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D2.08 Sustainable Governance of the Federation

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Abstract	This deliverable describes the work to date regarding Fed4FIRE+'s sustainability. The approach is founded upon a set of key principles, which are described below. ***The federation should operate as a public good for the benefit of the European research and innovation community.*** ***Sustainability comes from funding and funding comes from demonstration of value.*** ***Public funding is needed for Fed4FIRE+.*** Public funding is needed and is actively being pursued in the form of RI funding, where the target of ESFRI has been identified and is pursued via a scoping design study. ***Evidence is required to build a case for funding.*** In this deliverable, this has taken the form of analysis of user types, user feedback and testbed status. The overall conclusion is that Fed4FIRE+ provides genuine, unique value to experimenters, where the highest valued aspects are that Fed4FIRE+ provides a real environment for testing, the support provided by testbeds, the tools that enable easy setup of experiments, access to resources they cannot access otherwise.
Keywords	Sustainability, Public Good, Funding Sources, Evidence to Support Cases for Funding.

Nature of the deliverable	R	Report	X
	P	Prototype	
	D	Demonstrator	
	O	Other	
Dissemination level	PU	Public	X
	PP	Restricted to other programme participants (including the Commission)	
	RE	Restricted to a group specified by the consortium (including the Commission)	
	CO	Confidential, only for members of the consortium (including the Commission)	

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Executive Summary

This deliverable describes the work to date regarding Fed4FIRE+'s sustainability and governance. It concentrates on sustainability as the project's governance is well established after the Federation Board was set up as described in D2.3.

The approach is founded upon a set of key principles, which are described below.

Principle 1: Sustainability comes from funding and funding comes from demonstration of value. Whatever the funding source (e.g. public funding or paying customers), clear value to the users or the wider community needs to be demonstrated in order to justify that funding.

Principle 2: The federation should operate as a public good for the benefit of the European research and innovation community. To benefit the maximum possible users by lowering barriers of cost, Fed4FIRE+ should operate as a public good, free at the point of access, rather than restricted to those with the ability to pay for them.

Principle 3: Public funding is needed for Fed4FIRE+. Public funding is necessary to support Principle 2, operation as a public good. Hence the pursuit of public funding is a key objective of the Fed4FIRE+ sustainability. Commercial operation may be investigated as a sustainability option but any commercialisation should not compromise the effectiveness of Fed4FIRE+ as a public good.

Principle 4: Evidence is required to build a case for funding. A key objective of the sustainability work in Fed4FIRE+ to gather evidence so as to build a case for continuation and operational funding, demonstrating value:

- of the testbeds and the Federator to experimenters (e.g. the testbeds are useful and the Federator makes it quick and easy to access the testbeds); and
- of the Federator to the testbeds (e.g. the Federator brings users to the testbeds).

With these principles in mind, the key conclusions of this deliverable are as follows.

- The Federation should be provided as a public good rather than being run for commercial profit. For this, public funding is needed and is actively being pursued in the form of RI funding, where the target of ESFRI has been identified and is pursued via a scoping design study. Commercial operation may be pursued but must not conflict or compromise Fed4FIRE+ operating as a public good. Currently the focus is on public funding rather than commercial funding.
- For public funding, evidence is required to support the case for the award of funding. There is therefore a key requirement to build an evidence base. In this deliverable, this has taken the form of analysis of user types, user feedback and testbed status. The overall conclusion is that Fed4FIRE+ provides genuine, unique value to experimenters, where the highest valued aspects are that Fed4FIRE+ provides a real environment for testing, the support provided by testbeds, the tools that enable easy setup of experiments, access to resources they cannot access otherwise. The evidence base will evolve and grow as further experiments take place and additional feedback is gathered, so it is a major item of further work to continue analysis of the experimenter feedback. The evidence base will be used to support cases for continuation funding, such as the ESFRI application discussed above.
- To contribute to the evidence base, Fed4FIRE+'s Open Access programme needs to be promoted. Open Access is the acid test of the federation: here, experimenters are not paid but come because they see value in the resources, tools and support offered by Fed4FIRE+. If Fed4FIRE+ can attract significant numbers of Open Access

experimenters, this is convincing evidence of its value and therefore will support a case for continuation funding.

- To promote the federation, (especially Open Access), Fed4FIRE+ should enhance communication and dissemination to existing and new user groups with the intention of recruiting more users. It is recommended that a marketing / outreach manager be appointed to coordinate this.

Overall, the work reported in this deliverable contributes to the sustainability objective of Fed4FIRE+ as a public good as described in the following figure.

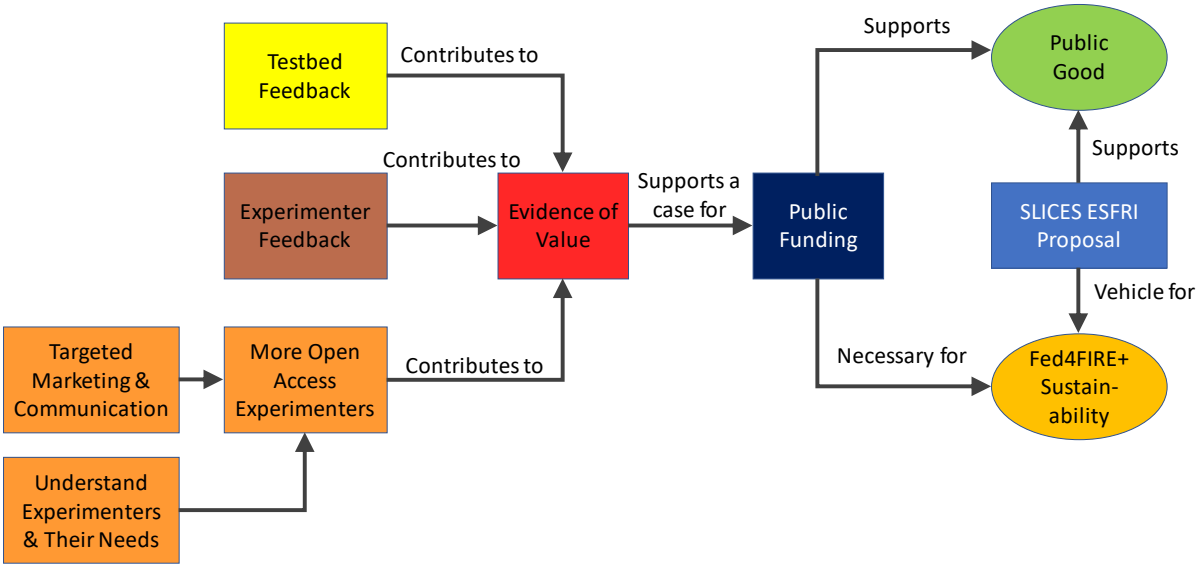


Table of Contents

1 Introduction - Approach to Sustainability

This deliverable describes the work to date regarding Fed4FIRE+'s sustainability and governance. It concentrates on sustainability as the project's governance is well established after the Federation Board was set up as described in D2.3.

This section describes the approach to sustainability evolved during the time from the previous sustainability report, D2.3. The approach has been developed within the Federation Board and at the wider project level in the Federation Engineering Conferences.

The approach is founded upon a set of key principles, which are described below.

Principle 1: Sustainability comes from funding and funding comes from demonstration of value. Whatever the funding source (e.g. public funding or paying customers), clear value to the users or the wider community needs to be demonstrated in order to justify that funding.

Principle 2: The federation should operate as a public good for the benefit of the European research and innovation community. To benefit the maximum possible users by lowering barriers of cost, Fed4FIRE+ should operate as a public good, free at the point of access, rather than restricted to those with the ability to pay for them.

Principle 3: Public funding is needed for Fed4FIRE+. Public funding is necessary to support Principle 2, operation as a public good. In addition, the original Fed4FIRE project, the clear conclusion was drawn that public funding was by far the most viable source of funding, compared to commercial operation[1]. Hence the pursuit of public funding is a key objective of the Fed4FIRE+ sustainability. Commercial operation may be investigated as a sustainability option but any commercialisation should not compromise the effectiveness of Fed4FIRE+ as a public good.

Principle 4: Evidence is required to build a case for funding. A key objective of the sustainability work in Fed4FIRE+ to gather evidence so as to build a case for continuation and operational funding, demonstrating value:

- of the testbeds and the Federator to experimenters (e.g. the testbeds are useful and the Federator makes it quick and easy to access the testbeds); and
- of the Federator to the testbeds (e.g. the Federator brings users to the testbeds).

As a result of the principles above, a key focus of this deliverable is on constructing an evidence base of the federation's utility. Section 3 considers the evidence question in terms of Fed4FIRE+'s value to experimenters via a thematic analysis of the feedback given in the experiment reports that all open call experimenters have to create upon completion of their experiment. Here, we consider the testbeds and the Federator together, as they are a package offered to experimenters. In addition, we have analysed the value of the Federator to testbeds. This evidence will be used to support cases for funding.

A key focus of sustainability is to identify and pursue opportunities for continuation funding, which will be naturally supported by the evidence base. One such opportunity has been identified, and its pursuit is discussed in Section 4. It is a standing objective of the sustainability work to remain observant, open to and to actively pursue, additional public funding opportunities.

[1] Van Ooteghem, Taylor, Vermeulen, Wauters, Demeester, Ahtes, Smirnov, Sawyer, 2015. Fed4FIRE D2.12 – Third Sustainability Plan. Zenodo. doi:10.5281/zenodo.1323478

To support the above objectives, a number of recommended action plans have been determined through discussion within the Federation Board and the wider project. These are discussed in Section 5. These are diverse in nature, and some are more advanced than others, but all contribute to the overall goal of achieving sustainability.

The Federation Board as the governance mechanism for Fed4FIRE+, and its status is discussed in Section 2. The Federation Board is by now well-established and runs smoothly, so discussion of its status does not warrant much space in this deliverable, whose deliberate focus is on the work towards Fed4FIRE+'s sustainability.

2 Federation Board

The Federation Board is by now well-established. The Board meets face to face at every Federation Engineering Conference / project meeting. There are teleconferences in between the face to face meetings.

The Board has established a standardised agenda for its meetings when discussing the steering of the Federation:

- Usage of the federation
- Subject matter and organisation of the Fed4FIRE+ Engineering Conferences
- Sustainability
- Dissemination and communication
- Project budget and its distribution

The discussions and decisions of the Board are not public, so cannot be included in a public deliverable, but the decisions regarding sustainability are incorporated into this deliverable in a form that may be made public.

The board membership has changed slightly since the previous deliverable. The notable changes are as follows.

- Peter Van Daele from IMEC has joined the Federation Board as of April 2019. As Fed4FIRE+'s project manager, Peter is a critical point of contact between the decision-making of the Board and the executive part of the project.
- Alexander Willner has resigned from the Board due to overload from other work commitments.
- Lucas Nussbaum from INRIA (operators of Grid'5000) has joined the Board as of October 2019 in replacement of Alexander Willner.

3 Sustainability Evidence

This section aims to provide evidence to support the claim that the federation is useful to both experimenters and testbeds. Firstly the experimenters are profiled to determine the types of user that comes to Fed4FIRE+. Secondly, the experimenter feedback provided in each open call experiment report is analysed to determine the overall value and satisfaction of the experimenters with Fed4FIRE+. Finally, the Testbeds are surveyed to determine their workload and the proportion coming via Fed4FIRE+.

3.1 Open Call Experimenters Profiling

From the beginning of the project, six open calls for experiments have been announced and funded the winners of each one. Additionally, a continuous call for SMEs is running with two submission dates every month started on November 2018. In total, 195 proposals have been submitted and 76 experiments were granted, while 119 proposal were either not eligible or eligible but not funded. The Open Call 2 and the SME call have two-stages and some of the experiments of these calls got funding for both stages.

The experimenters and proposers come from academia, SMEs and industry. Please note that within the context of this report, academia includes researchers from both universities and research institutes. The classification of companies to SME and industry is based on their public profile on Internet. Based on the proposer's profile, the submissions can be further divided into (a) 127 proposals by SMEs, (b) 59 proposal by academia and (c) 9 proposals by industry. These proposals were submitted by 116 different organizations, which are further divided by (a) 68 SMEs, (b) 41 academic institutes and (c) 7 industries, as it is shown in Figure **1**.

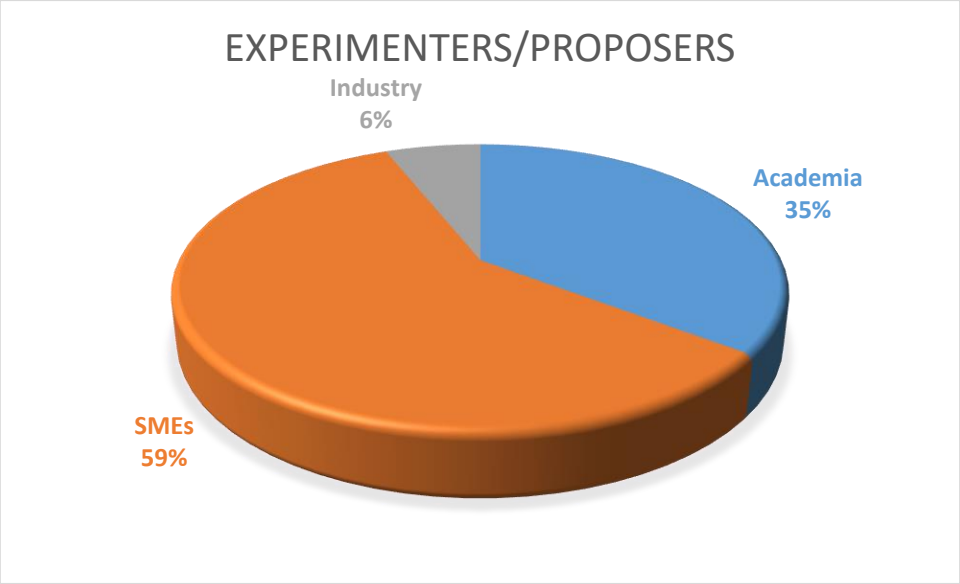
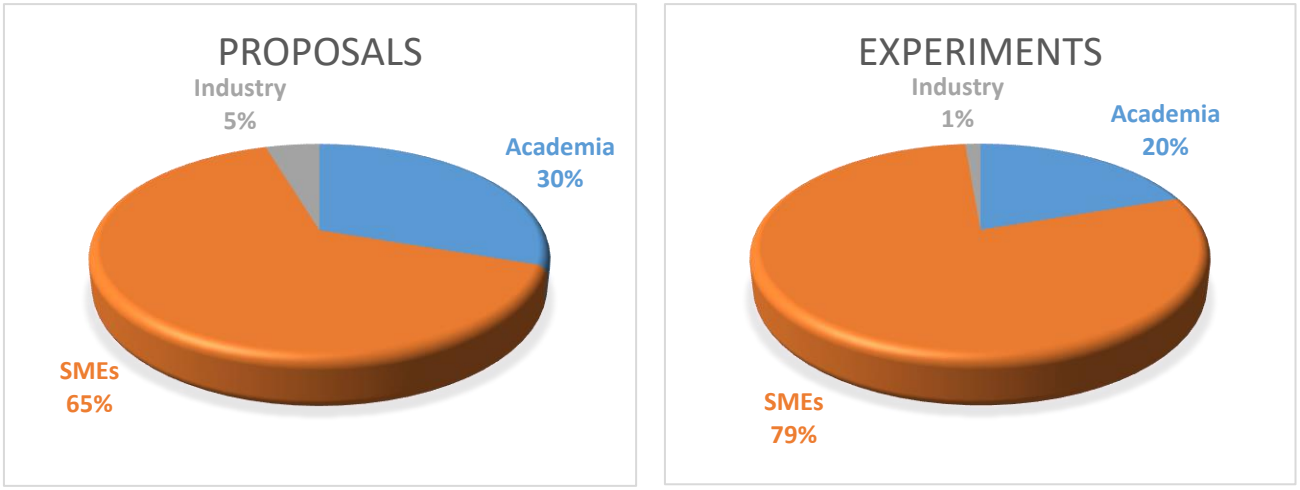


Figure 1 **– Profile of the Proposers**

Figure 2 (a and b) shows the percentage of the submitted and accepted proposals respectively for every category of the experimenters/proposers.



(a) Submitted Proposals (b) Accepted Proposals

Figure 2 – Profile of the Proposers

From the above two graphs, two useful remarks can be drawn; (a) 2/3 of proposals (65%) submitted by SMEs and (b) almost 80% of the experimenters are SMEs. Also, the academic institutes are interested in utilizing the federated testbeds and 20% of the experimenters comes from these institutes. The industrial candidates present a significant lower portion, thus, the proposal and experiments by industry are limited.

In the following, we highlight the profile of the current experimenters and the proposers, who are already interested in the federated facilities. Beyond the profiling of the current users, we aim to draw the profile of possible interested research communities, who can benefit from Fed4FIREplus infrastructure in the near future, which is envisioned critical component for the sustainability of the federation, with the aim of enabling targeted communication to recruit users.

Profile of SMEs

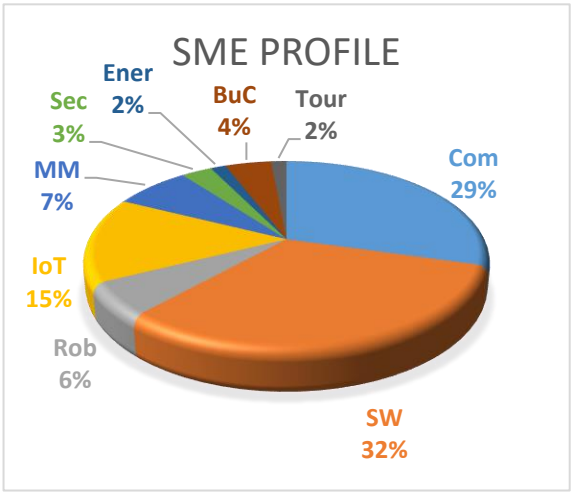
Until October 2019, 68 different SMEs submitted 127 proposal and 60 of them were funded. Most of these SMEs are active in the broad field of ICT, focusing on telecommunications, computer networks and software engineering/development. In our analysis, we further divide the profile of the SMEs in the following categories:

- Communications (Com)
- Software (SW)
- Robotics (Rob)
- Internet of Things (IoT)
- Multimedia (MM)
- Security (Sec)
- Energy (Ener)
- Business Consulting (BuC)
- Tourism (Tour)

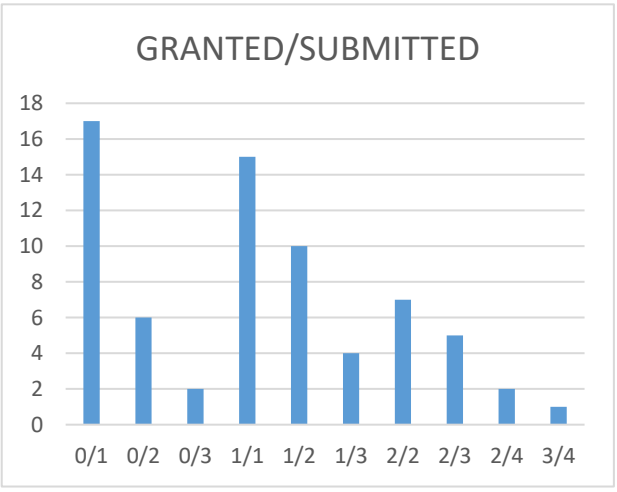
The classification is based on available public information and the analysis of the objectives of their proposal or experiment. Since several SMEs are active on more than one of the above

categories, the dominant classification criterion was the objective of the corresponding proposal/ experiment.

Figure 3a shows the outcome of such a classification of the SMEs involved in the experimentation and open call process of our project. As expected, SMEs with expertise on communications and software are mostly interested in utilizing the federated testbeds. In the next place are the SMEs focusing on IoT-related experiments, owing to the fact that the federation provides several wireless and cloud testbeds that can be combined to execute such kind of experiments. Subsequently, 16% of the SMEs are interested in experiments on multi-media, robotics and security, which are research problems firmly connected with computer networking era. At the end, 8% of the SMEs are active on fields of Energy, Business Consulting and Tourism, which are emerging use cases allowing for the development of appealing application with direct societal impact.



(a) Profile of SMEs



(b) Ratio of experiments and proposals

Figure 3 – Profile of SMEs and Proposal Success Ratio

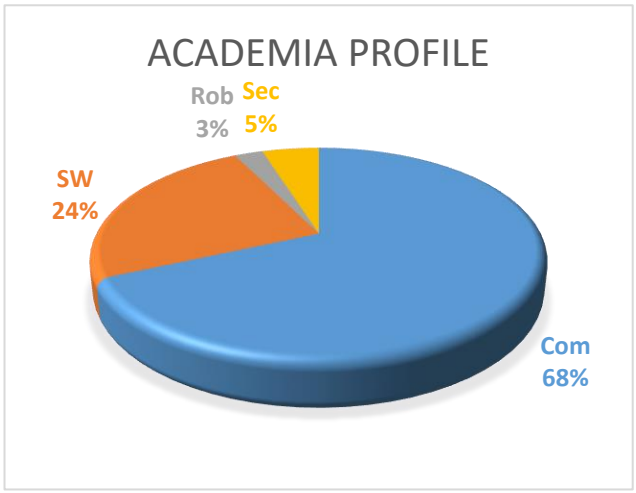
Figure 3b provides information about how many proposals are submitted by the SMEs and what is the corresponding success ratio of them. On average, the success ratio is 47.2%. Most of the SMEs (approximately 75%) submitted more than one proposal. The SMEs with two or more funded experiments submit their proposal either on two-stage calls or both open and SME calls. We remind that SMEs that successfully submitted a proposal on an open call are not prohibited to submit proposals on the SME call as well. The only restriction on continuous SME call is that an unsuccessful proposal cannot be resubmitted within a six-month period. From the above analysis, two useful conclusions are verified and drawn; (a) most of the attracted SMEs are active on core ICT fields and (b) the multiple submissions for the majority of SMEs indicates strong interests on the federated facilities and funding.

Profile of Academic Institutes

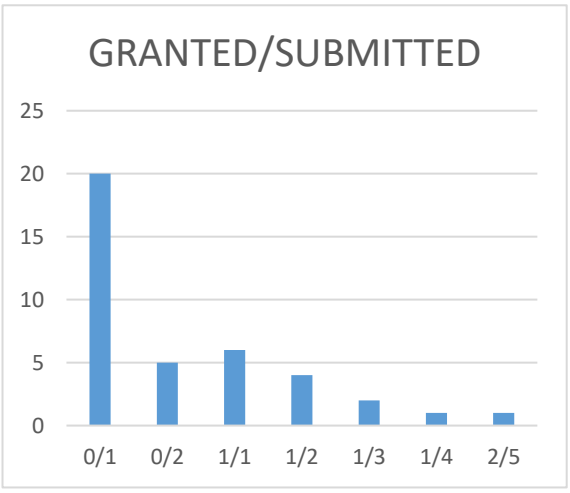
Academic researchers are the second largest group of interested people in experimenting over Fed4FIREplus facilities. From the beginning of the project, 41 different organisations submitted 59 proposal and 15 of them were funded. The profile of these academic institutes includes the following research areas,

- Communications (Com)
- Software (SW)
- Robotics (Rob)
- Security (Sec)

The classification is based on available public information and the objectives of their proposal or experiment. We have to mention that the research institutes consist of various research units and some proposals are submitted by different research groups of the same institute. Similarly, some proposals are submitted by different researchers or units/labs of the same university. The submitted proposals by an academic institute can be classified in more than one of the above categories. In that case, we classify the profile of the organisation based on the common category among the proposals.



(a) Profile of Academic Institutes



(b) Ratio of experiments and proposals

Figure 4 - Profile of Academic Institutes and Proposal Success Ratio

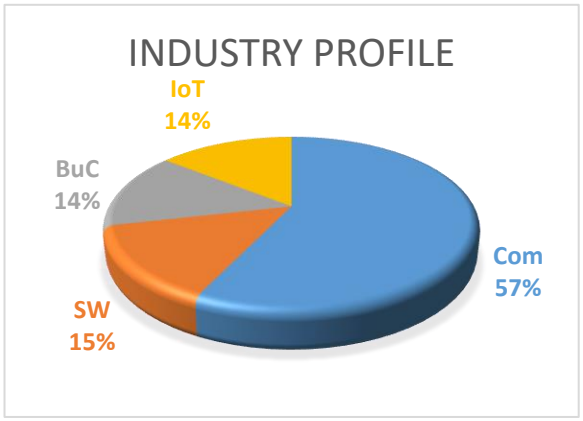
As shown in Figure 4a, communications and computer networks are the main research interests of the academic institutes that submitted at least one proposal. With descending order of interest, software, security and robotics follow. Figure 4b demonstrates the frequency of submissions by the academic institutes and their success ratio. From the above analysis, two useful remarks can be obtained; (a) most of the academic research submitted at most one or two proposals and (b) their success ratio is quite lower than the one of SMEs. Finally, it is observed that the researchers do not typically resubmit a proposal if it is not funded upon first submission.

Profile of Industries

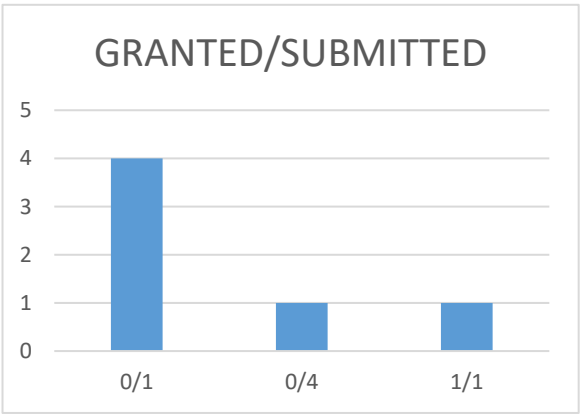
The submissions by large companies or industries correspond to less than 10% of the total amount of proposals. In particular, 9 proposals were submitted by 7 industries and only one is accepted. The profile of the industrial proposers can be divided in the following categories,

- Communications (Com)
- Software (SW)
- Internet of Things (IoT)
- Business Consulting (BuC)

This classification is based on available public information and the objectives of their proposal or experiment.



(a) Profile of Industries



(b) Ratio of experiments and proposals

Figure 5 - Profile of Industries and Proposal Success Ratio

As it is shown on Figure 5a, telecommunications era is the most common research interest among the industries. Figure 5b shows the frequency and the success ratio of the submitted proposals. Unfortunately, the proposals from industry are limited and do not allow to sketch an objective profile of the interested proposers.

3.2 Analysis of Experimenter Feedback

This section provides analysis of the experimenters' feedback from the experiment reports that each experiment has to create at the end of their experiment. To date, there have been 46 experiments completed within Fed4FIRE+, and this section summarises the feedback from the experimenters.

There are approximately 40 feedback questions in the experiment report template, but many of these are not relevant to the question of the value of the federation to experimenters (e.g. they concern technical feedback on testbed resources or suggestions for improvement), so this analysis has focused on the questions that directly indicate the federation's value. The relevant questions are described in the table below.

Section	*Feedback Question*
B.3.1 Value perceived	**What was the direct or indirect value for your company / institution?** What is the time frame this value could be incorporated within your current product(s) range or technical solution? Could you apply your results also to other scenarios, products, industries?
B.3.1 Value perceived	**If no federation of testbed infrastructure would be available, how would this have affected your product / solution?** What would have been the value of your product / solution if the experiment was not executed within Fed4FIRE? What problems could have occurred?
B.3.2 Funding	Would you (have) execute(d) the experiment **without receiving any external funding?**
B.3.2 Funding	**Would you even consider to pay for running such an experiment?** If so, what do you see as most valuable component(s) to pay for (resources, support, …)?
C.2.3 Fed4FIRE portfolio	**Was the current portfolio of testbeds** provided by the federation, with access to a large set of different technologies (sensors, computing, network, etc.) provided by a large amount of testbeds, **sufficient to run your experiment?**
C.2.3 Fed4FIRE portfolio	**Was the technical offering in line with the expectations?** What were the positive and negative aspects? Which requirements could not be fulfilled?
C.2.5 Experiment environment	Did you experience that the Fed4FIRE environment is unique for experimentation and goes beyond the lab environment and enables real world implementation?
C.3.1 Execution of the experiment	**Why did you choose Fed4FIRE for your experiment?** Was it the availability of budget, easy procedure, possibility to combine different (geographically spread) facilities, access to resources that otherwise would not be affordable, availability of tools, etc.? Please specify in detail
C.3.1 Execution of the experiment	Could you have conducted the experiment at a commercially available testbed infrastructure?
C.3.2 Added value of Fed4FIRE	**Which components did you see as highly valuable for the federation** (e.g. combining infrastructures, diversity of available resources, tools offered, support and documentation, easy setup of experiments, etc.)? Please rank them in order of importance.
C.3.2 Added value of Fed4FIRE	Which of these tools and components should the federation at least offer to allow experimentation without funding?

The responses experimenters gave in the experiment reports for each question are all textual, and they have been analysed using thematic analysis techniques, whereby common themes and sentiments were identified and collated for each question. The themes were not *a priori* determined: they emerged from the thematic analysis of the textual responses.

Results are discussed per question. The results are presented as pie charts, where the segments show the number of experiment reports ("respondents"[2]) who gave the same or similar responses (e.g. in Figure 6, *"Stability Testing, 7"* indicates that 7 respondents indicated that they used Fed4FIRE+ for stability testing). In some cases, an experiment report gave responses that corresponded to more than one of the identified themes or sentiments, and all of these responses are counted in the collation, so the totals may be more than the actual number of experiments in some cases.

3.2.1 Perceived value of Fed4FIRE+

The first question concerned the value as seen by the experimenters of Fed4FIRE+.

B.3.1 Value perceived	**What was the direct or indirect value for your company / institution?** What is the time frame this value could be incorporated within your current product(s) range or technical solution? Could you apply your results also to other scenarios, products, industries?

The responses to this question fall broadly into two categories: benefits to the experimenter of doing the experiment, and the value of different aspects of Fed4FIRE+.

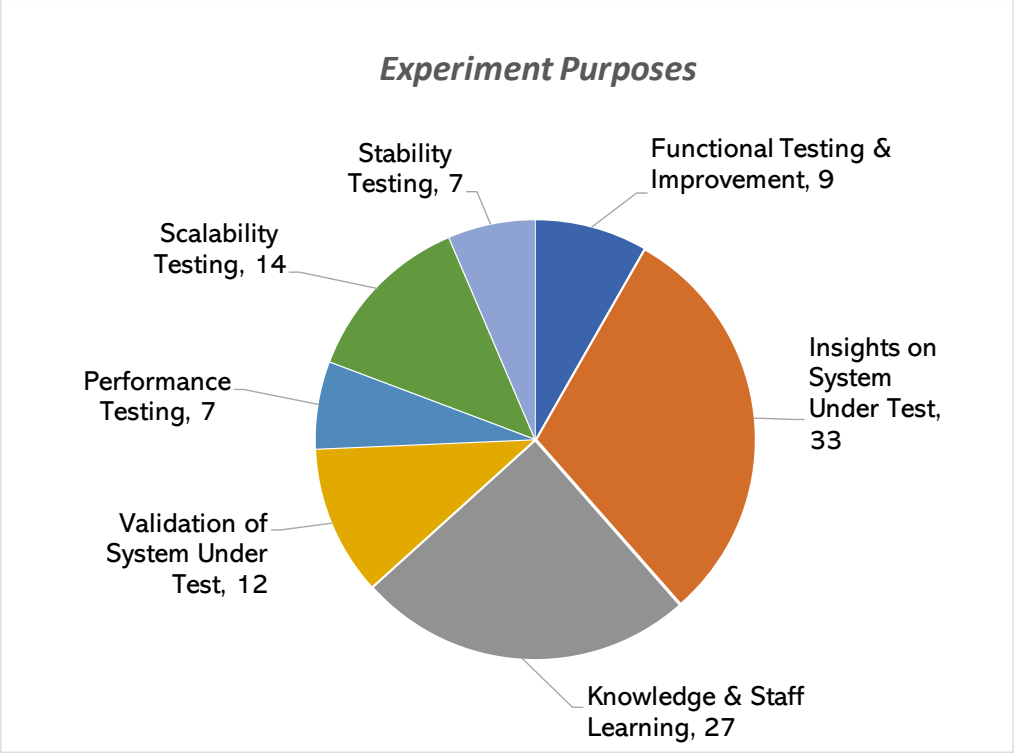


Figure 6: Experiment Benefits

[2] Each experiment report is a write up of one experiment, by its experimenters, and therefore an experiment report is considered as a single respondent in this analysis.

Figure 6 shows the distribution of the benefits to the experimenters as a result of the experiment. The benefits fall into two categories: institutional knowledge gained and staff learning (grey, with 27 respondents) and different types of understanding of the system under test, e.g. insights, performance testing, stability testing, scalability testing, validation and functional testing (represented by all other colours). This distinction is clearly to be expected, since experiments are primarily either testing an idea or a product, or an investigation with the objective to gain knowledge.

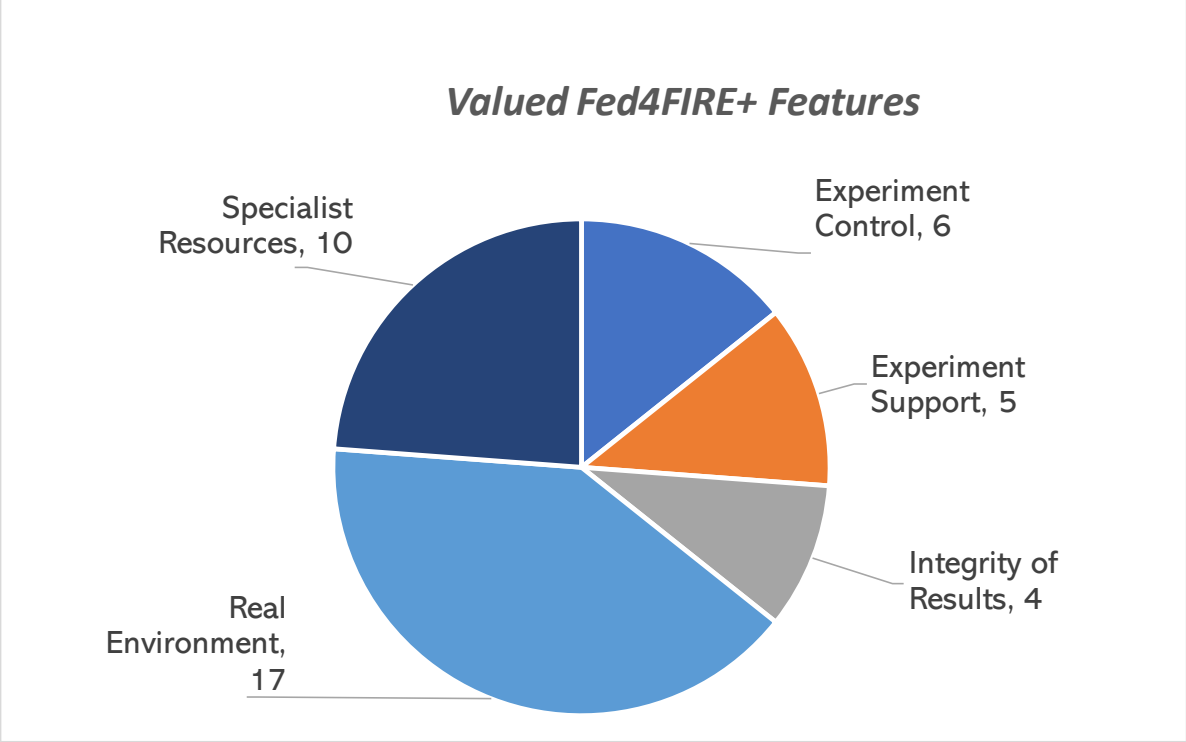


Figure 7: Benefits of Fed4FIRE+ Features

Figure 7 shows the distribution of the features of Fed4FIRE+ that experimenters found valuable.

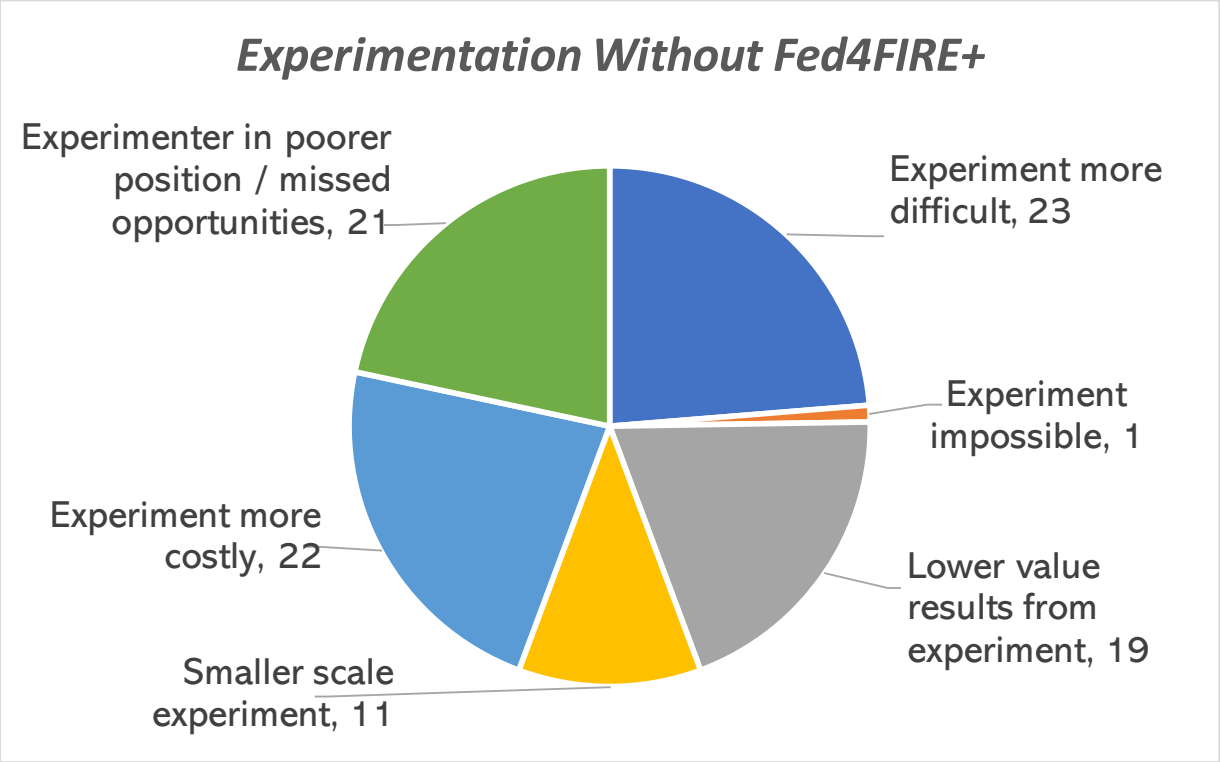
The most significant Fed4FIRE+ feature as rated by the experimenters (17 respondents) is that Fed4FIRE+'s testbeds provide real environments in which to perform experiments and testing. The specialist resources offered by Fed4FIRE+ is also important to experimenters. For both of these, experimenters frequently commented that they could not afford these types of resources to perform their experiments, so the provision of these resources was seen as a major selling point of Fed4FIRE+. Other non-functional aspects were also valued: the ability to control the experiment with a high degree of precision and the support provided by the testbed operators. Finally, the integrity of the results was valued, meaning that credibility of the results from experiments run on Fed4FIRE+ infrastructure is strong, due to the quality and realism of the environment and that Fed4FIRE+ is independent of any experimenter.

3.2.2 Experimentation Without Fed4FIRE+

The next question concerned how the experiments would have been different if Fed4FIRE+ did not exist.

B.3.1 Value perceived	**If no federation of testbed infrastructure would be available, how would this have affected your product / solution?** What would have been the value of your product / solution if the experiment was not executed within Fed4FIRE? What problems could have occurred?

The responses all concern how the experiment would have been poorer without Fed4FIRE+.



Without Fed4FIRE+, the experiments would have been restricted in the following ways.

- The experiment would have been more difficult to set up and execute. One respondent indicated that their experiment would have been impossible without Fed4FIRE+.
- The experiment would have been run at a smaller scale, mostly due to difficulties in accessing large numbers of resources.
- The experiment would have been more costly – in terms of whether the experimenter would have to pay for resources from commercial testbed offerings and the time cost of setting the experiment up and running it.
- The experiment would have had lower value results, because of their not being able to access realistic environments or large numbers of resources.
- The experimenters would have missed out on opportunities as a result of the knowledge or insight they acquired through experimentation. Many commercial experimenters indicated that without the resources provided by Fed4FIRE+, they would have been in a poorer competitive position.

3.2.3 Funded Experiments

A key element of Fed4FIRE+ is that Fed4FIRE+ provides funding for experimenters via open calls. Experimenters were asked whether they would have executed their experiment without receiving external funding.

B.3.2 Funding	Would you (have) execute(d) the experiment **without receiving any external funding?**

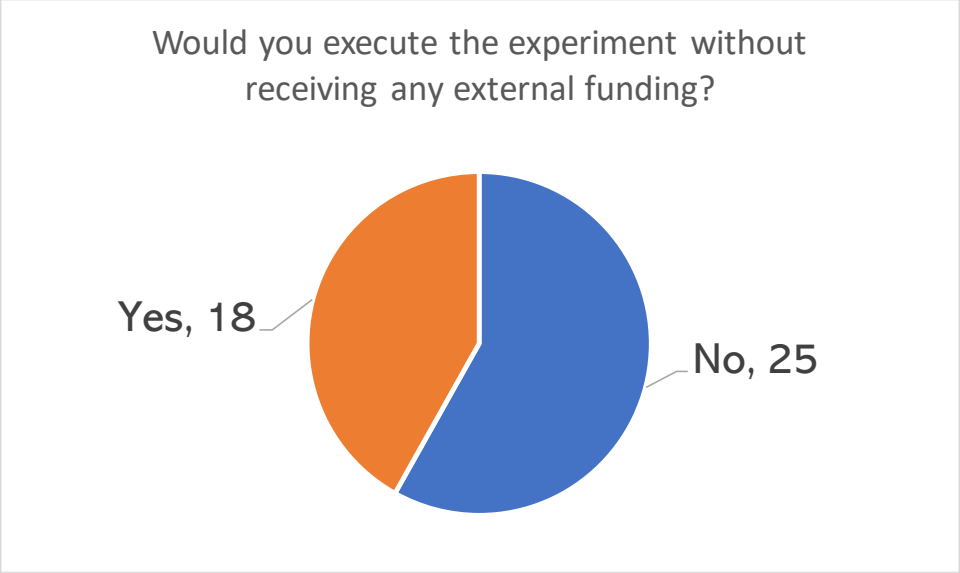


Figure 8: Experiment Funding

The response is split approximately 60% No, 40% Yes. Of the experimenters who responded in the negative, the main reason given was that they are small concerns and could not afford to justify the time and effort cost of running the experiment without funding. Many experimenters said that the funding they received has helped support their business cases.

Of those that said that they would run an experiment without funding, some said that they would have run a less ambitious experiment, while others said that the experiment is critical to their future development and would have been executed the same regardless of the funding.

Some respondents said that now they understand how to run an experiment, i.e. they have learned the required skills to do this, they would come back to run further experiments without funding.

The question does not make a distinction between funding supplied by Fed4FIRE+ and funding from other sources. Clearly, the experimenters' time has to be paid for from one source or another. It is not clear given the wording of this question whether the offer of funding from Fed4FIRE+ was a critical decision criterion for choosing Fed4FIRE+, but it is clear that Fed4FIRE+'s offer of funded experiments is attractive to experimenters.

3.2.4 Payment for Experimentation Resources

The next question concerned whether the experimenters would pay for resources.

B.3.2 Funding	**Would you even consider to pay for running such an experiment?** If so, what do you see as most valuable component(s) to pay for (resources, support, …)?

Given the response to the previous question, where 60% said they would not execute their experiment without funding, the results to this question are somewhat surprising, but the response does indicate some appetite for a paid-for commercial service.

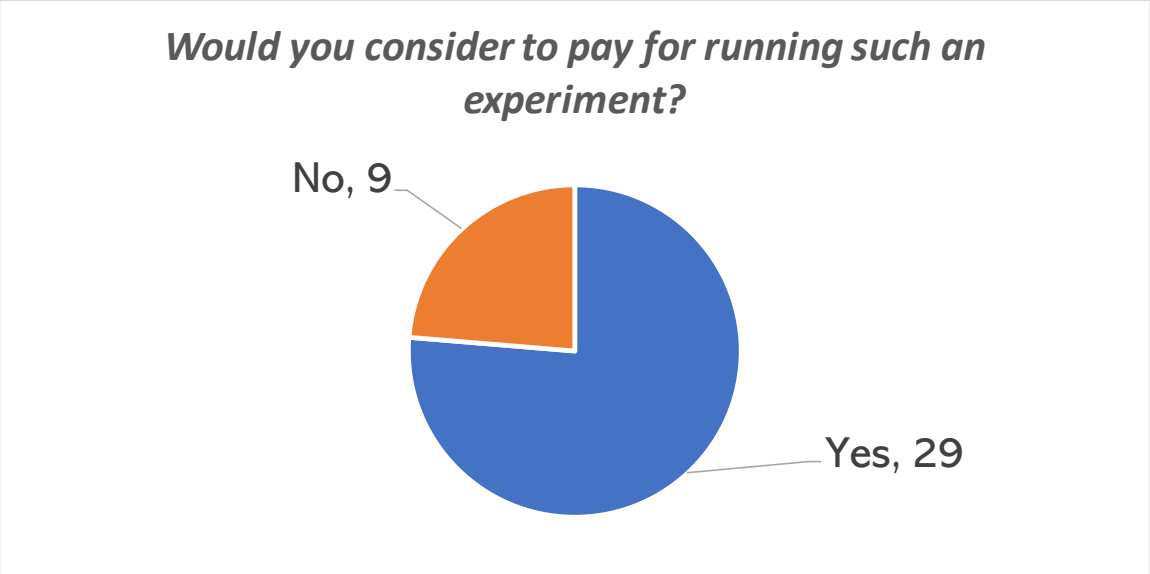


Figure 9: Payment for Experimentation Resources

Of those that said yes, four also said that their paying for resources would be subject to themselves receiving project funding to pay for the resources. This is possibly related to the previous question concerning funding for the experiment – i.e. funding, wherever it comes from, is needed to support the experiment, including both human effort and testing infrastructure resource costs.

Experimenters also commented on the most valuable features that are worth paying for, as shown in Figure 10.

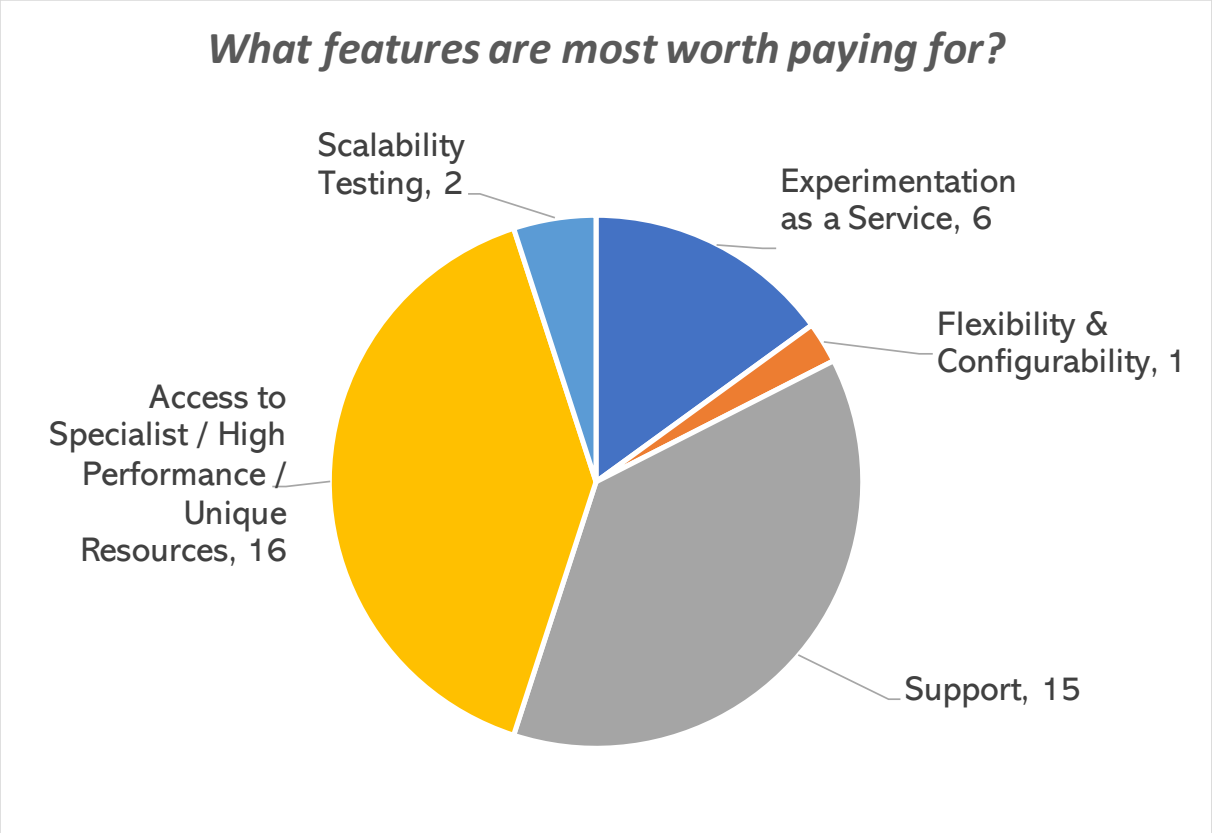


Figure 10: Paid-for Services

The clear favourite services are access to resources that the experimenters could not access otherwise, including specialist resources that are costly to purchase outright; and support to set up and run the experiment. Some experimenters alluded to “Experimentation as a Service”, where resources and support are packaged together and provided as a complete service by the federation to the client.

3.2.5 Portfolio of Testing Facilities

The next question concerned the adequacy of the existing testbed portfolio.

C.2.3 Fed4FIRE portfolio	**Was the current portfolio of testbeds** provided by the federation, with access to a large set of different technologies (sensors, computing, network, etc.) provided by a large amount of testbeds, **sufficient to run your experiment?**

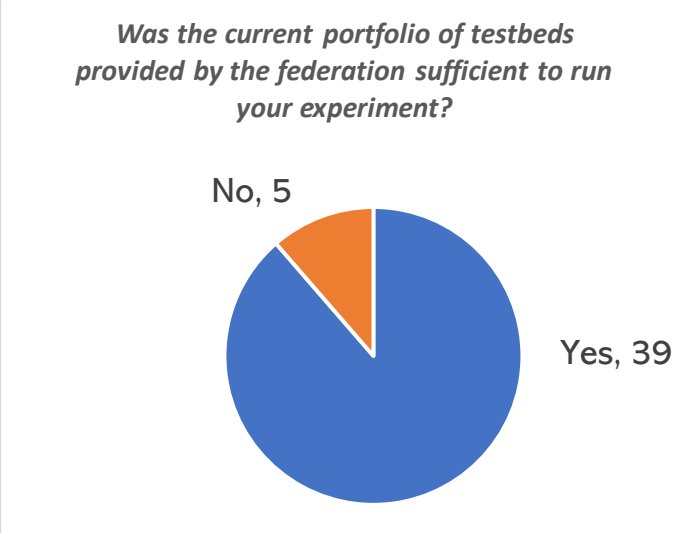


Figure 11: Testbed Portfolio Adequacy

The majority of the experimenters found the portfolio adequate, as shown in Figure 11. Experimenters also commented on the adequacy of the portfolio, as shown in Figure 12.

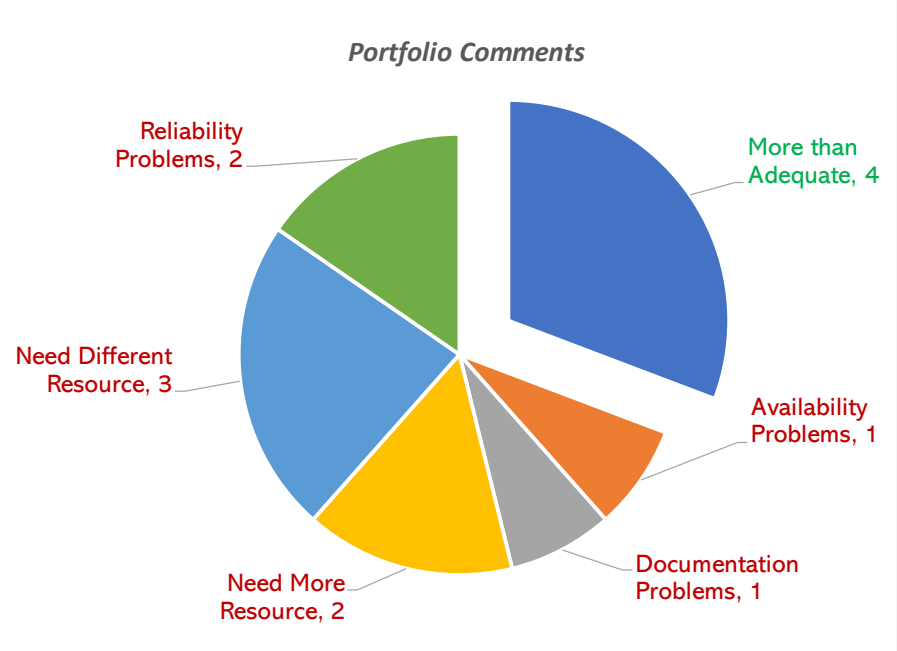


Figure 12: Experimenter Comments

In Figure 12, the positive comment is denoted with green labels, and 4 respondents indicated that the portfolio was more than adequate. The inadequacies are indicated with red labels, the most mentioned being that different resources than those available were needed. The types of resources needed included:

- Different wireless testing environments – one experimenter commented that the physical space within a wireless testbed was too small to allow the experiments they wanted.
- Voice over LTE.
- A wish to test at network speeds of 10Gb/s.

The next highest mentioned issues were reliability problems and the need for greater numbers of resources.

3.2.6 Technical Resources

The next question concerned the technical offering.

C.2.3 Fed4FIRE portfolio	**Was the technical offering in line with the expectations?** What were the positive and negative aspects? Which requirements could not be fulfilled?

All experimenters found the resources in line with expectations, as shown in Figure 13.

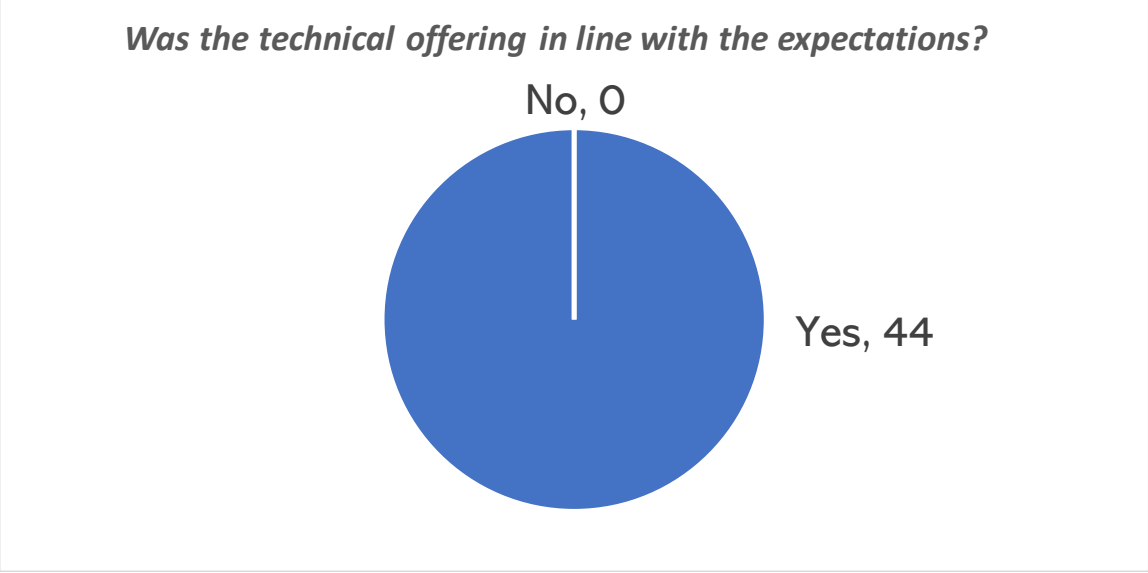


Figure 13: Technical Offering

The experimenters commented on the technical offerings, and the results are shown in Figure 14. As with the previous question, the positive comments are denoted with green labels, and the negative comments are denoted with red labels.

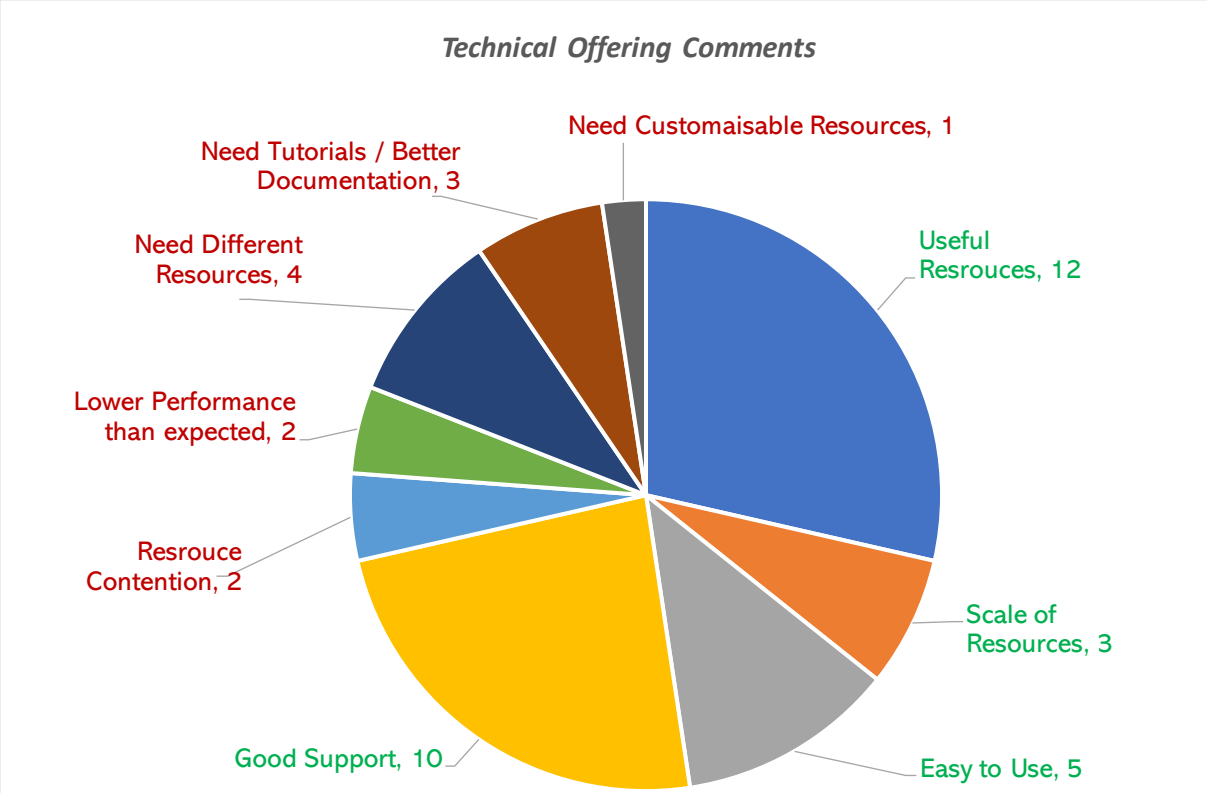


Figure 14: Technical Offering Comments

The positive comments commonly mentioned that the resources were useful, that the experimenters received good support and related to this, that federation was easy to use.

The negative comments included the need for different resources (crossing over with the previous question's responses), the need for better documentation, that they could not access the resources when they needed them, and that the performance of the testbeds was lower than expected.

3.2.7 Fed4FIRE+ Uniqueness

The next question concerned Fed4FIRE+'s uniqueness – the features that make Fed4FIRE+ stand apart from other testing infrastructures.

C.2.5 Experiment environment	Did you experience that the Fed4FIRE environment is unique for experimentation and goes beyond the lab environment and enables real world implementation?

The results are shown in Figure 15 and unanimously concur with the question statement – that Fed4FIRE+ is indeed unique and provides real world experimentation facilities.

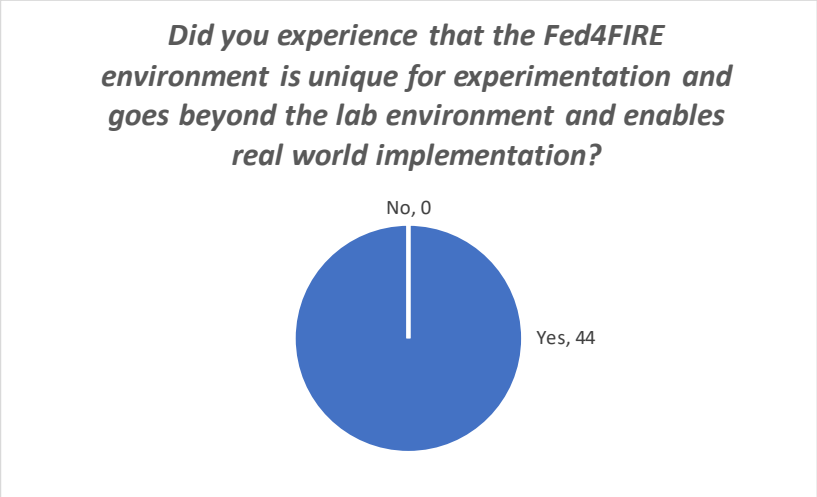


Figure 15: Fed4FIRE+ Uniqueness

Specific themes in the responses are shown in Figure 16.

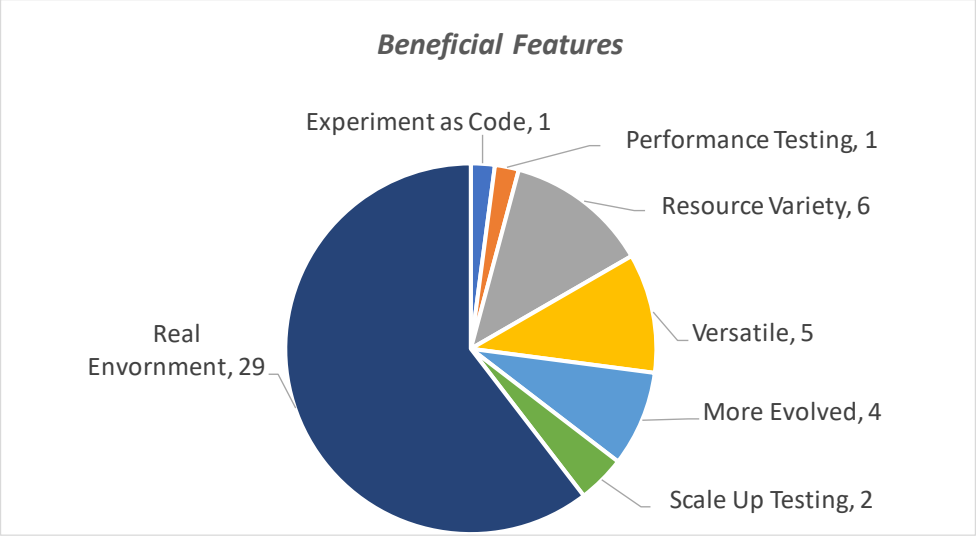


Figure 16: Beneficial Unique Features

The majority of respondents concurred with the question statement that Fed4FIRE+ provides a real environment in which to experiment and test systems. The variety of resources was also identified as a unique feature, as was the versatility of Fed4FIRE+ Four experimenters feel that Fed4FIRE+ is more advanced ("evolved") than other testing facilities.

3.2.8 Reasons for Choosing Fed4FIRE+

The next question concerned why the experimenters chose Fed4FIRE+ for their experiment.

C.3.1 Execution of the experiment	**Why did you choose Fed4FIRE for your experiment?** Was it the availability of budget, easy procedure, possibility to combine different (geographically spread) facilities, access to resources that otherwise would not be affordable, availability of tools, etc.? Please specify in detail

The results are split into the major reasons, which were prompted by the question, and supplementary reasons, which were unprompted by the question and more diverse. The major reasons (those mentioned in the question) are shown in Figure 17.

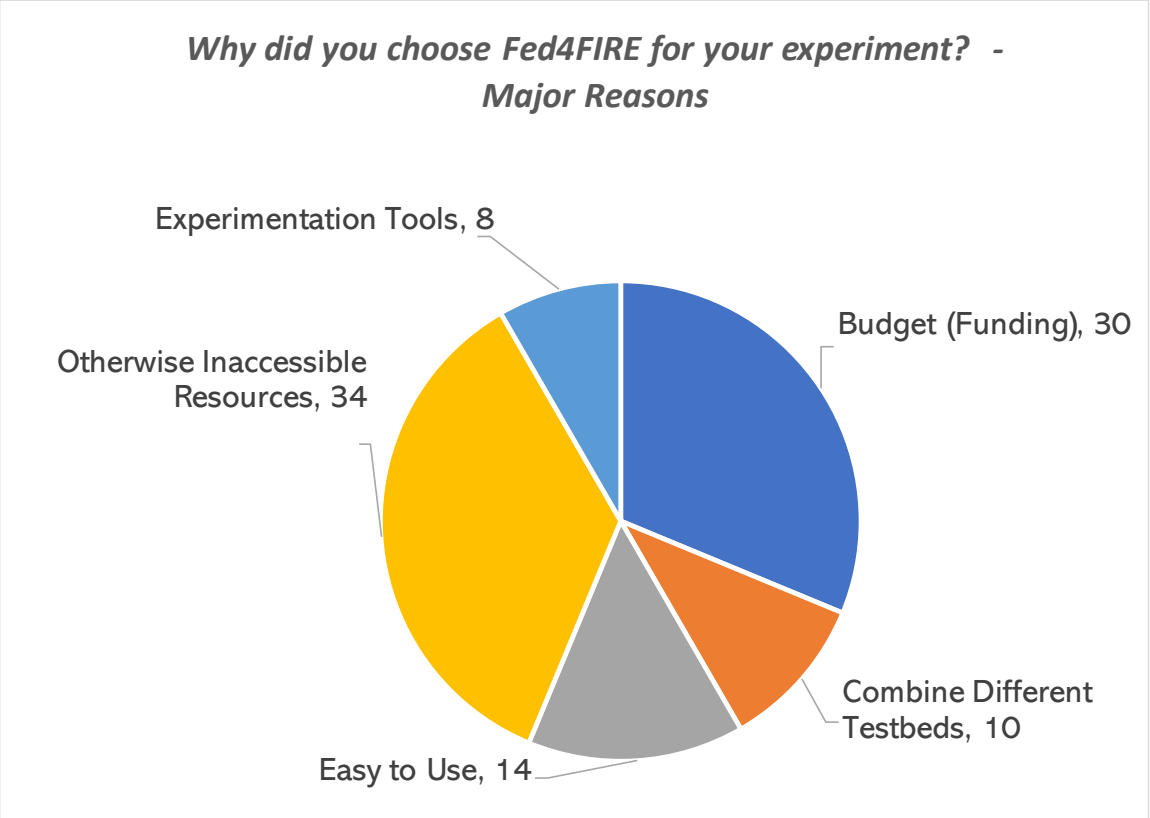


Figure 17: Major Reasons for Choosing Fed4FIRE+

The two clear most popular reasons are that Fed4FIRE+ makes resources available to experimenters who would otherwise not be able to access them, and that Fed4FIRE+ is a source of funding for experiments.

Other reasons were also offered by the experimenters unprompted. These supplementary reasons are shown in Figure 18.

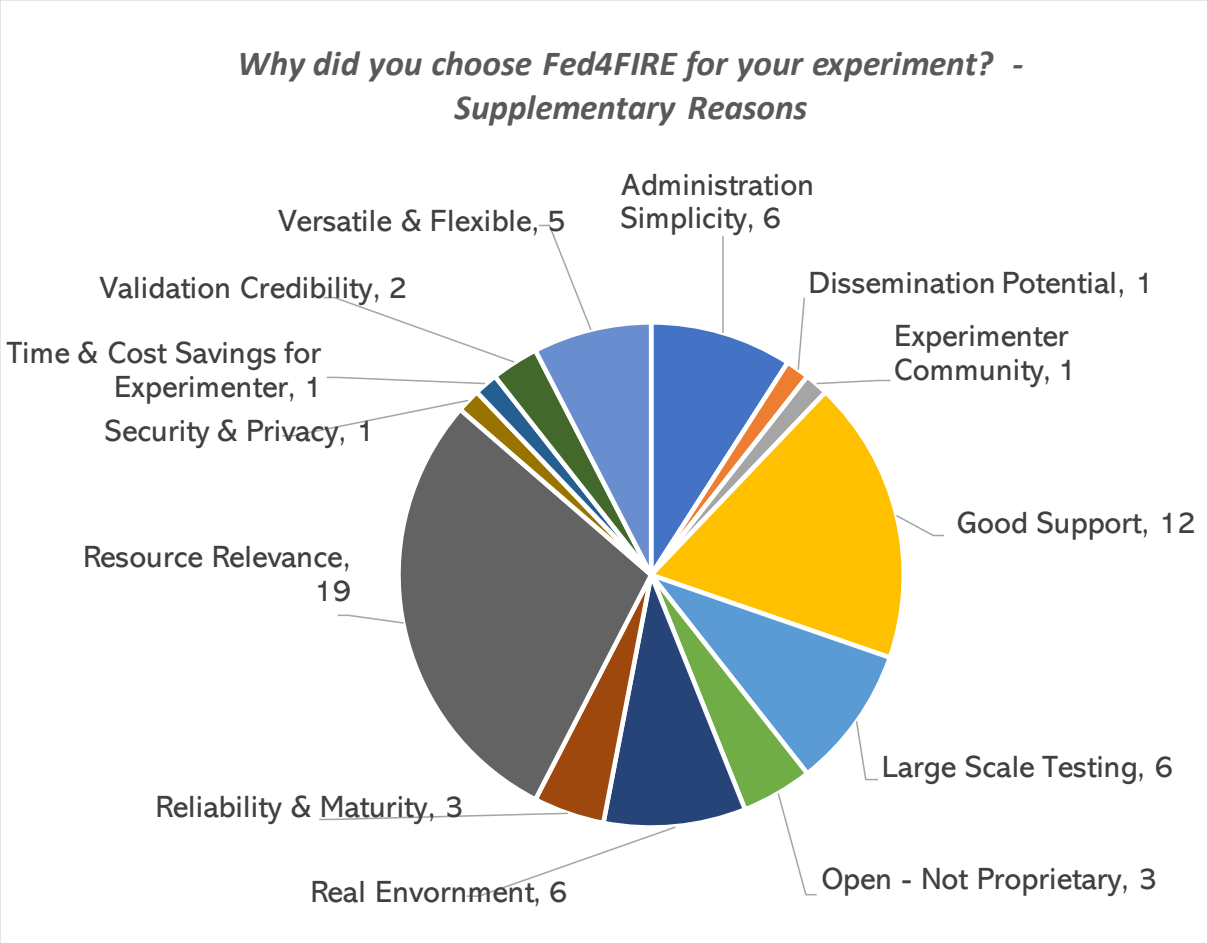


Figure 18: Supplementary Reasons for Choosing Fed4FIRE+

The clear winners here are the relevance of the resources to the experimenters and that Fed4FIRE+ provides good support to the experimenters. On the next level are that Fed4FIRE+ provides a real testing environment (backed up by responses to other questions), it supports large scale testing, and that the administration of the experimental proposal and management is straightforward to the experimenters.

3.2.9 Commercial Alternatives to Fed4FIRE+

The next question concerns whether there is a commercial alternative to Fed4FIRE+

C.3.1 Execution of the experiment	Could you have conducted the experiment at a commercially available testbed infrastructure?

The response is a strong advocation of Fed4FIRE+ in that most respondents indicated that they could not run their experiment on a commercial infrastructure.

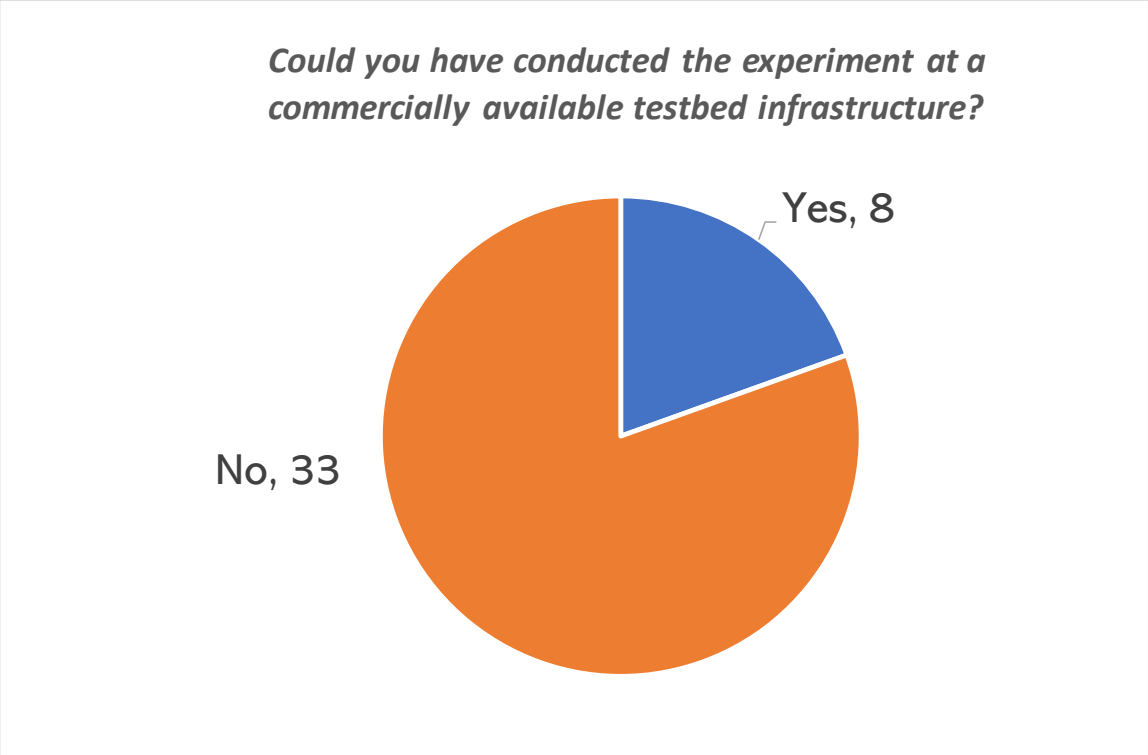


Figure 19: Commercial Alternative to Fed4FIRE+

Disadvantages of commercial infrastructures compared to Fed4FIRE+ were given by the respondents, as shown in Figure 20.

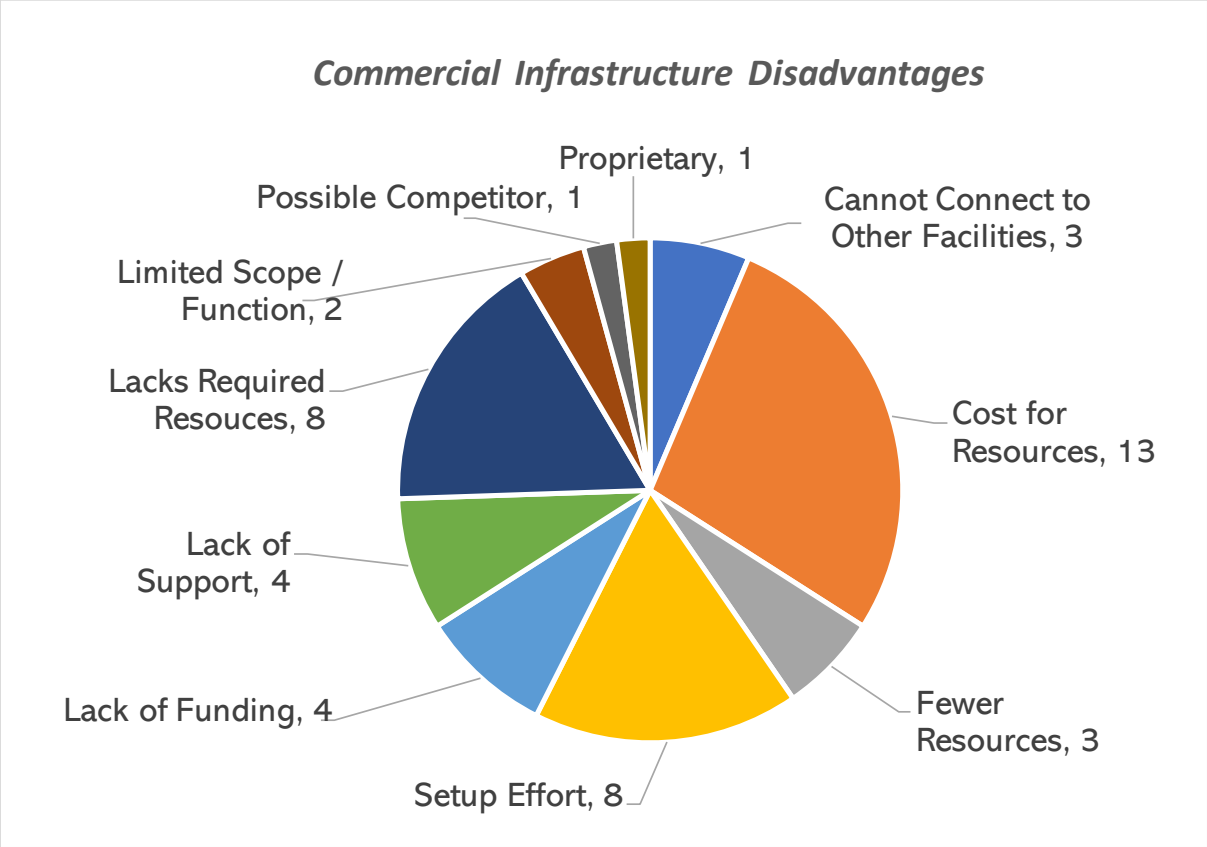


Figure 20: Commercial Infrastructure Disadvantages Compared to Fed4FIRE+

The chief disadvantage of a commercial testbed is naturally the cost for resources, and if Fed4FIRE+ operates in open access, providing resources as a public good and funded by public money, Fed4FIRE+ will always have this advantage. The lack of required resources in commercial testbeds is another major advantage of Fed4FIRE+, as is the effort to setup. Therefore the conclusion is that Fed4FIRE+ provides specialist resources that are not available in commercial testbeds, and the support and ease of use offered by Fed4FIRE+ is valued by experimenters.

3.2.10 Valuable Fed4FIRE+ Properties

The experimenters were asked to rank properties of Fed4FIRE+.

C.3.2 Added value of Fed4FIRE	**Which components did you see as highly valuable for the federation** (e.g. combining infrastructures, diversity of available resources, tools offered, support and documentation, easy setup of experiments, etc.)? Please rank them in order of importance.

Respondents ranked the properties of the question, and in the results graph in Figure 21, the highest rank scored 5, down to 1 for the lowest rank. The scores were summed for each property to give the overall ranking.

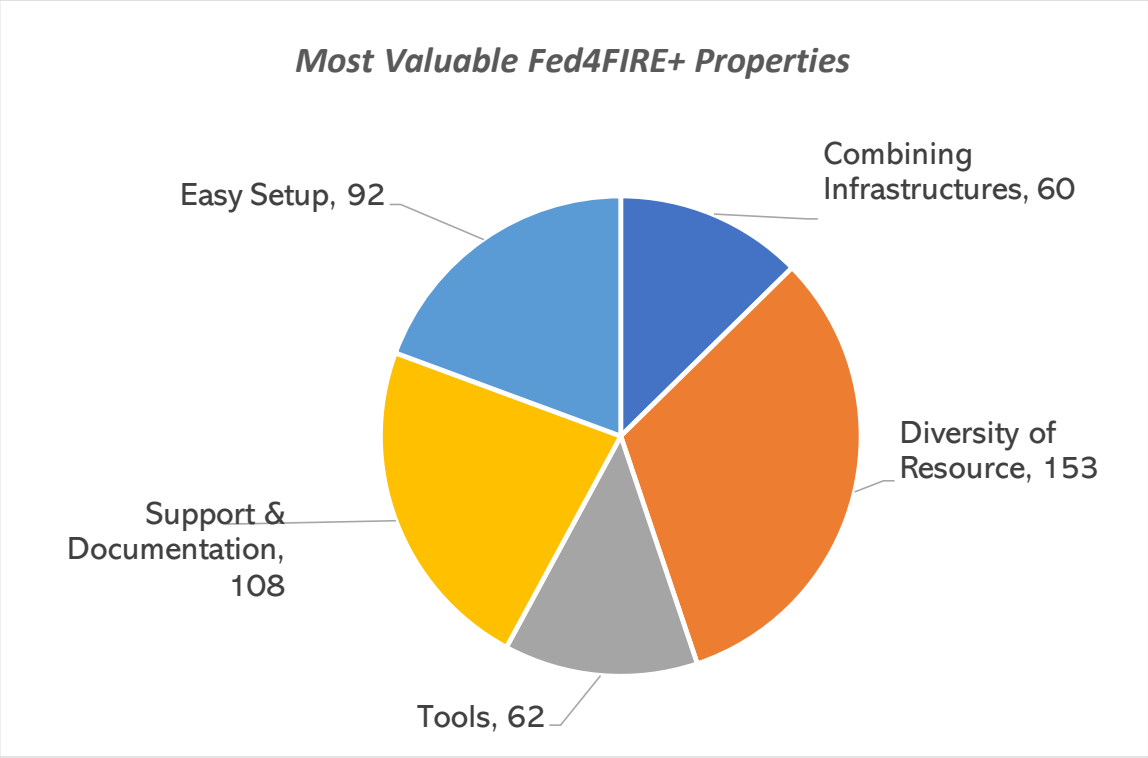


Figure 21: Most Valuable Fed4FIRE+ Properties

The diversity of the resources scored the highest, followed by support and documentation and the associated property of easy setup. The tools and the ability to combine the infrastructures were ranked lowest.

3.2.11 Desirable Open Access Features

A similar question was asked about the desirability of features, but only when the federation is does not offer funding for experimentation (known as “Open Access”, discussed in Section 5.2.1).

C.3.2 Added value of Fed4FIRE	Which of these tools and components should the federation at least offer to allow experimentation without funding?

This question did not prompt the experimenters about the features, nor asked them to rank the features, so the graph of Figure 22 shows how many respondents mentioned each feature.

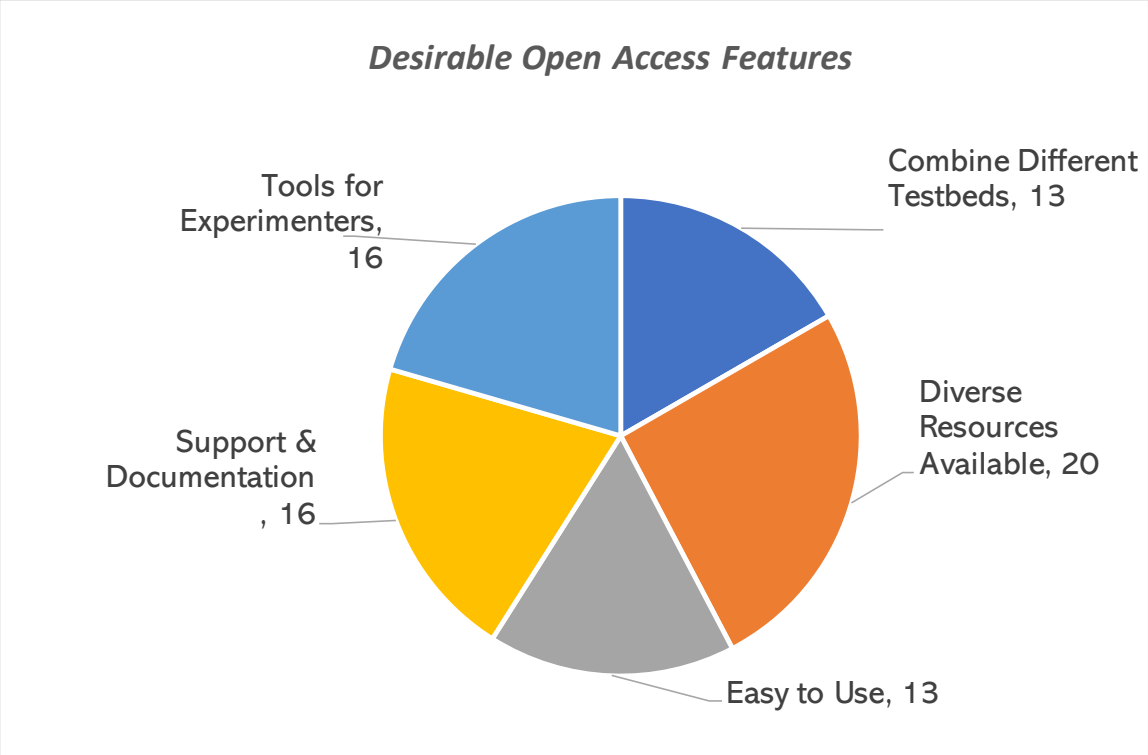


Figure 22: Desirable Open Access Features

The results are much more uniform than those of the previous question, with the most mentioned, resource diversity, being less clearly out in front.

3.2.12 Direct Feedback from Experimenters

During the Federation Engineering Conferences, direct feedback was gathered through discussion with the experimenters, as summarised next. This feedback corroborates the key points from the experiment reports.

- The Fed4FIRE+ Jfed tool that sets up experiments is easy to use, and once you have learnt it, you can access all the testbeds within Fed4FIRE+. Many experimenters said they would run more experiments beyond their original experiment (without funding), now that they have found out it is so easy. One person said "***just a few clicks and you have an experiment***".
- Having a wide variety of testbeds available from in one place: the Fed4FIRE+ portal is very useful.
- The resources provided by the testbeds would be expensive if the experimenters had to purchase them. Experimenters cannot justify buying them, so ***being able to use the expensive resources on a temporary basis, free of charge, is great***.
- The ***independence and integrity of the testbeds is great for both academic and commercial work*** – there can be no claim that results using the testbeds can be biased by the tester.
- Fed4FIRE+ should stress that the ***testbed resources are available to any experimenter FOR FREE!*** Just make a request through the website.

3.2.13 Summary of Key Themes

The overall conclusion is that Fed4FIRE+ provides genuine, unique value to experimenters. The key themes from the experimenter feedback are as follows.

- Fed4FIRE+ provides a real environment for testing.
- Support is strongly appreciated by the experimenters. Easy setup of experiments is also highly valued.
- Experimenters value access to resources they cannot access otherwise.
- Funding is important to experimenters, but not as much as expected.
- Some experimenters would pay for access to testing resources and associated services like support.
- The federation performs as expected by the experimenters.
- The resources provided by the federation are relevant for the experimenters' needs.
- Fed4FIRE+ is in advance of commercial testing infrastructures.
- The diversity of the Fed4FIRE+ resources is of high value to experimenters.

3.3 Value of the Federation to Testbeds

This section aims to evaluate the value of the federation to the testbeds. Each testbed was surveyed to determine:

- The total number of active accounts (used within last 12 months) on the testbed
- The number of active accounts that come through Fed4FIRE (i.e. use Fed4FIRE access tokens) & the number that are native to the testbed
- The number of active accounts that are internal students or researchers and number of active accounts that are external students or researchers.

Each testbed is discussed separately in the following sections.

3.3.1 IoT Lab

Mandat International is managing since several years the IoT Lab testbed which is focused on crowd-sourcing and crowd-sensing researches on Internet of Things (IoT). Indeed, IoT Lab permits to the researchers to create experiments about IoT using different tools and resources accessible by the crowd also: specific mobile application, surveys, different kinds of IoT sensors and actuators deployed in different locations in Europe. During the period from the 1st January 2019 until the 31st October 2019, the number of users, also called participants in the IoT Lab language, was 2803 for the IoT Lab testbed. From this number, there are 2266 anonymous users which are in fact the crowd: these users have installed the mobile application on their smartphone. The other part of the global number of participants encompasses the 537 researchers who have an account in the IoT Lab Web portal (https://www.iotlab.eu/). 92 researchers were very active during the year 2019. The following public link https://www.iotlab.eu/JoinTheWisdomOfTheCrowd/PlatformScores permits to see the current figures concerning the IoT Lab testbed statistics.

The IoT Lab testbed has joined the Fed4FIRE+ testbeds federation this year. The integration of the IoT Lab testbed in Fed4FIRE+ was natural because IoT Lab and Fed4FIRE+ are using the same technologies developed previously in the Fed4FIRE project. So, Fed4FIRE+ and IoT Lab can establish a strong collaboration and find a lot of synergies between the testbeds to offer better services to the research community in Europe. Originally, Fed4FIRE+ is oriented to technical researches like network communication protocols experimentations or cloud computing experiments. Fed4FIRE+ is offering different kinds of resources that IoT Lab doesn't provide: for instance, virtual machines, programmable IoT sensors and robots. This is particularly interesting for the researchers because from only one entry point, the jFed software, the researchers can access different sorts of resources which can be of course mixed together during an experiment. So, the heterogeneity of the different sorts of resources across the Fed4FIRE+ testbeds federation is an important point which is totally relevant for the sustainability of the Fed4FIRE+ services. Basically, a relative large panel of heterogenous resources provided by different testbeds will increase the number of users both in Fed4FIRE+ and in IoT Lab as the number of potential experiments or services is naturally increasing. This heterogeneity is quite uncommon and should be promoted by the federation of testbeds which is offering a better user experience for all the researchers involved in computer science, mainly in Europe, compared to other monolithic testbeds providing a very limited panel of different kinds of resources.

3.3.2 PlanetLab Europe

Another testbed involved in Fed4FIRE+ is PlanetLab Europe (https://www.planet-lab.eu/). This testbed is the European part of the global PlanetLab platform (https://www.planet-lab.org/). The main objective of PlanetLab is to provide the required support for the research and development of new network services across the world. Each organisation taking part to the PlanetLab Europe (PLE) testbed is providing two physical servers; these servers are offering Linux virtual machines connected to the Internet. The experimenter of PLE has full control over each virtual machine and can do tests and experiments concerning for instance the network measurements, the network security, the content distribution networks, the distributed systems and the peer-to-peer systems. The current number of active accounts is 250. From this number, only one account is coming from Fed4FIRE. The testbed is used internally among the PlanetLab Europe partners as the latest statistics show this fact: 219 students and 30 researchers are directly members of PlanetLab Europe. So, only one student or researcher is external to PlanetLab Europe. The advantage to use a Fed4FIRE account to access the resources available in PlanetLab Europe is that there is no need that the organisation or an individual experimenter must be already member of PlanetLab. This means that the external experimenters or users of PlanetLab Europe don't need to install the two required physical servers in their premises. At the end, the access to PlanetLabEurope through Fed4FIRE+ is the free way to do experimentations related to network technologies. But this solution is not used currently as the collected numbers show it: indeed, all the users, composed by researchers and students, are working for the organisations affiliated to the PlanetLab Europe testbed, so the users don't need to have a Fed4FIRE+ account. In conclusion, there is a strong potential to get more experimenters involved in PlanetLab Europe through the Fed4FIRE+ federation of testbeds.

3.3.3 Grid'5000

Grid'5000 (https://www.grid5000.fr/w/Grid5000:Home) is a testbed for the research concerning the computer science with a strong focus on the distributed and parallel computing. For example, the experimentations about cloud computing, high-performance computing (HPC), Big Data and Artificial Intelligence (AI) are in the scope of the Grid'5000 testbed. The resources are directly available at the bare metal level, which means that the experimenters are building their experiments directly from the hardware by installing a Linux operating system and software corresponding to the needs of their experiments. On the same manner, each experiment can be isolated at the network layer and different types of measurements are available to monitor the power consumption and the network itself. The number of active users of Grid'5000 is 605. 176 of them are external and are considered as guests by the Grid'5000 testbed; this number represents 29,1% of all the users of the testbed. In terms of testbed resources usage, the external users consume 13,4% of the global usage. Currently, the Grid'5000 testbed doesn't track the activities of the Fed4FIRE+ users connected to the testbed resources. So, it is difficult to determine the usage made by the Fed4FIRE+ users when they are connected to the Grid'5000 testbed.

3.3.4 PL-LAB

The next testbed is PL-LAB (https://www.fed4fire.eu/testbeds/pl-lab/) established in Poland. The equipment deployed in the different locations of the PL-LAB testbed allows to perform a lot of experiments concerning for instance IPv6, Content Aware Networks, Parallel Internets and 4K 3D video streaming. The infrastructure used in the context of the PL-LAB testbed is composed by servers, programmable switching devices, routers, measurement devices, Wi-Fi access points, 4K 3D sources and sinks. The PL-LAB is oriented towards experiments linked to the network and so, matches the research domains of the Future Internet. The total number of accounts for the PL-LAB is 60, but no one is an account emanating from the Fed4FIRE+

project. The majority of the users are internal researchers or students: 55 to be precise. Five accounts come from external users. So, in this testbed, there is a good probability to strengthen the number of experimenters issued from the Fed4FIRE+ federation of testbeds if the PL-LAB testbed is becoming more open worldwide.

3.3.5 OFELIA

The i2CAT OFELIA testbed (https://www.fed4fire.eu/testbeds/i2cat-ofelia/) provides resources to do experimentations about mainly software-defined networking (SDN) and virtualisation. Indeed, several OpenFlow packet switches and virtualisation servers are available in the premises of the testbed and allow the deployment of virtual machines for different sorts of tests. Currently, the number of users is 3. All the users own accounts coming from Fed4FIRE. 2 users are internal to the organisation managing the i2CAT OFELIA testbed and so, one is external to the testbed.

3.3.6 IRIS

The following testbed is IRIS, as known as the reconfigurable radio testbed (https://iris-testbed.connectcentre.ie/), which is managed by the Trinity College Dublin (TCD). This testbed offers different technologies to realise experiments concerning the radio: virtualised radio hardware, software virtualisation, Cloud Radio Access Network (RAN), SDN and NFV. A large choice of resources is available for the experimenters and permits to test all the layers involved in the radio research and development, from the physical layer with devices supporting LTE, 5G and Wi-Fi to the virtualisation layer and its different pieces of software.

The total number of active accounts for the IRIS testbed is 15. The users set up 1328 slivers, so 89 slivers per user. 5 accounts are internal, so linked to students and researchers, and the users have created 676 slivers (135 per user). 10 accounts are external and correspond to jFed accounts; the Fed4FIRE users have taking care of 652 slivers, so 65 slivers per user. On the other hand, the number of active users managed through the internal OpenStack Horizon website system at the IRIS testbed is 16 users which 10 users are external open call researchers and 6 internal users (students or academic researchers). This number encompasses the researchers from projects like 5GINFIRE, but there are also internal experimenters from the Trinity College Dublin. Many of these experimenters reserve resources for months at a time via this system put in place inside the testbed.

3.3.7 SmartSantander

The SmartSantander testbed (https://www.fed4fire.eu/testbeds/smart-santander/) is focused on the sensors deployed inside the smart city of Santander, in the north of Spain. The experimentations done in Santander are therefore oriented to the Internet of Things (IoT) in the context of smart cities and involved also the citizens, the researchers and the students. There are different ways to access the IoT sensors of the SmartSantander testbed like Fed4FIRE, FIWARE and CKAN. As the user management is different for each of these manners to access the IoT sensors, it is very hard to get the right numbers concerning the usage of the testbed. For instance, CKAN is a platform to put the data provided by the smart city of Santander in open access, without any credentials; so, at the end, it is not possible to determine the number of users accessing the data provided by the testbed. Taken into account these considerations, the number of active accounts for the year 2019 is more than 30. There is 3 accounts coming directly from Fed4FIRE. All the accounts mentioned here are external; indeed, the internal accounts don't use the production environment of the testbed, but only the development infrastructure.

3.3.8 Virtual Wall

The virtual wall testbed managed by imec encompasses 233 users who are coming only from Fed4FIRE. These users utilise 13'127 slivers, so 56 slivers for each user. 140 accounts are internal (students or researchers) with 7301 slivers; so, an account is using 52 slivers. 74 users are external and employ 2913 slivers, so 39 slivers per user. Finally, 19 classes is using also 2913 slivers; this means that one class is utilising 153 slivers. The virtual wall testbed is used to perform experiments for large networking and cloud.

3.3.9 GPULab

Concerning the GPULab, which is used to do experimentations through GPU-enabled Docker containers, the number of users is reaching 106 users who are only Fed4FIRE accounts.100 accounts are internal to imec, so 4 users are external. For the classes using the GPULab, 2 accounts are available for each class; one class is composed by 30 to 50 students.

3.3.10 w-iLab.t

Imec is also managing a wireless testbed named w-iLab.t actively used by 83 people. 6160 slivers are used in this testbed, so 74 slivers per user. All the accounts linked to this imec testbed are Fed4FIRE accounts, too. 29 accounts are used by internal users like students and researchers; they are using 1322 slivers, so 45 slivers per user. The number of external users is 48; these users have reserved 4693 slivers, so 98 slivers for each external user. 6 classes are using 145 slivers, so 24 slivers are used by each class.

3.3.11 Imec Portable Wireless Testbed

Imec is handling a portable testbed used when measurement campaigns must be done outside the imec premises. This testbed is composed by wireless components communicating though different protocols like Wi-Fi, IEEE 802.15.4 or Bluetooth. 2 accounts are dedicated to this testbed and the usage of slivers is quite limited with 11 slivers. These two accounts are provided by Fed4FIRE. One account is internal to imec and the other one is external.

3.3.12 Tengu

Tengu is another testbed managed by imec and the current number of active users is 19. From this number, there are 6 accounts coming from the Fed4FIRE+ open calls. 11 accounts are internal users from the imec organisation. 8 accounts are external and there are two kinds of external users: the open calls with 6 accounts and two open access accounts.

3.3.13 CityLab

The CityLab testbed (https://doc.lab.cityofthings.eu/wiki/Main_Page) is dedicated to the experimentations in the context of the smart cities. This testbed is implemented in the city of Antwerp in Belgium. The owners of the CityLab testbed is imec and the University of Antwerp. The nodes provided in the frame of this testbed are using Wi-Fi, Bluetooth 4.0, IEEE 802.15.4, DASH7 and LoRaWAN communication protocols. 15 active accounts are using 257 slivers; each user has 17 slivers. All the accounts come from Fed4FIRE. 8 users are internal to the CityLab testbed with 88 slivers (11 per user) and 7 users are external within 169 slivers (24 slivers for each external user).

3.3.14 NETMODE

Managed by the National Technical University of Athens (NTUA), the NETMODE testbed (http://www.netmode.ntua.gr/main/index.php?option=com_content&view=article&id=103&Itemid=83) is dedicated to experiments with wireless nodes deployed in the NTUA premises. 10 accounts are currently active in the NETMODE testbed. 6 accounts are coming directly from Fed4FIRE+ and the four other accounts are used internally by NTUA for the administration of the wireless testbed. 8 accounts belong to internal researchers and students of NTUA and two accounts are in fact Fed4FIRE+ experimenters.

3.3.15 TRIANGLE

The TRIANGLE testbed (https://www.triangle-project.eu/tools/), also known as PerformLTE testbed, is used for experiments associated to 5G network. Indeed, the testbed permits to test and evaluate applications and devices in the context of the new 5G technology. Currently, there are two running experiments done in the frame of the Fed4FIRE+ project and two other experiments realised for the TRIANGLE project.

3.3.16 LOG-a-TEC

LOG-a-TEC (http://www.log-a-tec.eu/) is a wireless testbed allowing a lot of experiments concerning different wireless technologies like LoRa, Sigfox, IEEE 802.15.4, etc. Currently, several students coming from different universities are using the testbed for their research work. So, four students from the Jožef Stefan International Postgraduate School (IPS), two students from the University of Ljubljana and three students from the University of Banja Luka are the main users of the LOG-a-TEC testbed. This testbed is also used in a Fed4FIRE+ open call.

3.3.17 NITOS

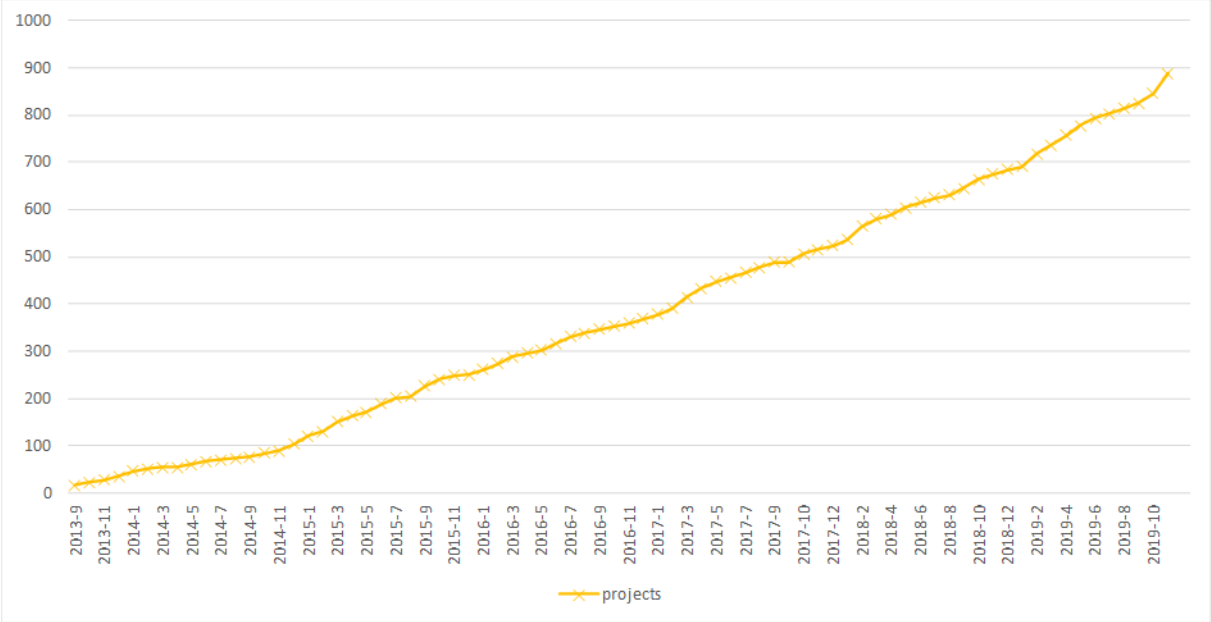
The NITOS Future Internet facility (https://nitlab.inf.uth.gr/NITlab/nitos) is composed by several testbeds providing support for experimentations about wired and wireless networks. The main NITOS testbeds are respectively focused on wireless experiments, cloud infrastructure, wireless sensor network (WSN), software defined radio (SDR) and software defined networking (SDN). The deployment of the testbeds components is done in different locations, including outdoor for wireless technologies like Wi-Fi, LTE and WiMAX, indoor for wireless experiments in a RF isolated environment and finally, in an office for a realistic environment for the wireless tests. The total number of users in the NITOS facility is 182. 150 accounts have been created from the NITOS testbeds directly and the remaining 32 accounts are issued from Fed4FIRE. 87 accounts are in fact students from the University of Thessaly attending the network courses or doing their master thesis. 20 other accounts are also internal to the testbeds, because they are linked to the researchers of the university. 43 accounts are external to the NITOS testbeds.

3.3.18 Summary

The testbeds' statistics are summarised in the following table.

Testbed	*Number of Active Accounts*	*Fed4FIRE+ Accounts*
IoT Lab	2803 (92 active in 2019)	0
PlanetLab Europe	250 (all active in 2019, comprised of 219 students, 30 researchers, all members of PL Europe)	1
Grid'5000	605 (176 external to Grid'5000)	Not tracked
PL-LAB	60 (55 students)	0
OFELIA	3 (2 internal)	3
IRIS	15 (5 internal)	10 (external)
SmartSantander	30 (all external)	3
Virtual Wall	233 (140 internal students)	233
GPULab	106	106 (4 external to Imec)
w-iLab.t	83 (29 internal)	83 (48 external)
Imec Portable Wireless Testbed	2	2 (1 external)
Tengu	19 (11 internal)	8 (6 open calls, 2 open access)
CityLab	15 (8 internal)	15
NETMODE	10 (8 internal)	6
TRIANGLE	4	2
LOG-a-TEC	Circa 10	Not declared
NITOS	182 (87 students, 20 internal, 43 external)	32

To resume the current situation of the Fed4FIRE+ federation of testbeds, 215 new projects were made during the year 2019 under the banner of the Fed4FIRE+ authority run by imec. 100 projects are internal to the imec organisation and 100 other are projects managed externally. The 15 remaining projects are dedicated to classes. 158 of those projects were started by new users registered in the year 2019. 57 projects were put in place by existing users. The following chart shows the evolution since September 2013 to October 2019:



Over the last 12 months, 338 different users were active on Fed4FIRE testbeds via a Fed4FIRE account. In total, they set up 23'004 slivers, so an average of 68 slivers per user.

Apart the Fed4FIRE testbeds mentioned above, non-European testbeds were used with Fed4FIRE accounts. The Brazilian Futebol testbeds counts 33 unique users over the last year with 1288 slivers, representing 39 slivers per user. The US GENI testbeds are composed by 31 unique users for a total of 310 slivers, within 10 slivers per user.

4 Fed4FIRE+ as a Public Good: Funding for Fed4FIRE+ as a Research Infrastructure

Based on the key principle that Fed4FIRE+ should operate as a public good, so as to enable democratised access based on the merit of an experiment rather than the ability to pay for resources or support, a major objective for Fed4FIRE+ is to seek out and pursue public funding opportunities.

To this end, this section discusses the pursuit of one such opportunity in the form of an ESFRI project called SLICES (Scientific Large-scale Infrastructure for Computing/Communication Experimental Studies).

The Fed4FIRE+ consortium will monitor, be open to, and actively pursue other funding opportunities as they become available.

4.1 SLICES Background and Need

Digital Infrastructures as the future Internet, constitutes the cornerstone of the digital transformation of our society. As such, Innovation in this domain represents an industrial need, a sovereignty concern and a security threat. Without Digital Infrastructure, none of the advanced services envisaged for our society is feasible. They are both highly sophisticated and diverse physical systems but at the same time, they form even more complex, evolving and massive virtual systems. Their design, deployment and operation are critical. In order to research and master Digital infrastructures, the research community needs to address significant challenges regarding their efficiency, trust, availability, reliability, range, end-to-end latency, security and privacy.

Although some important work has been done on these topics, the stringent need for a scientific instrument, a test platform to support the research in this domain is an urgent concern. SLICES ambitions to provide a European-wide test-platform, providing advanced compute, storage and network components, interconnected by dedicated high-speed links. This will be the main experimental collaborative instrument for researchers at the European level, to explore and push further, the envelope of the future Internet. A strong, although fragmented expertise, exists in Europe and could be leveraged to build it. SLICES is our answer to this need. It is ambitious, practical but overall timely and necessary.

This RI is centered on the research related to Digital Infrastructures, It has a strong potential for interdisciplinarity. Indeed, on the one hand, lessons learned could be advantageously exploited in other RIs where such infrastructure might be relevant in the near future. On the other hand, the digital transformation of various application domains opens an avenue for research in verticals such as smart grid, smart agriculture, autonomous vehicle, connected health etc.

SLICES is the outcome of our experience in the design, deployment, and operation of several large testbeds such as Grid'5000, FIT, Planet-lab Europe or FIRE testbeds since 2005. Given their number of users and outcomes (scientific publications, thesis, software suites, …) these test platforms have proven the strong needs from the distributed computing and networking communities. These previous initiatives have enabled the deployment of facilities that do not have the scope and size of SLICES but provides the foundation for the approach. Therefore, we propose the realization of SLICES with the support of the main teams that have been involved in these past projects and associated communities.

A design phase will be achieved (mid 2018 to mid 2021). Note that to better support this Design Phase, we have submitted an INFRADEV-01 H2020 proposal. In the rest of the proposal the Design Phase refers to the period 2018-mid 2021. A preparation (2021-2023) phase will enable

deployment (2023) and full-operation (2026 on). Note that a partial service will be made available as early as in 2023 based on existing infrastructures and limited updates.

The mission of SLICES is to provide the research and engineering community with a fully controllable, programmable virtualized digital infrastructure test platform going from IoT devices to data centres. It aims to answer the fundamental questions regarding digital infrastructures in an evolving environment, enable new technologies to support the vision (5G and beyond), support ICT breakthrough discoveries with the use of both OTS and ad-hoc programmable technologies together with advanced design and execution cloud-based solutions.

The scientific community is primarily focused on digital sciences and research domains involved in the design of large-scale digital infrastructures. It includes, but is not limited to distributed systems, networking, wireless research, interoperability/testing, embedded systems, software engineering, system management, security, reliability, etc.

Benefits and objectives towards the end-users are:

- Equip researchers and practitioners with a wide range of scientific and experimental resources and tools by deploying and operating a large-scale platform providing access to cutting-edge technologies in wireless networking, IoT, and Cloud;
- Offer a wide variety of advanced computing and networking resources in order to respond to the needs of future dynamic systems;
- Provide advanced test tools to ensure reproducibility through an automated data repository and support an open data approach for these communities;
- Build the capacity by strongly contributing to the important education effort targeting both students and engineers.
- Allow the evolution of the infrastructure following users' needs and availability of new technologies

The future generation of platforms is under construction and unfortunately already started in the US and China, with three different initiatives:

- USA PAWR (Platforms for Advanced Wireless Research): NSF + Industry, 2017-2022, 100 M$
- USA Fabric: NSF, 20 M€, 2019-2023
- China CENI (Chinese Experimental National Infrastructure): 2018-2022: 190 M€
- EU ICT 17/19 although more pilot than research: 2018-2020: 152M€

The European Open Science Marketplace, created as a part of services delivered by H2020 EOSChub project, provides catalogue of services available to EOSC and RIs users. This creates a significant step in making European RIs FAIR – findable, accessible and reusable.

However, the future scientific/research infrastructure platform should also ensure services interoperability and provide functionality for services and infrastructure composability and automation realising RI as a Service model (RIaaS).

From the perspective of current DG-Connect investments, it is well understood that infrastructures such as GEANT, PRACE and EGI are not appropriate for experimentation.

As a conclusion, ESFRI provides a Public good approach to facilities like Fed4Fire+. If successful it will be the first ever ESFRI project supporting digital sciences.

4.2 SLICES Support (at the time of writing)

SLICES received support from almost 60 international organisations (government, research and academia, industry, clusters and networks, NRENs), as listed in the table below.

4.3 State of Progress

The SLICES consortium decided to submit a proposal to the call for proposals H2020-INFRADEV-01-2019-2020 in order to prepare a Design Study. The deadline was 12 November.

The main objective of the SLICES Design Study is to adequately design SLICES in order to strengthen the research excellence and innovation capacity of European researchers and scientists in the design and operation of Digital Infrastructures. The SLICES Design study will build upon the experience of the existing core group of partners, to prepare in detail the conceptual and technical design of the new leading-edge SLICES Research Infrastructure for the next phases of the Research Infrastructure's lifecycle.

4 months will be needed from the submission to be informed about the evaluation results and in case of success an additional 4-month period, for the signature of the Grant Agreement with the European Commission. In case of success, the Design Study phase should start around mid-2020.

In parallel, we are preparing the ESFRI Roadmap 2021 call (deadline 5 May 2020). Next steps after submission: the critical questions and invitation to hearings are planned in October 2020, hearings in November – December 2020, ESFRI Forum decision in June-September 2021, and finally ESFRI Roadmap launch in October-November 2021.

5 Supporting Sustainability Options and Recommendations for Investigation

This section contains a number of recommendations for supplementary actions to support the sustainability effort. These have been determined through discussion within the Federation Board and the wider project. They are diverse in nature, and some are more advanced than others, but all contribute to the overall goal of achieving sustainability.

5.1 Consolidating Existing User Bases and Diversification to New Users

Based on evaluations of the profiles of the experimenters and proposers in Section 3.1, we conclude that Fed4FIREplus project is known to the researchers in the ICT field, however its visibility is more limited and its reputation is not widely spread in other scientific or business disciplines, and research communities. Following this key observation our sustainability plan focuses on two directions, trying on one hand to maintain and improve the current momentum within the ICT related field, while strengthening the penetration in other fields, thus improving the federation's positive externality. The two directions refer to:

(a) keeping the federation attractive to ICT researchers of both academia and SMEs, thus still maintaining this area as a core and stable experimenter basis, and

(b) attracting new experimenters from other disciplinaries.

Towards this direction and following the value proposition described in Section 3.1 of D2.03, we identify the following options in order to satisfy three major sustainability requirements, (a) critical mass, (b) cutting-edge technology and (c) financial support.

ICT academic research community. Academia represents one significant component of Fed4FIRE experimenters including graduate and undergraduate students, PhD candidates and researchers. The large number of academic experimenters fulfils the critical mass requirements and improve the visibility of the federation at the international level, and more importantly within the population of young researchers and scientists. In order to keep this momentum and further build on the potentials emerging from this group when they enter the market, the academic users may be provided with free access to the federated resources, while they should strongly be encouraged to contribute "in kind". In cooperation with testbed owners and the federator, the academic community could develop novel services and software extensions that will be integrated within the infrastructure and the federation tools. Furthermore, the academic researchers will be motivated to contribute different sets of data to an open data warehouse, which will be used as a baseline by future experimenters. The latter is further be analysed in the discussion below about the notion of repeatability and reproducibility.

ICT SME community. The federated resources and the associated funding are the major incentives and drivers for SMEs to execute experiments within the project infrastructure. After the end of the project, the basic prerequisite of SMEs to use the federation is the provision of cutting-edge technology in terms of hardware and software. The testbed owners are responsible for continuous upgrading of the infrastructure and this can be achieved using funding from other national and European projects and from future Fed4FIRE experimenters. A flexible fee model can be adapted for SMEs. The calculation of the fees will be based on the number of the reserved infrastructure and the time duration of the experiment. In order to motivate the experimentation with multiple testbeds, a discount could be offered in that case. In parallel with the flexible on-demand billing model, SMEs will be able to pay by donating hardware, services and software extensions similarly to the academic users. This is beneficiary for both testbed providers and experimenters. In this manner, the providers would reduce their CAPEX and SMEs would integrate their solutions with well-known infrastructure and could

invite future customers to test their products through the federation. Furthermore, SMEs will be encouraged to contribute to the open data warehouse of the project and better disseminate the efficiency of their solutions.

Open Data Warehouse. In accordance with the EC's Open Research Data Initiative[3], from Fed4FIRE+'s third open call, the experimenters are encouraged and supported to provide open research data of their experiment and a data management plan. Until now, open data of 15 experiments have been published in the Zenodo repository (https://zenodo.org/). Fed4FIREplus's contributions contribute to this large open data warehouse, and will be an extra incentive for future experimenters to utilize the federation. Apart from raw open data, the data warehouse can be enriched with prebuilt software components that allow the automatic execution of the Fed4FIRE+ experiment. This policy is already adopted by other projects such as 5GINFIRE (https://portal.5ginfire.eu/#!/experiments_marketplace).

With this capacity, the provided open data will satisfy the requirements of the repeatability and reproducibility. Repeatability defines that any researcher should be able to repeat his/her experiment following the same measurement procedure by utilizing the same measuring instrument available via the testbed and perform the experiment under the same conditions. Reproducibility also denotes that other researchers are able to reproduce experiments, which were performed over one or more testbeds, through different locations and utilize different devices to create the same examined topologies and the same conditions. Providing for these requirements means that the federation will offer a solid experimentation environment that contributes towards open and credible science, where users can easily implement and compare their results. In such a way, the reputation of the federation will be increased, and possibly new experimenters will join the federation.

Inviting non-ICT expert Research communities. As it is mentioned above, the profile of experimenters is very "ICT-specific" or "ICT-centric". In order to achieve and ensure the sustainability, non-ICT expert research communities must be invited and attracted to utilize the project infrastructure. Towards this direction, it is a requirement rather than simply a desire, for the federator to simplify the resource selection and the experiment execution for non-expert researchers. At the federation level, the development of novel high-level resource discovery tools will facilitate non-ICT experts to select the appropriate infrastructure for their experiment. With this capacity, the federation should leverage the results of Tasks 3.5 and WP4 and provide and extend information-enriched tools such as semantic resource modelling. At the testbed level, the testbed owners should provide support to non-ICT expert users and help them at the technical design of the experiment. Due to this, a flexible fee model could be adopted, which will include both monetary fee and provision of open research data.

Engage further with the Research Infrastructures Community via ESFRI. The European Strategy Forum on Research Infrastructures (ESFRI - https://www.esfri.eu/) is a strategic instrument to develop the scientific integration of Europe and to strengthen its international outreach. ESFRI encourages Member States and Associated Countries to develop national roadmaps for research infrastructures (RIs), which enable countries to set national priorities and to earmark funds for both national and pan-European RIs. Therefore, ESFRI is the best forum to setup new international collaboration and is directly linked with research organizations of many European countries. Fed4FIRE+ partners have engaged with ESFRI and a significant achievement of this engagement is that ESFRI have recently created a specific domain of Digital experimentation, which directly fits with the offering of Fed4FIRE+, and this will be pursued further, as described in Section 4. In addition to this, it is recommended to engage

[3] Discussed in D2.1 and D2.6. Also see e.g. https://www.openaire.eu/what-is-the-open-research-data-pilot

with specific organisations concerned with RIs so as to promote Fed4FIRE+'s offering and investigate other beneficial collaborations and synergies. Looking at the catalogue of European Research Infrastructure Consortiums (ERIC) under the umbrella of ESFRI, the federation could develop liaison with the following organizations from various disciplinaries:

- CESSDA - Consortium of European Social Science Data Archives, https://www.cessda.eu/.
- ESS - European Social Survey, http://www.europeansocialsurvey.org/.
- SHARE - Survey of Health, Ageing and Retirement in Europe, http://www.share-project.org/home0.html.
- CLARIN - European Research Infrastructure for Language Resources and Technology, https://www.clarin.eu/.
- DARIAH - Digital Research Infrastructure for the Arts and Humanities, https://www.dariah.eu/.
- PRACE - Partnership for Advanced Computing in Europe, http://www.prace-ri.eu/.
- ELIXIR intergovernmental organisation, https://elixir-europe.org/.
- ECCSEL - European Carbon Dioxide Capture and Storage Laboratory Infrastructure, https://www.eccsel.org/about/eccsel-eric/about-eccsel/.
- EU- SOLARIS, http://www.eusolaris.eu/Home.aspx.
- INFRAFRONTIER - https://www.infrafrontier.eu/.
- BBMRI – Biobanking and Biomolecular Research Infrastructure, http://www.bbmri-eric.eu/.
- EATRIS – European Infrastructure for Translational Medicine, https://eatris.eu/.
- ECRIN - European Clinical Research Infrastructure Network, https://www.ecrin.org/.
- Euro-BioImaging - European landmark research infrastructure for biological and biomedical imaging, https://www.eurobioimaging.eu/.
- INSTRUCT European research infrastructure in structural biology, https://www.instruct-eric.eu/.
- EU-OPENSCREEN - European Infrastructure of Open Screening Platforms for Chemical Biology, https://www.eu-openscreen.eu/.
- EPOS - European Plate Observing System, https://www.epos-ip.org/.
- EURO-ARGO - European contribution to the International Argo Programme, https://www.euro-argo.eu/.
- EMSO - European Multidisciplinary Seafloor and water-column Observatory, http://emso.eu/.
- EMBRC - European Marine Biological Resource Centre, www.embrc.eu.
- LifeWatch e-Infrastructure for Biodiversity and Ecosystem Research, https://www.lifewatch.eu/home.
- ICOS - Integrated Carbon Observation System, https://www.icos-ri.eu/.

5.2 Open Access and Commercial Operation

5.2.1 Open Access

The issue of whether experimenters are funded by Fed4FIRE+ in the Open Call programme is critical to the question of sustainability, because:

- The value proposition of Fed4FIRE+ has to be strong enough to warrant experimenters coming to experiment without the inducement of funding; and
- Any continuation funding is very unlikely to contain funding for experimenters – funding is likely to be restricted to the operating costs of the Federator plus (some) testbeds.

The overall conclusion from Section 3 is that Fed4FIRE+ indeed provides value to experimenters, but at the moment the majority of experimenters are funded through the Open Call programme.

Fed4FIRE+ also operates an Open Access programme, where resources are provided to experimenters free of charge, but experimenters' time is not funded by Fed4FIRE+. The Open Access programme is not actively promoted and so currently there is little take up. Anecdotal experience from talking to experimenters in the Fed4FIRE+ Engineering Conferences has indicated that even while the funding is attractive, many experimenters did not know that Fed4FIRE+ has an Open Access" programme, and would consider the possibility of unfunded experiments, especially to continue using Fed4FIRE+ after a funded experiment because they clearly see the benefits of the federation and understand how to use the federation tools and testbeds.

The Open Call programme, where experiments are funded from Fed4FIRE+, actually means that Fed4FIRE+ performs two functions, namely funding experimentation and providing facilities for experimentation. By providing funding, Fed4FIRE+ could be considered as an Innovation Agency that funds innovation projects[4] or as a small research council that provides research funding, but Fed4FIRE+'s value proposition concerns the utility of the tools, facilities and resources upon which to run experiments that may support research or innovation. This duality confuses the issue of sustainability and the value proposition of Fed4FIRE+, making it difficult to discern whether experimenters are coming for the resources and facilities, or for the money.

Experimenters coming via Open Access is an acid test of the value of the federation. In the Open Access programme, experimenters do not have the inducement of the funding for their time to perform experiment funding. Instead, if they come to use Fed4FIRE+, it is because there is clear benefit to them in the testing resources and support. In addition, the most likely operating model for a future Fed4FIRE+ is Open Access where testing resources a provided free of charge to experimenters, but experimenters are not funded by the federation to experiment.

There is therefore a clear benefit to Fed4FIRE+ in increasing the numbers of experimenters for the Open Access programme: evidence of significant numbers of users coming to use Fed4FIRE+ in the Open Access programme would be a compelling addition to the evidence base to support a case for public continuation funding for both the Federator and the testbeds used by the experimenters.

[4] See, for example "NESTA: How Innovation Agencies Work" https://www.nesta.org.uk/report/how-innovation-agencies-work/

There is a challenge with expansion of the Open Access programme, however. This is that the testbeds are not compensated for their provision of resources per experiment in Open Access. Conversely, in the Open Call programme, testbed partners who support an experiment (the so-called “patrons”) receive a payment for their provision of resources and support of the experiment. This gives them compensation for every experiment they support and thus, the best (i.e. most-used) testbeds are rewarded, helping them to grow and giving them a vested interest in providing useful resources and support for experimenters. However, in the current implementation of the Open Access programme, testbeds are not compensated at all for their support of an experiment, so there is no incentive to support experiments outside the Open Call programme.

There are therefore two recommendations to enable greater take-up of Open Access:

- Compensate each testbed who supports an Open Access experiment. The level of funding can be modelled on that in the Open Call programme.
- Actively promote Open Access in dissemination and communication – e.g. “resources are available for free to experimenters”. This is discussed in more detail in D6.04 (Dissemination and Communication).

5.2.2 Commercial Operation

Whilst it is a clear objective that public funding is the primary funding target for Fed4FIRE+, as described in Section 0, there is some evidence of an appetite for Fed4FIRE+ providing commercial services. According to this analysis, the key elements users would be prepared to pay for are access to high-performance, large scale or specialist resources they could not otherwise access; support to set up their experiment; or a provision of a full “Experimentation as a Service”, where Fed4FIRE+ could take over the running of a user’s experiment, doing all the work.

Commercial operation may be investigated as a possible supplementary funding source to the primary target of public funding. Hybrid funding models may also be investigated, where the federation and testbeds are funded by some commercial funding is alongside public funding. There may be added value services provided for commercial customers such as those described above, enhanced support or priority reservation of resources. Any commercial operation should not compromise the pursuit of public funding or the provision of Fed4FIRE+ free of charge at the point of use, because as Principle 2 states, the key operating principle of Fed4FIRE+ is that it should be a public good, for the benefit of European research and innovation.

The independence of Fed4FIRE+ is a valued attribute by the academic community, meaning that Fed4FIRE+ is independent - unfettered by any biases or favouritism that may be the result of commercial concerns, so Fed4FIRE+ is a credible testing / experimentation environment within which to execute experiments with high demands of academic integrity and reproducibility must not be compromised by any commercial interest.

5.3 Compliance with Standards and Regulations

When personal data is processed, Fed4FIRE+ must be compliant with the relevant mandatory regulations such as the GDPR. There is already work in WP2 on GDPR compliance, as discussed in D2.6, and testbeds must be aware of, and be compliant with the GDPR.

Commercial operation will require the highest standards of security. Observation and compliance with security standards such as ISO27001 will help Fed4FIRE+ become competitive in a commercial environment, and in many cases, commercial customers are demanding certification to these standards.

5.4 Fed4FIRE+ Marketing Strategy

The analysis from section 3.2 has shown that Fed4FIRE+ is genuinely useful to experimenters, once they have used it. This value provides evidence when building a case for continuation funding, which is a key sustainability objective.

There is, however a challenge in getting them to use Fed4FIRE+ in the first place. To build a strong case, we need more users coming to Fed4FIRE+ via the Open Access programme, where experimenters get resources for free, but are not funded for their time. This is the acid test of a public good federation of testing infrastructures, as experimenters come because they see clear value in the resources and services provided by the federation.

Based on the evidence that Fed4FIRE+ is useful to experimenters and that many would come without being funded through open calls and the stated objective of increasing the number of Open Access experimenters, our perception is that there is a need to disseminate Fed4FIRE+'s value more clearly and more widely than before. The key point is to target people beyond, as well as, the “usual suspects” (meaning people who know about EC projects, FIRE, NGI, etc).

These factors have determined our primary immediate marketing and communication objective, which is to attract more and diverse users: there is therefore a clear need for marketing analysis to determine additional users, their needs and how Fed4FIRE+ can help them coupled with pro-active, targeted, dissemination of Fed4FIRE+ and its benefits to the users. In the Federation Board meeting of 15 Oct 2019, it was decided to look for and, if necessary to dedicate specific effort to, possible actions to active marketing and associated targeted dissemination of the federation and Federator, with the specific objectives of attracting additional users, especially from outside its usual users, and to build on the existing brand of Fed4FIRE.

The following bullet points contain recommendations for extending the reach of Fed4FIRE+’s communication activities, all with the objective of reaching new and diverse users. These recommendations are developed in D6.04 concerning Dissemination and Communication, but are summarised here. These recommendations should be further discussed within the consortium as some of these might require shifts and transfers of financial means amongst partners and may also result in shifting efforts of some partners in other tasks and activities.

- It is recommended that user types are identified, to understand Fed4FIRE+’s “customers”. Who are they and what are their key needs? How do we reach them?
- It is recommended that the website of Fed4FIRE+ be targeted towards users, rather than as a front page for a project. The website should emphasise the different types of experimentation resource available, for free to experimenters and the simplicity with which they can be accessed (via the tools Fed4FIRE+ has created).
- It is recommended that Fed4FIRE+ orchestrates dissemination messages through multiple, different channels, targeting different user groups, aimed at attracting new experimenters, e.g. by advertising open calls, open access etc, along with the benefits of Fed4FIRE+.
- To provide leadership and management of this work, it is recommended that Fed4FIRE+ considers appointing a Marketing / Outreach Manager, whose responsibility is to coordinate all aspects of marketing and communication from an operational perspective, which is over and above the requirements of standard EC project dissemination. The key objective is to increase users of Fed4FIRE+ in regular

open calls, SME open calls and especially open access[5]. KPI to measure performance: number of new users in the open calls and open access per month. The appointment may be from within one of the existing partners but will be based on an agreed appointment specification, an initial draft of which can be found in D6.04, but can be summarised as

- Determine a marketing strategy for Fed4FIRE+ to be presented to the board
- Undertake a detailed market analysis to understand the value proposition of Fed4FIRE+
- Maintain a list of channels to advertise Fed4FIRE+ open calls and open access
- Seek out new channels beyond the usual channels we always use
- Determine advertising messages and media (e.g. graphics) to attract new users, tuned to target audience
- Monitor the effectiveness of the advertising message and channels

[5] Proposed definition of open access: A user registers on Fed4FIRE+ portal and uses their Fed4FIRE+ ID to access a testbed without support from open call funding.

6 Conclusions

This deliverable has described the approach for sustainability. The key conclusions are as follows.

The Federation should be provided as a public good rather than being run for commercial profit. For this, public funding is needed and is actively being pursued in the form of RI funding, where the target of ESFRI has been identified and is pursued via a scoping design study. Commercial operation may be pursued but must not conflict or compromise Fed4FIRE+ operating as a public good. Currently the focus is on public funding rather than commercial funding.

For public funding, evidence is required to support the case for the award of funding. There is therefore a key requirement to build an evidence base. In this deliverable, this has taken the form of analysis of user types, user feedback and testbed status. The overall conclusion is that Fed4FIRE+ provides genuine, unique value to experimenters, where the highest valued aspects are that Fed4FIRE+ provides a real environment for testing, the support provided by testbeds, the tools that enable easy setup of experiments, access to resources they cannot access otherwise. The evidence base will evolve and grow as further experiments take place and additional feedback is gathered, so it is a major item of further work to continue analysis of the experimenter feedback. The evidence base will be used to support cases for continuation funding, such as the ESFRI application discussed above.

To contribute to the evidence base, Fed4FIRE+'s Open Access programme needs to be promoted. Open Access is the acid test of the federation: here, experimenters are not paid but come because they see value in the resources, tools and support offered by Fed4FIRE+. If Fed4FIRE+ can attract significant numbers of Open Access experimenters, this is convincing evidence of its value and therefore will support a case for continuation funding.

To promote the federation, (especially Open Access), Fed4FIRE+ should enhance communication and dissemination to existing and new user groups with the intention of recruiting more users. It is recommended that a marketing / outreach manager be appointed to coordinate this.

Overall, the work reported in this deliverable contributes to the sustainability objective of Fed4FIRE+ as a public good as described in the following figure.

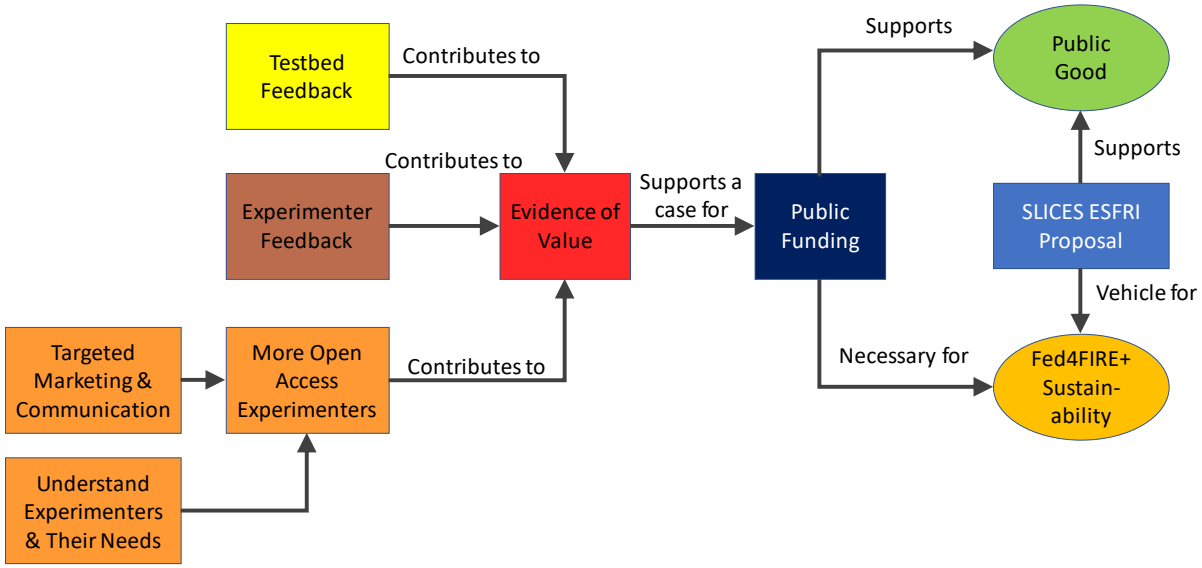


Figure 23: Fed4FIRE+ Sustainability Structure