significant volumes of talent from other industries...

After years of world-leading research, fusion is moving from a research era to one delivering power plants. The fusion industry is still in its infancy, currently employing around 2400 people directly in the UK. Around three-quarters of this workforce hold scientific, engineering or technical positions with the remainder working in business operations.

Tokamak Energy and First Light Fusion have seen significant growth in their workforces in the past year. (see table 1.)

Table 1

Company	Headcount	Growth 2022-2023
UKAEA	2,082	+7.8%
Tokamak Energy	221	+25.6%
First Light Fusion	79	+16.2%

Bond Global March 2023

...the UK must be globally competitive to attract and retain our highly skilled workforce...

Fusion operators must balance the teams needed to drive technical innovation with those needed to run and grow a stable engineering operation. This balance is key to ensuring that sustainable growth is achieved while solving some of the hardest engineering challenges ever faced.

Predicting future workforce requirements is challenging, however. This report does not provide numbers or timescales but is intended as a catalyst for future work. The workforce needs of a fusion company are deeply entwined with both technological progress and investment. We saw this in 2023 when General Fusion paused its plans to build its Fusion Demonstration Plant at Culham to concentrate on an intermediate machine in Canada and reduced its UK workforce.

Privately funded fusion companies need an agile workforce because priorities often change. Knowing what skills an organisation has and where to deploy them is critical. Hence, we need to look at fusion from a perspective of skills rather than job titles because within the next decade fusion will need to draw significant volumes of talent from other industries, and talent will need to be re-skilled for the journey.

This process has started, for example, with the UKAEA successfully launching a tritium training course and offering bespoke courses to industry, academia, graduates, engineers and scientists. Other areas in increasing demand are superconductivity, power systems, cryogenics and neutronics, where engineers are all in short supply and increasing demand.

RECRUITMENT CHALLENGES?

“What areas do you struggle with when recruiting”?

When this question was asked at a recent roundtable, the immediate reply was “all of them”.

It is clear that recruitment needs to be creative, flexible and international to meet the demand of the fusion industry’s growth plans, especially in light of a global macroeconomic context that is making attracting people to the UK more difficult, and candidates more reluctant to move to perceived high-risk industries, and bear costly relocations.

A truly global talent pool

Fusion is a global endeavour and this is an opportunity and a challenge from a workforce perspective. On one hand, it provides an opportunity to attract talent from overseas to fill vacancies in the UK. On the other, the UK needs to stay globally competitive to attract and retain its highly skilled workforce.

...For overseas candidates, the UK remains attractive in the short to medium term as it is one of the most highly concentrated fusion environments...

To recruit overseas candidates, most fusion companies need to sponsor visas. Data from recruitment agency Bond Global shows than 20 per cent of qualified candidates coming to the UK from overseas between March 2022 and March 2023 needed support with visas. The typical application fees for a tier 2 skilled worker visa costs approximately £655, plus relocation allowances associated with the job offer.

However, the process is quite time consuming: it typically takes 2-3 months from the point of accepting an offer before the candidate can arrange a visa, complete their relocation and begin work. This can impact time-critical R&D projects. Government support would be welcome to reduce visa processing times, potentially through fast-track routes for fusion/other strategically-important R&D sectors.

For overseas candidates, the UK remains attractive in the short to medium term as it is one of the most highly concentrated fusion environments. However, companies in the EU and US are likely to catch up. For example, in the US, a request for $1bn fusion funding has been tabled for 2024. And a number of new fusion start-ups have emerged in Europe.

The US could therefore become a more favourable funding environment. While the growing number of fusion companies in Europe, as well as ITER, could attract fusion talent from countries such as India, Japan, and Korea, as candidates see increasing opportunities and fewer barriers to move jobs across continents.

As the Spherical Tokamak for Energy Production (STEP) enters its second phase in 2025, which is focused around developing the engineering design and testing and optimising its subsystems, the West Burton site will begin to see activity. This could help mitigate this problem as the UK will still be seen as a favourable destination due to having an experienced fusion workforce and more mature supply chains.

Skills not job titles

Roles addressing specific research challenges or requiring highly specific, deep interdisciplinary knowledge usually at doctoral level, are very difficult to recruit for. And it is not uncommon for graduate researcher vacancies to go unfilled for more than 6 months because the timing of graduation date and identification of vacancies by industry do not always align.

An extreme example of the challenge facing fusion recruitment was a key leadership role within UKAEA remaining unfilled for nearly a decade as they sought to replace a unique skillset – it was ultimately required for the position to be broken down into multiple skillsets so that the capability could be replaced with multiple roles.

The lesson is to avoid focusing on job titles and instead organise roles into broader job families and map out the specific skills required for each role. This can identify skills gaps, aid workforce planning, and help create transparent pay structures based on skills, rather than job titles.

Table 2

The most common skills across the three largest Oxford-based fusion employers (LinkedIn Data of 1,346 profiles from UKAEA, Tokamak Energy and First Light Fusion). The skills mix in UK fusion is roughly 50 percent engineering and 20 percent physics, with a strong emphasis on modelling and programming and data analysis as core skillsets. It highlights the need to look at fusion from a skills point-of-view rather than job titles, and to identify areas where we might easily find transferable skills from other industries.

Skills	Total volume	%
Engineering	638	47.4%
MATLAB	327	24.3%
Mechanical Engineering	295	21.9%
Python	261	19.4%
Data Analysis	261	19.4%
Manufacturing	253	18.8%
Physics	238	17.7%
Research and Development (R&D)	211	15.7%
C++	180	13.4%
Computer-Aided Design (CAD)	171	12.7%
Simulations	160	11.9%
SOLIDWORKS	149	11.1%
Commissioning	149	11.1%
Nuclear	142	10.5%
Laboratory Skills	141	10.5%
Programming	140	10.4%
Electrical Engineering	138	10.2%
Analytical Skills	135	10.0%
Procurement	133	9.9%
Project Engineering	130	9.7%
LaTeX	128	9.5%
Finite Element Analysis (FEA)	121	9.0%
Science	120	8.9%
C	118	8.8%
AutoCAD	117	8.7%
Systems Engineering	114	8.5%
Linux	111	8.2%
Engineering Management	109	8.1%
Product Development	107	7.9%
Software Development	105	7.8%
Fortran	96	7.1%
Materials Science	92	6.8%
Recruiting	92	6.8%
Continuous Improvement	92	6.8%
ANSYS Products	87	6.5%
Mathematical Modelling	86	6.4%
Aerospace	82	6.1%
Energy	82	6.1%
Chemistry	76	5.6%
Instrumentation	76	5.6%
Technical Support	75	5.6%
Plasma Physics	75	5.6%
CATIA	72	5.3%
Programme Management	70	5.2%
Scientific Computing	68	5.0%
Numerical Analysis	67	5.0%
Risk Management	65	4.8%
Automotive	63	4.7%
Stakeholder Management	63	4.7%
Mathematics	61	4.5%
Process Engineering	61	4.5%
Operations Management	61	4.5%
Machine Learning	60	4.5%
Nuclear Engineering	60	4.5%
Risk Assessment	60	4.5%
Robotics	59	4.4%
Process Improvement	59	4.4%
Renewable Energy	58	4.3%
Supply Chain Management	57	4.2%
Finance	57	4.2%
Control Systems Design	56	4.2%
Programmable Logic Controller (PLC)	56	4.2%
Java	54	4.0%
Contract Management	54	4.0%
Presentation Skills	53	3.9%
Computational Fluid Dynamics (CFD)	53	3.9%
Lean Manufacturing	53	3.9%
Design for Manufacturing	52	3.9%
Microsoft Project	52	3.9%
Project Delivery	51	3.8%
Engineering Design	50	3.7%
Report Writing	49	3.6%
LabVIEW	49	3.6%
Acting	47	3.5%
Simulink	46	3.4%
Electrical Wiring	46	3.4%
Product Design	46	3.4%
Human Resources (HR)	46	3.4%
Automation	45	3.3%
Quality Assurance	44	3.3%
Embedded Systems	44	3.3%
Magnets	43	3.2%
Troubleshooting	43	3.2%
Databases	43	3.2%
Budgeting	43	3.2%
Autodesk Inventor	42	3.1%
Sustainability	42	3.1%
Operations	42	3.1%
HTML	41	3.0%
Algorithms	41	3.0%
Statistics	41	3.0%
SQL	40	3.0%
Materials	38	2.8%
Power Plants	38	2.8%
3D Printing	37	2.7%
Cross-functional Team Leadership	37	2.7%
Git	37	2.7%
Experimental Physics	37	2.7%
Modelling	36	2.7%
Gas	36	2.7%

WHERE IS THE TALENT COMING FROM?

...as the sector matures, engineers, scientists, and support staff from more traditional engineering settings will be needed...

In the UK, fusion has proven to have the ability to pull talent across from other industrial sectors such as automotive research and aviation. It also has straying power; during the last 12 months very little talent has left the fusion sector (see table 3 for the top five areas from which fusion is attracting talent).

As fusion continues in the R&D phase, it is no surprise that the main source of jobs requires applicants from a research background. This will change as the sector matures and engineers, scientists, and support staff from more traditional engineering settings will be needed. However, the number of new staff needed to deliver commercial fusion power is still unknown.

Table 3

Industry	Number of people moving out of sector	Number of people moving into Fusion	Net change
Research	1	22	+21
Automotive	1	12	+11
Aviation and Aerospace	2	7	+5
Higher Education	0	4	+4
Staffing and Recruiting	0	3	+3

ACADEMIC OVERVIEW

Education levels in private fusion

Historically, the fusion sector has been underpinned by PhD level candidates and staff working with innovative technologies through R&D phases. Over the next 10–15 years, as the industry progresses away from proofs of concept towards the delivery of major infrastructure projects, we would expect to see a relative decline in the share of PhD qualified candidates. Simultaneously, we would also expect to see an increase in the relative share of those holding Masters and Bachelors degrees, as the skills challenge moves away from solving research problems and more towards attracting engineers at volume to deliver significantly larger projects.

As we head further towards 2040, pilot plant testing and full operations and maintenance, the need for HND/HNC/ vocational qualifications will increase. At this time, fusion will compete with other traditional engineering industries for these skills.

Providing career paths for staff members is key for a business's Employee Value Proposition (EVP) and retention. Many other industries have examples of progressing technicians into engineers/ managers with a modernised training route and sponsorship for their studies. This is a great selling point for junior engineers and graduates looking for a stable career path in an industry they have a keen personal interest in.

Education levels across UK fusion

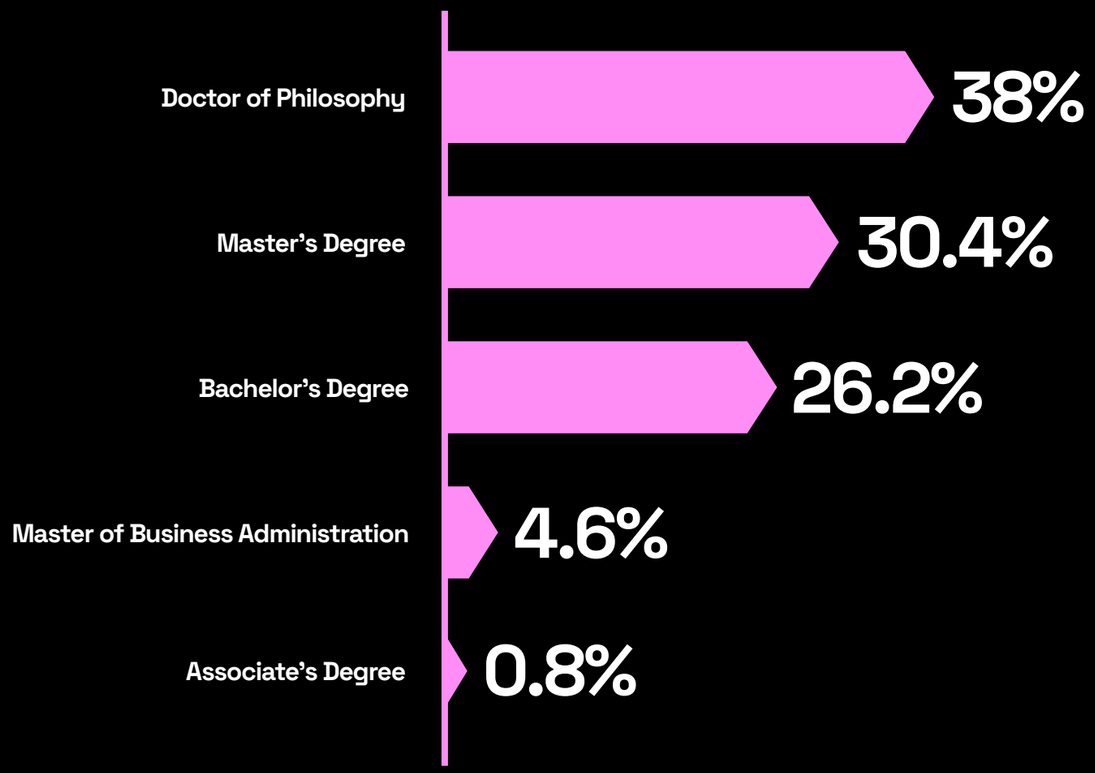

Table 4

Qualification level	Total professionals	Graduates in the last 12 months
Doctor of Philosophy	38%	47.5%
Master's Degree	30.4%	29.5%
Bachelor's Degree	26.2%	19.7%
Master of Business Administration	4.6%	3.3%
Associate's Degree	0.8%	0%

HIRING CHALLENGES

It was clear during the fusion skills workshop that everyone struggles with recruitment. A few common threads were identified, from which all attendees have challenges.

Re-framing fusion

Some fusion companies anticipate doubling their headcount in the next 2-3 years. This means attracting potential recruits from other sectors.

Fusion is a genuinely paradigm shifting technology and arguably one of the most important projects happening anywhere in the world. However, we need to make it more accessible and emphasise that rapid progress is being made. Too many individuals still perceive fusion as a technology that is 30 years away, whereas sectors such as automotive, aviation, and defence offer enticing opportunities to engage in projects and develop products that can be designed and constructed within a relatively short timeframe of 3 to 5 years. Consequently, some individuals may perceive the achievement of a tangible, finished product in fusion as too distant, leading them to prefer sectors that yield more immediate outcomes.

At the fusion skills workshop, First Light Fusion's Head of Talent highlighted that the target audience for most fusion companies' communications has been, and largely still is, investors rather than job seekers. While this is understandable, it is an issue that could be solved in the short-term with dedicated recruitment marketing campaigns, particularly as there is a growing attraction among job seekers towards sectors where they can have an immediate impact. LinkedIn remains a valuable hunting ground for new talent for the sector. 18–24-year-olds make up 21.7% of the total LinkedIn users. The largest section is dominated by 25–34-year-olds at 60%.

While in rapid scale, private fusion companies are often laser focused on the next funding round and technology milestones to satisfy funding partners. Other organisations need to play a role in communicating the shift away from the domain of blue-skies research to a tangible engineering and scientific challenge.

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Organisations such as the Fusion Cluster can help bring stakeholders together and communicate that fusion is more than a few companies tackling a gargantuan problem but a collective industry with a clear mission and great career opportunities. Engineers in industry, too, have a role to play in communicating fusion's mission in educational and outreach environments – enthusiastic engineers who are trained in communication are great advocates and role models.

Lack of diversity

According to the Fusion Industry Association's 2023 survey of fusion energy companies reports, 77 per cent of employees are male and 23 per cent female. As well as missing out on talent, the lack of representation across fusion is likely to further discourage potential applicants. Fusion is not the only STEM industry to have this problem and should engage with other sectors to learn from their experiences, rather than re-invent the wheel.

The rapid growth in headcount needed brings a risk of organisations repeatedly poaching employees with in-demand skills from local competitors. The dangers are that this fails to address underlying skills shortages and inflates salaries and recruitment costs to attract talent away from competitors. To avoid a situation in which all companies are worse-off, we need all stakeholders to invest in developing the next-generation of talent and growing the industry.

Early careers and apprenticeships

UKAEA presents a good model for this in their 2021/22 Annual Report and Accounts, employing 112 apprentices in partnership with Oxfordshire Advanced Skills (OAS), 81 graduates on leadership schemes and supporting 95 PhDs in partnership with universities.

Key leadership roles within UKAEA are commonly occupied by former apprentices. The retention rate is significantly higher (in some cohorts over 90%) than those of graduate schemes who typically stay with the organisation 2-5 years for engineering/physics roles. This suggests placing a greater emphasis on developing future leaders from early-career stages to preserve institutional knowledge and skills which are highly valuable in fusion.

Private fusion projects traditionally operate leaner and faster and have less resource/time to spare to support early careers development schemes. However First Light Fusion and Tokamak Energy are addressing this with apprenticeships, undergraduate placements, and PhD sponsorships. Notably, First Light Fusion is jointly funding 14 postdoctoral research associates, 12 PhD students and 40 undergraduate internships over the next five years with support from a £6 million grant from the Engineering and

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Physical Sciences Research Council. First Light Fusion is matching the funding, taking it to £12 million.

Apprenticeship schemes should be considered a priority for both the public and private sectors. However the timing of this needs to be carefully mapped out to avoid making the same mistake as the UK's nuclear fission sector. In many cases, apprentices were taken on and trained to a very high standard but had no work to go to at the end of their course.

Limited academic programmes

There are only a handful of academic programs worldwide that focus specifically on fusion energy. In the UK, this is primarily delivered by the Fusion Centre for Doctoral Training , which is composed of five elite universities: Oxford, York, Durham, Manchester, and Liverpool.

Collectively, the Fusion CDT will train 80 PhD students over four intakes between 2020-2024, with a particular focus on plasma physics, materials science and instrumentation. This seems to satisfy the current demand of plasma physics/ materials research challenges. If we do need to scale up in future, this should be relatively straightforward provided there is sufficient funding.

However, fusion is less well represented in university engineering courses. As fusion becomes a broader engineering challenge, this will become a problem. At the fusion skills workshop, the Director of the Fusion CDT said that support from industry is needed to build and deliver fusion-relevant engineering courses.

Inspiring the next generation

Looking beyond the more immediate pipeline of apprentice/graduate talent and into the longer-term, we must also consider outreach efforts into primary and secondary education. There is a lack of knowledge about fusion energy across many external stakeholders such as parents, schools, local government and local communities – those who are outside the immediate bubble of fusion industry workers and investment community. The industry needs to be able to sell the long-term benefits of fusion to those who do not necessarily see the argument as self-evident. UKAEA, Tokamak Energy and First Light Fusion have school outreach programmes. One of their strategies is providing science shows that are family-oriented, making them more effective in capturing everyone's imagination. They also recognize that decision-makers are ultimately the parents/guardians, so they need to find avenues to educate kids with their parents present, such as churches and community centers.

UKAEA and the OAS are working to educate and inspire communities around West Burton, home to the STEP prototype fusion power plant, to explain what fusion energy is and to design a programme to take to schools to improve access and awareness of fusion energy, which younger generations are more likely to engage with, such as robotics. They are also looking to replicate this programme in Oxford.

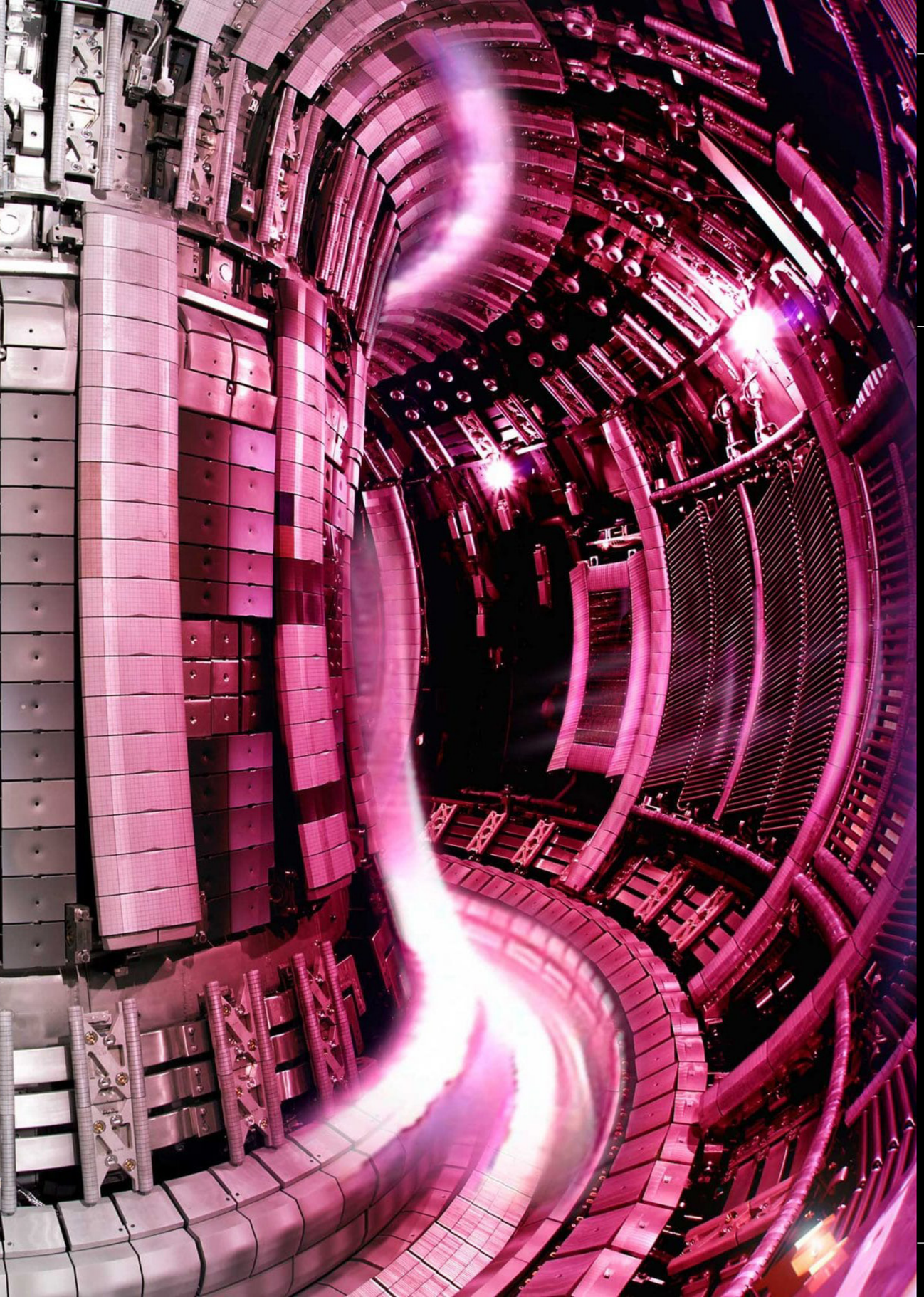
Talent retention

Because attracting talent to fusion can be tough, it's important to retain the talent that we have. Data from Bond shows that fusion is currently retaining its workforce. However, this may change. Fusion energy is a highly technical field, and individuals with the necessary skills and knowledge are in demand across a range of other industries.

It crucial to provide competitive salaries and benefits to retain top talent. Government and private organisations must prioritise funding for fusion energy research to ensure that the field remains viable. At the individual level, the retention challenges in the fusion industry have little variance from other sectors. Candidates ideally like to be well-rewarded for performing meaningful, challenging work, be well-managed in a high-performing team with the autonomy to influence their own tasks and objectives with a good work-life balance.

The Fusion Cluster needs to mature into an ecosystem with ample opportunities to keep people in the industry.

Companies that go from start-up to scale-up find that cool technology, rapid progress and a great mission can only take you so far. To retain talent, time and resource is needed to develop an employee value proposition that goes beyond salary. A mature EVP includes aspects such as a company's culture, work environment, opportunities for growth and development, benefits and other incentives.



CONCLUSION

As the industry stands in 2023, fusion energy has never been closer. There are a number of converging reasons for this positive outlook.

Number one, for the first time we are seeing huge technical progress being made in the subject, including the scientific proof that fusion can produce more energy out than in to the reaction.

Secondly, there has been more private investment going into the sector over the last two years than in its entire history. This has led to rapid technological progress in private fusion companies such as Tokamak Energy and First Light Fusion in the UK.

The third positive is the commitment from government in the form of a fusion strategy, regulations designed to speed deployment of fusion, and the commitment to build a fusion power plant, with industrial contracts being rewarded shortly.

All of this adds up to an encouraging – even unprecedented – time for the UK fusion landscape but this is not the end of the journey. To maintain the momentum and actually deliver fusion energy will require expertise from a wide range of people and industries. It will also require ongoing funding and consistent support from government.

There is a clear need to continue all conversations and collaborations between industry, UKAEA and universities. These will be needed to devise a far-reaching strategy that will grow the fusion workforce in the short term to satisfy immediate demands; then provide a pipeline of new recruits, in the medium and long term.

And it must be an iterative process, the strategy cannot be fixed. Progress in fusion will depend on funding, which will influence the pace of progress. As such, the strategy will need regular review. Each time, the current fusion landscape must be surveyed and compared to the existing strategy's baseline expectations. The strategy can then be adapted if needed to fit with whatever the pace of development and funding is in the future.

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