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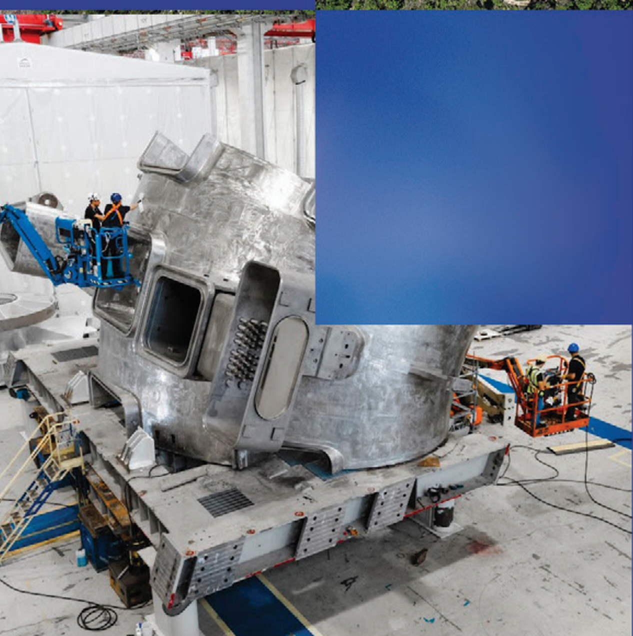
# Fusion for Energy Impact on Europe's Economy and Industrial Competitiveness (2018-2024)



## 13th Annual Assessment of Fusion for Energy

Prepared for Fusion for Energy
The European Joint Undertaking for ITER and the Development of Fusion Energy
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| | |
|---|---|
| **AMR** | Advanced Modular Reactor |
| **BA** | Broader Approach |
| **CERN** | European Organization for Nuclear Research |
| **CGE** | Computable General Equilibrium |
| **DG ENER** | Directorate-General for Energy (European Commission) |
| **DG RTD** | Directorate-General for Research and Innovation (European Commission) |
| **E3ME** | Energy-Environment-Economy Macro-Econometric model |
| **EC** | European Commission |
| **ESA** | European Space Agency |
| **EU** | European Union |
| **Euratom** | European Atomic Energy Community |
| **Eurofusion** | European Consortium for the Development of Fusion Energy |
| **F4E** | Fusion for Energy |
| **FOAK** | First-of-a-Kind |
| **GB** | Governing Board |
| **GVA** | Gross Value Added |
| **IFERC** | International Fusion Energy Research Centre |
| **IFMIF-EVEDA** | International Fusion Materials Irradiation Facility - Engineering Validation and Engineering Design Activities |
| **IEA** | International Energy Agency |
| **IO** | ITER Organisation |
| **ITER** | International Thermonuclear Experimental Reactor |
| **JT-60SA** | JT-60 Super Advanced (a fusion research project in Japan) |
| **MFF** | Multiannual Financial Framework |
| **MS** | Member States |
| **NACE** | Statistical Classification of Economic Activities in the European Community |
| **R&D** | Research and Development |
| **R&I** | Research and Innovation |
| **RIPATHS** | Charting Impact Pathways of Investment in Research Infrastructure |
| **RIs** | Research Infrastructures |
| **RTD** | Research and Technological Development |
| **STP** | Satellite Tokamak Programme |
| **SME** | Small and Medium-sized Enterprises |
| **SMR** | Small Modular Reactor |
| **SWOT** | Strengths, Weaknesses, Opportunities, and Threats |
| **TOR** | Terms of Reference |
| **VV** | Vacuum Vessel |
| **WP** | Work Package |

# EXECUTIVE SUMMARY

**This study assesses the impact of Fusion for Energy's (F4E) activities on the EU economy and on industrial competitiveness** in the field of fusion applications. Conducted as part of F4E's annual assessment, it complements the 2024 mid-term evaluation of the EU contribution to ITER and earlier impact studies from 2018 and 2020. The present study **covers the period 2018–2024 and includes all EU Member States as well as Switzerland.**

### *F4E spending over 2018-2024*

**Over the period 2018–2024, F4E-related spending amounted to nearly EUR 5.6 billion** (in 2024 prices)**, divided between two main categories: "F4E in-kind" and "Other F4E expenditures."** The "F4E in-kind" category — comprising contracts directly managed by F4E for construction, manufacturing, and technical services for ITER — represented over half of total spending (EUR 3.12 billion, in 2024 prices). This funding was mainly directed to the construction (53%) and industrial (41%) sectors, with France receiving around 60% of total contract payments. The "Other F4E expenditures" category (EUR 2.5 billion, in 2024 prices) includes cash transfers to the ITER Organisation, administrative costs, and contributions to international partners such as Japan. These expenditures were also concentrated in the industrial sector (62%), with additional allocations to non-business (22%) and business services (11%). Geographically, they were similarly dominated by France (58%), followed by Spain (22%) and Italy (10%), underscoring the strong sectoral and territorial concentration of F4E spending.

### *F4E impacts on EU economy, on supply chain and EU industrial competitiveness*

**Between 2018 and 2020, F4E-related spending generated positive impacts across the EU27 and Switzerland.** It increased Gross Value Added (GVA) and employment, with the strongest impact in France due to its role as ITER host country. Compared with a situation where F4E-related spending did not occur and funds were instead saved (the "Gross Impact scenario"), the approximately EUR 5.62 billion (in 2024 prices) spent by F4E is estimated to have generated about EUR 5.95 billion in additional GVA and supported around 39,000 job-years (see table below). These estimates capture not only the direct effects of F4E-related investments but also their indirect and induced effects, as modelled through the E3ME framework, which accounts for supply chain dynamics and consumption patterns. A similar pattern appears when considering the scenario in which F4E spending is suspended and accompanied by a proportional decrease in taxes in F4E financing countries (called "Tax Reduction" scenario). In this case, the gains are milder but relatively closer to those of the "Gross Impact" scenario. When compared with an alternative spending scenario in which the same amount of money is spent on a general investment programme (see "General Investment Programme" scenario), F4E-related spending still generates slightly better economic outcomes. However, the difference between the Baseline (F4E-related spending) and this alternative scenario is relatively modest.

| SCENARIO | GVA | EMPLOYMENT |
|---|---|---|
| Baseline vs Gross Impact scenario | +EUR 5.95 billion | +39,000 job-years |

| | | |
|---|---|---|
| Baseline vs Tax reduction scenario | +EUR 3.95 billion | +16,800 job-years |
| Baseline vs General Investment programme scenario | +EUR 0.37 billion | +5,500 job-years |

**The economic impacts of F4E-related spending are highly concentrated both by sector and by country**. The sectors most positively affected are business services and industry, with construction also playing an important role in the early years of the period. Together, these account for around 70% of the total GVA generated between 2018 and 2024 (baseline vs Gross Impact scenario). This concentration mirrors the sectoral distribution of F4E contracts, which rely heavily on physical infrastructure, advanced manufacturing, and specialised industrial inputs required for the ITER project. It also underscores ITER's dependence on advanced industrial capabilities and highly skilled professional services. At the country level, France stands out as the main beneficiary under all three scenarios. When F4E spending is compared with the "Gross Impact" scenario, France is estimated to gain EUR 3.8 billion in GVA and up to 23,400 job-years. Spain and Italy follow as the next largest beneficiaries, though with comparatively smaller effects.

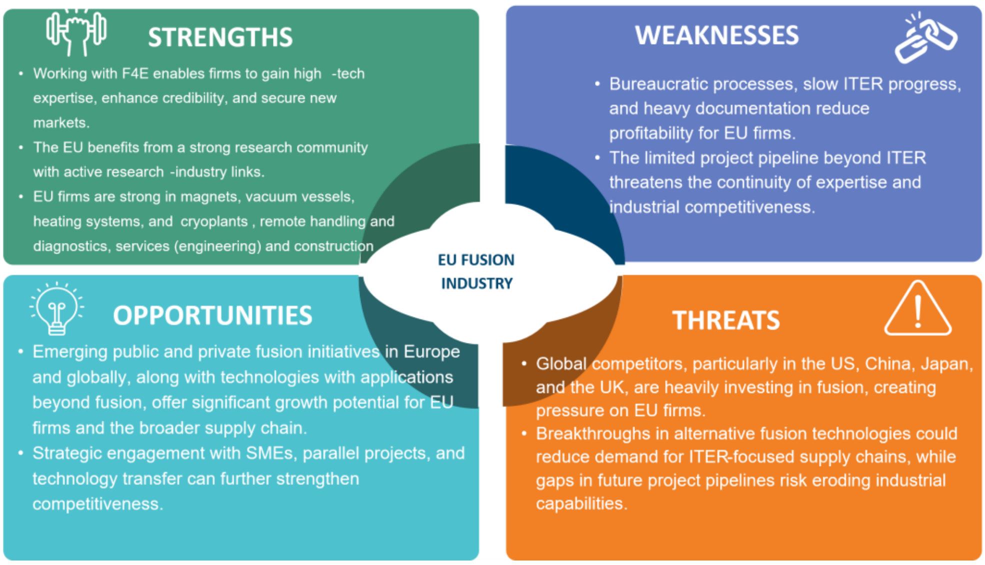
Turning to firm-level impacts, **companies that supplied goods or services to F4E between 2018 and 2024 reported significant learning effects**, **strengthening both technical and organisational capabilities**. Survey results show that 66% of firms indicated staff had acquired new skills and 77% noted improved technical know-how, with interviews confirming that ITER's technological complexity drove companies to develop advanced capabilities such as specialised welding, magnet handling, and facility construction. Collaboration also facilitated knowledge exchange, with 62% of firms forming new partnerships that enhanced process understanding and execution. Impacts on talent attraction and retention were more modest (54% and 43% respectively), reflecting broader labour market challenges and competition from public institutions, but still meaningful. Beyond technical skills, firms also acquired knowledge of public procurement processes, a strategic asset for future engagement in high-tech public–private partnerships.

**F4E collaboration has generated meaningful knowledge and innovation impacts, though less widespread than learning effects**. Around half of surveyed firms reported product or process improvements, often through technological adaptation, while more advanced outcomes such as patents, spin-offs, or cutting-edge technologies were concentrated among a smaller set of suppliers. Product innovation was largely fusion-focused, though some firms diversified into fission, medical, pharmaceutical, and aerospace sectors. Bibliometric analysis identified at least 1,648 publications directly linked to F4E since its establishment and up to 5,388 when supplier outputs are included—representing respectively 16% and 41% of the entire body of ITER/DEMO/BA publications—with strong international collaboration. Patenting remains limited (33 families since 2008) but shows knowledge spillover potential, especially through citations of F4E-related publications. Overall, the evidence underlines F4E's role as a catalyst for research, technological upgrading, and cross-sector innovation in high-tech industries.

**Working with F4E has primarily strengthened firms' credibility and networks**, with 80% of survey respondents reporting improved visibility, over half establishing new collaborations, and some achieving global technological leadership, though immediate client acquisition and commercial expansion were more limited. **Firm-level economic gains were more moderate**: nearly half of firms reported higher turnover, one-third expanded their customer base, and structural changes such as entry into new markets or creation of spin-offs were less common, while negative effects remained rare. Econometric analysis did not find statistically significant short-term effects on turnover or assets within the two-year observation window, suggesting that firms are investing in organisational capabilities and technological capacity that may only translate into measurable financial gains over a longer horizon.

**F4E procurement has contributed to workforce development primarily through selective upskilling and knowledge acquisition rather than broad job creation**. Survey results show that 41% of firms increased higher-skilled positions, while only 9% expanded lower-skilled roles, and 32% and 28% of firms reported growth in temporary and permanent staff, respectively. Firms emphasised that F4E work catalyzed the formation of dedicated fusion teams, improved project management and organisational capabilities, and developed specialised technical skills, particularly in engineering processes, materials, mechanical and nuclear engineering, welding, and advanced manufacturing. Counterfactual and mediation analyses confirm that engagement with F4E has a statistically significant positive effect on employment.

All in all, **F4E funded work for ITER and Broader Approach has significantly fostered EU industrial competitiveness in fusion technologies**. These are the strengths, weaknesses, opportunities and threats of EU industrial leadership in fusion technologies:




### *F4E's tasks and procedures*

**F4E's work programme and spending mix enable it to deliver ITER facilities while fostering European industrial expertise and innovation in advanced fusion technologies.** F4E allocates most of its spending toward infrastructure (53% of contracts in 2018–2024), reflecting European Union's role as ITER host, while the remaining 47% is dedicated to high-tech fusion components such as magnets, vacuum vessels, blankets, and cryoplants. Infrastructure-related contracts were found to be less innovation-intensive, whereas technology-related work packages drove significant R&D, customisation, and capability building among suppliers. Despite the dominance of building-related spending, F4E procurement has strengthened European firms' expertise, credibility, and leadership in high-tech fusion fields, gain access to new high-tech markets within and beyond fusion.

**F4E has made notable efficiency gains over the years but opportunities exist to further enhance procurement and project management.** Between 2017 and 2024, F4E reduced key process times (e.g. to recruit, procure, and manage contracts) substantially. Moreover, suppliers report generally positive experiences, citing clear communication, responsive staff, and constructive engagement when issues arise. However, challenges remain. Pre-contracting is often complex and lengthy, especially for SMEs unfamiliar with F4E procedures. Contracting phases are perceived as rigid, with highly detailed technical specifications, heavy documentation requirements, and uneven risk-sharing that often shifts disproportionate risks to suppliers. During project management, stakeholders note bureaucratic delays in decision-making, multiple review rounds, and extensive oversight leads to increased costs and reduces profitability. It is noted that some oversight and documentation requirements are linked to nuclear quality and safety requirements as ITER is a nuclear project. Whilst these nuclear safety requirements must be observed, there are opportunities more generally for F4E to further enhance efficiency through more agile procedures, streamlined administrative requirements, and collaborative and risk-aware approaches to improve participation, reduce costs, and maximize the economic impact of F4E's investments.

**F4E's procurement strategies are broadly aligned with peers (CERN, ESA) but are more rigid in requirements**. Like its peers, F4E uses structured calls, framework contracts, a network of Industrial Liaison Officers to engage suppliers, including SMEs, and activities to foster EU-wide collaboration. However, stakeholders note that F4E's processes are more bureaucratic, and less flexible than CERN's, with stricter technical specifications and extensive documentation at various steps – as noted above, these are partially linked to the nuclear safety requirements relevant to ITER, but which do not apply to CERN (or ESA).

**F4E procurement processes focus on efficiency and coherence with the ITER project, not geographical fairness.** This is in contrast to ESA and CERN both of which use geographical return mechanisms to ensure returns (in awarded contracts) to industry within a country are proportional to their contribution to funding these agencies. F4E does not use such a mechanism, selecting on other criteria, this has led to a high proportion of contracts being awarded to French, Italian and Spanish companies, and a low (relative to their share in EU industrial GVA) proportion to most other EU member states. Geographical return mechanisms have advantages (primarily political and fairness) and disadvantages (risks of inefficiency, poor value, strategic fragmentation, incoherence). The approach taken by F4E is likely the most suitable for its objectives as efficiency and procuring contributions in a coherent manner is crucial for ITER, nevertheless the lack of proportionality leads to questions from national policy and other stakeholders.

**F4E intellectual property** (IP) **rules are tied to ITER, many contractors find these restrictive, whilst F4E technology transfer activities are maturing.** On IP, F4E mandates background and foreground declarations with predefined ownership models, this is typically required as part of the ITER agreement. Contractors find this restrictive. This is in contrast to CERN's Consortium Agreements and ESA's where contractors can retain foreground IP, albeit with conditions on usage rights. For non-ITER contracting (e.g. IFMIF-DONES, Technology Development Programme) F4E has more flexibility with IP, similar to CERN and ESA. F4E has also shown flexibility in IP ownership for contractors on ITER, mainly retaining ownership where further technological development is still necessary and should be shared with ITER IO. For technology transfer, F4E has developed mechanisms such as the European Fusion Technology Marketplace and Demonstrator Calls. These are less mature than

CERN's and ESA's longer established (i.e. both organisations have been running decades longer than F4E) and better resourced programmes (i.e. CERN has 25 technology transfer officers, F4E just one).

**F4E has a clear potential to strengthen EU's industrial and technological leadership while fulfilling its primary mandate to deliver the EU contribution to ITER**. Stakeholders identify several opportunities: supporting parallel projects alongside ITER to maintain a pipeline for EU industry, integrating SMEs into high-tech work packages, and ensuring sustained procurement from EU suppliers to preserve skills and capabilities. This would also allow for the greater flexibility in IP management and more flexible ownership rules (outside of ITER) to encourage firms to invest and innovate. This would be supported by continuing maturation, growth and accessibility of the F4E technology transfer platforms. Additionally, leveraging AI in procurement and technology development, strengthening workforce skills through EUROfusion initiatives, and aligning the Technology Development Plan with industrial capabilities could further consolidate the European fusion ecosystem. Achieving these objectives requires careful balancing between ITER delivery and strategic industrial goals, particularly to maintain Europe's competitiveness in the face of international actors such as the US, China, Japan, and the UK, which benefit from well-resourced, agile, and commercially driven fusion programs.

# 1 OBJECTIVE AND SCOPE OF THE STUDY

The main objective of the required services is to provide a study on the impact of F4E activities on the EU economy and industrial competitiveness in fusion applications in accordance with its Industrial Policy. **The study is conducted in the framework of the annual assessment of F4E**, as mandated by the Council of the EU, following the recommendations from the Bureau and Governing Board, establishing the priorities for the 2025 F4E annual assessment exercise. This assessment aims to complement the inputs provided by the mid-term review of F4E as well as the two previous impact studies (conducted respectively in 2018 and 2020).

This study comes at a pivotal moment, as fusion has been identified as a key opportunity in the recent **Draghi Competitiveness Report** and the EU has announced it will **propose a fusion strategy**[2]. It is, therefore, essential to assess how F4E's actions contribute to increasing investments in fusion, fostering private-sector interest, and ensuring that Europe retains its fusion expertise and industrial leadership.

As required by the Tender Specifications, the study analyses both the macroeconomic impacts on the EU economy and the impact on individual industries and businesses. Beyond assessing the socio-economic impact of F4E, the study is also expected to provide recommendations to enhance F4E's future performance. Notably, several evaluation questions outlined in the Tender Specifications focus on F4E's strategies and actions, including measuring and tracking economic impact, procurement, and project management.

The analysis covers the **period 2018–2024**, but the macroeconomic assessment also includes a forward-looking dimension, which—following agreement with F4E—will be incorporated into the report after 25 September. In terms of geographical scope, the assessment includes **Switzerland in addition to EU Member States**, while the United Kingdom is excluded.

**This report presents the results** of the study. Section 2 recalls the overall methodological approach; Section 3 provides an overview of F4E-related spending; Section 4 and Section 5 present the results, organised by research question; and Section 6 provides conclusions. A set of annexes complements the report.

[2] https://energy.ec.europa.eu/news/focus-europes-road-fusion-energy-2025-04-15_en

# 2 OVERALL METHODOLOGICAL APPROACH

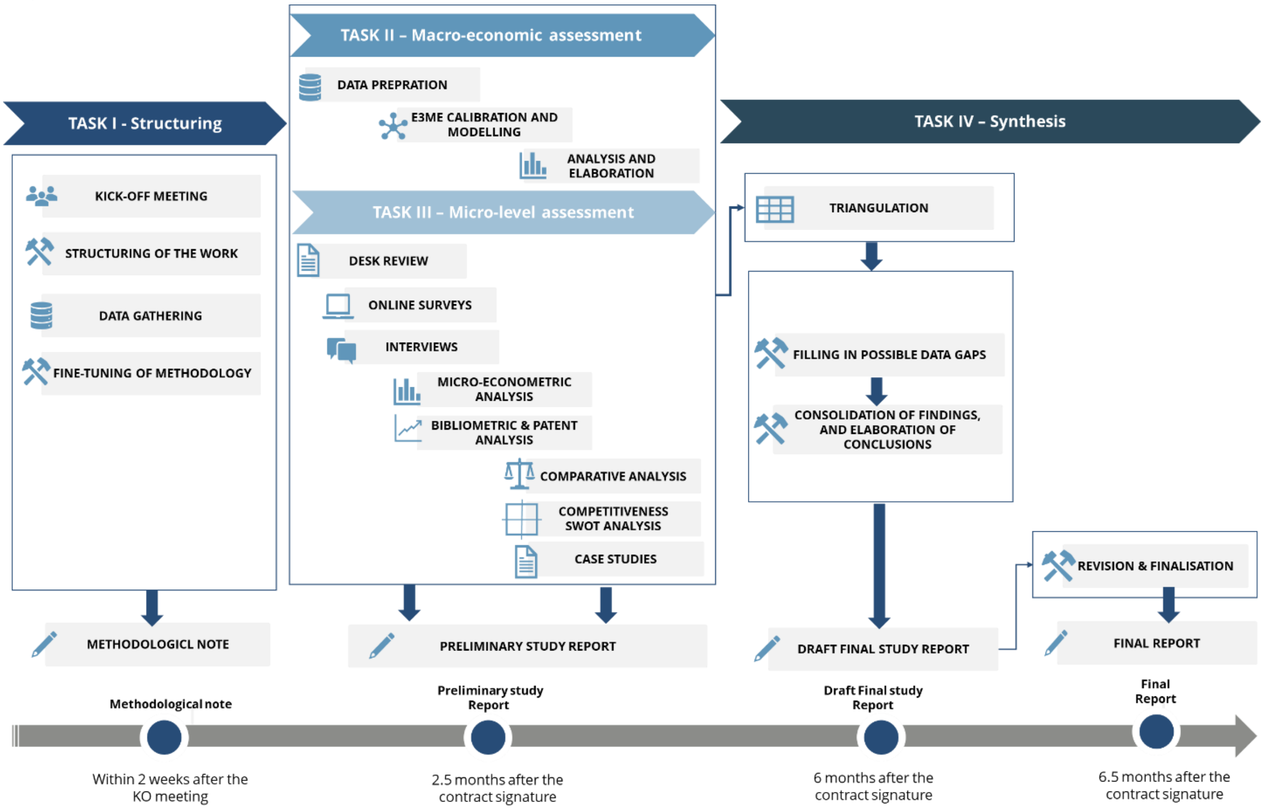
The overall methodological approach builds upon the **three building blocks**:

- A solid conceptual framework to capture the different **pathways to impact in a holistic way,** building upon the RI-PATHS framework[3], which is the European Commission's socio-economic impact assessment framework for research infrastructures. The framework presented in Annex 1 has been tailored to the specific context of F4E to best address the evaluation questions outlined in the Tender Specifications. The study team has identified five main channels through which F4E activities can generate an impact on the EU's economy and EU competitiveness in fusion. These pathways relate to scientific knowledge generation, innovation and technological spillover generation, supply chain development, skill and workforce development, and economic benefits. These pathways correspond to different assessment methodologies.
- An **assessment framework** (see Annex 2) that outlines the team's structured approach to address the questions set out in the Tender Specifications. It serves as a guiding framework for systematically collecting, analysing, and interpreting data and information to answer F4E's questions. While ensuring that all questions from the Tender Specifications have been incorporated, we have re-grouped them into two broad categories. On the one hand, there is a set of questions that refer to the impacts generated by F4E activities. On the other hand, there is a set of questions focused on F4E actions/procedures and how they can be improved.
- A **portfolio of methodological tools**, ensuring the collection and analysis of both qualitative and quantitative evidence necessary to address the evaluation questions. In general, the ambition of the proposed methodology is to build a solid evidence basis for the evaluation by attaching great importance to the collection of evidence from multiple data collection activities and analysis, as far as possible, of quantitative data.

From an operational perspective, the work followed four tasks broken down into various activities (see Figure below). What follows is a detailed overview of the activities performed.

[3] https://ri-paths-tool.eu/en

## Figure 1. Work breakdown structure




Source: CSIL

**Activity 1.0 Kick-off meeting**. It took place on April 4th. The minutes of the meeting were shared with F4E.

**Activity 1.1 Structuring of the study team's work**. This activity included: i) setting up a study folder in a dedicated cloud; ii) defining a study plan, including intermediate milestones, and a meeting plan for internal meetings.

**Activity 1.2 Documentary review**. The study team reviewed publicly available as well as internal documents shared by F4Es.

**Activity 1.4 Gathering of data from the client and external sources**. On April 8th, the study team sent a data request to F4E. The data provided by F4E were reviewed, and clarifications and follow-up requests were subsequently made. In parallel, the study team retrieved additional data from external sources, including the Orbis database and Lens.org. The data collection for the forward-looking part of the macro-economic analysis concluded only in mid-September 2025.

**Activity 1.5 Fine-tuning and drafting of the final methodological note**. Taking into account the comments received during the kick-off meeting and the review of available data, the team refined the methodology outlined in the offer.

**Activity 2.1 Database preparation for the macro-economic analysis.** Based on expenditure data (covering in-kind contributions, in-cash payments, and administrative costs) provided by F4E, payment records were matched with economic sectors using the NACE classification[4] to ensure consistency with the econometric model (E3ME). The matching was carried out using expert

[4] The Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE

judgement, the F4E Work Breakdown Structure (WBS), the F4E contractor assessment and technology code classification, and extracts from the Bureau van Dijk Orbis database. For the forward-looking analysis, data preparation was more challenging due to the absence of official projections beyond 2029. An initial proposal of expenditure for 2025–2039 was developed by the team in June 2025, based on previous projects and information on the new ITER baseline. Several iterations with F4E staff followed until mid-September.

**Activity 2.2 E3ME modelling**. The modelling exercise includes an ex-post analysis covering the period 2018–2025, as well as a forward-looking analysis extending to 2039.

The modelling exercise consists of four scenarios: a "Baseline" scenario, a "Gross Impact" scenario, and two alternative "Net Impact" scenarios ("Tax Reduction" and "General Investment Programme" scenarios). By comparing the results between the Baseline scenario and these scenarios, one can assess the direct, indirect, and induced effects of the absence of these expenses in the European economy. The scenarios are characterised as follows:

- **Baseline scenario**: This scenario includes F4E spending as it occurred historically and as such serves as the benchmark against which other scenarios are compared to assess the impact of F4E's grants and contracts. It includes the standard E3ME baseline, which is based on historical and projected data from Eurostat, International Energy Agency (IEA), and other reputable sources. The baseline underlying historical data implicitly contains F4E spending and its impacts.
- **Gross Impact scenario**: This scenario represents the hypothetical case in which F4E's expenses on grants and contracts do not occur, resulting in lower levels of demand within the economy. This scenario assumes that the unused total expenditure of F4E is saved and is therefore treated as a leakage from the economy. Such scenario was also considered as part of previous 2018 impact study.
- **Tax Reduction scenario**: This net[5] impact scenario explores a hypothetical case in which F4E's expenses on grants and contracts did not occur. However, instead of assuming a leakage from the economy, the unused F4E expenditures are assumed to be made available again to the government budget of the countries that finance it, leading to lower levels of taxation across the economy (due to the assumption of budget neutrality across scenarios[6]). The nature of contributions to F4E are taken into account in the distribution of government expenditure related with the programme.
- **General Investment Programme scenario**: This second net impact scenario characterises an alternative scenario in which F4E's expenses did not occur but are instead directed towards an alternative investment program across the European economy. The expenditure is distributed across countries following the nature of cross-country contributions to F4E together with the MFF criteria when distributing the portion that is due to the European Union. Within each country, disbursements are allocated to each sector in proportion to the

[5] The net impact refers to the overall effect of the F4E project against an alternative approach to utilise the same funds. Two alternative approaches are explored in this modelling exercise, one in which taxes are proportionally reduced and another with an alternative spending profile across sectors and geographies.

[6] This assumption determines that the government budget balances remain unaffected across scenarios. This means that in a scenario in which government expenditure is reduced (such as in the Tax Reduction scenario) this is accompanied by a proportional reduction in tax revenues. This reduction is assumed to be equally supported by lower levels of tax revenues from VAT, income tax, and employer's social security contributions.

national sector's output relative to the economy's total output. Such scenario was also considered as part of previous 2018 impact study.

### Table 1. Summary of macro-economic approach

| SCOPE OF RESULTS | SCOPE DESCRIPTION |
|---|---|
| **Economic variables** | Employment (thousand people employed).<br>Gross value added (million 2024 Euros). |
| **Geographic** | EU27 and Member States plus Switzerland |
| **Sectoral** | Results are presented at broad-sector level, which aggregates several related NACE 2-digit sectors together for the sake of a clearer presentation within the report. This classification includes the following sector classifications:<br>• Agriculture.<br>• Mining.<br>• Industry.<br>• Utilities.<br>• Construction.<br>• Distribution, retail, & H&C.<br>• Transport and communications.<br>• Business services.<br>• Non-business services.<br>Aggregate values, summing across all sectors are also provided. |

Source: Cambridge Econometrics

More details on the processing of the underlying data and assumptions can be found in Annex 4.

**Activity 3.1. Online survey.** The survey targets organisations that supplied goods or services to Fusion for Energy (F4E) between 2018 and 2024. The purpose was to gather evidence on the procurement relationship established between F4E and suppliers and the firm-level implications of being a F4E supplier. In particular, the analysis focuses on how engagement with F4E may have contributed to changes in firms' capabilities, workforce, market positioning, and overall economic and financial performance. The survey, managed through EUSurvey, was launched on May 13, 2025 and was closed on 7th July 2025. A total of 61 responses were received, representing 23% of the contacted firms[7].

**Activity 3.2 Semi-structured interviews**. Interviews with representatives of F4E, EC, F4E's supply chain, EU fusion community, and other research organisations were an important source of information to deepen the analysis. Specific interview guides per stakeholder type were developed. Feedback on the interview list was received from F4E at the end of May 2025, interview invites were sent out shortly afterwards. Team members attended the F4E supplier roundtable in Barcelona on 12-13 June, this proved an opportunity to interview key staff in-person and also to more informally engage with stakeholders with the aim to raise awareness of the study and secure interest to participate as an interviewee and/or case study. In total 30 interviews were conducted. Specifically, 3 with F4E staff and governing board, 3 with EC representatives, 21 with F4E supply chain representatives and/or European fusion start-ups, 3 with comparator organisations (CERN, ESA).

[7] Based on F4E's contacts, a total of 266 companies were contacted via email and asked to complete the questionnaire.

**Activity 3.3 Micro-econometric analysis.** This activity was meant to assess whether F4E procurement contracts have generated intermediate outcomes—such as learning and technological spillovers—as well as final outcomes, including enhanced innovation capacity, productivity, and profitability among suppliers. To this end, a mediation analysis based on the survey results was conducted, following the methodology of Castelnovo et al. (2023). In addition, by matching F4E procurement data with firm-level balance sheet data from the Orbis database (maintained by Bureau van Dijk), a staggered Difference-in-Differences analysis was carried out to identify and quantify the impact of F4E procurement on suppliers' economic performance. Preliminary findings from both analyses are presented in this report.

**Activity 3.4 Bibliometric and patent analysis**. This activity supported the assessment of the knowledge and innovation impacts of F4E activities. Publications and patents were searched using Lens.org. Relevant publications include those directly funded by F4E, well as those where F4E is indicated in the authors' affiliations. Author affiliation data was also used to identify publications involving F4E suppliers among the authors. Similarly, relevant patents were identified using a keyword-based search approach. The analysis includes publication and patent trends, citation analysis, and network analysis.

**Activity 4.5 Comparative analysis with CERN/ESA**. This analysis was meant to identify practices from other organisations (CERN/ESA) that may inform F4E approach. The comparison focused on procurement models, supplier engagement activities, innovation and technology transfer efforts, and the tracking of the impact of procurement decisions. The analysis was based primarily on desk review, with some gaps that were filled through interviews and follow up emails with key staff at each organisation.

**Activity 3.6 Competitiveness (SWOT) analysis**. Based on desk review, interviews and case studies the team carried out SWOT (Strength, Weaknesses, Opportunities and Threats) analyses of the European fusion supply chain, carrying out individual assessments for eight fusion technology and service groups: (1) Magnets and superconductors; (2) Vacuum Vessels; (3) Heating systems; (4) Cryoplant; (5) Blankets, tritium handling, divertors and first wall materials; (6) Remote handling and diagnostics; (7) Services (Engineering, design, safety, waste); (8) Construction and power supply infrastructure.

**Activity 3.7 Case studies.** Based on desk review, interviews and, where available, survey data the team prepared case studies (see Annex 9) which zoomed in on specific company cases and the benefits of the work for F4E. Benefits in company growth (employment, turnover), improved capabilities, credibility and reputation supporting new business opportunities, innovation and other aspects were highlighted in the cases.

**Activity 4.2. Triangulation of evidence.** This activity involved cross-validating findings through different types of evidence to strengthen the accuracy and credibility.

**Activity 4.3. Filling in possible data gaps**. This activity focused on collecting and agreeing with F4E the expenditure figures to be used for the forward-looking part of the macro-economic analysis.

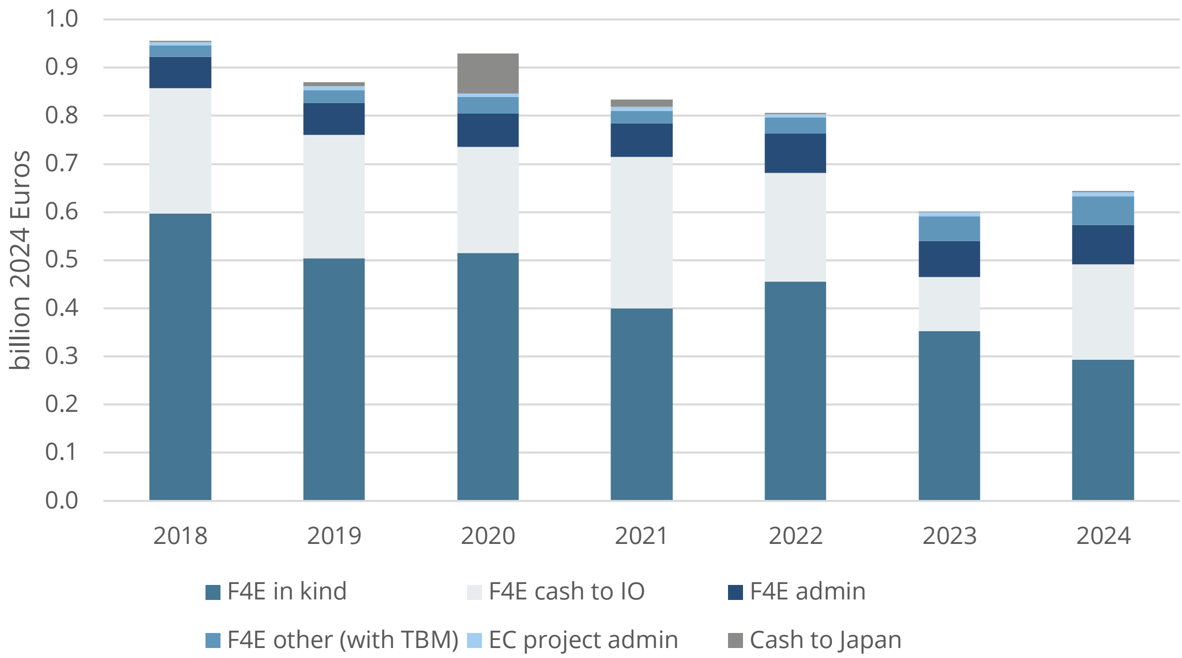
**Activity 4.4. Drafting the draft final study report**. After triangulation and data gaps filling, the team elaborated and consolidated findings and conclusions. The draft final report was presented at the F4E Board Meeting on September 25.

**Activity 4.5. Final study report**. The draft final was revised considering F4E and EC feedback.

# 3 ANALYSIS OF F4E-RELATED SPENDING

The graph below illustrates the breakdown of F4E-related expenditures by category from 2018 to 2024, expressed in 2024 prices for presentational purposes. **The most significant and consistent component throughout this period is 'F4E in kind'. It accounts for over half of the total expenditure for the entire period.** This category encompasses contracts managed directly by F4E for construction, manufacturing, and technical services essential to the ITER project. The other expenditures include 'F4E cash to IO', 'F4E administration', 'Cash to Japan', 'F4E other', and 'EC Project Administration'. Among these, 'F4E cash to IO' — representing direct financial contributions to the ITER Organisation — constitutes the largest share. The remaining categories, such as administrative costs under F4E, European Commission administrative expenses, and miscellaneous F4E expenditures, constitute smaller portions to the overall budget.

**Figure 2. Distribution of F4E expenditure by category (billion 2024 Euros)**



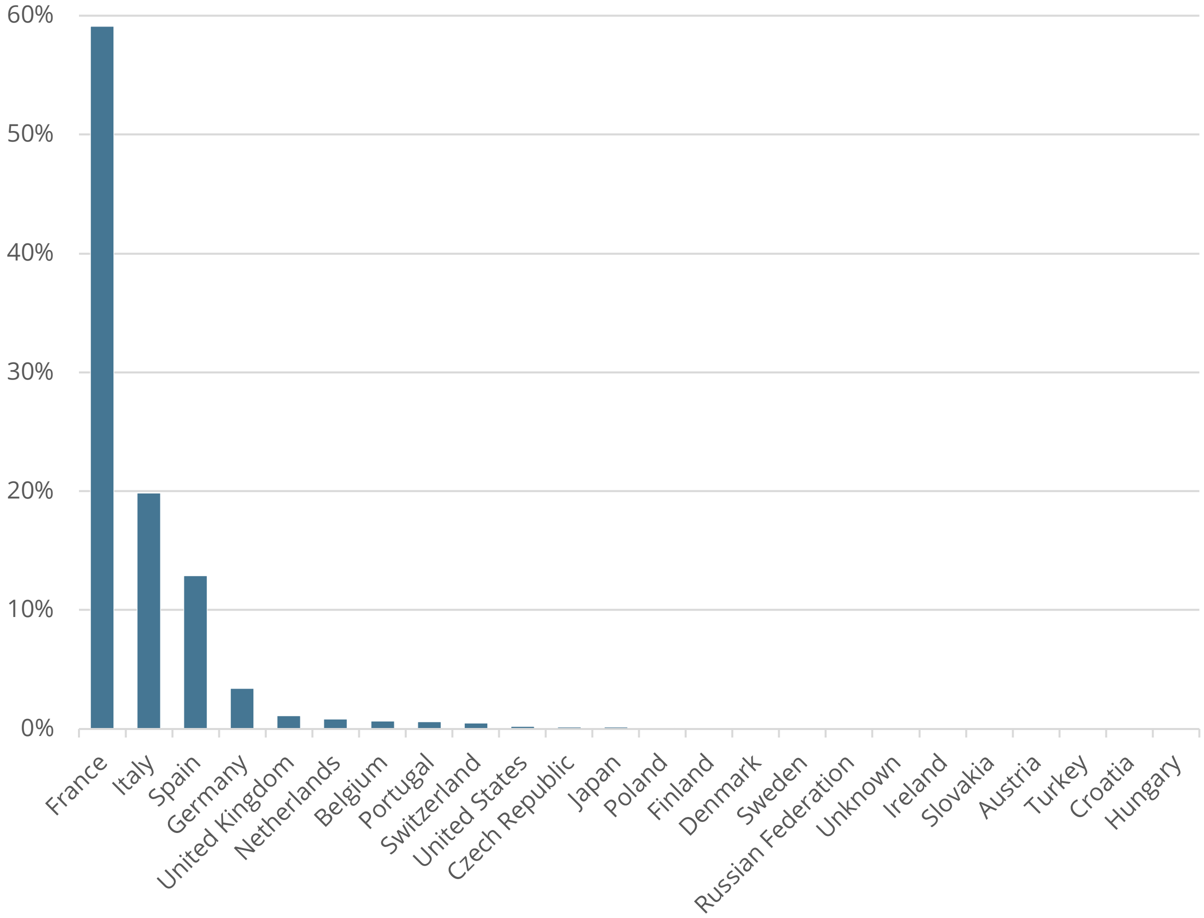

Source: F4E and European Commission data compiled by Cambridge Econometrics

## 3.1 Analysis of F4E contract payments

In this section we present an analysis of the contract payment data provided by F4E to supplement the impact analysis and provide insight into the data that was used as inputs in the econometric modelling. The analysis provides insight into the spread and distribution of activity by geography, ITER Work Package and economic sector. Based on data from **F4E in-kind payments totalled 3.12 billion Euros (expressed in 2024 prices) in the period 2018-2024**.

### 3.1.1 Geographical distribution

**Figure 3. Geographic distribution of F4E contract payments (%)**

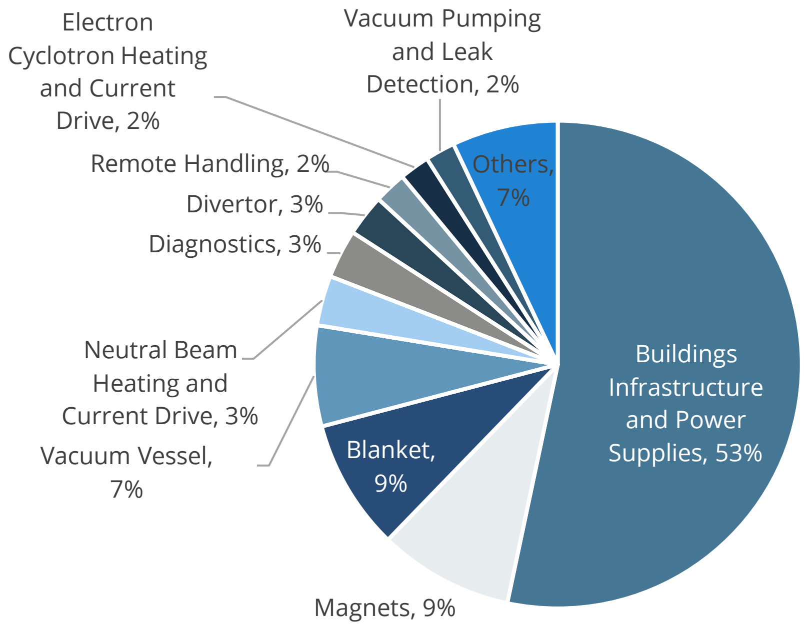



Source: Cambridge Econometrics (based on F4E data)

The graph above illustrates a concentration of F4E-related contract values among participating countries. France stands out as the primary recipient, receiving approximately 60% of the total contract value — reflecting its role as the host country and its substantial industrial involvement in the ITER project. Italy and Spain follow at a distance, accounting for around 20% and 13%, respectively. Other countries, including Germany, the United Kingdom, the Netherlands, Belgium, Portugal, and Switzerland, receive smaller yet still meaningful shares, each ranging between 1% and 3%. The remaining countries — comprising several EU member states and international partners such as Japan and the United States — receive much smaller shares, below 1%. This distribution highlights the central role of a few key players in the ITER supply chain, while also pointing to potential opportunities for broader engagement across the partnership.

### 3.1.2 Work package distribution

**Figure 4. Work package distribution of F4E contract payments (%)**

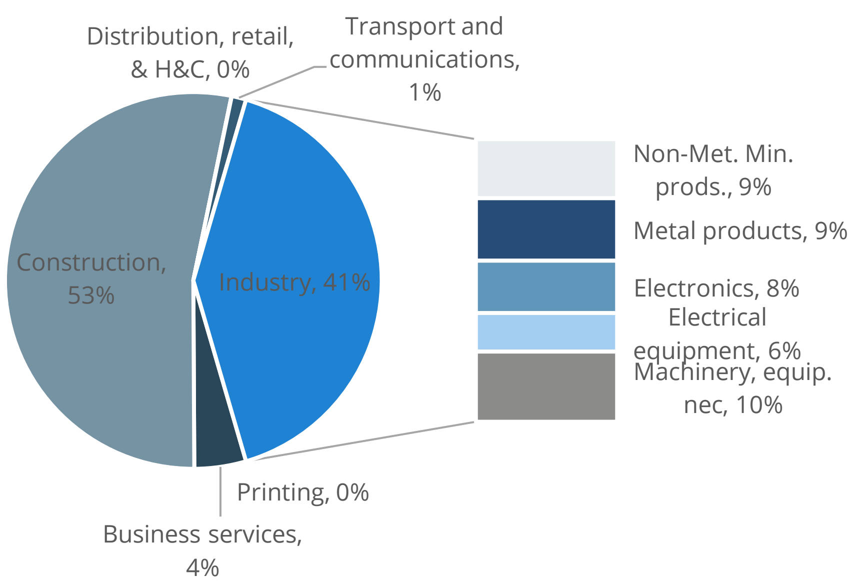



Source: Cambridge Econometrics (based on F4E data)

The pie chart above illustrates the allocation of F4E's contract spending across its main programmes. The largest share, 53%, is directed to the Buildings, Infrastructure, and Power Supplies Programme. The Magnet and Blanket Programmes follow, each accounting for 9%, while the Vacuum Vessel represents 7%. The remaining is distributed among other programmes. Overall, the chart highlights the significant portion of F4E's budget dedicated to construction, the vessel, and its core components.

### 3.1.3 Economic sector distribution

**Figure 5. Economic sector distribution of F4E contract payments (%)**




Source: Cambridge Econometrics (based on F4E data)

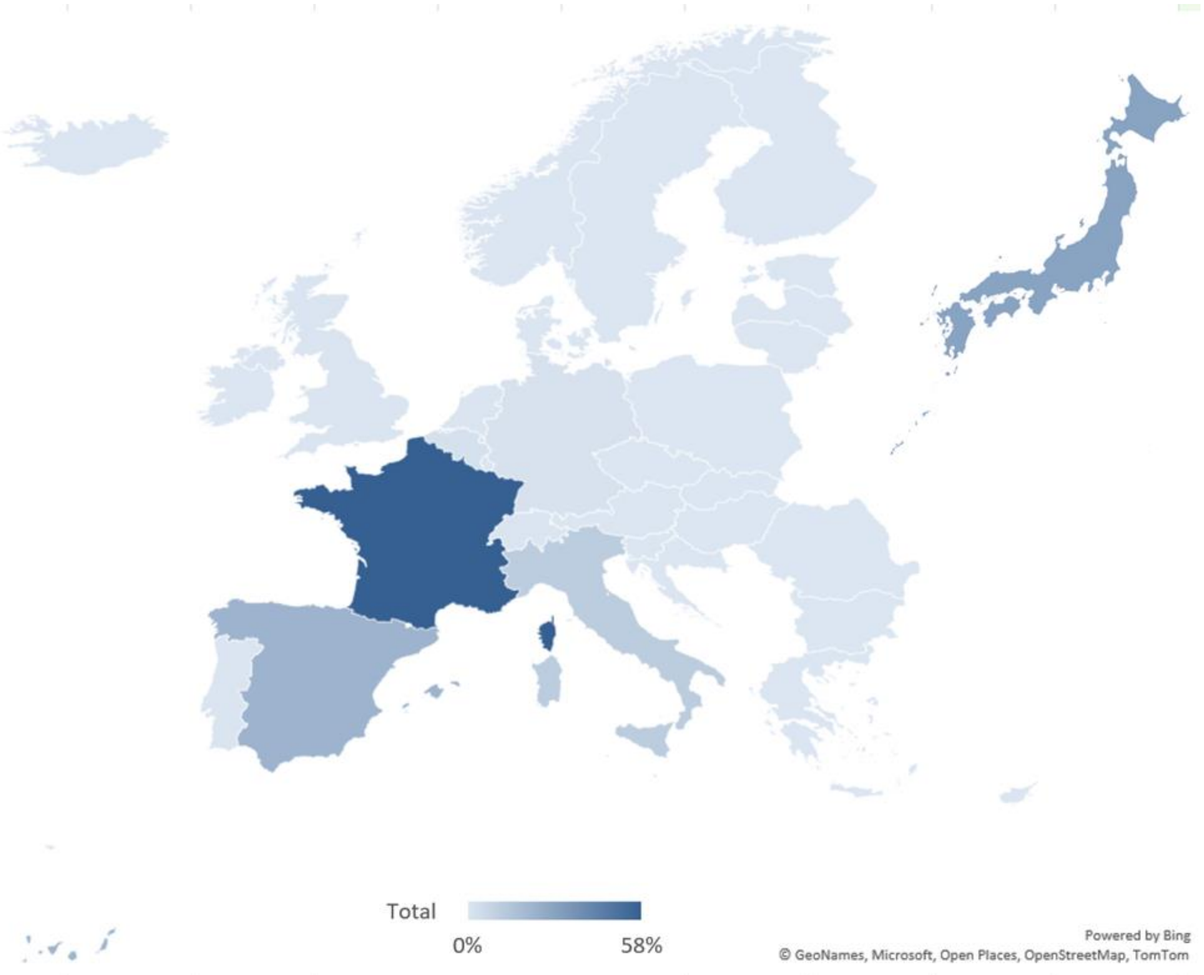
The distribution of F4E project contract expenditures from 2018 to 2024 reveals a strong concentration in a limited number of key sectors. Construction represents the largest share at 53%, followed by Industry at 41%. Within the industry segment, the most significant contributors are Machinery and Equipment (25%), Metal Products (22%), and Non-metallic Mineral Products (21%). Other sectors, such as Business Services (4%) and Transport and Communications (1%), play a more limited role. This distribution underscores the project's heavy reliance on physical infrastructure and specialised industrial inputs.

## 3.2 Analysis of other expenditure data

The macro-economic impact analysis considers not only the in-kind payments (proxied by the contract data) analysed in the previous section (from 2018 to 2024) but also all other payment types in this same period (this encompasses all other F4E expenditure categories beyond "F4E in-kind", such as 'F4E cash to IO', 'F4E administrative expenditures', 'F4E other expenditures', 'European Commission project administrative expenditures' and 'cash to Japan'). This encompasses a further **EUR 2.5 billion** (in 2024 prices) **of spending**.

### 3.2.1 Geographical distribution

**Figure 6. Geographical distribution of other F4E expenditure (%)**

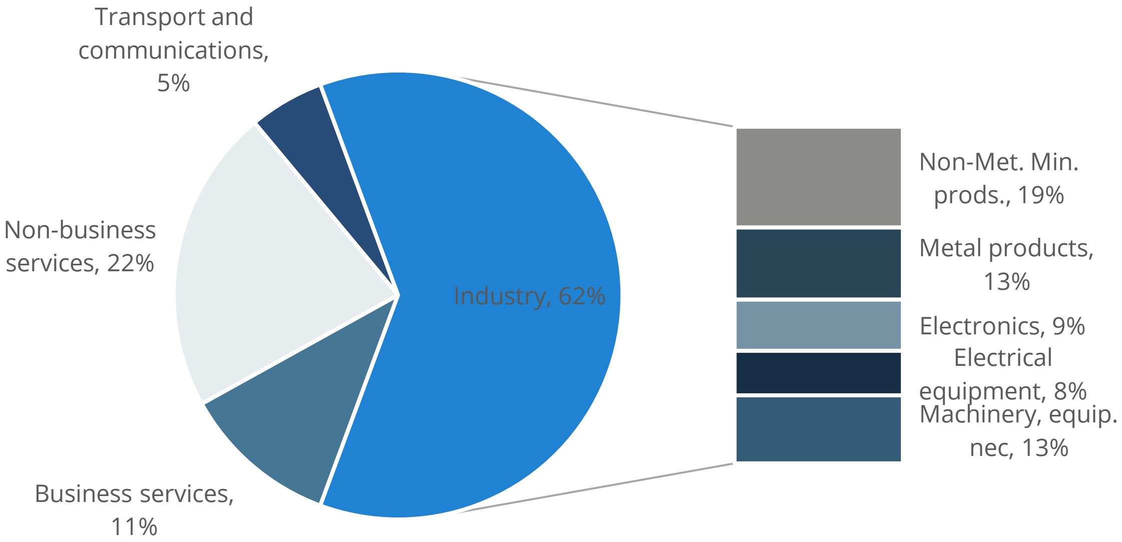



Source: Cambridge Econometrics (based on F4E data)

From 2018 to 2024, the geographical distribution of F4E expenditures under all categories outside "F4E in-kind" shows a highly concentrated pattern. **France accounts for the majority of the spending, with 58% of the total, followed by Spain at 22% and Italy at 10%.** Japan and Belgium account for 5% and 2% respectively, while Germany and the United Kingdom represent 1% and 5%. All other countries, including several EU member states and international partners account for either zero or negligible (less than 1%) shares in F4E "Other" expenditures. Overall, the map highlights the strong geographical concentration of these expenditures, even among EU member states.

### 3.2.2 Economic sector distribution

**Figure 7. Sector distribution of other F4E expenditure (%)**



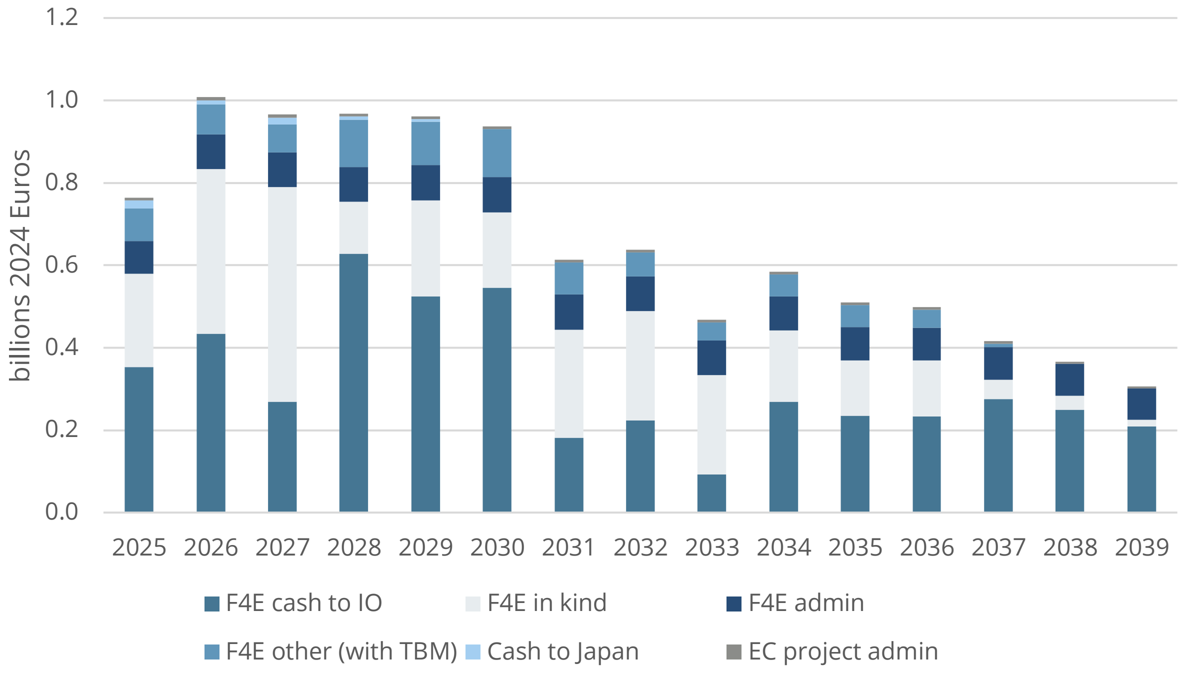

Source: Cambridge Econometrics (based on F4E data)

The pie chart above illustrates the sectoral distribution of F4E expenditures under all categories outside "F4E in-kind" within the 2018 to 2024 period. The majority of these expenditures, 62%, are allocated to the industry sector, underscoring its central role in supporting ITER-related activities. Within this sector, non-metallic mineral products, metal products, and machinery and equipment represent the largest shares, accounting for 19%, 13%, and 13% respectively. Electronics and electrical equipment also contribute significantly, with 9% and 8% of industry-related spending. Non-business services account for 22% of total "Other" expenditures, reflecting a substantial contribution from sectors such as public administration. Business services represent 11%, while transport and communications make up the remaining 5 percent. This distribution highlights the project's strong industrial orientation, complemented by support from various service sectors.

## 3.3 Analysis of future payments

Updated projections of future F4E payment appropriations are expected to be released in a European Commission Staff Working Paper after the study's conclusion. Therefore, the payment appropriation projections used in the forward-looking impact analysis were the best available at the time of writing and were validated with F4E staff. The data by category is disaggregated by country and sector, drawing upon the previously mentioned breakdowns of F4E spending by category, contract data from 2018 to 2024, and the methodological assumptions outlined in Annex 4. This approach provides a detailed forecast of how F4E payment appropriations will be distributed across countries and sectors over the period 2025-2039.

**Figure 8. Distribution of F4E projected expenditure by category (billion 2024 Euros)**




Source: F4E and European Commission data compiled by Cambridge Econometrics

# 4 RESULTS OF F4E IMPACTS

## 4.1 What are the macroeconomic effects of F4E's activities on the EU economy, particularly in terms of gross value added (GVA) and job creation?

The macroeconomic impact of F4E-related spending on the EU27 and Switzerland over the 2018–2024 period, as well as potential future impacts for 2025–2039, has been quantitatively assessed using the E3ME model (see Annex 3 for details). The analysis focuses on GVA and employment impacts across three scenarios, each compared against the modelling Baseline. The Baseline and two of these scenarios are consistent with those present in the 2018 study[8], while an additional scenario (the Tax Reduction scenario) has been introduced to extend the analysis. Results are reported as the absolute difference between the baseline and each scenario. GVA impacts are expressed in million 2024 Euros, and employment impacts in thousands of people. The modelling captures not just the direct effects of F4E-related spending but also its indirect[9] and induced effects[10], which are modelled within the E3ME framework of supply chains and consumption accounts.

### 4.1.1 Backward-looking estimates

**The macro-economic impact analysis indicates that between 2018 to 2024 F4E-related spending has generated positive outcomes for Gross Value Added (GVA) and employment** – an estimated EUR 5.95 billion in gross value added and creating roughly 39,000 job-years – relative to the Gross Impact scenario (i.e. a world in which the investments had not happened). The timing of the largest GVA impacts is observed when the highest levels of investments are made.

**Table 2. 2018-2024 Cumulative impact on GVA and employment (comparing baseline to scenarios)**

| SCENARIO | GVA | EMPLOYMENT |
|---|---|---|
| Baseline vs Gross Impact scenario | +EUR 5.95 billion | +39,000 job-years |
| Baseline vs Net impact 1: Tax reduction scenario | +EUR 3.95 billion | +16,800 job-years |

[8] In 2017, the European Commission assigned Trinomics and Cambridge Econometrics to evaluate the impacts of the European contribution to ITER through F4E's activities for the period 2008 to mid-2017. This study analysed F4E spending and estimated its economic impact in terms of Gross Value Added and job-years created by using the E3ME economic model. The model was used to examine two scenarios: a counterfactual "non-ITER scenario" where ITER would not have existed, and an "alternative spending scenario" assuming the same amount was spent that corresponded to the collected data on F4E spending for ITER. In the alternative scenario, the amounts were allocated to the corresponding economic sectors. The modelling results of this study showed that F4E spending, compared to the no-spending scenario, has produced 34,000 job-years and almost EUR 4.8 billion in GVA over the period of 2008-2017. With a positive cumulative impact of EUR 132 million on GVA, the alternative spending scenario calculated that 5,800 job-years in non-business services were created over the similar period.

According to a subsequent study by LGI and IHS Markit (2020), the incremental GVA attributed to ITER on the EU economy from 2008 to 2019 amounted to EUR 1.7 billion. Over this period, ITER activities directly or indirectly supported nearly 29,500 jobs annually, with a peak observed in 2018 and 2019. Comparing these outcomes to an alternative spending scenario, all ITER-related expenditures in EU member countries from 2008 to 2019 yielded a net GVA benefit estimated at EUR 104 million, inclusive of direct, indirect, and induced effects. By the end of 2019, the net job creation peaked at 792 jobs, predominantly within the supply chain due to indirect impacts (770 jobs).

[9] Indirect effects are those that are indirectly caused by a shock through the interaction of a directly impacted sector with other sectors upstream it's supply chain.

[10] Induced effects are those caused by a shock as a consequence of higher or lower disposable income in an economy brought about through its direct and indirect effects.

| | | |
|---|---|---|
| Baseline vs Net impact 2: General Investment programme | +EUR 0.37 billion | +5,500 job-years |

Source: Cambridge Econometrics

The GVA multiplier, or return on investment, is defined as the ratio between the initial investment and the economic impact it generates. **Over the period 2018 to 2024, this multiplier is estimated to average 1.057. This means that for every euro spent by F4E, an additional 0.057 is created in the wider economy.** This result is consistent with findings from a previous study on the economic impact of F4E spending between 2008 and 2019, which reported a multiplier of 1.002[11]. Comparison with the previous study shows that overall, F4E spending demonstrates a stable and positive impact on the economy.

**The economic and employment benefits, while positive overall, are unevenly distributed across countries, with France, Spain, and Italy seeing the greatest gains.** Compared to alternative scenarios where F4E funds are either saved or redirected, the direct investment in F4E (i.e. the baseline) has consistently delivered higher GVA and employment, though the level of benefit varies depending on the scenario assumptions and each country's participation in and receipts from the programme.

### 4.1.2 Gross value added

To evaluate the economic impact of F4E spending, we analyse gross value added (GVA) by sector. GVA, which is akin to GDP but at a sectoral level, includes labour, profits, and production taxes, excluding intermediate input purchases. All figures are expressed in 2024 prices.

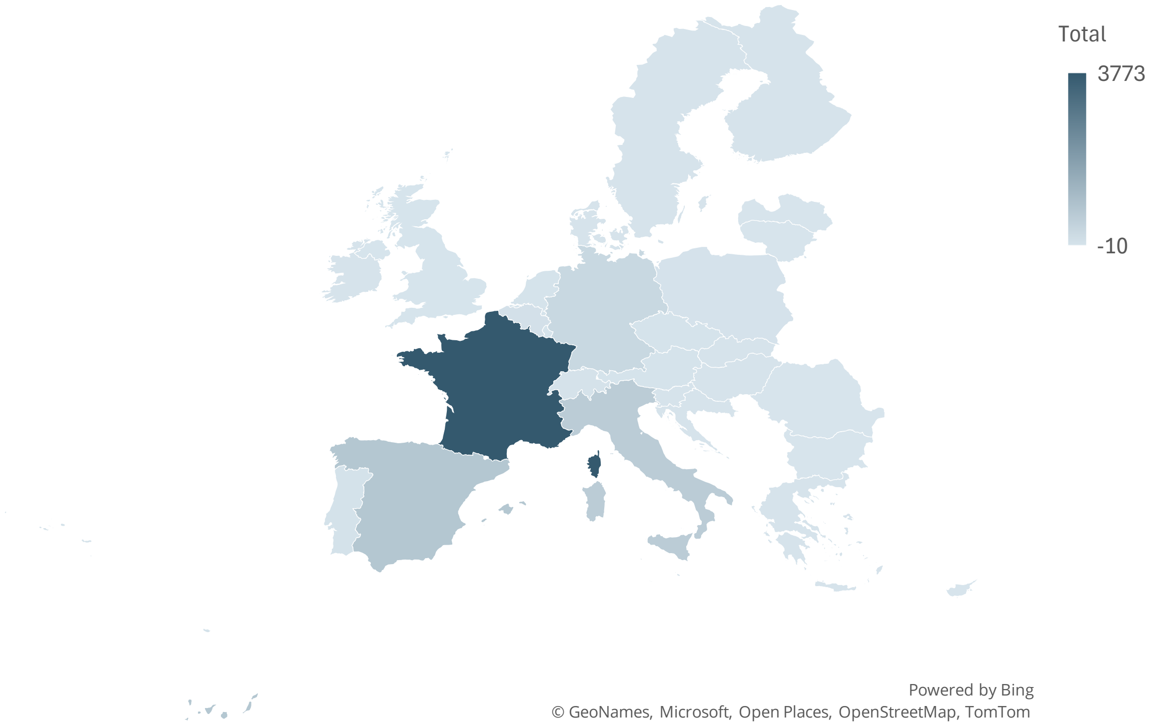
#### 4.1.2.1 Gross Impact scenario

Spending by F4E generated significant positive economic impacts compared with a no-spending scenario. In other words, comparing the results of the Baseline against those of the "Gross Impact" scenario, i.e., a situation where spending does not take occur and is instead saved, indicates that F4E expenditure produced overall positive economic impact in terms of GVA. The model estimates that, across the EU27-Swiss economy, **F4E spending is tied to the creation, in aggregate, of EUR 5.95 billion in gross value added over the 2018-2024 period.**

**A comparison of the GVA impact of F4E expenditure across countries** (EU27 member-states plus Switzerland) **shows that the impact is most pronounced in France**. This is due to the country's hosting of ITER in Cadarache, and thus receiving the lion's share of F4E spending, particularly in construction, as analysed in Section 3.1. France's total GVA impact due to F4E spending over the 2018-2024 period is close to EUR 3.8 billion, of which EUR 868 million on construction alone. This reflects the extensive construction efforts and resources allocated that surround the ITER project.

[11] Follow up study on the economic benefits of ITER and BA projects to EU industry, Publications Office, 2021, https://data.europa.eu/doi/10.2833/51838 (p.24)

### Figure 8. Gross Impact across the EU27+Switzerland: GVA by country (million 2024 EUR)




Source: Cambridge Econometrics

**Other than France, Spain, Italy, and Germany have been positively impacted in terms of GVA for F4E-related spending**. Each of these countries account for EUR 793, 648, and 328 million respectively. The remaining countries all have smaller GVA impacts. Spain and Belgium saw a higher impact in public administration sector's GVA. This is due to administration activities at F4E headquarters in Spain (Barcelona) and project administration work performed by the European Commission in Brussels.

#### 4.1.2.2 Tax Reduction scenario

The difference between the Baseline (reflecting actual historical F4E spending) and the "Tax Reduction" scenario is smaller than the difference observed between the Baseline and the Gross Impact scenario, as previously described. This results from differing assumptions in each scenario. The "Gross Impact" scenario assumes that funds used for F4E are saved, effectively removing them from the economy, while the "Tax Reduction scenario" assumes the saving is matched by a corresponding tax reduction.

**For the aggregate EU27-Swiss economy, suspending F4E spending alongside a proportional tax reduction leads to a GVA decrease of about EUR 4 billion**, relative to the baseline where F4E spending continues as it did historically (see Table 2). This suggests that, although a tax reduction proportional to F4E-related expenditure can partially mitigate the reduction in economic demand associated with the suspension of F4E spending, its effect on GVA does not surpass that of actual F4E spending. This pattern remains consistent throughout the modelling period.

**While the aggregate GVA level for the EU27 plus Switzerland in the Baseline exceeds that of the "Tax Reduction" scenario, some countries experience a net-negative difference in GVA between these two cases.** This outcome reflects the distinct contributions to and receipts from F4E expenditure across countries. In certain instances, the magnitude of tax reductions is sufficient to counterbalance the economic effects associated with the suspension of F4E spending, resulting in higher GVA levels under the Tax Reduction scenario compared to the Baseline (where F4E spending follows historical patterns).

**France again is the most positively affected country** when comparing the Baseline to the Tax Reduction scenario, exhibiting only a modest change in the impact relative to the Gross Impact assessment, and reporting a gain of EUR 3.6 billion over 2018-24. For Italy and Spain, the respective impacts are EUR 0.4 and 0.6 billion across the same period, representing a slightly smaller difference than that observed against the Gross Impact scenario.

**Germany, however, records a small net-negative GVA difference of EUR 354 million under the Baseline versus the "Tax Reduction" scenario over 2018-24.** This suggests that the increase in demand within Germany's consumer-oriented sectors, driven by tax reductions, surpasses the GVA decline - mainly in industrial segments - attributable to the suspension of F4E-related expenditures. This finding is largely due to Germany's comparatively higher contribution to F4E financing through Euratom, as part of the European Budget, relative to the funds allocated by F4E within Germany. Similarly, net-negative results are observed for the Netherlands, Poland, and Romania, though to a lesser extent, with estimated losses of approximately EUR 92, 58, and 59 million, respectively.

#### 4.1.2.3 General Investment Programme

**From 2018 to 2024, F4E expenditure generated a net positive contribution to GVA even when compared with an alternative spending scenario.** Among the three counterfactuals considered, the "General Investment Programme" scenario produced GVA results most similar to those of the Baseline scenario, in which F4E-related spending occurred as it did, although overall GVA levels were lower across the period. **In total, GVA creation in the Baseline scenario exceeded that of the "General Investment" scenario by about EUR 365 million across the EU27+Switzerland**. The higher GVA in the Baseline reflects the stimulus from F4E spending, which is comparable in magnitude to the alternative investment scenario but differs in its sectoral and geographic profile (see Annex 4 for more details on the processing and assumptions used). Small net-negative impacts for 2023 and 2024 suggest a shift in the direction of impacts over time driven by changes in the allocation of F4E expenditures.

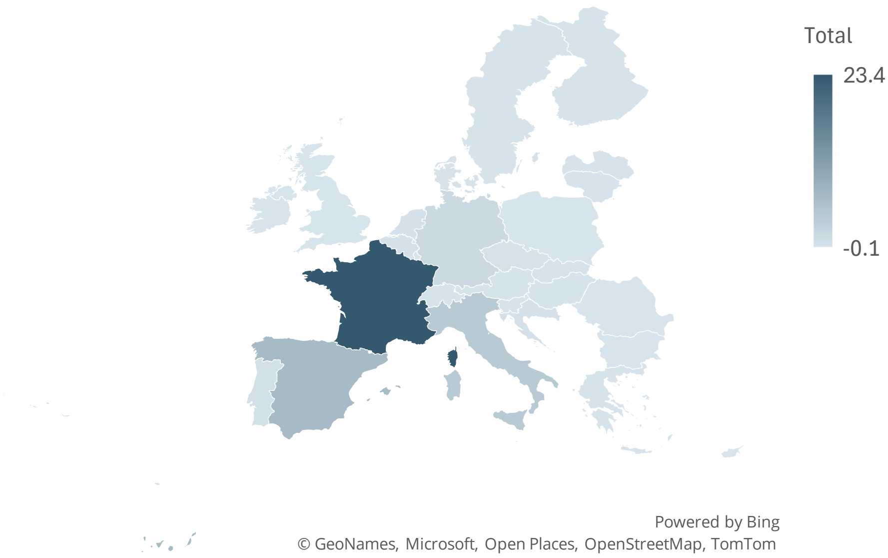
**France once again benefits the most from F4E spending, with an impact of EUR 2.2 billion over the 2018-24 period, though to a lesser extent.** Similarly, Spain and Italy, which are the second and third most positively impacted countries, also experience moderated effects, with benefits of EUR 0.5 and EUR 0.4 billion respectively. Except for Portugal, all other countries show, instead, higher GVA levels in the "General Investment Programme" scenario compared to the Baseline. This is due to the allocation of expenditure in the General Investment programme, which benefits these countries more than F4E's allocation. Germany, Poland, and Romania benefit the most from this alternative investment programme, with increases of EUR 0.5, 0.5, and 0.3 billion respectively.

### 4.1.3 Employment

#### 4.1.3.1 Gross Impact scenario

According to the model results, **F4E expenditures are associated with the creation of approximately 39,000 job-years across the EU27 and Switzerland over the 2018–2024 period**. This figure captures not only the direct employment effects of F4E-related activities but also the indirect impacts through supply chains and the induced effects generated by household consumption. The direct effects refer to the immediate economic impact generated by the F4E project within specific sectors. Indirect effects capture the ripple impact on other sectors that supply goods and services to the directly affected sectors, reflecting the inter-industry linkages in the economy. Finally, induced effects arise from the increased household income and consumption resulting from both direct and indirect effects, as workers and suppliers spend their earnings on goods and services, further stimulating economic activity across various sectors.

**Figure 9. Gross Impact across the EU27+Switzerland: Employment by country (Thousands of jobs)**




Source: Cambridge Econometrics

The map illustrates the geographical distribution of F4E expenditures' impact on employment across EU countries between 2018 and 2024 (in aggregate job-years). **France stands out with the darkest shade, indicating the highest employment gains - up to 23.4 thousand job-years** - reflecting its role as the host country for the ITER project. Spain, Italy and Germany follow with an increase of respectively 6.8, 4.4 and 1,8 thousand job-years across the period. In contrast, all other European countries do not experience much positive effect of F4E expenditures with less than one thousand job-years created across 2018-2024. Only three countries, Ireland, Bulgaria, and Romania experience a slightly negative impact from F4E expenditures. Overall, the map underscores a heterogenous impact of F4E expenditures across EU countries and Switzerland, mostly benefitting to France, Spain, Italy and Germany.

#### 4.1.3.2 Tax Reduction scenario

**Compared to the "Tax Reduction" scenario, F4E expenditures are estimated to have generated 16.8 thousand additional job-years over 2018-24**, approximately half the employment impact observed in the Gross Impact scenario. This discrepancy arises from the differing assumptions underlying each model. The Gross Impact scenario treats the funds allocated to F4E as entirely saved, removing them from the economy and treating them as a leakage. In contrast, the Tax Reduction scenario assumes that reductions in government spending are matched by equivalent tax cuts, thereby preserving household or business spending capacity. As a result, the Tax Reduction scenario yields a more conservative estimate of employment gains.

**France again stands out with the highest employment gain, recording 18.5 thousand additional job-years, reflecting its central role as host of the ITER project. Spain and Italy also show notable impacts,** with 3 and 2.7 thousand additional job-years created, respectively. Other countries see little or even negative effects. A key difference from the "Gross Impact" scenario is that 23 out of 28 countries experience a negative employment impact from F4E spending, if compared to tax reductions. While the overall effect of F4E expenditures on employment remains positive over time, the benefits are unevenly distributed; only five member states see a positive return in terms of job creation, with the majority of gains concentrated in France, Spain, and Italy.

#### 4.1.3.3 General Investment Programme scenario

**Compared to the "General Investment Programme" scenario, F4E expenditures are estimated to have generated 5.5 thousand additional job-years,** approximately a third of the employment impact observed in the "Tax Reduction" scenario. This discrepancy arises from the differing assumptions underlying each scenario. The "Tax Reduction" scenario assumes that reductions in government spending are matched by equivalent tax cuts, thereby preserving household or business spending capacity. In the "General Investment Programme" scenario, the saved budget from F4E expenditures is instead reinvested into a general investment programme. As a result, the employment impact is still positive yet smaller when compared to the "General Investment Programme" scenario.

France again stands out with 16.2 thousand additional job-years created, compared to a more general investment programme. Spain and Italy follow at a distance, with positive impacts of 3.8 and 2.8 thousand additional job-years, respectively. **Similarly to the previous scenario is that, aside from France, Spain, and Italy, all other countries experience either negligible or negative employment effects from F4E expenditures.** This is particularly striking in the case of Poland, which, according to the analysis, would have gained 4.6 thousand job-years between 2018 and 2024 in the "General Investment Programme" scenario. Similar, albeit smaller, negative impacts from F4E spending compared to a more general investment programme are observed in Romania (-2.8 thousand job-years), the Czech Republic (-1.5 thousand), and Germany (-1.4 thousand).

### 4.1.4 Forward-looking estimates

Similar results are projected for forecasted F4E expenditures. Over the 2025 to 2039 period, F4E is expected to generate positive impacts on both GVA and employment compared with a no- spending scenario, contributing an estimated EUR 9.88 billion in GVA and 67,400 job-years. The time profile of economic effects closely follows the spending schedule, while the distribution of economic gains is uneven, with countries geographically closer to the host, France, and receiving most of the investment, generally reaping greater benefits.

**Table 3: 2025-2039 Cumulative impact on GVA and employment (comparing baseline to scenarios)**

| SCENARIO | GVA | EMPLOYMENT |
|---|---|---|
| Baseline vs Gross Impact scenario | +EUR 9.88 billion | +67,400 job-years |
| Baseline vs Net impact 1: Tax reduction scenario | +EUR 3.67 billion | +8,500 job-years |
| Baseline vs Net impact 2: General Investment programme | -EUR 0.99 billion | -12,700 job-years |

Source: Cambridge Econometrics

When comparing to the "Tax Reduction" scenario, the net impact is still visibly positive, generating EUR 3.67 billion in GVA extra and 8,500 additional job-years, across the period (2025-2039). France, Spain, and Italy again emerge as key beneficiaries, while some other countries (e.g. Germany) may see a small net-negative GVA impact (i.e. a tax reduction could bring these individual countries a greater economic benefit in terms of GVA) depending on the expected share of F4E spending being investment in their economy.

When comparing the effect of F4E expenditures to a similar amount of spending on alternative investments (i.e. the "General Investment" scenario), F4E spending is projected to yield a small net-negative impact (cumulative, 2025-2039) of less than EUR 1 billion and about 12,700 fewer job-yeas. The main reason for this difference lies in the allocation of investments. Under the "General Investment" scenario, investments are spread across a wider variety of countries and sectors, including some of the most productive and labour-intensive sectors in each member country, whereas F4E expenditures (and the resulting economic benefits) are more concentrated in specific countries and sectors.

These findings are broadly consistent with the 2018 impact study (with simulations only up to 2030) and the 2020 impact study (with simulations only up to 2035). The difference in the GVA and number of jobs between the Baseline and General Investment scenarios remain very small in each year, so it can be reasonably concluded that their overall economic effects are approximately the same over the projection period. The modest divergence from the results of the previous impact studies reflects updated input assumptions, including a higher share of spending in the constructions sector, and a longer time horizon (2039 instead of 2030 or 2035).

However, as was the case also in the 2018 study, the model results don't capture the additional impact of potential technological spin-offs or new business opportunities that may arise as a result of F4E activities, suggesting that the overall growth impact of F4E investment could be higher if the additional GVA attributed to spin-offs and the subsequent investment this may generate is taken into account. Furthermore, the longer-term objectives of F4E would not be achieved in a "General Investment" programme.

## 4.2 Are there industries or sectors that have benefited from F4E's activities and those that could still benefit from it?

### 4.2.1 Backward-looking estimates

The Baseline (vs Gross Impact) scenario demonstrates that **the benefits of F4E expenditures are strongly concentrated in a handful of sectors - primarily Industry, Business Services, and Construction** - which together account for approximately 72% of the total gross value added (GVA) generated between 2018 and 2024. The positive results in both GVA and employment are primarily driven by the nature of F4E spending: substantial investment in advanced manufacturing, complex engineering, and physical infrastructure, all of which have strong multiplier effects through supply chains and support services. The procurement of specialised machinery and the need for advanced technical and professional services further amplify these impacts, creating a ripple effect in the broader economy. Indirect and induced effects are also evident, as increased activity in the core sectors stimulates demand in supporting sectors.

**Table 4. Impact on GVA (million 2024 EUR) by broad sector, 2018-2024**

| | Gross Impact scenario | Tax Reduction scenario | General Investment Programme scenario |
|---|---|---|---|
| Agriculture | 21 | -20 | -85 |
| Mining | 39 | 37 | 8 |
| Industry | 1770 | 1615 | 717 |
| Utilities | 129 | 80 | -21 |
| Construction | 1006 | 1064 | 719 |
| Distribution, retail, & H&C | 531 | -125 | -270 |
| Transport and communications | 367 | 231 | -3 |
| Business services | 1540 | 657 | -658 |
| Non-business services | 552 | 415 | -42 |

Source: Cambridge Econometrics

**In terms of GVA, "Industry" leads with a cumulative impact of EUR 1.77 billion, followed by "Business Services" (EUR 1.54 billion) and "Construction" (EUR 1.01 billion) over the period.** The "Industry" sector's gains are driven by both basic and advanced manufacturing, including the production of machinery, electrical equipment, and fabricated metal products—sectors directly involved in the supply and installation of ITER's complex components. "Business Services" is bolstered mainly by legal, accounting, architectural, and engineering activities, which support the technical, regulatory, and administrative dimensions of the project. Construction's substantial GVA reflects the capital-intensive nature of building and assembling the ITER facility.

**Employment effects mirror the GVA effects, with the highest job creation in Industry, Construction, and Business Services.** Compared with the "Gross Impact" scenario, job creation peaked at around additional 6,900 additional jobs in 2022, before gradually declining as construction activity tapered (see Figure below). The Construction sector experienced the largest employment growth during the project's peak building years, while Industry maintained a consistently strong contribution to jobs throughout the period. Business Services saw a notable rise in employment as the project shifted towards more service-oriented activities in later years. Job creation in other sectors, such as Distribution, Retail, Hospitality, Agriculture, and Mining, was more modest.

**Compared with the "Tax Reduction" scenario, F4E spending generated around 2,500 additional jobs per year,** peaking modestly in 2022 before slightly declining. Job creation was strongest in Construction, Industry, and Business Services, broadly mirroring the "Gross Impact" scenario. However, in this scenario comparison some sectors experienced net job losses - most notably Distribution, Retail, and Hospitality. This underscores two insights: first, F4E expenditures still yield greater employment benefits than an equivalent budget used for tax reductions; and second, the employment impact is not uniformly positive across all sectors. For instance, the Distribution sector appears to be more negatively affected under this scenario than it would have been under a tax reduction approach. A likely explanation is that the Distribution and retail sector activity is highly dependent on the level of taxes: lower taxes boost the distribution and retail activity, which in turn increases employment in the sector.

**Figure 10. Gross Impact across EU27+Switzerland: Employment by broad-sector (Thousands of jobs)**

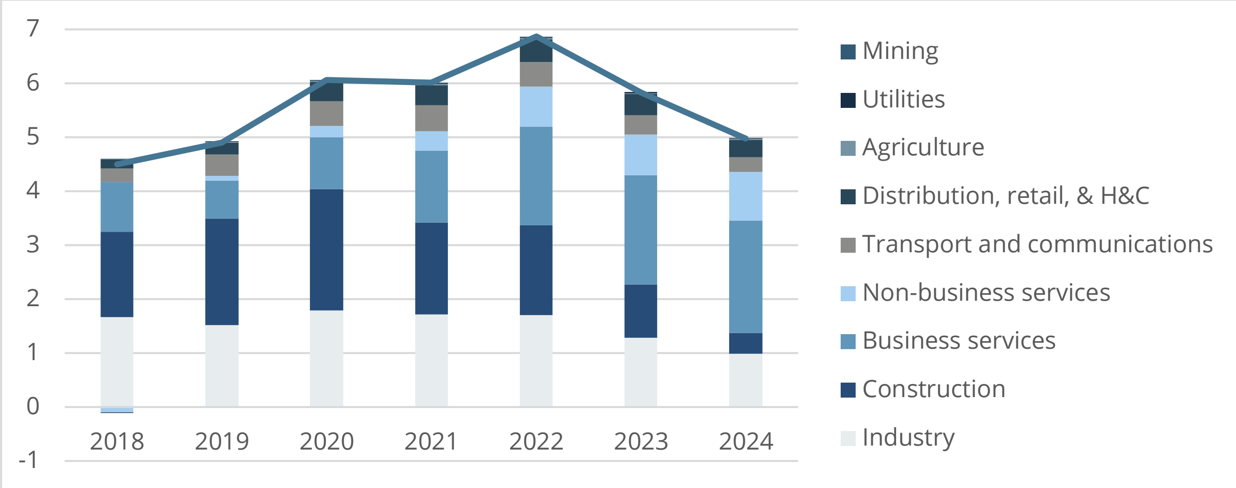
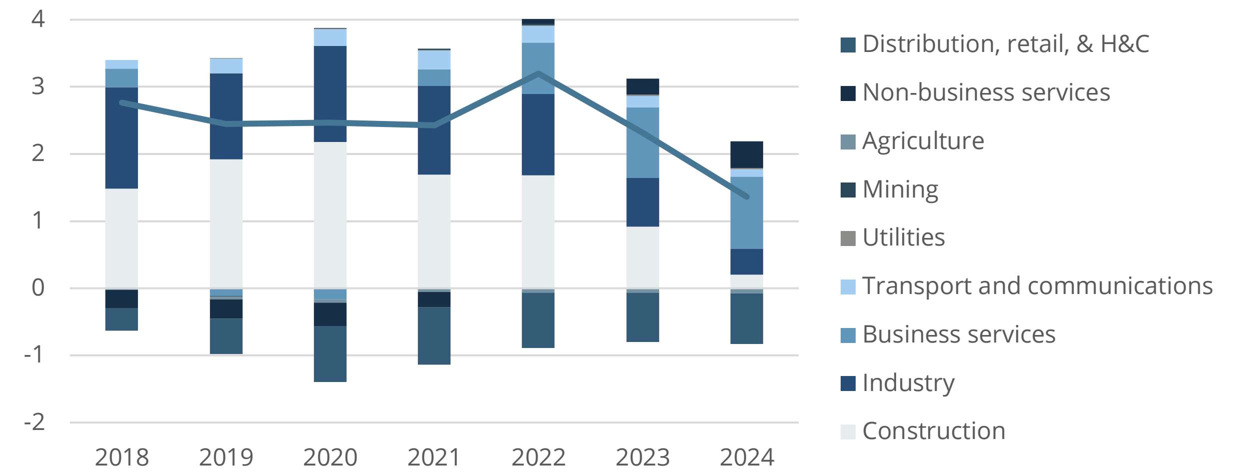
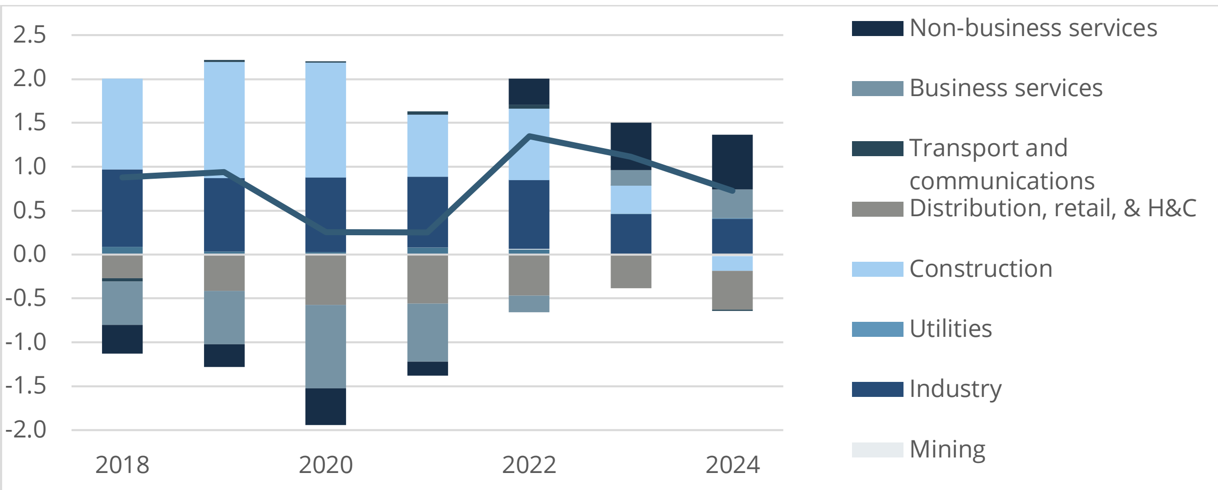



**Figure 11. Net Impact (Tax Reduction) across EU27+Switzerland: Employment by broad-sector (Thousands of jobs)**




Source: Cambridge Econometrics

**Figure 12. Net Impact (General Investment Programme) across EU27+Switzerland: Employment by broad sector (Thousands of jobs)**




Source: Cambridge Econometrics

**Even when compared with the "General Investment Programme" scenario, the overall economic effect of F4E spending was net-positive,** generating around 1,000 additional jobs annually. However, the sectoral impact diverges from that of a general investment programme. Between 2018 and 2022, F4E expenditures primarily benefit the Construction and Industry sectors, with gains of 5.2 and 4.1 thousand job-years respectively, reflecting the construction-intensive phase of the project. This trend changes in 2023, as extra job creation in the Construction sector starts to taper somewhat and net job-creation in business and non-business services becomes stronger. The net-positive employment impact in the Industry sector is consistent, generating between 400 and 900 job-years annually and underscoring the strong industrial orientation of the ITER project under various scenario assumptions.

**In summary, the modelling highlights the significant benefits of F4E activities in terms of GVA and employment,** with the most substantial gains realised in sectors directly linked to the construction and operation of ITER. The sectoral concentration of these benefits underscores the project's dependence on advanced industrial capabilities and highly skilled professional services, which act as primary drivers of the observed positive economic outcomes.

A more detailed discussion of the GVA impacts across sectors is included in Annex 5.

### 4.2.2 Forward-looking estimates

Similar results are projected for the F4E expenditures between 2025 and 2039. The economic impact is particularly pronounced in Business Services, Industry and Construction, reflecting the project's strong emphasis on professional, manufacturing, and infrastructure activities. These benefits peak around 2030, with job creation gradually declining thereafter as the project transitions from construction to a longer-term operational phase. The employment impact is most pronounced in countries such as France, Spain, Italy, and Germany, reflecting the project's sectoral and geographical focus.

**Table 5: Impact on GVA (million 2024 EUR) by broad sector, 2025-2039**

| | Gross Impact scenario | Tax Reduction scenario | General Investment Programme scenario |
|---|---|---|---|
| Agriculture | 54 | -56 | -156 |
| Mining | 62 | 55 | 21 |
| Industry | 2318 | 1740 | 643 |
| Utilities | 339 | 147 | 68 |
| Construction | 886 | 762 | 222 |
| Distribution, retail, & H&C | 941 | -698 | -809 |
| Transport and communications | 443 | 57 | -303 |
| Business services | 3597 | 1038 | -823 |
| Non-business services | 1237 | 620 | 151 |

Source: Cambridge Econometrics

F4E's investment focus is stronger on construction and industry than what is assumed in the "General Investment" scenario, leading to lower levels of additional GVA in certain years, as these sectors use a high proportion of intermediate outputs, and therefore have lower levels of value added. Later in the simulation period, investment in business services and non-business services sectors become more important and GVA levels in these sectors are closer to those of the levels in the "General Investment" scenario, with similar trends for employment figures.

**Table 6: Impact on employment (Thousands of job-years) by broad sector, 2025-2039**

| | Gross Impact scenario | Tax Reduction scenario | General Investment Programme scenario |
|---|---|---|---|
| Agriculture | 0 | -0.5 | 0.4 |
| Mining | 0.5 | 0.4 | 0 |
| Industry | 10.4 | 5.3 | 0.9 |
| Utilities | 0.7 | 0.6 | 0.2 |
| Construction | 9.3 | 6.1 | 1.6 |
| Distribution, retail, & H&C | 8.3 | -10.6 | -6.2 |
| Transport and communications | 1.8 | -0.3 | -1.6 |
| Business services | 20.7 | 0.4 | -5.7 |
| Non-business services | 15.7 | 7 | -2.3 |

Source: Cambridge Econometrics

## 4.3 What is the impact of F4E activities in fostering competitiveness of industries directly or indirectly involved in fusion?

### 4.3.1 Firm-level learning impacts

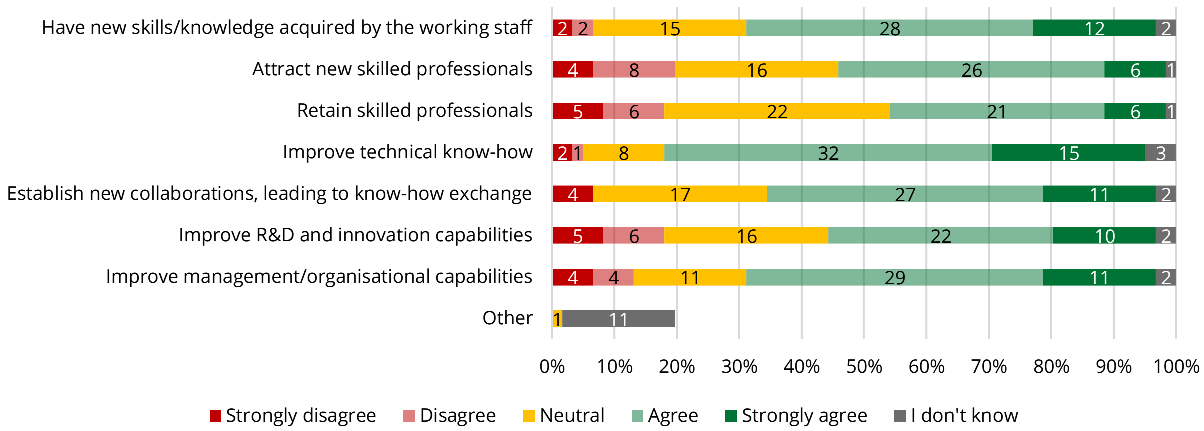
**F4E procurement generated significant learning outcomes, with firms reporting widespread skill development and enhanced technical know-how**. Survey results show that 66% of firms indicated their staff gained new skills or knowledge through F4E collaboration, while 77% noted improvements in technical know-how (see Figure 13). These findings are supported by insights from supplier interviews, where some companies emphasised how ITER's technological complexity pushed them to develop advanced capabilities, ranging from new competencies in magnet handling and specialised welding processes to the construction of dedicated facilities, ultimately strengthening their know-how and internal processes.

**Knowledge exchange through collaborative partnerships emerged as a key driver of capability development.** According to the survey, 62% of respondents established new collaborations that facilitated knowledge transfer (see Figure 13). One interviewed company specifically explained how feedback and insights gained from partners helped them better understand requirements, thus leading to significant learning and greater familiarity with complex processes. This collaborative knowledge sharing appears to create a multiplier effect, as learning occurs not only through direct interaction with F4E but also through peer-to-peer exchanges that broaden overall project understanding and execution capacity.

**While collaboration with F4E strengthened firms' internal capabilities, impacts on talent attraction and retention were more mixed, reflecting wider structural challenges in the fusion labour marker**. Survey results indicate more modest, though still meaningful, effects in these areas, with 54% of respondents reporting improved talent attraction and 43% noting better retention rates (see Figure 13). A couple of interviews suggested some reasons that might contribute to these lower figures. One supplier highlighted the difficulty that private companies face in competing with the attractive salaries and conditions offered by public institutions like F4E itself, ILOs, or particle accelerators, with some firms experiencing a negative impact as their trained employees moved to these organisations. In addition, an ILO representative pointed to a broader shortage of qualified workforce in the fusion sector, which inherently limits firms' ability to attract talent.

**Learning effects also extended beyond technical capabilities to encompass valuable institutional knowledge of public sector engagement**. Interviews with F4E supply chain actors indicate that contractors have gained expertise in working with public organisations, in particular regarding procurement processes. This institutional learning represents a strategic asset that can help firms to better navigate complex public-private partnerships in high-technology sectors.

**Figure 13. Learning effects of F4E procurements**




Note: N=61

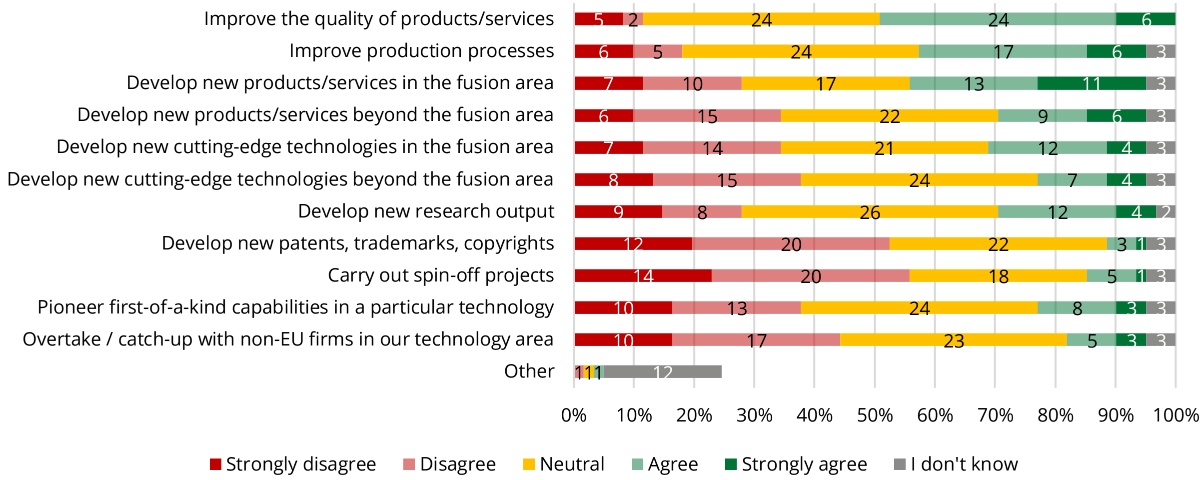
Source: CSIL

## 4.3.2 Knowledge and innovation impacts

**Innovation effects were reported less frequently than learning outcomes but remain meaningful. About 49% of firms reported improvements to products or services, and 38% reported enhanced their production processes** (Figure 14). Evidence from interviews also suggests that innovation often took the form of technological adaptation and enhancement rather than the creation of entirely new technologies. For example, one interviewed company reported adapting their existing technology to suit the fusion First-Of-A-Kind (FOAK) project requirements. Similarly, another company innovated in existing technologies like welding, non-destructive examination, and metrology by investing in state-of-the-art equipment, including unique portal machines in the EU, and new software. More advanced innovation outcomes, such as the development of cutting-edge technologies (27% in fusion; 18% elsewhere), formal IP (7%), or spin-offs creation (10%), were concentrated among a smaller group of suppliers (Figure 14).

**Product innovation was predominantly fusion-focused, but collaboration with F4E also enabled diversification into other sectors**. Survey results show that 39% of respondent firms developed new offerings related to fusion (39%), while 25% innovated beyond the fusion domain (Figure 14). These outcomes suggest that product innovation has been more prevalent in areas directly related to F4E activities, although a smaller subset of firms has also used the collaboration as a basis for diversification into other markets or technologies. Interviews with F4E supply chain actors confirm the latter impact, with many companies reporting that working for/with F4E has opened up opportunities in other sectors, including in fission (e.g., SMR and AMR technologies), medical applications (e.g., technologies related to magnets like prototherapy, ionotherapy), pharmaceuticals and aerospace sector.

### Figure 14. Innovation effects of F4E procurements




Note: N=61

Source: CSIL

**The econometric mediation analysis[14] shows that the quality of firms' relationships with F4E plays a pivotal role in shaping innovation outcomes.** Suppliers who perceive such a relationship as well-structured and effectively managed are significantly more likely to report improvements in innovation performance. Specifically, a 10-percentage point increase in the perceived quality of procurement relationships is associated with a 4.2-percentage point increase in reported intermediate innovation outcomes (see further details in Annex 8). This suggests the importance of clear, well-structured, and collaborative engagement in enabling suppliers to innovate, whether through the development of new products or services, the strengthening of internal processes, or the capacity to generate patents and copyrights.

**Among the innovation effects, F4E meaningfully contributed to the development of new research outputs (publications)**. The bibliometric analysis identified a total of 1,648 publications that can be considered somehow related to F4E during the period from the establishment of the European agency in 2007 until 2024 (see solid line and filled area in dark blue in the figure below).[15,16] These were identified using a conservative approach, i.e. focusing only on publications that indicate F4E as an affiliation body or funding organisation, or explicitly mention F4E in the title, abstract or text. By including ITER/DEMO/BA-related publications authored by F4E suppliers[17] raises the total to 5,388 (see the dashed blue line and hatched area in the figure below), an upper-bound estimate given that not all outputs can be directly attributed to F4E (e.g., some may be linked to the work of other

[14] Based on 49 survey replies.

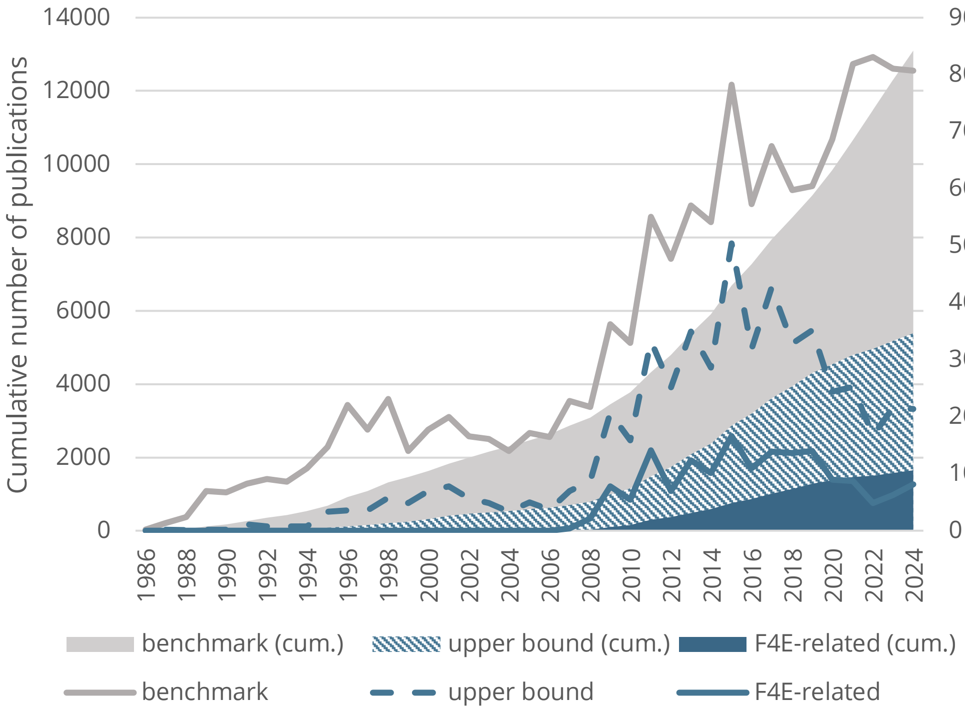
[15] F4E-related publications were identified searching on Lens.org for publications that were either funded by F4E, (co-)authored by F4E, or mentioned F4E in their full text. The retrieved publications were then manually revised to ensure that only relevant data were included before proceeding with the data analysis.

[16] Of these, 1,233 publications indicate F4E as an affiliation, 236 are funded by F4E, and an additional 179 mention F4E in the title, abstract, or full text.

[17] We considered F4E suppliers that received payment lines over the period 2018-2024.

domestic agencies or to the ITER Organisation itself). As a benchmark against which to compare the number of F4E-related publications, the analysis considers the broader body of publications related to ITER, DEMO, and the Broader Approach (see the grey line and shaded area in the figure below). Based on the conservative definition of F4E-related publications, **F4E has contributed to at least 16% of all ITER/BA/DEMO-related publications since its establishment**. **When publications from F4E suppliers are also considered, this share may reach 41%.** This range is consistent with F4E's central role in the project, as the agency is responsible for nearly half of Europe's overall contribution to ITER. F4E-related publications have generated an academic impact comparable to the broader body of ITER/BA/DEMO-related publications, with both averaging 17 citations per publication. Also, F4E-related publications involved 570 unique institutions, primarily universities, laboratories, and companies, with 77% co-authored across multiple affiliations[18], underlying F4E's role as a catalyst for international scientific cooperation in fusion research (detailed analysis available in Annex 10).

**Figure 15. Evolution in the cumulative and yearly number of ITER/DEMO/BA publications (grey) vs. F4E-related publications ranging from a minimum bound (solid blue line and area) to an upper bound (dashed blue line and hatched area)**




Source: CSIL based on Lens.org

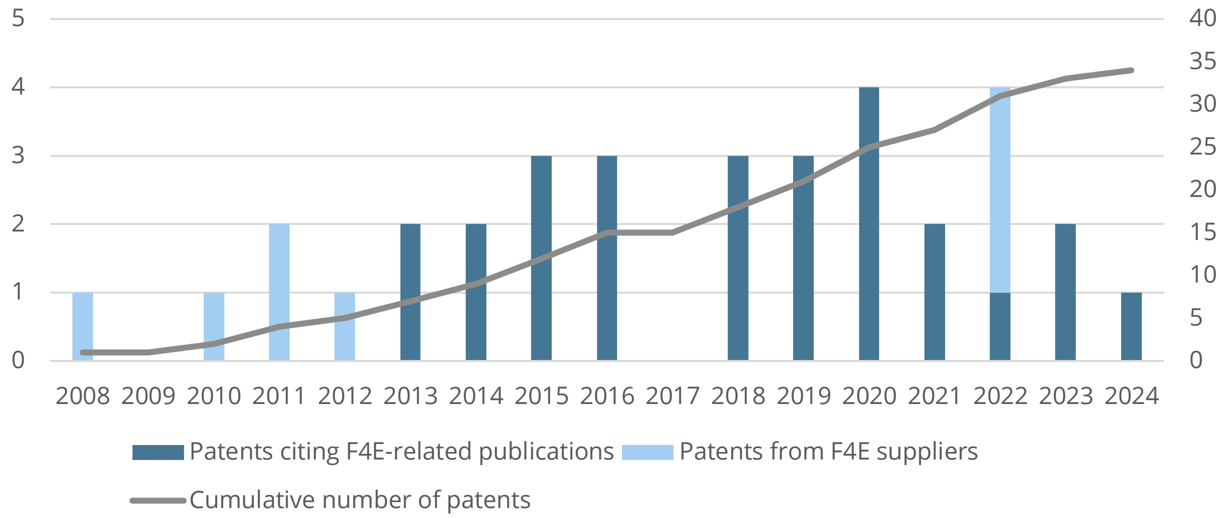
**Patent analysis confirmed that, among innovation effects, F4E's impact on patent activity is still limited**. Since the first F4E-related patent[19] filed in 2008 (it relates to a phase shifter and was

[18] As a note, F4E suppliers that contributed to F4E-related publications tend to collaborate exclusively within their group, rather than with external entities, thus establishing a sort of 'closed' collaboration network.

[19] F4E-related patents were identified as either patents that cite publications, that were either authored or funded by F4E, or patents filed by F4E suppliers that have an explicit reference to either F4E or its mandates (ITER/BA/DEMO). The retrieved patent data were then manually revised to ensure that only relevant data were included before proceeding with the data analysis.

filed by a F4E supplier), 33 additional distinct patent families[20] have been identified. While overall number of patents remain modest (see solid line in the figure below), it is possible to observe that patents citing F4E-related publications increased steadily from 2013, peaking in 2020. The trend from 2021 onwards may be partially attributed to the COVID-19 pandemic's impact on research timelines and the inherent lag in patent publications (see figure below). F4E-related patents span a diverse range of technological fields, especially mechanical and electrical engineering, reflecting the multidisciplinary nature of fusion. Applicants are internationally distributed, with most based outside the EU, this is primarily due to patents citing F4E-related publications which often involve international co-authors and generate global knowledge spillovers, while patents filed directly by F4E suppliers are all European-based. About one-third of these patent families received citations, confirming their knowledge spillover potential. Overall, F4E emerges not only as a coordinator of fusion-related procurement/manufacturing but also as a driver of collaborative research and innovation across high-tech sectors (see Annex 10 for further details).

**Figure 16. Evolution in the number of new patent families filed (2008-2024)**




Source: CSIL based on Lens.org

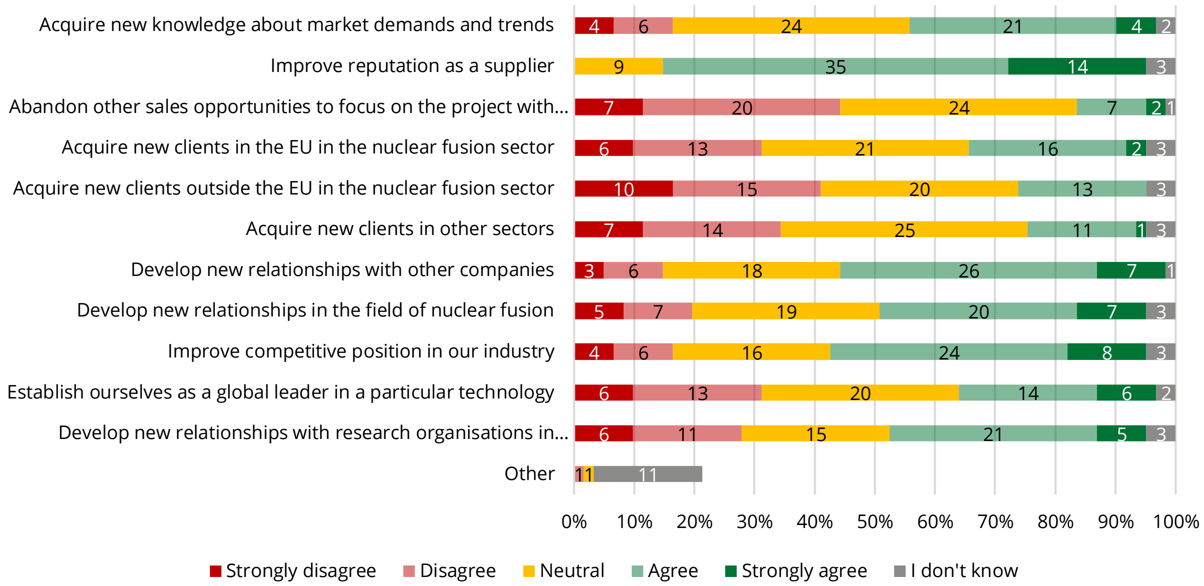
### 4.3.3 Firm-level market impacts

**In terms of market positioning, working with F4E strengthened firms' credibility and connections**, rather than leading to immediate commercial expansion (Figure 17). The most widely reported market effect was reputational: **80% of respondents said their visibility or credibility as suppliers improved thanks to F4E collaboration**. For example, one interviewed supplier indicated that their collaboration with F4E for the ITER project has strengthened their credibility as a supplier and served as a reference for securing contracts with organisations such as CERN and Siemens. Network benefits were also significant, with over half of respondents forming new relationships—54% with firms, 42% with research bodies, and 44% with fusion actors. Client acquisition was more modest: 29% reported gaining new clients within the EU fusion sector, and fewer did so outside the EU or in other domains. A smaller group (33%) reported achieving global leadership in a specific

[20] The present study uses patent families as unit of analysis to avoid double-counting. Whereas a patent application is a formal submission an applicant makes to a patent office to request legal protection for an invention, a patent family organises related patent applications from different countries that protect the same invention based on a shared "priority" application, often the first filed.

technology. For example, one interviewed supplier developed special welding processes (TZM into graphite, and Cu-Cr-Zr bonding to Cu-OFE and Tungsten), thus placing the company among the very few worldwide (estimated at no more than four to five) with such capabilities. In parallel, 41% of respondents gained valuable insights into market trends.

**Figure 17. Market effects of F4E procurements**

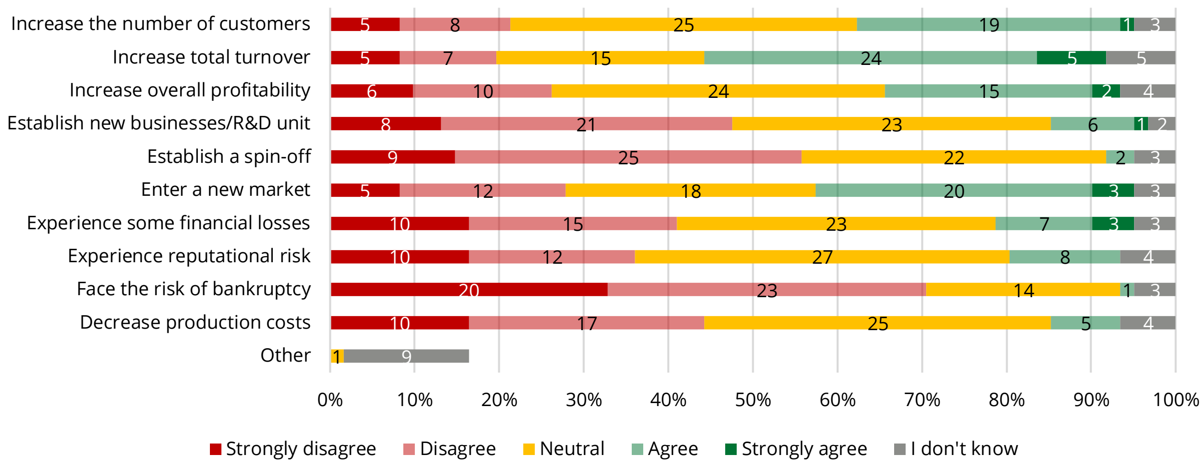



Note: N=61

### 4.3.4 Firm-level economic and workforce impacts

**Collaboration with F4E generated tangible economic gains for a notable share of firms** (Figure 18). Roughly half (47%) of survey respondents reported increased turnover, 28% noted higher profitability, and 33% expanded their customer base (see figure below), pointing to business growth linked to procurement. However, efficiency gains were limited, with only 8% reporting reduced production costs. Structural developments were more selective: 38% entered a new market, 12% created a new business line or R&D unit, and 3% launched a spin-off. While broad economic consolidation was common, more transformative changes such as diversification or new business creation were confined to fewer firms. Negative effects linked to procurement with F4E were relatively uncommon: only 16% reported financial losses, and 2% faced bankruptcy risk—suggesting that F4E procurement generally acts as a stabilising factor.

**Figure 18. Economic effects of F4E procurements**




Note: N=61

Source: CSIL

**Employment effects were moderate, with firms more likely to consolidate their workforce than expand it.** According to the survey results, 41% of firms reported growth in higher-skilled positions, while only 9% noted increases in lower-skilled roles, indicating a trend toward selective upskilling (Figure 20 under next section 4.3). Permanent employment increase in 28% of firms, and 32% saw growth in temporary staff. These patterns suggest that while F4E procurement contributes to workforce development, the effects tend to be incremental rather than indicative of widespread job creation.

Whereas the previous paragraphs show how suppliers perceive the outcomes of their participation in F4E procurement, the following ones provide the key findings on the counterfactual and an econometric mediation analysis[21]. These analyses help understand whether a measurable impact can be attributed to the relationship with F4E and the mechanisms through which it materialises.

**The results from the counterfactual analysis indicate that F4E contracts have a statistically significant and positive effect on employment**. More precisely, signing a contract with F4E is associated with a 10% increase in the number of employees, a result that is statistically significant at the 10% level of confidence (see table below). This result is obtained when the analysis considers a time window spanning one year before and two years after contract signature. Even extending the pre-treatment period to at least two years (instead of just one) does not alter the results, thereby reinforcing the robustness of the finding. **The mediation analysis, in turn, reveals that the positive impact of the relationship with F4E on suppliers' employment is at least partly mediated by intermediate outcomes** (see box below).

Both **the counterfactual analysis and the mediation analysis did not find a statistically significant effect on turnover or total assets within the observed period.** While no robust evidence has been found of an impact on turnover or total assets (see the last two columns in the table below), this does not necessarily mean there is no impact at all. The counterfactual analysis relies on a limited two-year post-contract observation window that might be insufficient to capture the full economic effects of F4E procurement relationships. The significant 10% employment increase

[21] Such analysis allows to understand how procurement features influence suppliers' intermediate and final outcomes, and if the former mediate the impact on the latter. See annex 8 for further details on the methodology.

demonstrates that firms are already responding to F4E contracts by scaling their human capital and organisational capacity. This suggests that suppliers may be building foundational capabilities, such as investing in skilled personnel and R&D capacity, before these translate into measurable financial outcomes.

### Table 7: Main results from the counterfactual analysis

| | Employment | Turnover | Total assets |
|---|---|---|---|
| Treated in *t* | 0.1045* (0.0828) | 0.1348 (0.1438) | 0.0708 (0.5630) |
| No. of treated observations | 53 | 48 | 54 |
| No. of unique controls | 286 | 289 | 314 |
| Mean n. of matches | 6.094 | 6.854 | 6.574 |

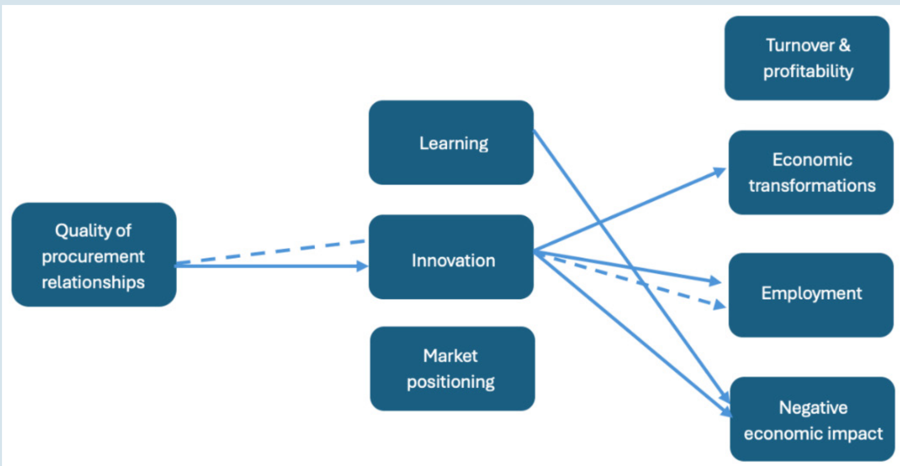
Note: Statistical significance is indicated by asterisks. A coefficient with one or more asterisks is statistically different from zero. The number of asterisks reflects the precision of the estimate: more asterisks indicate greater precision in measuring the effect. The numbers in parentheses beneath the coefficients represent standard errors, which help gauge how close the presented result might be to the true value. In this way, standard errors indicate the level of uncertainty in our estimates. Larger standard errors suggest less confidence in the results, potentially leading to estimates that are not statistically significant (i.e., without asterisks).

Source: authors' elaboration on F4E data matched with ORBIS data. Notes: Standard errors in parenthesis

### Box 1. Mediation analysis main results

The mediation analysis found a direct benefit of clear, effective and collaborative relationships with F4E on suppliers' employment outcomes, with a 10 percentage point improvement in the perceived quality of procurement relationships associated to a 4.1 percentage point increase in workforce expansion. The analysis also established that procurement relationship quality is directly linked to innovation intermediate outcomes (see *Knowledge and innovation impacts* on Section 4.3), and that these intermediate outcomes are themselves directly associated with final employment outcomes. To understand how these different forces interact, the analysis examined what happens when both variables related to F4E relationship quality and innovation are jointly considered as potential drivers of employment growth. The results showed that the direct impact of F4E relationship quality on workforce expansion diminished from 4.1 percentage points to a smaller, non-significant value. This attenuation coincides with a strong and positive association between innovation and employment growth. Taken together, these results suggests that part of the employment gains is not solely attributable to well managed relationships with F4E but is also mediated by the innovations that such engagement helps support and enables. The mediated path is illustrated through the dashed line in the figure below.

**Figure 1919. Detected relations among procurement features, intermediate and final outcomes**



Note: Solid lines denote independent direct effects. Dashed lines the detected mediation path.

Source: CSIL

Beyond the identification of the mediation channels, the analysis also offers insight into the broader role of innovation as an internal driver of final outcomes. Specifically, the results show that suppliers reporting innovation gains are systematically more likely to achieve structural economic transformations and, as already mentioned, workforce expansion (see solid lines linking innovation with economic transformations and employment in the figure below). At the same time, innovation appears to expose suppliers to higher levels of risk. Suppliers that innovate more extensively are also more likely to experience negative effects, such as financial losses, reputational risks, or even exposure to bankruptcy. These outcomes reflect the uncertainty and complexity often associated with technological development and organisational changes. In this context, innovation has an overall ambiguous effect: it may lead to long term growth as well as to short term vulnerabilities. Crucially, the quality of relationship with F4E appears to partly mitigate these risks (see the Annex 8 for further details).

Source: authors

### 4.3.5 Competitiveness impacts

**The SWOT analysis demonstrates that the work for F4E has made a significant contribution to maintaining and boosting EU industrial competitiveness**, especially through boosting innovation and reputation, and by helping firms to establish credibility as reliable, high-quality providers. There are significant opportunities in many fusion and related sectors that can still be taken advantage of in future, and the F4E contracts have helped EU position industry, but there remain a number of threats to this. Amongst the most relevant to F4E is the ongoing project pipeline, with EU firms identifying this as crucial to maintaining their knowledge, expertise and competitive edge.

**General views on the competitiveness of the EU fusion industry**

***Strengths***

- **F4E funded work on ITER[22] has helped EU firms establish themselves as leaders in many fusion technology areas:** by taking the largest share in ITER and this being spread across almost all technology areas the F4E funded work has provided EU firms with the experience and allowed them to develop and demonstrate the expertise which has established them amongst the global leaders in most fusion technologies[23].
- **F4E funded work on ITER has especially helped firms to boost their reputation and credibility – opening new markets and boosting competitiveness:** EU industry has not only boosted its expertise but the high profile and demanding nature of the work has boosted the reputation of EU firms that have worked on ITER. Many firms in the supply chain have noted how this boost to their credibility and reputation, has opened up new opportunities both inside and outside the fusion sector.

[22] And also other F4E funded work such as Broader Approach and in future IFMIF-DONES.

[23] SWOT analyses were carried out for 8 fusion technology and service groups: (1) Magnets and superconductors; (2) Vacuum Vessels; (3) Heating systems; (4) Cryoplant; (5) Blankets, tritium handling, divertors and first wall materials; (6) Remote handling and diagnostics; (7) Services (Engineering, design, safety, waste); (8) Construction and power supply infrastructure.

- **The EU has a world-leading research community with strong existing research-industry links:** EU research institutions are amongst the leading scientific institutions on fusion, providing in some areas a potential competitive advantage. In some technology areas research-industry partnerships have been boosted by F4E funding of ITER which has helped bring together consortia and/or encouraged this type of cooperation.

***Weaknesses***

- **Slow pace of ITER, and EU and Member State policy making:** delays to ITER and slow processes at EU and country level lead to inertia, lower confidence in fusion overall and the concerns of capacity of the EU to back its industry in a timely manner to take advantage of the opportunities.
- **Bureaucracy and 'heavy' processes mean the work for F4E is often not profitable:** firms across multiple sectors noted that the work for F4E is documentation and process heavy, more so than for their other clients. This adds costs to already complex, in many cases first-of-a-kind, projects, burdening EU firms.

***Opportunities***

- **New fusion initiatives, both public and private, promise significant growth for the fusion supply chain:** New publicly funded fusion-relevant devices in Europe include DTT and IFMIF-DONES, in the neighbourhood STEP (UK), and globally many more. Private fusion industry and start-ups are also ramping up investments with the most advanced building their next devices. These projects all contribute to a growing market for fusion, and an opportunity for EU industry.
- **Many fusion technologies have diverse applications beyond fusion, expanding the market opportunities for EU industry:** many opportunities are found in the adjacent energy sector (nuclear fission and others), but opportunities in the space, materials, chemicals, health and other sectors also exist. Entrepreneurial firms can take advantage of these broader market opportunities.

***Threats***

- **Emerging gap in project pipeline for EU industry:** in the coming years, as ITER assembly progresses then the pipeline of work for some industries will decline. Despite the opportunities listed above there is not a project equivalent to the size of ITER in the short-medium term pipeline. Any potential DEMO-equivalent effort may still be 10 years or more in the future. This gap that ITER will leave creates a problem for large parts of the EU fusion industry to sustain their knowledge, expertise and competitiveness.
- **Global competition is strong in every area, varying per technology, but especially from Japan, the United States, and China:** Industry is also well developed globally, EU firms face competition from Japanese manufacturers in nearly every technology, and from US firms in others. China remains opaque, it is clear that their fusion supply-chain industry is investing heavily and developing in support of their national programmes which provides a strong pipeline of work. China is highly likely to emerge as one of the main competitors to the EU fusion industry in the coming years.
- **Risks of breakthroughs in competing technologies or by firms in competing countries:** F4E funding and EU programmes are focused especially on ITER and the tokamak approach,

whereas many of the other fusion initiatives are looking at alternatives. There is a risk that breakthroughs in one of the alternatives could render irrelevant a large part of the fusion supply chain involved in ITER. This could also occur at firm level, if for example a firm could make a breakthrough in the manufacture of HTS magnets.

When looking at **specific technologies** or markets a few further observations can be made. Further details are presented in Annex 11 of this report.

- **Magnets and superconductors:** EU firms have a strong current position in magnet manufacturing, but are weak on superconductors with most manufacturing of HTS wire/tape happening elsewhere. Market opportunities are high in fusion and other industries but EU firms face strong competition, not least from start-ups such as Commonwealth Fusion Systems (CFS) which some have remarked is effectively a magnet firm (they have already sold magnets to another fusion start-up), and which can generate massive funding that EU firms cannot match. Similarly, but at smaller scale, Tokamak Energy in the UK.
- **Vacuum Vessels:** EU firms can be regarded as global leaders in this technology area with the work on ITER already leading to additional work. However, market opportunities in this area are more limited, and other countries do have their own capabilities. Especially China is likely to be a strong competitor.
- **Heating systems (Cyclotrons-Gyrotrons, Neutral Beam):** EU firms are well positioned in both supply chains but don't necessarily stand-out as leaders, for example there is only 1 cyclotron-gyrotron manufacturer in the EU (Thales). EU partnerships with the research community are notable in this group. Major competition in these sectors comes from Japan and Russia. There are some niche opportunities for these technologies, with applications both inside and outside fusion.
- **Cryoplant:** EU has a group of well established firms in this (more mature) supply chain. Competition from firms in India, Japan and the US is notable. Cryosystem opportunities in the energy sector (LNG) and chemicals industry exist, and growth in ICT infrastructure may lead to more opportunities.
- **Blankets, Tritium handling, Divertors and Wall materials:** EU institutes and firms are playing a leading role in these activities for ITER, however these activities remain at an early stage and the whole supply chain is quite immature. Opportunities for this technology area appear more limited, although materials developments in particular could have broader applications. Global competition is largely from public institutes at this moment, with the UK, US and China having similar capabilities to the EU and/or potentially outpacing the EU.
- **Remote handling and diagnostics:** EU firms are well positioned amongst the leaders in both supply chains through strong involvement in these areas on ITER, have broader manufacturing strengths (strong firms not engaged with ITER e.g. KUKA, ABB) and good links to research (e.g. DIFFER-Gauss-Fusion, VTT). However, competitors in the US, UK, Russia and Japan also have strong research and manufacturing capabilities. These are significant opportunities for these technologies in other sectors such as nuclear fission, space, healthcare, offshore and industry.
- **Services (design, engineering, safety and waste):** The EU has a large group of well established engineering firms which have gained experience in fusion through ITER and other projects and that are also finding opportunities in the UK and US. However, large consultancies in the US and UK also have strong capabilities and, in some cases, a larger scale which EU firms

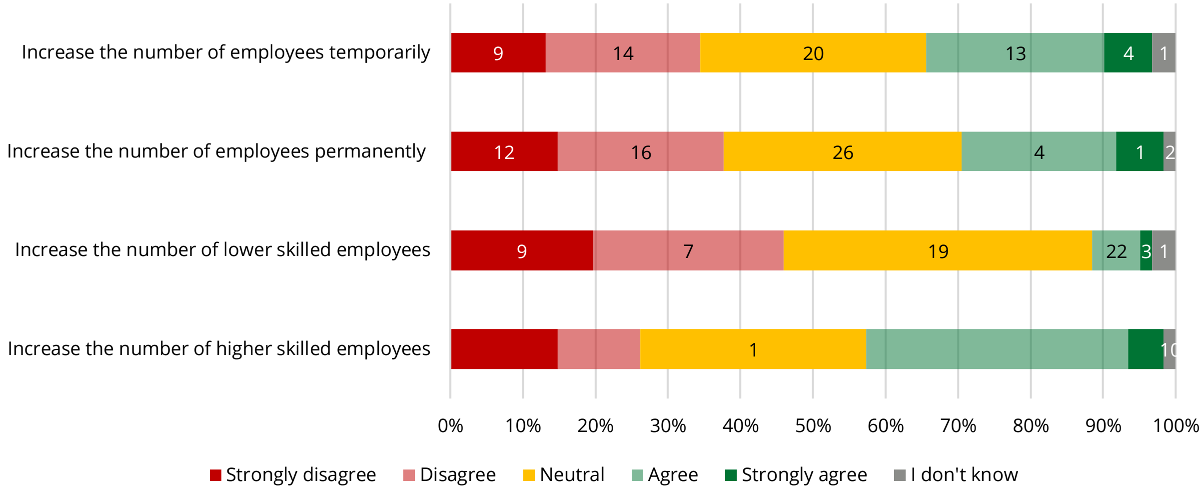
cannot match. There remain opportunities for EU firms in ITER and broadly across many sectors, however, in addition to competition the export market is tough due to especially public, but also private, organisations favouring domestic firms.

- **Construction, buildings and power supply infrastructure:** EU firms have carried out all the main construction and building work for F4E for ITER and are also making a major contribution to the power infrastructure, proving strong experience and capabilities of EU firms in these areas. However, the largest part of the skills and required capabilities are similar to other large infrastructure projects, and clients also tend to favour domestic firms for this type of work, meaning export opportunities for EU firms are somewhat limited, although some EU firms are involved in the UK bidding processes for STEP.

## 4.4 What is the qualitative impact of F4E's work on the European job market? What specific types of jobs and expertise are being created, and in which regions of Europe?

**Employment generated is specifically high skilled, with firms collaborating with F4E more likely to consolidate their workforce than expand it.** Survey data show that 41% of firms reported growth in higher-skilled positions, while only 9% noted increases in lower-skilled roles, indicating a trend toward selective upskilling (see Figure 20 below – last two bars). Interviewees reflected that the work for F4E had a positive impact on upskilling, particularly in developing project management and organisational skills. For SMEs the processes required by the work for F4E required changes to internal processes and practices for which at least one firm observed benefits beyond the work for F4E. Specific technical skill development was not noted by most interviewees, however advanced (nuclear) welding was brought up by multiple interviewees as something that was developed through the work for F4E, and that will also need further development. In interviews many firms directly identified the work for F4E as a catalyst for employment growth in their firms, often leading to significant increases in staff. Many firms, prior to securing work for F4E had only one or a handful of staff working on fusion. The work for F4E allowed firms to build out full teams focused on fusion, this was described in multiple cases, demonstrating how the work F4E procured has built up the EU fusion supply chain and employment. However, survey results suggest a more modest effect on overall job creation, with 32% of firms reporting increases in temporary positions and 28% in permanent positions (see Figure below 20 – first two bars).

## Figure 20. Employment effect of F4E procurement[24]



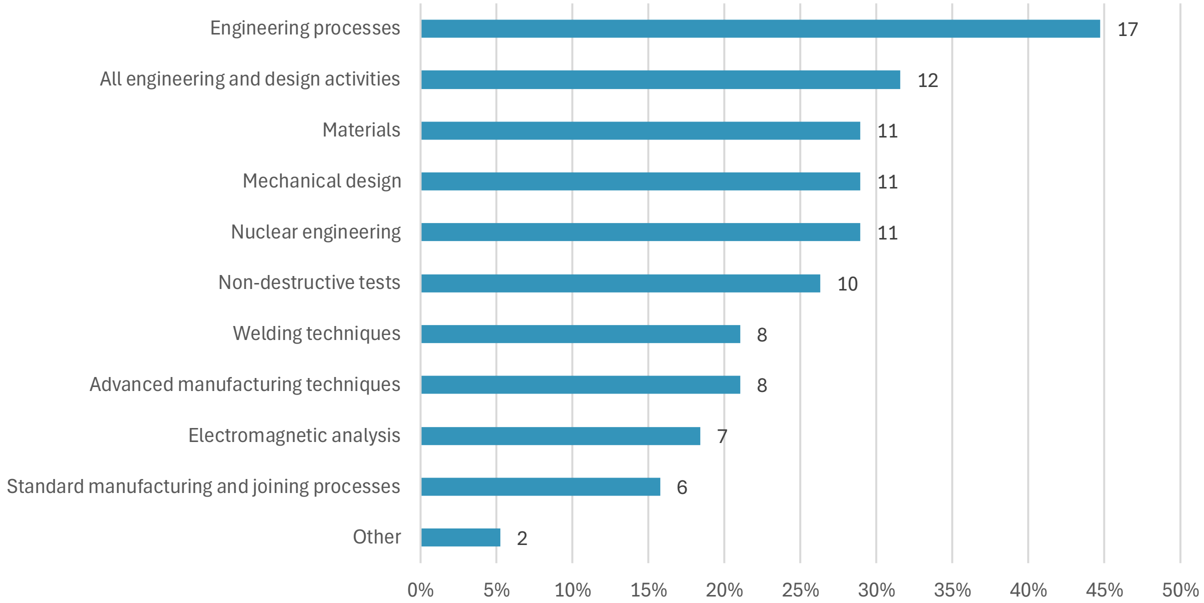

Note: N=61

Source: CSIL

**New knowledge and skills were developed in highly specialised fields that are crucial to the future fusion industry, in particular, in engineering processes.** As previously mentioned (see Section 4.3.1), around 66% of firms indicated that their staff gained new skills or knowledge thanks to F4E procurement. Among these firms, it was also asked to indicate the field in which new knowledge had to be acquired and/or new skills had to be developed (see Figure below). Nearly half of them (45%) indicated engineering processes as the primary area for knowledge acquisition, followed by all engineering and design activities (32%). Other significant areas of learning include materials, mechanical design, and nuclear engineering (each 29%), and non-destructive tests (26%). Additional specialised fields, although less frequent, include welding techniques and advanced manufacturing techniques (each 21%), electromagnetic analysis (18%), and standard manufacturing and joining processes (16%).

[24] Question 13. To what extent do you agree with the following statements? Thanks to the work for F4E from 2018 to 2024, my organisation was able to...

**Figure 21. Learning fields**[25]




Note: N=38

Source: CSIL

Skills shortages were noted in interviews, whilst EU initiatives such as FuseNet were acknowledged, perhaps the most successful actions to address this were noted by firms in Italy and Slovakia which partnered with local educational institutions (including high schools, technical schools and universities) to build a pipeline of interested students with relevant qualifications. Skills shortages covered various types of skills, advanced welding techniques, engineering and project management skills were amongst those most highlighted by respondents.

## 4.5 What has been the impact of F4E activities in establishing synergies across national boundaries and industrial sectors?

While the evidence presented in Section 4.3 has already shown that F4E has played a key role in driving collaborative research and innovation among different actors/stakeholders[26], this section focuses on the impact of F4E in establishing synergies across national boundaries and industrial sectors.

**The analysis of F4E procurement data reveals that cross-border collaboration was established in approximately one-tenth of all contracts active between 2018 and 2024**. Of the 2,440 active contracts identified in this period[27], 248 contracts involved multiple suppliers and sub-contractors from different countries. Most of these collaborative contracts involved entities from two different countries (87%), while the remainder (13%) included larger collaborations involving up to 10 different countries.[28] The largest collaboration, in terms of number of countries involved, was established for

[25] Question 9.b Can you indicate the field in which new knowledge had to be acquired and/or new skills had to be developed?

[26] See the results from the survey and publications/patents analysis in Section 4.3

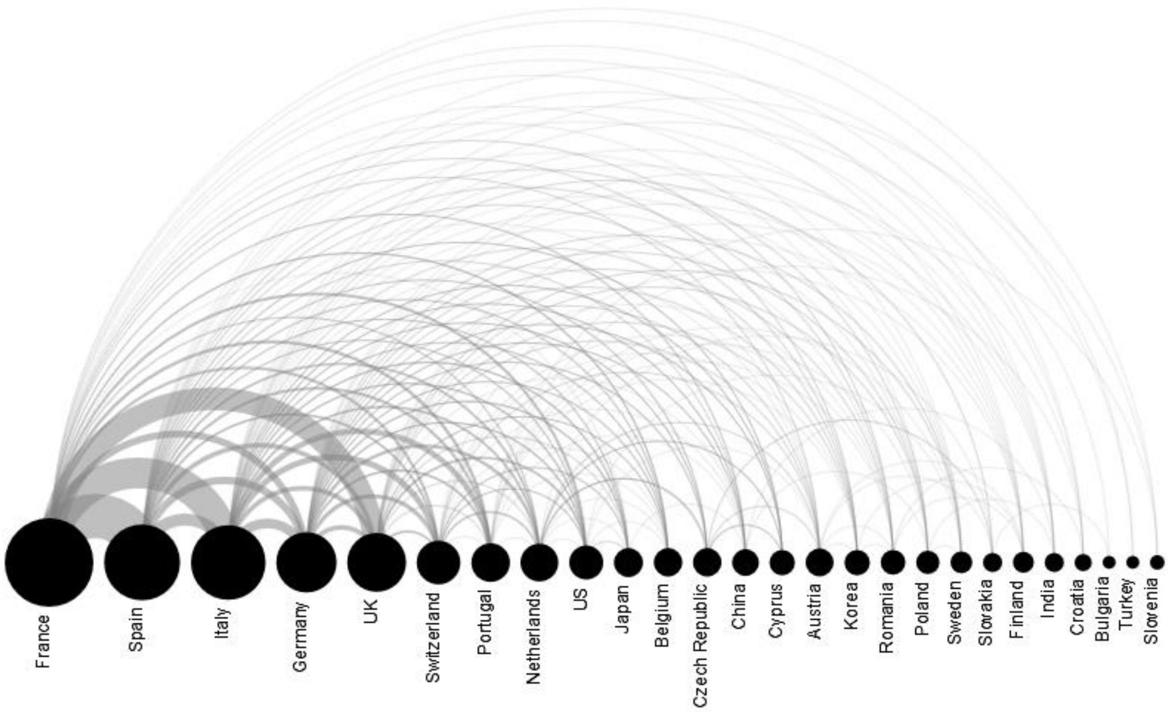
[27] These are the contracts associated to payments occurred during 2018-2024.

[28] The remainder (13%) includes contracts involving companies from 3 countries (3%; 7), 4 countries (2%; 5), 5 countries (2%; 6), 6 countries (3%; 7), 7 countries (2%; 4), 8 countries (1%; 2), and one exceptional case involving 10 countries.

the contract for the supply of the EU Vacuum Vessel (VV) sectors. This was delivered by a consortium of Italian companies – Ansaldo, Walter Tosto and Mangiarotti (Westinghouse Italia) – with the additional involvement of sub-contractors from France, Spain, Italy, Austria, Germany, Switzerland, Romania, Korea, the United Kingdom and Finland.

**Cross-border collaborations were most frequently established between France, Italy, Spain and UK.** The arc diagram below illustrates the network of cross-border synergies formed through these collaborative agreements.[29] The larger the node in the horizontal axis, the higher the level of participation of countries in collaborative contracts. The thicker the arc linking two countries, the higher the number of collaborations between them. As shown in the arc diagram, France is the country with the highest level of participation in collaborative contracts, with French companies working on approximately 80% of all collaborative contracts. This is not surprising since France was the main beneficiary country of F4E procurement activities (see Section 3.1 Analysis of F4E contract payments). These French suppliers primarily collaborated with neighboring countries, particularly Spain (in 38% of collaborative contracts) and Italy (27%), as well as the United Kingdom (20%). These countries were also among the top beneficiaries of F4E contracts, especially Spain and Italy.

**Figure 22. Cross-border collaborations between countries in active contracts during 2018-2024**




Source: Authors based on F4E data. Note: Countries are represented as nodes along the horizontal axis, while arcs indicate the presence of at least one collaborative contract between each pair of countries. The thickness of each arc reflects the total number of contracts shared by the two countries. Node size corresponds to the overall level of participation, with larger nodes indicating countries involved in a higher number of collaborations. For contracts involving more than two countries, all pairwise combinations were considered to capture the full extent of multilateral collaboration (e.g., a contract between France, Italy and Spain generates three bilateral collaborations: France–Italy, France–Spain, Italy–Spain).

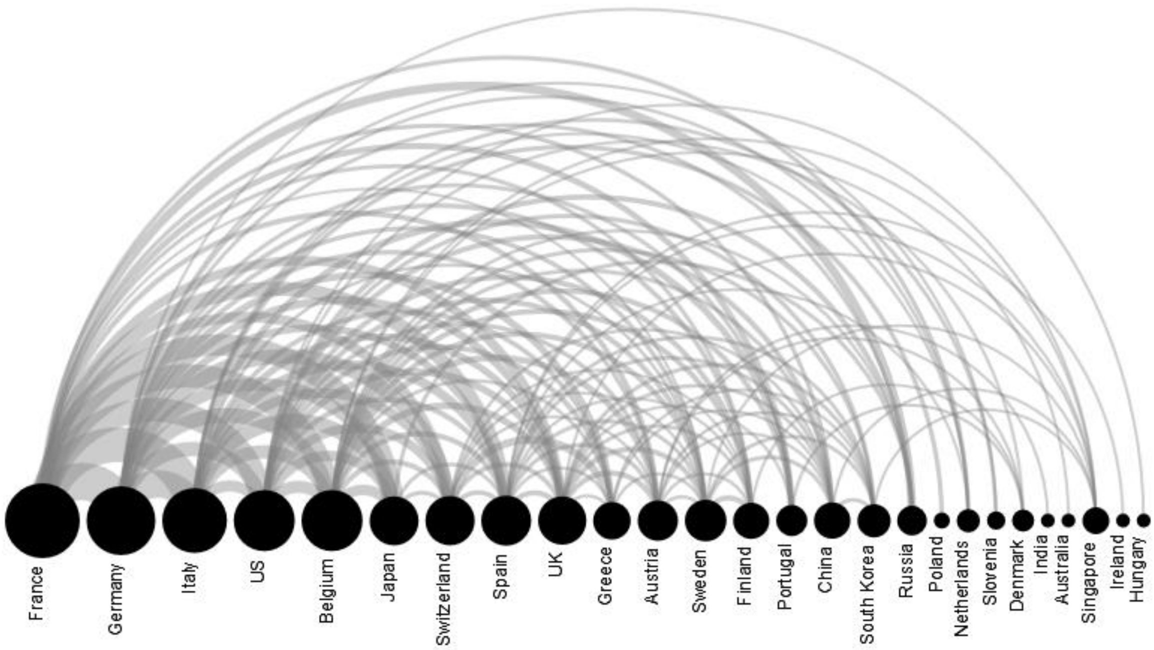
**The impact of F4E in establishing cross-border collaborations is even more evident in publications.** As previously noted, 77% of F4E-related publications involve multiple affiliations, primarily from academia, laboratories, and industry. Importantly, when F4E is excluded from

[29] In this paragraph, collaborative contracts refer to contracts involving collaboration between multiple countries.

publication affiliations – since F4E affiliation was one criterion for identifying F4E-related publications – the share of multi-institutional publications remains almost unchanged. This suggests that F4E acts as a catalyst rather than a unique actor, facilitating connections between organisations that collaborate independently. It is also interesting to note that collaboration usually occurs across national boundaries, with more than half (51%) of F4E-related publications involving affiliations from different countries.

**Collaboration in publications span a more diverse geographical range, reflecting the global nature of scientific knowledge exchange in fusion research.** While procurement collaborations concentrate on a small group of countries such as France, Italy, Spain and UK, publication collaborations reveal a more distributed network involving a broader range of European countries and extending to global partners. The arc diagram below reveals an extensive global network, with collaborations spanning from traditional European partners to Asia-Pacific countries (Japan, China, South Korea), North America (US, Canada), and other regions. Some publications involve highly multinational consortiums, with the most extensive collaboration including 27 different countries across Europe, Asia, the Americas, and other continents.[30]

**Figure 23. Cross-border collaborations between countries in F4E-related publications**



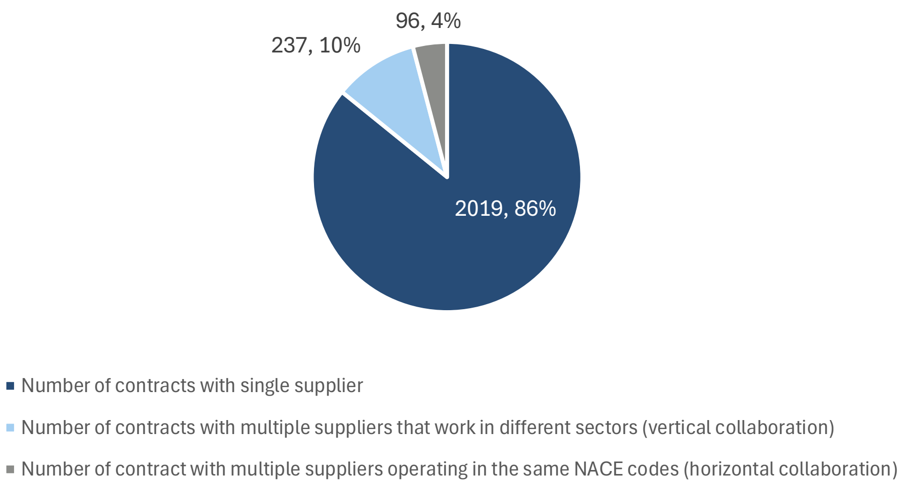

Source: Authors based on LENS data. Note: Countries are represented as nodes along the horizontal axis, while arcs indicate the presence of at least one co-authored F4E-related publication between each pair of countries. The thickness of each arc reflects the total number of publications shared by the two countries. Node size corresponds to the overall level of participation to co-authored publications, with larger nodes indicating countries involved in a higher number of collaborations. For publications involving more than two countries, all pairwise combinations were considered to capture the full extent of multilateral collaboration.

[30] This refers to the publication "Overview of the JET preparation for deuterium–tritium operation with the ITER like-wall", which involves hundred of authors and tens of affiliations, including major research institutions and laboratories such as CEA-IRFM (France), CCFE (UK), Forschungszentrum Jülich (Germany), Max Planck Institute for Plasma Physics (Germany), ENEA (Italy), Consorzio CREATE (Italy), CIEMAT (Spain), VTT Technical Research Centre of Finland, University of Helsinki, Uppsala University (Sweden).

**The analysis of F4E procurement data reveals that collaboration across different sectors was established in approximately one tenth of all contracts active between 2018 and 2024.** Of the 2,352 active contracts in this period for which information on the NACE code was available[31], 237 contracts involved suppliers and sub-contractors operating in different economic sectors. Most of these cross-sectoral contracts involved suppliers from two different sectors (79%), while the remainder (21%) included larger collaborations involving up to 46 different sectors. The largest collaboration, in terms of number of sectors involved, was established for the contract covering the series production of the ITER blanket first wall panels. This contract was led by Fusion Business Leadership SL, with the involvement of several subcontractors working in different fields ranging from advanced metalworking, welding and machining services to engineering design, ICT solutions and specialised research centres.

**Vertical collaboration is more frequent than horizontal when F4E contracts involve multiple beneficiaries**. As shown in the pie chart below, cross-sectoral contracts involving suppliers from different industries (vertical collaboration) represent 10% of all active contracts during 2018-2024, compared to only 4% of contracts with multiple suppliers operating within the same NACE codes (horizontal collaboration). The most frequent cross-sectoral partnerships involve engineering activities (NACE code 7112) combined with other specialised sectors: 16% of cross-sectoral contracts pair engineering with other professional, scientific and technical activities (NACE code 4676), 14% combine engineering activities with computer programming and consultancy (NACE code 6202), and another 14% link engineering activities with technical testing and analysis services (NACE 7120). An example of vertical collaboration is illustrated in the box below.

### Figure 24. Synergies across sectors (NACE codes)




Source: authors based on F4E data and ORBIS database

### Box: Vertical collaboration in the contract for the supply of ITER Toroidal Field Winding Packs

This contract exemplifies vertical collaboration across the entire manufacturing value chain, with ASG Superconductors, an Italian company specialised in electrical equipment manufacturing, leading a consortium that spans multiple industrial sectors:

[31] The total number of active contracts during 2018-2024 is 2,440, meaning that the information on the NACE code was available for contractors and sub-contractors that have worked on 96% of total active contracts in that period.

- **Engineering and design activities**: ELYTT Energy and Iberdrola Ingeniería provide specialised engineering services, handling technical design and project management for these unprecedented superconducting components, as winding packs of this size have never been manufactured before.
- **Advanced insulation materials procurement**: Arisawa and Gavazzi Tessuti Tecnici both supply critical insulation materials. The former provides specialised insulation cover materials featuring S glass cloth laminated with polyimide film using cyanate ester resin, while the latter contributes to technical textiles, all designed to withstand the extreme conditions within the tokamak.
- **Precision manufacturing**: multiple subcontractors (including Simic, Talleres Gometegui, Terruzzi Fercalx) handle ultra precise metalworking and machining required for superconductor housings and structural components.
- **Specialised machinery**: companies like Castellini Officine Mécaniques, Demak, and Ridway Machines provide custom manufacturing equipment and tooling designed specifically for large scale superconductor assembly.
- **Installation and final integration**: IDS handles complex electrical installation work, while lead contractor ASG Superconductors performs final system integration.

Source: authors

# 5 RESULTS OF ANALYSIS OF F4E'S TASKS AND PROCEDURES

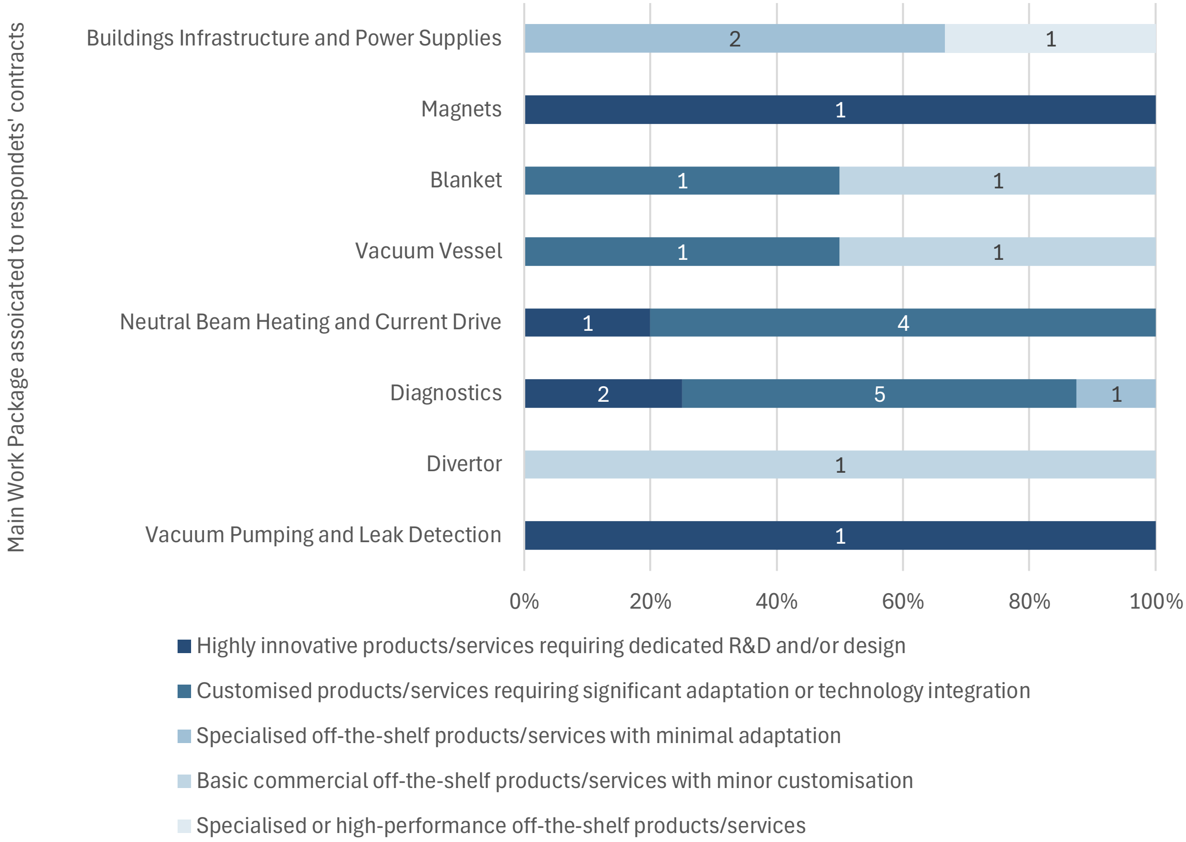
## 5.1 To what extent does F4E orient its deliveries on high-tech, fusion-related technologies, as opposed to lower-tech infrastructure? What are the consequences?

**F4E allocates most of its spending to building infrastructure rather than cutting-edge fusion technologies due to its role as ITER's host country agency.** Unlike other domestic ITER agencies that allocate their budgets almost entirely to fusion-specific technologies[32], F4E bears the institutional mandate of overseeing the complete construction, equipping, and commissioning of ITER buildings and associated infrastructure, reflecting Europe's position as the host nation for the ITER machine. This distinct responsibility is reflected in F4E's expenditure patterns, where the largest share of contract spending is directed toward "Buildings, Infrastructure, and Power Supplies" during 2018-2024 (53%), as illustrated in Section 3.1. Analysis of F4E contract payments. Specific fusion-related components like the "Magnet" and "Blanket" each account for 9%, while the "Vacuum Vessel" represents 7% of over the same period.

**Survey results show that contracts under the Work Package (WP) related to Buildings, Infrastructure, and Power Supplies tend to be less innovative compared to fusion specific WPs**. An analysis was conducted to understand the variation in technological sophistication across F4E's Work Packages, by combining procurement data (including information on the WPs) and the answers to the survey of F4E suppliers regarding the level of innovation of products and services provided to F4E (see figure below). Survey respondents with contracts related to the Work Package "Buildings, Infrastructure, and Power Supplies" indicated that they mainly provided specialised or high-performance off-the-shelf products/services or specialised off-the-shelf products/services with minimal adaptation. In contrast, supplier respondents whose contracts are primarily linked to WPs like Magnets, Vacuum Vessel, and Blanket reported much higher innovation levels, with nearly all contracts involving the provision of either highly innovative products/services requiring dedicated R&D and/or design, or customized products/services requiring significant adaptation or technology integration. Considering the distribution of F4E spending across Work Packages, this overall suggests that F4E's activities involve a mix of high-tech, fusion-related technologies and lower-tech infrastructure. It should be noted however that the number of survey responses is relatively small, so this evidence should be interpreted with caution.

[32] ITER Organisation annual reports

**Figure 25. Innovation level of contracts by Work Package**




Note: N=23. When respondents indicated multiple contracts in the survey, the average innovation level of these contracts was considered. When suppliers signed contracts associated to different WPs in the procurement database, authors considered the most significant Work Package based on the value of contracts.

Source: CSIL based on F4E data and survey results

**Despite F4E's spending allocation being strongly focused on buildings, F4E activities have strengthened European industrial competitiveness in the fusion domain and beyond.** While 53% of F4E contract spending is directed towards buildings and campus facilities—which are less likely to generate technological spillovers and limit potential for innovation and high-tech industrial learning—the remaining 47% allocated was allocated to develop the high-tech components of the ITER machine. As discussed in Section 4.3 and as emerge in the case studies (see Annex 9), through F4E contracts, European firms have built recognised expertise in high-tech, fusion-related fields such as vacuum vessels, magnets, heating systems, and cryoplants, while also enhancing their credibility and reputation as reliable, high-quality providers. This visibility has opened access to new markets both inside and outside the fusion sector, allowing EU companies to translate the demanding experience of ITER into competitive advantages across a range of high-technology industries. According to the SWOT analysis, despite strong international competition, EU firms are well positioned in different supply chains, including vacuum vessel manufacturing, magnet production, cryoplants, blankets, tritium handling, divertors, and wall materials. Overall, this evidence suggests that, even though a large share of F4E's spending is devoted to buildings and facilities, the investments in high-tech components of the ITER machine have effectively strengthened European industrial leadership, generating technological spillovers and competitive advantages that extend well beyond the fusion sector.

**As F4E progresses in the completion of its tasks related to ITER components construction, it has started developing a more strategic approach to technology management to ensure Europe's continued leadership and successful commercialisation of fusion energy beyond ITER.** As discussed in previous sections, F4E's management of the EU in-kind contribution and relationship with supplier firms have generated know-how and expertise in the EU in high-technological fusion-related fields. This has however created the need (now urgency) to develop an effective technology/knowledge management and transfer that are essential to reap off benefits in the long term. To address this, F4E is actively enhancing technology transfer efforts and collaborating with EUROfusion to streamline operations and advance commercialisation of fusion technologies. Key initiatives include the development of a Technology Development Plan (TDP), which aims to identify technology fields where competences need to be developed and expanded within Europe and align long-term technological needs with industrial capabilities, fostering early engagement of partners in research and development. [33,34]

**The integration between F4E and the ITER Organisation (IO) could potentially impact the current allocation of tasks and European industrial leadership built through F4E's work package management**. An ambitious integration strategy between IO and domestic agencies (including F4E) is ongoing to improve project efficiency and ensure a more cost-effective implementation of the ITER project.[35] Among others, this may involve transferring the management of some procurement contracts from F4E to IO (contracts made available at the global level instead of keeping them at the European level only).[36] Another action concerns the implementation of an Integrated Project Team (IPT), a unified project and technical organisation with a mandate covering the entire construction scope of ITER, including most of the EU's in-kind contributions. A previous study by the European Commission (2025) acknowledges that the proposal for a unified IPT marks a significant and welcome potential progress compared to the past and current situation in order to speed up the conclusion of the ITER project. However, the study also highlights that the practical effects of the IPT remain to be seen and are difficult to forecast. Its success will depend on how effectively F4E and IO staff continue to develop their collaboration. Potentially, the integration process could lead to positive effects such as extending the job roles of F4E employees beyond their initial responsibilities, potentially involving them in subsequent stages such as component assembly and future maintenance tasks at Cadarache. At the same time, the integration – especially the programmes/projects transfer – could potentially lead to a reduction of F4E scope and control over the supply chain, with an impact on F4E's Industrial Policy.

## 5.2 Is F4E employing the most efficient procurement and project management strategies to optimize its positive economic impact?

**F4E's management of procurement and contracts has positively evolved over the years.** As shown in the table below, the time to manage different procedures has been reduced (see below)

33 European Commission (2024). Analysis on a strategic public-private partnership approach to foster innovation in fusion energy. Authored by Trinomics et al.

34 According to interviews with representatives of F4E, the Technology Development Plan has identified 5 key technologies to be at the centre of a Technology Roadmap.

35 F4E (2023) F4E-IO Integration Plan.

36 F4E (2024) F4E-IO Integration Status and Action Plan. The action plan adopted in June 2024 introduces three new mechanisms aimed at accelerating project delivery by refining how the project scope is allocated between the IO and the DAs. Two of these mechanisms are introducing the possibility to transfer scope without transferring financial risk. However, these mechanisms are still under investigation, and their efficiency has not yet been fully tested

and most of the supplier companies replying to a survey carried out in 2024[37] have declared to have had a good relationship with F4E during the management of their contracts. When asked about their satisfaction with various aspects of the procurement processes[38], more than half of the respondents indicated that they "strongly agree," "agree," or are "neutral." Positive assessments ranged from 91% for the procurement e-submission tool to 57% for the management of compensations in cases of deviations from the technical specifications.

**Table 8. Efficiency gains in procurement process**

| INDICATOR (DAYS) | BEFORE 2017 | END 2020 | END 2021 | END 2022 | END 2023 | END 2024 | EFFICIENCY GAINS (2024/BEFORE 2017) |
|---|---|---|---|---|---|---|---|
| Time to recruit | 152 | 110 | 109 | 113 | 117 | 103 | 32% |
| Time to procure | 287 | 189 | 183 | 184 | 185 | 181 | 37% |
| Time to sign a contract | 41 | 11 | 14 | 13 | 27 | 26 | 37% |
| Time to prepare technical assessment report of the supplier deliverables related to a payment | 16 | 12 | 8 | 11 | 7 | 7 | 56% |
| Time to pay before 30 days | 23 | 15 | 13 | 19 | 16 | 18 | 22% |
| Time to perform a contractual deviation | 90 | 36 | 49 | 49 | 46 | 40 | 56% |

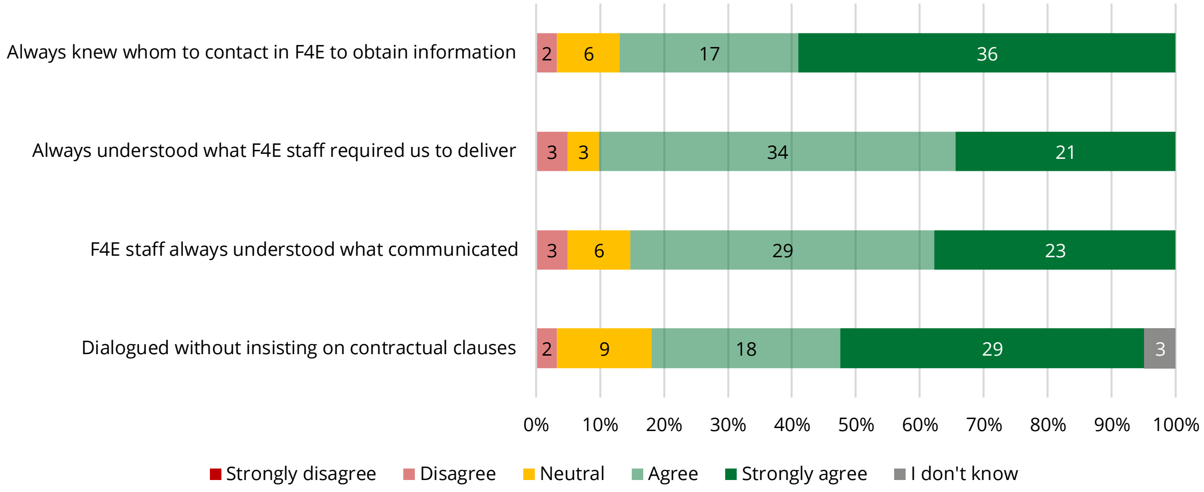
Source: Authors on the basis of F4E Consolidated Annual Activity Reports 2020-2024

**The survey conducted in the context of the present study also suggest that F4E's interactions were perceived as technically competent and procedurally sound**. Overall, respondents indicate a broadly positive perception of the quality of the procurement relationship established between F4E and the respondent suppliers (Figure 26). Suppliers reported high levels of clarity in communication, responsive staff, and a shared understanding of contractual expectations. Many also noted that communication with F4E was well-structured and effective throughout their contracts. Most respondents consistently knew whom to contact for information, understood what was expected of them at each contract stage, and felt that F4E staff grasped the information they provided. Similarly, most agreed that when issues arose, F4E engaged in constructive dialogue to find solutions, rather than rigidly enforcing contractual clauses.

[37] This survey was conducted in the context of the mid-term evaluation of the ITER programme on behalf of the European Commission. See the final report here: Interim evaluation study of the implementation of the Council decision (Euratom) 2021/281 amending decision 2007/198/Euratom establishing the European joint undertaking for ITER and the development of fusion energy and conferring advantages upon it.

[38] See Annex 4, Section D, Q14 of the report Interim evaluation study of the implementation of the Council decision (Euratom) 2021/281 amending decision 2007/198/Euratom establishing the European joint undertaking for ITER and the development of fusion energy and conferring advantages upon it.

**Figure 26. Quality of the relationships with F4E**



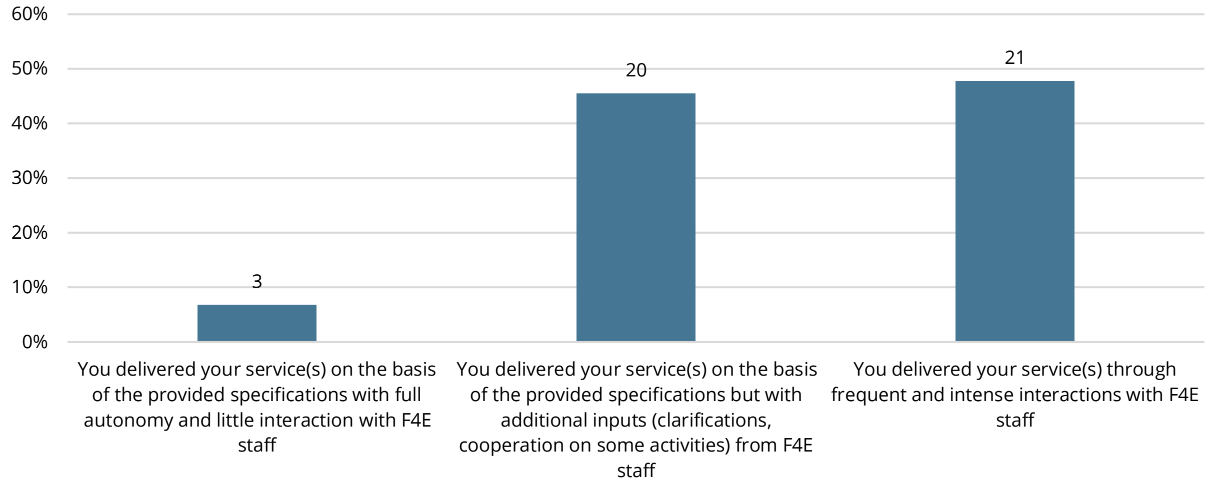

Note: N=61

Source: CSIL

**In terms of the interaction intensity between firms and F4E staff during service delivery, responses showed more variation**. About half of the respondents (48%) reported delivering their services through frequent and intensive collaboration with F4E. Another 45% indicated they worked primarily from provided specifications but received occasional input, such as clarifications or limited cooperation. A small minority (around 7%) operated with high autonomy, relying mainly on initial documentation and maintaining minimal contact. This variation likely reflects differences in contract complexity, the maturity of the technologies involved, and the degree of interdependence required for successful delivery (Figure 27).

Understanding the nature of the relationship is essential, as it helps shape the environment in which firms operate and influence how procurement activities translate into organisational development and firm performance. In terms of the type of procurement activities, most firms (45%) delivered customised solutions requiring significant adaptation or integration, while 27% provided highly innovative outputs based on dedicated R&D or design. Only a small share of suppliers relied on off-the-shelf products, whether specialised (9%), basic with minor customisation (11%), or high-performance (7%). These patterns point to a clear emphasis on tailored and technically demanding procurement deliveries. In terms of technological maturity, most of the activities were concentrated around TRLs 5 and 9 (18% each). TRLs 6 and 7 also featured prominently (16% each), while early-stage research (TRLs 1-3) was marginal (see Annex 7).

**Figure 27. Intensity of interactions between F4E and its suppliers**




Note: N=44

Source: CSIL

Despite improvements over the years and the overall positive picture emerging from the surveys, **persistent weaknesses remain in F4E's procurement process, underlining the need for further enhancement**. This was highlighted in interviews conducted for the study and echoes many of the observations raised in the recent mid-term evaluation of the European Commission's contribution to the ITER programme[39]. These are presented by procurement/project management phase:

- **Procurement – pre-contracting: A point raised by multiple stakeholders was that the complexity of the F4E tendering processes is high**, and that this becomes a barrier, especially for SMEs. Learning how to prepare successful tenders for F4E is quite a long and costly process for many, taking years. Stakeholders reflected that further steps could be taken to help involve SMEs, for example in connecting them with larger firms, so that first the SMEs could learn about F4E processes as a subcontractor. Others mentioned the possibility of sharing more information ahead of procurement calls, but a concern was flagged that this information could end up being shared in a way that disadvantage some firms.
- **Procurement – contracting:** Industry stakeholders highlighted various challenges they faced with procurement processes at F4E, they contrasted their experiences with other public and private sector clients, such as CERN or private utilities, and found that the **F4E processes were much more bureaucratic and 'heavy'**. For firms this adds significant costs to the process, which they need to weigh when making the decision to respond to the procurement or not. Specifically, firms found the technical specifications too complex and rigid, with too many requirements, and requiring high levels of proof in terms of documentation. Industry suggested that allowing more dialogue in the procurement phase (and also later in project management) would help to generate requirements that still meet the needs of ITER, but that are also more realistic to implement. To set against this, it was noted by F4E that ITER remains a nuclear project and that the nuclear aspect imposes certain safety and quality requirements

[39] European Commission (2025). Interim evaluation study of the implementation of the Council decision (Euratom) 2021/281 amending decision 2007/198/Euratom establishing the European joint undertaking for ITER and the development of fusion energy and conferring advantages upon it. Authored by CSIL and GAC.

that must be observed, and that this is one of the drivers of a necessary ‘weight’ to the process. Further issues were flagged on risk-sharing where multiple stakeholders feel that the risk of the projects, which in many cases is high as the work is first-of-a-kind, is not well shared, with industry bearing a disproportionate share. One stakeholder referenced other sectors where reward-sharing is used in procurement, where a piece of work is contracted to a group of consortia, with a mechanism to ensure that each consortia received some work through the contract to compensate for bidding costs and risks. Finally, the issue of IP ownership was also raised, with a strong request for an alternative approach from F4E on any non-ITER work, allowing firms to retain greater ownership of output IP. It is understood that there is sufficient flexibility in F4E processes to allow for differentiated approaches to IP ownership, and that this is also sometimes applied in the context of ITER contracting.

- **Project management – contract management**: Stakeholders had generally positive reflections on the operational staff at F4E and how a constructive, pragmatic approach is taken in most cases. This is also reflected in the survey results presented above. However, there were also a number of critiques and improvement points noted by consulted industry stakeholders. First, **there is a widespread conviction that F4E management processes are (too) heavy on bureaucracy.** This is partly embedded from the large number of technical requirements set out at the procurement stage but is also present in the way in which contract management is approached. Interviewees noted steps in contract implementation requiring documentation that are not documented by other clients. It was also noted that there are numerous quality review rounds, with multiple stakeholders from F4E and ITER IO. These significantly add to the time and expense of implementation. Again, it is noted that part of this is linked to the nuclear nature of the ITER project. Secondly, **industry stakeholders perceive that the bureaucratic processes and a risk averse culture at F4E contributed to delays in decision making.** Stakeholders found this an important factor in delays, with even small decisions taking a long time as it seemed, from the industry perspective, unclear who could take the decision. This was also perceived to be an issue that had grown over time at F4E, with more flexibility and agility shown earlier in F4E history. Third, **many industry stakeholders noted that the heavy processes contributed to their work for F4E not being particularly profitable.** They flagged that first-of-a-kind work is inherently uncertain, with risks, but that the way in which contracts were managed added to their costs, causing issues. Firms then need to justify their work for F4E in other ways. In conclusion, **industry stakeholders requested a more flexible and agile approach to contracts,** which would work more closely with industry to deal with the uncertainties in first-of-a-kind projects, reduce the rigidity and number of technical requirements, reduce documentation needs and bureaucracy, and allow for risks to be managed more efficiently**.**

## 5.3 How do F4E's procurement strategies compare to other organizations like CERN and ESA in terms of achieving and measuring return on investments?

### 5.3.1 Procurement processes and procedures

Analysis of procurement processes and procedures, including thresholds for different procurement types and use of framework contracts, shows that **F4E has very similar overall procurement processes and procedures to CERN and ESA**, for example in the way calls are launched and managed, and how framework contracts are used. However, industry stakeholders that have worked for both F4E and CERN noted how the CERN approach to procurement is simpler, less bureaucratic and that they are comparatively more flexible in how they apply the processes and procedures whilst F4E is more rigid, partially as a consequence of being a nuclear project.

### 5.3.2 Procurement strategy – engaging suppliers

**F4E and CERN both use Industrial Liaison Officer networks as a key method to engage suppliers. ESA takes a different approach with more online materials and other facilities and fora.** The supplier engagement activities can be further detailed:

- **At F4E, a network of Industrial Liaison Officers (ILOs) help companies** identifies upcoming opportunities, navigate documentation, and form consortia. Information days, matchmaking events and brokerage sessions are organised to promote first-time participation and SME involvement.[40] Particular attention is given to SMEs, which are encouraged to engage in direct contracts or participate as part of larger consortia. F4E has committed to offering SME-friendly qualification thresholds. These include simplified procedures, adjusted financial guarantees and flexible payment terms.[41] In addition F4E also engages with suppliers by hosting information days and events, and through regular market surveys, these have a focus on informing potential suppliers of upcoming procurement and aligning F4E procurement strategy to market conditions.
- **At CERN, similar to F4E, an Industrial Liaison Officer network assists suppliers** in identifying opportunities, understanding procedures and connecting with CERN technical teams.[42] CERN also offers a Supplier Portal, which provides guidance, tender notifications, qualification instructions, and access to registration and documentation tools.[43] CERN organises information sessions, publishes procurement forecasts and encourages supplier engagement across sectors.[44]
- **ESA offers the ESA Learning Hub online platform** that targets SMEs and new suppliers, providing them with a large range of trainings. This includes R&D proposal writing, product assurance in ESA projects.[45] There are also training courses organised by the SME office at ESA.[46] Beyond this, through the European Components Initiative (ECI), ESA suppliers also collaborate with European industry consortia to develop and qualify components for space missions. Within this initiative, the European Space Component Coordination (ESCC) is a body that represents all major stakeholders such as component manufacturers and prime contractors.[47] This demonstrates how ESA operates more as a long-term industrial policy initiative with more formalised, strategic goals. F4E also has an industrial policy objective as a key strategic objective, however this is often subordinate to the objective of providing the EU contribution to ITER.

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[40] Implementation of the Industrial Policy, 2018.

[41] IPWG Implementation Follow-Up.

[42] CERN Procurement Rules, 2023.

[43] CERN Supplier Portal, 2024.

[44] CERN Supplier Portal, 2024.

[45] ESA Learning Hub online platform - ESA Commercialisation Gateway

[46] ESA - Training

[47] ESA - European Component Initiative (ECI)

### 5.3.3 Procurement strategy – innovation and IP

**All three organisations leverage procurement to incentivise innovation but differ in their approaches,** F4E emphasises collaborative networks in the EU, CERN fosters deep co-development partnerships and ESA uses contractual rules to promote competitive SME involvement. To promote innovation at F4E, open calls are used to encourage collaboration between industry, national laboratories, research institutes across EU MS to develop new products/technologies. Other platforms like the F4E industry portal also encourage collaboration across EU MS between industry.[48] In the case of **CERN**, CERN Openlab encourages a collaborative framework for industry and research organisations to work with CERN researchers.[49] Within **ESA's** procurement and industrial policy, the C2 and C4 clauses ensure open competition with encouragement of subcontracting to SMEs.[50]

**Concerning IP ownership and licensing F4E** requires access to contractors' (and subcontractors') existing intellectual property and information (background) needed to perform or use the goods/services under a contract. Contractors must declare this background to preserve its integrity and protect the contractors IP assets. Each contract also requires a decision on the ownership of newly generated IP (foreground), with a declaration to distinguish it from the background and to ensure proper protection. Unless explicitly excluded, background and foreground declarations are required for every contract. F4E provides model contracts outlining IP provisions for various ownership regimes, this includes joint, contractor-owned or F4E-owned.**Error! Bookmark not defined.** F4E IP rules are guided by the ITER agreement which embeds sharing of IP between the ITER parties, as noted in section 5.2, firms find these requirements onerous. For non-ITER work, e.g. BA, IFMIF-DONES, Technology Development Programme (TDP), F4E can be much more flexible in application of IP rules.

In **CERN**, regarding IP generated by EU projects, ownership is defined in the Consortium Agreement, with each partner retaining ownership of their background IP and granting rights to other partners as needed. Across EU projects, all contractors have an obligation to protect the results if they are capable of industrial or commercial exploitation, to use/exploit the results they generate either for further research, commercial purposes or by establishing licensing deals/partnerships to allow exploitation by other entities, and to disseminate the results they own, hence ensuring open access. For many EU projects, this is agreed upon in a Consortium Agreement.[51]

Under **ESA** contracts, the contractor retains ownership of the IP, ESA does acquire the right to use it for its own purposes (foreground IP).[52] [53] [54] [55] If IP generated through work for ESA is not further registered or exploited by the contractor then ESA retains mechanisms to claim ownership of the IP to try to put this to use. IP existing prior to or independently of the ESA contract remains the property of the original holder, in this regard contractors must declare any background IP used during the contract.[56]

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48 Industry and Fusion Laboratories Portal
49 About – CERN openlab
50 ESA - Procurement policy on fair access for SMEs - the C1-C4 Clauses
51 IPR | EU Projects Office
52 ESA - ESA contracts: types, monitoring and intellectual property rights
53 ESA - IP policy at ESA
54 Fully funded Projects - Guidelines for Preparation of Proposals | ESA CSC
55 ESA - ESA, Industry and Intellectual Property
56 ESA - Ownership of intellectual creations

**In summary there are similarities in F4E's approach to IP** with the approach of CERN and ESA, for example in distinguishing between background and foreground IP, requiring contractors to declare existing IP and managing newly generated IP under clear terms. All three emphasise the protection, use, and dissemination of results, with obligations to ensure IP is properly managed and exploitable. However, there are important differences, F4E mandates background and foreground declarations for each contract and offers predefined ownership models, CERN follows EU project rules where ownership is defined in the Consortium Agreement, with background IP retained by partners and strong emphasis on exploitation and dissemination of results, whereas ESA allows contractors to retain ownership of foreground IP, while ESA secures usage rights, requires declaration of background IP used during the contract and has mechanisms to take ownership of unused foreground IP.

### 5.3.4 Procurement strategy – technology transfer

**F4E** has partnered with EUROfusion to launch the platform **European Fusion Technology Marketplace** in 2024,[57] which promotes technology transfer from fusion research to other domains, offering companies access to a diverse portfolio of technologies developed by EUROfusion's industrial partners. Additionally, F4E encourages the commercialisation of foreground IP, specifically in fields outside fusion. Contractors are offered rights for the exploitation of IP acquired in both the fusion and non-fusion fields. F4E has also launched a Technology Transfer Demonstrator Call to support projects that plan to apply a technology or know-how developed under F4E activities in a new market place, and also offers professional brokerage services to the industry.[58]

In comparison, **CERN actively promotes technology transfer** and spin-offs through initiatives and programmes that are managed by an internal department called the Knowledge Transfer Group.[59] CERN also has the Venture Connect Programme, which links CERN investors with entrepreneurs and investors to create start-ups based on CERN technologies.[60] Similarly, **ESA has a Technology Transfer Programme Office** which facilitates the transfer of technologies to a wide range of applications, such as automation and robotics, electronics, sensors, power and energy devices etc.[61] ESA also has the Open Space Innovation Platform[62] that allows individuals and organisations to submit innovative concepts for space technologies and applications and the General Support Technology Programme[63] that encourages participating states and industry to work together to convert innovative engineering concepts into a broad spectrum of usable products.

**Overall, the technology transfer mechanisms at F4E are less mature than those at CERN and ESA** which have much longer standing apparatus for promoting and tracking technology transfer due to also being active decades longer than F4E. This shorter experience with its Technology Transfer Programme, Technology Development Programme (TDP) and new platform, means that F4E will need time to develop, evaluate and refine its approach. There is also a disparity in resources available for technology transfer between the organisations, with both ESA and CERN having internal departments that manage technology transfer initiatives, for example the team at CERN is around 25 people

[57] European Fusion Technology Marketplace - Fusion Technology Transfer
[58] F4E launches the 2025 Technology Transfer Demonstrator Call - Fusion for Energy
[59] About Us | Knowledge Transfer
[60] CERN Venture Connect Homepage | VentureConnect.web.cern.ch
[61] ESA - Technology Transfer Programme
[62]https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/The_Open_Space_Innovation_Platform_OSIP? a
[63] ESA - About the General Support Technology Programme (GSTP)

strong, whilst in comparison F4E has only one FTE. If F4E resources for technology transfer could be scaled up then it would be possible to speed up and further build on the new programmes.

### 5.3.5 Industry Return/Participation Policy & Geographic Balance

**Return on investment is a key political concern for member states, who look to geographical balance in multi-country projects they contribute to.** Simply put member state governments like to see a return to their industry reflective of their share in contributions to a programme. For F4E the contributions come from the Euratom budget, which is funded by Member State contributions. **However, F4E has no formal geographic return policy**, the focus is on value for money and transparency in procurement. This leads to a divergence between contributions to the budget and the geographical distribution of procurement (see Figure 3 and Figure 6), with a very high share of spending on firms in France (as ITER host), Italy and Spain, and relatively low returns to other countries e.g. Germany. There are rational reasons for high concentrations of spending in France based simply on sourcing construction and site services in-country, this partially explains the 60% shares in spending highlighted in Chapter 3. However, for the remainder of the spending, comparing to the general distribution of industrial GVA in the EU, Italy (e.g. share of EU industrial GVA of 12.5% vs 20.4% share of F4E contracts) and Spain (6.6% of GVA vs 12.8% F4E contracts) have relatively high shares and Germany (32.4% GVA vs 3.5%) and others (37.5% GVA vs 2.1% F4E) relatively very low shares. This shows a clear disproportionality, even if the numbers could be further refined to remove the skew to France. This can lead to political friction, with this issue of balance and proportionality being identified as a Member State concern by multiple F4E and policy stakeholders in interviews.

**CERN and ESA take a contrasting approach to F4E, both employ (geographical/industry) return coefficients** to ensure a high proportionality of returns to contributions. For example, CERN compares each MS's share of contracts to its contribution to the CERN budget. To correct imbalances in return, CERN uses limited tendering reserved for the underrepresented countries and alignment options, which allows slightly higher bids from poorly balanced states to win contracts, as well as contract splitting between multiple suppliers.[64] Similarly, ESA also awards contracts to align the return with member contributions. Interviewees at these organisations highlighted both the positive and negative aspects of their return mechanisms, analysis of this feedback is summarised below:

**Table 9. Pros and Cons of geographical / industrial return mechanisms**

| POSITIVE ASPECTS | NEGATIVE ASPECTS |
|---|---|
| + Countries without expertise can build this up through contributing more, allowing strategic industrial policy to be effective<br><br>+ Politically easier to 'sell' funding of initiatives in Member States as there is a clear link between their contributions and tangible economic returns | - Procurement is affected – effectively a procurement requirement to purchase from certain countries, meaning less room for competition.<br><br>- Equity become a priority – sometimes competing against the other objectives and interests of the organisation, and absorbing disproportionate staff time and resources.<br><br>- Fosters a national mindset to spending, i.e. 'what's in it for us?' rather than a cooperative European mindset working towards a common goal – can lead to internal fragmentation e.g. countries pet projects. |

[64] CERN Procurement Impact Report, 2019

- Can lead to uncompetitive industries – industry knows they can secure work by lobbying their government to contribute funds, consequently quality, price and innovation are less important incentives.

- Companies can game the system, opening offices in particular countries to access contracts

Source: authors based on interviews

**When examining the geographical return mechanisms used by CERN and ESA, stakeholders at these organisations identified more drawbacks than benefits,** with clear risks associated**. At the same time,** it was acknowledged that **such mechanisms can be essential to securing political support from key contributing countries**, for example if they perceive too strong an imbalance and unfairness, that this may place overall funding at risk**.** This is a risk that F4E needs to manage as it does not employ a geographical return mechanism.

## 5.4 How effectively is F4E measuring and tracking the economic impact of its initiatives, and what methodologies are in place to assess both the direct and indirect outcomes of its activities?

**F4E activities are closely monitored and extensively audited**, in desk review for the preparation of this study, 17 different audit, reporting and control instruments that are used by F4E and other governing stakeholders were identified. **However, this measuring and tracking is focused almost entirely on the F4E delivery of contributions to ITER**, and on cost, quality and use of appropriated funds, and **not on tracking economic impacts**. The audit processes have identified some areas for improvement, for example in risk assessment and management, (over)reliance on external contractors, changes to monitoring methodologies, (over) optimistic forecasts and (too) heavy administrative requirements[65]. The audit reports also sometimes highlight case studies with economic impact, but these do not represent a structured system of monitoring of economic impacts. The **lack of a structured system for monitoring economic impacts** on the supply chain was also confirmed by F4E interviewees.

The **F4E ILO network** provides for some understanding of the industrial and economic impact of F4E activities, this is unstructured and more qualitative, anecdotal knowledge which is shared through more informal networks.

The main actual tracking of economic impact of F4E has occurred through periodic, independent studies such as this work. Two previous economic impact studies were commissioned in the past (both by the European Commission DG ENER), namely (1) the 2018 **Study on the impact of the ITER activities in the EU[66]** led by Trinomics which provided a detailed analysis F4E funded activities and their direct and indirect economic impact, including through the use of macro-econometric modelling, descriptive statistics, qualitative analysis and case studies; and (2) a 2021 follow-up **study on the economic benefits of ITER and BA projects to the EU industry[67]** which largely repeated the analysis for the additional years since the 2018 study.

[65] See for example the Annual report on EU Joint Undertakings for the financial year 2023; or the 10th Annual Assessment Report 2022, F4E

[66] Study on the impact of the ITER activities in the EU - Trinomics

[67] Follow up study on the economic benefits of ITER and BA projects to EU industry - Publications Office of the EU

When looking at comparator organisations we find that **at CERN and ESA socio-economic impact monitoring is carried out in a similar way to F4E**. For example, socio-economic impact studies are commissioned by CERN periodically and at specific programme milestones. These are carried out by independent consultants (a current 2025 study is ongoing in parallel to this work) using similar metrics and methodologies to the studies commissioned by F4E. CERN uses a mix of methods, econometric models,[68] a large-scale supplier survey, and in-depth interviews,[69] and ESA uses socio-economic impact assessments, life cycle assessments and cost benefit analysis. All three organisations use technology transfer as a metric, which can indirectly measure potential economic impact, on the basis that innovation can generate economic impacts. Interviewees at CERN reflected that further consideration could be given to economic and industrial impact, for example developing a metric or co-efficient to assess projects economic impact to help prioritise work. However, similar issues to F4E are noted, including that the organisational priorities are focused on quality, cost and implementation, with staff focused on scientific and technical goals. Socio-economic impact remains relatively low in CERN operational priorities.

## 5.5 Within the limit of its mandate, how can F4E contribute to better supporting the EU to remain competitive compared to non-EU actors?

As noted in section 4.3 **the EU competitive position is strong overall, with F4E having played an important role in establishing this position. However, looking forward there are increasing challenges** for Europe to maintain its industrial and technological edge, both internal challenges, e.g. a shrinking EU project pipeline to feed the European supply chain; and external challenges e.g. private sector fusion development in the US, state-supported fusion development in China, and competition from other nations such as the UK and Japan which also have a combination of a strategic plan, regulatory certainty, and strong scientific, technological and industrial bases.

Looking at the mandate of F4E this encompasses the following areas:

- **2007 Council Decision establishing F4E** to: (1) Provide Euratom's contribution to the ITER Organisation, in accordance with the ITER International Agreement; (2) Provide Euratom's contribution to Broader Approach activities with Japan for the rapid realisation of fusion energy as foreseen in the Broader Approach Agreement; (3) Prepare and coordinate a programme of activities in preparation for the construction of a demonstration fusion reactor and related facilities including the International Fusion Materials Irradiation Facility (IFMIF).
- **2012 F4E Industrial Policy** with three objectives: (4) Deliver the European contributions to ITER and the Broader Approach within the agreed budget and schedule making best use of the industrial and research potential and capabilities of all F4E members, in line with competition rules; (5) Broaden the European industrial base for fusion technology for the long-term development of fusion as a future energy source and to ensure a strong and competitive European industrial participation in the future fusion market; (6) Foster European innovation and competitiveness in key emerging technologies to further the development of the Innovation Union and its impact at international level.

[68] This includes ordered logit regression and Bayesian networks, as well as longitudinal analysis of firm-level data such as balance sheets and patent records (Florio et al., 2018).

[69] CERN Procurement Impact Report, 2019

Objectives (1), (2) & (4) are strongly overlapping – and especially **(1) the (timely and efficient) delivery of the European contribution to ITER, should remain the primary mission of F4E**, as key stakeholders have pointed out during this work in interviews and also at public events such as the F4E suppliers roundtable in June 2025. For objective 2 the F4E contributions to Broader Approach are now relatively small, the main work on this is now operational and scientific with EUROfusion taking the lead on the EU side. Part of the 2007 objective (3) for IFMIF is being taken up through IFMIF-DONES[70]. The work for IFMIF-DONES is being led by a Spanish-Croatian partnership, although F4E has announced a large funding contribution, of around EUR 202 million, or around 25% of the project cost. This provides an important opportunity to support EU industry in the coming years.

**Objectives (5) and (6) provide a clear mandate for F4E to aim at boosting European competitiveness, industrial capacity and technological edge – the main limitation is how much priority F4E can give to these objectives whilst also addressing objective (1)**. Objective (3) and a 'programme of activities in preparation for the construction of a demonstration fusion reactor' also potentially provides additional mandate for broader action by F4E, but this is currently the lowest priority of the original 2007 objectives, given the need to focus on ITER. In summary, there is a mandate for F4E action in this area, but with limits given the overriding priority on ITER. On this basis there were two main areas highlighted by stakeholders as potential opportunities for F4E to continue to support EU competitiveness, technological edge and industrial capability in fusion, including:

- **Examine the possibilities of parallelisation, i.e. to support projects and programmes in parallel to ITER.** Whilst potentially in competition with objective (1) to complete ITER contributions, the desire for parallel work in the EU was strong amongst many stakeholders, particularly those in industry. This is needed for various reasons including (i) to **feed a project pipeline to sustain European industry** as ITER spending declines; (ii) as an opportunity to demonstrate **greater agility and speed** to give confidence that the EU could seize the moment in a way that competitors in China, the US and elsewhere already appear to have done; (iii) as a way to look at **alternative fusion approaches** or to **support EU fusion start-ups**. Many stakeholders saw a leading role for F4E in any potential parallel efforts, although this was not specified, there was support for making use of the structure, skills and competences F4E has developed. Indeed, maintaining the **specific competences and skills as an organisation that F4E has developed since its founding** was also marked as crucial by multiple stakeholders, especially if the EU were in future to pursue a follow-on project to ITER.
- **Continue to support (fund / procure from) EU industry.** Industry stakeholders highlighted the need for F4E to continue to procure work from industry given the still low maturity of the fusion market and risks involved. Other stakeholders, particularly from the policy and scientific community, more often reflected that they thought that EU industry needed to take more risk, to invest, 'put money on the table'. This was seen as necessary to keep pace with competitors, and especially the US, where private fusion firms have secured significant capital and investment. However, some industry stakeholders pushed back on this, noting that the situations are very different between U.S. start-ups raising funds and EU supply chain firms, which are often SMEs and may not have access to similar financing due to differences in EU capital markets. Moreover, many of these firms supply only components for larger systems.

[70] Work on objective 2 under the Broader Approach on IFMIF-EVEDA is also highly relevant, laying the groundwork for IFMIF-DONES.

For these firms, their work for F4E on ITER already represents a significant investment of time, staff, facilities, and money, carrying substantial risk. As a result, procurement from F4E remains crucial for these firms in the short-medium term, i.e. until EU and global fusion markets have grown further, to maintain their workforce, competences and capabilities.

Multiple suggestions were made on how **F4E could improve its ways of working t**o benefit industry and contribute to the objectives, including for F4E to:

- Review processes to adopt more agile procedures, with a focus on developing a more commercial / private sector mindset (to risk, quality, speed, cost).
- Improve matchmaking facilities, particularly to encourage SMEs to partner with larger firms to gain entry points to the fusion supply chain – this point should start to be addressed though the new F4E industry portal and its Partnership tool and SME channel.
- Take a different approach to Intellectual Property ownership in any future non-ITER work, as this would help firms to justify investments in fusion and to improve general competitiveness and innovation – the flexibility is available to F4E and signs are that this is being done, for example in contracts for TDP.
- Examine opportunities for using AI in F4E processes and technology development work.
- Improve and better resource technology transfer processes, so that these are better communicated and accessible and that EU industry and start-ups can more fully leverage the EU investment in ITER to innovate and grow.
- Work with others e.g. EUROfusion (FUSEnet), to support further EU fusion workforce skills development.

**More generally for EU policymakers (i.e. looking beyond only F4E) stakeholders reflected that an EU Strategy would be helpful** – and that this should demonstrate **vision and ambition**, should show the **urgency and speed** required, and should also **commit the scale of funding** to allow the EU to maintain and grow leadership. Some stakeholders feared that this was already being lost, especially to China and the US. A few stakeholders also noted the risk that EU Strategy and plans (current and in-development) are heavily determined by the research community (labs, scientists, EUROfusion) and this has drawbacks including: (i) a slow, bureaucratic, risk-averse working culture; (ii) objectives based on scientific goals, rather than on societal needs, i.e. continuing to require first-of-a-kind solutions to explore new science, rather than using current technology and focusing on engineering and the urgent societal need for clean power. F4E could have a role in the latter approach, leveraging ITER experience to help support a more quickly implementable project pipeline for industry.

# 6 CONCLUSIONS

This study shows that F4E spending generated significant positive economic returns for the aggregate economies of the EU27 and Switzerland during 2018–2024. The results reinforce and expand on the findings of the earlier Trinomics study (2018) and the 2020 follow-up assessment, both of which had already highlighted F4E's substantial contribution to economic growth of the EU. The present analysis found that this positive trend has continued, with **F4E-related expenditure estimated to have generated about EUR 5.95 billion increase in GVA and created around 39,000 job-years compared with a counterfactual scenario in which no F4E-related spending takes place**. Compared to alternative scenarios where F4E funds are either saved or redirected, direct investment in F4E still result in positive impacts, though of smaller magnitude, confirming the overall robustness of the findings.

The analysis also confirms that **the economic and employment benefits, while positive overall, are unevenly distributed across countries, with France, Spain, and Italy seeing the greatest gains**. This imbalance reflects the location of major ITER activities and the concentration of relevant industrial capabilities within these countries. Unlike some international organisations such as CERN and ESA, F4E operates without a formal geographical return policy, prioritising value for money and transparency in procurement processes. Stakeholders at CERN and ESA observed that while return mechanisms can help ensure political support in cases where contributing members perceive the distribution of benefits as unbalanced, they also introduce significant drawbacks and risks. The challenge for F4E is therefore to manage potential political sensitivities while maintaining procurement practices that are competitive, efficient, and aligned with its mandate.

Beyond the impact in terms of GVA and employment, **F4E activities also contribute to the intellectual, human and industrial capital, strengthening the European industrial competitiveness**. According to F4E payment data, 345 main suppliers alongside 820 sub-contractors were involved in active contracts with F4E during the period 2018-2024. Working for and with F4E created substantial learning opportunities, enabling firms to acquire new skills, technical know-how, and organisational capabilities. These learning effects partly translated into innovation outcomes, including the improvement of existing products and services, the development of new solutions/high-tech technologies, and the transfer of knowledge into practical applications, some of which extended beyond the fusion sector. Firms also experienced market and reputational effects, such as improved visibility, access to new markets such as nuclear fission, healthcare and aerospace, and the formation of international and inter-sectoral partnerships. These impacts were accompanied by workforce development, in particular the consolidation of high-skilled positions. Employment gains are however not only linked to the procurement relationship with F4E but are also mediated by the innovations that engagement with F4E helps to foster.

**EU industry demonstrates strong capabilities across key fusion technologies, though competitive dynamics vary by sector**. Magnet manufacturing is a European strength, yet dependence on foreign HTS superconductor suppliers exposes vulnerabilities against well-funded competitors such as CFS and Tokamak Energy. EU firms hold global leadership in vacuum vessels, but market opportunities remain limited and Chinese competition is intensifying. In heating systems, European players benefit from strong research ties but face concentrated competition from Japan and Russia, while cryoplant suppliers are well-established with diversification potential in LNG, chemicals, and ICT. For blankets, tritium handling, divertors, and wall materials, EU actors lead ITER developments, though these supply chains are still immature and at risk of being outpaced by the

UK, US, and China. EU firms are gaining valuable expertise in remote handling and diagnostics through ITER and amongst the global leaders. Similarly for related services in design, engineering, safety and waste, EU firms are amongst the global leaders with strong fusion experience, but face strong competition from US and UK firms. Finally, for construction, buildings and power supply infrastructure, the EU has well established firms, but the capabilities for this work are more generic and clients will tend to select domestic firms over EU or other firms.

**While F4E has played an important role in strengthening EU competitive position, there are increasing challenges for Europe to maintain its industrial and technological edge**. The progressive reduction of ITER-related activities could leave gaps in the project pipeline for the European supply chain, and firms also note the complexity of participating in large-scale international projects. At the same time, competition in fusion is intensifying worldwide. The US is seeing rapid advances led by private companies, China is pursuing state-supported programmes, and other countries such as the UK and Japan combine clear strategic plans, regulatory clarity, and strong scientific and industrial ecosystems.

**Looking ahead, there are several avenues through which F4E could contribute to sustaining EU's competitiveness within the limits of its mandate.** While the primary responsibility remains the timely and efficient delivery of the EU contribution to ITER, stakeholders emphasised that F4E has developed structures, skills, and competences that could be leveraged more broadly. One area concerns the possibility of parallel work alongside ITER to help sustain the European industrial base, maintain a pipeline of projects, and provide space for greater agility, experimentation with alternative approaches, and support for emerging EU fusion start-ups. Continued support to EU firms also remains key, particularly for SMEs and mid-sized companies that cannot access private capital markets in the same way as competitors in the US, Japan, or China. Several suggestions were raised to improve F4E's practices in support of industry, including adopting more agile and commercially minded procedures, strengthening matchmaking facilities to connect SMEs with larger firms, applying the more flexible approaches to intellectual property available to F4E in any future non-ITER projects, and enhancing the communication, accessibility and resourcing of technology transfer processes. Stakeholders also pointed to opportunities for using digital technologies, such as artificial intelligence, to improve F4E's internal processes and technology development work. Finally, collaboration with partners such as EUROfusion and FuseNet could be intensified to address future skills needs in the European fusion workforce.

# ANNEX 1. PATHWAYS TO IMPACT

## Table 10. The pathways to impact

| IMPACT AREA | IMPACTS | METHODOLOGIES TO ASSESS | DATA/INFORMATION NEEDED |
|---|---|---|---|
| 1. KNOWLEDGE IMPACT | The construction of a research infrastructure – including ITER and BA activities - is expected to generate **new scientific knowledge**.<br>The research output can take different forms – such as technical reports, proceedings, preprints or working papers, articles in scientific journals, research monographs, etc. | -Mapping the publications and citations: searching for publications (P0) funded by F4E or mentioning F4E activities and also the references (citations, (P1)) that are made to those original publications.<br>-Publications network analysis to investigate the relationship /network of collaborations between institutions involved in F4E-related publications and their evolution over time. | List of publications and other scientific outputs (e.g. papers, technical reports, etc.) along with authors, years and DOI details.<br>Number and volume of publications and citations. |
| 2. INNOVATION IMPACT | Procurement contracts of F4E may generate **technological spillovers** and learning opportunities for supplier firms. They often require the development of nonroutine technologies and ideas, which challenge firms to supply new, improved and sometimes cutting-edge products, services and technological solutions. These effects are likely to positively impact the future innovativeness, productivity and profitability of supplier firms. The demand for new technologies can also allow for the establishment of new businesses entering the market. In the literature, a distinction exists between intermediate and final outcomes accruing to supplier firms. **Intermediate outcomes include learning, innovation, and market penetration**. These intermediate outcomes have a cascade effect on firms' economic performance in terms of **an increase in sales, profits, employment, and business development.** | - Multi-dimensional online survey to suppliers addressed to i) analyse the relationships between F4E and its suppliers; ii) assess suppliers' intermediate outcomes, namely, learning, innovation, and market penetration; iii) evaluate suppliers' performance in terms of sales, profits and business development; iv) analyse outcomes for second-tier suppliers.<br>- Micro-econometric analysis: a logit analysis will be conducted using the results of the survey. If possible, this analysis will be complemented by an analysis of firms' balance sheet data. It consists of exploring possible changes in companies' profits or R&D spending triggered by the beginning of their collaboration with F4E.<br>- Analysis of direct and indirect patents: Patent applications can be used to i) assess whether the collaboration with F4E has increased the hazard of filing a patent for the first time; ii) estimate the impact of F4E's procurement on the number of patents filed by its suppliers. Moreover, by analysing the patents that either mention F4E activities or cite F4E-related publications, it is possible to analyse the indirect effects of knowledge disseminated through F4E collaborations in the development of new technologies and products.<br>- Qualitatively examination of cases where fusion-related technologies are applied in other industries | Mapping and description of F4E suppliers (number, sector of activity, nature of procurement, etc.)<br>Contractors' replies to the survey on the procurement relationship with F4E and gained intermediate and final outcomes<br>Mapping and description of innovations developed by industries<br>Mapping and description of patents developed by F4E contractors<br>Mapping of patents citing F4E-related publications<br>Mapping and description of cases of spin-off technologies or cross-sector applications |
| 3. SUPPLY CHAIN | Procurement contracts of F4E and F4E's industrial policy actions are expected to **strengthen European supply chains** (i.e. cross-border collaboration between SMEs, research institutions, and large corporations) in the field | - Supply Chain Mapping: Identify the companies involved (large enterprises, SMEs, startups) and their role in the fusion supply chain (advanced materials, components, engineering, construction, etc.).<br>- Industrial/Geographical Concentration: Assess which countries or regions are most active in the development of fusion technologies and | Procurement database, possibly including information on subcontractors.<br>F4E's recent work on supply chain mapping |

| | | | |
|---|---|---|---|
| | of nuclear fusion. | whether there are competitive industrial hubs. | |
| 4. Skill and workforce impact | The learning opportunities for F4E's supplier firms and research institutions may **increase human capital and skill development** among the EU fusion research and engineering community and supply chain among Member States and beyond. These might also spur the training of new generations of fusion physicists, engineers and technicians as well as talent retention within the EU, helping prevent brain drain in high-tech fields. | - Qualitative assessment of the new capacity and skills from experience with F4E.<br>- Track changes in demand/offer for fusion-related skills and employment levels.<br>- Assessment of workforce, i.e. new jobs created and retention of skilled workers. | Number of firms/research organisations' staff involved in F4E contracts/grants benefitting from skill improvements.<br>Learning process and knowledge sharing amongst F4E/ITER staff and firms/research organisations' staff involved in F4E contracts/grants |
| 5. Economic impact | F4E's investments lead to long-term economic changes in terms of **Gross Value Added (GVA) growth and employment**. The impacts have multiple potential levels; firstly, the **direct benefit** to contracted suppliers, boosting turnover (and in turn, GVA) and employment. These also lead to **indirect impacts** on the supply chain of these firms and an **induced impact** on the wider economy from the extra spending. Additionally, the **technological spillovers** highlighted in 2 above **can also lead to improved economic impacts**, with similar direct, indirect and induced benefits.<br>Furthermore, impacts on the economic **competitiveness** of the EU fusion industry should be considered. | - Quantitative analysis based on procurement data to provide insights into the sectors and technologies where the greatest economic impacts are experienced.<br>- Macro-econometric modelling to estimate the direct, indirect and induced impacts on GVA and jobs across the EU economy from the spending of F4E. Macro-econometric tool can be used for this modelling exercise (E3ME)<br>- Competitiveness assessment of the EU industry considering its positioning, capabilities and success-to-date in the global fusion supply chain. SWOT analysis for the EU industry or potentially per key technology branch.<br>- Case studies of firms that have gained economic benefits from technological spillovers from their work on ITER to more deeply understand and illustrate how the contracts with F4E have led to economic benefit, especially from follow-up contracts in fusion or other industries. | Procurement database, with information relevant to economically classifying activities<br>Macro-econometric model tailored to the F4E spending and with defined scenarios to be modelled<br>Survey responses from suppliers on economic impacts, innovation and technology spillovers, employment and skills<br>Interviews with case study firms on the impacts |

# ANNEX 2. ASSESSMENT FRAMEWORK

**Table 11. Assessment Matrix**

| QUESTIONS | RELATED IMPACT PATHWAY | INDICATORS / DESCRIPTORS | JUDGEMENT CRITERIA | METHODOLOGICAL TOOLS |
|---|---|---|---|---|
| **IMPACTS** | | | | |
| What are the **macroeconomic effects** of F4E's activities on the EU economy, particularly in terms of GDP growth and gross value added (GVA), and job creation? | #5 | ▪ Value-added (GVA) contribution<br>▪ Employment | ▪ F4E activities positively contributed to the EU economy in terms of GVA and employment (both in gross and net scenarios)<br>▪ The impact of F4E is aligned with estimations done in previous studies. | ▪ Analysis of the F4E procurement database (after association with the NACE code)<br>▪ Macroeconomic impact analysis (E3ME modelling) |
| What is the impact of F4E activities in fostering **competitiveness of industries** directly or indirectly involved in fusion? | All | ▪ New knowledge acquired and/or new skills developed<br>▪ New cutting-edge technologies (fusion-related and beyond fusion)<br>▪ New spin-off products /services<br>▪ New markets outside fusion<br>▪ Perceived EU industry competitive position | ▪ F4E activities positively impact the competitiveness of industries directly and indirectly involved in fusion by increasing their skills, scientific knowledge, innovation outputs, and economic performance.<br>▪ EU industrial leadership is strengthened or maintained. | ▪ Online survey with suppliers and grants beneficiaries<br>▪ Micro-econometric analysis<br>▪ Interviews<br>▪ Competitiveness and SWOT analysis<br>▪ Case studies |
| What has been the impact of F4E activities in establishing **synergies across national boundaries and industrial sectors**? | #3 | ▪ Geographical distribution of contractors/publications/patents<br>▪ Number/typologies of cross-border collaboration<br>▪ Vertical and horizontal synergies (identified through NACE) across industries | ▪ F4E activities contributed to strengthening European supply chains (i.e. cross-border collaboration between SMEs, research institutions, large corporations) in the field of nuclear fusion. | ▪ Online survey with suppliers and grants beneficiaries<br>▪ Analysis of the F4E procurement database (after association with the NACE code)<br>▪ Bibliometric and patent analysis |

| | | | |
|---|---|---|---|
| Are there **industries or sectors that have benefited from F4E's activities** and those that could still benefit from it? | #3 | ▪ Number of contracts per firm<br>▪ NACE distribution of contractors<br>▪ Number of firms per programme | ▪ F4E activities benefitted particular sectors or technologies.<br>▪ There is still room for further benefits in certain sectors | ▪ Analysis of the F4E procurement database (after association with the NACE code)<br>▪ Interviews with F4E<br>▪ Online survey with suppliers and grants beneficiaries |
| What is the **qualitative impact of F4E's work on the European job market**, particularly in terms of developing high-quality jobs, as well as fostering relevant know-how and skills critical for the future fusion industry? What specific types of jobs and expertise are being created, and in which regions of Europe? | #4 | ▪ Employment, including breakdowns by skill level and/or NACE code/technology and region. | ▪ F4E activities have created employment. This employment is specifically high skilled and is in technologies/sectors identified as crucial to sthe future fusion industry. | ▪ Online survey with suppliers and grants beneficiaries<br>▪ Interviews with firms and research organisations<br>▪ Interviews with fusion experts and F4E, Eurofusion, and EC representatives. |

| QUESTIONS | INDICATORS / DESCRIPTORS | JUDGEMENT CRITERIA | METHODOLOGICAL TOOLS |
|---|---|---|---|
| **F4E's ACTIONS/PROCEDURES** | | | |
| How effectively is F4E **measuring and tracking the economic impact of its initiatives**, and what methodologies are in place to assess both the direct and indirect outcomes of its activities? | ▪ Monitoring process analysis<br>▪ Stakeholder opinion | ▪ F4E systematically collects all data needed to assess the economic impact of its activities<br>▪ F4E has methodologies in place to assess both direct and indirect outcomes of its activities | ▪ Desk research<br>▪ Interviews with F4E |
| Is F4E employing the most **efficient procurement and project management strategies** to optimize its positive economic impact and what lessons can be drawn from the experiences learned in participation in the ITER and BA projects? | ▪ F4E procurement and project management strategies are positively assessed by suppliers<br>▪ Stakeholder opinion | ▪ F4E procurement and project management strategies are efficient<br>▪ F4E procurement and project management strategies can be further improved to optimize F4E economic impact | ▪ Desk research (incl. recent mid-term evaluation of EU participation in ITER)<br>▪ Interviews with F4E<br>▪ Online survey with suppliers and grants beneficiaries |

| | | | |
|---|---|---|---|
| How do **F4E's procurement strategies compare to other organizations** like CERN and ESA in terms of achieving and measuring return on investments? | ▪ Comparison of key metrics<br>▪ Comparison of procurement models<br>▪ Comparison of supplier engagement activities<br>▪ Comparison of technology transfer activities<br>▪ Stakeholder opinion | ▪ F4E's key metrics to measure return on investment of procurement are comparable to those of CERN and ESA<br>▪ F4E's procurement models and supplier engagement activities are comparable to those of CERN and ESA<br>▪ F4E's technology transfer activities are comparable to those of CERN and ESA | ▪ Desk research (incl. procurement guidelines, recent mid-term evaluation of EU participation in ITER, impact studies)<br>▪ Interviews with F4E<br>▪ Interviews with CERN and ESA<br>▪ Interviews with firms |
| Within the limit of its mandate, how can **F4E contribute to better supporting the EU** to remain competitive compared to non-EU actors? | ▪ Perceived competitive position of EU industry<br>▪ Stakeholder opinion | ▪ Types of support are within the F4E mandate.<br>▪ Does support contribute to the EU fusion industry's global competitiveness. | ▪ Online survey with suppliers and grants beneficiaries<br>▪ Interviews with F4E, firms, research organisations |
| To what extent does **F4E orient its deliveries on high-tech, fusion-related technologies**, as opposed to lower-tech infrastructure (e.g., buildings)? What are the **consequences of the current allocation of tasks assigned to F4E** on Europe's industrial Leadership? How to improve its positioning? | ▪ TRL distribution of contracts<br>▪ Concentration of contracts in high-tech vs low-tech contracts<br>▪ Heterogeneity of GVA/employment/profitability indicators<br>▪ Stakeholder opinion | ▪ F4E has limited power to orient its deliveries to high-tech fusion-related technologies.<br>▪ The current allocation of tasks assigned to F4E has generated a specific high-low tech balance, can this be improved.<br>▪ The EU's position in nuclear fusion could be improved if F4E would be granted additional resources and missions to tackle. | ▪ Desk research<br>▪ Analysis of the F4E procurement database (after association to TRL or high/low-tech intensity)<br>▪ Interviews with F4E, EU associations, firms, research organisations |
| How can F4E activities be **better oriented to support the development of key fusion technologies** in order to contribute to Europe's technological edge and industrial capabilities? | ▪ Key technology focus, allocations per technology.<br>▪ Stakeholder opinion | ▪ Activities support key fusion technologies.<br>▪ Activities support European technological leadership and/or industrial capabilities. | ▪ Desk research<br>▪ Interviews with F4E, firms, research organisations |

Source: authors

# ANNEX 3. E3ME MODEL DESCRIPTION

E3ME is a model of the world's economic and energy systems, and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used for policy assessment, forecasting and research purposes. E3ME was used to assess the socioeconomic impact of the European Commission's 2030, 2040 and 2050 emission reduction target proposals as part of the official impact assessments and has been used for many other studies and impact assessments by the European Institutions and other international organisations.

The full model manual is available at the model website www.e3me.com.

## Main purpose

E3ME has been designed to assess the impacts of climate change mitigation policy on the economy and the labour market. The basic model structure links the economy to the energy system to ensure consistency between economic and physical indicators.

E3ME can provide a comprehensive analysis of policies in each of its 71 regions:

- direct impacts, for example, reduction in energy demand and emissions, fuel switching and renewable energy
- secondary effects, for example, on fuel suppliers, energy prices and competitiveness impacts
- rebound effects of energy and materials consumption from lower prices, spending on energy or other economic activities
- overall macroeconomic impacts on jobs and the economy at a high level of sectoral detail and (where data allow) household income group

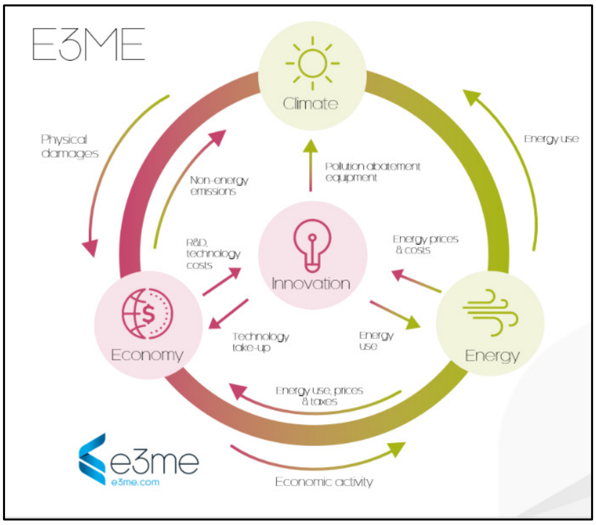
## Theoretical underpinnings

E3ME is designed primarily as an empirical tool. It draws on the Cambridge (UK) tradition of macroeconomics, supplemented by more recent applications of complexity theory to economics. The key properties of the model include recognition of fundamental uncertainty, possible non-rational behaviour and market structures determined by the available data.

The model has been shaped to meet the needs of policymakers, both in terms of the types of scenarios assessed (e.g. a wide range of market-based and regulatory climate policies) and output indicators (e.g. detailed employment, unemployment and measures of inequality).

E3ME incorporates bottom-up technology models of four major energy-using sectors[71] (power, personal transportation, steel and household heating). These models follow the 'S-shaped' diffusion paths of new technologies as they gain market acceptance and incorporate cost reductions through learning rates.

[71] Called the FTT (Future Technology Transformation) models. See e.g. Mercure et al (2014) for details.




E3ME is often compared to Computable General Equilibrium (CGE) models. In many ways the modelling approaches are similar; they are used to answer similar questions and use similar inputs and outputs. However, there are differences between the modelling approaches. In a typical CGE framework, optimising behaviour is assumed, output is determined by supply-side constraints, and prices adjust fully so that all the available capacity is used. In E3ME, output is driven by demand with supply-side constraints and prices don't always prices always adjust to market clearing levels.

The differences have important practical implications because they mean that E3ME regulation and other policies could potentially lead to increases in output if they are able to draw upon the available spare economic capacity. The role of the financial sector is key (see the model manual for further details).

The econometric specification of E3ME gives the model a strong empirical grounding. E3ME uses a system of error correction, allowing short-term dynamic (or transition) outcomes, moving towards a long-term trend. The dynamic specification is important when considering short and medium-term analysis (e.g. in Covid-19 recovery).

## Basic structure and data used

The structure of E3ME is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, including both voluntary and involuntary unemployment. The other econometrically estimated equations cover the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by region and by sector.

E3ME's historical database covers the period 1970-2023, and the model projects forward annually to 2070. Apart from the IEA energy balances and prices, the model's data is based entirely on freely available information from international sources and national statistical agencies. Gaps in the data are estimated using customised software algorithms.

The main dimensions of E3ME are:

- 71 countries – all major world economies, the EU28 and candidate countries plus other countries' economies grouped.
- 44 (or 70 in Europe) industry sectors, based on standard international classifications.
- 28 (or 43 in Europe) categories of household expenditure.
- 25 different fuel users of 12 different fuel types.
- 14 types of air-borne emission (where data are available), including the 6 GHGs monitored under the Kyoto Protocol.

# ANNEX 4. DATABASE PREPARATION

This annex delves into the methodology and assumptions employed in the processing of data that was fed into the E3ME modelling exercise, whose results are explored in Sections 4.1 and 4.2 of this report. For this end, this annex is split into three parts, each describing a part of the preparation of the datasets employed in the analysis:

- Preparation of F4E payments dataset
- Preparation of the F4E expenditure dataset
- Processing of the datasets into model inputs.

## Preparation of F4E contract and grant payment dataset

The dataset provided by F4E containing payments to suppliers from 2018 to 2024 is one of the datasets used as input in the modelling exercise to inform the level and country distribution of F4E in-kind expenditures. The main objective of preparing this dataset was to map each payment value to a NACE sector. This NACE classification could then be converted into the E3ME sector classification. The mapping exercise was initially developed for a previous study in 2018[72] and has been replicated as closely as possible in the current project. The mapping of contracts to a NACE sector code is carried out in four steps:

1. In the F4E data, each payment is associated to a contract, which in turn is associated with a WBS code. In the previous project, experts developed a conversion table from WBS to NACE codes. This converter serves as the primary mapping source.
1. If a contract's WBS code is not mapped to any NACE code using the above converter, an alternative mapping is applied. Each contract in the F4E dataset is also assigned a technology code. Experts created a mapping from technology codes to NACE sector codes.
2. If neither the WBS code nor the technology code is available or mapped to a NACE code, the legal entity awarded the contract is matched with the ORBIS database, which lists firms by country and their officially registered primary NACE sector. If a contract still lacks a NACE code after these three mappings, the most frequent NACE code among contracts sharing the same WBS code is assigned. If still unmatched, the most frequent NACE code among contracts with the same technology code is used.

This layered approach ensures maximum coverage and consistency in classifying contracts by economic activity. As a result of this mapping methodology, 99.6% of F4E in-kind expenditures were successfully mapped to a NACE sector and incorporated into the model. The absence of contract descriptions in the databases provided by F4E prevented the manual verification of the mapped NACE sector.

## Preparation of the F4E expenditure dataset

The F4E expenditure dataset is the second of the two key datasets that inform the inputs used in the modelling exercise present in this report. This table includes the expenses of F4E disaggregated across multiple expenditure categories in terms of billion current Euros. This table was populated

[72] Trinomics and Cambridge Econometrics (2018). Study on the impact of the ITER activities in the EU. https://trinomics.eu/wp-content/uploads/2019/04/impact_of_the_iter_activities_in_the_eu-trinomics.pdf

with data inputs provided to us directly by F4E and the European Commission, and further validated with F4E. The expenditure categories are the same considered in previous studies.

**Table 12. F4E expenditure by category (billion current Euros)**

| | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|
| F4E cash to IO | 0.222 | 0.218 | 0.189 | 0.279 | 0.213 | 0.109 | 0.199 |
| … Construction | 0.222 | 0.218 | 0.189 | 0.279 | 0.213 | 0.109 | 0.199 |
| … Operations | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| … Upgrades & operational spares | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| … Decommissioning / deactivation | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| F4E in kind | 0.507 | 0.428 | 0.441 | 0.356 | 0.429 | 0.344 | 0.293 |
| F4E admin | 0.055 | 0.057 | 0.059 | 0.062 | 0.076 | 0.073 | 0.082 |
| F4E other | 0.020 | 0.023 | 0.030 | 0.024 | 0.032 | 0.050 | 0.059 |
| Cash to Japan | 0.002 | 0.007 | 0.072 | 0.014 | 0.002 | 0.001 | 0.003 |
| EC project admin | 0.006 | 0.007 | 0.006 | 0.007 | 0.007 | 0.008 | 0.008 |
| **Total** | **0.812** | **0.740** | **0.796** | **0.742** | **0.759** | **0.586** | **0.643** |

Source: authors based on F4E and EC data

The data included in this table underpins the inputs provided to the model, with the F4E-related spending laid down in this table being distributed across countries and sectors based on the shares estimated from the F4E contract and grant dataset and a series of assumptions specific to each expenditure category specified within this table.

## Processing of the datasets into model inputs

The data inputs utilised in the E3ME modelling exercise are processed based on the two datasets described above. These data inputs consist of two exogenous variables: one that determines a country-sector specific demand shock, and a second variable that determines the change in expenditures to a governments budget in the case F4E-related spending is suspended. The four scenarios (including Baseline) of the modelling exercise are determined by different combinations of what is included in these two variables. The scenarios and their underpinning assumptions are similar to the scenarios simulated in previous studies, with the exception of the 'Tax Reduction scenario' (which is a new scenario compared to the previous studies).

**Table 13. Variable set up in each scenario**

| SCENARIO | EXOGENOUS DEMAND SHOCK VARIABLE | EXOGENOUS SHOCK TO GOVERNMENT COSTS VARIABLE |
|---|---|---|
| Baseline | Set to 0. Assumes F4E spending to occur as it did historically. | Set to 0. Assumes F4E spending to occur as it did historically. |
| Gross Impact scenario | Negative demand shock as to exclude the demand generated by F4E spending. | Set to 0. Assumes unrealised F4E spending to be saved and thus a leakage from the economy |
| Tax Reduction scenario | Negative demand shock as to exclude the demand generated by F4E spending. | Reduction in government expenditure, based on how much cost is allocated by country. The model then endogenously ensures government budget neutrality across scenarios by reducing tax revenue in equal manner across income tax, employer's social security contributions, and VAT. |
| General Investment Programme scenario | Demand shock of ambiguous direction. It combines the exogenous decrease in demand present in the two scenarios above plus a positive demand shock stemming from the general investment programme. | Set to 0. The General investment programme is set to be of the same size as F4E spending and have no additional impact on government's spending. |

Source: Cambridge Econometrics

## Exogenous shock to government costs variable

The yearly values for the exogenous shock to government costs are estimated (for the Tax Reduction scenario) based on the yearly sum of F4E-related spending ("Total" row of the F4E expenditure dataset) and distributed across countries based on a simplification of F4E's funding distribution:

- 80% to Euratom (all the shares are consistent with the previous 2018 impact study)
    - The costs allocated to Euratom are supported by the European Budget, thus these costs are assumed to be allocated to each EU27 member-state in accordance to the MFF contribution shares.
        - The distributions for the 2014-2020 MFF were used for the period of 2014-2020 this MFF was active. Please note that this includes the UK throughout the whole period.
        - The 2021-2027 MFF distributions are used for all years after 2020. Note that these distributions no longer include the UK.
    - The UK (post-Brexit) and Switzerland are considered for the distribution of F4E expenditure costs to governments following their status of Associated Member States to the Programme.
        - This entails that their contribution is proportional to the country's GDP relative to the aggregate EU GDP at market prices. The EU Member-State's contributions (determined by MFF shares) are proportionally downsized.
        - Switzerland is considered an Associated Member-State during the period of 2018-2020. Since then, Switzerland has been suspended from the F4E programme and remain so as of the writing of this preliminary report. As such, during the period they are suspended from F4E, it is assumed that

they do not contribute to the programme. The cross-country distribution of costs reflects this assumption.

    - The UK is considered an Associated Member State during the period 2021-2022, after which the country has left the F4E programme. Before this period, they were included in the MFF distribution as the UK was a Member-State of the European Union.

- 19% to ITER's host country (France).
- 1% to each F4E member-state (EU27 + Switzerland + UK)
    - These costs are assumed to be distributed equally across all Member-States of the EU27 and Associated Member-States of the F4E programme. The UK is considered part of F4E up to 2022 (first as an EU Member-State, after as a F4E Associated Member-State). Switzerland being suspended from F4E in 2021, is considered to contribute to F4E (as an Associate Member-State) up to 2020.

## Exogenous demand shock variable

As specified in the table, this variable can exhibit two states, one in which it accounts only for the unrealised demand associated with the hypothetical suspension F4E-related spending, and a second state which accounts for the additional demand generated by the general investment programme on top of the already mentioned unrealised demand. The processing for each of these states is explained in order since the latter (ambiguous demand shocks) depends on the first (negative demand shocks).

### Estimating negative demand shocks

As with the processing of the "exogenous shock to government costs variable", the starting point for the estimation of the "exogenous demand shock variable" is the F4E expenditure dataset. For each of the expenditure categories present in the dataset, a different set of processing and mapping rules are employed to estimate the country-sector specific exogenous demand shocks that are to be used in the modelling exercise. These rules are as follows:

- **Construction (sub-category of F4E cash to IO):** allocated across country-sector combinations in accordance with each specific combination's share of contract and grant value present within a restricted subset of the F4E contract and grant dataset and a set of informed assumptions.
    - Excludes all entries related to the "Buildings infrastructure and power supplies" WBS code from the F4E contract and grant dataset.
    - The distribution shares for France and the rest of the EU27 plus Switzerland and the UK are estimated separately. 80% of this F4E expenditure category is exogenously set to be spent in France, while the remaining 20% are spent in the rest of the EU27 plus Switzerland and the UK.
    - The sector distribution for France is based uniquely on dataset entries related to French firms, while the country-sector combination distribution for the remaining countries exclude entries related to France and any other country outside the set.
- **Operations (sub-category of F4E cash to IO):** allocated across country-sector combinations in accordance to each specific combination's share of contract and grant value present within a restricted subset of the F4E contract and grant dataset and a set of informed assumptions.

- The distribution shares for France and the rest of the EU27 plus Switzerland and the UK are estimated separately. 80% of this F4E expenditure category is exogenously set to be spent in France, while the remaining 20% are spent in the rest of the EU27 plus Switzerland and the UK.
- The 20% spent across to the rest of the EU27 plus Switzerland and the UK is entirely allocated to scientific research (M72). The country distribution shares for this payment are based on the F4E contract and grant dataset entries which maps to this NACE 2-digit sector. Only countries belonging to this set are considered in the estimations of these distribution shares.
- The payments allocated to France are split equally between the economic sectors for power supply and scientific research (M72). The payment to power supply is split (at NACE 2-digit level) equally again between both “D351 Electricity” and “D352-353 Gas, steam and air conditioning”. The data present in the F4E contract and grant dataset is not used for this disaggregation. These payments represent both the (fuel) consumables to operate the device and staff and other costs in its operation and associated research.

- **Upgrades and operational spares (sub-category of F4E cash to IO):** allocated across country-sector combinations in accordance to each specific combination’s share of contract and grant value present within a restricted subset of the F4E contract and grant dataset and a set of informed assumptions.
  - Excludes all entries related to the “Buildings infrastructure and power supplies” WBS code from the F4E contract and grant dataset.
  - The distribution shares for France and the rest of the EU27 plus Switzerland and the UK are estimated separately. 80% of this F4E expenditure category is exogenously set to be spent in France, while the remaining 20% are spent in the rest of the EU27 plus Switzerland and the UK.
  - The sector distribution for France is based uniquely on dataset entries related to French firms, while the country-sector combination distribution for the remaining countries exclude entries related to France and any other country outside the set.
- **Decommissioning / Deactivation (sub-category of F4E cash to IO):** allocated entirely to the French Waste remediation economic sector (E38).
- **F4E in-kind**: allocated across country-sector combinations in accordance to each specific combination’s share of contract and grant value present within the full scope of the F4E contract and grant dataset. The mapping of this dataset is explored at the beginning of this annex.
- **F4E Admin**: exogenously allocated to France (20%) and Spain (80%). to the Public Administration sector (O84) in both cases.
- **F4E Other**: allocated across country-sector combinations in accordance to each specific combination’s share of contract and grant value present within a restricted subset of the F4E contract and grant dataset and a set of informed assumptions.
  - Excludes all entries related to the “Buildings infrastructure and power supplies” WBS code from the F4E contract and grant dataset.

    - The country-sector combination distribution shares only account for those entries marked as having been made to entities within the EU27 plus Switzerland and the UK.
- **Cash to Japan**: allocated across sector combinations in accordance to each specific sector share of contract and grant value present within a restricted subset of the F4E contract and grant dataset and a set of informed assumptions.
    - The spending is allocated in its entirety to Japan.
    - The sector distribution only considers dataset entries with a WBS code relevant to activities within the Broader Approach programme.
- **EC project admin**: allocated in its entirety to Belgium's Public Administration sector (O84).

The resulting variable values for the exogenous demand shock are of either of negative nature or equal to zero, representing the loss of demand in the economy in the hypothetical case of a suspension of F4E-related spending.

### Estimating ambiguous demand shocks

The estimation of ambiguous demand shocks is made on top of the already estimated negative demand shocks, by summing the positive demand shocks brough about in the general investment programme included within the General Investment Programme scenario.

The size of the general investment programme is, across all geographies, of the same size as the F4E-related spending across all geographies. Moreover, it's financing is similar as that of F4E, ensuring thus budget neutrality across the scenarios of the modelling exercise.

The general investment programme assumes that its disbursement follows a similar pattern to the one F4E's financing, with country specific disbursements mirroring country specific contributions to F4E, and an MFF-like disbursement for the contributions of Euratom. The following distribution is observed:

- **80% to an MFF-like disbursement across the EU27 Member-States.** This distribution is in accordance with MFF disbursement shares. The 2014-2020 MFF and 2021-2027 MFF disbursement shares by country are used for their respective time periods.
    - Given the UK's (post-Brexit) and Switzerland's status as Associated Member-States of F4E, they are also considered within this 80% disbursement alongside the EU27 Member-States. The disbursement for either of these two countries within the 80% is proportional to the country's GDP relative to the aggregate EU GDP at market prices. The EU Member-State's disbursements (determined by MFF shares) are proportionally downsized.
        - Switzerland is considered an Associated Member-State during the period of 2018-2020. Since then, Switzerland has been suspended from the F4E programme and remain so as of the writing of this preliminary report. As such, during the period they are suspended from F4E, it is assumed that they are not subject to the programme's disbursements.
        - The UK is considered an Associated Member State during the period 2021-2022, after which the country has left the F4E programme. Before this period, they were included in the MFF disbursement distribution as the UK was a Member-State of the European Union.

- **19% is disbursed directly to ITER's host country (France).**
- **1% to each F4E member-state (EU27 + Switzerland + UK)**
    - These disbursements are assumed to be distributed equally across all Member-States of the EU27 and Associated Member-States of the F4E programme. The UK is considered for disbursements up to 2022 and Switzerland is considered to be subject to disbursements up to 2020.

The resulting modelling inputs may be positive, negative, or zero, depending on the country, sector, year combination.

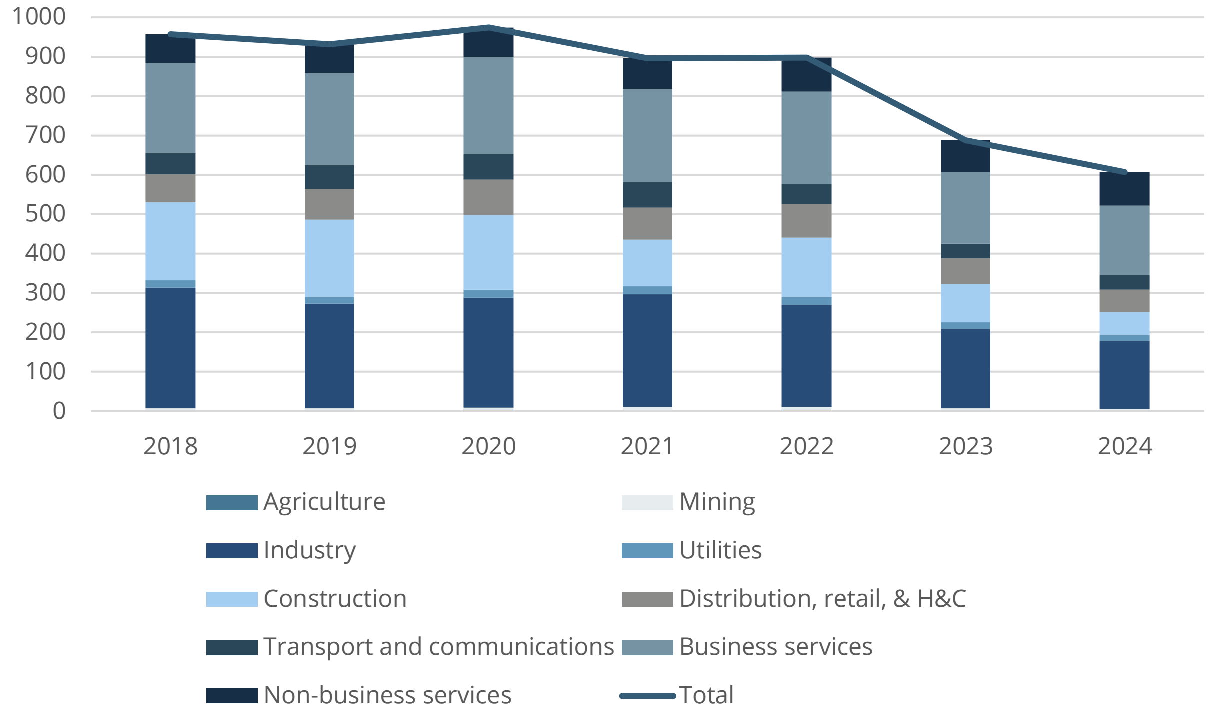
# ANNEX 5. GROSS VALUE ADDED IMPACT BY SECTOR

## Gross Impact scenario

**Among the nine broad sectors utilised in this analysis, the three most impacted in the EU27-Switzerland economy are "Industry", "Business services", and "Construction"**. Over the whole period, these account for 1.8, 1.5, and 1.0 billion Euros respectively, together 72% of the whole GVA impact across the 2018-24 period. This sectoral distribution of the GVA impact is intimately linked with the nature of F4E spending as described in Section 3.

The "Industry" sector includes not just basic manufacturing sectors such as metals but also more advanced manufacturing activities such as computers, electrical equipment and other machinery. Among these, "C28 - Manufacture of machinery and equipment n.e.c", "C25 - Manufacture of fabricated metal products, except machinery and equipment", and "C23 - Manufacture of other non-metallic mineral products" are the NACE 2-digit level sectors that were most affected (accounting for approximately half of the impact within the broad-sector), reflecting not only the direct procurement by F4E of specialised machinery, equipment, and other material necessary for the construction and set up of ITER's facilities such as magnets, other components of the tokamak and its supporting systems, but also the different levels of demand for industrial inputs that feed into the production of machinery and material needed for ITER and other F4E projects.

Figure 28. Gross Impact across EU27+Switzerland: GVA by broad-sector (million 2024 EUR)




Source: Cambridge Econometrics

Table 14. Gross Impact across EU27+Switzerland: GVA by broad-sector (million 2024 EUR)

| | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2018-24 |
|---|---|---|---|---|---|---|---|---|
| **Agriculture** | 2.52 | 3.04 | 3.88 | 3.12 | 3.43 | 2.87 | 2.10 | 20.96 |
| **Mining** | 5.63 | 4.47 | 5.79 | 7.07 | 7.07 | 4.59 | 4.14 | 38.75 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Industry** | 305.27 | 265.75 | 279.03 | 287.48 | 258.64 | 201.61 | 171.76 | 1769.55 |
| **Utilities** | 19.34 | 16.85 | 19.80 | 19.63 | 20.99 | 16.25 | 15.66 | 128.52 |
| **Construction** | 198.24 | 196.71 | 189.10 | 118.45 | 150.45 | 96.19 | 57.17 | 1006.31 |
| **Distribution, retail, & H&C** | 70.93 | 77.97 | 89.73 | 82.02 | 85.33 | 66.59 | 58.17 | 530.74 |
| **Transport and communications** | 54.04 | 60.33 | 64.30 | 62.77 | 50.24 | 38.17 | 37.21 | 367.06 |
| **Business services** | 228.60 | 233.98 | 247.53 | 237.73 | 234.62 | 181.02 | 176.35 | 1539.81 |
| **Non-business services** | 73.31 | 72.57 | 75.15 | 77.89 | 87.56 | 80.93 | 84.68 | 552.10 |
| **Total** | 957.89 | 931.67 | 974.32 | 896.16 | 898.34 | 688.21 | 607.23 | 5953.81 |

Source: Cambridge Econometrics

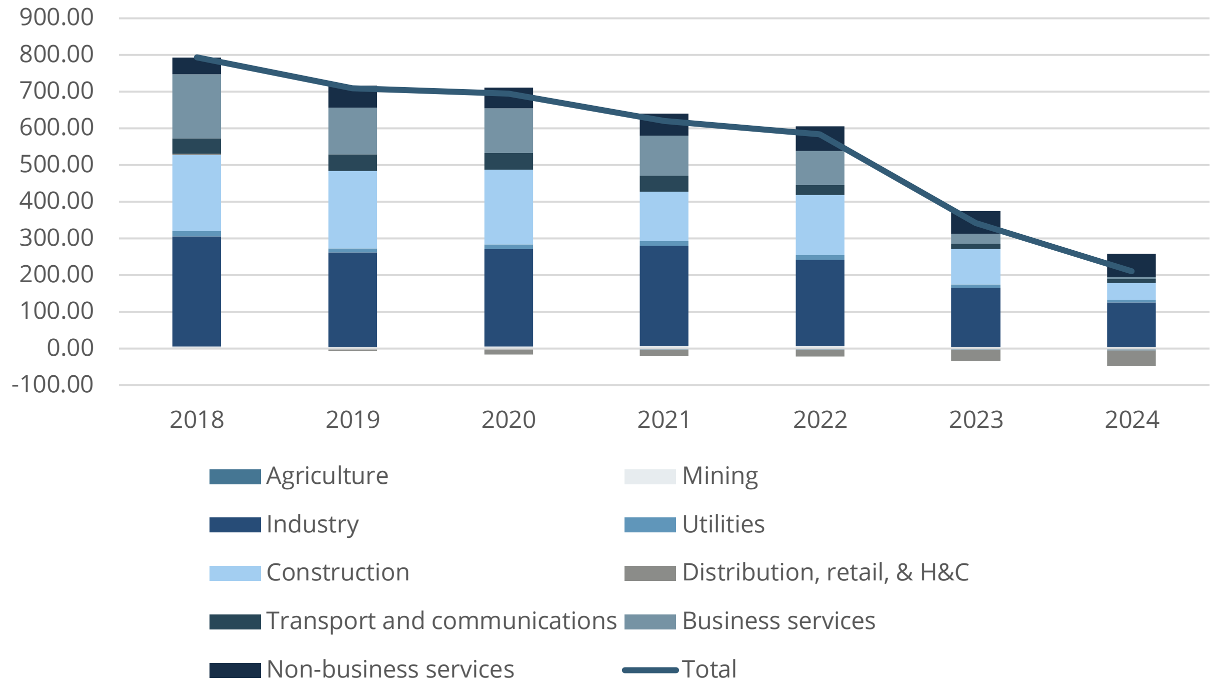
“Business services” includes activities such as legal & accounting services, architectural & engineering services, R&D and security & administration services. Among these “M69_M70 - Legal and accounting activities; activities of head offices; management consultancy activities” and “M71 - Architectural and engineering activities; technical testing and analysis” alone account for around a third of all impact in this broad sector. One should also be mindful that the impact on business services also reflect the effect on demand for inputs to other sectors such as construction and industrial sectors.

F4E spending on GVA shows two phases: higher expenditures from 2018-2022 led to a greater impact than in 2023-2024. Construction saw the most significant change, with its average GVA impact during 2018-2022 being about double that of 2023-2024. Industry and transport were also notably affected by reduced spending in the last two years, largely due to lower levels of F4E in-kind contributions and construction cash expenditures, which drive demand directly and indirectly (through supply chain effects) in these sectors.

Examining other sectors, the indirect and induced effects of F4E expenditure appear significant in sectoral GVA impacts. For example, “Distribution, retail, & H&C,” which represents the residual portion of F4E expenditure, experiences a GVA impact of around 530 million Euros across the EU27-Swiss economy. This results from both indirect effects, as sectors directly affected by F4E procurement require inputs from “Distribution, retail, & H&C” within their supply chains, and induced effects, whereby increased economic activity leads to higher incomes and, consequently, greater consumption and demand in “Distribution, retail, & H&C.” Similar patterns are observed in other sectors such as “Agriculture,” “Mining,” and “Utilities.”

### Tax Reduction Scenario

**Figure 29. Net Impact (Tax reduction) across EU27+Switzerland: GVA by broad-sector (million 2024 EUR)**




Source: Cambridge Econometrics

**Table 1515. Net Impact (Tax reduction) across EU27+Switzerland: GVA by broad sector (million 2024 EUR)**

| | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2018-24 |
|---|---|---|---|---|---|---|---|---|
| **Agriculture** | -0.21 | -0.87 | -2.49 | -3.69 | -3.51 | -3.98 | -4.90 | -19.65 |
| **Mining** | 5.56 | 4.40 | 5.64 | 6.94 | 6.83 | 4.17 | 3.58 | 37.13 |
| **Industry** | 299.68 | 258.01 | 265.71 | 272.70 | 234.74 | 162.01 | 121.95 | 1614.80 |
| **Utilities** | 14.86 | 10.54 | 12.12 | 13.45 | 14.06 | 8.59 | 6.81 | 80.42 |
| **Construction** | 208.07 | 211.63 | 203.82 | 135.26 | 162.49 | 96.38 | 45.99 | 1063.64 |
| **Distribution, retail, & H&C** | 2.42 | -5.99 | -14.01 | -16.38 | -18.41 | -30.02 | -42.63 | -125.01 |
| **Transport and communications** | 42.48 | 44.46 | 46.27 | 43.50 | 27.84 | 14.68 | 11.53 | 230.77 |
| **Business services** | 175.03 | 128.44 | 121.11 | 108.07 | 92.81 | 26.23 | 5.08 | 656.77 |
| **Non-business services** | 45.70 | 58.51 | 55.98 | 60.61 | 67.38 | 63.20 | 63.32 | 414.70 |
| **Total** | 793.60 | 709.14 | 694.15 | 620.46 | 584.24 | 341.26 | 210.73 | 3953.56 |

Source: Cambridge Econometrics

Looking at GVA impacts at sectoral level, the impact of the induced effects becomes clearer. Just as before with the Baseline's difference against the Gross Impact scenario, "Industry", "Construction", and" Business services" are the broad-sectors most impacted in terms of GVA by the suspension of F4E spending; each with a reduction of 1.6, 1.1, and 0.7 billion Euros over the 2018-2024 period respectively. Although, "Construction" and "Industry" were barely affected by the scenario's different assumptions, the effect of induced effects of lower taxes is visible in "Business services", leading to a GVA level in this scenario that is closer, but still lower, to the one found in the Baseline, in which F4E spending is assumed to occur.

Although "Business services" is the broad sector in which we see the greatest impact in absolute terms of the induced effects brought about by the tax reduction present in this scenario, the induced effects of the reduction in taxes can also be found in other sectors. Chief among these, are "Distribution, retail, & H&C" and "Agriculture", followed by "Utilities" and "Transport and communications", which are impacted to a lesser degree. Most notably, the difference between the Baseline and this scenario yields a negative difference for both "Distribution, retail, & H&C" and "Agriculture". This means that these two broad sectors, unlike all others broad sectors and the economy as a whole, benefit in terms of GVA levels from a suspension of F4E-related spending accompanied by a proportional reduction in taxes.

These two sectors ("Distribution, retail, & H&C" and "Agriculture") best illustrate how the induced economic effects of the reduction in taxes may result to higher GVA levels. Lower taxes lead to more disposable income within the economy, which in turn prompts consumers to demand more consumer goods (including food) and services for their own use, leading to increased demand for the sectors included in "Agriculture", "Business services", and "Distribution, retail, & H&C". This increased sectoral demand in turn is met with increased output, and thus GVA. It should also be noted that this increased output also impacts these sector's supply chains, leading to greater demand and economic activity (though at a much-reduced scale) in other sectors upstream in the supply chains. A similar effect as the one seen in there three consumption-sensitive broad-sectors can also be observed in the "Utilities" and "Transport and communications" but in a milder form due to these two broad-sectors being less sensitive to increases in changes to disposable income.

### General investment programme

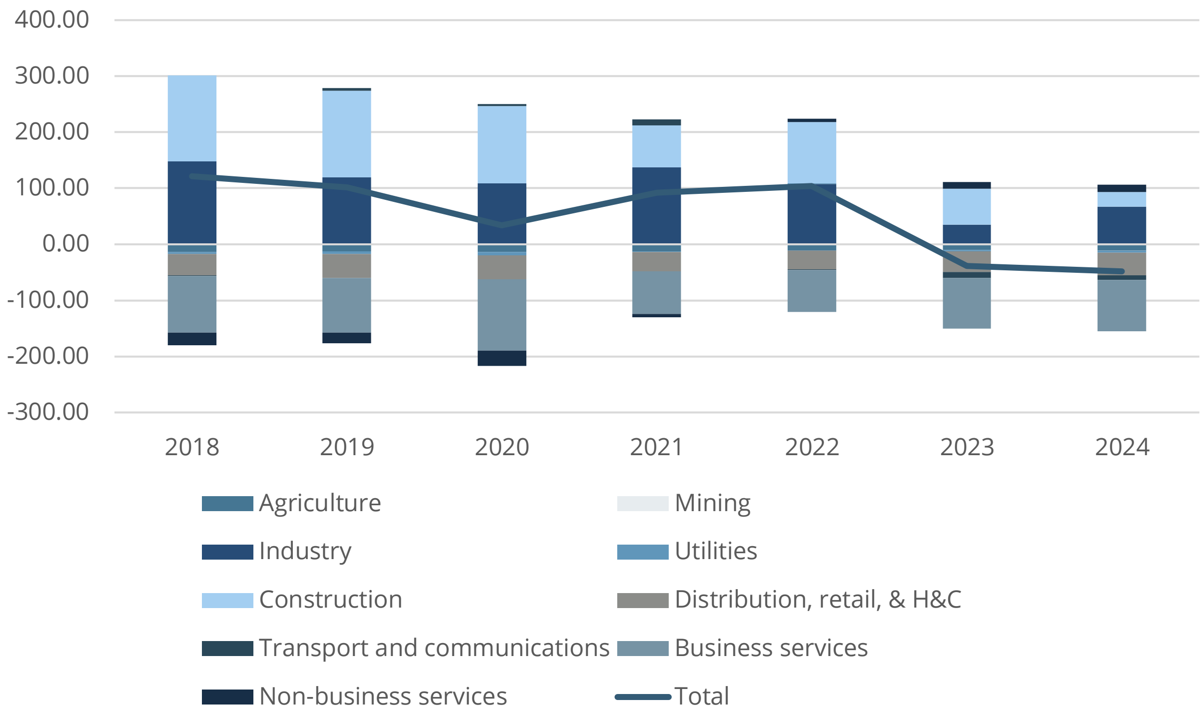
At sectoral level, one can see that sectors are impacted in different ways; some sectors see a positive change when comparing the Baseline to the General Investment scenario, while other sectors see a negative change. These results are driven by the interaction between the sectoral distribution of F4E-expenditure and the sector-country distribution of the general investment programme assumed within the scenario. The former has already been explored in Section 4.1, whilst the latter is co-determined by three factors:

- Each country's contribution to F4E, both directly to F4E or indirectly through Euratom and the European Budget. This is used to determine part of each country's disbursement of the general investment programme, as well as the portion of the programme (proportional to the share of Euratom's contribution to F4E) that is to be disbursed in a manner similar to a European programme.
- The country-distribution used in the disbursement of MFF programmes. These shares are used in the distribution across EU member states for the portion of the programme that is to be disbursed in the manner similar to a European programme.

- Each country's sector share of output relative to total national output. These country-specific shares determine how each country's portion of the programme is distributed across the country's sectors.
- More details on the processing and assumptions in these distributions can be found in Annex 4.

Under this framework, sectors included within "Construction" and "Industry" have a greater weight in the F4E-related expenditure than in the general investment programme (and thus relative to the share of the sectors within the economy). This contrasts with other sectors such as those in "Distribution, retail, & H&C" and "Business services" which are more prominent role within the general investment programme assumed in this scenario than in F4E-spending. Particularly, other sectors such as "Non-business services" have initially (2018-2021) a negative GVA difference of the Baseline relative to the scenario which then becomes positive (2022-24) due to a higher share of importance in F4E spending in the later years.

**Figure 30. Net Impact (General investment programme) across EU27+Switzerland: GVA by broad sector (million 2024 EUR)**




Source: Cambridge Econometrics

**Table 1616. Net Impact (General investment programme) across EU27+Switzerland: GVA by broad-sector (million 2024 EUR)**

| | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2018-24 |
|---|---|---|---|---|---|---|---|---|
| **Agriculture** | -13.17 | -12.29 | -13.38 | -12.46 | -11.76 | -10.50 | -11.29 | -84.86 |
| **Mining** | 1.54 | 0.21 | 1.15 | 2.37 | 2.39 | -0.01 | -0.03 | 7.62 |
| **Industry** | 146.33 | 119.89 | 108.21 | 135.44 | 105.58 | 35.06 | 66.79 | 717.30 |
| **Utilities** | -4.54 | -4.85 | -6.22 | -1.06 | 0.62 | -1.78 | -3.44 | -21.26 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Construction** | 153.26 | 153.59 | 137.93 | 74.46 | 109.10 | 63.90 | 26.34 | 718.58 |
| **Distribution, retail, & H&C** | -37.96 | -43.37 | -42.24 | -35.17 | -32.51 | -37.45 | -40.83 | -269.55 |
| **Transport and communications** | -0.98 | 4.62 | 2.91 | 10.38 | -1.91 | -10.37 | -7.85 | -3.20 |
| **Business services** | -101.09 | -97.13 | -127.24 | -75.91 | -74.57 | -90.53 | -91.53 | -658.01 |
| **Non-business services** | -21.90 | -19.11 | -27.74 | -5.49 | 6.56 | 12.59 | 13.58 | -41.51 |
| **Total** | 121.50 | 101.55 | 33.39 | 92.55 | 103.50 | -39.09 | -48.27 | 365.13 |

Source: Cambridge Econometrics

# ANNEX 6. SURVEY QUESTIONNAIRE

## Section A – General information

* = compulsory question

I. ***Name of the organization: ___________________**
II. ***VAT number: __________________**
III. ***Country of the organization:** dropdown menu
IV. **NACE sector:** dropdown menu
V. **Year of establishment:** _________________
VI. **Position of the respondent within the organisation:** (CEO, CTO, Project Manager, President, Vice-President, General Director, Director, Professor, Researcher, *other [specify]*)

## Section B – Relationship with F4E, with a focus on the years 2018-2024

* = compulsory question

| | | | | | |
|---|---|---|---|---|---|
| ***1. When did your company start working with F4E?** | Dropdown menu with years | | | | |
| ***2. Before becoming a F4E supplier, my organization had previous experience in working ….** | **NEVER** | **ONCE** | **SOMETIMES** | **OFTEN** | **I DON'T KNOW** |
| On other nuclear fusion-related projects (e.g. JET, SPARC, Wendelstein 7-X, …) | ☐ | ☐ | ☐ | ☐ | ☐ |
| With other large-scale research infrastructures (e.g. CERN, ESA, …) | ☐ | ☐ | ☐ | ☐ | ☐ |
| With (other) universities and research institutes | ☐ | ☐ | ☐ | ☐ | ☐ |
| With non-science-related customers | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***3. Could you specify the number of F4E contracts or grant agreements your company has worked on between 2018 and 2024?** | **N OF CONTRACTS** | | | | |
| Operational contracts | _____ | | | | |
| Administrative contracts | _____ | | | | |
| Grants | _____ | | | | |
| ***4.a (only for operational contracts) What was the INNOVATION LEVEL of the products and services supplied to F4E between 2018-2024?**<br><br>[one question for each contract] | ☐ Highly innovative products/services requiring dedicated R&D and/or design<br>☐ Customised products/services requiring significant adaptation or technology integration<br>☐ Specialised off-the-shelf products/services with minimal adaptation<br>☐ Basic commercial off-the-shelf products/services with minor customisation<br>☐ Specialised or high-performance off-the-shelf products/services<br>☐ Basic commercial off-the-shelf (COTS) products/services | | | | |
| **4.b Please briefly comment on your answer to the above question (e.g., by providing some examples):** | ☐ _________________________________ | | | | |
| ***5. (only for operational contracts) What was the maturity level of the technologies covered by the subject matter of the contract?**<br><br>[one question for each contract] | ☐ TRL 1 Observation of the basic principles<br>☐ TRL 2 Formulation of a technological concept.<br>☐ TRL 3 Proof of experimental concept.<br>☐ TRL 4 Technological validation in laboratory environment<br>☐ TRL 5 Industrial technology validation in relevant environment<br>☐ TRL 6 Demonstration of technology in the industrial field<br>☐ TRL 7 Demonstration of the prototype in a real operating environment<br>☐ TRL 8 Definition and full qualification of the system<br>☐ TRL 9 Full system demonstration in real operational environment<br>☐ Classifiable in another way: Please provide a brief description __ | | | | |

| | |
|---|---|
| ***6. During the RELATIONSHIP WITH F4E…**<br>[multiple answers possible] | ☐ You delivered your service(s) on the basis of the provided specifications with full autonomy and little interaction with F4E staff.<br>☐ You delivered your service(s) on the basis of the provided specifications but with additional inputs (clarifications, cooperation on some activities) from F4E staff.<br>☐ You delivered your service(s) through frequent and intense interactions with F4E staff. |

| ***7. Thinking about the relationship of your organisation with F4E between 2018 and 2024, to what extent do you agree with the following statements?** | STRONGLY DISAGREE | DISAGREE | NEUTRAL | AGREE | STRONGLY AGREE | I DON'T KNOW |
|---|---|---|---|---|---|---|
| Your organisation always knew whom to contact in F4E to obtain required additional information | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Your organisation always understood what F4E staff required you to deliver | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| F4E staff always understood what your organisation communicated to them | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| During unexpected situations, F4E and your organisation dialogued to reach a solution without insisting on contractual clauses | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

| | |
|---|---|
| ***8. What percentage of your company's turnover is related to F4E activities in the last three years?** | ☐ 1-20%<br>☐ 21-40%<br>☐ 41-60%<br>☐ 61-80%<br>☐ 81-100%<br>☐ I don't know |
| ***9. What percentage of your company's employees have been involved in F4E activities in the last three years? Refer to a full-time equivalent measure.** | ☐ 1-20%<br>☐ 21-40%<br>☐ 41-60%<br>☐ 61-80%<br>☐ 81-100%<br>☐ I don't know |

## Section B – The impact of working with F4E on your organisation

* = compulsory question

| ***9.a LEARNING EFFECTS. To what extent do you agree with the following statements?**<br>**Thanks to the work for F4E from 2018 to 2024, my organisation was able to…** | STRONGLY DISAGREE | DISAGREE | NEUTRAL | AGREE | STRONGLY AGREE | I DON'T KNOW |
|---|---|---|---|---|---|---|
| Have new skills/knowledge acquired by the working staff | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Attract new skilled professionals | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Retain skilled professionals | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Improve technical know-how | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Establish new collaborations, leading to know-how exchange | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Improve R&D and innovation capabilities | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Improve management /organisational capabilities | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Other, please specify | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| *IF Q11.a "Have new skills/knowledge acquired by the working staff" = STRONGLY AGREE or AGREE* | ☐ Engineering processes<br>☐ All engineering and design activities<br>☐ Mechanical design | | | | | |

| **9.b Can you indicate the field in which new knowledge had to be acquired and/or new skills had to be developed?** | ☐ Non-destructive tests<br>☐ Welding techniques<br>☐ Advanced manufacturing techniques<br>☐ Nuclear engineering<br>☐ Electromagnetic analysis<br>☐ Standard manufacturing and joining processes<br>☐ Materials<br>☐ Other. Please specify: ____________________________ |
|---|---|

| ***10. INNOVATION EFFECTS (OUTPUT). To what extent do you agree with the following statements?**<br>**Thanks to the experience gained through our work for F4E from 2018 to 2024, my organisation was able to......** | STRONGLY DISAGREE | DISAGREE | NEUTRAL | AGREE | STRONGLY AGREE | I DON'T KNOW |
|---|---|---|---|---|---|---|
| Improve the quality of products/services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Improve production processes | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Develop new products/services in the fusion area | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Develop new products/services beyond the fusion area | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Develop new cutting-edge technologies in the fusion area | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Develop new cutting-edge technologies beyond the fusion area | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Develop new research output (such as new technical reports, proceedings, working papers, articles in scientific journals, etc.) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Develop new patents, trademarks, copyrights, or other intellectual property rights | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Carry out spin-off projects | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Pioneer first-of-a-kind capabilities in a particular technology | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Overtake / catch-up with non-EU firms in our technology area | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Other, please specify | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| **11. MARKET EFFECTS. To what extent do you agree with the following statements?**<br>**Thanks to the work for F4E from 2018 to 2024, my organisation was able to...** | STRONGLY DISAGREE | DISAGREE | NEUTRAL | AGREE | STRONGLY AGREE | I DON'T KNOW |
| Acquire new knowledge about market demands and trends | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Improve its reputation as a supplier | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Abandon other sales opportunities to focus on the project with F4E | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Acquire new clients in the EU in the nuclear fusion sector | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Acquire new clients outside the EU in the nuclear fusion sector | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Acquire new clients in other sectors | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Develop new relationships with other companies | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Develop new relationships with other companies working in the field of nuclear fusion | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

| | | | | | | |
|---|---|---|---|---|---|---|
| Improve our competitive position in our industry | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Establish ourselves as a global leader in a particular technology | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Develop new relationships with other research organisations working in the field of nuclear fusion | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| ***12. ECONOMIC EFFECTS. To what extent do you agree with the following statements?**<br>**Thanks to the work for F4E from 2018 to 2024, my organisation was able to...** | STRONGLY DISAGREE | DISAGREE | NEUTRAL | AGREE | STRONGLY AGREE | I DON'T KNOW |
| Increase the number of customers | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Increase total turnover | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Increase overall profitability | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Establishment of new businesses/R&D unit | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Establishment of a spin-off | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Enter a new market | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Experience some financial losses | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Experience reputational risk | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Face the risk of bankruptcy | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Decrease production costs | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Other, please specify | | | | | | |
| ***13. EMPLOYMENT EFFECTS. To what extent do you agree with the following statements?**<br>**Thanks to the work for F4E from 2018 to 2024, my organisation was able to...** | STRONGLY DISAGREE | DISAGREE | NEUTRAL | AGREE | STRONGLY AGREE | I DON'T KNOW |
| Increase the number of employees temporarily | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Increase the number of employees permanently | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Increase the number of lower skilled employees | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Increase the number of higher skilled employees | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

## Section C – Sub-contractors

* = compulsory question

| | |
|---|---|
| ***14. Has the company used subcontractors in order to carry out the project(s) for F4E between 2018 and 2024?** | ☐ Yes (continue Section C)<br>☐ No (Section D) |
| ***15. How are sub-suppliers selected?** Through…<br>[multiple answers possible] | ☐ Calls for tenders<br>☐ On the basis of an established and proven experience in the sector<br>☐ Following meetings and/or workshops organised by F4E<br>☐ Due to geographical proximity<br>☐ Knowledge / personal ties<br>☐ Other (please specify) |
| ***16. Has the way in which you choose your suppliers changed as a result of your cooperation with F4E?** | ☐ Yes<br>☐ No |

| *17. With regard to the benefits of your sub-contractors, to what extent do you agree with the following statements? | STRONGLY DISAGREE | DISAGREE | NEUTRAL | AGREE | STRONGLY AGREE | I DON'T KNOW |
|---|---|---|---|---|---|---|
| Subcontractors have increased their know-how | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Subcontractors have experienced product or process innovations | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Subcontractors improved the production process | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Subcontractors attracted new customers | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

## Section D – Availability for an interview

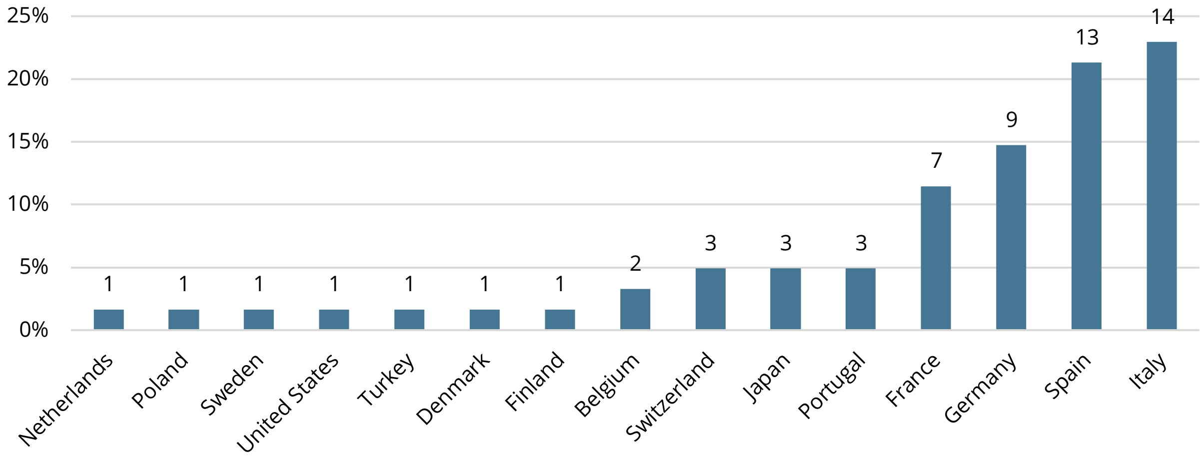
| | |
|---|---|
| **18. Would you be interested in being contacted to contribute further to the study? If yes, please provide us with your contact details and/or those of colleagues who might be interested in participating (optional).** | ☐ ______________ |

Source: CSIL

# ANNEX 7. SURVEY RESULTS

## Section A – General information

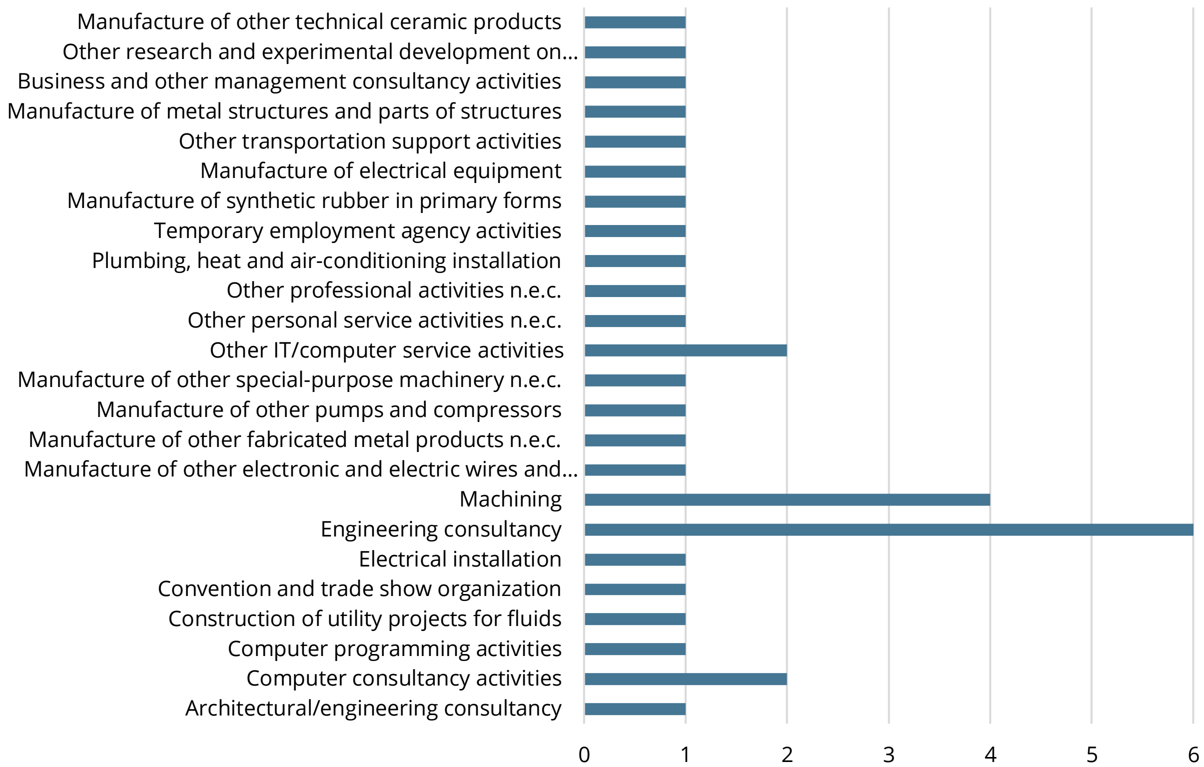
### A1. Country of the organization




Note: N=61

Source: CSIL

### A2. NACE sector

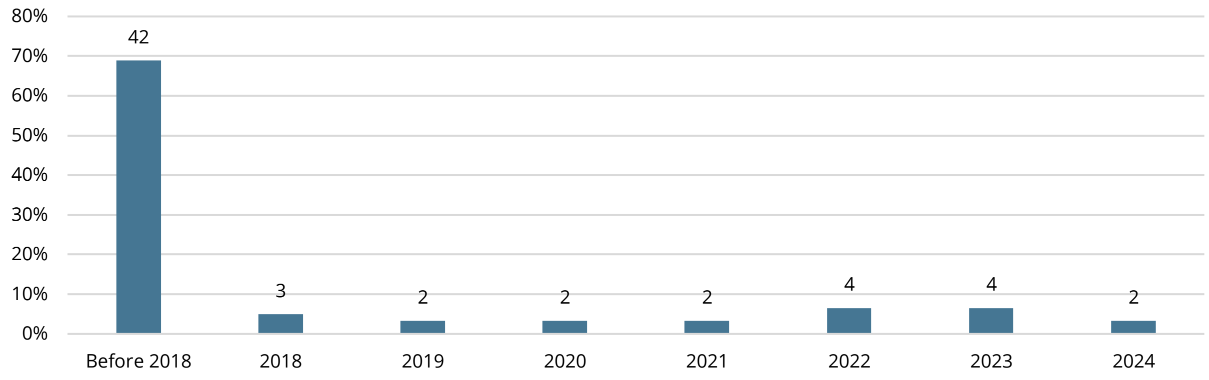



Note: N=34

Source: CSIL

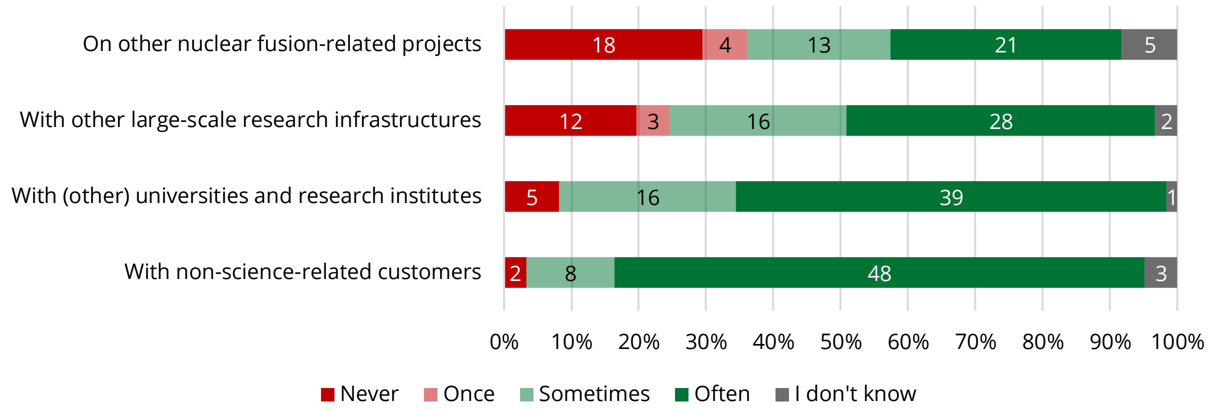
## Section B – Relationship with F4E, with a focus on the years 2018-2024

### Q1. When did your company start working with F4E?



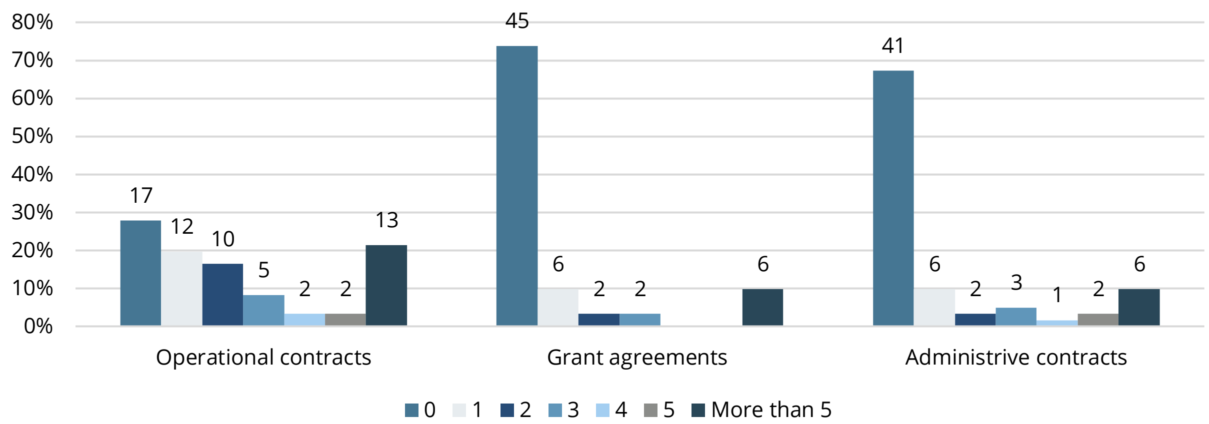

Note: N=61. Source: CSIL

### Q2. Before becoming a F4E supplier, my organization had previous experience working...



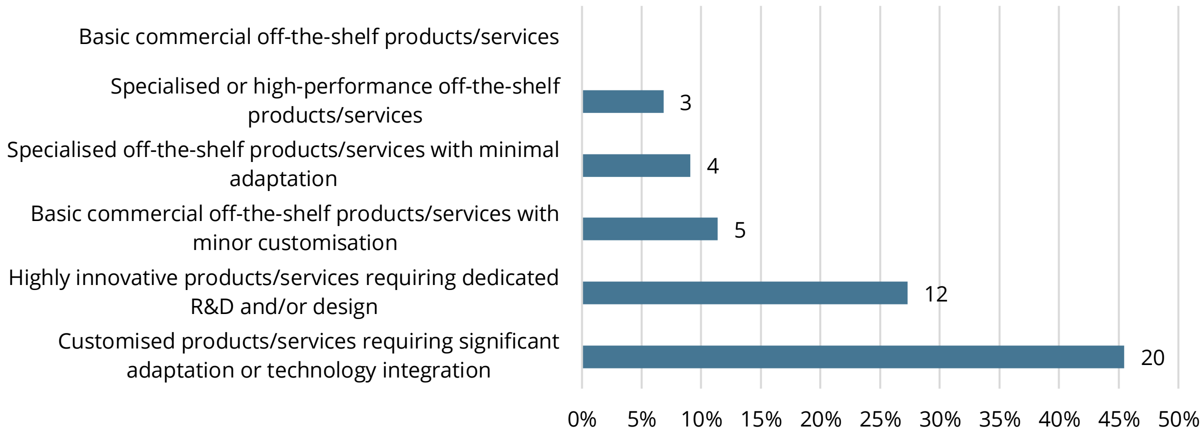

Note: N=61. Source: CSIL

### Q3. Could you specify the number of F4E contracts or grant agreements your company has worked on between 2018 and 2024?



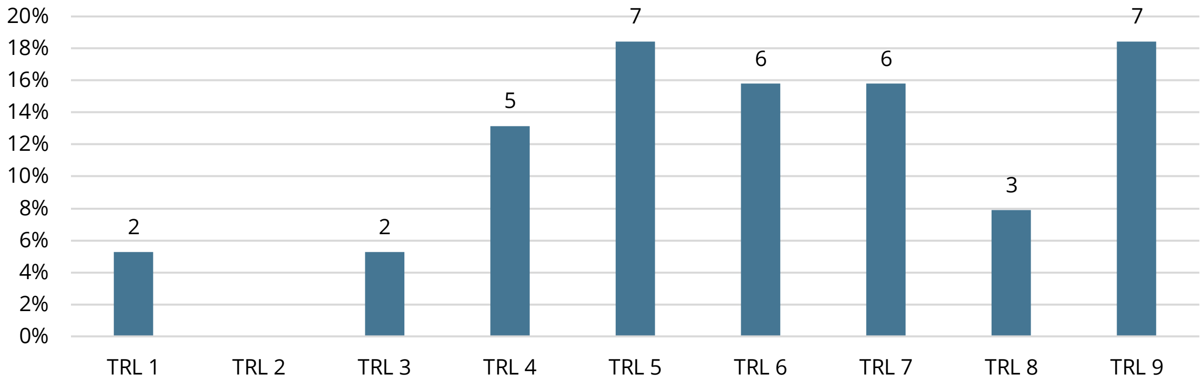

Note: N=61. Source: CSIL

**Q4a. What was the INNOVATION LEVEL of the products and services supplied to F4E between 2018-2024? (only for operational contracts)**



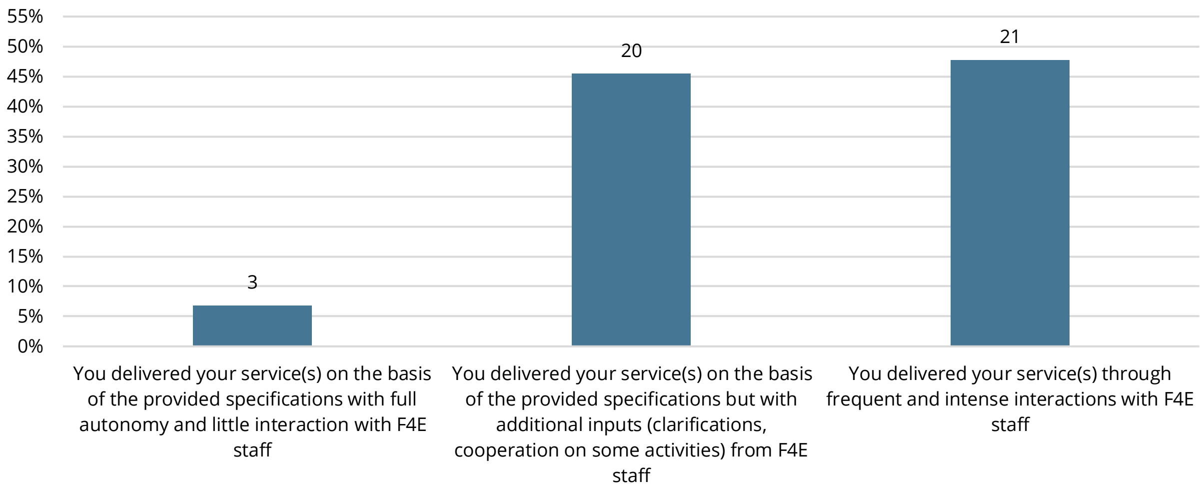

Note: N=44. Average across contracts. Source: CSIL

**Q5. What was the maturity level of the technologies covered by the subject matter of the contract? (Only for operational contracts)**



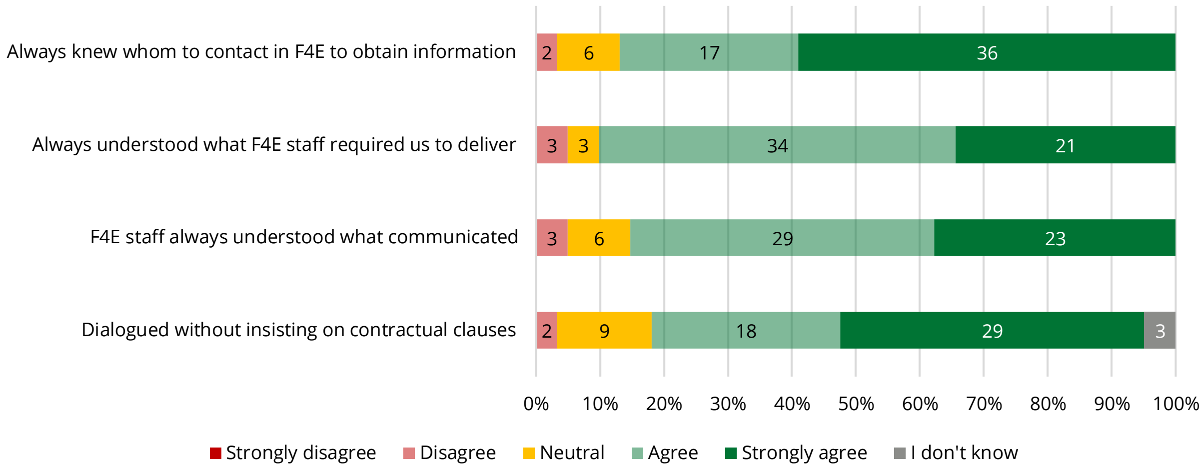

Note: N=38. Average across contract. The" Classifiable in another way" is not considered. Source: CSIL

**Q6. During the relationship with F4E...**



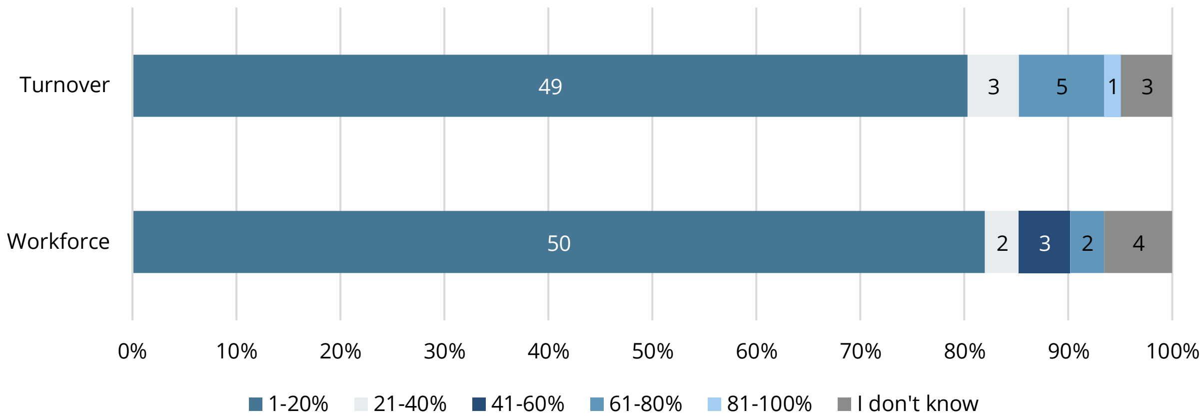

Note: N=44. Source: CSIL

### Q7. Thinking about the relationship of your organisation with F4E between 2018 and 2024, to what extent do you agree with the following statements?




Note: N=6. Source: CSIL

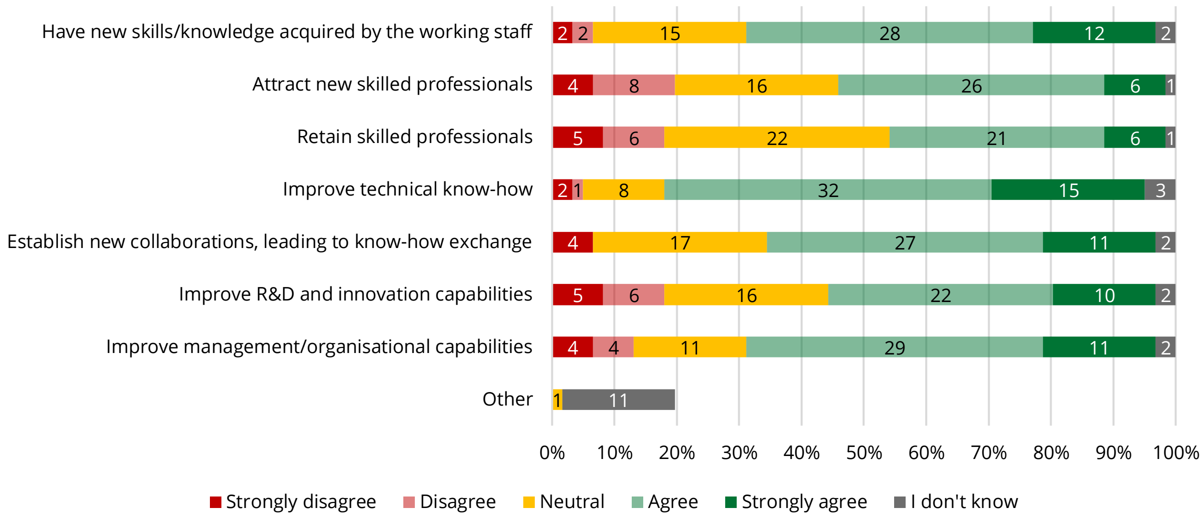
### Q8-Q9. What percentage of your company's turnover and employees is related to F4E activities in the last three years?




Note: N=61. Source: CSIL

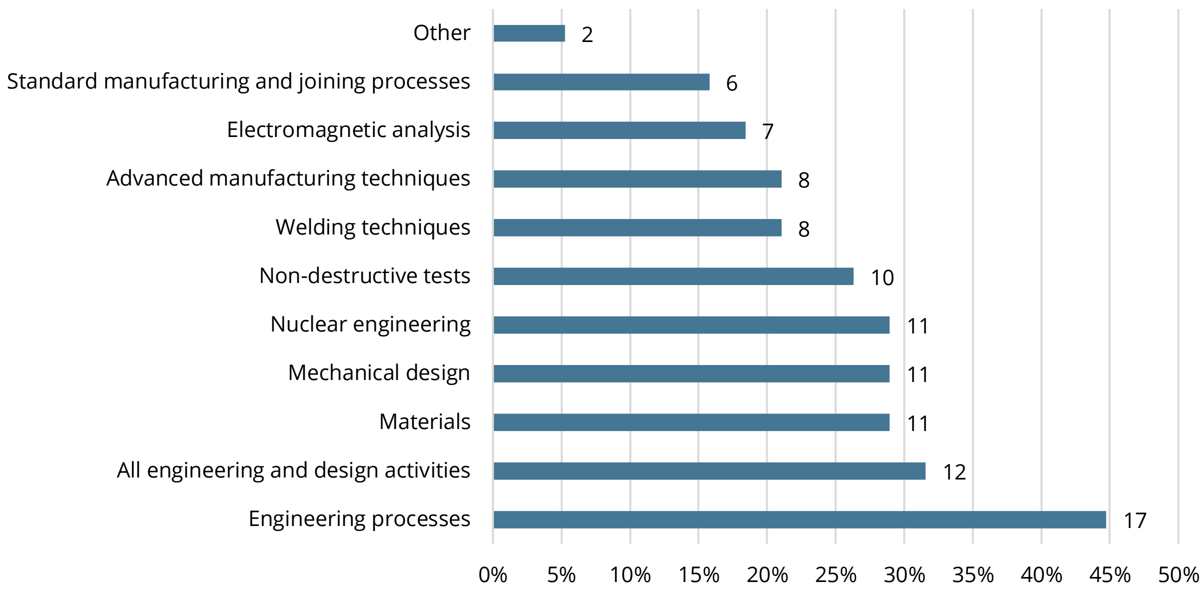
## Section B – The impact of working with F4E on your organisation

### Q9a Learning effects. To what extent do you agree with the following statements? Thanks to the work for F4E from 2018 to 2024, my organisation was able to...



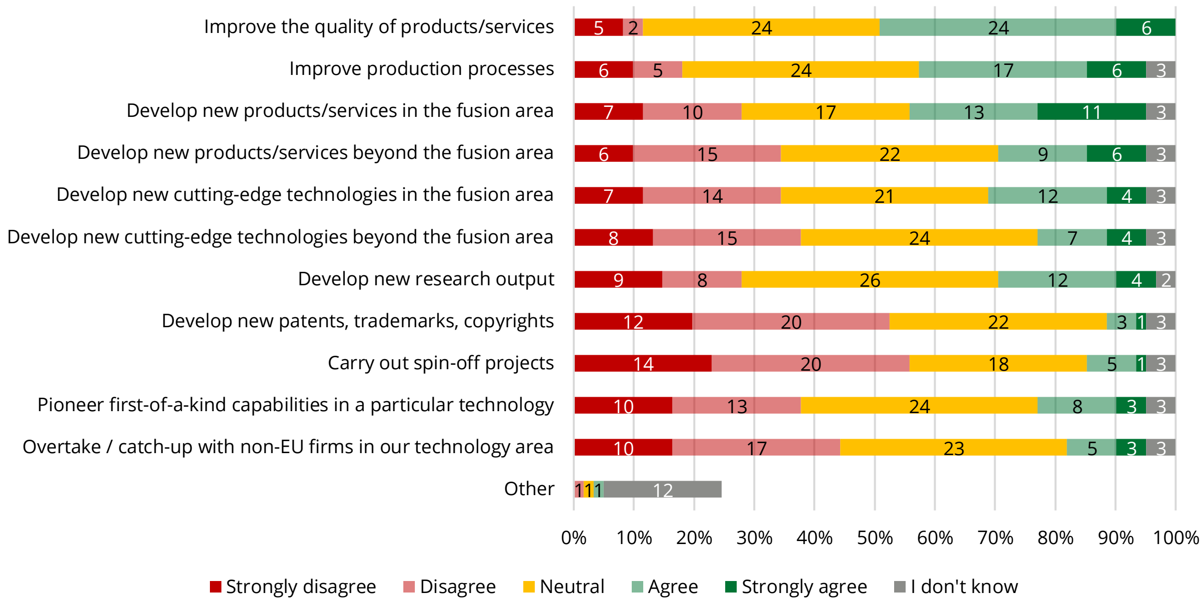

Note: N=61. Source: CSIL

## Q9b Can you indicate the field in which new knowledge had to be acquired and/or new skills had to be developed?



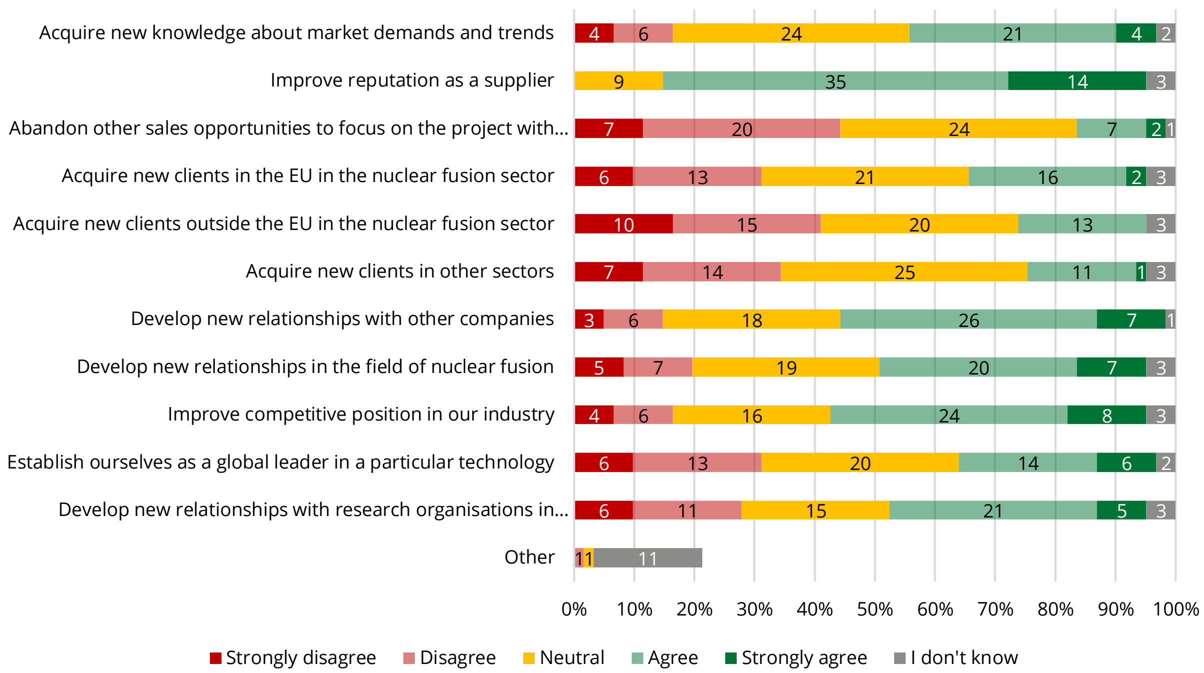

Note: Number of respondents=38. Multiple answers allowed.
Source: CSIL

## Q10. Innovation effects. To what extent do you agree with the following statements? Thanks to the experience gained through our work for F4E from 2018 to 2024, my organisation was able to...



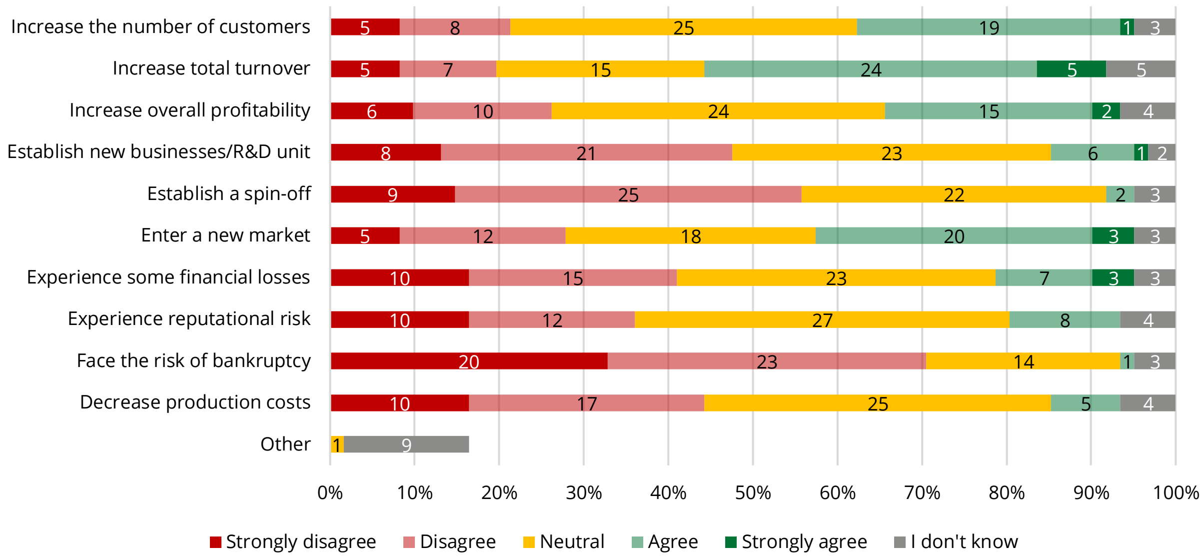

Note: N=61. Source: CSIL

## Q11. Market effects. To what extent do you agree with the following statements? Thanks to the work for F4E from 2018 to 2024, my organisation was able to...



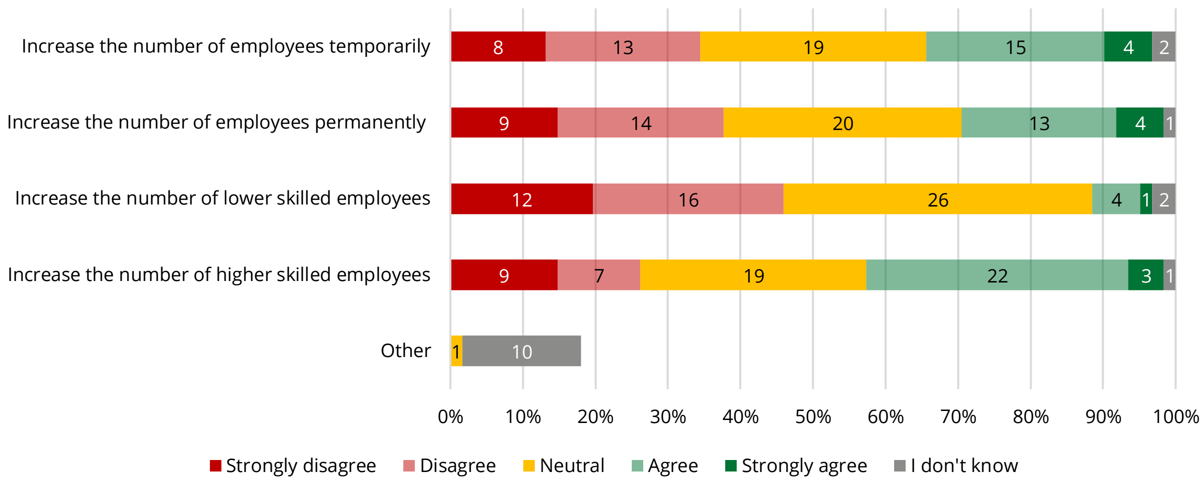

Note: N=61. Source: CSIL

## Q12. Economic effects. To what extent do you agree with the following statements? Thanks to the work for F4E from 2018 to 2024, my organisation was able to...




Note: N=61. Source: CSIL

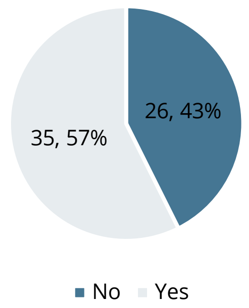
### Q13. Employment effects. To what extent do you agree with the following statements? Thanks to the work for F4E from 2018 to 2024, my organisation was able to...




Note: N=61. Source: CSIL

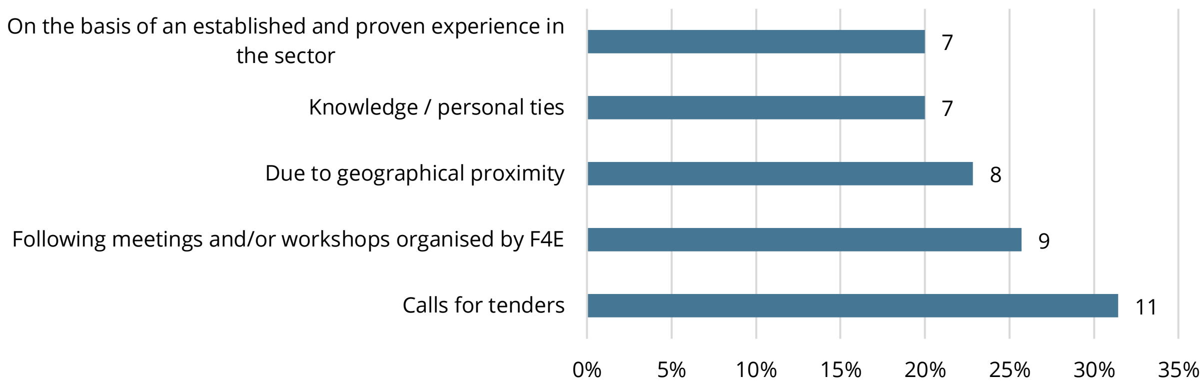
## Section C – Sub-contractors

### Q14. Has the company used subcontractors in order to carry out the project(s) for F4E between 2018 and 2024?



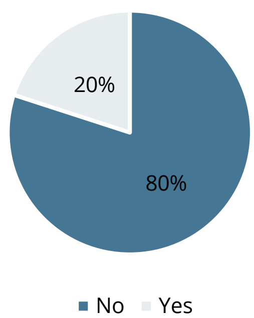

Note: N=61. Source: CSIL

### Q15. How have you selected sub-contractors? Through...



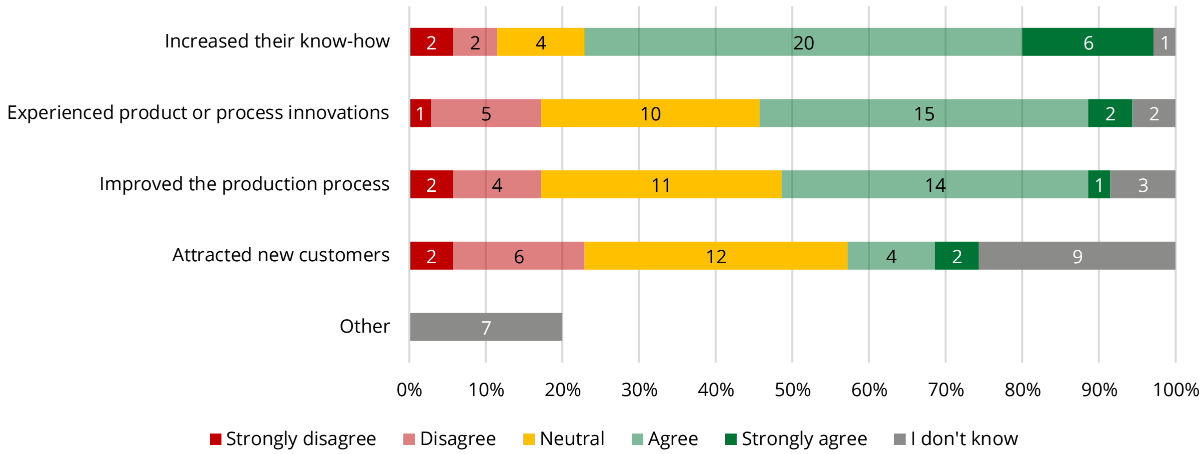

Note: Number of respondents=35. Multiple answers allowed. Source: CSIL

### Q16. Has the way in which you choose your suppliers changed as a result of your cooperation with F4E?




Note: N=35. Source: CSIL

### Q17. With regard to the benefits of your sub-contractors, to what extent do you agree with the following statements?




Note: N=35. Source: CSIL

# ANNEX 8. MICROECONOMETRIC MODELS

## Mediation analysis

The **mediation analysis** helps to understand how the procurement features affect suppliers' intermediate and final outcomes, and if the former mediates the impact on the latter. More specifically, rather than focusing solely on direct impact of procurement on firm's performance, the mediation analysis explores whether certain internal outcomes—such as knowledge acquisition, the development of new products or processes, or improved market positioning—serve as intermediate channels through which engagement in procurement contributes to broader economic and employment performance outcomes. This approach helps to clarify not only whether the quality of procurement relationships matters, but how it matters, offering a more structured view of the dynamics activated by public procurement, particularly in high-technology environments. This Annex outlines how the variables used in the mediation analysis were constructed and details the mediation framework applied.

**Starting from the items included in the survey**, a set of variables measuring the suppliers' intermediate and final outcomes were built for the econometric analysis, as well as the variable describing the procurement features (refer to Annex 6 for a complete overview of the survey questions).

- The first set of variables concerns how firms assess the quality of their procurement relationships with F4E, including the clarity, consistency, and responsiveness of the interactions.
- The second set of variables covers three distinct dimensions related to intermediate outcomes, i.e. internal or strategic changes that may mediate the link between the quality of procurement relationships and final economic performance. The first is the learning dimension, which reflects whether firms acquired new knowledge about market demands and trends or strengthened their internal capabilities more broadly, including technical know-how, managerial practices, organisational structures, or R&D capacity. The second dimension focuses on innovation, encompassing the development of new products, services, or cutting-edge technologies, improvements in production processes or product quality, and the creation of intellectual property such as patents, trademarks or copyrights. The third dimension concerns market positioning, capturing improved reputation or the ability to attract new clients.
- The third set of variables covers final performance outcomes that procurement may influence either directly or through the intermediate internal outcomes or transformations. The final outcome variables include: i) economic impact on turnover and profitability; ii) economic transformations and expansions, defined as strategic developments such as the creation of new units, entry into new markets, or the establishment of spin-offs; iii) employment-related effects, particularly changes in workforce size; iv) negative economic outcomes, such as exposure to bankruptcy, reputation damages, or financial losses, that suppliers may associate with their procurement experience.

In practice, a set of composite indices were constructed based on firms' responses to the survey questions related to each of the above-mentioned variables. Each question was rated on a five-point

Likert scale, from “strongly disagree” to “strongly agree.” These responses were first converted into numerical values (from 1 to 5) and then rescaled to fall between 0 and 1. Within each thematic area, the rescaled scores of the relevant questions were averaged to produce a continuous aggregate index. This approach ensures comparability across items, reduces the influence of any single response, and provides a stable and robust measure of the underlying concept. All resulting indices are continuous variables bounded between 0 and 1, with higher values indicating stronger reported experiences or outcomes. In the regression analysis, each coefficient can be interpreted as the expected change in the outcome associated with a full range (0 to 1) increase in the corresponding index.

The empirical strategy relies on a series of **ordinary least squares (OLS) regressions** to explore the relationship between the quality of procurement relationships, internal firm-level outcomes, and final economic and employment outcomes.

**The analysis involves three main steps**.

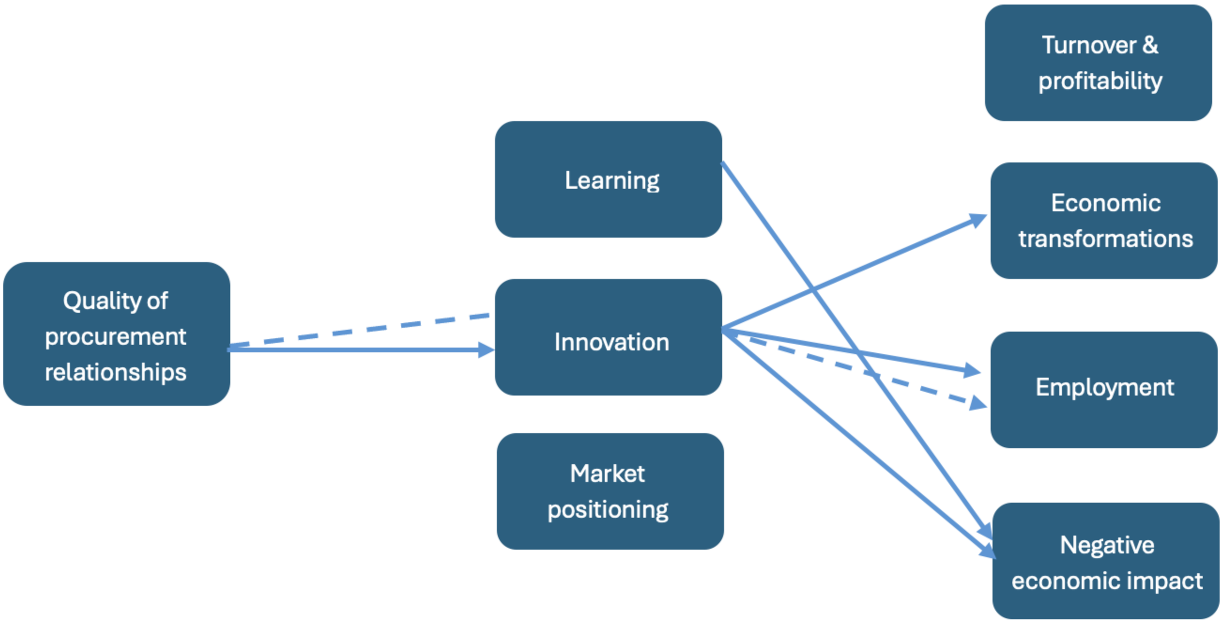
1. Assessing the extent to which higher perceived quality of procurement relationships is directly associated with improved final outcome indicators—including turnover and profitability, strategic business development, workforce expansion, and fewer negative economic effects— as well as with stronger internal intermediate outcomes—learning, innovation, or improved market positioning. This initial step establishes a baseline view of how different forms of procurement engagement relate to both final firm-level outcomes and internal intermediate changes.
2. Examining the relationship between intermediate and final outcomes. This step evaluates whether internal intermediate outcomes—such as innovation, learning, or improved market positioning —are systematically associated with better economic and employment outcomes. In doing so, it helps clarify the potential pathways through which procurement may influence firm-level final outcomes.
3. Considering both the indicator of the quality of procurement relationships and intermediate outcome indices within the same model to assess whether the effects of the procurement relationship quality on final outcomes, identified with the first step, are mediated by internal intermediate outcomes.

A mediation path is identified when three conditions are met: (i) procurement quality is significantly associated with final outcomes; (ii) it is also significantly associated with internal intermediate outcomes such as learning, innovation and market positioning; and (iii) these intermediate outcomes significantly predict final outcomes when included in the same model as procurement quality. If, in this aggregate specification, the coefficients on procurement quality decrease in magnitude or lose statistical significance while at least one the intermediates remain significant, this indicates that part of the relationship between procurement quality and final firm-level outcomes is mediated through internal changes within the firm.

All the regression models include a consistent **set of control variables** to account for observable firm-level characteristics that may independently influence outcomes, regardless of the quality of procurement relationships. These controls include firm age, firm size (measured by the total number of employees) a dummy variable distinguishing high-technology firms from others, a dummy variable denoting previous experience on other nuclear fusion-related projects, and a set of country indicators to account for national-level heterogeneity. By including these variables, the analysis aims to isolate the associations between the quality of procurement relationships, internal outcomes, and final economic and employment outcomes, minimizing the risk that results are driven by structural or contextual heterogeneity across firms.

The **results of the analysis** are reported in Table 14. The figure below provides a graphical representation of the detected relations among the quality of procurement relationships, intermediate and final outcomes.

**Figure 31. Detected relations among procurement features, intermediate and final outcomes**




Note: Solid lines denote independent direct effects. Dashed lines the detected mediation path.

Source: CSIL

**The results**[73] **shows that the quality of the relationships with F4E plays a pivotal role in shaping suppliers' internal transformations—**referred to here as intermediate outcomes**.** Suppliers who perceive such a relationship as well-structured and effectively managed are significantly more likely to report improvements in innovation performance. Specifically, a 10-percentage point increase in the perceived quality of procurement relationships is associated with a 4.2-percentage point increase in reported intermediate innovation outcomes. While positive associations are also observed for learning and market positioning, these effects are not statistically significant. This suggests that clear, effective, and collaborative engagement with F4E is particularly important in supporting suppliers' capacity to innovate, whether through the development of new products or services, the strengthening of internal processes, or the capacity to generate patents and copyrights.

**The direct benefits of clear, effective and collaborative relationship with F4E extend beyond intermediate internal outcomes.** The same suppliers also report better final economic and employment outcomes, such as increased turnover, profitability, and number of employees. Specifically, a 10-percentage point improvement in the perceived quality of procurement

[73] Based on 49 survey replies.

relationships is associated with a 5.2-percentage point increase in reported economic performance and a 4.1-percentage point increase in workforce expansion. These findings underscore the idea that well-managed procurement relationships directly contribute not only to short-term internal transformation of the companies but also to their broader economic and employment growth.

To better understand how these changes unfold, it is useful to further examine the direct link between intermediate and final economic and employment outcomes. Indeed, **intermediate outcomes are not only valuable effects in their own right, but potentially also serve as key drivers of broader supplier growth.** Actually, innovation is significantly associated with improvements in structural position—such as the creation of new business, the development of spin-offs, or the entry into new markets—and employment growth, though it also correlates with an increase in reported negative economic outcomes—such as financial losses, reputational risk, or bankruptcy. In particular, a 10-percentage point increase in reported innovation outcomes is associated with a 7.4-percentage point increase in structural transformation and a 6.2-percentage point increase in workforce expansion, but also with a 6.1-percentage point increase in the likelihood of experiencing negative economic effects. By contrast, learning is associated with a reduction in negative economic outcomes, suggesting a positive effect, although it does not show a significant relationship with other final outcomes. In particular, a 10-percentage point increase in reported learning outcomes is associated with a 6.4-percentage point decrease in the likelihood of experiencing financial losses, reputational risk, or bankruptcy.

As explain above, to explore whether the quality of procurement relationships influences economic and employment outcomes only directly, or whether its impact is mainly mediated by the internal intermediate outcomes it helps generate within the firm, a join regression model is estimated, including both procurement quality and internal intermediate outcomes. This specification allows to identify possible mediation channels, and to assess their independent contribution to final outcomes.

**The impact of the quality of the relationship with F4E on suppliers' final outcomes is at least partly mediated by internal outcomes.** Specifically, once intermediate outcomes, such as innovation, learning, and market positioning are taken into account, the direct impact of the quality of the relationship with F4E on final outcomes diminishes. This is evident in the decline of the estimated effect of procurement quality on workforce expansion, which drops from 4.1 percentage points to a smaller, non-significant value. This attenuation coincides with a strong and positive association between innovation and employment growth. Taken together, these results suggests that part of the employment gains is not solely attributable to well-managed relationships but is also mediated by the innovations that such engagement helps support and enables.

For the previously detected economic outcomes, the effect of procurement quality also declines when intermediate outcomes are included—from 5.2 percentage point to a smaller and non-significant value. However, in this case the positive association with innovation in the joint model is not statistically significant. As a result, the evidence does not support the existence of a mediation path for economic profitability and turnover, even though the aforementioned direct effect weakens in the joint model.

Beyond the identification of the mediation channels, the joint model also offers insight into the broader role of innovation as an internal driver of final outcomes. The results show that suppliers reporting innovation gains are systematically more likely to achieve structural economic transformations and, as already mentioned, workforce expansion. Holding the quality of procurement relationships constant, a 10-percentage point increase in innovation is associated with a 7.3 percentage point increase in structural economic outcomes and a 5.7-percentage point increase in workforce size.  At the same time, innovation appears to expose suppliers to higher levels of risk. **Suppliers that innovate more extensively are also more likely to experience negative effects**, such as financial losses, reputational risks, or even exposure to bankruptcy. These outcomes reflect the uncertainty and complexity often associated with technological development and organisational changes. In this context, innovation has an overall ambiguous effect: it may lead to long-term growth as well as to short-term vulnerabilities. Crucially, the quality of relationship with F4E appears to partly mitigate these risks. Holding constant the effect of intermediate outcomes, a 10-percentage point improvement in the perceived quality of relationship with F4E is associated with a 4.4 percentage point decrease in the likelihood of negative economic effects, even for suppliers that are actively innovating.

## Table 17. Determinats of suppliers outcomes

| | (1)<br>Turnover and profitability | (2)<br>Economic transformations | (3)<br>Economic negative | (4)<br>Employment | (5)<br>Innovation | (6)<br>Market positioning | (7)<br>Learning | (8)<br>Turnover and profitability | (9)<br>Economic transformations | (10)<br>Economic negative | (11)<br>Employment | (12)<br>Turnover and profitability | (13)<br>Economic transformations | (14)<br>Economic negative | (15)<br>Employment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Procurement feature* | | | | | | | | | | | | | | | |
| Quality of procurement relationships | 0.518**<br>(0.217) | 0.312<br>(0.218) | -0.293<br>(0.246) | 0.413*<br>(0.222) | 0.420*<br>(0.232) | 0.182<br>(0.181) | 0.349<br>(0.208) | | | | | 0.306<br>(0.196) | 0.0421<br>(0.138) | -0.442*<br>(0.237) | 0.151<br>(0.172) |
| *Intermediate outcomes* | | | | | | | | | | | | | | | |
| Innovation | | | | | | | | 0.306<br>(0.254) | 0.742***<br>(0.172) | 0.614*<br>(0.313) | 0.618***<br>(0.217) | 0.211<br>(0.255) | 0.729***<br>(0.180) | 0.751**<br>(0.309) | 0.571**<br>(0.224) |
| Market positioning | | | | | | | | 0.171<br>(0.362) | 0.330<br>(0.245) | 0.275<br>(0.446) | 0.206<br>(0.309) | 0.287<br>(0.361) | 0.346<br>(0.255) | 0.108<br>(0.437) | 0.263<br>(0.317) |
| Learning | | | | | | | | 0.276<br>(0.266) | -0.275<br>(0.180) | -0.638*<br>(0.328) | -0.0371<br>(0.227) | 0.204<br>(0.264) | -0.285<br>(0.186) | -0.533<br>(0.319) | -0.0729<br>(0.232) |
| Constant | -0.348<br>(0.331) | -0.175<br>(0.333) | 0.540<br>(0.375) | -0.226<br>(0.338) | -0.336<br>(0.354) | 0.0497<br>(0.276) | -0.226<br>(0.317) | 0.0949<br>(0.207) | 0.0351<br>(0.140) | 0.175<br>(0.254) | 0.104<br>(0.176) | -0.246<br>(0.297) | -0.0117<br>(0.209) | 0.667*<br>(0.359) | -0.0633<br>(0.261) |
| *Control variables* | | | | | | | | | | | | | | | |
| Firm age | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Hight tech. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm size | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Experience | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 |
| R-squared | 0.679 | 0.425 | 0.268 | 0.652 | 0.546 | 0.611 | 0.622 | 0.780 | 0.822 | 0.408 | 0.834 | 0.798 | 0.822 | 0.476 | 0.838 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

## Counterfactual analysis

The **counterfactual analysis** uses a staggered Difference-in-Differences (DiD) approach to assessing whether being a F4E supplier has an impact on the firms' economic performance by comparing the outcomes of treated units, or beneficiaries – those holding F4E procurement contracts – with a comparable group of non-treated units (the so-called control group). The control group consists of units, i.e. firms, that are similar to the treated group in all observable dimensions, except that they did not receive any procurement contract. This approach also allows for estimating the impact over time through an event study approach, considering that some benefits may take some years before (fully) materialising.

The counterfactual analysis follows three main steps:

- **The match of F4E beneficiaries (the treated group) with Orbis data**

  The first step was to integrate F4E procurement and grant data with balance sheet data from the Orbis database to retrieve information on the economic and financial performance of F4E beneficiaries (the treated group).

  Orbis is a commercial database maintained by Moody's, to which CSIL has access through a proprietary licence. The database is widely used in economic research as a source of firm-level data for micro-econometric analysis. It includes information on company assets (tangible fixed assets and intangible fixed assets), operating revenues, number of employees, various financial ratios, ownership data, listing status, incorporation year, activity sector (based on NACE codes), geographical location, and so on.

  The search returns the corresponding BvD ID, which is Orbis's unique firm identifier, along with a matching score that indicates the quality of the match. This score ranges from A (highest quality) to D (lowest quality). To ensure the reliability of the analysis and to avoid the inclusion of incorrect matches, only companies with high-quality matches (score A) were automatically retained. In cases where the matching score was lower, we manually validated and assigned the most appropriate match based on additional desk research.

  Exploiting the online database maintained by Moody's, it was possible to retrieve balance-sheet information about companies, such as total assets, turnover, number of employees. This was complemented by demographic characteristics, such as the year of incorporation, the sector of activity (based on NACE classification) and the geographical location. These variables were useful for profiling F4E suppliers and were instrumental in the identification of the control group (see next step).

  A cleaning procedure was applied to exclude observations with odd or inconsistent values following the approach by Amamou et al. (2020). Firm-year observations in which data from the balance sheet (e.g. total assets, fixed assets, intangible fixed assets, total shareholder funds, liabilities, and so on) had negative values were dropped. We checked the consistency of the data and drop the firm-year financial statements when the basic balance-sheet equivalences are violated by more than 10%.

The final database obtained after combining the F4E procurement and grant database with Orbis and cleaning data consisted of 335 beneficiaries over a starting sample of 345 beneficiaries (97%) and 7,098 observations over the period 2004-2024 (panel dataset).

- **The identification of comparable firms that were never treated (control group)**

  The goal of this step is to identify companies that are as comparable as possible to F4E beneficiaries. The identification of counterfactual control sample was performed via a combination of exact- and propensity score matching.

  Treated units were first matched to potential controls through **exact matching** on a set of structural variables. To do that, treated units were stratified according four key variables, notably the country where the firm is located, the sector of activity (according to NACE classification at two digits), the size class based on the number of employees, and the age range at the year of the signature of the contract. The sample of treated firms was then restricted to those with available financial data in the year before and for the three years following the signature of the first contract. This process helped generate the unique strata from which potential controls were drawn. For each stratum, a group of non-treated firms was identified in the Orbis database. For each treated firm we randomly sampled ten potential controls. Hence, the number of potential controls per stratum ranged from 10 to 30, depending on the number of treated firms within each stratum (which ranged between one and three).

  The exact matching strategy was improved by the **Propensity Score Matching (PSM)** to identify the final sample of controls. Propensity score matching (Rosenbaum and Rubin, 1983) is a non-parametric estimator of causal effects widely used in the evaluation literature. It addresses the limits of least square analysis in the presence of observational data, while it also avoids the so-called curse of dimensionality, significantly restricting the feasibility of matching estimators. The PSM was performed on each of the three key outcome variables of interest: number of employees, turnover, and total assets. It was re-run ad hoc for each outcome variable because the specific sample of observations used in the analysis varied depending on the availability of financial data for that particular outcome (e.g., turnover data might be available for a firm where total asset data is missing, leading to different sample sizes for each estimation)

  The table below summarises the variables used in the matching phase.

**Table 18. Variables used in the matching phase**

| Variable | Firm's structural features | | | | | Firm's financial history |
|---|---|---|---|---|---|---|
| | Country | Sector (NACE) | Size category | Age category | N employees (ln) | Outcome variable (ln) |
| Type of matching | Exact | Exact | Exact | Exact | PSM | PSM |

Source: CSIL elaboration

- **The estimation phase**

The causal impact attributable to the signature of F4E contracts is estimated by looking at the difference in the outcome variables between treated and control firms. We measured impacts for three main outcome indicators, i.e., number of employees, turnover and total assets.

The flexible conditional difference in differences approach recently developed by Dettmann et al. (2020) was adopted to obtain the DID estimator, which has the advantage to properly account for time-related information on treatment and outcome variables in our database. First, this command allows to deal with varying dates (years) of treatment. Second, the information on the outcome development is fully considered. The estimation procedure estimates the casual impact comparing the individual differences in the outcome development between treated and respective controls during both the matching and the estimation phase. For instance, if a F4E supplier signed a contract in 2017, the command assigns a control firm which has similar characteristics in 2016. Third, it integrates the possibility to combine the exact matching and the PSM in a flexible way and incorporates efficient and different distance functions in the matching phase by distinguishing continuous and categorical variables (see for details Dettmann et al. (2020)).

**Table 19. Main results from the counterfactual analysis**

| | Employment | Turnover | Total assets |
|---|---|---|---|
| | 0.1045* | 0.1348 | 0.0708 |
| Treated in *t* | (0.0828) | (0.1438) | (0.5630) |
| No. of treated observations | 53 | 48 | 54 |
| No. of unique controls | 286 | 289 | 314 |
| Mean n. of matches | 6.094 | 6.854 | 6.574 |

Note: Statistical significance is indicated by asterisks. A coefficient with one or more asterisks is statistically different from zero. The number of asterisks reflects the precision of the estimate: more asterisks indicate greater precision in measuring the effect. The numbers in parentheses beneath the coefficients represent standard errors, which help gauge how close the presented result might be to the true value. In this way, standard errors indicate the level of uncertainty in our estimates. Larger standard errors suggest less confidence in the results, potentially leading to estimates that are not statistically significant (i.e., without asterisks).

Source: authors' elaboration on F4E data matched with ORBIS data. Notes: Standard errors in parenthesis

- **Limitations**

**Data loss may cause a potential sample selection**. The analysis was implemented on subset ranging between 48 (14%) and 54 (16%) firms. The reason why the size of the treated sample reduced so much is twofold: companies were excluded either because they had limited availability of relevant variables (especially financial data) or because no adequate controls were found throughout the matching procedures.

# ANNEX 9. CASE STUDIES

The following case studies explore and illustrate the benefits gained by seven selected companies from technological or reputational spillovers resulting from their involvement in F4E contracts for ITER/BA. More specifically, these cases provide insights into how such contracts have contributed to the following impacts:

3. **Learning effects** (e.g., development of new skills, capabilities, or technical know-how; formation of new collaborations; process improvements or quality enhancements)
4. **Innovation effects** (e.g., creation or enhancement of products, services, or technologies; generation of intellectual property, patents, or trademarks; new research outputs or spinoff initiatives)
5. **Market effects** (e.g., securing follow-on contracts within the same industry or across sectors; gaining access to new markets or industries; reputational improvements, marketing advantages, or new relationships with other companies)
6. **Economic effects** (e.g., revenue growth directly linked to client engagement; increases in turnover or profitability; establishment of new businesses or R&D units; potential reputational risks or financial losses)
7. **Employment effects** (e.g., growth in employee numbers, including temporary or skilled staff; creation of new jobs or upskilling of existing employees)

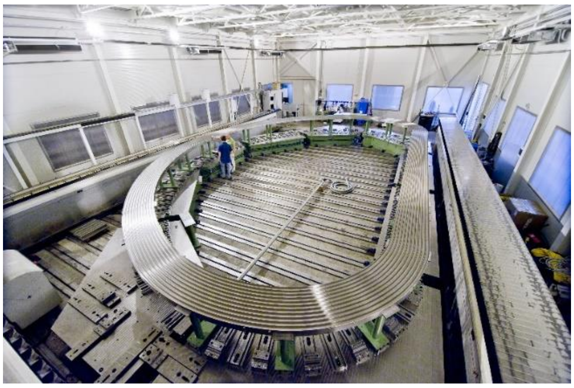
In agreement with F4E, the companies were selected among those that have reported on multiple of these impacts in their survey responses, and/or have expressed a willingness to participate in interviews, and/or have been recommended by F4E as suppliers to highlight.

# 1. CASE STUDY – SIMIC S.p.A

| 1. Company Profile |
|---|
| ➢ Company name: **SIMIC S.p.A (Italy)**<br>➢ Company size: **438 employees, large-size enterprise**<br>➢ Industry sector: **engineering, manufacturing, testing and installation of heavy machinery and mechanical components with very strict tolerances and special integrations**<br>➢ Value of contracts with F4E since collaboration started: **Approximately EUR 395 million**[74] **from F4E alone and up to EUR 555 million including contracts with ITER Organisation (IO).**<br>➢ Products/services supplied to F4E: manufacturing of **vacuum vessel poloidal sector model, cassette body prototype, ITER TF radial plates series production and coils, ITER cryogenic distribution boxes, cassette bodies series, blanket cooling manifold system, on site assembly of ITER Tokamak main components**<br>➢ Website: [Home - Simic S.p.A.] |

**2. SIMIC's role in advancing nuclear fusion technology through ITER**

Since 1977, SIMIC has developed experience in the design and production of high-quality critical process equipment, maintenance and assembly of industrial plants. The company already started to work on nuclear fusion in the early phases of the ITER project, supporting the manufacturing of a fusion reactor using a plasma magnetic confinement (Tokamak machine) in Cadarache, France. They manufactured important prototypes such as the vacuum vessel prototype, cassette body, dome liner, inner vertical target, outer vertical target of ITER divertor and radial plates. In 2014, SIMIC was selected to supply 10 out of a total of 18 toroidal field coils in the ITER project, which were successfully completed and shipped to Cadarache by 2024. This specific contract represented an important milestone for SIMIC's growth, as well as the advancement of nuclear fusion.[75] These contracts have allowed SIMIC to push the boundaries of its technological capabilities, particularly in areas such as high-precision machining of complex geometries, welding and assembly of large-scale steel structures under stringent tolerances, development of new quality control and testing methodologies to meet the high nuclear-grade standards.



**3. Fusion innovations fuel growth across sectors**

The contracts with F4E challenged SIMIC to solve multiple first-of-a-kind engineering problems, triggering a wave of innovation. The company was faced with the technical challenges of producing

[74] This estimation was provided by the company.

[75] Company - Simic S.p.A.

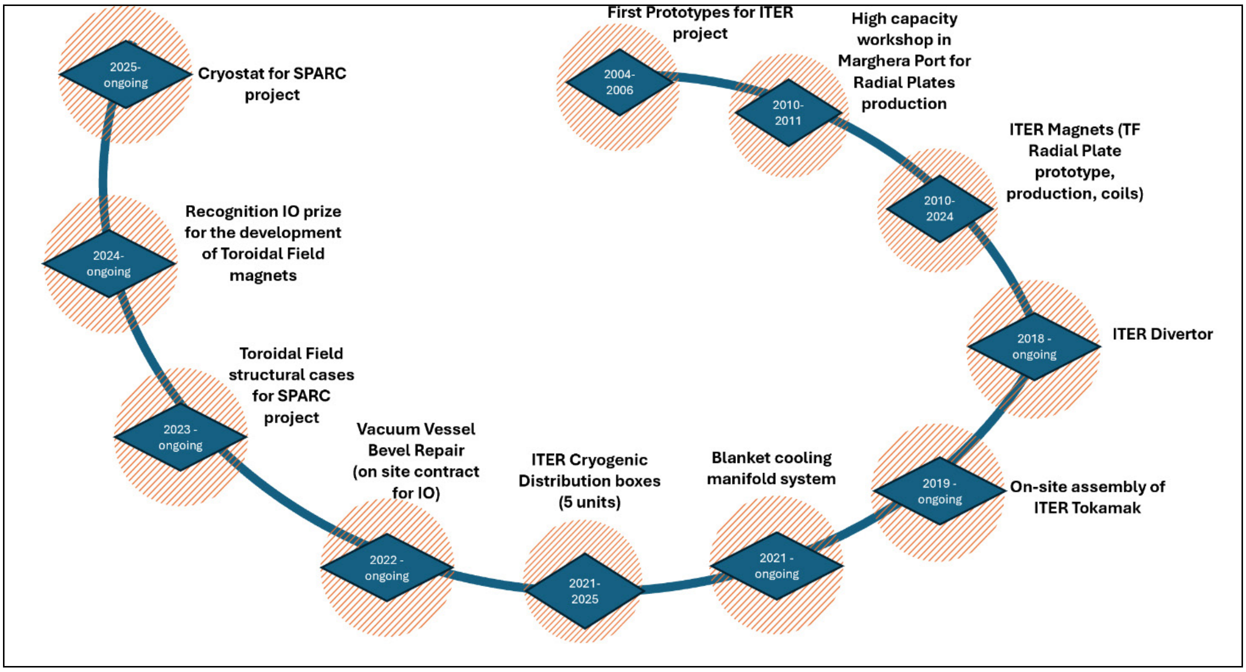
ITER's toroidal field magnet and radial plate components, they also developed novel fabrication processes and built in-house infrastructure to accommodate large magnets. Dedicated special tools, facilities and equipment had to be designed and produced on purpose to achieve the demanding technical and quality requirements. While they developed new competences in the magnet field, they also developed competences in their existing technology, such as robotic welding, mechanical processing, non-destructive examination and metrology, where they had to innovate by investing in state-of-the-art equipment, installing new portal machines (considered to be unique in the EU) and software combined with instruments that they did not initially have in-house. This has resulted in opening up commercial opportunities beyond the fusion sector. SIMIC is now applying similar innovations in sectors such as nuclear medicine, aerospace, the nuclear fission sector, as well as scientific research sector. For example, for a medical specialty combining molecular imaging and targeted radionuclide therapy, mainly in relation to the integration of magnets, as well as vacuum vessels and beam line, can be applied to the medical sector.

**4. Growing markets and capabilities via fusion**

Since 2010, the company has secured contracts worth EUR 395 million from F4E alone[76] and up to EUR 555 million including contracts with ITER Organisation. These engagements, along with the contracts for ITER Organisation provided the financial stability and confidence needed to invest heavily in new equipment, facilities and workforce development. The contracts directly contributed to **growth in revenue and operational scale** with an impact of approximately 30%. F4E's support acted as a **de-risking mechanism**, enabling SIMIC to invest in advanced technologies and bid for future oriented projects that would otherwise have been out of reach. The company's improved profitability and industrial maturity have made it a **reference point in global fusion manufacturing**. Through participation in European consortia and supply chain networks established under the F4E ecosystem, SIMIC built **strategic relationships** with companies and institutions across Europe and worldwide, for e.g. projects such as Divertor Tokamak Test (DTT) in Italy and for the American start-up Commonwealth Fusion Systems (CFS), amongst other major players in the fusion sector.


**5. Timeline of key events**

[76] This estimation was provided by the company.


2025-
ongoing
Cryostat for SPARC project
2024-
ongoing
Recognition IO prize for the development of Toroidal Field magnets
2023 -
ongoing
Toroidal Field structural cases for SPARC project
2022 -
ongoing
Vacuum Vessel Bevel Repair (on site contract for IO)
2021-
2025
ITER Cryogenic Distribution boxes (5 units)
2021 -
ongoing
Blanket cooling manifold system
2019 -
ongoing
On-site assembly of ITER Tokamak
2018 -
ongoing
ITER Divertor
2010-
2024
ITER Magnets (TF Radial Plate prototype, production, coils)
2010-
2011
High capacity workshop in Marghera Port for Radial Plates production
2004-
2006
First Prototypes for ITER project

## 2. CASE STUDY – ANSALDO NUCLEARE S.P.A.

### 1. Company Profile

- Company name: **Ansaldo Nucleare S.p.A. (Italy)**
- Company size: **233 employees, large-size enterprise**
- Industry sector: **Nuclear energy sector, architectural and engineering activities and related technical consultancy**
- Value of contracts with F4E since collaboration started: **EUR 550 million**[77]
- Products/services supplied to F4E: **Remote handling technologies; European Vacuum Vessel sectors**
- Website: Ansaldo Nucleare SpA

### 2. Ansaldo Nucleare's role in advancing fusion technology through ITER

Ansaldo Nucleare, part of Ansaldo Energia, is an Italian company active in the nuclear engineering sector, in both fission and fusion technologies. The mother company Ansaldo Eenrgia was founded in 1853, and covers every phase of the design, construction, commissioning, support, and maintenance of power plants and high-tech machinery.[78] Ansaldo Nucleare is active internationally: its activities abroad include the UK, through the holding Ansaldo Nuclear Ltd, and in Romania, through involvement in the Cernavodă nuclear plants.[79]


Fusion activities began as early as the 1980s, including early contributions to ITER's vacuum vessel sectors and divertor technologies. In the fission domain, nuclear remains a core part of Ansaldo Nucleare business, including a long-standing collaboration with Westinghouse, notably on the AP1000 reactor design. From around 2010, Ansaldo Nucleare has been part of major ITER-related contracts with F4E, operating within the AMW consortium alongside Westinghouse and Walter Tosto. Europe is responsible for building five of the nine ITER vacuum vessel sectors, all manufactured in Italy, and Ansaldo's consortial role includes five sectors, involving extensive welding, machining and instrumentation-handling equipment design and manufacturing quality control. The second vacuum vessel sector was completed in March 2025 and shipped from Italy as part of a multi-year production schedule, with full delivery expected by 2027. Additionally, Ansaldo

[77] Data sourced from F4E's payment database, which contains payments made to F4E suppliers during the period 2007-2024, including associated contract information for each payment line.

[78] https://www.ansaldoenergia.com/it/offerta/nucleare/innovazione-per-le-tecnologie-nucleari-del-futuro/fusione

[79] In November 2024 Ansaldo Nucleare, as part of a JV with Candu, Fluor, Serget&Landi was awarded by EN the LTNP for the completion of Unit 3 and 4 and in December 2024 alongside with Candu and KHNP, the Contract for Plant Life Extension of Cernavoda Unit 1.

| |
|---|
| independently handles divertor technologies (originated in early 80' in Ansaldo Ricerche) and remote handling equipment for ITER. |
| **3. Leading innovation in remote handling** |
| Ansaldo's expertise in remote handling was initially developed for nuclear decommissioning tasks involving radioactive components. This foundational knowledge has since evolved into a strategic asset for the company. The remote handling intellectual property (IP) has proven particularly valuable in contracts with F4E and is expected to play a key role in the next generation of fission technologies, especially in the handling of nuclear fuels. Ansaldo not only possessed this IP early on but has also continued to develop and expand it over time through subsequent contracts with F4E. The company sees this competence as a key driver for further innovation, with clear intentions to further invest in its advancement. These capabilities are expected to support future technologies and strengthen Ansaldo's position in upcoming contracts.[80] |
| **4. Balancing commercial challenges and reputational gains** |
| The impact of F4E contracts on Ansaldo's operations varies significantly depending on their structure and terms. While some contracts pose economic and managerial challenges - often because their conditions are not fully aligned with the specific nature of the projects - they are nonetheless seen as strategically essential. These contracts enable scope expansion, competence building, and reputational gains, even as they create a recurring tension between strengthening turnover and profitability, establishing new business areas or R&D capabilities, and managing reputational risks while avoiding financial losses. To address this, Ansaldo engages in frank and open discussions aimed at restoring conditions for profitability, thereby balancing short-term commercial pressures with long-term strategic value.[81] |
| **5. Ansaldo shaping education in fusion** |
| Being a firm believer in the future of nuclear energy, Ansaldo is actively strengthening its workforce to support ongoing and future projects, particularly in the nuclear and civil engineering sectors. The company currently employs approximately 180 professionals across engineering, project management, and quality assurance.[82] To address capacity needs and enhance capabilities, Ansaldo plans to expand its total workforce to 250. This includes the growth of the sub-hub in France, with new engineering team in Cadarache to be closer to the ITER project, additional branches in the United Kingdom and Romania.<br><br>As part of its talent development strategy, Ansaldo has launched a new Master's program in collaboration with Politecnico di Milano and other Italian universities offering nuclear programs[83]. The program, which began in April initially targeted 20 chemical engineers. However, it received an overwhelming 341 eligible applications. From these, 40 strong candidates were shortlisted, and 28 are currently being hired. The program covers both fusion and fission technologies. Participants |

[80] Based on the interview with Ansaldo Nucleare, on July 29, 2025.

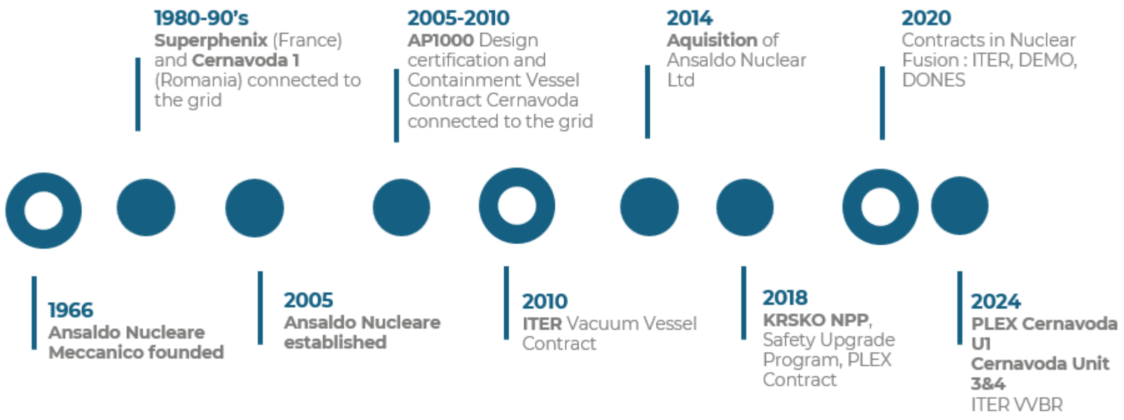
[81] Idem.

[82] Key support functions such as procurement and human resources are managed by the parent company, Ansaldo Energia.

[83] Al via il Master Corporate in collaborazione con Ansaldo Nucleare - Dipartimento di Energia

split their time between academic training and hands-on experience, contributing directly to existing contracts. This initiative supports both job creation and upskilling within the nuclear sector.[84]

**6. History and references allow the company to play across the whole nuclear sector**




[84] Idem.

# 3. CASE STUDY – MAGICS TECHNOLOGIES

**1. Company Profile**

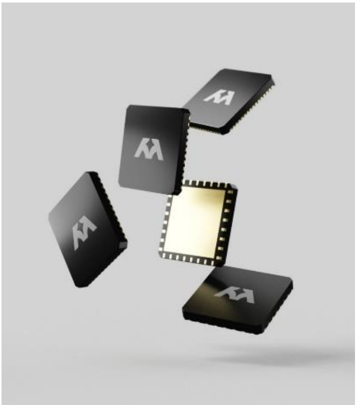
- Company name: **Magics Technologies NV. (Belgium)**
- Company size: **42 employees, SME**
- Industry sector: **Semiconductor and microelectronics development for high-radiation environments, applicable in fusion, nuclear fission, space, big science**
- Value of contracts with F4E since collaboration started: **EUR 7-8 million**[85]
- Products/services supplied to F4E: **Custom semiconducting hardware (chips)**
- Website: [Magics: Innovation & Reliability in Rad-Hard Technology]

**2. From the laboratory to real-life applications**

Magics Technologies, founded in 2015 as a spin-off from KU Leuven and Belgium's nuclear research center SCK·CEN, is a fabless semiconductor company headquartered in Geel, Belgium, with additional references to Antwerp. The company specializes in radiation-hardened semiconductor solutions using its proprietary Radiation-Hardened-by-Design (RHBD) methodology, targeting extreme environments such as space, nuclear facilities, and other high-reliability applications. Its product portfolio spans several series, including imaging solutions for nuclear and inspection systems; precision timing and clock generation for satellites and LiDAR; sensor interfaces and control ICs for robotics in harsh settings; as well as radiation-tolerant DC/DC converters sold together with their Vision and Motion products for the nuclear market.

**3. Enhanced quality processes and spill-over innovation**

The company has developed a specialised semiconductor solution for F4E, tailored for the fusion energy environment. This technology withstands mega-grade radiation levels in high-radiative settings, leading to simplified operations, reduced maintenance costs and enhancing system resilience of remote handling and diagnostics at ITER. This initiative enabled Magics to **advance** its **technical expertise**, while also improving the quality and reliability of its internal processes. These learning effects have **catalysed broader innovation** at Magics and contributed to market success.



The company's collaboration with F4E led Magics to establish **stronger quality management practices**. These processes are assets to Magics and are embedded into every contract, ensuring consistent standards. This has supported Magics in acquiring new contracts in the space and nuclear fission sectors. Since their F4E collaboration, Magics has commercialised its chip technology, and expanded its activities in

[85] This estimation was provided by the company.

the space sector, working at the forefront of EU semiconductors manufacturing for strategic market segments.

**4. Market expansion and partnership building**

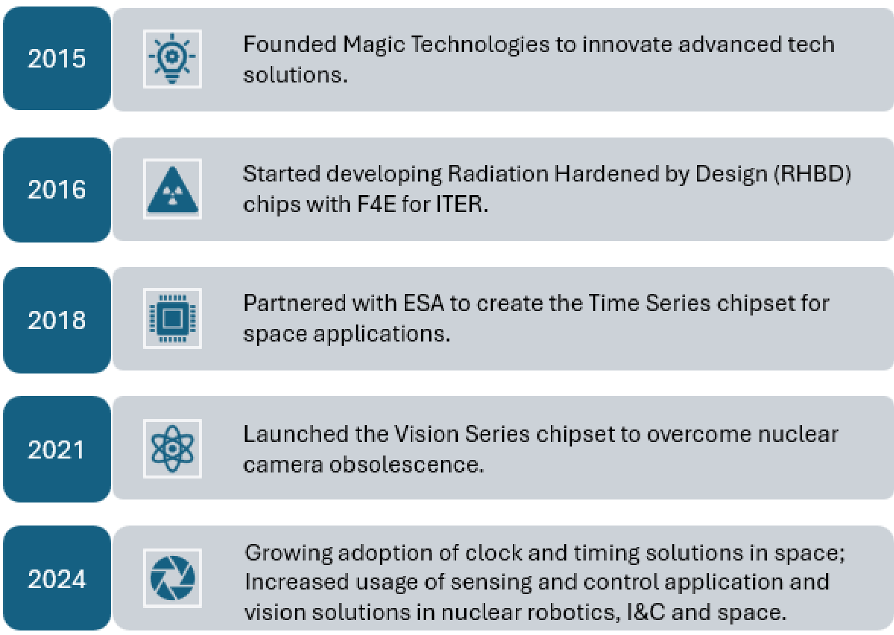
Participation in F4E projects elevated Magics' profile, positioning it as a credible EU-based alternative to overseas semiconductor suppliers. This **reputational boost** facilitated entry into **new markets and collaborations**, including with the European Space Agency and firms like Veolia Nuclear (previously Oxford Technologies), Jacobs, UKAEA, Ansaldo, and Wälischmiller.

Following the project, Magics began commercialising the semiconductor hardware within the civil nuclear industry. This has led to follow-on contracts and the establishment of new customer relationships. The reputational strength gained through its involvement with F4E has also played a pivotal role in supporting market expansion and building credibility in adjacent sectors, including space applications and collaborations with the European Space Agency.

**5. Knowledge and capacity deployment**

Since their F4E collaboration, multidisciplinary teams in microelectronics, embedded systems, and integration have been created at the company, that where the basis for other chip developments and customer projects. Magics supports strategic autonomy by relying on and reinforcing European-based semiconductor and systems manufacturing capacity. By developing key enabling technologies in Europe, Magics helps reduce reliance on non-EU suppliers. The knowledge created within fusion projects is leveraged to generate growth in adjacent industries.

**6. Timeline showing major milestones in Magics' development**



# 4. CASE STUDY – RTC ENGINEERING/REVOL TT CONSULTING

| 1. Company Profile |
|---|
| ➢ Company name: **Revol TT Consulting, s.r.o. (ltd) (Slovakia)**<br>➢ Company size: **Over 120 employees, SME**<br>➢ Industry sector: **Engineering, manufacturing, testing and integration services in sectors such as plasma fusion energy, semiconductor industry, space exploration, particle accelerators and research organisations.**<br>➢ Value of contracts with F4E since collaboration started: **EUR 16.661.916**[86]<br>➢ Products/services supplied to F4E: **High heat flux components for JT-60SA, engineering design and R&D for divertor components, specialised welding processes for advanced material bonding, engineering services (design to prototype to production).**<br>➢ Website: https://www.rtc-engineering.com/ |
| **2. RTC Engineering's growth in nuclear fusion energy** |
| RTC Engineering is a leading technology organisation specialising in cutting-edge research and development, engineering, manufacturing, testing and integration services. The organisation is at the forefront of technological advancements in diverse sectors, such as plasma fusion energy, the semiconductor industry, space exploration, particle accelerators and research organisations.[87] In the fusion sector, they are presently partnering with major public projects such as ITER, JT-60SA, Compass-U and private sector initiatives, such as Proxima Fusion. Working with F4E has had a notable impact on the organisation's level of innovation (e.g. the development of High Heat Flux components) and has opened up market opportunities for clients in the scientific and research sphere. |
| **3. Evolution from a Tier 2 subcontractor to a Tier 1 supplier** |
| RTC Engineering began its involvement as a subcontractor to Elytt Energy on an F4E contract and gradually moved up the supply chain. This collaboration enabled the company to evolve from a Tier 2 subcontractor into a Tier 1 supplier in fusion projects. The transition was not without challenges: the steep learning curve stemmed from the complexity of procurement procedures and the high technical standards required. Over time, however, RTC Engineering benefited from partnerships with more experienced players and from participation in collaborative consortia, which provided valuable insights into F4E's expectations and procedures. In parallel, the company invested in strengthening its internal capacity: staff received extensive training to adapt to procurement requirements, while these learnings supported the development of new testing infrastructure and cleanrooms. |
| **4. Development of advanced High Heat Flux components** |

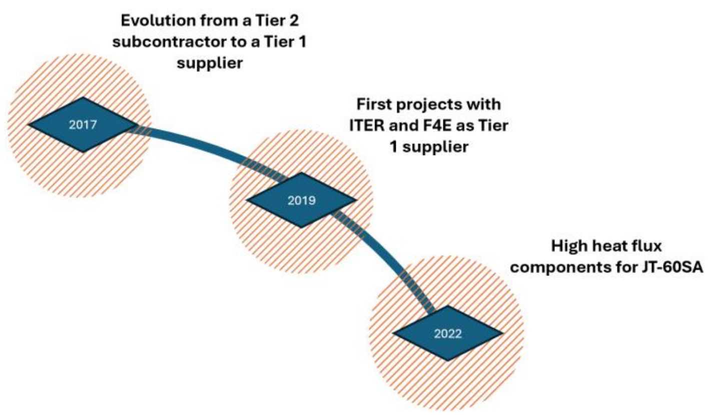
[86] This estimation was provided by the company.
[87] About Us | RTC Engineering

The collaboration with F4E led to the development of novel High Heat Flux (HHF) components for the JT-60SA, which is a current, ongoing project with F4E. This project has played a key role in RTC Engineering building **new facilities** (testing infrastructure and cleanrooms mentioned earlier) and **strengthening** their **team**, as a result of the financing for the project (EUR 15 million). The organisation is also responsible for engineering services for the JT-60SA, which includes the full development of the components for the divertor in the reactor. Presently the first phase of prototype delivery is ongoing, while serial production of the components for the divertor are expected by the end of 2025. Through the ongoing F4E contract they are also working on proprietary bonding techniques, such as welding different types of metals and graphite. These innovations have **strengthened RTC Engineering's portfolio** and have opened up opportunities for technology transfer.


## 5. Gateway to strategic high value contracts

F4E served as a **gateway for market expansion**. The prestige associated with working on ITER and JT-60SA significantly boosted RTC Engineering's credibility. The EUR 15 million contract for JT-60SA is the organisation's largest contract to date. While the F4E projects directly impacted revenue and enabled infrastructure investments, they also had an indirect economic effect by unlocking access to other high-value contracts. As a result, it has strengthened the company's position as a **strong partner for scientific institutions** such as CERN, GSI Helmholtz Centre for Heavy Ion Research, Paul Scherrer Institute (PSI) in Europe, Diamond Light Source, ISIS Neutron, Muon Source in the UK and institutes from the United States such as Stanford University's SLAC and Lawrence Berkeley national laboratory.

## 6. Timeline of key events



## 5. CASE STUDY – WALTER TOSTO S.P.A

### 1. Company Profile

- Company name: **Walter Tosto S.P.A (Italy)**
- Company size: **650 employees, medium-large enterprise**
- Industry sector: **Manufacturing of large industrial components e.g. high-pressure equipment and vessels**
- Value of contracts with F4E since collaboration started: **EUR 142.7 million directly contracted, more through subcontracting in other consortia, total around EUR 350 million**[88]
- Products/services supplied to F4E: **ITER (vacuum vessel, divertor cassette bodies, vessel for neutral beam), JT-60SA (toroidal field coils)**
- Website: https://www.waltertosto.it/en/big-science/

### 2. Spurring growth and creating employment

Walter Tosto decided in 2008 to re-enter the nuclear sector, starting with just one person, they first engaged with F4E in 2009. In 2010, as a subcontractor in a larger consortium, it secured its first contract for F4E to work on the ITER vacuum vessel welding. This was followed by further work from F4E to supply components for the JT-60SA tokamak in Japan under the Broader Approach. Since then, further work has followed. This has helped Walter Tosto grow its fusion-related revenues to around EUR 20 million annually, and employ around 250 people, a significant increase over the last 15 years. Close ties and investments with educational institutions in the region have also allowed Walter Tosto to train skilled local staff to support this growth.

Photo: Vacuum Vessel sector for ITER, manufactured by Walter Tosto and partners, credit: Walter Tosto

### 3. Work for F4E on ITER opened the door to renewed work in nuclear fission markets

The work for F4E also brought a clear broader market benefit for Walter Tosto, enabling it to re-establish itself in the nuclear fission supply chain. The credibility and supplier references gained in working for F4E were crucial in enabling this growth, allowing Walter Tosto to prove its capability to supply high quality, precision manufactured components generally on time and according to specification. From this entry point Walter Tosto has grown its work in the nuclear fission sector, which now accounts for more turnover and employment than the fusion work. The total revenue

[88] This estimation was provided by the company.

of Walter Tosto has almost doubled since 2008, with the nuclear fusion and fission work amongst the major drivers.

**4. Boosting technological and other capabilities through work for F4E**

The nature of Walter Tosto's work for ITER in developing, manufacturing and engineering First-of-a-kind (FOAK) components poses a challenge for the profitability of this work. However, Walter Tosto is clear that it receives a large overall benefit from its work for F4E through the boost it gives to innovation and technological development, and also to management and organisation. For example, the work for F4E allowed Walter Tosto to invest in Electron deep welding technology, an advanced welding technique. By establishing their own facility and expertise, they are now among only a handful of firms that are able to perform this kind of work. They have also developed metrology and simulation software and technologies to simulate tolerances and materials reactivity, this has boosted their capabilities in advanced engineering. The long-term nature of projects for F4E and ITER, with their high quality and precision requirements, has led Walter Tosto to invest in its staff and organisation to deliver this type of work effectively and efficiently. These investments in fusion technology, innovation, staff and organisation are highly beneficial to the company, with management estimating that the benefits are more than twice as much as they experience from investments in their other business sectors.

**5. Follow-on work for private fusion initiatives: Supplying Commonwealth Fusion Systems**

The work Walter Tosto carried out for F4E on both ITER and JT-60SA established a strong reputation and credibility in the fusion field. Combined with their existing networks in the United States they had the right expertise, capabilities and investments to win the contract to supply the vacuum vessel for the SPARC tokamak that Commonwealth Fusion Systems is building in Massachusetts, USA. The experience gained over 15 years in supplying ITER allowed Walter Tosto to demonstrate that they can deliver high quality products and quickly, with the contract re-producing similar components to those supplied to ITER, re-using and further developing their capabilities. This example demonstrates how the work for F4E on ITER has helped Walter Tosto establish itself as a global leader in the fusion supply chain, and how it is now well positioned to take advantage of the small, but rapidly growing fusion market.

**6. Walter Tosto's fusion journey**

# 6. CASE STUDY - AMPEGON

## 1. Company Profile

- Company name: **Ampegon Power Electronics AG (Switzerland)**
- Company size: **35 employees, Small Medium Enterprise**
- Industry sector: **Design and Manufacture of power electronics (High voltage power supplies and modulators), high frequency radio equipment and high power RF amplifiers**
- Value of contracts with F4E since collaboration started: **EUR 17.6 million**[89]
- Products/services supplied to F4E: **Electron Cyclotron (high voltage power supplies), Ion cyclotron, switchgears**
- Website: https://ampegon.com/

## 2. Ampegon as power electronics provider

Ampegon provides bespoke power solutions for various industrial clients and projects, this requires close cooperation and a similar to first-of-a-kind (FOAK) approach to all projects. Ampegon was first contracted by F4E in 2013 to provide 8 of 12 high voltage power supplies for the electron cyclotron heating and current drive system of ITER, and 16 body power supplies. These technologies are essential for ITER, they take electricity from the grid and ensure a stable but rapidly adjustable high voltage electricity supply to the gyrotrons, which in turn will produce strong electromagnetic waves to heat the ITER plasma. This has been likened to 'providing the matches to light the plasma'.

Figure: High voltage units get delivered to ITER site (source: F4E)

## 3. Working on ITER improved visibility and reputation – helping secure other clients

Since working for F4E on providing the high voltage power supplies for ITER, Ampegon has secured further contracts with for example, the Karlsruhe Institute of Technology (KIT) in Germany and NAT in Japan. Whilst Ampegon was already an established name in this specialist field, the additional visibility and credibility of the contract with ITER played an important role in securing work with new clients. It has also been relevant to ongoing business development and sales discussions, with Ampegon registering interest from private fusion start-ups from the US, UK and Europe about potential equipment purchases.

## 4. Developing new expertise and partnerships – gyrotron specific power supplies

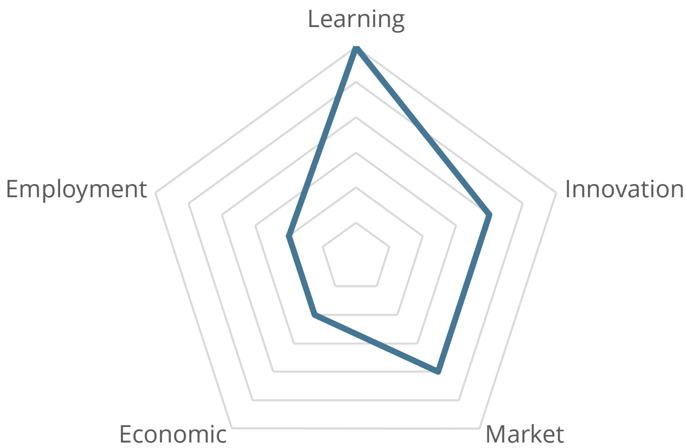
[89] Data sourced from F4E's payment database, which contains records of payments made to F4E suppliers from 2007-2024, including associated contract information for each payment line.

Before working with F4E Ampegon already possessed specialist manufacturing and engineering expertise in high voltage power supplies, however, the work for F4E on ITER also allowed for the acquisition of new knowledge. As part of their work for ITER they collaborated with the Swiss Plasma Centre at EPFL (École Polytechnique Fédérale de Lausanne) and through this collaboration were able to learn more about the equipment and testing it with a gyrotron, something they had not done before. As a result, they were able to further adapt their systems to meet the specific needs of a gyrotron, the benefits of this were two-fold, improving the system delivered to ITER and also developing a competitive product which has opened further opportunities now that new applications for gyrotrons are being explored, for example in deep drilling.

**5. Strengthening internal processes and management**

The work Ampegon carried out for ITER required development of various internal competences. For example, the work required greater attention to standards and quality assurance processes, Ampegon adjusted its internal processes to meet the requirements of French standards relevant for ITER. These improvements to processes have been adopted more broadly within the company. Similarly, project management skills and processes were developed to support the implementation of multi-year ongoing projects.

**6.Perceived benefits gained thanks to work for F4E**



# 7. CASE STUDY – WESTINGHOUSE FRANCE/WESTINGHOUSE MANGIAROTTI

| 1. Company Profile |
| --- |
| ➢ Company name: **Westinghouse France, Westinghouse Italia**<br>➢ Industry sector: **Nuclear engineering and manufacturing**<br>➢ Value of contracts with F4E since collaboration started: **Westinghouse Mangiarotti, Ansaldo Nucleare, Walter Tosto consortium: EUR 381 million, new contract signed with ITER Organization for the full vacuum vessel welding in the value of EUR 180 million**<br>➢ Products/services supplied to F4E: **Vacuum vessel sector components and welding, safety operations**<br>➢ Website: Westinghouse France \| Westinghouse, Westinghouse Mangiarotti \| Westinghouse Mangiarotti |

**2. Westinghouse's role in advancing fusion technology through ITER**

Westinghouse Electric Company is a global leader in nuclear energy, with deep expertise in engineering design of power plants, safety systems, component manufacturing, and large-scale project delivery. The company contributes to both traditional fission energy and next-generation fusion efforts, including the ITER project. Part of Westinghouse's EU operations is Westinghouse France (Operations Business Unit) and Westinghouse Mangiarotti, an Italian nuclear manufacturing company. As part of a larger industry consortium (with Walter Tosto and Ansaldo Nucleare), the Italian arm has been involved in the fabrication of five out of nine vacuum vessel sectors[90] over the past decade. In June 2025, Westinghouse France and ITER announced that the company was awarded a USD 180 million contract by the ITER Organization to perform the final assembly and welding of the full vacuum vessel[91] - the tokamak's most critical component that will contain the fusion plasma.

Two of the nine vacuum vessel sectors at ITER's tokamak facility in Cadarache, France (Source: Westinghouse)

**3. Precision welding tools open new frontiers in engineering know-how**

The learning effects of Westinghouse's past involvement in the manufacturing of ITER's vacuum vessel sectors are now being applied in a new phase through the new assembly and welding contract, which involves joining the full toroidal vacuum vessel on-site at the ITER facility in Cadarache, France. The

[90] Westinghouse has been in charge of sectors 2, 5 and 9, Walter Tosto was responsible for sectors 3 and 4, Ansaldo Nucleare was the engineering leader

[91] Westinghouse and ITER sign a $180M Contract to Advance Nuclear Fusion

completed vessel will span 19.4 meters in diameter and enclose 1,400 cubic meters of vacuum—the largest high-vacuum volume ever constructed for a fusion device.[92]

The work will unfold inside the bioshield pit of the tokamak, with welding set to begin around 2027 and continue for an estimated 30 months. This technically intensive assembly phase places Westinghouse at the heart of ITER's construction timeline and relies on its previous expertise in managing precision manufacturing under extreme specifications.

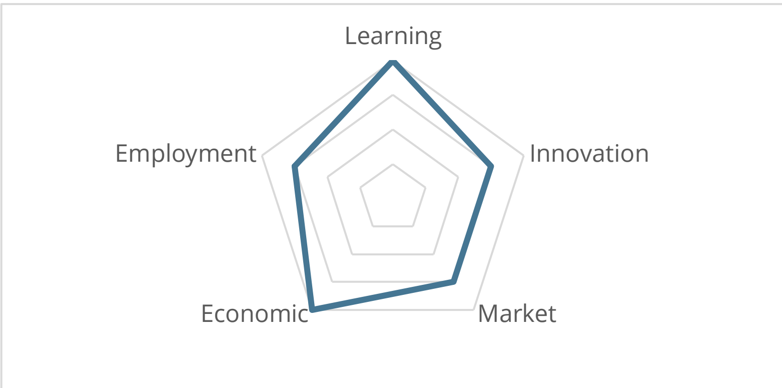
**4. Fusion engineering and its spin-offs: multi-sector technological innovation**

The robotic welding systems and methodologies Westinghouse previously adapted for ITER vessel fabrication represent a significant evolution of the company's technology base. While the mentioned new contract does not introduce entirely novel technologies, it does extend the proven welding platform into one of the most complex fusion integration tasks attempted to date. The deployment of these techniques in a first-of-a-kind (FOAK) fusion environment has implications for other domains where exacting weld quality and spatial constraints intersect - including small modular reactors, cryogenic systems, and space-rated pressure vessels.

**5. Reputational and employment gains in a growing fusion ecosystem**

Securing the ITER vacuum vessel welding and assembly contract represents a key milestone for Westinghouse France, marking a transition from component fabrication to full-system integration in the fusion domain. The high-profile nature of the contract - focused on one of ITER's most complex and critical phases - enhances Westinghouse's credibility as a trusted partner for large-scale, technically demanding fusion projects. Looking ahead, Westinghouse France expects workforce growth tied to the vacuum vessel welding contract, with projections indicating a scale-up from approximately 50 to over 200 employees within three years - reflecting both direct project needs and long-term strategic expansion in the fusion sector.

**6. Perceived benefits gained thanks to F4E and ITER**




[92] Westinghouse wins major contract for vacuum vessel welding

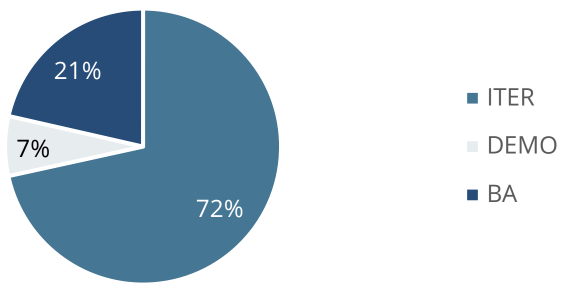
# ANNEX 10. BIBLIOMETRIC AND PATENT ANALYSIS

## Bibliometric analysis

The analysis considers only publications indicating F4E as an author's affiliation or as funding body, or that explicitly mention the agency in the title, abstract, or full text.

The F4E-related publications that mention ITER, DEMO, and BA in the title, abstract, or full text, shows that the topics covered are consistent with the allocation of F4E's efforts across the agency's three core missions. As shown in the figure below, most F4E-related publications (72%) between 2007 and 2024 were focused on the construction of the ITER tokamak, which has represented the agency's main area of activity since its establishment. A further 21% of publications concern the Broader Approach, while only 7% are linked to DEMO. This limited share is explained by the slowdown in the ITER construction, which postponed F4E effort towards DEMO. Only in recent years, as several components have been completed, DEMO has started to gain greater attention.

**Figure 3232. Distribution of F4E-related publications across the Agency's three core missions**




Source: CSIL based on Lens.org. Note: Publications mentioning more than one F4E mission were fractionalised.

The citation analysis found that **F4E-related publications have been cited by a total of 15,770 other scholarly works**. On average, each publication in our scope has been cited 17 times, with one publication reaching up to 768 citations.[93] They have also been mentioned in patent documents, with each publication being cited by an average of two patents. The two tables below summarise the main statistics for citations by other scholarly works and patents.

**Table 20. Statistics on publications' citations by other scholarly works**

| MIN | MAX | AVERAGE | MEDIAN |
|---|---|---|---|
| 1 | 768 | 17 | 7 |

Source: CSIL based on Lens.org

**Table 21. Statistics on publications' citations by patents**

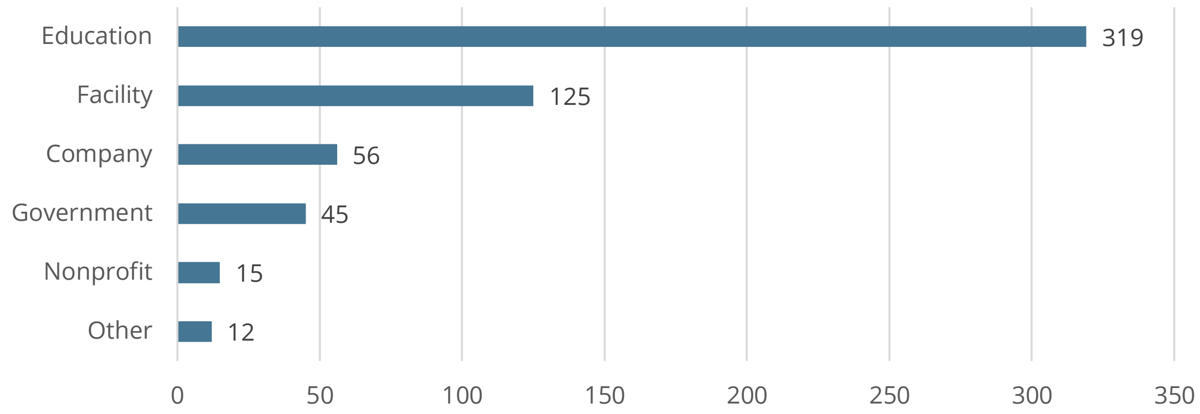
| MIN | MAX | AVERAGE | MEDIAN |
|---|---|---|---|
| 1 | 8 | 2 | 1 |

[93] The publication is the following one: Roth, J., Tsitrone, E., Loarte, A., Loarer, T., Counsell, G., Neu, R., ... & ITER PWI Team. (2009). Recent analysis of key plasma wall interactions issues for ITER. Journal of nuclear materials, 390, 1-9.

Source: CSIL based on Lens.org

Where affiliation names were reported, **we identified 570 unique entities that contributed to the F4E-related publications**. As shown in the figure below, these are mainly educational organisations such as universities or similar institutions (e.g., the German Karlsruhe Institute of Technology). They are followed by facilities such as laboratories (e.g., the LIP - Laboratory of Instrumentation and Experimental Particle Physics in Portugal), and companies (e.g., Ansaldo in Italy). Each affiliation contributed to an average of 8 publications, ranging from a single publication to almost 1 thousand.

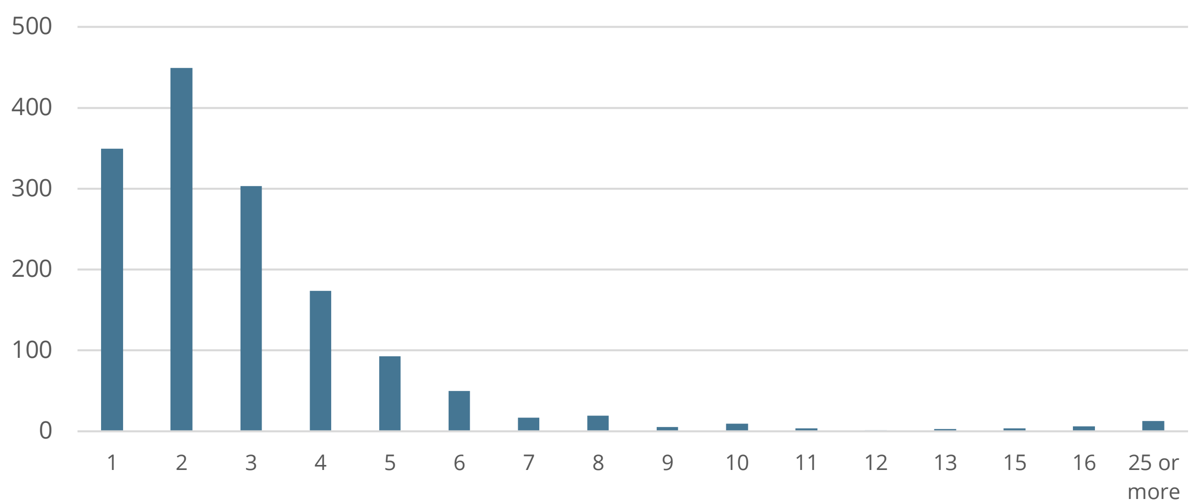
**Figure 3333. Distribution of affiliations of F4E-related publications by typology**




Source: CSIL based on Lens.org. Note: organisations were classified using ROR methodology (more details on the definition of the different types of organisations are available in the ROR metadata.

The network analysis revealed that these affiliations tend to collaborate with each other. As shown in the figure below, **77% of F4E-related publications, where affiliation names were reported, involve two or more affiliations**. More than 9% of publications include collaborations among over 5 affiliations. Only 23% involve a single affiliation.

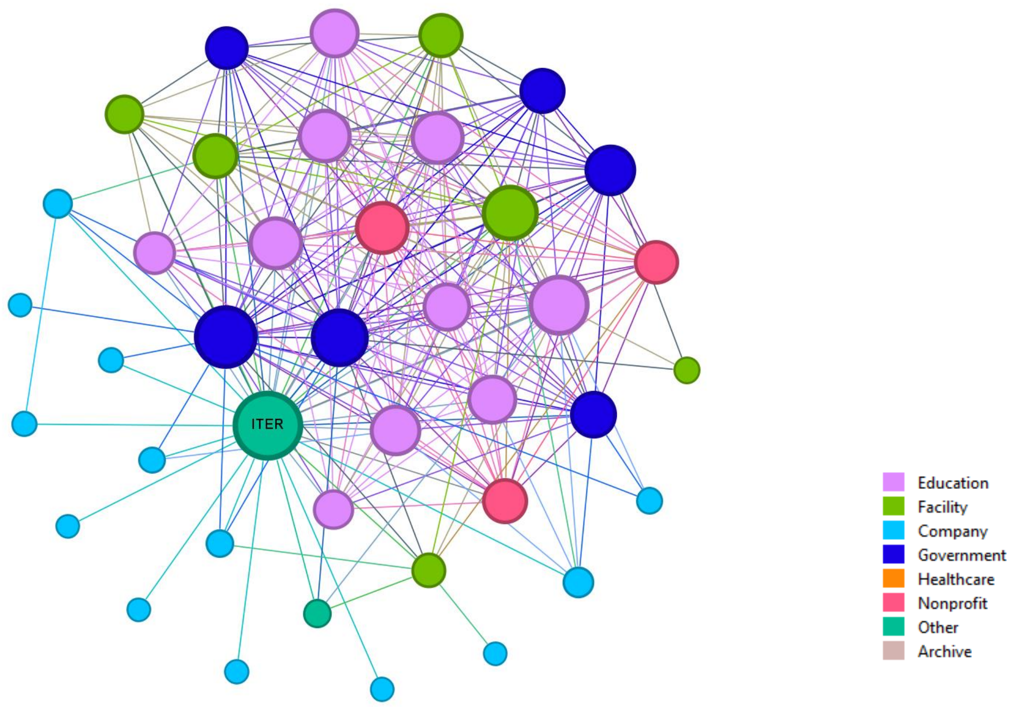
**Figure 3434. Distribution of publications by number of collaborations**




Source: CSIL based on Lens.org

The bibliometric analysis also indicates that **F4E suppliers that received payments during the period 2018-2024 authored 40 publications related to ITER, DEMO, and the Broader Approach**. These suppliers contributed to a total of 4,672 publications that are related to the ITER/DEMO/BA project, with the ITER Organisation (as supplier of F4E) accounting for the highest number (2,436). Interestingly, F4E suppliers tend to collaborate exclusively within their group, rather than with external entities. They have established a sort of 'closed' collaboration network, in which they are directly or indirectly connected, as illustrated in the figure below.

**Figure 3535. Network of collaboration involving F4E suppliers**




Note: Each circle represents a F4E supplier of an entity a F4E supplier co-published with. The size of the circles is proportional to the number of collaborations the entity established. The thickness of the line connecting the entities is proportional to the number of publications the two entities published together.

Source: CSIL based on Lens.org

## Patents analysis

F4E-related patents were identified as either patents that cite publications, that were either authored or funded by F4E, or patents filed by F4E suppliers that have an explicit reference to either F4E or its mandates (ITER/BA/DEMO). The retrieved patent data were then manually revised to ensure that only relevant data were included before proceeding with the data analysis.

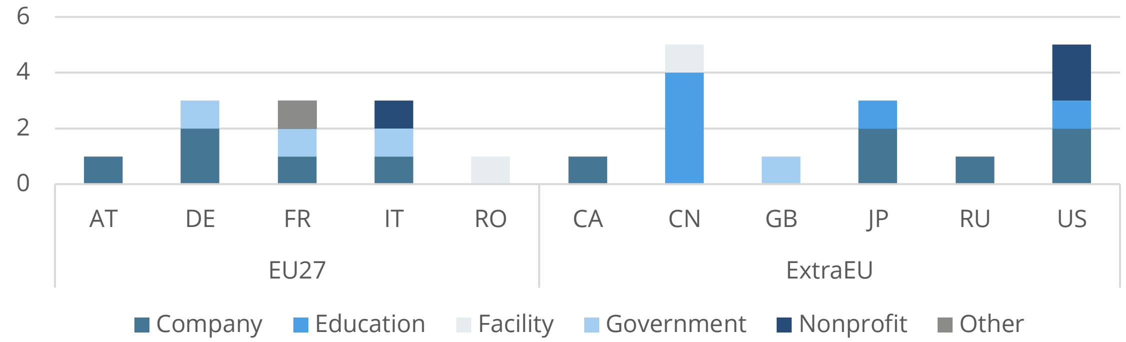
The figure below shows the breadth and multidisciplinary nature of technological domains influenced by F4E. The most prominent cluster appears within mechanical engineering, particularly in areas such as engines, pumps, and turbines, which aligns with ITER's core focus on plasma containment and thermal systems. Electrical engineering also features strongly, reflecting the complexity of power systems and electromagnetics intrinsic to fusion technologies. Other significant domains include materials, metallurgy, and environmental technology, critical for addressing challenges such as plasma-facing materials, neutron damage, and tritium breeding. Notably, areas like computer technology, optics, and measurement demonstrate the importance of digital systems and precision instrumentation, supporting control, monitoring, and simulation functions.

**Figure 3636. Distribution of patents across technological sectors and fields**


Source: CSIL based on Lens.org

**The identified patent families were filed by 27 distinct entities**, including companies (11), education institutions (6), governmental institutions (4), nonprofit organizations (3), facilities (2), and other (1). The analysis of where F4E-related patent applicants are located shows a diverse and international ecosystem. Whereas 11 entities are located in the EU and where responsible for 13 patents, 16 entities were located on an extra-EU country and filed the remaining 21 patents. Out of the 27 patent applicant entities, six entities also categorise as F4E suppliers. In most cases, patents were filed by a single entity (30; 88%) whereas the remaining 4 (12%) patents were filed by two distinct entities that collaborated together towards the invention.

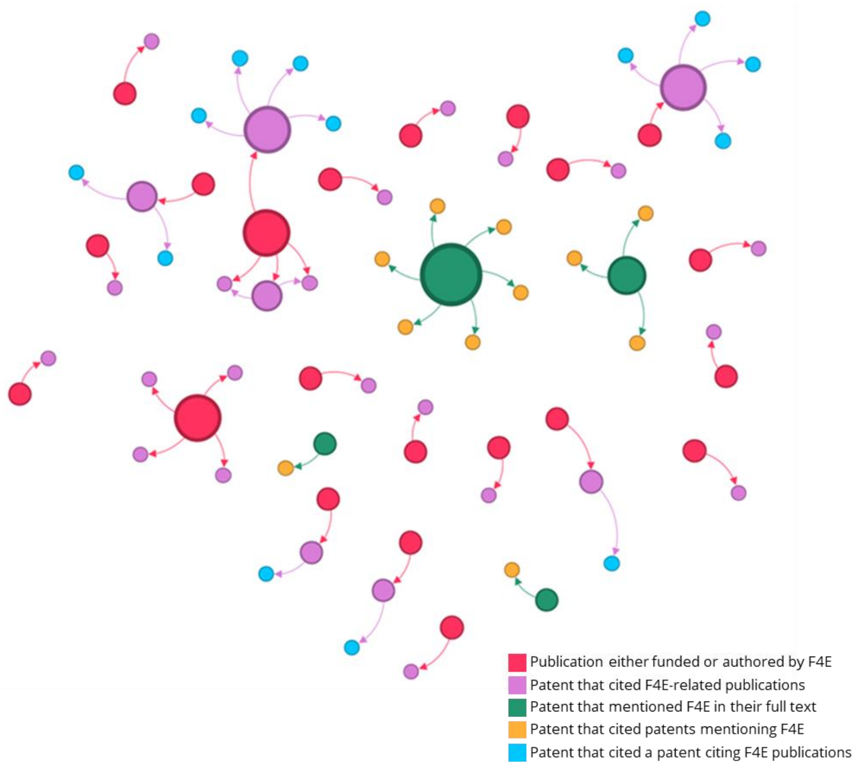
**Figure 3737. Distribution of patent applicants by country and type**




Source: CSIL based on Lens.org and RoR

The F4E-related patents generated additional knowledge which can be proxied by the citations they received. **Out of 34 patent families analysed in our sample, 11 (32.4%) were cited by at least one subsequent patent, for a total of 26 subsequent patent applications**. The number of citations each patent received ranges between 1 (5 patent families, 45.5%) and 6 (1 patent family, 0.86%). The most cited patent was first filed in 2011 by the Commissariat a L'energie Atomique Et Aux Energies Alternatives and relates to a nuclear fusion reactor first wall component. The figure below shows the resulting patent citation network.

**Figure 3838. Patent network citation**




Note: Each circle represents either a patent or a F4E publications. The size of the circles is proportional to the number of citations it received. The direction of the arrows shows the knowledge flow.

Source: CSIL based on Lens.org

# ANNEX 11. SWOT ANALYSES

## MAGNETS AND SUPERCONDUCTORS

### STRENGTHS

- Globally leading firms in the field: multiple EU firms acted as ITER suppliers (e.g., Bruker, ASG Superconductors, CNIM, Elytt Energy), others also active (Bilfinger).
- Start-ups pioneering HTS magnet designs (Gauss Fusion, Proxima Fusion, Renaissance Fusion)
- Strong industry-research partnerships.

### WEAKNESSES

- Project pipeline: Next major EU-funded device may not start before 2030, risking a business gap for EU firms.
- HTS wire/tape manufacturing: Limited EU firms (Theva)

### OPPORTUNITIES

- Multiple magnetic confinement-based devices being developed, especially by private fusion initiatives, will require advanced magnets and expertise – EU firms have the technology and highly credible experience via ITER.
- Quality of HTS tape/wire not yet high, opportunity for manufacturers who can achieve high volume, high quality production
- Magnets and superconductors have diverse applications beyond fusion, creating industrial opportunities in both public and private sectors.

### THREATS

- Global fusion startups: some of the start-ups e.g. CFS, Tokamak Energy, are pioneering HTS magnet technologies in competition to EU industry and have more funds to experiment (iterate, fail, learn)
- Lack of project pipeline: insufficient opportunities may lead to loss of staff and expertise in EU firms.
- Global competition: Other nations have developed expertise in manufacturing, e.g. China (Shanghai SCT), Japan (Faraday factory, Fujikura, Furukawa), US (Arnold, Canyon Magnet, MetOx [US DoE investing in HTS wire facility]).
- Rapid pace of innovation: in superconductors could lead to breakthroughs elsewhere.
- Material access: Critical raw materials for superconducting tape may be limited in the EU, posing a supply risk.

## VACUUM VESSEL

### STRENGTHS

- Globally leading firms in the field: multiple EU firms acted as ITER suppliers for 5 sectors (e.g., Walter Tosto, Ansaldo, Mangiorotti).
- EU firm secured contracts for vacuum vessel with start-ups (Walter Tosto for CFS)
- Strong industry expertise, also taking advantage of related engineering and welding services, and with applications in other sectors (fission, oil & gas)

### WEAKNESSES

- Project pipeline: Next major EU-funded device may not start before 2030, risking a business gap for EU firms.

### OPPORTUNITIES

- Magnetic confinement-based devices being developed, especially by private fusion initiatives, will require vacuum vessels – EU firms have the technology and highly credible experience via ITER.
- Issue with thermal shielding of Korean sectors provides opportunity for EU industry to establish lead.
- Potential applications in other sectors of advanced containment devices and engineering.

### THREATS

- Lack of project pipeline: insufficient opportunities may lead to loss of staff and expertise in EU firms.
- Global competition: Korea (Hyundai) supplied 4 of the 9 vacuum vessel sectors for ITER. Russia and India also contribute. US firm (Westinghouse) gaining expertise through EU branch (Mangiorotti) and ITER IO contract. Also UK (Lti Metaltech) and China (Opaque, but capable and cheap). Provides credible experience and competition.
- Magnetic confinement start-ups more focused on Stellarators – different manufacturing challenges.

## HEATING SYSTEMS (Cyclotrons, Gyrotrons, Neutral Beam systems)

### STRENGTHS

- Globally leading firms as ITER suppliers:
  - Cyclotrons - Gyrotrons (Thales – also supplying DTT; Ampegon, Siemens both provide components)
  - Neutral Beam (AVS-Tecnalia, Siemens, NIDEC ASI as supplers to MITICA and SPIDER)
- Strong industry -research partnerships ( e.g Thales with Swiss Plasma Centre, Ecole Polytechnique Federale de Laussane, KIT; AVSTechnalia ).

### WEAKNESSES

- Project pipeline: Next major EU-funded device may not start before 2030, risking a business gap for EU firms.
- Cyclotrons - Gyrotrons: only 1 EU manufacturer, other main firms in US and Asia (Japan, Russia, India– all also supply ITER).

### OPPORTUNITIES

- Multiple fusion devices being developed, especially by private fusion initiatives, will require heating systems – EU firms have sufficient technology and highly credible experience via ITER.
- Opportunities for some systems in other sectors, i.e. drilling for deep geothermal; materials processing; remote imaging, sensing and communication, and more.

### THREATS

- Lack of project pipeline: insufficient opportunities may lead to loss of staff and expertise in EU firms.
- Global competition: (cyclotrons -gyrotrons) EU firms are competitive but competition is high – leading firms and institutes in Japan (Toshiba, QST, Uni of Tsukuba, Kyoto Fusioneering, Sumitomo, Canon), Russia (GYCOM) and US (CPI, GE); (neutral beam) EU firms amongst leaders, also competitors in Japan (Hitachi, SPP Technologies), Russia (Budker Institute), India and US (Lockheed Martin).

## CRYOPLANT

### STRENGTHS

- Globally leading firms acted as ITER suppliers (e.g., Air Liquide, Research Instruments, Alsymex, GTD), others also active in sector (Linde, Fives, Atlas Copco).
- Air Liquide a leading supplier to multiple fusion devices

### WEAKNESSES

- Project pipeline: Next major EU-funded device may not start before 2030, risking a business gap for EU firms.

### OPPORTUNITIES

- Almost all fusion devices will require cooling systems – EU firms have the technology and credible experience via ITER.
- Cryosystems have already well established applications in other sectors (Gas LNG, chemicals) and potential growth in cooling demand for data centres or energy storage, also other applications.

### THREATS

- Lack of project pipeline: insufficient opportunities may lead to loss of staff and expertise in EU firms.
- Global competition: India also provided large part of cryoplant , i.e. cryostat (L&T Heavy Engineering, INOX); leading firms also in US (Air Products and Chemicals, Chart industries, Parker Hannifin, Flowserve) and Japan (Nikkiso, EBARA, SHI Cryogenics).

## BLANKETS, TRITIUM HANDLING, DIVERTORS, WALL

### STRENGTHS

- Europe has a leading share in ITER systems.
- Globally leading firms in the field: multiple EU firms acting as ITER suppliers (e.g., Walter Tosto [divertor cassettes], Alsymex, Research Instruments, Saarschmeide), many others also active.
- Strong industry-research partnerships – and research strength in TBM (EUROfusion, KIT), materials (FZJ, DIFFER), Tritium fuel-cycle (KIT, CEA, IPP, ENEA)

### WEAKNESSES

- Project pipeline: Next major EU-funded device may not start before 2030, risking a business gap for EU firms.
- Longer timeline for application of these technologies (e.g. TBM)

### OPPORTUNITIES

- Multiple fusion devices being developed, many will require these technologies – EU firms can establish technology and credibility through ITER.
- Tritium fuel cycle still in infancy – opportunity to establish lead in blankets and handling.
- Materials developed for these technologies can have multiple applications in other sectors with harsh environments, e.g. space, maritime, fission, industry.

### THREATS

- Global competition: researchers and firms in the US, China (CRAFT), UK (Oxford Sigma, UKAEA).
- Tritium and blanket technologies have more limited applications outside fusion.
- Material access: Limited tritium supplies (primarily in Canada) and Lithium isotope used in blankets is also relatively rare, either could hinder market development.
- Non-tritium fusion: some of the start-ups e.g. Helion, TAE, are pioneering fusion technologies that do not use Tritium as a fuel and would not need some of these technologies – however, many evaluate these technologies as 'long-shots', i.e. the actual threat is likely small.

## REMOTE HANDLING AND DIAGNOSTICS

### STRENGTHS

- EU has a leading role in remote handling at ITER, and significant role in diagnostics with multiple EU firms supplying ITER (e.g., IDOM, Alsymex, AVS, GTD, Ariane Group, CNIM, Assystem, Bertin Technologies, Reel, Latesys, many more), others also more broadly have expertise (e.g. KUKA and ABB in remote handling, Bruker in diagnostics).
- Strong industry-research partnerships (e.g. VTT for remote handling, Consorzio RFX, DIFFER Gauss Fusion).

### WEAKNESSES

- Project pipeline: Next major EU-funded device may not start before 2030, risking a business gap for EU firms.

### OPPORTUNITIES

- Applications across fusion, regardless of approach – EU firms have relevant technology and are gaining highly credible experience via ITER.
- Diverse applications beyond fusion (e.g. for nuclear fission, space, hazardous industrial environments and processes, deep sea, healthcare), creating industrial opportunities in both public and private sectors.

### THREATS

- Global competition: Strong expertise in the US (Oak Ridge NL, Princeton PPL, LLNL, Jacobs, General Atomics, Thermo Fisher Scientific), UK (e.g. via UKAEA – RACE, Hyde Group, Capula, Oxford Instruments), Russia and Japan
- Specialisation of advanced, niche technologies, some with wider application technologies: competition is wide, many firms have niche or general capabilities.

## SERVICES (Design, Engineering, Safety, Waste)

### STRENGTHS

- Globally leading firms in the field: multiple EU firms are ITER suppliers (e.g., Assystem, Simic, Thales, IDOM, De Pretto, Alsymex, Bertin Technologies, Tecnalia, Ansaldo), others also active or have capabilities (Framatome).
- EU firms involved in multiple projects in fusion, including in the UK and US.
- Longer timeline for provision of services to ITER, lower risk of project pipeline gaps.

### WEAKNESSES

- Scale: EU firms may not bring scale that US and other global competitor firms are able to bring.

### OPPORTUNITIES

- All fusion devices will require design and engineering services, wide market – EU firms have highly credible experience via ITER.
- Opportunities remain at ITER for EU firms, i.e. Hot Cell facility, eventual decommissioning.
- EU is fully responsible for safety and waste at ITER, providing opportunity to gain unique experience.
- Harnessing AI effectively could give EU firms an edge – equally a threat if others manage to do so first, e.g. Enable Fusion (Korea)
- Cross-over to other sectors which require similar services (fission, aerospace, space, offshore, energy)

### THREATS

- Global competition: Leading design and engineering services firms are also well established in other leading nations especially US (GA, Westinghouse, Ansys, Jacobs) and UK (AtkinsRealis, Frazer-Nash).
- Geography: Firms tend to select services firms in own countries, making it more difficult for EU firms to access global markets – unless using subsidiary offices. Markets in US (private) and China (state-funded) are largest.
- Start-ups can choose to bring large parts of the design work in-house: reduced opportunities for EU firms.

## CONSTRUCTION, BUILDINGS & POWER SUPPLY INFRASTRUCTURE

### STRENGTHS

- Leading firms in the field: multiple EU firms acted as ITER suppliers (e.g. Ferrovial, Dalkia, Vinci Construction, Axima Concept, Campenon Bernard Sud), many others also have relevant capabilities.
- EU delivered all main buildings and construction at ITER, also significant contribution to power supply infrastructure

### WEAKNESSES

- Project pipeline: Next major EU-funded device may not start before 2030, risking a business gap for EU firms.

### OPPORTUNITIES

- Multiple fusion devices and facilities being developed, globally – EU firms have highly credible experience via ITER
- EU firms are part of or leading consortia for UK STEP construction.

### THREATS

- Lack of project pipeline: insufficient opportunities may lead to loss of staff and expertise in EU firms.
- Geography: Governments and firms tend to select construction and infrastructure firms in own countries.
- Generic nature / mature technologies: for buildings and power supply infrastructure, mean competition is high and it is difficult for exporting firms to compete.