Project Acronym	**Fed4FIRE**
Project Title	**Federation for FIRE**
Instrument	**Large scale integrating project (IP)**
Call identifier	**FP7-ICT-2011-8**
Project number	**318389**
Project website	**www.fed4fire.eu**

D2.12 – Third sustainability plan

Work package	WP2
Task	T2.3
Due date	31/03/2015
Submission date	17/04/2015
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Version	1.0
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Abstract	This deliverable focuses on the complex landscape regarding sustainability within FIRE, considering the need for a federation (its added value), what we could offer (service portfolio), how much it will cost to offer (the total cost of ownership for Federator and facilities) and how to finance it (potential funding models).
Keywords	Sustainability, federation, value proposition, services, cost/benefit model, business scenario evaluation, funding models

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

The growing complexity of the Future Internet landscape has driven the need for large-scale federations of experimental testbeds that support the next generation of research and experimentation. However, such facilities are typically difficult to sustain in the long term, particularly in the transition from a publicly funded development to a self-sustaining operation. Fed4FIRE is a cross-domain federation of Future Internet testbeds that seeks to lower the barrier to complex experimentation.

The goal of this deliverable was to present our view on the FIRE environment, how our federation benefits that environment (its value proposition), what it could offer (the services), how much it costs (total cost of ownership for the Federator to offer its services, as well as the TCO for the testbeds to implement it), and options to fund all of this. This deliverable builds further upon the work presented in the previous deliverables D2.3 and D2.6.

The federation of testbed facilities has been defined as "*a collection of multiple independent testbeds that can be coordinated in different ways for the creation of rich, multi-functional environments for testing and experimentation; and has clear benefits for its main stakeholders - experimenters, and facility providers.*" The main value proposition towards experimenters is presented through key features delivered by the operational federation, including choice among testbeds, combination of (heterogeneous) testbeds, ease of access (single point of contact, lower barrier of entry), scalable facility (capacity and functionality) and various benefits through its added-value services and tools. Since the last iteration of the sustainability series (D2.6), effort was made to further validate, refine and prioritize this value proposition. This analysis was conducted as conclusion of Open Call 1, where the experimenters were surveyed in order to provide feedback about the perceived federation's value proposition. For Open Call 2, proposal experiments were requested to evaluate characteristics needed by the federation, as well as the perceived value of these characteristics. A differential analysis between SMEs, industry partners and academic research institutes was conducted to refine the federation's future marketing towards additional experimenters and testbeds.

Feedback from the SME experiments was similar to that of the larger Open Call 1. However, areas such as ease of use, barrier of entry and technological/organizational support rose in importance for SMEs. The heterogeneity of testbeds, affordability of access, repeatable use for their experiment, and reduced time-to-market were the top priorities. SME's need to be efficient and have much less margin for lost productivity and overrunning setup costs when compared with their larger counterparts. More apparent is that, unlike some large tech companies and research institutes, SMEs often lack access to a sufficient testbed infrastructure, let alone a single point access to a federation of testbeds recreating diverse deployment environments. The value of a single stop for choice helps alleviate the overhead in discoverability and difficulty of comparison. Their objective is always quality products and time-to-market, where first-mover advantage is key. Larger industry proposals were similar to their smaller SME counterparts, but prioritized higher longer-term strategic value that did not necessarily generate immediate ROI, such as access to a wider community of experimenters; and larger control, such as service level guarantees and more fine-tuned resource management tools. Research and academic institutions looked to go beyond lab environments with more extensive support, documentation and management tools to do so, without the same time-to-market pressure and pace than their SME and large industry counterparts.

A survey in early 2015 was dedicated to the Fed4FIRE testbeds, addressing a wider range of technical and sustainability related topics, including how much added value they saw being part of the federation. All the testbeds referenced the access to new users as a top benefit and rationale for joining such a federation, including the visibility, accessibility and added support services to make the testbed more competitive for experimentation. The second most referenced benefit were that of new functionalities, where Fed4FIRE tools have improved the value of the testbed service, making it more attractive to users and better able to adapt to new requirements and scale. Finally, some select testbeds highlighted the optimization and increased efficiency of operation (OpEx) in their infrastructure, due to adoption of Fed4FIRE federation management tools.

Next we furthermore built upon the detailed analysis of potential services, presented in the previous deliverable D2.6. First an overview of the potential service portfolio is presented, enlisting its components and the added value for offering it. We refer then to the minimal service components that should be offered to by the testbeds. The detailed descriptions of the technical components are described in D2.7.

Based upon this service analysis, a total cost of ownership analysis is made and presented in section 4. The Total Cost of Ownership (TCO) is a metric to define and analyse the overall cost of keeping a product or service up and running. A TCO analysis includes total cost of acquisition and operating costs. An analysis has been made to estimate the total cost of ownership for the Federator, the organization that will operate the federation after the end of the project. We estimated that for sustaining the current set of facilities, around 4 full time equivalents per year, spread out over a number of people, should be sufficient to run the federation, whereby we included support for tools and components for the facilities, technical support towards the experimenters, promotion and business support and effort for managing the Federator and federation. We calculated the cost for adding new testbeds to the federation. The effort required will depend on the type of facility, ranging from several days (for facilities with comparable setups as already available in the federation) up to 3 person months (for complete new types of testbeds). We also indicated how the TCO could scale when more experiments will be conducted. Next to this TCO analysis for the Federator, we analysed the effort required for the different facilities to implement the components requested by the federation. This estimation is based upon valuable input from the different partners. An indication is given on the effort required to install, support or upgrade each component. For the majority of testbeds it ranges between 4 and 8 person months for an initial installation. The effort highly depends on the starting point and complexity of the infrastructure. This analysis will be extended and validated in the upcoming work, where we will consider the impact of additional components (cost for implementation and support versus added value) for the Federator and testbeds.

The environment context and the need for sustainability within FIRE was analysed. There is a particular challenge associated with the way that facilities for conducting experimentation are funded in the existing FIRE program. To address this, we need an established mechanism for EC funding of experimental facilities, and their federation. Within this deliverable, an in-depth analysis is made how the different Fed4FIRE research infrastructures are currently funded. Different financial scenarios are worked out and discussed, considered from the point of the EC, how the Federator and FIRE testbeds could financially be supported. A first list of recommendations is proposed to the European Commission and other European entities.

Acronyms and Abbreviations

AM	Aggregate manager
CapEx	Capital Expenditures
CSA	Coordination and Support Actions
EC	European Commission
EU	European Union
FIRE	Future Internet Research and Experimentation
FLS	First Level Support
FP7	The Seventh Framework Programme (2007 – 2013)
FTE	Full Time Equivalent
H2020	Horizon 2020
ICT	Information and Communication Technology
IP	Internet Protocol
IT	Information Technologies
KPI	Key performance indicator
OC	Open Call
OML	ORBIT measurement library
OpEx	Operational Expenditures
PM	Person month
QoE	Quality of Experience
R&D	Research and Development
SLA	Service Level Agreement
SME	Small and Medium Enterprises
SPoC	Single point of contact
SSH	Secure Shell
SWOT	Strengths, Weaknesses, Opportunities & Threats
TCO	Total cost of ownership

Table of Contents

1. Introduction 9
1.1 Background information 9
1.2 Goal and structure of this deliverable 10
1.3 Contribution to the project objective 11
2. Value offered by the federation 12
2.1 Our definition 12
2.2 Value proposition and stakeholder feedback 12
2.2.1 Experimenter Value 13
2.2.2 Testbed Value 16
3. Potential service offering by the Federator 17
3.1 Service portfolio 17
3.2 Service offering 22
3.2.1 Minimally supported 22
3.2.2 Options 23
4. Total Cost of Ownership 24
4.1 TCO for the Federator 24
4.1.1 Cost for supporting existing facilities 24
4.1.2 Cost for adding new facilities to the federation 25
4.1.3 Scaling the Federator 26
4.2 TCO for the testbeds 28
4.2.1 Minimal requirements 28
4.2.2 Optional components 31
5. Potential funding scenarios 33
5.1 The environmental context 33
5.2 Current situation 34
5.2.1 Current stakeholder funding model 34
5.2.2 The Fed4FIRE model 36
5.2.3 Validation and comparison 37
5.3 Potential models for future funding 41
5.3.1 How could the different stakeholders be funded 41
5.3.2 Scenario 1: Experimenter centralized model 43
5.3.3 Scenario 2: Structural Federator and testbed funding 44
5.3.4 Scenario 3: Federator centralized model 46

5.3.5 Scenario 4: Combining project based and structural funding 47
5.4 Criteria and incentives for allocating funds 48
5.5 Recommendations 50
6. Conclusions and future work 52
References 54

1. Introduction

With the growing interest in the area of Future Internet and the related demand for ever more complex experimental facilities to test and validate new concepts, technologies protocols, software, … there is a strong requirement to set up a sustainable federated infrastructure which groups available and new facilities within the FIRE community. This federated structure of experimental facilities should cover a broad range of technologies:

- to ensure the latest cutting-edge facilities are available to a large number of both experienced experimenters as well as new players in the field and both to industrial partners, SMEs and research institutes
- to offer centralized services and minimize operational costs and
- to create a sustainable solution to continually generate value and impact beyond the original funding.

The objective of the Fed4FIRE-project is the creation and maintaining of such a sustainable federated infrastructure for experimental facilities in the area of Future Internet. One of the activities within the Fed4FIRE-project is therefore aimed at bringing together the requirements, knowledge and competences of different stakeholders within the FIRE scene [1] to collaborate and set up this federated platform.

In this task we explore options on how to sustain such a federation of experimental facilities in order to serve the needs of both experimenters (as users) and testbeds (as providers) in the area of Future Internet. A complex value network of different types of stakeholders must be managed. The big challenge is to define the value for all stakeholders, and to incorporate their interests in order to make sure they all clearly benefit from this federation.

This document focuses on the complex landscape regarding sustainability within FIRE and potential beyond; the need for the federation (its added value), what we could offer (service portfolio), how much it will cost to offer (the total cost of ownership for Federator and facilities) and how to finance it (potential funding models).

1.1 Background information

In earlier work (Fed4FIRE D*eliverable D2.3 (First sustainability plan)* [2]) we defined a federation of testbed facilities as “a collection of multiple independent testbeds that can be coordinated in different ways for the creation of rich, multi-functional environments for testing and experimentation and that has clear benefits for its main stakeholders - experimenters, and facility providers”. This definition was supported by a thorough literature review on the current status, and sustainability and exploitation plans from other federation projects within and outside FIRE.

Current and potential future stakeholders within the FIRE landscape were identified. Amongst these, we considered the experimenters and facility providers to be the main stakeholders besides the Federator (the organization responsible for operating the federation). Others, such as end users, funding bodies and policy makers, software developers and suppliers of infrastructure and services, and research initiatives also play an important role and will affect the value network.

An initial list of potential services to be offered to experimenters and the facilities that could be offered by the federation was provided and an indication of the cost model methodology was shown. Starting from the value proposition, five business scenarios were defined, ranging from the “Invisible Coordination” up to the “Integrator” scenario. In order to analyze the scenarios in a structured way, we created an evaluation checklist.

Deliverable D2.6 (Second sustainability plan) [3] explored insights in the differing values experimenters and testbeds see from the Fed4FIRE federation. Our value proposition towards experimenters would include a choice of testbed resources, combination of different facilities, easy access, continuous innovation of available resources and availability of tools. The facilities, themselves, mostly value the potential access to new users, promotion and advertisement of their facilities, and tools and assistances. Next we presented the different services that our federation could offer. We made use of the FitSM service IT methodology in order to describe the service components, estimate of the cost to provide for Federator and facilities, and added value towards experimenters and facilities. This information was the basis for describing different business scenarios, where cost/benefit trade-offs were made. A cost/benefit model has been created in order to support this task. A first evaluation of a potential federation business scenario was presented.

1.2 Goal and structure of this deliverable

We are concerned here with how to sustain the federation of testbeds. We see two major types of participant in the federation:

- The experimental facilities (testbeds)
- The Federator (who enables the federation)

Together these make up the federation, and both types of participant need to work together to provide useful experimental facilities for experimenters, who are in effect the “customers” of the federation. The facilities provide individual experimental services, and the Federator adds value to this in a number of ways by offering:

- Greater choice for experimenters
- One place to go to get a wide choice of testbeds
- Ease of access to a wide choice of testbeds
- A single experiment can be run using multiple testbeds

Our concern in this deliverable is sustaining the federation, and by this we mean sustaining the Federator and looking for opportunities to sustain our stakeholders, the testbeds upon which experiments can be conducted. There is a critical dependency in this federated situation: the Federator, and therefore the whole federation, is dependent on the reliable existence of experimental facilities. Without testbeds, there would be no need for federation and therefore no Federator. Hence, in addition to the sustainability of the federation and Federator, we must be concerned with the reliable sustainability of experimental facilities. This is discussed in Section 5.

Section 2 presents the value offered by the Federator. This analysis focused on the value offered to the testbeds and experiments is based upon detailed information gathered from the Open Call proposals and Open Call experimenters in the project.

The potential service portfolio is presented in section 3, indicating per service components the added value for our stakeholders. We indicate what we minimally should sustain and list the optional components that could furthermore be considered for offering depending on the potential uptake of the facilities.

Based upon this selection of minimal components, a total cost of ownership calculation is shown in section 4, where the cost and effort estimation for the Federator is split up in three parts: cost for supporting the existing set of facilities, additional cost for adding new testbeds, and the evolution of effort requirements for coping with an uptake of experiments in the future (economies of scale). As the individual testbeds also have to make changes to their facilities in order to become compliant, a TCO analysis for them is presented, where we indicate the effort required for each component to install, upgrade and support.

Section 5 focuses in more detail on the long-term financial sustainability after Fed4FIRE and the European Experimental Infrastructures, as was requested during the last review meeting. The probability of covering TCO through monetization of experiments by the industry is very low, as only a small part of the federation cost can be supported that way. We start by analyzing the present situation, with an in-depth analysis how the different Fed4FIRE research infrastructures are currently funded. Next we present all options how to cover the Total Cost of Ownership (TCO) for the Federator, but also for its stakeholders. Different financial scenarios are worked out and discussed, considered from the point of the EC. A first set of recommendations is proposed to the European Commission and other European entities.

Finally, this document also provides initial recommendations, conclusions and next steps.

This is the third deliverable of this task. Our methodology and results will be refined during the remainder of the project when more information becomes available. The FIRE landscape is a vast, complex and dynamic environment therefore we realize that this is a continuing exercise to capture the essence of sustainability in the context of a federation model after Fed4FIRE. As we continue to learn and gather new insights and results from other FIRE projects and the project's reviews, our work plan can be altered to respond to these changes and opportunities.

1.3 Contribution to the project objective

The major goal of this task is to understand the sustainability requirements, build the business scenarios and identify technical constraints to obtain a sustainable, federated Future Internet experimentation facility in Europe. Different subtasks have been identified and are described below.

Clear understanding of what sustainability means

Within this task we study the different aspects of sustainability, based on inputs from the different stakeholders and common practices in other areas of ICT research infrastructures. Also, the work performed in other FIRE projects is taken into account and links are established with the CSA project AmpliFIRE [4]. This subtask will contribute input to *Task 8.3 "Sustainable standardization"*.

Business models

Business models are developed, focused on certain scenarios, depending on the type of experimenter and facility provider. A clear value proposition needs to be developed. A cost model has been built for the Fed4FIRE federation, by identifying and quantifying all costs involved in setting up, maintaining, developing and managing the different service components that the federation could offer. An indication of the potential costs for, and benefits to, an individual testbed when joining the facility is given. A challenge will be to find a sustainable balance of funding for supporting the federation in its upcoming long term activities, considering a stable service development, operation and management, and dealing with the ability of (FIRE) facilities to join and leave the federation in a flexible way. Results of this subtask will contribute to *Task 2.4 "Federation Board"*.

Input to the architecture

Input will be provided to the *architecture task (Task 2.1)* in order to take into account technical constraints that are derived from sustainability requirements. Examples are requirement to have an open architecture that is capable of supporting different experimenter communities, being able to reuse existing components, allowing easy adaptation and enhancement of existing infrastructures, providing building blocks for new research infrastructures, allowing easy access to the facilities for the experimenters, providing support for facility management by the facility owners.

2. Value offered by the federation

The FIRE environment has a large potential for continuing to help European researchers in creating innovation, by decreasing the learning curve for experimenters and lowering the threshold in accessing the testbeds by offering them tools and technical support and a wide range of testbed resources. An extra value and an extra help in creating a sustainable landscape of testbeds, is the creation of a federation of testbeds. This section of the document identifies the role of the federation and its Federator regarding sustainability of testbeds.

2.1 Our definition

As outlined before, we defined in earlier work [2] a federation of testbed facilities as "*a collection of multiple independent testbeds that can be coordinated in different ways for the creation of rich, multi-functional environments for testing and experimentation; and has clear benefits for its main stakeholders - experimenters, and facility providers.*"

The added value, which can be offered by this federation, is based on the role the Federator can play as technical coordinator by helping heterogeneous facilities becoming more homogeneous by simplifying experimentation setup, execution and evaluation, and by providing tools and support for the experimenters. This "broker" will clearly help the European Commission in sustaining the FIRE testbed portfolio.

The components of our value proposition for both testbeds and experimenters have been evaluated with our stakeholders, and is presented in the following sections.

2.2 Value proposition and stakeholder feedback

Out of earlier work (D2.6) a summary is picked up of the value proposition of Fed4FIRE towards experimenters and testbeds, both of which are critical to the success of a sustainable federation (Figure 1).

Since then, Task 2.3 has surveyed the project's experimenters and testbeds to analyze, prioritize and better focus its delivered value. The larger objective of these surveys was to refine the sustainability model behind the post-project federation and prioritize its tools and services offered on top of the underlying testbeds. As a side-benefit, this feedback analysis of perceived value is also useful in influencing the stakeholder engagement, communication and marketing activities of the Federation Board (see also D2.13 [5]).

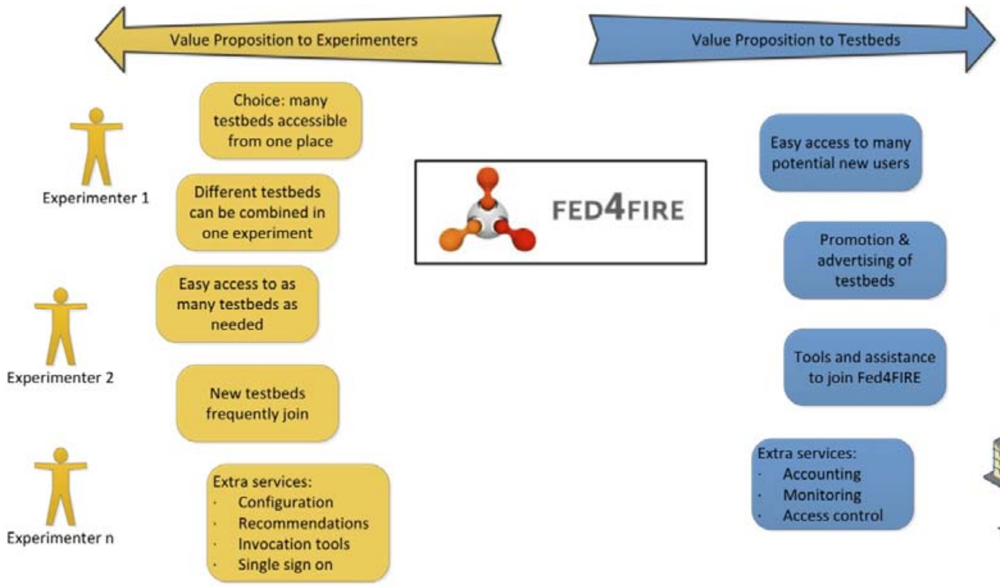

Figure 1: Value proposition towards its stakeholders

2.2.1 Experimenter Value

The initial value proposition for experimenters was considered as follows:

- **Choice among Testbeds**: Easier discovery and comparison of diverse testbeds. Heterogeneous testbeds and their environments provide a larger capacity and differentiation for experimentation.
- **Combination of Testbeds**: Combining multiple testbeds for a single, ambitious experiment. The federation of these testbeds is a unique value proposition that individual testbeds are unable to replicate.
- **Ease of Access**: Single access point eases the barrier of entry, increases deployment & testing efficiency and accelerates time-to-market for commercial experiments.
- **Scalable Facility**: A federation that is scalable in both capacity and functionality, adding new testbeds to the interconnected facility and providing new environments for innovative experiments.
- **Added-Value Services:** On top of the federation of testbeds is a variety of tools and services created exclusively to enable and facilitate single- or multi-testbed FIRE experimentation.
- **Support:** In a federated set of less heterogeneous testbeds, a guaranteed support and documentation is easier to set up and maintain lowering the threshold for accessing the testbeds by newcomers and smaller industry.

Surveys amongst the Open Call experimenters yielded some extra information, which allowed us to further validate, refine and prioritize Fed4FIRE’s value proposition.

Open Call 1 Surveys:

During the execution of Open Call 1 experiments, ongoing communication with the experimenters helped scope the value proposition through their eyes (see also D2.6). To continue this feedback, upon the conclusion of Open Call 1, within their final reports experimenters were also surveyed to provide feedback to the federation’s value proposition.

The following conclusions can be drawn for the value perceived by experimenters:

- *Ease of Access*: Experimenters responded that they had initially underestimated the setup time of their experiment, and to a lesser extent, the administrative overhead of their FP7 involvement. They valued ease of access, and suggested additional activities such as workshops, better tutorials, and a single point of technical support and documentation. Since then, Fed4FIRE has prioritized and developed these support activities.
- *Choice and Combination of Testbeds*: When asked if they would have been able to run an experiment of such scope without Fed4FIRE, all responded that they couldn't, whether single- or multi-testbed use. Some experimenters, such as larger tech. companies, said that they could run a significantly downsized experiment, resembling a limited validation activity but with significant sacrifice to quantity and quality of results. Other experiments, in particular some academic organizations and SMEs, responded that they did not have the CapEx or infrastructure to carry out their experiment.
- *Scalable Facility and Added-Value Services*: When looking towards the future prospect of continued use of Fed4FIRE experimentation and related services, the majority of experimenters responded positively, depending on the sustainability model and costs involved. They validated the core value proposition of the federation (e.g. single access point to a scalable, heterogeneous collection of testbeds), and highlighted added-value features and qualities of the future offering that they deemed most useful, including first-level support, federation management tools with compatibility/support across testbeds, and potential consultancy services.
- *SME perspective*: Feedback from the SME experiments was similar to that of the larger Open Call 1. However, areas such as ease of use, barrier of entry and technological/organizational support rose in importance for SMEs. SME's need to be efficient and have much less margin for lost productivity and overrunning setup costs when compared with their larger counterparts. More apparent is that, unlike some large tech. companies and research institutes, SMEs often lack access to a sufficient testbed infrastructure, let alone a single point access to a federation of testbeds recreating diverse deployment environments. The value of a single stop for choice helps alleviate the overhead in discoverability and difficulty of comparison.

Open Call 2 Survey:

For Open Call 2, proposal experiments were requested to evaluate characteristics needed by the federation, as well as the perceived value of these characteristics. A heat map is provided below (Table 1) representing priorities (H = high priority; M = medium priority; L = low priority) per SME, industry and research/academia institution. It should be noted that the survey is not weighted equally between profiles. SMEs outweigh larger industry experiments significantly in number.

Table 1: Open Call 2 - Value heat map

Open Call 2 Proposals' Value Heat-Map (red, orange and yellow in order of most important to least)	**SMEs**	**Industry**	**Research Institute & Academia**
… have access to a large and ideal set of different technologies (sensors, computing, network, etc.), provided by a large amount of testbeds. This way I can experiment with edge technology in all current research trends.	H	M	M
… have access to resources that otherwise would not be affordable.	H	H	M

… have access to testbeds that are geographically distributed.	L	L	M
… the user experience is that I only have to deal with a single service provider (i.e. single point of contact and service) instead of dealing with each testbed on my own. This relates to many aspects of experimentation such as authentication, learning about available resources, reserving those resources, controlling them during the experiment, getting the results out of your experiment, hiring training services, getting support, etc.	M	H	H
… can experiment using a small set of common well-documented experimenter tools. This brings me several benefits: simplicity (since those tools can hide many of the testbeds' complexities), a single federated interface, a uniform input/output from different systems, and allows me to use a single user account while experimenting with resources over all these different testbeds. All these benefits result in a lower entry barrier, allowing me to experiment quickly, without investing much effort in learning how to work with a plethora of different tools for the different testbeds.	M	L	H
… can reduce the effort required to experiment and hence to take my product to the market (since the federation provides me easy access to the resources at the different testbeds, and user-friendly experimenter tools as described above).	H	H	M
… have access to a wider experimenters community. This leads to a greater impact of results, shared dissemination and the possibility to share experience and knowledge with other experimenters.	L	H	H
… acquire new competences to, e.g., optimize my solutions. This way I can increase my own technical scope and competeviness.	M	M	M
… have a trustworthy environment for my experiments: my data is protected and the privacy of me and my experiment is guaranteed.	L	M	L
… can experiment in a controlled environment where experiments are repeatable. This allows the thorough execution of performance assessments and allows easy comparison of results.	H	H	L
… feel that I pick what I need beyond my initial ideas because of the greater choice in facilities and resources, which leads to greater inspiration (supermarket effect).	L	M	L
… can experiment in a unique environment for experimentation that goes beyond the lab environment and enables real world implementation.	M	M	H
… have the support I need to successfully complete my experiment: the federation provides a federation-wide First Level Support Service (hotline), and I can get in touch with the experts of every testbed using the same mechanism.	M	M	H
… have service level guarantees concerning the facilities used in my experiment (availability during my experiment, incident solving time,…)	M	H	M

For SMEs the heterogeneity of testbeds, affordability of access, repeatable use for their experiment, and reduced time-to-market were the top priorities. This largely corresponds with the conventional wisdom that SMEs, with limited access to CapEx, highly value the accessibility and affordability of a federated testbed infrastructure that they cannot replicate themselves. Their objective is always quality products and time-to-market, where first-mover advantage is key.

Larger industry proposals were similar to their smaller SME counterparts, but prioritized higher longer-term strategic value that did not necessarily generate immediate ROI, such as access to a wider community of experimenters. They also focused on larger control, such as service level guarantees and more fine-tuned resource management tools.

Research and academic institutions looked to go beyond lab environments with more extensive support, documentation and management tools to do so, without the same time-to-market pressure and pace than their SME and large industry counterparts.

2.2.2 Testbed Value

The initial value proposition for testbeds is considered to be as follows:

- *Easy Access to Users*: By participating in the federation, each testbed can reach a wider numbers of users, expanding their "customer base".
- *Promotion & Advertising of Testbeds*: The federation is an additional channel to each testbed, meaning they can continue with their core base of users, and exploit the federation for wider visibility and introduction to new communities.
- *Tools and Assistance to Join Federation*: Tools, services and support activities by the federation facilitate the barrier of entry for new testbeds, improving the cost/benefit analysis of joining.
- *Added-Value Services*: Testbeds can increase their functionality with the federations' tools and services, in some cases either increasing operational efficiency (OpEx) or the cumulative value of the testbed (in terms of capacity, functionality and adaptation to new requirements/users).

Testbed Survey

A survey in early 2015 was dedicated to the testbeds, and addressed a wider range of technical and sustainability related topics. A part of this feedback was an open-ended question related to perceived value proposition of the federation: *"How much added value do you see for yourself when having installed the Fed4FIRE components (e.g. cost savings, attracting new customers, new functionalities)?"*

The testbeds unanimously referenced the access to new users as a top benefit and rationale for joining such a federation, including the visibility, accessibility and added support services to make the testbed for competitive for experimentation.

The second most referenced benefit were that of new functionalities, where Fed4FIRE tools have improved the value of the testbed service, making it more attractive to users and better able to adapt to new requirements and scale.

Finally, some select testbeds highlighted the optimization and increased efficiency of operation (OpEx) in their infrastructure, due to adoption of Fed4FIRE federation management tools.

3. Potential service offering by the Federator

The existence of a Federator is justified by the provision of benefits to its main stakeholders, experimenters and testbeds. These benefits are the result of a set of services provided by the Federator to each of them. This section lists the potential services the Federator could offer to justify its existence. It is key, within this task of the project, to make the trade-off between the cost to offer, and added value for the different stakeholders. The services analysis in Fed4FIRE makes use of FitSM, an IT service management methodology designed by the FedSM project [7].

This section provides first an overview of the potential service portfolio, enlisting its components and the added value for offering it to our stakeholders. In a next step, we compose a minimal service offering to be offered by the Federator and supported by the testbeds. A total cost of ownership analysis, based upon this analysis, is conducted and presented in section 4.

3.1 Service portfolio

We have defined in our previous work our core service as "*Make it simple to find, use and combine IT testbeds such as FIRE testbeds, to support research.*" Services were categorized based on two criteria: the user of the service (experimenters and experimentation facilities) and the importance of the service (core and supplementary services). Core services are considered as a capability expected by end users. Additional or supplementary services are considered as nice to have.

The federation focuses on the provisioning of the core service components but could also implement certain optional services components. It is key to grasp the benefits of a service and to understand how the delivery of a service will contribute to the cost of a running federation, as well as the potential for revenue generation. Some services may have a large added value but only cost a little to be delivered while for others the opposite may be true. However the choice for supporting those components should depend on experimenter and testbed demand and adoption potential.

The potential service components, identified within D2.6, are presented in Figure 2. For each component, the value for the experimenter and testbed is described (Table 2). Section 4 focuses on the cost to offer these components. For a more detailed description and analysis of the service components, see D2.6 [3] and D2.7 [8].

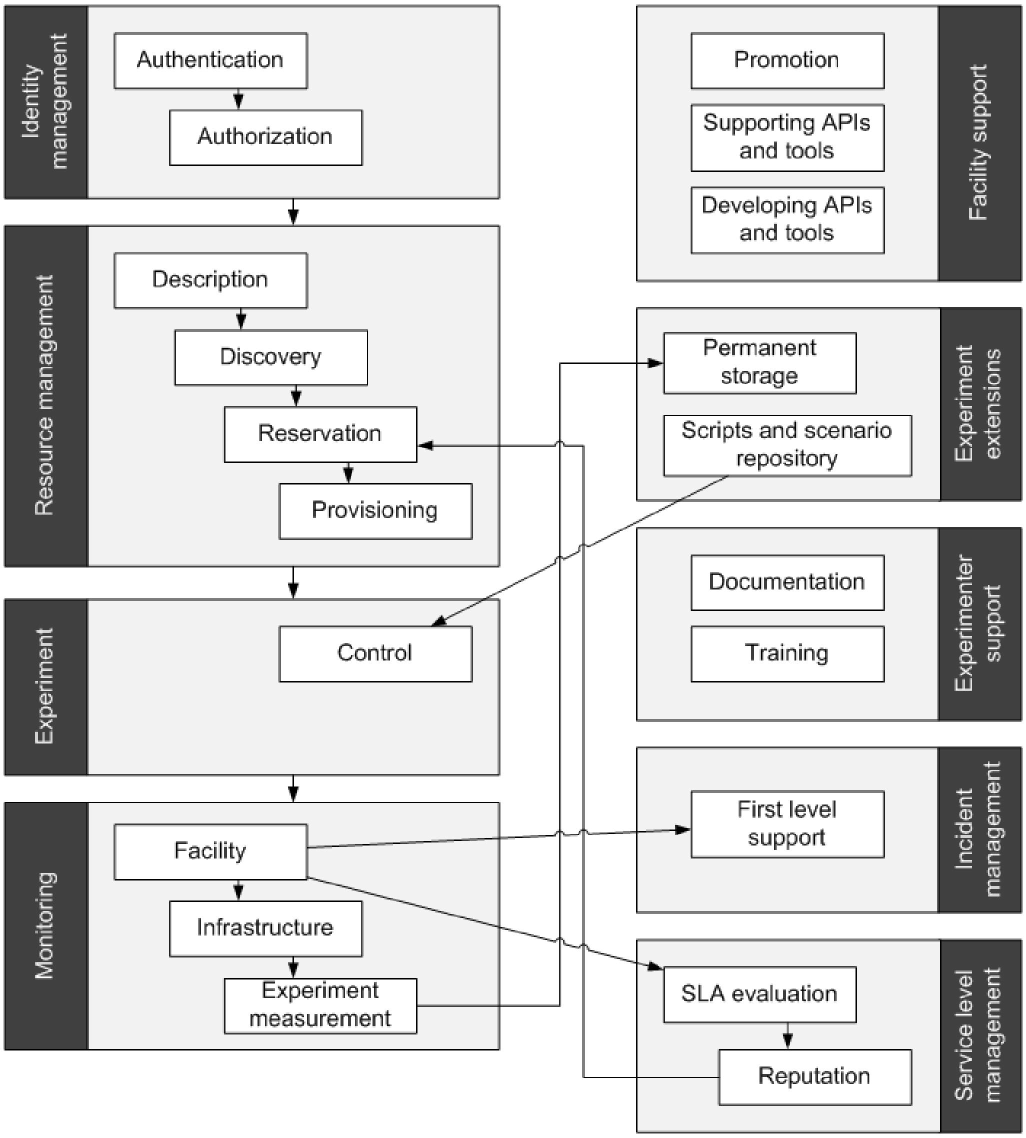

Figure 2: Overview service components

Table 2: Service components - added value for experimenter and testbeds

		Added value experimenter	Added value facilities
Identity management	**Authentication & authorization**	Central login – ease of use – one account – directly linked to what he can use depending on his type of account (quota)	Reduced operational activity Centralized administration, increased customer base when linked with other authentication registries, ...
Resource management	**Resource description and discovery**	Discovering all resources in a centralised manner is easy and a benefit to the end user (instead of fragmenting resources across different facilities that the experimenter has to visit independently).	The unified listing of resources can promote the usage of certain facilities that were not initially planned for an experiment.
	Resource reservation	Direct reservation of resources is a necessity. Advanced reservation is useful when for scarce resources or resources of which demand is very high, or when there are timing constrains such as education or for training purposes involving a large number of interested experimenters.	Advanced reservation is mostly useful when demand is very high. Most facilities have currently today no capacity issues. When focusing on specific target groups e.g. education, for which such component is very valuable, increased usage of the testbeds will be an added value for them.
	Resource provisioning	Provisioning of the requested resources is fundamental for experimentation. It gains more value for more sophisticated experiments (e.g. orchestrated provisioning across different facilities).	Facilities have their own provisioning mechanisms. However within the context of a federation, this should be coordinated in a standardized manner.
Control	**Experiment control**	This is a basic functionality the experimenter is expecting. When orchestrated in a centralized way (one script that commands nodes in different testbeds, or visually changing configurations), this becomes even more valuable.	There is no special benefit in providing this information as far as testbeds are concerned, apart from trust aspects that might affect reputation.
Monitoring	**Facility monitoring**	Experimenters need to know when a testbed is not running. One centralized point for all information, rather than distributed among the test-beds.	There is no special benefit in providing this information as far as testbeds are concerned, apart from trust aspects that might affect reputation. This is needed for providing basic support towards the experimenters. Reputation might increase when delivering this information to a centralized point.
	Infrastructure monitoring	The added value will depend on type of experiment(er) and the necessity of this information related to the experiment	There is no special benefit in providing this information as far as testbeds are concerned, apart from trust aspects that might affect reputation. Can be an added value feature for the facility to offer more detailed information towards the experimenter.

	Experiment measuring	The level of detail can depend on type of experiment(er). If this information is gathered centrally, and synchronized, a more detailed and quicker view on test results and correlations between effects on different testbeds could be detected.	There is no special benefit in providing this information as far as testbeds are concerned, apart from trust aspects that might affect reputation. Can be an added value feature for the facility to offer more detailed information towards the experimenter.
Extended experiment services	**Permanent storage**	This depends on the experimenter's requirements and own storage means.	Facilities do not gain much value from this central component.
	Repository of experimenter scripts	Reuse of existing experiment settings, scripts, etc. Reproducibility of experiments	There is no special benefit for facilities, unless the experimenters allow facilities to share these pieces of development with other experimenters. In that case, testbeds would increase in popularity as these shared.
Experimenter support	**Training**	This eases the life of the experimenters and helps them becoming familiar with federation concepts, resources and tools as well as inspiration for experiments.	This helps promote facilities. Tutorials provided will indicate the added value of the facility towards new experimenters.
	Documentation	Documentation is very important in order to guide the experimenter through the interaction with the federation resources and tools	This helps promote facilities and contributes to reputation aspects.
Incident management	**First Level Support**	FLS is an important support tool that eases the interaction of the experimenter with the federation. This can be augmented with secondary more detailed technical advice.	Facilities can benefit from the federated support and reduce their own support effort.
Service management	**SLA management**	Experimenters can benefit from service guarantees, above all if compensation is applied in case of failure. The amount of added value will depend on type of experiment(er)	SLA agreements may also help facility providers protect their infrastructure against potential abuse, misuse or damages introduced by experimenters by establishing a trust framework including rights and obligations of all parties involved in an experiment.
	Reputation service	The experimenter may receive very valuable information concerning the testbeds' performance and could give feedback to facilities and federation about this.	This component contributes to trust. Based upon quality of experience (QoE) information of the experimenter, the facility could furthermore adapt its service delivery depending on the experimenters' expectations. When the facility is trusted, it has a positive effect on its usage by experimenters.

Facility support	**Promoting experimentation (and facilities)**	The experimenter can be aware of existing testbed facilities and their perceived performance within the community, resources, possibilities for experimentation, tools but also the conditions how to perform these experiments within the proposed boundaries.	This contributes to self-promotion and trust. The Federator can increase the exposure to the FIRE community if it acts as a representative for its stakeholders. For each individual facility it is not possible or economically optimal to be present at every relevant meeting, congress or event related to FIRE.
	Support of existing tools and APIs	This is expected by the experimenter and must be transparent for him (described in the documentation). A number of basic tools should be provided and supported.	This lowers the effort required by facilities when support is provided for adopting updates of the components, APIs and tools.
	Development and support of new components, APIs and tools	Adding new functionality and tools will increase the value of the federation and its facilities.	This lowers the effort required by facilities when new components, API standards and tools are developed centrally. The added value will depend per facility on the functionality (and the amount of facilities that will adopt these) and will be case specific.

3.2 Service offering

3.2.1 Minimally supported

Based upon the analysis presented in the previous section and Table 2, it is obvious that some components should minimally be offered. A number of components that should be minimally offered by the testbeds and Federator, in order to support experimenters and ease the experimentation lifecycle, were proposed in D2.7 [8]. The total cost of ownership analysis presented in section 5, is based upon the following list.

Federator

Following components have been selected to be supported by the Federator, based upon added value analysis as presented in the previous section, and technical implementation.

- *Identity management:* for authentication/authorization between experimenters and testbeds, Fed4FIRE adopts a trust model where testbeds and authorities establish trust relationships among each other. To support authentication decisions at the testbeds, specific experimenter properties are included in the experimenter's certificate, which is signed by an authority. This approach allows testbeds to implement basic authentication functions or even rules-based authorization if they want to. To ease the creation of such a web of trust across the federation, there should be a trusted location that bundles all root certificates of the federation's authorities. This way a testbed can query/trust the central authority directory to see which root certificates it should trust. At least 1 authority to provide credentials will be foreseen
- *Resource management*: An aggregate manager (AM) is used for resource discovery, specification and provisioning. Fed4FIRE uses as such the GENI AMv3 API (while GENI AMv2 is still supported), and is working together with GENI on a Common AM API as a next version.
- The *First Level Support dashboard* gives a real-time, comprehensive but also very compact overview of the health status of the different testbeds included in the Fed4FIRE federation. To determine this health status it combines facility monitoring information provided by the testbeds with specific measurements performed by the dashboard component itself. The dashboard is a very useful tool to have. It combines data from the different testbeds in a single health overview. Next to this support (Google group, NOC) for first and second help and single point of contact should be foreseen.
- A *documentation center* which gives an overview of available tools, testbeds and tips for the experimenter (http://doc.fed4fire.eu)
- *Promotion and training*: the Federator should furthermore coordinate promotion of the Federation and its testbeds towards current and potential experimenters. Additional activities could be offered to new facilities and experimenters such as training sessions (e.g. summer schools).
- Several tools should be supported such as the portal (a central starting place and registration place for new experimenters) and JFed tool (client based tool for experimentation).

Testbeds

The testbeds will have to implement several components:

- *Support for AMv2 or AMv3 (or later versions)*: This is used for authentication, authorization, resource description and discovery, instant provisioning and control.

- *Documentation* (on a webpage maintained by the testbed): testbed description, RSpec description, and URLs of the AM API. A basic experiment showing the testbed (and with a F4F tool), described as a tutorial, should be provided.
- *Policies*: everyone with a valid F4F certificate should be able to execute the basic experiment without extra approval
- *Facility monitoring*: This monitoring is used in the first level support to see if the testbeds are up and running. The testbed has the freedom to adopt any solution to gather this type of monitoring data as it sees fit (e.g. an existing monitoring framework such as Zabbix, Nagios or similar), as long as it is able to export that data as an OML stream to the Federator's central OML server, which will store it in a database for First Level Support. In the first cycle of Fed4FIRE, the facility monitoring was rolled out on all testbeds.
- *Connectivity*: Public IPv4 for AM, public IPv4 or IPv6 for ssh login
- Testbed has to provide *basic support* on the testbed functionalities towards experimenters

Experimenter

From the experimenter point of view, different options are possible can be used:

- Some of the tools made available to the experimenter are hosted tools (e.g. the portal, future reservation broker, documentation center, possibly some application services, etc.). The experimenter will make use of these tools through a *browser*.
- Several experimenter tools already exist and run locally on the experimenter's computer. So these are *stand-alone tools* instead of hosted tools. Examples are Omni, SFI, NEPI and jFed. The experimenter has the freedom to choose any tool of his or her preference, it will be supported by Fed4FIRE as long as it is compatible with the adopted AM APIs.

3.2.2 Options

Besides the components described above, other components are furthermore in development and testing, and are still under consideration (from sustainability point of view) for further support by the Federator. A first adoption and cost analysis can be seen in section 4.2.2, based upon a first enquiry with the different Fed4FIRE testbeds. This work will be updated and extended in the next deliverable.

4. Total Cost of Ownership

The Total Cost of Ownership (TCO) is a metric to define and analyse the overall cost of keeping a product or service up and running. A TCO analysis includes total cost of acquisition and operating costs [9].

An analysis has been made to estimate the total cost of ownership for the Federator, the organization that will operate the federation after the end of the project. This estimation is based upon valuable input from the different partners. Next to this we analysed the effort required for the different facilities to implement the components requested by the federation. This is presented in the second part of this section.

4.1 TCO for the Federator

We start by evaluating the TCO for the Federator. Therefore we split up the analysis in three parts: cost for supporting the existing facilities, thus the ones that have been implementing the components set out by the Fed4FIRE project through the three development cycles, the cost for adding new testbeds to the federation, and an indication how the federation could scale when the number of experiments will increase.

4.1.1 Cost for supporting existing facilities

The results in this section represent the minimum effort needed to sustain the current group of facilities part of the federation, and a maximum of about 100 experiments per year. The effort, estimated in full time equivalents (FTE) per year, is split up in four categories: support for tools and components for the facilities, technical support towards experimenters, promotion and business support, and management of the Federation Board and Federator.

Support for tools and components for the facilities: the effort for this task includes bug fixing for the different components and tools offered by the federation to the different facilities and experimenters such as jFed, AM wrapper and portal.

Technical support towards experimenters: A two-step approach is proposed. First level support (FLS) is the first entry point for questions by experimenters. FLS provides a high level overview of the status of the different facilities. When this information is insufficient, more detailed technical support should be given to experimenters having specific questions (on general aspects, tools and testbeds) when setting up and executing their experiments, thus managing the different Google groups that are currently used within Fed4FIRE for communication with experimenters. Next the people involved in this task should be able to understand, execute and explain the different technical tutorials offered by the facilities. A cost and efficiency trade-off will have to be made whether this task should best be executed by experts at each testbed site, or could happen in a more centralized manner.

Promotion & business support: The federation should continue to promote its added value as broker to support experimentation, within the FIRE community and beyond. This task should focus on representing the federation at future events, being a Single Point of Contact (SPoC) for new contacts, convincing new facilities to join the federation by “selling” the federation, arranging potential contracts with the different stakeholders. Dedicated effort should be allocated to this task.

In order to *manage the Federator* and *the Federation Board*, several people will be involved at different functions e.g. management, organization of meetings, etc.

The results are presented in Figure 3. In total we estimate that for the different categories presented above around 4 FTE per year, spread out over a number of people, should be sufficient to run the federation. Note that this is for the current set of facilities, and with a maximum of 100 experiments a year.

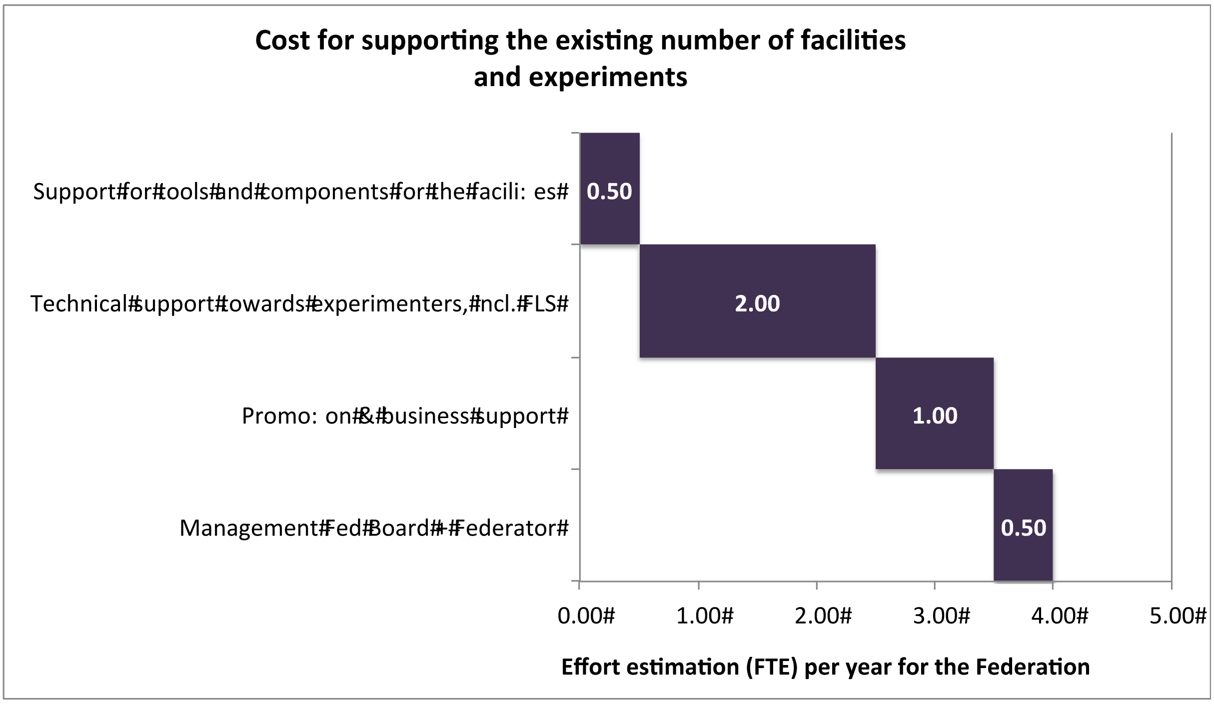

Figure 3: Cost for supporting the existing number of facilities and experiments

4.1.2 Cost for adding new facilities to the federation

The federation should be able to cope with change, thus dealing with facilities joining and leaving. An estimation of effort has been made to look at the cost for adding new facilities to the federation. The tasks are described in the following paragraphs.

Support for tools and components for the facilities: the effort for this task includes incorporation of specific parts and adaptations of the available components and tools offered by the federation. It is important to make a differentiation depending on the type of facility that is added:

- New type of facilities: this relates to facilities where extensive effort is required to incorporate and adapt the different tools e.g. new type of resource, different manner of working, etc. Examples could be testbeds with drones testbed, undersea sensors, automatic guided vehicles testbed, etc.
- Same type, alternative facility: Even within facilities belonging to the same type, large differences can be observed. It takes less effort as knowledge and implementation is gained when the first type of facility is included. Examples could be specific cloud or open flow facilities
- Comparable facility already available in the federation: little effort is required to add new facilities with same or similar characteristics as testbeds that are already included in the federation. The main question is how much added value this testbed will bring to the federation e.g. situated in a different environment, improving scalability by adding extra resources when requested by the experimenters, etc.

Technical support towards experimenters: The additional effort is included in the previous task.

Promotion & business support: Some effort is required for business development related to the attraction and administration to deal with the membership of the facility to the federation.

The effort is presented in Figure 4. As depicted above, adding a similar facility only requires limited technical effort (some days) compared to a new type of facility (3 PM). Business development is considered to be the same for all types of facilities (0,5 PM). Scalability will play an important role in the future. As there are only a limited number of types of facilities, and more facilities will adopt in the future standardized components and APIs, more and more alternative and comparable facilities will join the federation, thus with limited effort to incorporate them. This is represented on the right side of Figure 4.

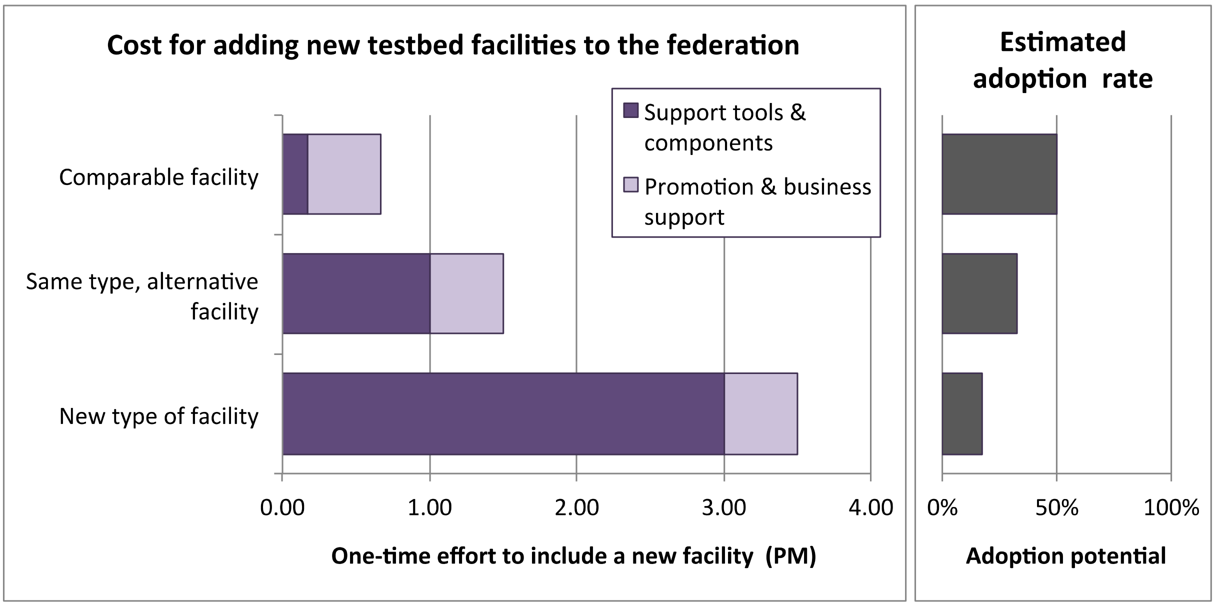

Figure 4: Cost for adding new facilities to the federation

4.1.3 Scaling the Federator

When the federation becomes more used and extended, the effort presented above will scale. The question to be analysed is how the effort will increase as a function of increasing numbers of facilities and experimenters.

The analysis for estimating the amount of effort required for technical support is based on the current figures from the Google groups. This can be seen in Figure 5, where the number of unique topics and its posts are depicted for the last year. The ratio between them is about 1 to 4, thus for each topic about 4 posts. The Google groups started in February 2014. In the first months of operation, the number of topics was on average around 20 up till May. This was due to the start-up of the first series of open call experiments, and finalization of the documentation and tutorials. As more information has become available, the number of topics decreased. As about 20 experiments made use of this forum, and there were about 80 topics during the last year, we can assume that the technical support has to deal with 4 topics per experiment on average. As the knowledge database increases over time, and experimenters could find information on their own, or other experimenters could start interacting, the amount of topics where technical support is required will decrease. An estimation on the number of potential topics related to the number of experiments per year is shown on the left side of Figure 6 (dotted line). The increase in number of required FTE per year for technical support is indicated with the full line on the right graph.

The business support and promotion will follow a similar pattern. It will depend on the number of testbeds in the federation and the potential amount of testbeds that could join the federation, and the current and potential amount of experimenters.

When new functionality is requested, dedicated development effort should be foreseen. This is not included in our analysis here. This could be part of a new project, or a specific budget. We elaborate on this in section 5, where the potential funding models are discussed.

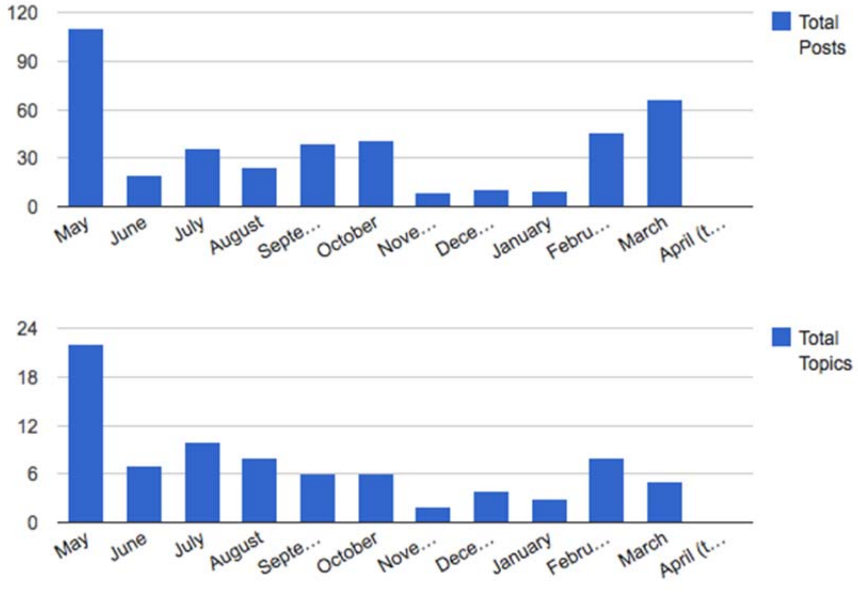

Figure 5: Technical support - number of topics over the last year (Google Groups)

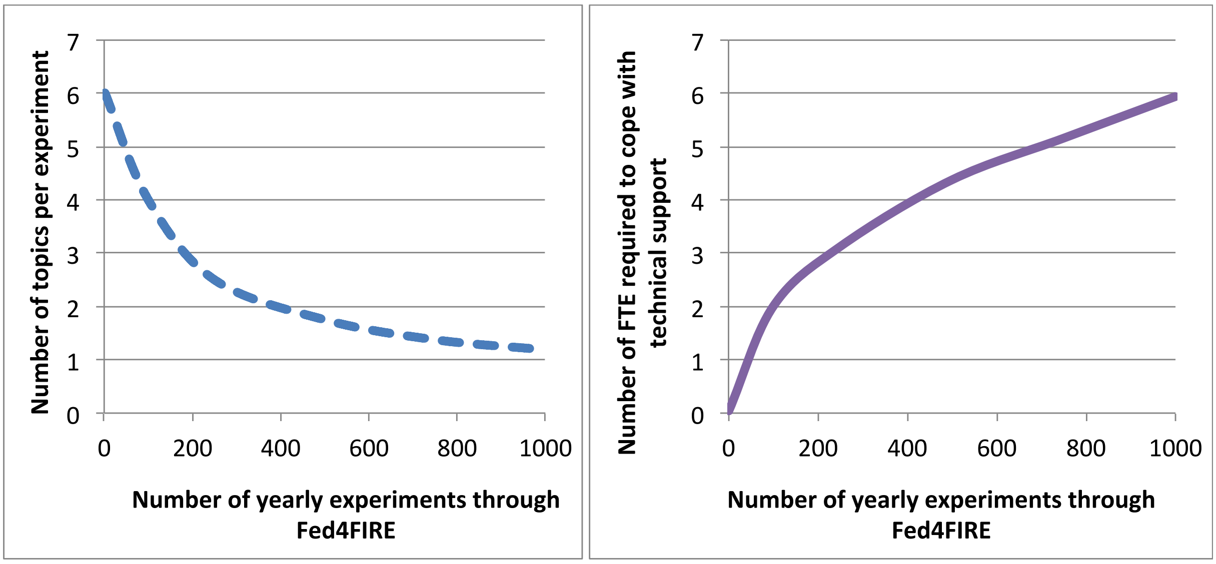

Figure 6: Technical support - Scaling related to number of experiments

4.2 TCO for the testbeds

In this section we consider what the testbeds involved in the project had to invest in effort to implement the minimal components set out by the Fed4FIRE project. We also consider a first outlook on the optional components: their adoption potential by the different testbeds and a rough estimation on the cost to implement those.

4.2.1 Minimal requirements

This is the effort required for implementing the minimal components in the different facilities taking part in Fed4FIRE. This is an overview of all facilities, including open call 1 and 2 testbed partners.

The minimal components described in section 3.2.1 have been considered for this analysis. We split up the cost estimation in three parts: initial installation effort (including specific adaptations), effort required upgrading to a new version of the component, and the effort required to offer support (maintenance, fault repair, helpdesk, etc.) for the component. The results are presented in Figure 7, Figure 8 and Figure 9. We used boxplot figures for presenting the costs, a convenient way of graphically depicting groups of numerical data through their quartiles. The bottom and top of the box are always the first and third quartiles, and the band inside the box is always the second quartile (the median). The ends of the lines represent the minimum and maximum of all of the data. On the right side of each figure, we included the percentage of relevant answers.

Support for AM: The installation time differs largely depending on the starting point of the infrastructure. More than half started from scratch to install this component; the others started from a previous or alternative version or solution. In almost all cases, local adaptations are required to be made to be compliant to the APIs. From all components, this one includes most features and thus will take most of the effort to implement on the facility. The median is 3 person months (PM), ranging from nearly 0 up to 8 PM. In most cases the effort to upgrade the solution takes about 1-2 PM. Support takes less than a month work per year.

Documentation and tutorials: This component comprises the description of the testbed and Rspecs, URL of the AM API, and a tutorial comprising of a basic experiment showing the functionalities of the testbed (with a F4F tool). For most facilities (50% between Q1-Q3) this takes about 1 to 1,5 PM to complete. Support and adaptations each year take less than half a person months work.

Policies: Facilities that have adopted the AM component indicate that no specific effort is required, as the Fed4FIRE certificates are granted complete access to their facilities. The effort is thus quiet low (less than 1 PM), mainly dedicated to testing, or in some rare cases specific adaptations to the current implementations. However if we want to enforce dedicated policies, additional some dedicated implementation is required, which will range between 3 and 6 PM (not indicated in Figure 7). Limited support is needed during the year, mainly for validating experimenter accounts.

Facility monitoring: This component is essential for support to the Federator and towards its experimenters. The effort for an initial implementation is on average between 0,5 and 1,75 PM. Upgrade effort takes less than 1 PM. Yearly support is estimated to be less than 1 PM.

Connectivity: This effort relates to making the AM component public, either on IPv4 or IPv6. It highly depends on the type of facility and their starting point. For most facilities this ranges between 1 to 3 PM of effort. No support is further needed.

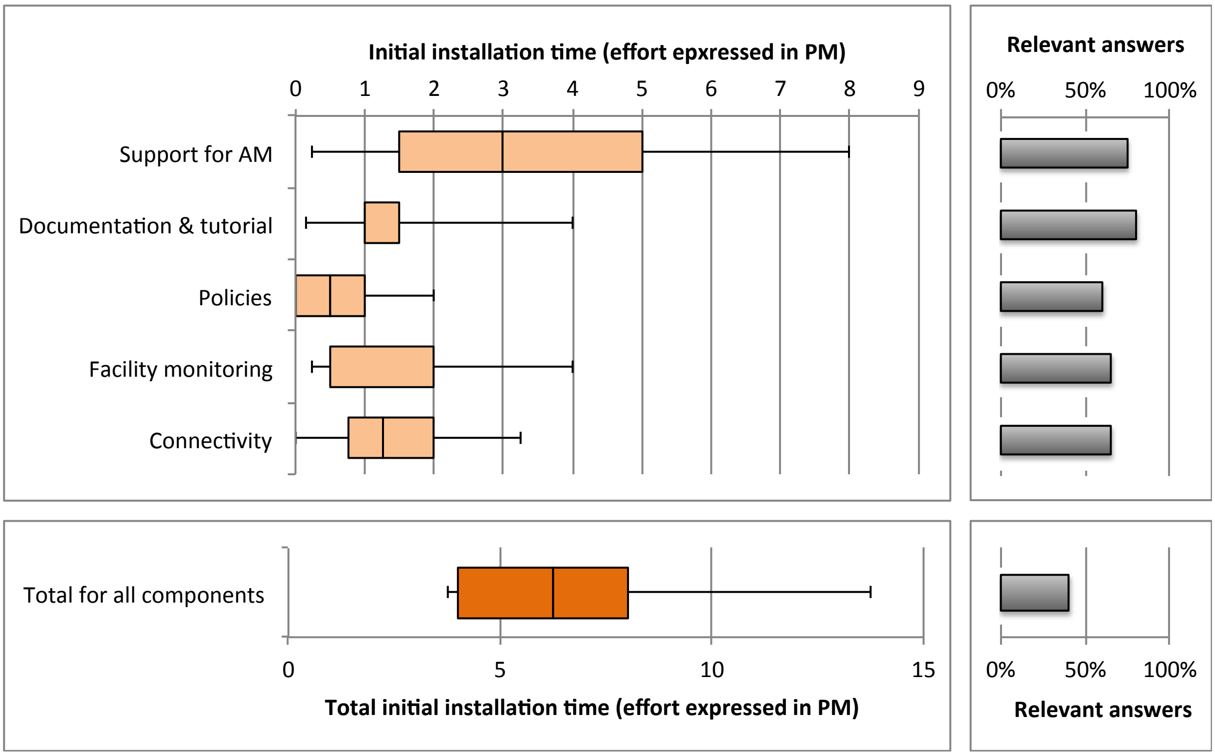

Figure 7: Initial implementation effort for the minimal components

It is important to look at the total effort for initial installation of the minimal set of components required by the federation (bottom graph of Figure 7). We only considered the relevant answers from testbeds on the effort spent for installing all components. The mid 50 % of the Fed4FIRE testbeds (between Q1 and Q3) showed an initial installation effort between 4 PM and 8 PM. Minimum was 3.75 PM, max 13.75 PM and median 6.25 PM.

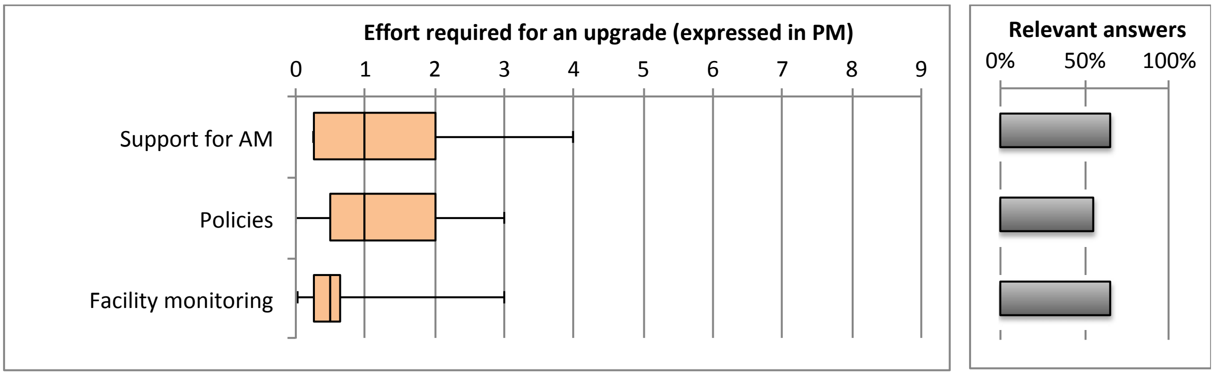

Figure 8: Effort estimation to implement an upgrade of the components

The overall cost for service updates will depend on the number of upgrades of the components. Upgrading the AM component will be most relevant for the facilities, as this will include additional functionality. Normally once the components are installed, the upgrading will be supplementary and up to the facilities to decide, unless it is crucial and demanded by the Facilitator.

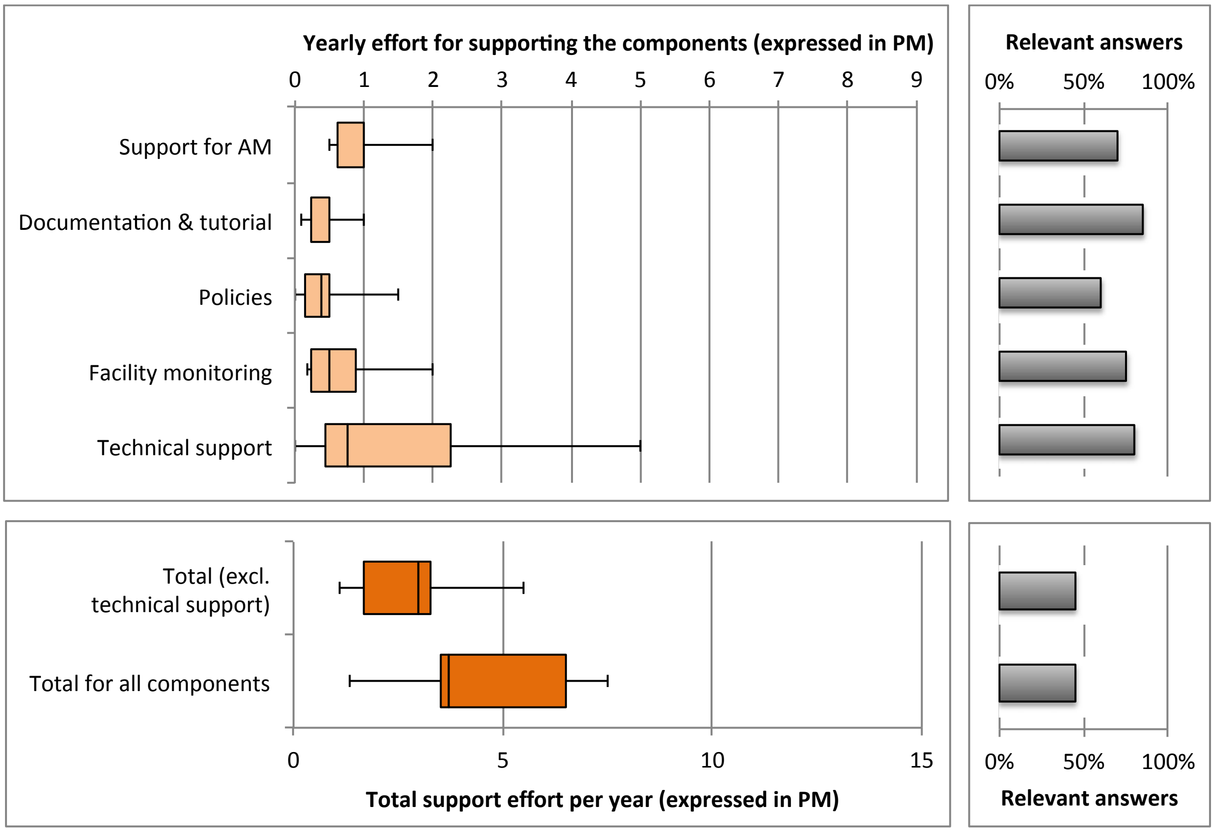

Figure 9: Effort estimation for supporting the components (yearly effort)

The total yearly effort related to operational support of a testbed for being part of the federation can be seen in Figure 9 (bottom graph). It fluctuates between 4 to 6 PM a year. This is the aggregation of the support activities of all previously mentioned components, each resulting in small effort. In the effort estimation of Federator, we indicated that technical support could be centralized and offered by the Federator. If we exclude the effort at testbed side, in order to manage this in a centralized manner, this would benefit the different facilities, as can be seen in the bottom graph.

We tried to see whether there would be a difference in effort between the testbeds who initially joined at the start of the project (left side of Figure 10) and Open Call facilities, which joined during OC1 and OC2 (right side of Figure 10). We would expect that an evolution could be seen, where implementation time would be less as they could learn from previous installations. This is not the case. However we have to note that several factors play an important role. All facilities joining the federation are heterogeneous, thus specific adaptations will still be required for each testbed and infrastructure. Some of the effort is still a basic estimation as some components are still being adapted to the local situation or tested. Testbeds that were initial partners also had, in most cases, the benefit of starting from previous versions or solutions for some of the components, where the testbeds who joined later mostly had to start from scratch. As this is a first estimation, the results will be updated in the forthcoming deliverable.

During Open Call 1 and 2, funding has been provided to new facilities to join the federation, 100k and 80k respectably. This relates to an effort of about 8 to 10 PM, which is within the range presented in Figure 10 (right side bottom image).

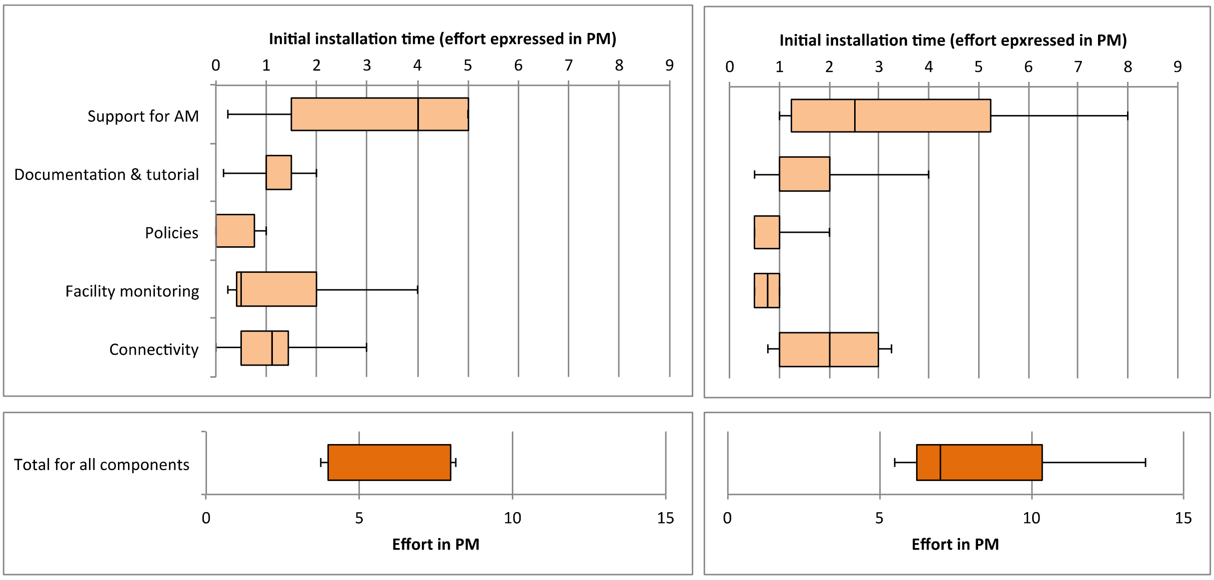

Figure 10: Initial installation effort estimation between the testbeds initially joined at the start of the project (left) and Open Call facilities joined during OC1 and OC2 (right)

4.2.2 Optional components

During the enquiry conducted with the Fed4FIRE facilities, the question was also posed whether they would be interested in adding the optional functionalities described in section 3.2.2 to their facility. It is very important to know what the adoption potential would be for these components, to see if the Federator could sustain these components with additional developing and technical support. We should note that most functionalities and technical requirements are not all defined yet. This might change the opinion of the testbeds. It is a rough first estimation, and when more information becomes available, the results will be refined.

The adoption potential can be seen in Figure 11. Infrastructure monitoring and advanced reservation, both interesting and added value components, would be supported by more than 60% of the testbeds. All other components stay under 50% adoption rate.

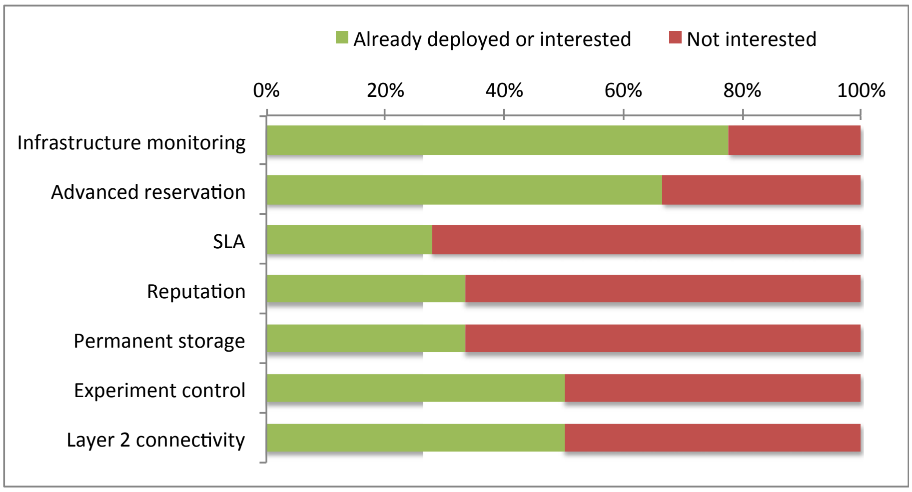

Figure 11: Adoption potential for optional components

A first estimation on the cost for the facility to implement the component is given in Figure 12. Again we have to state that the technical requirements were not yet available, so it is merely based upon first guesses and previous experience. The big variations between the answers verify this conclusion. An update of this analysis will be part of our upcoming work. Of course we need to align the costs for managing these components centrally by the Federator, the costs for implementing and supporting the components by the testbeds and the added value / benefits for all stakeholders.

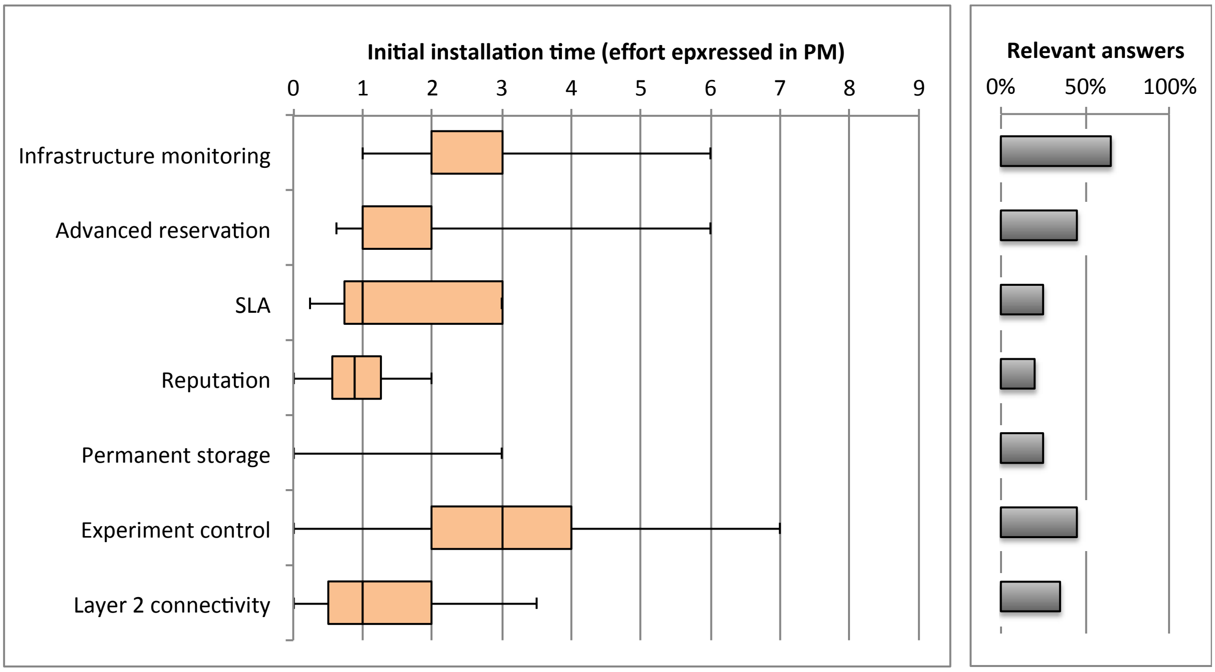

Figure 12: Initial effort estimation for installation of optional components

5. Potential funding scenarios

Setting up a sustainable model for the Federator cannot be discussed without considering also plans to sustain its stakeholders (experimenters and testbeds). We address first the environmental context (this bigger picture) and the need to consider this within our work.

5.1 The environmental context

In order to create a sustainable plan for the Federator and federation, we first need to take a look at the current environment and its problems. Today testbeds are funded through different channels: EC funded infrastructure projects, national/regional/local funding and private money. For each facility this will differ, depending on its type, size, country, etc. Most facilities highly depend on public money. This will be shown in the further analysis (section 0).

A lot of testbeds are taking part in FIRE infrastructure projects. These are interesting for stimulating further developments and attracting new experimenters. However, the dependency on this type of funding is for some testbeds very high, mostly for covering their operational costs (as the infrastructure costs are mostly covered through other channels). When an infrastructure project ends, some testbed in it often die because no other stable sources of money can be found to fund at least the operational costs, even though there is potential for them to be used by others. As an effect of this, there is a danger that the same wheel is continually reinvented, thus if the functionality offered by those testbeds is needed again, similar testbeds must be created again in new research projects. This is not a stable solution.

The core of the problem is that the source of funding today is not in a one-to-one relationship tied to how useful a testbed is. EC projects get funded based on the anticipated quality of the research, carried out on an available testbed, rather than solely on the quality and the need for the testbed itself. Therefore testbeds within research projects are hostages to fortune, as they are not funded based on the quality, demand or usefulness of their experimental facilities, but on criteria related to research quality of the work enabled through the testbed.

To address these problems, we need an established mechanism for funding FIRE facilities for experimentation, and their federation. This could follow the rationale of the e-Infrastructures program [6], but the key difference is that it is applied to experimental test facilities, such as FIRE.

We start by giving an overview of current funding mechanisms (EC, national/regional/local or private funding) for FIRE facilities and experimenters. This is validated for the Fed4FIRE facilities, split up between funding for infrastructure (investment) and operations, represented on the OSIRIS funding triangle [9].

We will also present some options as to how the EC could manage, exploit and fund the FIRE facility portfolio in a more consistent (sustainable) manner. The use of current available testbed facilities should be stimulated, and investments in new testbed facilities should only be granted if they fill gaps in technologies and competences not available today, or if totally innovative solutions are proposed. Several funding options are presented for the EC, based upon information from OSIRIS [11], as to how FIRE could evolve in order to sustain the different stakeholders in the future (federation, facilities and experimenters). A SWOT analysis is presented for each model.

5.2 Current situation

5.2.1 Current stakeholder funding model

We start by taking a look at the current funding model for experimenters and FIRE facility providers, and their relations. This is expressed in Figure 13. A SWOT analysis is presented in Table 3.

Experimenters can be funded through different channels:

- *European funding*: This funding comes through European research projects, where experimenters can be part of the project itself from the start, or can join during projects through open calls.
- *National / regional funding*: This relates mostly to academic users, where universities and research centres apply for funding with local authorities. Other potential funding flows are national funding agencies supporting experiments in local research or development projects or special funds for PhD students.
- *Private funding*: This relates to private initiatives paying for experimentation such as SMEs, industry or non-public funded research centres.

Facilities can be also funded through different channels. However the funding can be allocated for specific reasons: dedicated towards investment in new infrastructure or to cover the operational running costs of the facility.

- *European funding*: This funding comes through European infrastructure projects (short/medium term with maximum of 3 years). This money has historically been used for new (smaller) facilities as starting point to set up its infrastructure. However for most (existing) facilities, it is used for further development or new extensions e.g. new software components, API compliancy, introduction of new hardware components, etc.
- *National funding*: Most testbeds have received initial funding from the national or regional authorities in order to create and set up new research infrastructures. This could happen through national funding agencies or through funds allocated to universities or other public research instances.
- *Private funding*: Specific investments in facilities can be provided by private partners e.g. specific software or hardware that is part of a larger facility. However this is rather limited.
- *Experimentation*: Some funding is received by facilities for the usage of the infrastructure and services. This relates mainly to support and consulting service to assist experimentation, mostly provided by private experimenters such as SMEs, or for instance through dedicated reservations for educational purposes. However in most cases the access to, and usage of, the resources of the facilities is free of charge, thus with only very limited or no remuneration of the costs made by the facility providers.

Table 3: Current funding model - SWOT analysis

Strengths	Weaknesses
• Funding available for experiments and testbeds	• No Federator • Fragmentation/duplication of test facilities • Missing features
Opportunities	**Threats**
• Free access allows speculative research (high risk, high reward)	• Others will develop research infrastructures that provide missing functionality, stealing experimenters and EU loses edge.

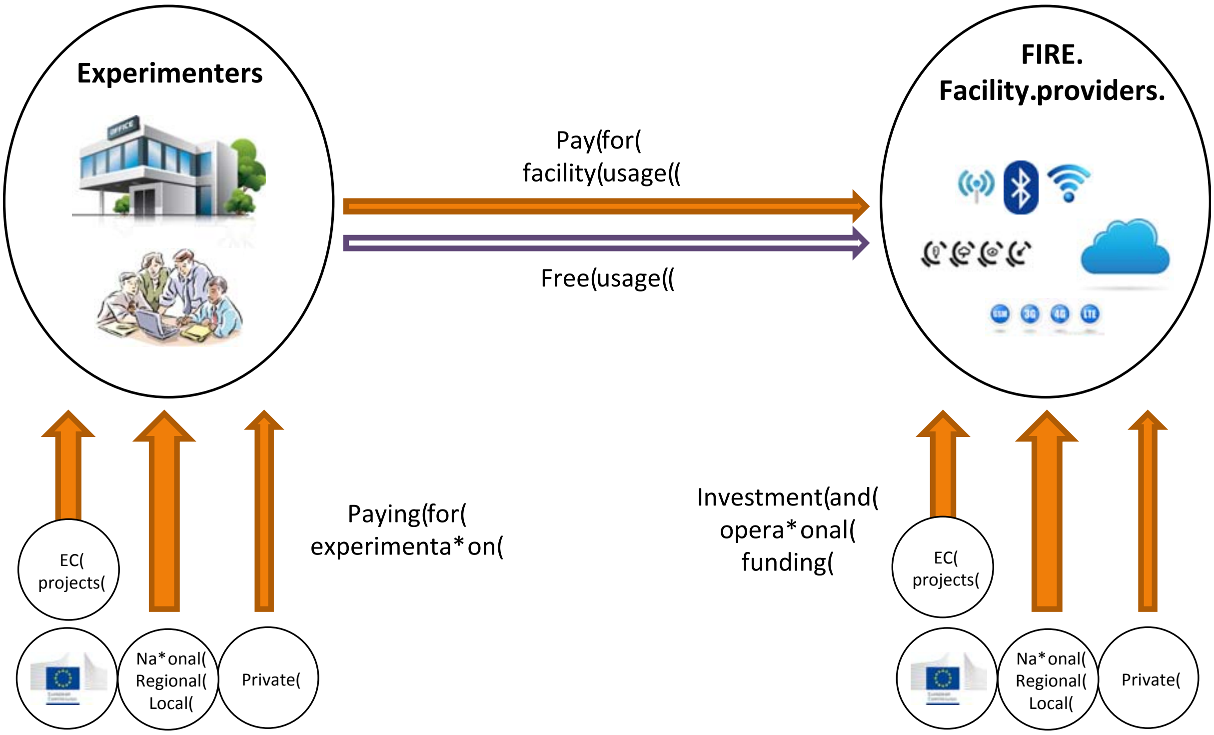

Figure 13: Current funding model

5.2.2 The Fed4FIRE model

The Fed4FIRE project incorporated some (small) differences compared to other federation projects. The model is presented in Figure 14. The flows are split up according to the receiving stakeholder. A SWOT analysis is presented in Table 4.

Fed4FIRE project

- The project is funded directly by the European Commission. This incorporates funding for the project partners, a large amount of money for open calls, and unallocated funds for additional demand driven developments.

FIRE facility providers

- Partners who joined the project from the beginning are receiving funding from the EC, through the Fed4FIRE project, for developing and implementing the different components in three cycles. This will enhance the functionality of the various facilities.
- Partners who joined the project through the open calls received only dedicated funding for implementing (most of) the components and APIs requested by the project.
- Dedicated funding was given to the different providers (patron service) that were involved in the approved open call experiments (10k for Open Call 1, 5k for Open Call 2 to be split amongst the different facilities involved), in order to support the experimenters, not for facility usage. This system thus stimulates a funding mechanism based upon experimenter demand.
- There is an open access mechanism available, where experimenters can use Fed4FIRE and the resources of the project partners' facilities, without funding for the facilities.

Experimenters

- The experiments conducted in the project are based upon an open call system. Different open calls have been set up, targeting specific groups (SME, academics, facilities), each with specific funding scheme. As indicated above, some funding is provided for the facility providers for supporting the experiments.
-

Table 4: Fed4FIRE funding model - SWOT analysis

Strengths	**Weaknesses**
• Federator is funded providing stability	• Testbeds die when funding dries up • Hard to match supply to demand – features may be missing
Opportunities	**Threats**
• Federator can address both experimenter and facility needs	• High risk to have all funding through the Federator

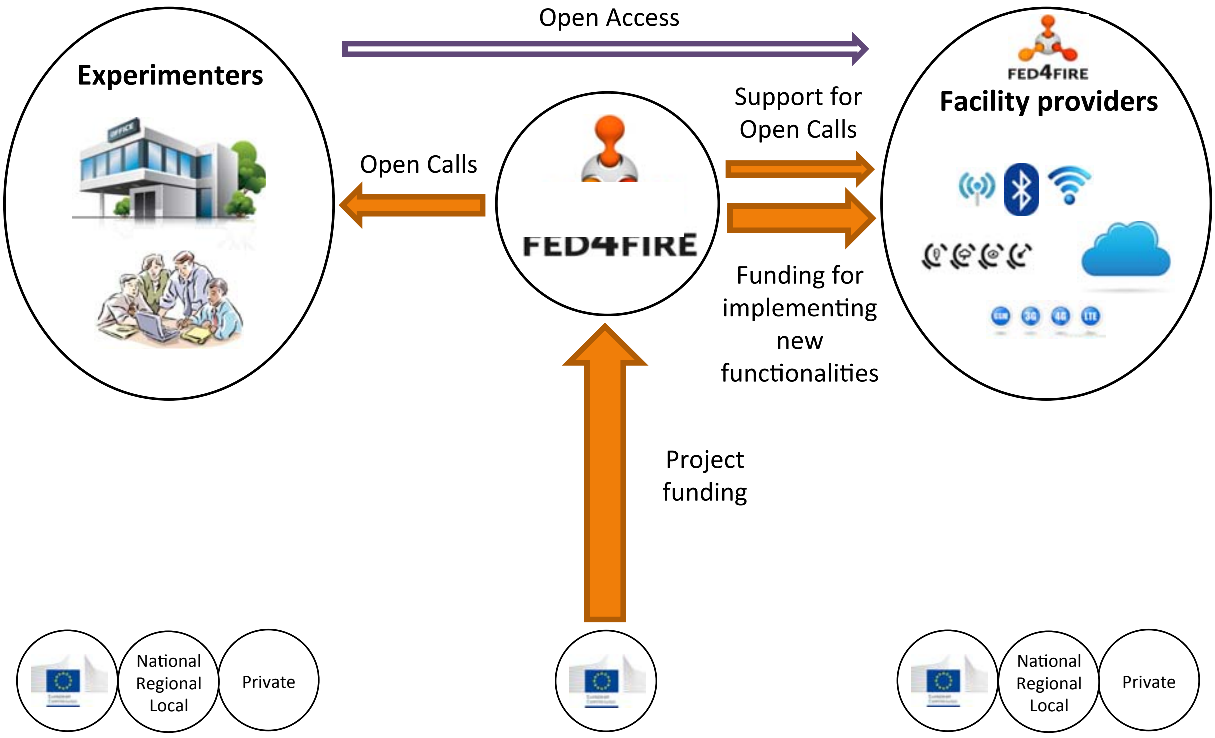

Figure 14: Fed4FIRE model

5.2.3 Validation and comparison

Validation within FIRE

In order to validate the model presented in Figure 13, a survey was conducted amongst the different partners of the Fed4FIRE project. As mentioned before difference is made between funding for making the initial and recurring investments, in other words funding of the infrastructure and funding for keeping the infrastructure operational.

At this point we introduce the OSIRIS funding triangle [10]. On the vertical and horizontal axis, the funding percentage of respectively European and national/regional/local instances can be seen. The diagonal lines give thus an indication on the relative percentage of public funding compared to private funding. Thus points closer to the left and lower side of the graph indicate more private funding. The results of both funding for infrastructure and operations can be seen in Figure 15 and Figure 16.

The infrastructure funding can be split up in two types of categories:

- *Infrastructures funded with all or mainly public funding*: This category comprises most of the facilities. The private funding part on all of those testbeds never exceeded 30%, and this is only for the small or medium sized facilities. For the large and very large facilities, public funding never exceeds 15% of the total investment. Two main groups can be spotted:
    - Testbeds that mostly relied on, or still are relying on, EU funding, which can be found in the upper left corner of the graph. Examples are BonFIRE, IRIS, NITOS, C-Lab.

- o Testbeds that mostly relied on, or still are relying on national, regional or local funding, which can be found in the bottom right side of the graph. These include iMinds Virtual Wall and wi-Lab.t, Netmode, PerformLTE, LOG-e-TEC and PlanetLab Europe.
- Only two facilities within the Fed4FIRE consortium are *mainly privately funded*. For Fuseco, most of the infrastructure cost was covered by money received by selling licenses such as OpenEPC. For SmartSantander, funds come from companies, which are operating public services in the city.

Only (some) national/regional/local funding can be seen as structural, and in some cases private funding (e.g. through selling licence), however this is very limited.

Besides the infrastructure, funds should be foreseen in order to keep the facilities up and running. This is one of the most difficult tasks as, in most cases, this heavily depends on project funding, which is only short to medium term. Some conclusions can be drawn from this:

- Although, the pattern is more diverse than with the infrastructure funding, most facilities rely for over 70% of their operational funding on European and national bodies.
- It is depicted that most of the facilities have some sort of private funding. This comes mainly from private experimenters, which use the facilities and pay for the operational costs e.g. for UBristol and Fuseco through industrial collaboration. Some testbeds offer a consultancy service helping their users throughout the experimentation life cycle by providing dedicated support, such as iMinds (Virtual Wall, Wi-lab.t) and UAM (10G Trace Tester).
- A few facilities rely mostly, or fully, on private funding. This is the case for Smart Santander (as explained above with infrastructure funding) and FIONA (Adele robots), where a commercial company leads the testbed.

A detailed overview for funding of the different Fed4FIRE facilities, split up between funding for the infrastructure and operations, as shown in Figure 15 and Figure 16, can be found in Table 5.

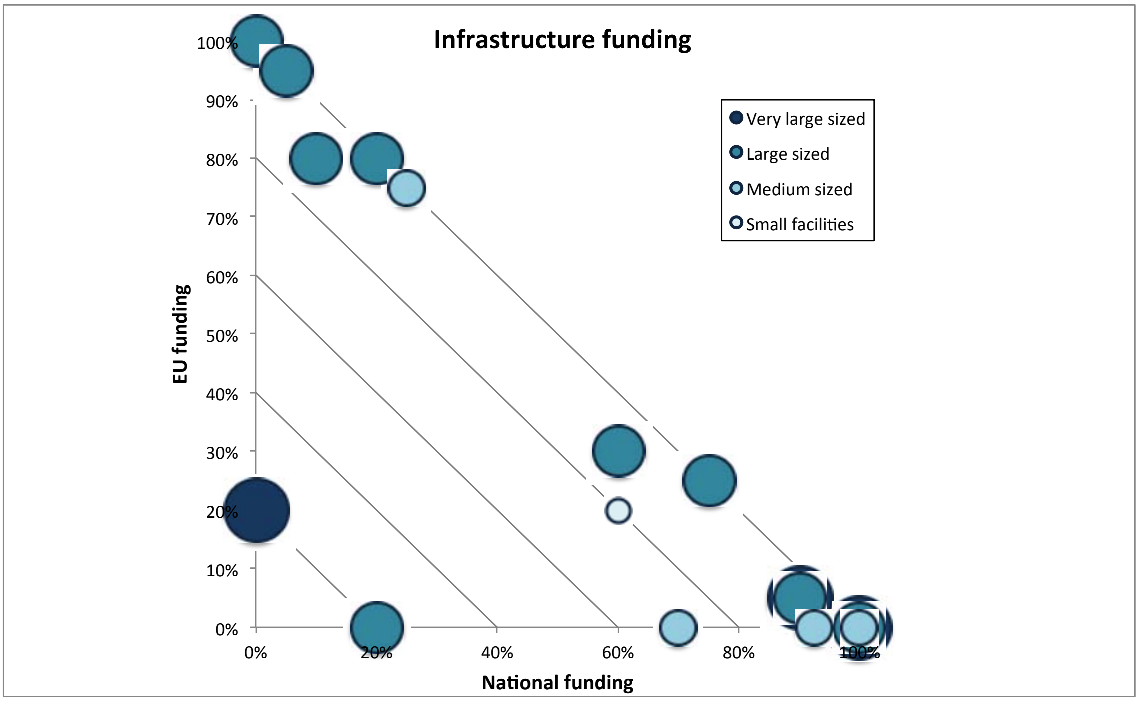

Figure 15: Infrastructure funding for Fed4FIRE facilities

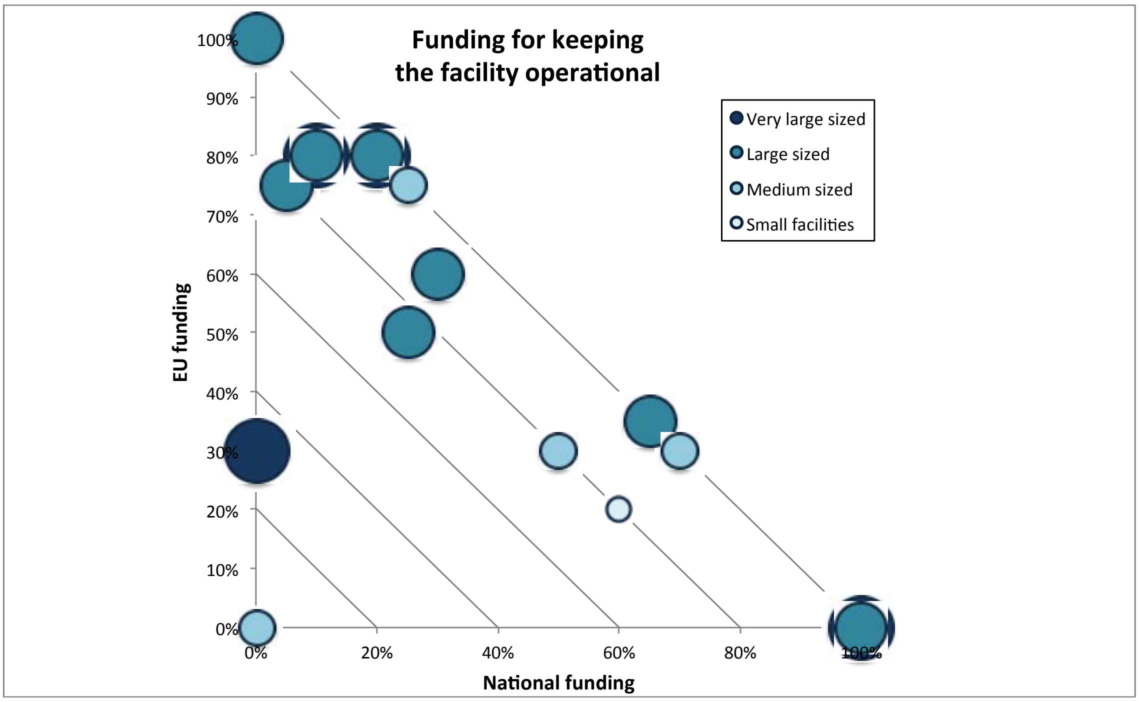

Figure 16: Funding for keeping the Fed4FIRE facilities operational

Table 5: Detailed overview of funding flows for the different Fed4FIRE facilities

Fed4FIRE facility	Funding for infrastructure			Funding for operations		
	EU	National / regional / local	Private	EU	National / regional / local	Private
10G Trace Tester (UAM)	20%	60%	20%	20%	60%	20%
BonFIRE cloud sites (EPCC)	100%	0%	0%	100%	0%	0%
BonFIRE cloud sites (Inria)	100%	0%	0%	100%	0%	0%
C-Lab (UPC)	95%	5%	0%	100%	0%	0%
FIONA (Adele Robots)	0%	70%	30%	0%	0%	100%
FuSeCo (FOKUS)	0%	20%	80%	50%	25%	25%
i2CAT OFELIA island	80%	10%	10%	75%	5%	20%
IRIS (TCD)	75%	25%	0%	75%	25%	0%
Koren (NIA)	0%	100%	0%	0%	100%	0%
LOG-a-TEC (JSI)	25%	75%	0%	35%	65%	0%
Netmode (NTUA)	0%	100%	0%	30%	70%	0%
NITOS (UTH)	80%	20%	0%	80%	20%	0%
PerformLTE (UMA)	0%	92%	8%	30%	50%	20%
PL-LAB (PSNC)	0%	100%	0%	0%	100%	0%
PlanetLab Europe (UPMC)	0%	100%	0%	80%	20%	0%
SmartSantander (UC)	20%	0%	80%	30%	0%	70%
UBristol OFELIA island	30%	60%	10%	60%	30%	10%
Virtual Wall (iMinds)	5%	90%	5%	80%	10%	10%
w-iLab.t (iMinds)	5%	90%	5%	80%	10%	10%

Comparison to other types of infrastructures

Within the OSIRIS project five types of ICT research infrastructures (RI) were analyzed [10]:

- Network RIs with DANTE as the key example;
- Grid / Cloud computing, also known as Distributed Computing Infrastructures (DCI) with EGI as the key example;
- High Performance Computing (HPC) with PRACE as the key example;
- Data infrastructures, with Lifewatch as an example;
- Micro and Nano-Technologies (MNT) with CEA-LETI and IMEC as examples.

The funding has been discussed in depth with each of these types of infrastructures during interviews. The outcome of the funding discussion is presented in Figure 17. The graph shows the actual sources of funding and the direction that the key people in the RIs stated they wanted their funding to take. As can be seen from this picture, MNT is the only type that is not nearly entirely funded by public money. Furthermore, PRACE stated their wish to increase the European proportion of their funding (indicated by the blue arrow).

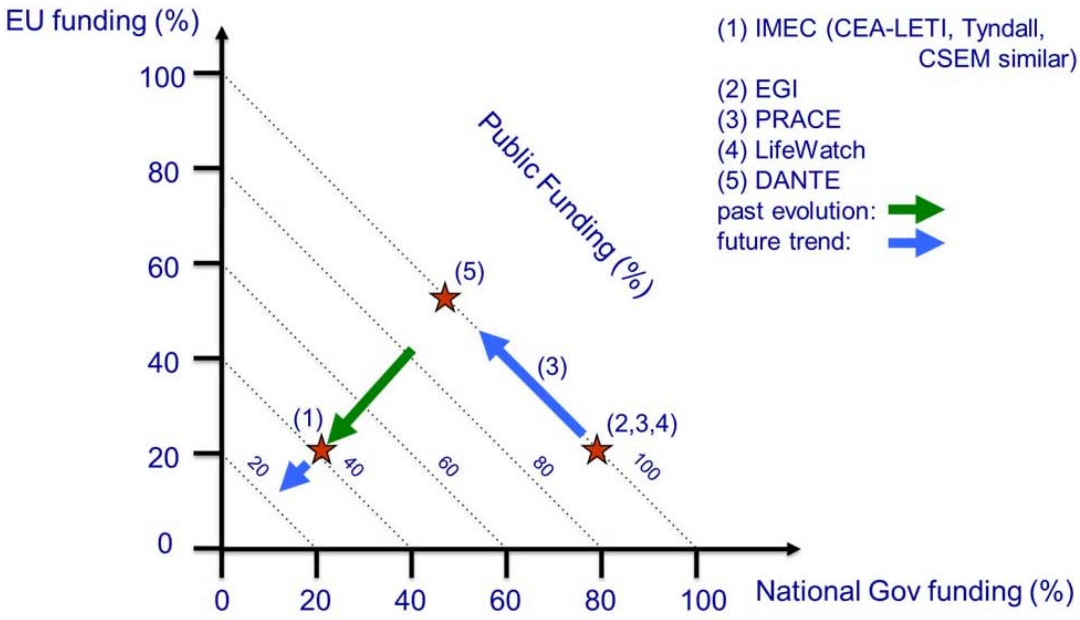

Figure 17: The sources of funding for the different types of ICT RIs with the desired trends. Note that the star points are indicative.

FIRE showed a lot of similarities in terms of sources of funding, according to the OSIRIS analysis, as Grid computing (EGI), HPC (PRACE) and Data (LifeWatch). Our results presented in the previous section thus validate this conclusion.

5.3 Potential models for future funding

Within this task of the project we are looking for models to sustain the federation. In order to do so we need to take a look at the bigger picture and seek options to sustain our stakeholders: experimenters and facilities.

We see that FIRE facilities today are not well enough used. There is currently no structured manner in order to get experimenters stimulated to use them more, in a sustainable way.

The European Commission provides significant amounts of financial resources within the FIRE and the allocation of the budget is organised on a scientific project basis, thus funding research partners, facilities and experimenters. This model makes sense. However this doesn't lead to structural funding for the different stakeholders. Focus (and funding) in the upcoming H2020 calls is even more put on experimentation within the infrastructure projects, with strong focus on involvement of industry.

There are different ways the EC could manage, exploit and fund the FIRE facility portfolio in a more consistent (sustainable) manner. Firstly, the use of current available FIRE testbed facilities should be stimulated and supported (financially) in a consistent matter. Setting up new testbed facilities should only be funded if they fill gaps in technologies and competences not present today, or when total innovative solutions are proposed. New developments, based upon experimenter demand and functionality improvements, should still be stimulated in current infrastructures. Secondly, facility providers should be stimulated to become more standardized by implementing the minimal set of common interfaces and APIs defined by the Federator. Existing facility providers should become compliant, possibly with some additional funding. Newly developed facilities, set up within EC projects, should be required to become compliant by the end of the project.

Within the next sections we present how the different stakeholders could be funded. Then we work out four potential funding schemes by matching some funding streams. A SWOT analysis is presented for each model. The models are not exclusive. Some of them can be used interchangeably.

5.3.1 How could the different stakeholders be funded

We first start by providing all options whereby the different stakeholders (experimenters, facilities, Federator) could be funded. In a next phase we can combine different options in order to build potential funding scenarios.

The types of potential flows are based upon the OSIRIS model for funding (Figure 18).

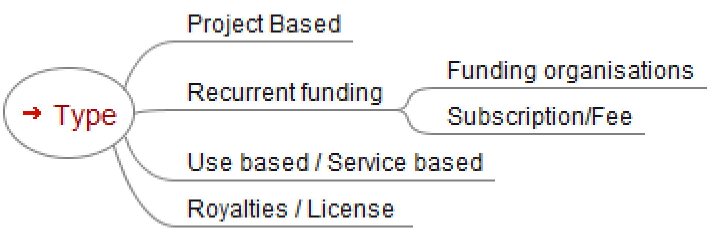

Figure 18: Funding options as presented by the OSIRIS project [12]

In the upcoming sections our analysis will only focus on the funding provided by the EC, thus leaving out national and private funding, as the latter differs immensely depending on each country and type of facility (as presented in the previous section).

Experimenters

As project partners in EC (FIRE) funded projects: Experimenters take part in infrastructure and research projects in order to develop, test and/or validate the innovative solutions. These experimenters are mainly from academic & other research centres, but also SMEs and industrial partners. These types of projects provide medium term funding (max of three years).

Through open calls in EC (FIRE) funded projects: Many EC funded projects have offered and will continue to offer open call mechanisms to attract experimenters to make use of their project and its offering (facility resources, tools, etc.). This is a very effective system for funding experiments, as this happens in a controlled environment on a proposal-based manner, with review process and verification by the EC. Specific funds are provided for short-term experimentation (around 1 year). This mechanism will furthermore be sustained in the upcoming H2020 calls for facility projects.

Through the Federator: Federation projects (as happens now in Fed4FIRE) can coordinate broader scoped open calls with dedicated funding from the EC in order to stimulate usage of the existing FIRE facilities. The Federator becomes a matching broker between facilities and experimenters.

Other EC funded channels: Besides FIRE there exist other channels for experimentation such as FI-PPP, EIT-ICT, etc., all focused on testing and validating innovations through experimentation.

Facilities

The EC funds testbeds directly: This would lead to longer term funding than research projects and gets over disadvantage that testbeds are funded by short term research projects. An explicit funding stream for experimental platforms could be funded through Coordination and Support Actions (CSA). Testbeds would need to demonstrate on the other hand their continued value to be able to obtain a next round of funding.

Testbed are funded by experimenters' research projects: Focus is put on demand-based experimentation, where facilities are paid according to usage. This 'survival of the fittest' will lead to a situation where only facilities with unique and/or sufficient available resources will sustain. A procedure must be set up on order to oblige research projects to use FIRE facilities when the required resources are available. Different tariff options are possible: pay-per-resource (pay for actual usage), pay-per-experimentation or some sort of subscription (for unlimited usage for the duration of the project).

Testbeds are funded by a Federator: A broker type of organization (the Federator), funded by the EC, will be in charge of funding facilities. The Federator can choose how it will allocate the appropriate funds to the different testbeds. This could be based upon different drivers: testbed size, number of experiments conducted, number of resources consumed, level of integration (where facilities could be stimulated to implement additional components), reputation, etc. The different facilities will have to demonstrate their value to the Federator, related to the drivers mentioned above. The Federator on the other hand will have to justify its allocation policy to its sponsors, namely the EC.

Other EC funded channels: Besides FIRE there exist other channels for experimentation such as FI-PPP, EIT-ICT, etc., all focused on testing and validating innovations through experimentation. Testbeds could take part within those frameworks in order to receive funding for offering additional functionality and promoting their facility to obtain more experiments and increase resource usage.

Federator

Funded by EC direct: A dedicated recurrent funding stream could be set up for sustaining the Federator for its operational activities (service management). This will be based upon the services offered and usage of the federation (number of experiments) Possibly the EC could provide some extra funding to support new facilities (to become compliant to the components and APIs) and experimenters (open calls for promoting the usage of the facilities). Additional funding could be allocated on a project basis e.g. through a new H2020 facility project or through a CSA for furthermore developing new functionality (components and APIs) for the federation.

Funded by their testbeds: The testbeds being part of the federation could pay a subscription fee to support the Federator in its activities. This could be executed by paying in cash the fee, or in kind by offering resources for operating the Federator.

Funded by experimenters: Some of the money paid for experimentation through the federation could be allocated partly for the Federator (fixed fee or percentage on size of the experiment).

Funded via royalties and licences: Tools and APIs developed by the Federator could be licenced, possibly leading to recurrent revenues for its usage.

5.3.2 Scenario 1: Experimenter centralized model

This first scenario shown in Figure 19 focuses on a pay-for-experimentation model with quality of service (QoS). Experimenters, funded as part of EC projects as project partners or through open call mechanisms, can use the different facilities of the federation.

Projects are funded by the EC to conduct innovative research. Within the current H2020 calls, part of the funding should be allocated to experimentation. A clear procedure should be worked out that, when experimentation will be conducted during the project, the usage of FIRE facilities should be stimulated and a money flow should occur towards the different facilities for the use of their resources and services. A clear explanation on potential use of resources should be stated from the start of the project in the proposal. The Federator should play an important role as broker between the different projects and the FIRE facilities by selecting the appropriate facilities, allocating resources, follow-up on resource usage, first and second level support, tools, etc. Part of the funding for using the different resources for experimentation should be allocated to the Federator for covering its operational costs. Open Access experiments should still be possible free for small experiments, with best effort resource reservation, limited access and support. The SWOT analysis is shown in Table 6.

Table 6: Funding scenario 1 model - SWOT analysis

Strengths	**Weaknesses**
• Demand driven by experimenters • Money flow incentivizes good QoS	• Test facilities and Federator dependent on demand. Hard to plan, stifles ambition. • Niche facilities unlikely to be viable due to low demand
Opportunities	**Threats**
• Federator and facilities can make profit • Experimenters can carry out more speculative research (high-risk, high reward.	• Others will develop research infrastructures that provide missing functionality, stealing experimenters and EU loses edge.

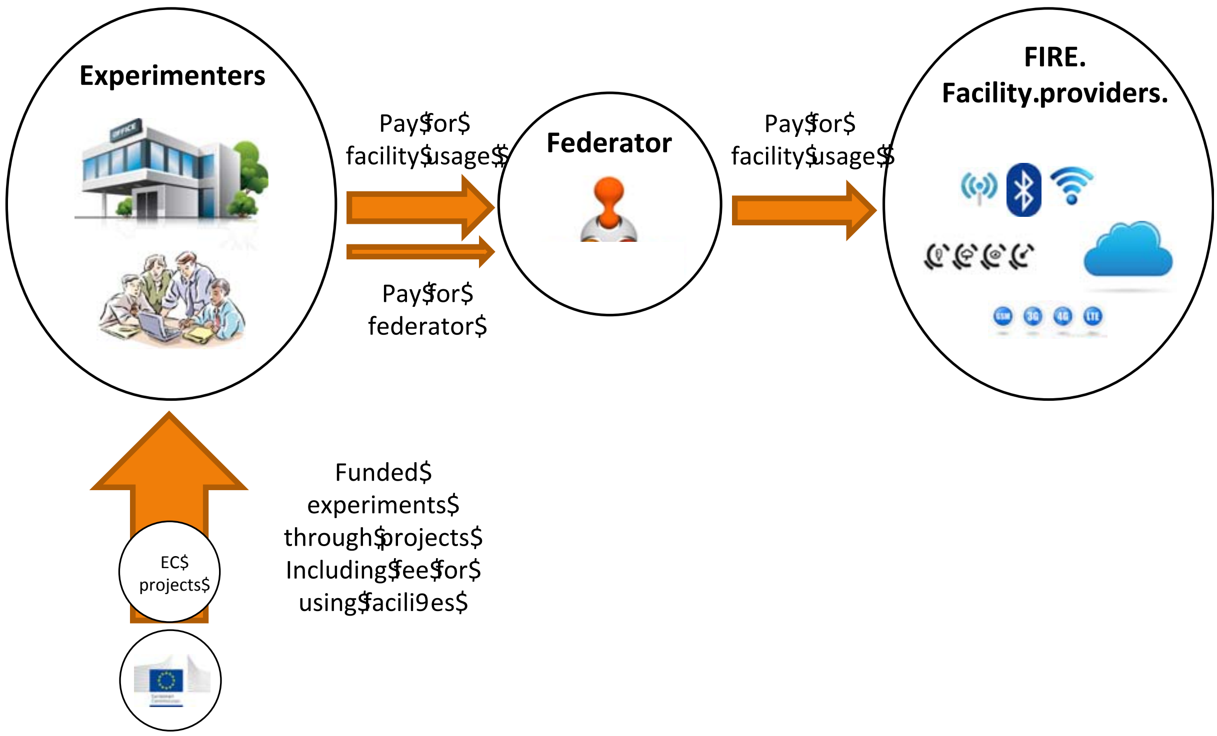

Figure 19: Funding scenario 1

5.3.3 Scenario 2: Structural Federator and testbed funding

The following model focuses on a more structural based funding model for the Federator and facilities, as can be seen in Figure 20.

Projects are funded by the EC. As indicated in the previous scenario, part of the funding should be allocated to experimentation. However this funding should only be based on the effort required for executing the experiment, not for using FIRE facility resources and the Federator. Each experimenter should be allowed free access to the Federator services and FIRE facility resources.

The EC provides structural funding to the Federator. This could incorporate money for the operational activities of the Federator, as well as structural funds for the facilities, to be allocated by the Federator. This allocation procedure could be based upon different drivers (as indicated in previous section): testbed size, number of experiments conducted, number of resources consumed, level of integration, reputation, etc. A clear KPI (key performance indicators) based feedback mechanism should be put in place in order to justify the funding allocation. The SWOT analysis is shown in Table 7.

This model, with free access to the facilities, will probably only be valid for EC funded projects. There could be a risk of free riding when users with interests outside the EC funded projects start using the Federator. It is up to the Federator to control the certificates and authentication in order to minimize the risk.

Table 7: Funding scenario 2 model - SWOT analysis

Strengths	**Weaknesses**
• Free to use for experimenters, encouraging high-risk high reward research	• No direct funding to testbeds – all controlled by Federator • Free service does not create incentive for good QoS
Opportunities	**Threats**
• Structural funds allow investment (e.g. tools, building facilities to meet future demand).	• Others will develop research infrastructures that provide missing functionality (or better QoS), stealing experimenters and EU loses edge. • Possibility of free riders

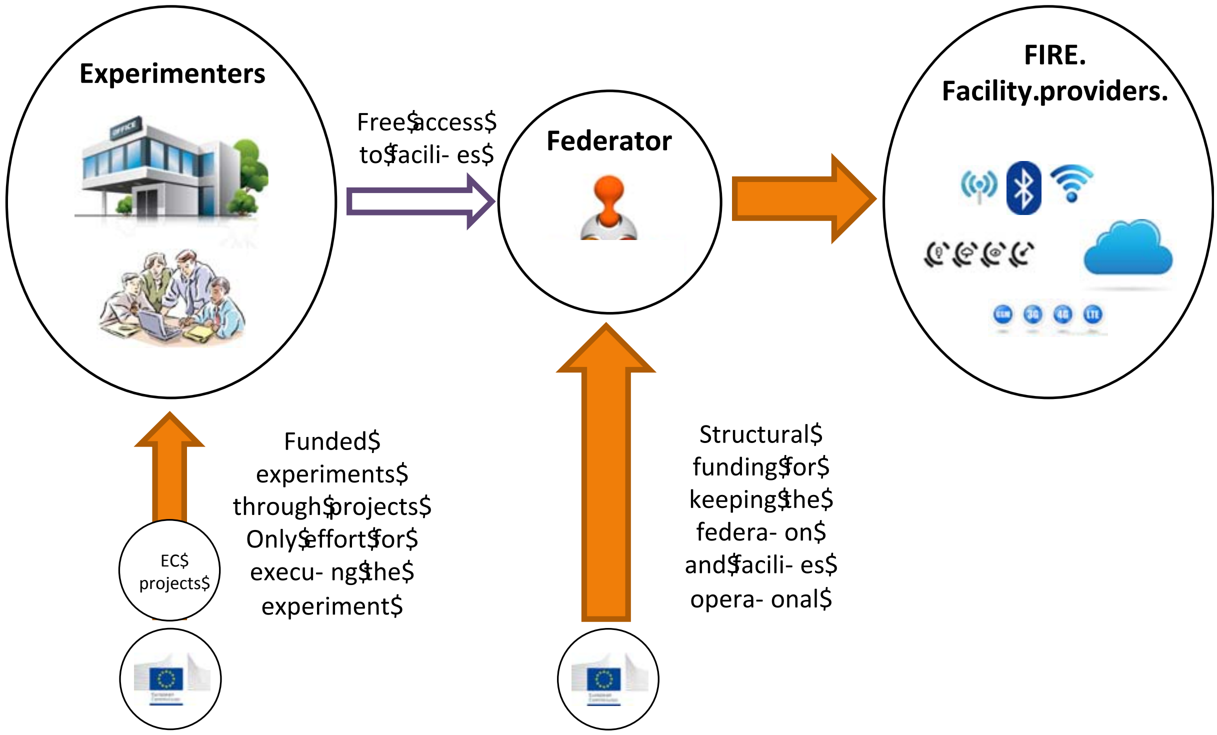

Figure 20: Funding scenario 2

5.3.4 Scenario 3: Federator centralized model

Another type of funding model is a centralized facilitator model, where the European Commission allocates funds directly to the Federator, who can spend this accordingly. This scenario is in line with the current Fed4FIRE model, presented above. Part of the funding can be used for developing new features and functionalities that can be adopted by the FIRE facility providers that are part of the federation. A large part of the money should go to open calls for experimentation, where funding is provided for executing the experiment (effort by the experimenters), and appropriate funds are foreseen for supporting the facilities of which the resources are used during the experiment. New innovative testbed facilities can also be funded through an open call mechanism in order to extend the federation. The SWOT analysis is shown in Table 8, and the scenario is represented in Figure 21.

Table 8: Scenario 3 model - SWOT analysis

Strengths	Weaknesses
• Simple model for funding agency • Centrally coordinated	• No direct funding for test facilities. • Lack of incentive for good QoS • Demand not fed through directly from experimenters
Opportunities	**Threats**
• Structural funds allow investment (e.g. tools, building facilities to meet future demand).	• High risk as all money flows via Federator. • May not match supply to demand

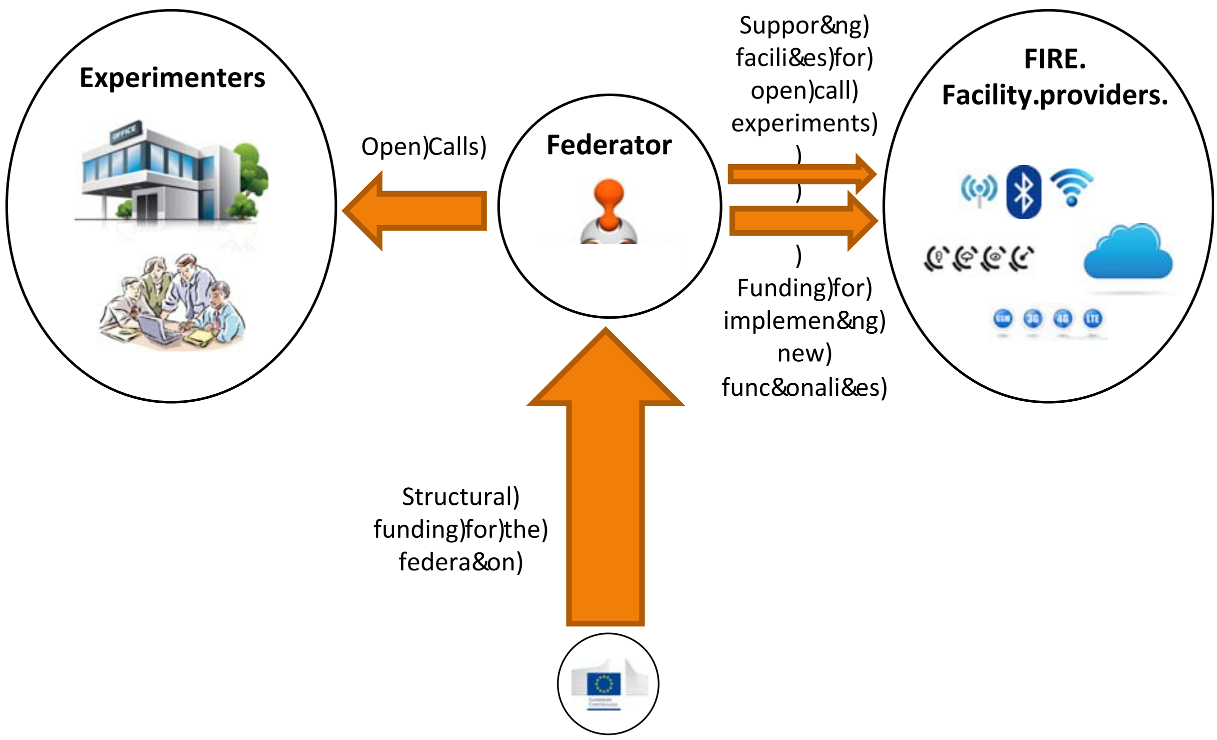

Figure 21: Funding scenario 3

5.3.5 Scenario 4: Combining project based and structural funding

The final scenario that we propose is a combination of structural and project / demand based funding, where some of the weaknesses in the previous models could be solved.

The FIRE testbed portfolio contains a lot of interesting and unique facilities that should continue to be supported. However, this is also considered as a dynamic market, where new testbeds can join and others leave. Sustaining the facilities in the portfolio should be a core target for the European Commission, subject to certain financial constraints. The Federator can play a very important role in coordinating (technically) the different facilities, and stimulating and supporting experimentation with in FIRE. This activity should be supported in a sustainable long-term manner.

Testbeds o could also apply for some structural, or recurring, funding, only as part of the federation. This funding could be proposal based e.g. for adding extra functionality or specific resources. However, the amount of funding requested should be in relation to the size of the facility and the added value it will bring.

We could still keep the pay-for-experimentation model from scenario 1, where EC funded projects allocate specific money for setting up and executing experiments, with financial support for the facilities of which their resources are used.

The scenario is presented in Figure 22, with a SWOT analysis shown in Table 9.

Table 9: Scenario 4 model - SWOT analysis

Strengths	**Weaknesses**
• Experimenter demand is fed through to test facilities • Facilities and Federator can invest – not solely dependent on current demand • Incentivizes QoS	• Three-way funding stream needs to be well balanced.
Opportunities	**Threats**
• Experimenters can carry out more speculative research (high-risk, high reward • Could offer commercial service	• Some testbeds might not survive

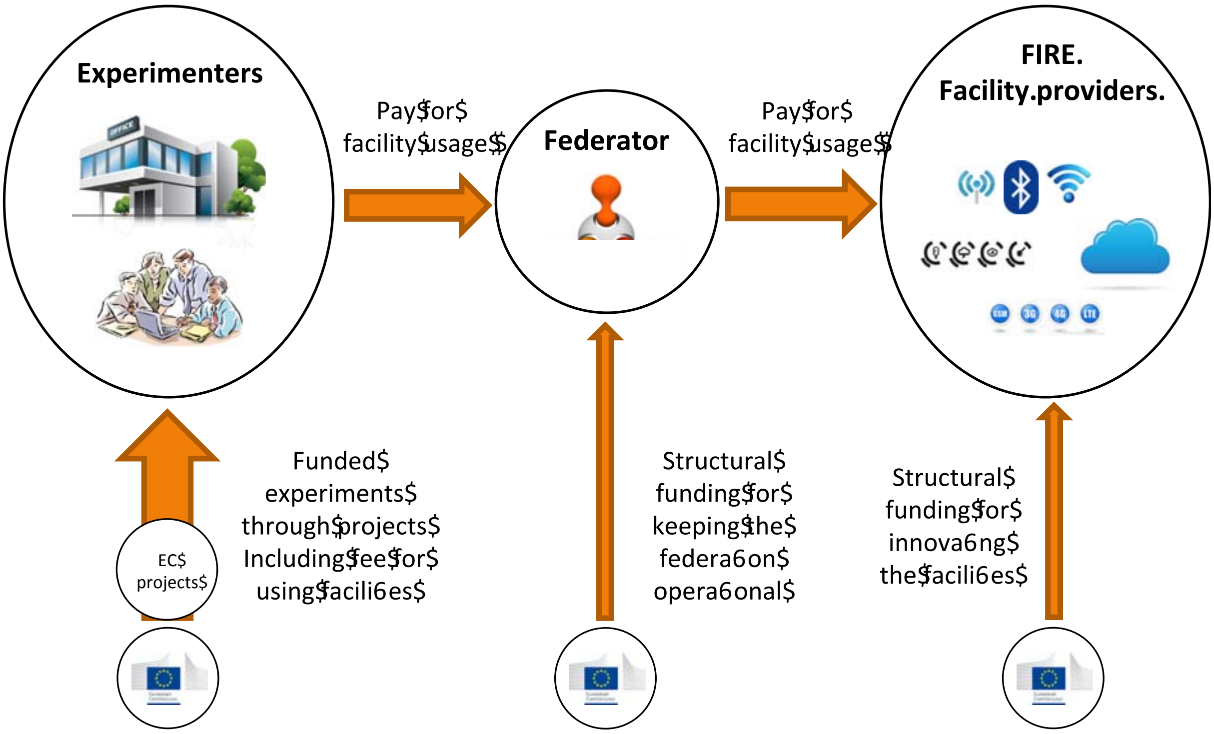

Figure 22: Funding scenario 4

5.4 Criteria and incentives for allocating funds

Different criteria or incentives could be used for funding the different stakeholders. It should be split up between funding for the facilities and the Federator, and drivers for tariff schemes for experimentation.

For the Federator and testbed facilities

Within the OSIRIS project, a list of evaluation criteria for research infrastructures has been defined. Evaluation has been defined as “the rigorous analysis of completed or on-going activities that determine, or support, management accountability, effectiveness, and efficiency”. [12] These criteria presented in Figure 23 could be used by the EC for allocating structural funds towards the Federation and the different FIRE facilities.

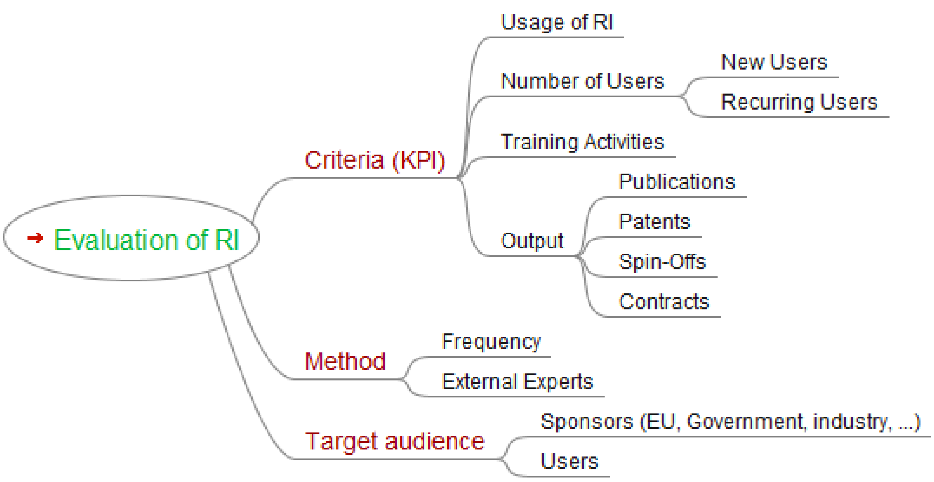

Figure 23: The evaluation of research institutes of the operational principles

The primary objective is to ensure that a testbed is delivering value to the experimental community and Europe in general.

The following criteria could be used for existing facilities

- *Usage of the facility*: the number of experiments conducted, percentage utilization of testbed resources (aka idle time vs. actual usage), etc.
- *Number of new and recurring users* of the facility: evolution, type of users (industry, SME, academic, education, local users), nationality, etc.
- *Training activities*: number of people who followed promotion and training activities such as summer schools, online tutorials followed by potential users, etc.
- *Output*: number of refereed publications resulting from experimentation on the testbed, patents pending and granted, notable success stories e.g. a product was developed or tested on the testbed and is now a top seller.
- *Others*: reputation based upon experimenters' experiences, governance structure and management of the facility (related to professionalism), service management approach used, its cost structure, strategy and future plans, etc.

For new testbeds, we need to consider different metrics because there are no usage metrics available.

The criteria could contain:

- How relevant is the testbed within the context of FIRE and the federation?
  - Is there demand for the testbed? How to determine?
  - Is the testbed in line with an EC-determined strategy?
  - Does it bring added value compared to the ones already available in the federation?
- What is the potential impact of the testbed (positively affect on research in Europe)?
- If the testbed came from a research project, how was the testbed used in the research project?
- How will the testbed get experimenters?

For experimenters

Different options could be presented to tariff experimenters.

- *Subscription fee* e.g. for research institutes or per EC project, based upon a reasonable usage.
- *Fee per experiment*: This could be a fixed fee independent on resource usage per experiment, could be based upon an "average experiment", or could be a specific offer tailored to the request
- *Pay-per-actual used resource*: A detailed overview / bill of consumed resources, based on a clear cost accounting model.

Ideally each facility has a detailed cost overview of its testbed, with indications of the investment and operational costs, and income. The main question is which parameters to consider for facilities for tariffing resources for experimentation:

- Just cost for basic business and technical support
- Including a fee for operational costs e.g. housing, electricity
- Including a margin for recuperating infrastructure investments
- Or even adding a cost+ margin for supporting future investments

A common ground should be found upon which the tariffs should be determined. On the other hand the funding for the different aspects should also be incorporated which might lead to a very broad range of tariffs for similar resources e.g. facilities with a lot of public funding (which have in most cases other KPIs (e.g. spin-offs, publications) than financial return) versus facilities with private funding (where a financial return on investment is required).

When looking at the facilities within the Fed4FIRE project, only 35% of the testbeds have a cost model. In most cases this covers all costs, thus CapEx and OpEx for the infrastructure, which could be allocated to the cost per resource per hour. This cost is then used to make an offer for “premium” access to the testbed. In addition, most of those testbeds also offer a “consultancy service” for dedicated technical/scientific support. Some testbeds offer this free (part of project cost or best effort), for others a day-rate is applied. The amount of effort for this additional work also varies and depends largely on the type of experiment and experimenter.

5.5 Recommendations

Based on the above-described analysis, a set of recommendations can be presented on possible ways the EC could manage, exploit, enhance and fund the FIRE facility portfolio in a more consistent (sustainable) manner.

Recommendations

As a first recommendation, it can be clearly stated that the use of current available FIRE testbed facilities should be stimulated and supported (financially) in a consistent manner. Setting up new testbed facilities should only be granted if they cover gaps in technologies and competences not present today, or when total innovative solutions are proposed. New developments, based upon experimenter demand and functionality improvements, should still be stimulated in current infrastructures. The funding mechanism should be in place long term, so as to provide the stability needed for experimenters to rely on the presence of testbeds. This does not mean that the testbeds within it will all be funded long-term. There will need to be shorter term funding cycles, and testbeds should have to reapply for funding, in competition (based on e.g. user and research demand, performance and usefulness metrics) with new ones that come out of infrastructure projects. This means the set of testbeds will evolve as needed by its community of users.

A second recommendation focuses on the facility providers, which should be stimulated to become more standardized by implementing the minimal set of common interfaces and APIs defined by the Federator. Existing testbeds should become compliant with the federation procedures, technical measures, terms and conditions etc, possibly with some additional funding. Newly developed facilities, set up within EC projects, should take steps in order to become compliant by the end of the project.

As most testbeds started off on resources originating from projects, our third recommendation aims at creating mechanisms, which financially support the testbeds beyond the project duration. However clear rules should exist which testbeds should be supported ongoing e.g. if facility is useful to a wider community, based upon demand from SME or industry, if it fills a necessary gap in competences, etc.

A fourth recommendation targets the requirement for the EC to monitor the different stakeholders in more detail. This will lead to a better overview of the status of the testbed infrastructures (number of users & experiments, funding, governance).

The Federator offers an added value service being in the middle between experimenters and testbeds. It can help experimenters in choosing the appropriate infrastructures based upon their requests. This could be based upon different parameters: technical requirements, availability of resources, reputation of the testbeds, cost-driven, etc. For testbeds it can be an additional source for attracting new experimenters. For the EC the Federator could monitor the status of the FIRE testbed portfolio.

A final recommendation includes cost-awareness. A cost-based approach should be demanded of each testbed facility. This could be used for billing experimenters, either directly or through EC project funding. Experimenters should be aware of the cost of using experimentation infrastructures, in order to make use of these scarce resources. Some testbeds might compete on a cost basis (some can be more expensive than other due to their cost structure), but on the other hand could offer a better service. It is up to the experimenters to choose the infrastructure of their liking. Besides, this will stimulate testbeds to either invest in their infrastructure or become more lean and professional.

Benefits

The result of this could have the following benefits:

- Europe will have a well-established network of diverse, interconnected and compatible experimental facilities that will evolve over time as needed, but with greater stability than the FIRE situation before where operational costs for running its testbeds are nearly solely funded through research projects.
- Research projects and researchers can use these experimental facilities without having to reinvent them, and in the knowledge that they won't disappear in the near future (tied to funding cycles)
- Researchers and experimenters from industry experience a lower threshold in accessing the testbeds as they are assured of receiving established technical support while using these testbeds.
- Current and new experimental facilities have a mechanism for sustainability and exploitation beyond the end of EC projects.

The actual mechanism for implementing the above will need to be determined, and this is one of the purposes of the next phase of the sustainability work.

6. Conclusions and future work

The goal of this deliverable was to present our view on the FIRE environment, how our federation fits within this environment (its value proposition), what it could offer (the services), how much it costs (total cost of ownership for the Federator to offer its services, as well as the TCO for the testbeds to implement it), and options to fund all of this. This deliverable builds further upon the work presented in the previous deliverables D2.3 and D2.6.

First we further validate, refine and prioritize our value proposition. The main value proposition towards experimenters includes choice among testbeds, combination of (heterogeneous) testbeds, ease of access (single point of contact), scalable facility (in terms of capacity and functionality) and offering of added-value services (e.g. tools). This analysis was conducted as conclusion of Open Call 1, and for Open Call 2. A differential analysis between SMEs, industry partners and academic research institutes was conducted. The Fed4FIRE testbeds were asked to indicate their added value for being part of the federation: access to new users including the visibility, accessibility and added support services to make the testbed more competitive for experimentation, new functionalities making it more attractive to users and better able to adapt to new requirements and scale, and optimization and increased efficiency of operations.

Next we furthermore built upon the detailed analysis of potential services, presented in the previous deliverable D2.6. An overview of the potential service portfolio is given, enlisting its components and the added value for offering it. We refer then to the minimal service components that should be offered by the testbeds. Based upon this service analysis, a total cost of ownership analysis is conducted for the Federator (to sustain its services for existing facilities, to add new testbeds and how it could scale with an increased number of experiments) and the testbeds (for implementing, supporting and updating the required components). We estimated that for sustaining the current set of facilities, around 4 FTE per year, spread out over a number of people, should be sufficient to run the federation, whereby we included support for tools and components for the facilities, technical support towards the experimenters, promotion and business support and effort for managing the Federator and federation. For the majority of testbeds the one time effort for becoming compliant to the Federator's demands ranges between 4 and 8 person months for an initial installation.

Finally the environment context and the need for sustainability within FIRE was analysed. There is a particular challenge associated with the way that experimental facilities are funded in the existing FIRE program. Testbeds in FIRE can only be funded by EC infrastructure projects at the moment, besides national or (limited) private support. To address these problems, we need an established mechanism for EC funding of experimental facilities, and their federation. Within this deliverable, an in-depth analysis is made how the different Fed4FIRE research infrastructures are currently funded. Different financial scenarios are worked out and discussed, considered from the point of the EC, how the Federator and FIRE testbeds could financially be supported. A first list of recommendations is proposed to the European Commission and other European entities.

As we continue to learn and gather new insights and results from other FIRE projects and the project's reviews, our work plan can be altered to react to these changes and opportunities.

Figure 24 presents the plans for the upcoming deliverables for this task 2.3 on sustainability. In the next deliverable (due M36) we will present out final sustainability plan, aligned with the work of the Federation Board and the exploitation plans of the project, the different testbeds and project partners.

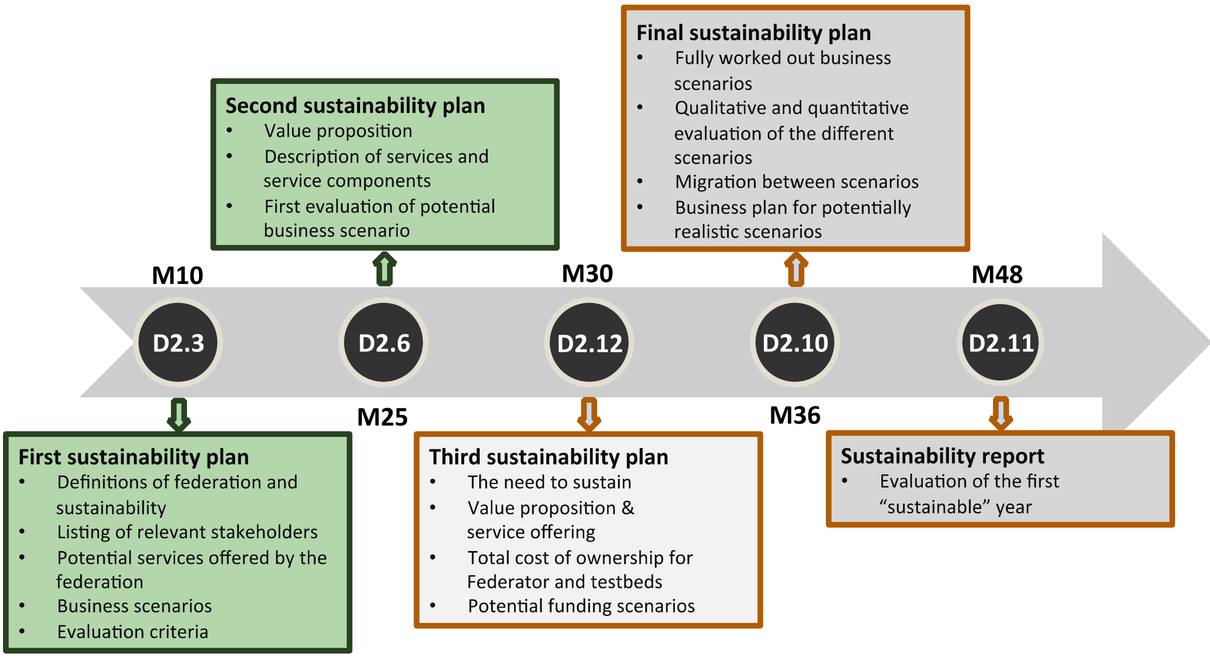

Figure 24: Steps towards the upcoming deliverables

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