The 2023 HUMAN RESOURCES (HR) SURVEY FOR THE EUROPEAN FUSION RESEARCH PROGRAMME

By the 2023 HR Survey Panel

April 2024

Leveraging the unique strengths of individual EUROfusion members and show the unified power and mutual benefit of collaboration.

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- Alessia Vecchio (F4E) and Emmanuelle Nassaux (F4E)
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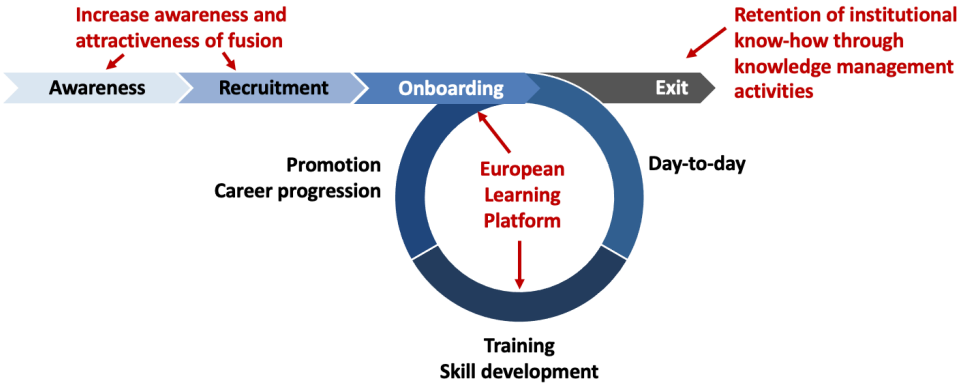
Executive Summary

The European fusion programme and ecosystem have changed over the last years. ITER needs are evolving as the commissioning phase of some of its plant systems is approaching and the increasing role of private companies and industry creates the need for a larger, more diverse well-trained work force.

The EUROfusion Consortium launched the next edition of its Human Resource Survey in 2023 to provide an overview of the competencies and demographics of the European fusion community. The survey allows to assess the current staff contingent of the EUROfusion Beneficiaries and Affiliated Entities, compare them to current and future needs, and strengthen current activities and/or develop new initiatives to further support the European fusion community. Particularly, the Human Resource Survey together with the Education Programmes Overview, EUROfusion Knowledge Management and Implementation Plan provides the basis for the next set of activities for the remainder of the FP9 framework programmes and plans for FP10 and the future in view of creating a workforce that fit the future needs.

The EUROfusion Human Resources Report describes the analysis of the 2023 Human Resource Survey data, accompanying reports and describes the current or planned EUROfusion activities. The main findings of the review include:

- Recruitment and retention of qualified engineers and operators are difficult in the strong job market competition. A joint effort at European level is needed to raise the awareness and attractiveness of fusion as a career opportunity for people with diverse backgrounds.
- Access to fusion-focused academic programmes and courses is limited or not accessible in some European countries. New initiatives are required to make fusion courses accessible across Europe and create new educational/training material on scarce topics for students and mid-career specialists entering the public and private fusion industry.
- With the start of the ITER plant commissioning phase, there is a need for professional staff for the commissioning of plant systems, training of operators, in addition to continued engineering support for design and construction.
- Following the closure of JET and the increased recruitment dynamics between the industry, public and private sector, efficient knowledge management is even more vital together with effective talent management.



As the recruitment and HR policies are local to the affiliated institutes, EUROfusion activities concentrate on joint commitments and coordinated actions, focusing on raising awareness of the attractiveness and stability of fusion research as a career path, strengthen education and training across Europe and contribute to the knowledge capture and transfer of institutional/European know-how in fusion science, technology and operations.

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1. Introduction

The EUROfusion human resource (HR) survey provides an overview of the competencies and demographics of the European fusion community as agreed in the D24.16 grant deliverable *"Publication of the results of the Europe-wide HR survey in fusion research and development"* of the EUROfusion Consortium Grant Agreement with the aim to

- assess the current staff levels and distributions comparing them to current and future needs,
- assess the progress since the previous surveys, and
- support the development and implementation of an education and training strategy including possible industry involvement.

The 2023 HR survey template was prepared by the EUROfusion Training and Education Office jointly with the HR survey panel with feedback from the HR survey consultants. The survey was structured into 5 areas:

1. Free-text comments related staff recruitment and talent retainment
2. Current staffing levels (at the time of the survey) including country of origin, year of birth, gender, degree type and level, technical and operational skill, contract type.
3. Incoming staff levels for the 2019-20 (FP8), 2021-22 (FP9) related to hiring of staff from other public fusion institutes, ITER, F4E, private fusion companies and industry. An expected/target staff per competence in 10-years' time.
4. Outgoing staff levels for the 2019-20 (FP8), 2021-22 (FP9) related staff leaving to other public fusion institutes, ITER, F4E, private fusion companies, industry or end of work.
5. Staff involved in education activities and students.

To allow easier assessment of the evolution of the work force over each decade, the 2023 survey template followed the templates of previous surveys:

- 2004 Human Resources Survey by the European Fusion Development Agreement (EFDA)
- 2015 Human Resources Survey by the EUROfusion Consortium and the European Commission

Modifications of the survey template compared to the 2015 survey included:

- Opportunities to add further comments such as "What roles/competences are particularly difficult to recruit and why?"
- Inclusion of operational competencies aligned with ITER's commissioning phase.
- Inclusion of private fusion companies.

The 2023 EUROfusion Human Resources Survey was launched on 5 June 2023 with a deadline of 31 July 2023, later extended to 7 August 2023. Submissions were received in August and September 2023. The response of the EUROfusion Beneficiaries and affiliated entities is summarized in Table 1.
No information was received from INRNE (Bulgaria), LEI (Lithuania), IAP (Romania) and UIT (Norway). Partial information was received from UKAEA (UK), however due to the missing information, the data was not used in the analysis. It is noted that the Human Resource or People's department do not necessarily possess the data required (technical/operational competence, previous/next employer).

To compliment the Human Resources Survey, the panel considered two additional surveys:

- 2022 and 2023 Education Programmes Overview at a undergraduate (BSc), graduate (MSc) and post-graduate (PhD) level (Grant Deliverable Report D24.1 and D24.12) conducted by the EUROfusion Training and Education Office.
- Operator roles and training overview of the European fusion devices conducted by the EUROfusion Operations Network under the Preparation for ITER Operations Work Package (Grant Deliverable Report D6.9)

Table 1. Response of the EUROfusion Beneficiaries and Affiliated Entities

Total submissions (31 Beneficiaries, 164 affiliated entities, + 3 potential future affiliated entities)	**114 out of 198**
Beneficiary submissions	**26 out of 31**
Total number of people	**5380**
Institutes that provided **current staff information** (country of origin, year of birth, gender, degree type and level, technical and operational skill, contract type)	113
Institutes that provided **incoming staff in 2019-2022**	62
Institutes that provided **outgoing staff in 2019-2022**	54
Institutes that provided **involvement in Education**	60
Institutes that provided **additional information related to talent recruitment and retainment**	34

Summary of the 2004 Human Resource Review under the European Fusion Development Agreement (EFDA)

In 2024, an Ad-Hoc group formed on request from the EURATOM committee CCE-FU to "Survey of Human Resources in the European Fusion Programme". The objective was to assess the staffing status and needs of the future fusion programme. The work of the group involved an appraisal of the European Commission Services report and an assessment of staff survey questionnaire to the EFDA Associations.

The main findings of the review were:

- There had been a general decline in the engineering capacity of the Fusion programme;
- A distinct danger was perceived in that important knowledge was being lost from the programme through the retirement of very experienced staff;
- With the ITER construction, there was an immediate need for professional staff for the construction and the plasma engineering;
- For the projects in the Broader Approach and the Fast Track to Fusion Energy it was necessary to further enhance the competences in physics and engineering over a longer time scale;
- It was becoming increasingly difficult to identify high quality engineers, but it was hoped that the start of ITER construction would alleviate the situation because it would increase the attractiveness of fusion science and technology.

The main recommendations of the ad-hoc group were summarised as follows:

- Enable and support European staff to contribute to the ITER project.
- Develop long-term staffing policy to meet the future needs of the (primarily technology) programme balancing the need for physicists and engineers.
- Strengthen the training programme: Implement the EURATOM Fusion Training Scheme and make use of the EURATOM fellowship and training schemes targeting early career researchers.
- Raise awareness of fusion at high school and university level.
- Establish a roadmap for technical and scientific development.

In response, EFDA established the EFDA Goal Oriented Training Programme for researchers and engineers developing competencies in scarce skill areas, dedicated significant effort for outreach in schools and universities and developed the European Research Roadmap to the Realisation of Fusion Energy which later informed the strategy of the new EUROfusion Consortium.

Summary of the 2015 EUROfusion Human Resource Survey

The European Commission and the EUROfusion Consortium launched a survey on the competencies and demographics of the EUROfusion workforce following the recommendation of the expert group that evaluated the EUROfusion proposal in 2014 as follows:

"*In view of the importance of education and training vis-à-vis the total budget, the Consortium, in conjunction with the Commission, should develop and implement a strategy on education and training, including possible industry involvement. Following the contract signature and in order to guide further evolution of the strategy, a commitment should be made to conduct a review of the staffing requirements in terms of competencies and demographics.*"

The 2014 HR survey report noted the success of many EFDA initiatives, particularly:

- The increase of young engineers and scientists joining and remaining in the fusion programme partially thanks to the growth and quality of the outreach activities and educational programmes including the European Masters programme in fusion.
- Move of European researchers and engineers to the ITER project.
- In general a positive but not yet sufficient trend in gender balance and engineers in scarce competences.

The recommendations of the 2014 HR survey included:

- Additional effort required to maintain level of technical support staff, project managers and attract more engineers with emphasis on nuclear engineering, health and safety, magnets, high voltage, remote handling, heating and current drive.
- Strengthen and develop dedicated education and training programmes in scarce areas including nuclear and safety culture.
- Develop partnership with relevant nuclear industry and safety authorities.
- Strengthen connection with F4E to update the list of scarce competences annually and provide feedback on the educational and training material.
- Active measures should be taken to stimulate the participation of female professionals in the fusion programme.

In response, EUROfusion has strengthened educational activities under the FuseNet Association, supported early career scientists and engineers with the EUROfusion Researcher and Engineering Grants focusing on scarce skill areas, and continued to align its activities to the European Research Roadmap to the Realisation of Fusion Energy.

2. Overview of the capabilities and needs of the EUROfusion workforce

The EUROfusion Human Resource survey provides an overview of the current workforce in the EUROfusion Beneficiaries and Affiliated Entities. The survey provides information on their:

- Personal background (age, gender and country of origin)
- Educational background (highest degree level and type)
- Contractual situation (permanent staff, temporary contract or student, part-time or full-time employment)
- Acquired skill (it was possible to select two skill types per person) and operational role

2.1 General characteristics and diversity

Equality and diversity, including but not limited to gender, race, nationality or ethnic origin, religion, physical ability, age, sexual orientation and identity, are a top priority for the European Commission. As EUROfusion is a consortium of 198 institutes (members and their affiliated entities), employment and HR policies are local to the institutes. The importance of diversity is however enshrined into the EUROfusion values (figure 3), policies and processes.

Figure 1 – EUROfusion values

The demographics and distribution of the staff in the STEM fields (Science, Technology, Engineering and Mathematics) and supporting roles is provided in Table 1, Figure 1 and Table 2 respectively. The two diversity characteristics captured by the 2023 EUROfusion HR survey are gender and geographical diversity, which are provided in Table 3 for each country.

Table 1 – Overview of the staff at EUROfusion Beneficiaries and Affiliated Entities in STEM fields in regards to gender balance, geographical diversity, percentage of permanent staff and students. Data is provided from the 2015 survey for comparison where available.

	2023					2014	
Degree type	**No. of staff**	**% women**	**% foreign**	**% permanent**	**% student**	**No. of staff**	**% women**
Physics	1802	17.4	29.3	62	21.7	1578	18.1%
Engineering	1304	13.7	11	74.5	8.1	1108	11.3%
Technician	457	12.5	6.5	90.4	2.8	905	7.2%
Computer Science	137	13.1	15.3	67.9	12.4		
Chemistry	101	49.5	8.9	83.2	7.9		
Mathematics	52	25	44.2	48.1	32.7		

Table 2 – Overview of the staff at EUROfusion Beneficiaries and Affiliated Entities in a supporting role as a primary competence in regards to gender balance, geographical diversity, percentage of permanent staff. (Foreign workers are defined as where the country of origin is not the same as country of employment.)

	2023			
Competency	**No. of staff**	**% women**	**% foreign**	**% permanent**
Administration	299	72.6	4	90.6
Project Management	96	35.4	13.5	91.7
Procurement	29	58.6	0	96.6
Quality Assurance	10	30	10	80

Table 3 – Gender and geographical diversity per country of employment

Country	Total	% women	% foreign	No. of countries of origin
Austria	39	20	33.3%	8
Belgium	156	12.8	28.8%	24
Croatia	38	23.7	10.5%	4
Czechia	157	12.1	21.7%	12
Denmark	45	13.3	46.7%	10
Estonia	9	0	11.1%	2
Finland	160	20	25.0%	23
France	213	22.5	2.8%	5
Germany	1387	20.5	21.3%	49
Greece	69	17.4	1.5%	2
Hungary	44	13.6	2.3%	2
Ireland	3	0	66.7%	3
Italy	1010	25.9	6.3%	16
Latvia	52	26.9	5.8%	3
Malta	5	60	20.0%	2
Netherlands	94	14.9	22.3%	15
Poland	207	25.1	6.8%	9
Portugal	41	14.6	0.0%	1
Slovakia	18	44.4	55.6%	5
Slovenia	61	14.8	9.8%	6
Spain	362	24.9	10.5%	23
Sweden	53	18.9	41.5%	16
Switzerland	222	12.2	67.1%	35
Ukraine	110	19.1	0.0%	1
Total	4555	21.1	17.4	81

Gender balance

Over the last two decades the number of female professionals in fusion has steadily, although slowly increased from 12% in 2004, to 18% in 2015, and to 21% in 2023. The percentage of women is however still very low in STEM fields (Science, Technology, Engineering and Mathematics) and high(er) in the supporting roles (see table 1 and 2).

- Physics, Engineering and Computer Science has a low percentage of women 13-17%, Mathematics and most of the supporting role have around 25-35%. Gender balance is achieved in Chemistry and Procurement, whereas Administration is overwhelmingly female (72.6%) as shown in Tables 1 and 2.
- The age distribution of women is flat across Europe, showing no significant increase in the early career age range (shown in figure 2).
- The overall percentage of female colleagues is driven by the two largest beneficiaries. The gender distribution of the fusion groups per institute in relation to the size of the fusion team is shown in figure 3. There is no clear trend with geography or other captured characteristics.

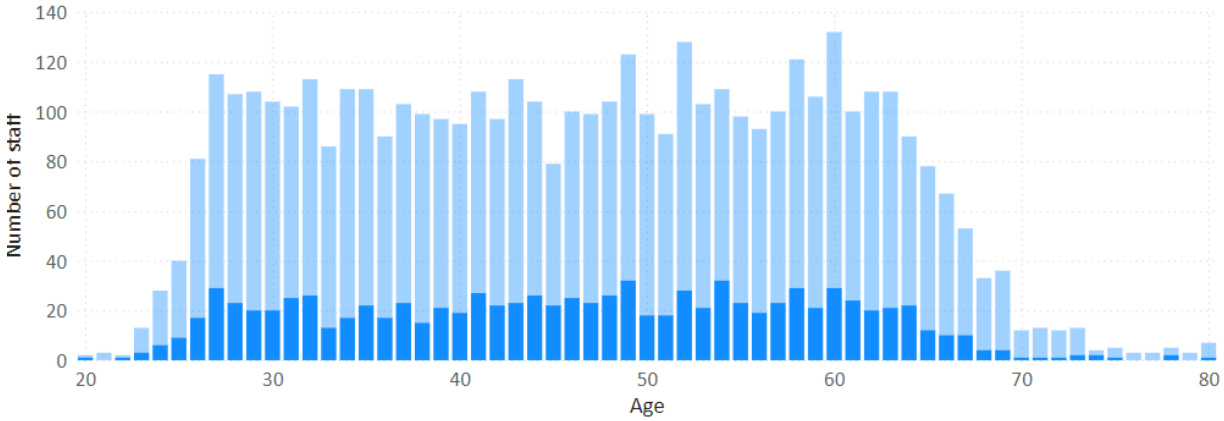


Figure 2 – The age distribution of women (in dark blue) compared to the total work force (light blue)

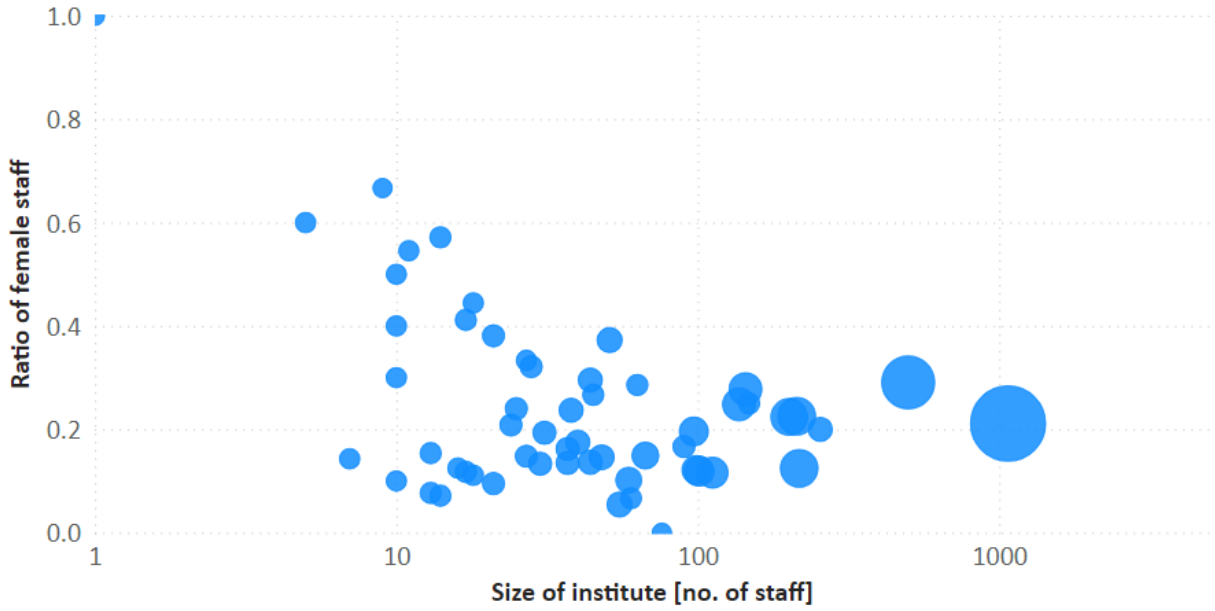


Figure 3 – The percentage of women and size of institutes in the four regions of Europe. Note the logarithmic scale on the size of the institute.

The current percentage of women in the fusion teams is still far from gender balance, and we need more effort and initiatives to identify, then remove barriers to entry, support career progression and improve retention of women in the fusion work force. Women occupy approximately 25% of research positions in science and engineering worldwide. The gender balance in EUROfusion laboratories (tables 1 and 3) is similar to other EIROforum organisations in Europe such as

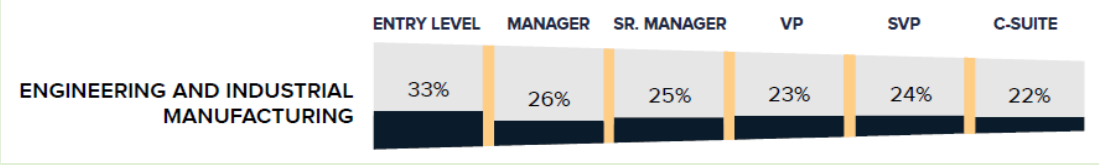
- CERN (21% in 2019),
- XFEL (27.2% overall, technical staff: 19.6%, scientists 19.8%, engineers: 13.4%),
- ESRF (27.2% overall, engineers: 16.3%, scientists 18.8%, technicians: 12.3%, operators: 0%),
- ILL (26.7% overall,) and
- ESO (26.4% in 2021).

Initiatives often target recruitment such as the "25 by 25" diversity initiative at CERN. This is not possible as recruitment is local to the laboratories, however EUROfusion can support raising awareness of fusion as a long-term, stable and exciting career path and support access to educational programmes to attract and develop more diverse candidates to recruit from. Furthermore EUROfusion can connect individuals in Europe working to further equality, diversity and inclusion initiatives (in all diversity characteristics beyond gender) to share best practices, lessons learned, activities and events across Europe to encourage and support local activities and initiatives.
In addition to local women networks, EUROfusion experts participate in the Women in Fusion, Women in Nuclear societies and work together on joint European policies as member of the EIROforum Diversity Network.

Learn from industry – McKinsey Report on Women in the Workplace 2023
McKinsey, one of the top 4 consulting companies worldwide, have been conducting annual surveys since 2015 with participation of over 900 companies and 450.000 employees. The 2023 report highlighted the following key takeaways (276 organisations with 10+million employees, 270.000 employees surveyed directly):

- Representation at the mid- and senior leadership level matters to attract and recruit a diverse workforce.
- The critical step and biggest hurdle is the first step to management responsibilities. Even if companies are successful in driving more applicants of diverse backgrounds, bias is a strong driver in recruitment, performance reviews, promotions, and career opportunities.
- Microaggressions, demeaning or dismissing comments and actions, have a lasting impact on people impacting their work behavior, career progression and health. It makes people less likely to feel psychologically safe, harder to take risks, propose new ideas or raise concerns.
- Following the pandemic era, both men and women take steps to prioritize their personal lives enabled by flexible working arrangements. Flexible working is seen as a top 3 employee benefit and critical to the companies' success.

Figure 4 - Gender balance in the engineering and industrial manufacturing sector (black – percentage of women at the different seniority levels)



Geographical diversity

The fusion workforce employed at the EUROfusion Beneficiaries and Affiliated Entities comes from 81 different countries, though the geographical diversity of the institutes varies strongly from country to country.

- Students and early career scientists and engineers tend to be more mobile (shown in figure 5).
- 36% of students and 38% of temporary contract holders are foreigner (country of origin is not the same as country of employment). Whereas the number of foreigners with permanent contracts goes down to 10.6% as shown in table 4.
- Scientific staff (foreign staff in physics 29.3% and mathematics 44.2%) are mobile whereas the technical staff (foreign staff in engineering 11% and technicians 6.5%) usually work in their country of origin as shown in tables 1 and 2.

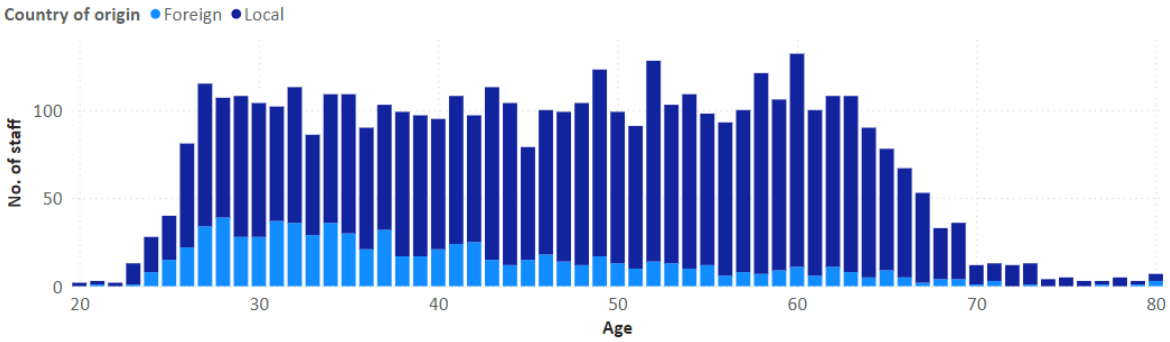


Figure 5 – Age distribution of foreign (country of origin is not the same as country of employment) and local staff (country of origin is the same as country of employment) at the EUROfusion Beneficiaries and Affiliated entities.

Table 4 – Employment status of foreign and local staff the EUROfusion Beneficiaries and Affiliated entities.

Employment status	Local worker (country of origin is the same as country of employment)	Foreign worker (country of origin is not the same as country of employment)
Student (MSc or PhD)	63.9%	36.1%
Temporary contracts	61.8%	38.2%
Permanent contracts	89.3%	10.7%

Communities

Traditionally there is a strong community, with extensive mobility (short visits, secondments, and employment) and exchange of experience in the scientific competencies supported by the dedicated task forces, work packages and tasks under EUROfusion. JET has played a strong role in building this European fusion community with over 500 scientists visiting the Culham Centre hosting JET annually. On the contrary, technical fields (technicians and operational staff) tend to be more local with less mobility between European teams. The fusion devices are traditionally run in the local language which creates a larger barrier to entry to foreign recruitment and external visits. This is unlikely to change as personnel and machine safety, protection systems require clear communication with (primarily local) staff members.

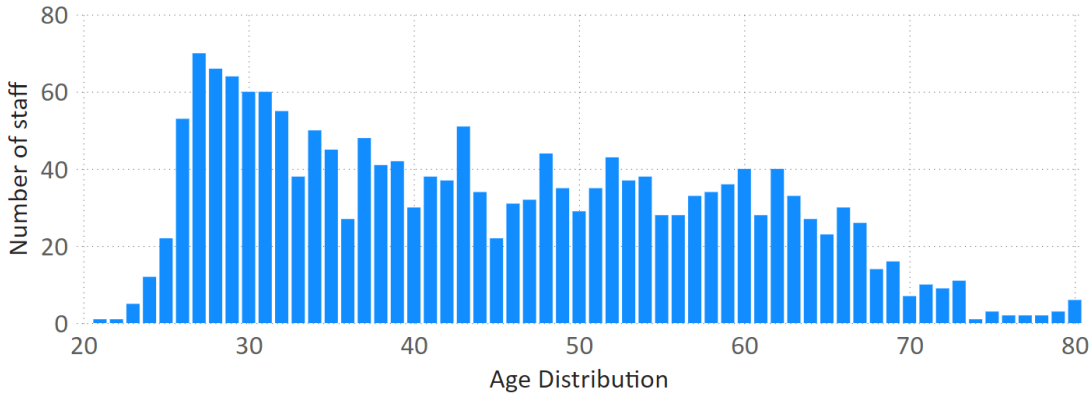
With the increased collaboration with international members, beyond the language barrier, cultural differences need to be navigated as well in order to build a strong joint team e.g. for the exploitation of JT-60SA and ITER.

2.2 Workforce capacity

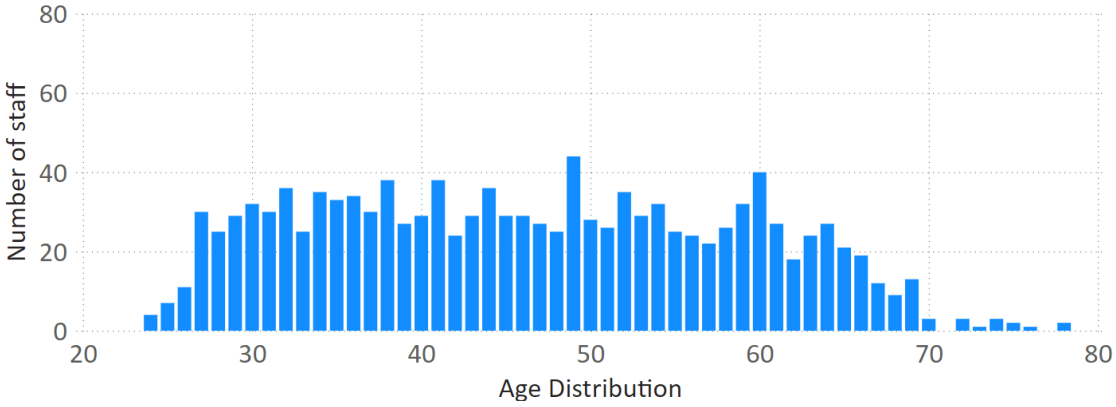
It is noted that whereas the number of physicists and engineers increased by around 15% (shown in Table 1), the number of technicians continued to decrease over the last decade. This is supported by the age distribution of the technicians (figure 6) showing lack of early career entries compared to physicist with a significant number of young entrants to the fusion programme.

Figure 6 – Age distribution of the staff at EUROfusion Beneficiaries and Affiliated Entities with in the STEM fields

Physics – Count 1802, 17.4% female, 29.3% foreign, 62% permanent, 21.7% student



Engineering – Count 1304, 13.7% female, 11% foreign, 74.5% permanent, 8.1% student



Technician - Count 457, 12.5% female, 6.5% foreign, 90.4% permanent, 2.8% student

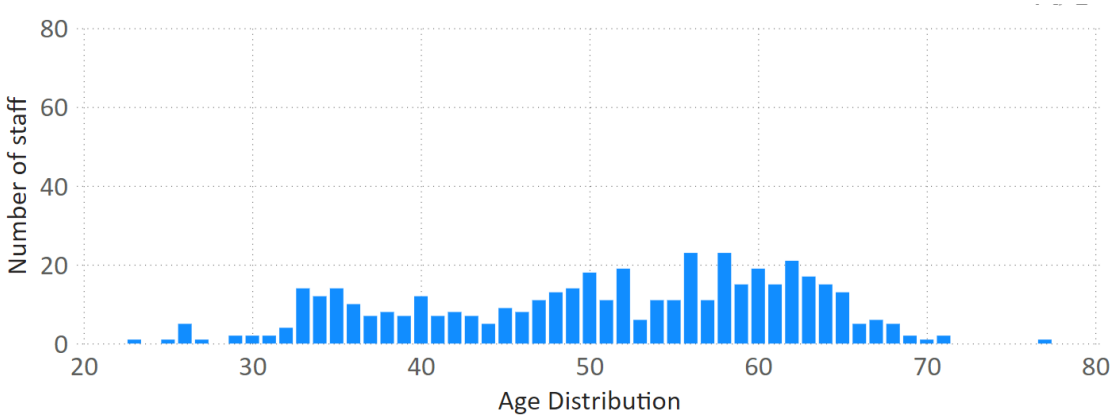


Table 5 – Overview of the highest academic degree, acquired skills (indicated as primary or secondary skill) operational competence of the staff at EUROfusion Beneficiaries and Affiliated Entities. Data is provided from the 2004 and 2015 surveys for comparison where available. Note that the 2004 and 2015 survey provided the distribution in person years (ppy) contrary to the 2023 survey, where the breakdown of a single person into multiple skills is not available.

	2023 Highest Academic Degree							
Acquired Skill	**BSc**	**MSc**	**PhD**	**2023 Total**	**2004 ppy**	**2015 ppy**	**2015/2004 ratio**	**2023/2015 ratio**
Administration	40	60	28	327	39.45	67.77	1.7	4.8
Diagnostics	14	71	127	258	136.85	133.13	1.0	1.9
Engineer - Cryo	5	8	2	32	22.9	24.9	1.1	3.3
Engineer - Vacuum	10	18	8	50				
Engineer - High Voltage	12	31	23	74	62	29.3	0.5	2.5
Engineer - Low Voltage	9	29	4	56	19.45	39.8	2.0	1.4
Engineer - Magnet	6	14	22	47	38.55	15.4	0.4	3.1
Engineer - Nuclear Design	4	38	14	57	28.3	30.9	1.1	1.8
Engineer - Other	25	161	64	297				
Engineer - Remote Handling	3	26	19	49	23.45	7.9	0.3	6.2
Engineer - Safety & Waste	0	25	21	47	15	5.75	0.4	13.9
Health Physics, Radiation Protection	2	15	11	33				
Engineer - Systems Engineering & Design	63	132	77	291	86.2	178.63	2.1	1.6
Engineering Analysis - Electromagnetic	0	96	29	126				
Engineering Analysis - Nuclear	3	49	41	98				
Engineering Analysis - Structural & Mecha	7	123	62	196				
Engineering Analysis - Thermofluid	1	37	58	97				
Heating and Current Drive	3	11	55	73	84.95	48.95	0.6	1.5
IT - Data Acquisition, CODAS/CODAC.	7	27	26	78	8	7.9	1.0	9.9
IT - Instrumentation and Control	16	62	27	152	89.65	67.45	0.8	2.3
IT - Software Development	23	46	48	129	68.7	49.95	0.7	2.6
Materials	23	101	138	319	81.7	58.75	0.7	5.4
Other	42	43	26	447				
Physicist - Computational / Numerical	17	202	345	574	139.3	137.32	1.0	4.2
Physicist - Experimental	18	313	603	961	423.45	417.03	1.0	2.3
Physicist - Other	2	20	15	43	137.65	224.83		
Physicist - Theoretical / Analytical	2	95	202	311	227.65	133.5	0.6	2.3
Procurement	1	10	0	33				
Project Management	15	73	78	176	48.25	21.7	0.4	8.1
Quality Assurance	1	11	4	24	6.6	5.2	0.8	4.6
Tritium handling	1	5	5	11	13.2	23.05	1.7	0.5

Operational skill	**BSc**	**MSc**	**PhD**	**2023 Total**
Engineering Operator - Engineer Pilot	5	11	2	20
Engineering Operator - Cryo	4	11	2	32
Engineering Operator - Heating Systems	12	9	15	51
Engineering Operator - Pellet Systems				1
Engineering Operator - Power Supplies	18	19	4	56
Engineering Operator - Shift Technician	1	4	1	8
Engineering Operator - Vacuum	8	13	7	40
Engineering Operator - Other	13	77	60	215
Safety, Health Physics	1	4	1	6
IT - CODAS, Data Acquisition	9	25	17	76
Scientific Coordinator		16	176	199
Scientific Operator - Physics Pilot		8	50	60
Scientific Operator - Cameras		9	5	14
Scientific Operator - Diagnostics	3	120	147	277
Scientific Operator - Disruption Mitigation		3	7	10
Scientific Operator - Real-time Control		10	8	18
Scientific Operator - Other	7	55	62	129

Acquired skills

An overview of the acquired skills shown in table 5 indicates that compared to 2004 and 2015 the number of staff with particular skill types have increased except for tritium handling. In case of tritium handling, a significant percentage of this skill resides at UKAEA, whose data is not part of the 2023 dataset. The need for more engineering competences however remain.

The number of staff with operational skills is also underestimated as the UKAEA staff is not included in the survey analysis. Additional information on the operational roles and training is provided by the survey conducted by the EUROfusion Operations Network (EON) in 2022. The survey, available in the grant deliverable report D6.9, included the list of operator roles (rostered and on-call), number of people, roster, training type (shadowing, on-the-job, lecturers, qualifications), length of the training (at beginner and advanced level). The assessment of the operational role survey indicated that

- the number of operator roles increases with the size of the device from small to medium-size devices. However, ASDEX Upgrade and JET have a similar number of operator roles. 31-35 engineering roles, 11 scientific roles and 4 support roles with rostered shifts or on-call role related to the operation of the device.
- in most roles training to basic competence level takes 2-6 months, and it takes 1-3 years to become an expert operator. The exception with training over 1-year are tritium operators (3 levels with 1-3 year each) and session leaders (physics pilot, 3 levels with > 1 year each) on JET. Experience from other devices can reduce training time up to 50%.
- sharing experience, best practices and lessons learned can further avoid commissioning/operational issues thereby preventing lengthy delays, improving operational reliability and performance.

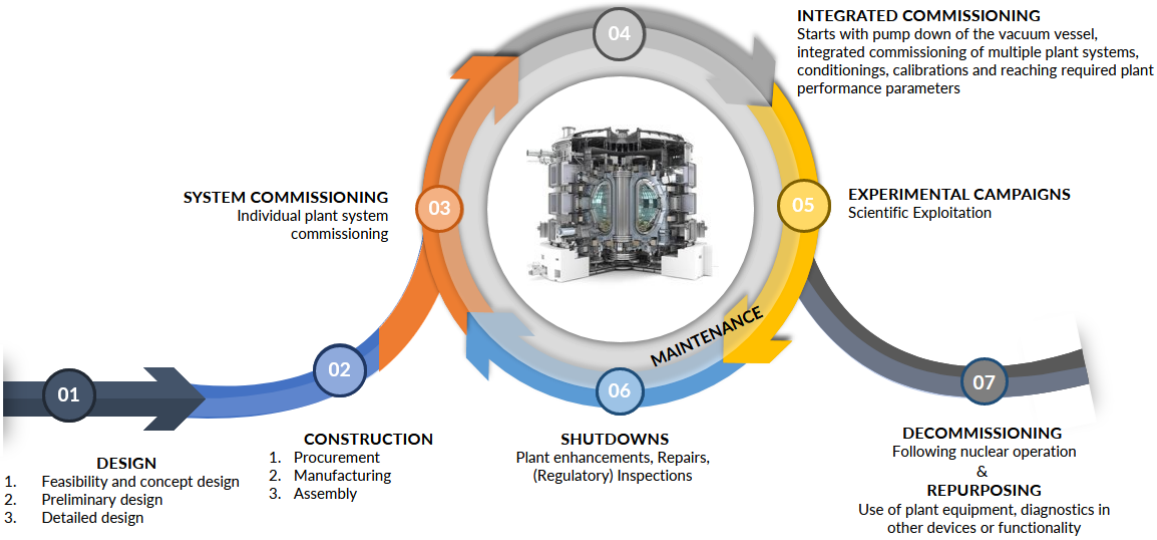


Figure 7 – The fusion product life cycle

Capacity needs

ITER has transitioned into its operational phase (figure 7), having completed the system commissioning of its first plant systems since the last EUROfusion Human Resources survey. In the coming years, ITER is simultaneously in its design, construction and system commissioning phase depending on the timeline of its plant systems and diagnostics. Thus 2021 forecast provided by Fusion for Energy (F4E) indicates increased need for engineering competences (such as remote handling, diagnostics, and in-vessel) for mechanical design, manufacturing and operations phase in the coming years.

The capability forecast (table 4) indicates that Mechanical Design and Manufacturing have the biggest demand of resources (over one third of total FTEs – Full Time Equivalent staff - as of 2021 until 2027).

Table 4 – Capabilities forecast provided by Fusion for Energy showing the type of skills and knowledge needed in the future. (Units are FTE – full time equivalent staff)

ITER-D profile forecast	2021	2022	2023	2024	2025	2026	2027
Programme Management	10	10	10	10	10	10	10
Product Specialist	20	20	20	20	20	20	20
Head of Department	5	5	5	5	5	5	5
Effort other programmes	16.3	16.3	16.3	16.3	16.3	16.3	16.3
Engineering Unit	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Metrology	6.82	9.34	9.9	9.74	10.63	10.48	10.8
Mechanical Design	65.77	58.37	65.33	66.32	53.92	43.34	29.16
Manufacturing	50.85	76.12	78.78	75.47	84.75	88.08	94.52
Engineering Analysis	21.58	25.23	27.01	26.54	26.79	24.57	23.16
Data Management	13.69	18.69	19.81	19.49	21.25	20.97	21.61
CODAC, I&C, Electrical Engineering	26.88	28.51	32.8	34.05	31.71	28.85	26.02
CAD Design & Integration	10.82	12.2	13.11	13.27	13.4	11.38	10.8
Administrative Assistance	10	10	10	9	8	8	8
Total [full time equivalent staff]	269.21	301.26	319.54	316.68	313.25	298.47	286.87

The role distribution (table 5) shows increasing demand for engineering roles covering management of suppliers, fusion specific engineering know-how and operational competencies as more plant systems start their system commissioning.

Table 5 – Roles forecast provided by Fusion for Energy indicating the criticality of the positions within the organisations. (Units are FTE – full time equivalent staff)

ITER-D ROLE forecast	2021	2022	2023	2024	2025	2026	2027
Head of Department	5	5	5	5	5	5	5
Effort other programmes	16.3	16.3	16.3	16.3	16.3	16.3	16.3
Engineering Unit	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Product Specialist	20	20	20	20	20	20	20
Project Manager	29.46	34.27	37.01	36.7	36.37	34.15	32.41
Programme Manager	10	10	10	10	10	10	10
Engineering (TPO)	68.74	79.96	86.36	85.64	84.86	79.69	75.62
Engineering (Fusion Specific)	39.28	45.69	49.35	48.94	48.49	45.54	43.21
Engineering	58.92	68.54	74.02	73.41	72.73	68.3	64.82
Administrative Assistant	10	10	10	9	8	8	8
Total [full time equivalent staff]	269.2	301.26	319.54	316.49	313.25	298.48	286.86

As indicated in the programmatic overview (table 6), there will be a need for skilled workers particularly in remote handling, diagnostics and in-vessel components.

Table 6 – Overview of the programme provided by Fusion for Energy (Units are FTE – full time equivalent staff)

ITER-D Program Forecast	2021	2022	2023	2024	2025	2026	2027
Effort other programmes	16.3	16.3	16.3	16.3	16.3	16.3	16.3
Engineering Unit	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Vacuum Vessel	24.05	20.62	19.76	3	3	3	3
TBM and Materials Development	13.25	13.94	15.87	14.08	14.38	35	50
Remote Handling	36.25	45	52	60	52	45	40
Plasma Engineering & Operations	5.2	4	4	4	4	4	4
NBI and EC power supplies	24.6	25.37	33.93	35.8	37.06	28.68	28.06
Magnets	18.75	18.53	11.19	4	3	3	3
In-Vessel	30.7	45	45	45	45	45	45
Diagnostics	43.25	45	50	55	50	45	30
Cryoplant and Fuel Cycle	15.25	16	20	18	17	17	16
Antennas	25.1	35	35	45	55	40	35
Total [full time equivalent staff]	269.2	301.26	319.55	316.68	313.24	298.48	286.86

EUROfusion actively identifies the engineering needs on an annual basis following consultation with the EUROfusion Beneficiaries, work packages and Fusion for Energy. The required activities are incorporated into the annual work programme of the EUROfusion work packages and form the basis of the call for applications for the EUROfusion Engineering Grant programme to train early career engineers in scarce competency areas. The engineering competency areas and their scarcity rating in the 2024 EUROfusion Engineering Grant application round is shown in Table 7.

Table 7 – (Scarce) competences of the EUROfusion Engineering Grants

Topic	Competence Area	Scarcity
Balance of Plant	Pulsed operation of a Steam Generator	High
	Turbine generator control modelling	Medium
Breeding blanket	Thermomechanical, thermohydraulic analysis of breeding blanket concepts	Medium
	Ceramic breeder development	Medium
Cryoplant and fuel cycle	Fuel cycle systems plant integration	High
	Tritium behaviour and related technologies	High
	Tritium handling	High
	Techniques for cryogenic pellet production for fuelling, seeding and shattered pellet injection	Medium
Diagnostics	Long-pulse capabilities of fusion diagnostics	Low
	Instruments and Diagnostics in Harsh Environments	Low
	Diagnostic design and engineering analysis	Low
	Electric and magnetic diagnostics for fusion devices	Low
Electrical systems	DEMO plant electrical system	Medium
	DC current interruption technology	Medium
	Advanced electrical conversion technologies	Medium
Engineering Analysis	RAMI Engineering	High
	Thermohydraulic analysis simulations	Low
	Systems codes for design parameter space exploration	Low
	Product Lifecycle Management	Medium

	System engineering for fusion plant systems	Medium
	Engineering of critical DONES systems	Medium
Heating and Current Drive	ECRH system commissioning and operations	Medium
	Engineering of negative NBI systems	Medium
In-vessel	DEMO Design Criteria for In-Vessel components	High
	Structural and high heat flux material/joints/components qualification	High
	Lifetime analysis of divertor components	Low
	Tungsten armour surface shaping	low
	Divertor target design	Medium
	Divertor target geometry optimisation in 3D space	Medium
	Gap size and tolerance control of plasma facing components	Medium
	Runaway electron-induced damage to Plasma Facing Components	Medium
	Additive manufacturing of complex 3D structures	Medium
	Joining technology for dissimilar materials and related non-destructive testing	Medium
Magnets	Superconducting Magnet Feeders	High
	Materials for next-generation magnets	Medium
	High-voltage technology for Superconducting Magnets	Medium
	Non-electrical means for quench detection in High-Temperature Superconducting magnets	Medium
	Engineering of High Temperature Superconducting (HTS) magnets	Medium
	Magnets and Cryogenics	Medium
	Coil design and enhancement	Medium
Materials	Scale-bridging neutron-irradiated material exploitation between micromechanics, Small Specimen Test Technology, and conventional specimens	Medium
	Advanced material development and qualification	Medium
	Activated structural / T containing functional DEMO-relevant material handling and Post-Irradiation Examination	Medium
Nuclear	Safety codes	High
	Neutronic analysis	Low
	Nuclear transport analysis	Medium
	Activated product transport fluid systems	Medium
Plasma Engineering and Operations	Flight simulator for tokamak discharge preparation/operation	Low
	Data Engineering and control room tools	Low
	Wall monitoring system for plasma facing component protection	Low
	Data Engineering and control room tools	Low
	Long pulse control	Low
	Control engineering	Low
Power supplies	Ultracaps based power supplies for reactive power reduction and energy storage	Medium
Remote handling	Remote maintenance development and validation	High

2.3 Talent recruitment and retention

The EUROfusion Human Resources survey provided an opportunity for Beneficiaries and Affiliated entities to share information on their difficulties and experience with talent acquisition and retention.

Difficulties in talent acquisitions were mainly attributed to a strong job market competition for skilled workers. Low salary offered in civil servant or governmental organisation coupled with the lack of awareness of fusion as an attractive and stable long term career prospect makes it difficult to attract highly skilled workers and compete with the private industry. Recruitment is further made difficult in some countries due to the lack of candidates with the right qualification and skills due to the lack of dedicated educational and training programmes.

The strong job market competition makes retention of skilled talent also difficult particularly with the pull of strong industry and private sector opportunities. Lack of long-term stability rises from project-based hiring practices, time limit on temporary contracts and the lack of permanent positions in publicly funded fusion institutes. The loss of experienced staff members due to retirement or move to the private sector causes a significant loss of institutional know-how particularly in the technical and operational competences where the regular capture and transfer of tacit knowledge is less prevalent.

The rise of private fusion companies and increased involvement of industry in the fusion supply chain, increases the need for a larger diverse, trained, highly skilled fusion workforce, thus increasing the need for availability and access to dedicated academic educational and training programmes across Europe and strong knowledge capture and transfer activities. EUROfusion can further support raising awareness through outreach activities in schools and support of students through the FuseNet Association funded by EUROfusion.

2.4 Education and Training in Europe

As indicated earlier, with the increased number of private investment and expected increasing interest/need from industry, **the European education system will have to educate and train increasing number of students for the future fusion work force not just the public sector, but for the private fusion companies and industry as well. T**he Human Resource identified job market competition and the lack of educational opportunities as a barrier for recruitment. The EUROfusion educational programmes survey conducted in 2023 confirmed the lack of dedicated fusion focused academic programmes and limited to no fusion courses in multiple European countries. The educational programmes overview is now a mandatory element of the annual education reporting by all EUROfusion Beneficiaries.

Summary of the 2022 (D24.01 grant deliverable report) and 2023 (D24.12 grant deliverable report) educational programmes overviews conducted in 2023:

- There are only few MSc programmes and PhD programmes fully dedicated to fusion. Most MSc and PhD programmes include only few courses on fusion science and/or technology.
- The availability of courses varies significantly geographically from none to 1-2 introductory to several courses. There are significant gaps in courses particularly in fusion engineering.
- There are no courses or summer schools on operation of fusion devices, compared to 9 physics-oriented and 2 technology-oriented summer schools.
- There is a lack of fusion engineering textbooks (2 books). There is no textbook or educational material on operations.
- Training should include more practical and interactive elements in order to create deeper understanding, ability to apply and create new innovative knowledge.

The 2023 education reporting revealed an increased number of full academic programmes and courses related to fusion science and technology. There is still a strong geographical variation in the availability of full academic programmes and courses with a number of countries having no or very limited access to fusion courses as shown in figure 8.

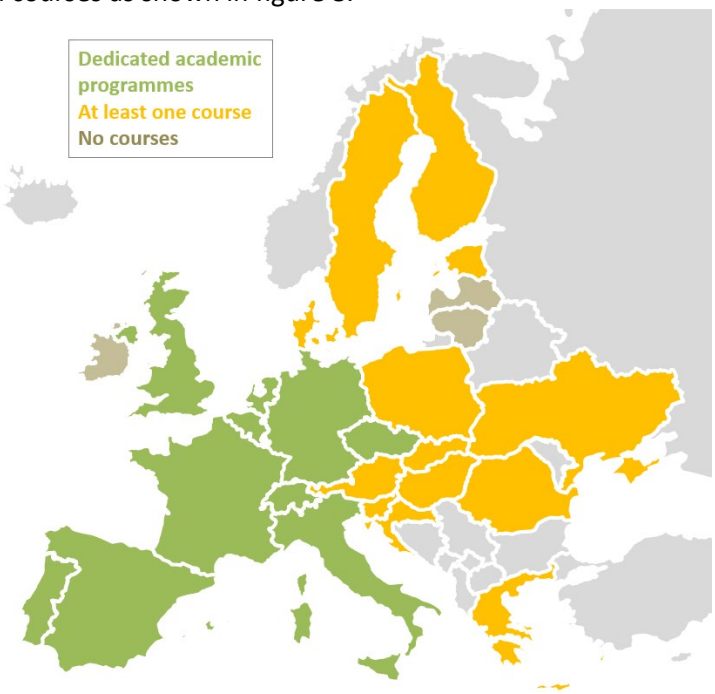


Figure 8 - Availability of academic programmes and courses in Europe

Diversity in education and training

The availability of academic programmes impacts the geographical diversity and number of PhD students (figure 9) as well as applications to the EUROfusion Researcher and Engineering grants (figure 10).

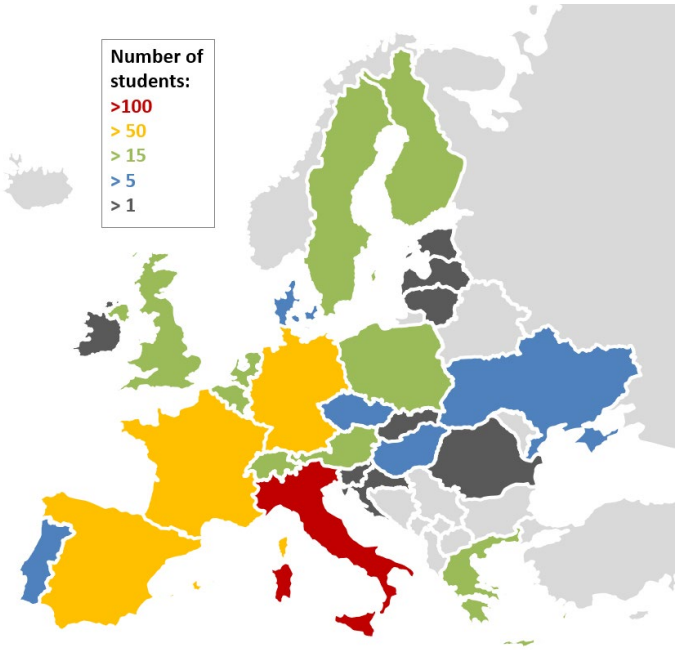


Figure 9 - Number of PhD students per Beneficiary based on the education reporting

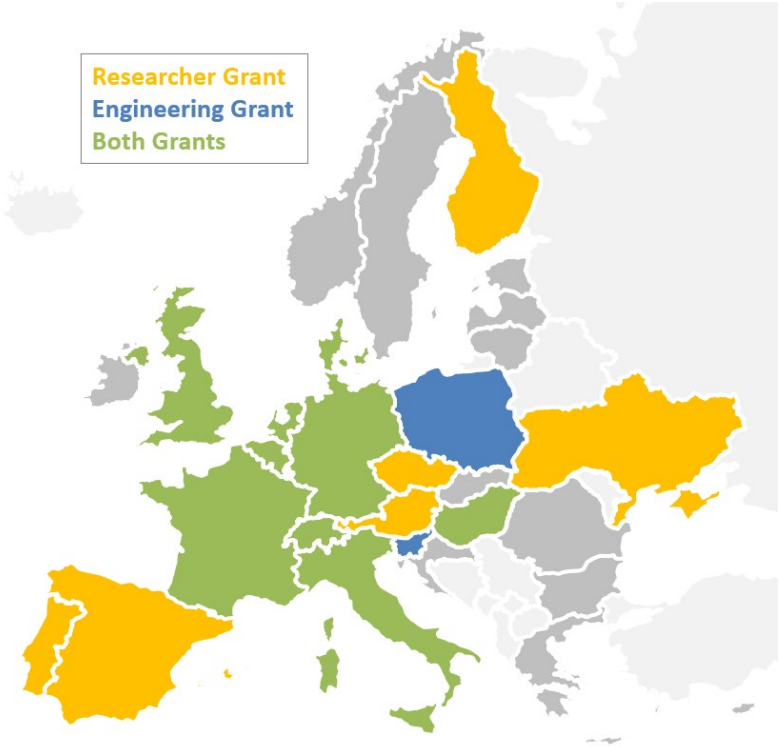


Figure 10 - Awarded EUROfusion Researcher and Engineering Grants in 2021-2024

For the 2024 EUROfusion Grants, 20% were awarded to women. The review of the applications identified a lack of diversity in applications, both gender and geography. Thus, in this case a gender quota would not be suitable and would be detrimental to the awarded candidates (mistaken perception of awarding the grants due to diversity considerations rather than excellence of the candidate).
EUROfusion is committed to fostering equality, diversity and inclusion in the evaluation process of the EUROfusion grants to ensure a diverse cohort in all its form, including but not limited to gender, nationality, socioeconomic background and disabilities. For this reason, in 2023 the personal letter replaced the motivation letter to highlight any additional information (e.g. challenges overcome) that the candidate would like to share with the panel. During the selection process, the panel considered also the academic opportunities available to the applicants.

The 2023 PhD registrations on the EUROfusion Indico platform included self-registration of 624 PhD students across Europe. The percentage of women and academic fields (table 8) is similar to the information obtained from the 2023 HR survey. In addition, the PhD registrations provide the geographical and work package breakdown (table 9) of the European PhD research projects. It should be noted that whereas PhD in Physics is a common career path for all fusion scientists, PhD in engineering fields are more common in some countries than others. Thus the number of engineering PhDs does not reflect on the number of engineers entering the fusion workforce.

Table 8 – Gender and academic field distribution of the 2023 PhD student registrations

Gender	No. of students	Percentage
Female	120	19.2%
Male	493	79.0%
Other	1	0.2%
Prefer not to say	10	1.6%
Academic field (multiple choice)		
Physics	420	67.3%
Engineering	278	44.6%
Chemistry	19	3.0%
Mathematics	47	7.5%

Table 9 – Geographical distribution and PhD projects associated with EUROfusion work packages based on the 2023 PhD student registrations.

Country	No. of PhD students
Italy	127
France	78
Germany	75
Spain	53
Switzerland	40
Finland	39
Belgium	31
United Kingdom	30
Netherlands	23
Greece	20
Poland	17
Sweden	17
Austria	16
Hungary	9
Denmark	8
Ukraine	8
Portugal	7
Czechia	6
Croatia	4
Slovakia	4
Latvia	3
Romania	3
Slovenia	3
Estonia	1
Ireland	1
Lithuania	1

EUROfusion work package		No. of PhD students
WP01-TE	Tokamak Exploitation	90
WP02-SA	JT-60SA Exploitation	5
WP03-W7X	W7-X Exploitation	14
WP04-AC	Advanced Computing	30
WP05-PWIE	Plasma Wall Interaction and Exhaust	51
WP06-PrIO	Preparation for ITER Operation	9
WP07-ENR	Enabling Research	32
WP08-DES	Design Activities	12
WP09-MAG	Magnet Systems	8
WP10-BB	Breeding Blankets	19
WP11-PES	Plant Electrical Systems	6
WP12-DIV	Divertor	26
WP13-HCD	Heating and Current Drive Systems	25
WP14-TFV	Tritium, Fuelling and Vacuum Systems	6
WP15-BOP	Heat Transfer, Balance-of-plant and Site	3
WP16-DC	Diagnostic and Control	21
WP17-RM	Remote Maintenance Systems	18
WP18-MAT	Materials	53
WP19-SAE	Safety and Environment	5
WP20-ENS	Early Neutron Source	10
WP21-PRD	Prospective Research and Development	10
WP22-SES	Socio-economic Studies	3
Unallocated		168

3. EUROfusion activities and initiatives

The EUROfusion Consortium consists of 198 institutes, 28 members and their affiliated entities. Human resources policies and recruitment are local to the laboratories, thus EUROfusion cannot impact the recruitment process. EUROfusion however can support joint commitment and coordinated actions, including raising awareness of the attractiveness and stability of fusion research as a career path, strengthen education and training across Europe and contribute to the knowledge capture and transfer of institutional/European know-how in fusion science, technology and operations.

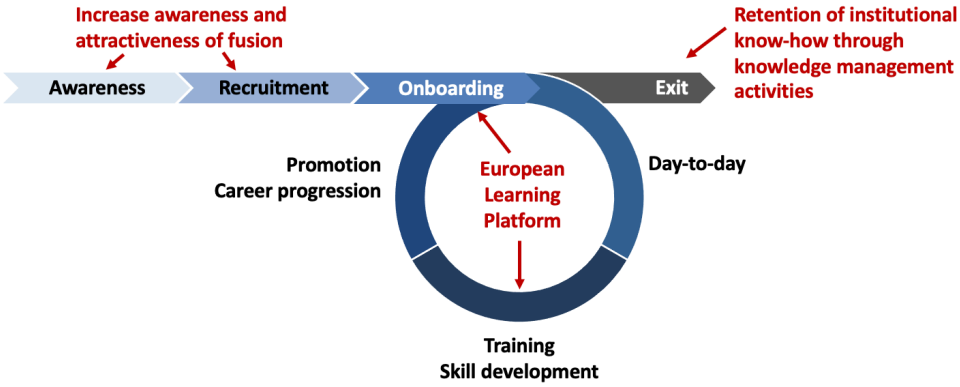


Figure 6 – Employee life cycle

3.1 Raising awareness of fusion and attractiveness as a career path

Raising awareness of fusion starts in schools and through public outreach activities. Many EUROfusion Beneficiaries have strong outreach programmes with public events and visits, day/night of science festivals, school visits and school events as indicated in their annual education reporting (grant deliverable D24.16). Historically EFDA, the predecessor of EUROfusion had excellent outreach material which is still available on the EIROforum Science in Schools website. Currently EUROfusion outreach activities are through the FuseNet organisation with an annual teacher's day event reaching teachers in most European countries and preparing teaching materials on fusion for 5 classes in native European languages.

FuseNet organises annual events for Master and PhD students across Europe. These events provide students up-to-date information on the European fusion research programme and opportunities to join. Particularly students have opportunities to participate in summer/winter schools and do up to 6 months internships in Europe, ITER or worldwide funded by EUROfusion through FuseNet.

New activities in 2024-25:

- Increased **support of schoolteachers** to bring fusion education to schools, increase number of **student internships** and **lecturer mobility** through FuseNet.
- Include **Bachelor students in the FuseNet Master event** as decision to pursue fusion is often taken at the Bachelor level when choosing one's Master degree curriculum.
- Organise **career path events** interviewing diverse fusion experts with interesting career paths to inspire early career scientists and engineers as well as motivate mid-career experts to join fusion research.
- Showcase profile of diverse EUROfusion Grantees and FuseNet interns on social media to promote our early career scientists, advertise both programmes and motivate future applications.
- Setup a **network of people with expertise and interest in equality, diversity, and inclusion (EDI)** to share best practices, lessons learned, organise joint events across Europe.

Further to the activities, the EUROfusion Training and Education (TRED) Office is committed to better understand the individual situation and difficulties of the different fusion groups. In addition to reaching out for one-on-one discussions, the Training and Education Office together with the EUROfusion Administration Department holds monthly information sessions to answer any questions related to the EUROfusion training and education activities. These sessions also act as information sessions for the application to the EUROfusion Researcher and Engineering Grants as well as the JT-60SA school organised jointly by EUROfusion and QST.

3.2 Strengthening educational and training activities

Education

The 2022 and 2023 educational programmes overview showed an uneven and at times limited access to educational programmes in some of the European countries affecting student numbers and recruitment. Education and training are also identified as one of the cornerstones of capture and transfer of tacit knowledge within the fusion community as described in the EUROfusion Knowledge Management Strategy.

EUROfusion is thus in the early stages of testing the technical elements of setting up a European Online Learning Platform using the free, open-source tool Moodle used by many European universities to host their online courses. The aim is to:

- Widen connections with the European academic networks, in particular in the nuclear education sector.
- Make existing fusion educational material and academic courses accessible across Europe.
- Develop courses and workshops on scarce and important competency areas.
- Record and provide access the trainings and schools organised by EUROfusion.
- Support lecturers to make their courses more practical along Bloom's updated taxonomy (figure 7) to develop skills to understand and use the new know-how as well as accessible to students with diverse learning preferences and capabilities.

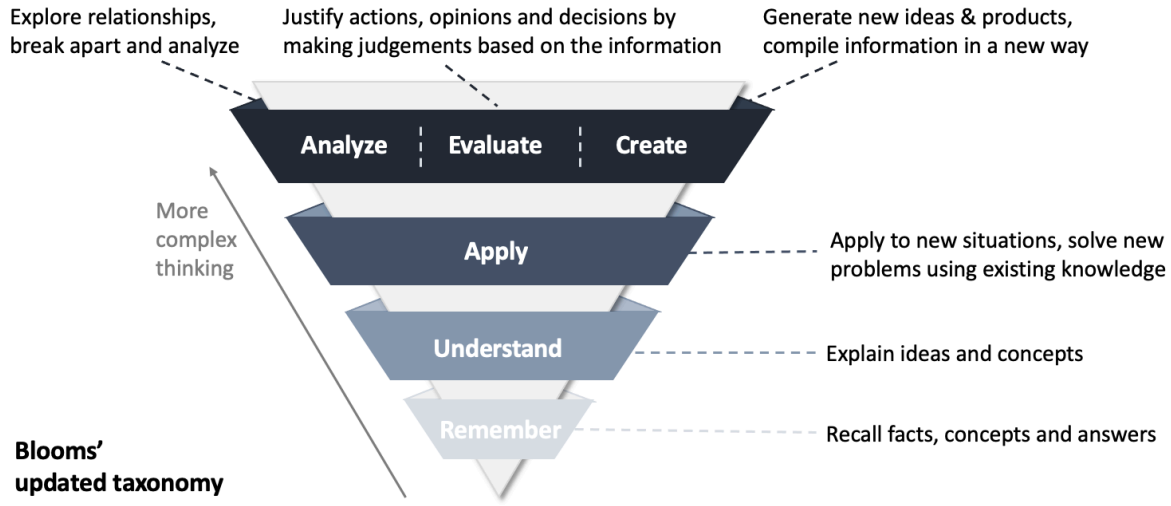


Figure 7 - Bloom's updated taxonomy of learning from simple to complex skills

New activities in 2024-25:
Develop a new European Online Learning Platform hosting academic level and post-graduate training courses accessible across Europe (EUROfusion experts and collaborators such as F4E, ITER and Japan). This platform will complement, rather then replicate the repositories of introductory fusion materials provided by FuseNet and INFUSED (ITER platform).

The platform can offer academic courses, training courses such as the EUROfusion Engineering Training Programme, as well as behavioural training material on topics such as diversity, unconscious bias, cultural awareness. Type of training material and implementation steps planned are:

1. **Past courses:** make recorded courses accessible on-demand from universities that are happy to share. Offer a limited number of open hours with the lecturer to ask any questions.
2. **Remote academic lectures:** selected lecturers to repeat existing courses online and live through the new learning platform.
3. Create a **database of practical exercises** with tips and full solutions to be used by lecturers and students.
4. **On-demand online courses:** create on-demand online courses updating the format of the courses with short, recorded videos and exercises along the best practices of academic online courses.
5. **Support the development of new courses** in scarce and important competency areas.

The aim is to launch the new learning platforms with steps 1 and 2 following a call for participation for a limited number of lecturers in 2024-25 to test and optimise the process and platform.

Additional activities:

- Encourage students to upload their public theses to the EUROfusion pre-print server accessible to the public (students and industry) to **create a repository MSc and PhD thesis**. This provides students additional learning material, connect researchers working on similar projects and support technology transfer activities.
- Support lecturers by share best practices on how to include more practical and interactive elements in the lectures and use remote experimental equipment provided through FuseNet.

Training

The EUROfusion Researcher and Engineering Grant programmes encourage excellence and career development of researchers and engineers who are already in the programme and attract high quality potential candidates from outside the programme. The EUROfusion Researcher Grants supports post-doctoral scientists to conduct a 2-year individual research project. The EUROfusion Engineering Grant scheme supports post-master engineers to specialise and broaden their competences in fusion while conducting individual research projects in scarce engineering competences aligned with the European Research Roadmap to the Realisation of Fusion Energy.

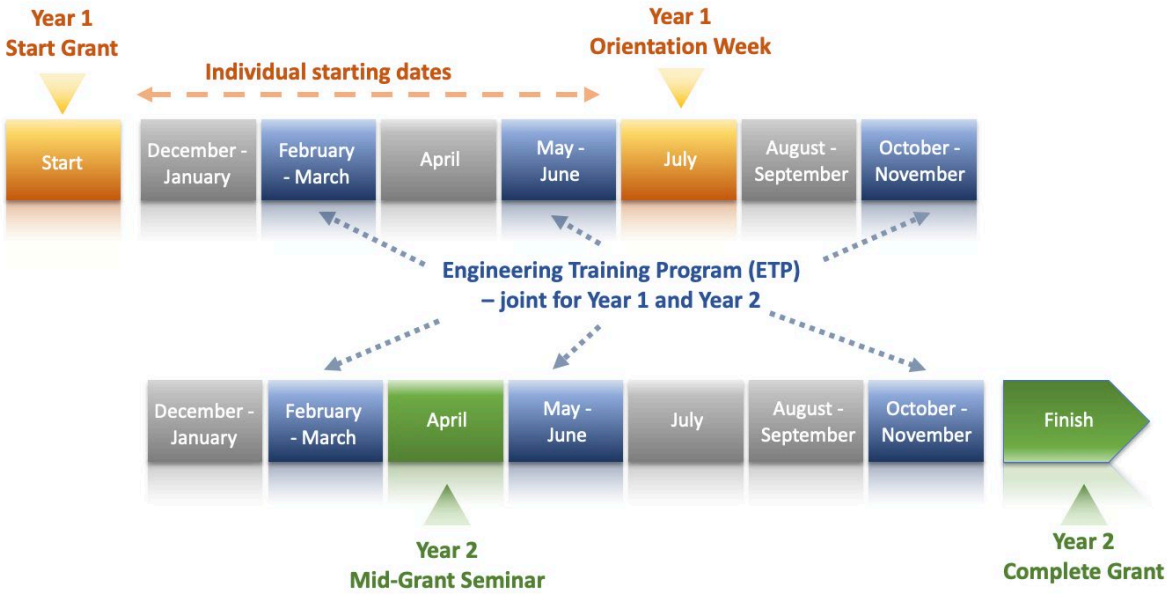


Figure 8 – EUROfusion grant structure tested in 2024, and included in the 2025 call for applications

The EUROfusion grant scheme has been updated to include:

- **6 in-depth training courses** per year (1 full day training each spread across multiple days) called the EUROfusion Engineering Training Programme,
- **Orientation days at the EUROfusion Headquarters** in Garching, Germany for a programme induction, and to connect with each other and experts in the Programme Management Unit thereby creating a stronger network and community for them.
- **Mid-grant review** in the format of an online seminar to review the progress and provide feedback/support to the grantees half-way through the grant programme.

The new format will be tested on a voluntary level in 2024 and implemented in the calls for the 2025 grants.

EUROfusion continues to organise training sessions under various EUROfusion work packages as well as co-organises the EIROforum School on Instrumentation (jointly with EIROforum) and the JT-60SA International Fusion School (jointly with QST, Japan).

Schools organised by EUROfusion in 2024-25:

- **EIROforum School on Instrumentation (ESI)** is an event, jointly organised by the Instrumentation Working Group of the EIROforum organisations (EMBL, ESA, ESO, ESRF, EUROfusion, CERN, ILL, European XFEL). The aim is to teach the basic principles of instrumentation to young engineers and researchers (PhD students, postdocs) with EIROforum lecturers covering theory, practical examples, and hands-on sessions on a variety of instrumentation-related topics.
- The **JT-60SA International Fusion School (JIFS)** focuses on a comprehensive training on fusion science, engineering and tokamak operation primarily based on the experience on JT-60SA, as well as including extensive know-how from Europe. Topics include scarce competencies not usually covered in other schools such as the engineering design, construction and commissioning challenges of a large-scale tokamak device.
- **Introductory course on session leading and operation** is also foreseen under the EUROfusion Operations Network with a plan to write a textbook on tokamak operations in the coming years in collaboration with IAEA. The session leader (physics operator) role is particularly interesting as it encompasses understanding (and development) of plasma scenarios, engineering and physics limits of plasmas and the plant systems, how to programme a plasma discharge to achieve the physics target while exploiting the plasma and engineering space to the maximum in a safe way and management of the control room. This know-how can support the optimal development of experimental proposals pre-session and analysis of discharges post-session, thus would be beneficial to students, scientific coordinators, task force leaders and any scientists contributing to experiments. Furthermore, a basic understanding of operations can also support engineering staff in design and implementation of systems related to the plant systems and control room work.

3.3. Capturing and transferring tacit knowledge

The capture and transfer of tacit knowledge is vital in highly technical, scientific, and research-driven sectors such as nuclear fusion research. Benefits of effective knowledge management include:

- Risk mitigation: safeguard critical knowledge by preventing its loss due to retirements, job transitions to outside EUROfusion and natural erosion of memory over time.
- Synthesis of knowledge: integrate know-how and experience from diverse teams to identify underlying physics and engineering principles, distil best practices and lessons learned.
- Efficiency increase: embed knowledge capture and transfer into everyday processes, make knowledge accessible and encourage its reuse.
- Active prevention of similar issues and faults: avoid repetition of similar errors by implementing insights gained from other facilities and past experiences. Incorporate lessons learned and best practices into engineering design, operational procedures, and commissioning of plant systems.

- Learning and development support: improve training and education opportunities and materials fostering continuous learning and skill enhancement.
- Leverage collective expertise as competitive advantage: capitalize on the collective knowledge of EUROfusion as a strategic advantage in building external collaborations.

The EUROfusion General Assembly endorsed the EUROfusion Knowledge Management Strategy in December 2023 with the aim to establish effective knowledge management activities to ensure tacit and explicit knowledge is managed strategically and efficiently, aligned with the needs and goals of the EUROfusion Consortium. The 4 pillars of the EUROfusion Knowledge Management strategy (Figure 9) combined together aims to develop an educated and well-trained workforce while cultivating a European fusion community that shares experience and supports each other.

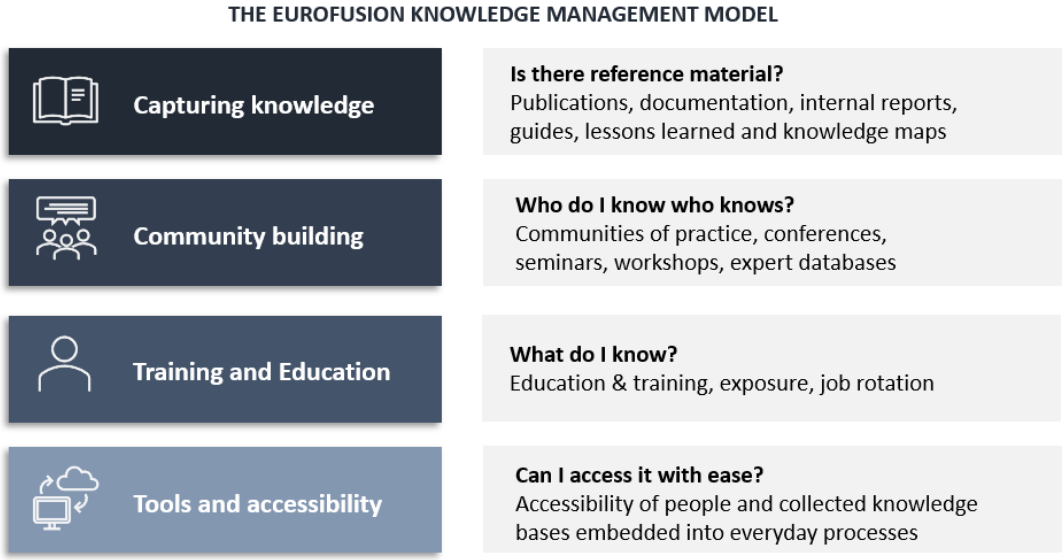


Figure 9 – The four pillars of the EUROfusion Knowledge Management Framework

To implement the EUROfusion strategy approved in December 2023, the resources-loaded Knowledge Management Implementation Plan on the 2024-25 activities is submitted to the EUROfusion General Assembly in April 2024 for approval. Examples of the new knowledge management activities are:

1. **Capturing knowledge**: The **ITER Engineering Basis Handbook** is a EUROfusion project to, in collaboration with ITER, capture the design methodologies and principles, the underlying technical design basis for ITER, its evolution from the years of conception, assembly, construction, as well as detail the technical, scientific, and regulatory rationale behind the major decisions.

2. **Community building:** Beyond the communities of the Fusion Science and Fusion Technology work packages, the EUROfusion Operations Network connects operational staff between different facilities and enable/strengthen sharing of operational know-how and experience in order to improve operational reliability/performance and reduce commissioning times and faults.
In 2024, EUROfusion in collaboration with F4E set up a joint **ECRH community of practice** as ECRH has been identified to be on the critical path for ITER for the First Augmented Plasma Operation Phase as well as thought to be vital for a set of new European devices (WEST, MAST-U, STEP, COMPASS-U, JT-60SA) and current facilities (ASDEX Upgrade, TCV, W7-X). Europe has a strong experience on current devices and test facilities. As part of this new ECRH network, the EUROfusion Operations Network organises regular online seminars to share operational know-how and experience as well as a joint European training programme led by EPFL for new ECRH operators. The community can also strengthen the connection with the ITER and JT-60SA teams, thus providing opportunities to collaborate and fast response to potential questions and issues.

3.4 Strengthening collaborations

Collaboration in fusion research is key to bring together the diverse interdisciplinary expertise and activities of various fusion laboratories/organisations within and outside Europe, in the industry, public or private sector. This allows the community to leverage their complimentary skills and perspectives leading to more robust and innovative solutions to physics, engineering, and commissioning challenges of current and future devices such as ITER and DEMO.
The EUROfusion Consortium activities are carried out in close collaboration with various fusion stakeholders including Fusion for Energy, the ITER Organisation and the Fusion Industry Innovation Forum as shown in their valued input into the definition of the new EUROfusion Roadmap.

Fusion for Energy

EUROfusion has strong collaborations with F4E including the implementation of the restructured European programme for the ITER Test Blanket Module, the DEMO Breeding Blanket, the conceptual design of DEMO, the development and qualification of fusion materials, Broader Approach projects (JT-60SA, IFMIF-EVEDA and the International Fusion Energy Research Centre (IFERC)), Neutral Beam Test Facility, and fusion technology transfer. Recent discussions between F4E and EUROfusion aim to further widen collaborative activities bringing together the strengths of the two organisations to benefit the EU fusion effort.

ITER

EUROfusion has been involved primarily in the development of the physics basis and engineering design for ITER. In the 2023 and 2024 EFPW workshop, the ITER Organisation has indicated interest in participation from ITER members (including F4E and EUROfusion in Europe) in the preparation and execution of system commissioning of plant systems happening in the coming years. The experience and know-how of current devices (many European devices) are highly valuable to support commissioning of ITER as the system commissioning of new plant systems is critical to maintain the ITER timeline and/or to reduce any further delays. Further to the contributions to the Neutral Beam Test Facility, in 2024, EUROfusion is expected to participate in the commissioning of the first ITER gyrotron system connected to the F4E-EUROfusion ECRH network.

International Collaborations

International collaboration activities are expected to intensify around the international ITER project and joint contributions to experiments. Existing and new experimental facilities in Europe are well suited to address some of the physics, design, engineering and operational issues while new facilities expected to become operational in the countries of the ITER Parties have the potential to significantly enrich the European programme. EUROfusion together with the European Commission (DG-RTD and DG-ENER) coordinate international collaboration policies and activities under the EURATOM Third Country bilateral agreements including the USA, South Korea, China and Japan focusing on physics and engineering activities in mutually beneficial collaborations.

Industry

Fusion research activities generate an increasing number of fundamental technologies that can be transferred and benefit other European industries. EUROfusion fosters fusion technology transfer (FUTTA) by identifying and supporting innovative projects thereby increasing the short-term return of the investments in fusion. Using industry brokers covering various European regions, the FUTTA programmes support the dissemination and exploitation of Intellectual Property Rights from EUROfusion beneficiaries to non-fusion industry. In 2024, EUROfusion set up its Industry Relations Office with the goal to identify and open a continuous dialog with industrial partners, and to prepare the upcoming Public-Private-Partnerships. This office will initiate informal discussions with selected companies to gauge and raise interest in partnerships with EUROfusion research institutes.

4. Closing remarks

The European fusion programme and ecosystem have changed over the last years. The increasingly important role of Private companies and industry creates the need for a larger, more diverse well-trained work force. The ITER specific needs are also evolving as the commissioning phase of some of its plant systems is approaching.

The EUROfusion Human Resources Report describes the analysis of the 2023 Human Resource Survey data. Together with the Education Programmes Overview, EUROfusion Knowledge Management and Implementation Plan, this provides the basis for the next set of activities for the remainder of the FP9 framework programmes and plans for FP10 and the future in view of creating a workforce that fit the future needs.

The main findings of the HR survey review include:

- Recruitment and retention of qualified engineers and operators are difficult in the strong job market competition. A joint effort at European level is needed to raise the awareness and attractiveness of fusion as a career opportunity for people with diverse backgrounds.
- Access to fusion-focused academic programmes and courses is limited or not accessible in some European countries. New initiatives are required to make fusion courses accessible across Europe and create new educational/training material on scarce topics for students and mid-career specialists entering the public and private fusion industry.
- With the start of the ITER plant commissioning phase, there is a need for professional staff for the commissioning of plant systems, training of operators, in addition to continued engineering support for design and construction.
- Following the closure of JET and the increased recruitment dynamics between the industry, public and private sector, efficient knowledge management is even more vital together with effective talent management.

As the recruitment and HR policies are local to the affiliated institutes, EUROfusion activities described in this report concentrate on joint commitments and coordinated actions, focusing on raising awareness of the attractiveness and stability of fusion research as a career path, strengthen education and training across Europe and contribute to the knowledge capture and transfer of institutional/European know-how in fusion science, technology and operations. Further observations from the EUROfusion Human Resources Survey panel to motivate possible further ways forward are included in Table 10.

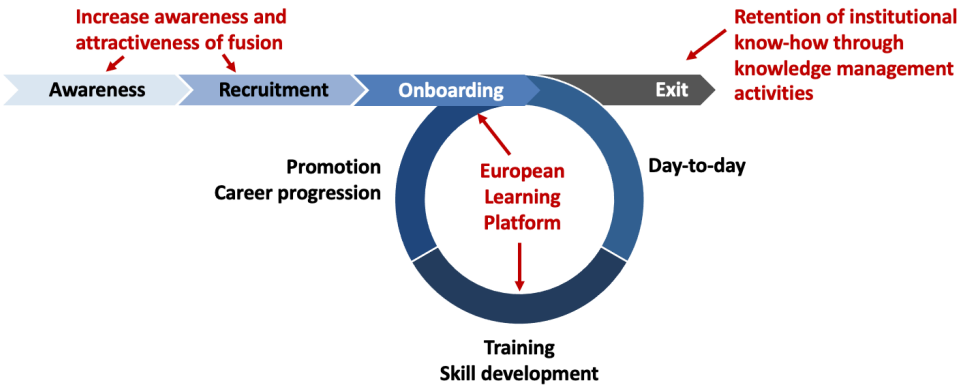


Figure 10 – Main EUROfusion activities along the employee life cycle

Table 10 – Possible ways forward proposed by the EUROfusion Human Resources Survey Panel

Topic	Possible ways forward
Diversity	Move to gender inclusion and extension of diversity to other protected characteristics (age, race, sexuality, socio-economic background, small/large laboratories). Continue to identify and remove barriers to entry for diverse staff at early and mid-career.
	Support mentoring schemes through mentor support and/or (peer) training.
	Offer remote connection to EUROfusion meetings on request. This provides an inclusive environment for people with physical disabilities, neurodiversity, care responsibilities or with temporary or long-term medical conditions. Furthermore, the ability to participate in meetings remotely reduces travel (good for the environment and reduces cost).
Cultural awareness	Raise the understanding and address cultural differences within and outside Europe as well as between public and private sector, industry.
Connection with industry and private sector	Liaise with the private sector and industry, by involving them in future HR surveys to understand the dynamics, needs and workforce movements of the whole European fusion community.
	Include education and training in the setup of the public-private partnership.
	Establish an EUROfusion alumni network to strengthen connection with fusion experts.
Operations	Develop plant simulator of individual plant systems for scenario development, training, and operator support (preparation and post-pulse analysis). Test ITER and EUROfusion plant simulators on current devices.
	Complement the foundation course on tokamak operation and session leading with in-person training opportunities on current devices for new operators. The transferable knowledge and experience from multiple devices can improve operators' capabilities and reduce operator training time by up to 50%.
Student	Add short student/training projects with comprehensive elements to the European Learning Platform. Projects can involve individual or group work (e.g. physicists and engineers working together).
	Organise a hackathon(s) to raise awareness of fusion and offer internship for best teams/students. First round can be based on online submission, whereas the second, final round could take place at the ITER site in Cadarache, France.
	Develop a publicly available introductory course to fusion engineering similar to the EFPL MOOC on plasma physics on the EdX platform. The course can raise awareness and support recruitment worldwide at early and mid-career levels.