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D2.6 – Second Sustainability Plan

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Abstract	This document provides an insight in the different values experimenters and testbeds see for this federation, a list of services and service components that the federation could offer with cost/benefit indication, and a first evaluation of a potential federation business scenario.
Keywords	Sustainability, federation, value proposition, services, cost/benefit model, business scenario evaluation

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	P	Prototype	
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	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. This deliverable builds further upon the work presented in the previous deliverable 2.3 entitled "First sustainability plan". We explore the methodology for extracting potential value propositions towards experimenters and testbeds, list potential services and service components the federation could offer with first indication of cost and value, and present a first evaluation of a potential federation business scenario.

Firstly we describe a methodology to determine a first value proposition for Fed4FIRE. Fed4FIRE has organized open calls for experimenters and additional test-beds. These calls have provided the opportunity to gain insight into the motivation of experimenters and test-beds to use the federation. Information concerning potential values for experimenter and facilities has been extracted from the different proposals. These include, for experimenters, a choice of testbed resources, combination of diverse facilities, easy access, continuous innovation of available resources and availability of tools. On the other hand facilities value mostly the potential access to new users, promotion and advertisement of their facilities, and tools and assistances. The results will be verified with feedback received from experimenters and testbed participating in the open calls.

We chose the FitSM IT service management approach for exploring sustainability within the project as Fed4FIRE is building a federation based on IT solutions. Moreover, IT service management is a recognized solution for the delivery of high quality IT services that meet the demands and expectations of users. We presented the different services our federation could offer by describing the service components, their cost to offer by the federator and facilities, and their added value towards experimenters and facilities. This information is the basis for describing different business scenarios, where cost/benefit trade-offs will be made. A cost/benefit model was created to support this task. A first evaluation of a potential federation business scenario is presented to indicate he working of our proposed methodology.

More models will be analysed and evaluated, based upon more accurate information that can be retrieved from open call experimenters and newly added testbed infrastructures. 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.

Acronyms and Abbreviations

CapEx	Capital Expenditures
CI	Configuration item
CPU	Central processing unit
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
GUI	Graphical User Interface
H2020	Horizon 2020
ICT	Information and Communication Technology
IP	Integrated Project
IT	Information Technologies
NIC	Network interface card
OMF	ORBIT measurement framework
OML	ORBIT measurement library
OpEx	Operational Expenditures
QoE	Quality of Experience
R&D	Research and Development
SC	Service Component
SCS	Stitching Computation Engine
SLA	Service Level Agreement
SME	Small and Medium Enterprises
SOSP	Symposium on Operating Systems Principles
STREP	Specific Targeted REsearch Projects
VM	Virtual machine

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1 Introduction

The Fed4FIRE project is bringing together the knowledge and competences of different stakeholders within the FIRE scene [1] to collaborate and set up a federated platform of test-bed facilities, mostly focused on technical and operational solutions. With the growing demand for ever more complex Future Internet systems and experiments, there is a strong requirement to sustain federated cross-domain experimental facilities: i) to ensure the latest cutting-edge facilities are available to a large and experienced set of established communities; ii) to offer centralized services and minimize operational costs; and iii) create a sustainable solution to continually generate value and impact beyond the original funding.

In this task we explore how to sustain such a federation of experimental facilities in order to serve the needs of experimenters and testbeds in the future of the Internet. A complex value network of different types of stakeholders, experimenters, developers, test-bed operators, etc. must be managed. The big challenge is to define the value for, and to incorporate the interests of all stakeholders in order to make sure they clearly benefit from this federation.

1.1 Overview of previous work within this task

We defined a future 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.”

Within deliverable D2.3 (First sustainability plan) [2] we presented our methodology to be used in the remainder of the sustainability task within the Fed4FIRE project. First we defined “federation” and “sustainability”. This work was supported by a thorough literature review on the current status, and sustainability and exploitation plans from other federation projects within and outside FIRE. Next we analyzed the Fed4FIRE landscape with current and potential future stakeholders, where we considered the federator (the organization responsible for operating the federation), the experimenters and facility providers to be the main stakeholders. 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. The final goal is to present a business plan for the future federation, by evaluating the proposed business scenarios and indicating the most realistic strategy. This methodology was thus the first result of our work and will be applied and refined in the upcoming months and next deliverables.

1.2 Goal and structure of this deliverable

In this deliverable entitled “Second sustainability plan”, we focus on the different “options” that the federation can choose from in order to make a business plan: value offering towards its stakeholders (experimenters and facilities) and the potential service components, including a first estimation of cost and benefit, that could be supported. A first plausible federator scenario is analysed and evaluated.

Following key contributions have been made:

- *Identification of the value proposition*. We describe how we identified the value proposition of Fed4FIRE and how this impacts on the continuing and changing needs of experimental users and testbeds. And, in turn, how long term sustainability must plan for such changes.
- *What is the service offering*? Services provided by the federation come with a cost; such costs add to the challenge of sustainability. We propose the key services that are required in the long term and examine the appropriate federation and business models that underpin their delivery.
- *Evaluation of a potential federation scenario.* Based upon the requirements from testbeds and experimenters we make a selection of the most suitable service components and calculate the costs and benefits for facilitator and testbed.

We end this deliverable with initial recommendations, conclusions and next steps.

This is the second 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 are envisaged.

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 [3]. This subtask will contribute input to *Task 8.3 "Sustainable standardization"*.

Business models

Business models are developed that are adapted to specific cases and 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 fluid way. Results of this subtask will contribute to *Task 8.2 "Establish and operate federation authority"*.

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 enhancing 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, etc.

2. Scoping sustainability

Sustainability can be considered as the *ability to continue*. Sustaining a federation of experimental testbed facilities is driven by three important factors:

- *Sustainable need:* there is an ongoing need for someone to use the federation to compose experiments across heterogeneous experimental facilities. Once the need disappears there is no need to continue providing the service. An important consideration is that market needs change over time; this is especially relevant to research-based facilities where the need for today's hot technology dies once innovation is saturated. Hence sustainable need must consider changing customer needs, and may change its service accordingly.
- *Sustainable capability:* the continued provision of a service, i.e., generating the required resources (e.g. money) to maintain operation of the federation. Long-term sustainability plans typically focus on evaluating the direct costs and developing diverse and reliable revenue streams to recover the costs [4]. Experimental facilities that wish to be sustainable beyond the initial project funding (e.g. a European Commission Capacity building project) must examine future customer relationships and be creative in seeking alternative revenue streams. For example, open source software projects generally migrate from a project model to a service model (e.g. consultancy and support for the use of free software) on top of which commercial relationships can be built [5].
- *Sustainable community:* a set of people who are willing to commit their time and skills in order to add value to the federation. This can be in terms of bug identification, suggesting new requirements and features, testing, project management and traditional software development practices.

Sustainability plans generally focus on capability; however, "it is not about the money; it's not about getting by; **it is about identifying value to a specific group or stakeholder**" [4]. Similarly, "continuity of effort and requirement/need is fundamental" [5]. Sustainable need and capability are strongly coupled and hence **value is the capability that answers a sustainable need**. A clear value proposition offers something unique, of need and continues to add value based on changing user demands [4].

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 has clear benefits for its main stakeholders - experimenters, and facility providers."* We should thus support an experimenter infrastructure that enables innovation. Our focus will be, in the end, to define what the federation should do, how it should do it and how it could be funded. The Fed4FIRE sustainability plan does not directly tackle the sustainability of individual testbeds; however, the sustainability of the federation could of course have an impact on the sustainability of each facility. As the testbeds are the key stakeholders of the federation, we should provide some mechanisms to help (partially) sustain them (e.g. via the 'patron service' used, by Fed4FIRE in its Open Call mechanism, whereby testbeds are also funded for helping experimenters during their experiments). Within the H2020 calls of the EC, there is a strong push towards funding experimentation during projects (50% of the project budget being allocated for this), but little is set up for supporting the used facilities. Incentives should thus be provided to testbeds that are demanded by experimenters and are performing well (e.g. based upon reputation). We should of course stimulate innovation and technical upgrades, and motivate testbed infrastructures to provide additional value added services.

The above principles drive Fed4FIRE's approach to the sustainability of the federation. The federation should offer a set of key services that meet the desired value proposition. We chose an IT service management approach, based on a standardised methodology developed to define services, to

deliver these services because Fed4FIRE is building a federation based on IT solutions. Moreover, IT service management is a recognized solution for the delivery of high quality IT services that meet the demands and expectations of users. However the management of service components should be underpinned by business models that optimize their delivery (through procedures), and hence lead to a more sustainable capability.

3. Potential Value Proposition

This section describes our methodology to determine a first value proposition for Fed4FIRE, together with the value proposition itself. This is a first draft and is likely to change over time as experience and new considerations come to light.

To identify the value proposition, we analysed information obtained from open call submissions to help us identify what experimenters and testbeds saw the value of Fed4FIRE to be. Fed4FIRE operated an open call where new testbed facilities and experimenters could seek funds to either join the federation as a testbed or use the facilities as an experimenter. Within the proposals we found very valuable insights concerning their expectations in terms of what value they thought they would gain from collaboration with Fed4FIRE. In addition, all proposers were surveyed as to the value they saw in the Fed4FIRE offering. We analysed the proposals and survey results to highlight the common value statements, and also those where it was clear significant value was provided.

3.1 Initial Value Proposition

Fed4FIRE uniquely provides the ability to combine multiple distributed, heterogeneous testbeds to support Future Internet experimenters. A future operator of Fed4FIRE (the federator) is ***not*** an experimenter or a testbed: instead, it is an organization that *enables* federation to happen - an organization that mediates between experimenters and testbeds and enables experimenters and testbeds to join together for their mutual benefit. Fed4FIRE goes beyond single-function federations of testbeds: the diverse collection of testbeds in Fed4FIRE, and the potential to allow others of different types to join (and leave) in the future offers a novel and desirable platform for experimenters to utilize and testbeds to be a part of.

In terms of a future Fed4FIRE value proposition, we think it is important to have two related value propositions, each one targeting a different type of stakeholder:

- a value proposition targeted at the experimenters;
- a value proposition targeted at the testbeds.

The experimenters and testbeds are the two key stakeholder types that Fed4FIRE is concerned with, and ***both*** are needed for Fed4FIRE to work and continue into the future! Our current thinking is that a significant part of Fed4FIRE's two value propositions is concerned with enabling experimenters and testbeds to work together with each other. We assert that the two value propositions should be compatible and consistent. If this is not the case, the operation of Fed4FIRE may be made difficult or impossible.

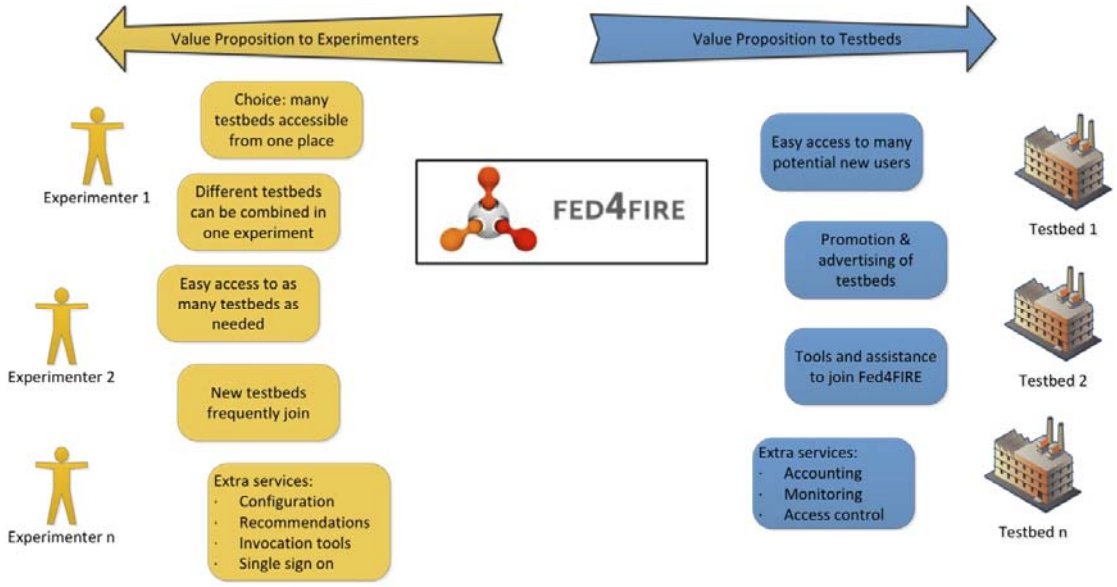

Figure 1: Value Propositions of Fed4FIRE to Testbeds and Experimenters

Figure 1 illustrates this compatible and consistent proposition delivered by Fed4FIRE. The blue and orange boxes in the picture are examples respectively of benefits to the testbeds and experimenters, i.e. the value proposition of Fed4FIRE to each stakeholder type. These are derived from the analysis of the open call 1 experiments, where the proposals and survey responses were examined and analysed to determine potential value of Fed4FIRE to both experimenters and testbeds. Fed4FIRE should offer significant value to both experimenters and testbeds in order to be sustainable. Hopefully it is clear from the above that if Fed4FIRE is able to mediate between experimenters and testbeds, it will bring benefits for both.

In the next two sections, we consider the individual value propositions to the experimenter and the testbed operator respectively.

3.1.1 Experimenters

Potential value

Figure 2 highlights the value available to experimenters. This also demonstrates the important concept: it is the federator (the organization responsible for operating the federation) and the testbeds together, in combination, that add value for the experimenters. The most important are choice of testbeds, combination of testbeds and easy access. Hence, Fed4FIRE allows experimental functionality to be flexibly created by the user, for example:

- An experimenter can pick and choose which testbeds to combine.
- An experimenter can select facilities based upon location or other non-functional requirements.
- The combination of testbeds generates new experimental testbed functionality.
- Functionality can be quickly configured that would be expensive and time-consuming for an experimenter to replicate themselves.

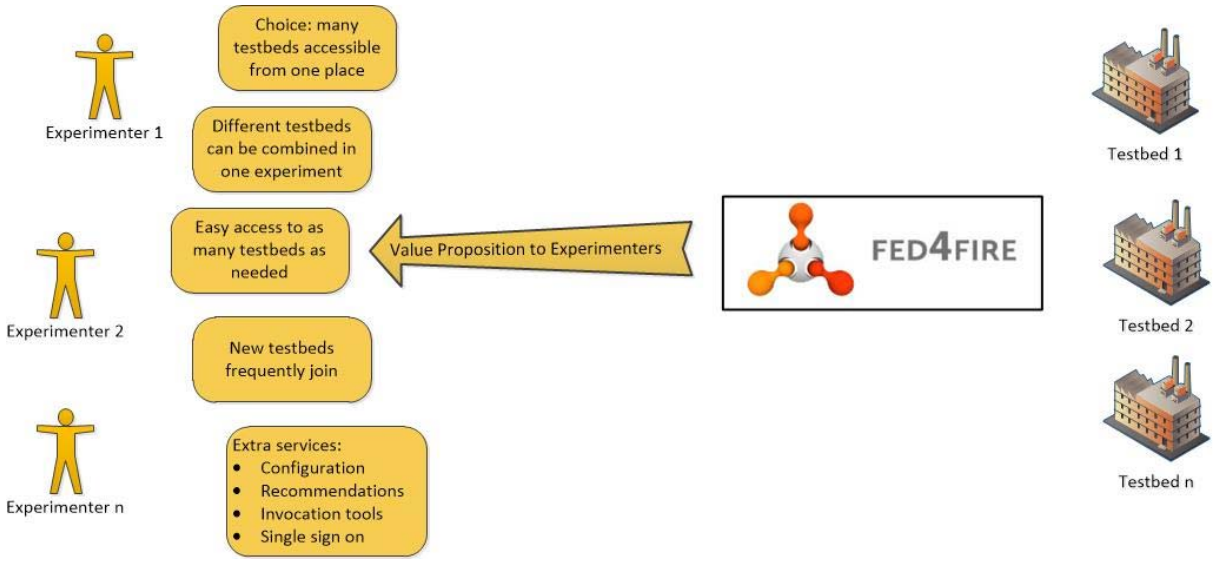

Figure 2: Value proposition to the experimenters

Sustainable need

A key question regarding the sustainability of Fed4FIRE is the extent to which there is a *sustainable need*. That is, once the exercise of federating testbeds is complete and the value proposition is fully realized, is there a market of users who will benefit from the offering and, more importantly, will this *need* be sustainable in the long term?

At present, and until the end of the Fed4FIRE project, Fed4FIRE users (customers) can be broken down into two categories:

- Members of the Fed4FIRE consortium who use Fed4FIRE as a demonstrator for their work within the project.
- Potential users of Fed4FIRE via the open call funding mechanism. These users have expressed interest in carrying out cross facility experiments, supported by funding from the EC. In the initial open call 55 proposals were submitted.

The response to the open call clearly shows there is interest in Fed4FIRE, and it is difficult to assess whether this is driven by experimenter demand or by funding push (i.e. they are paid to leverage Fed4FIRE). In order to be sustainable, Fed4FIRE must go beyond these parameters and target a wider market audience, determine their needs and factor these needs into an updated value proposition. As a step towards identifying this wider audience, we have analysed some initial user types, and these are discussed next.

User types

1. *Experimental computer scientists*. Academics whose general goal is to produce novel innovations in the field of computer science, typically through the development of new systems, software, protocols, etc. They validate their hypothesis using experimental methods rather than the proofs employed by theoretical computer scientists. The expected outcome is a publication in a high-impact venue (e.g. conference or journal); a small proportion of these computer scientists will seek to transfer their innovation to a commercial product or service.
2. *Technology innovator*. These are people who explore how new technology can be applied. Whether this is for an intellectual challenge or for community good (other people can build

upon the work c.f. open source initiatives) the work can often be a springboard for commercial uptake or for wider social impact.

3. *Commercial R&D engineers (start-ups, SMEs, industry)*. Commercial R&D is typically expensive with a high risk of no return. Hence, there is pressing need to offer low cost, easy access entry facilities in order for commercial engineers to quickly assess the viability of an innovation before committing further resources.
4. *Educators*. There is a need to educate tomorrow's technologists in Future Internet technologies and hence students and educators can leverage the FIRE facilities to perform training exercises to understand both technologies and concepts. Such educators will be university professors teaching undergraduate, masters and Ph.D. students. PlanetLab [6] has consistently been used to educate graduate students.

In the short term, experimental computer scientists, researchers and educators are clearly the most relevant users of the Fed4FIRE facility (i.e. these are the most part of the Fed4FIRE consortium and experiment proposers in the open call). The key questions we need to research further are:

- Does Fed4FIRE meet their needs?
- What needs do they have that Fed4FIRE does not, but could, meet?
- Does Fed4FIRE provide value to attract more of these users?

Experimental practice requirements

A key value proposition of an experimental facility to these users is the acceptance of this facility as a standard tool for evaluation of results. For example, if you are writing a paper about a P2P technology or overlay network then an evaluation based upon PlanetLab is a recognised method positively favoured by reviewers. [7] states that "a key point regarding scientific experiments is their need to be comprehensively and unambiguously described when reporting their results. An experiment described in such a manner would then be reproducible by peer researchers. While such a practise is not common in the networking world, it is part of the peer-review approach used in other fields such as chemistry or physics". This is demonstrated with an analysis of the evaluation of a subset of ACM Sigcomm submissions: 12% do not validate, 21% miss adequate replication, 58% do not indicate precision [7].

There are many papers written about evaluation practices and the peer-review process; but it is clear that experimental testbeds are an important instrument in the process. Hence, marketing Fed4FIRE as a key tool in the R&D process is important to its success. Methods to do this include conference advertising, conference sponsorship, and acceptance of papers using Fed4FIRE. In addition, Fed4FIRE must establish its credentials as a robust experimental platform, where attributes such as controllability and repeatability of experiments are prioritised.

Both academic (and industrial) researchers seek to publish results in high-ranking journals and conferences. This is driven by the goal of achieving impact (typically measured using citation metrics). This is not restricted to academics—indeed at top levels systems conferences (SOSP, Usenix, Eurosys, etc.) academic papers will be in the minority. One way we can assess the potential market of experimenters is to examine publication submission statistics [8] —if we assume that a paper at an experimental venue requires experimentation to validate its hypothesis. While information is incomplete for recent years, it can be seen that even with a small portion of venues there is a large pool of researchers in the fields relevant to Fed4FIRE. There are a consistent number of submissions to networking (~7000) and systems conferences (~3000), and it is clear that research into cloud computing is generating increasing numbers of submissions. While not all researchers would need Fed4FIRE facilities, it is clear the market is significantly greater than the open call

proposers. We should indicate that already a number of publications have been published by Fed4FIRE open call participants.

3.1.2 Value for testbeds

Value proposition

Figure 3 highlights the value available to testbeds. As with the other value proposition, this is created by the usage of the federation by a stakeholder (in this case experimenters):

- *Greater potential market for testbeds*. Fed4FIRE has an existing customer base that a testbed can target once joining the federation.
- *Advertising and promotion.* There are channels for each testbed to advertise and promote their service to the Fed4FIRE users.
- *One stop shop*. Their testbed can be combined with other testbeds to broaden the service offering and increasing the potential user base.
- *Lowering operational costs* for testbeds when tools and assistance are provided by the federation
- *Common additional services*; reusable services like accounting, monitoring, access control, and invocation tools support standard integration of testbeds and also provide added value services on joining.

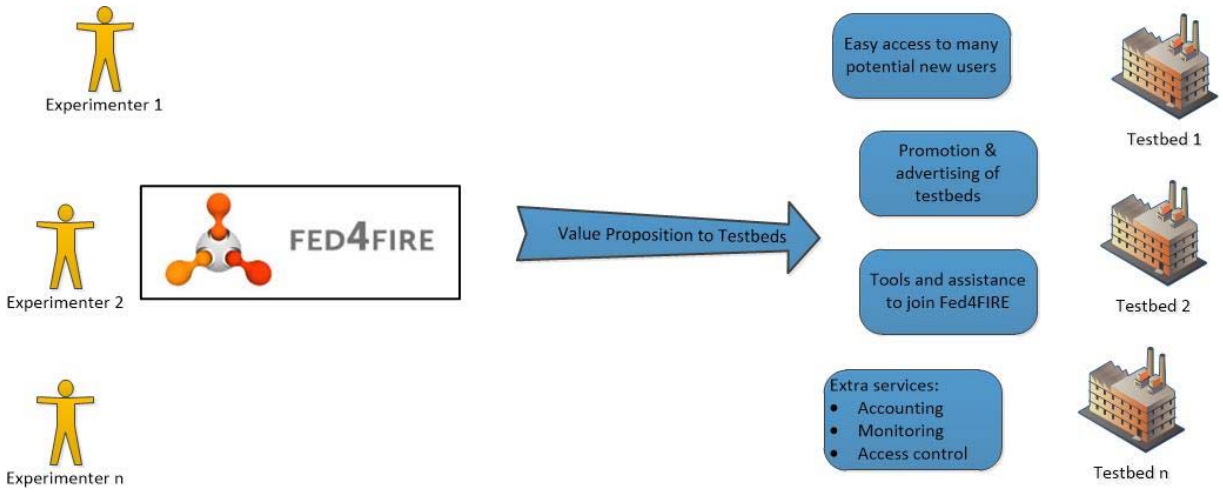

Figure 3: Value proposition to the Testbeds

Sustainable need

Following on from the *sustainable need* of experimenters; is there a sustainable need for testbeds to gain value from the federation? This is naturally tied to the needs of the users; where users require federation of testbeds there will be a market of users that can be targeted by the testbeds.

At present and until the end of the Fed4FIRE project, Fed4FIRE testbeds can be broken down into two categories:

- Existing federation testbeds: 17 testbeds joined from the initial Fed4FIRE federation and the extension after the first open call.
- Potential federation testbeds: during the project, several open calls for testbeds have been conducted, with large amount of submissions. Up to now, around 120 European testbeds are registered in XIPI [9], an on-line catalogue of Future Internet infrastructures, which indicates

the large potential testbed base. Besides, in Horizon 2020 new testbeds will continue to be funded (in the first work programme 2014-2015 there will be two new experimental facilities with one targeted to experiment-as-a-service) [10].

Therefore, Fed4FIRE's market share of European testbeds is currently low but there is significant potential for growth in order to sustain the need for the federation. By interacting with experimenters Fed4FIRE also has the opportunity to monitor trends in order to spot gaps in the market and make proposals for new testbeds to join the federation based upon the needs of experimenters.

3.2 A changing value proposition

An organisation's value proposition is necessarily linked to the continuing needs of its user community. Anticipating the needs of the research community is a difficult task; however, research trends show that Fed4FIRE's value proposition of combinable heterogeneous testbeds is highly relevant for today's researchers. Increasingly Internet usage combines various different systems and technologies. In order to develop services and to innovate in this environment there needs to be a flexible test environment that mirrors these developments. There are existing test-beds that enable the testing of individual parts of this heterogeneous environment. By combining them in a federation, in such a way that they are compatible and harmonized you enable such a flexible testing environment.

A key point of Fed4FIRE's value proposition is that new testbeds can join the federation, so the federation can adapt to changing needs. The users decide the combination of testbeds that meet their needs, and new testbeds joining the federation means users have greater choice. As new needs emerge, testbeds can be created to serve these needs and can be integrated into the federation. This means the federation of heterogeneous testbeds offers a unique value proposition in comparison to a single integrated facility and it is this property that allows the federation's value proposition to meet changing demands—new facilities can join the federation offering the latest experimental facilities. In order to address this aspect of the value proposition, a key requirement is that the federation must provide services or tools to make it easy for new testbeds to join the federation.

Fed4FIRE directly supports changing value due to the value proposition of being a delivery channel for experimental facilities with a low entry barrier for new facilities and services. Fed4FIRE will keep track of new needs from its existing and future user communities, by using methods already mentioned in this section. Specifically, Fed4FIRE has further open calls (open call 2 and the SME open call) providing new surveys, where experimenters and testbeds can provide their opinion about the value of Fed4FIRE, and these will be analysed to provide an updated value proposition reflecting the needs of this expanded user community.

4. Potential services offered by the federator

The federator provides benefits to its main stakeholders, experimenters and experimentation facilities. These benefits are the result of a set of services provided by the federator to each of them.

The goal of this section is to identify, classify and describe the potential services. It is key within this task of the project to make the trade-off between the cost to offer, and benefits aligned for the different stakeholders for each service offering.

The services analysis in Fed4FIRE leans on FitSM, an IT service management methodology designed by the FedSM project [12] and described in the following subsection.

The next step in this process is to evaluate the value of these services in a cost-benefit analysis. To shed light on the costs of a service a lightweight and easy-to-use cost accounting template is used, which is presented in section 5. This template will be used during the project to estimate the cost of a service. Some first results have been gathered which are presented in section 6.2. As quantification of the value of a service is much harder and may often provide unreliable results, a qualitative approach will be pursued during the project.

4.1 The Service Management Model

We chose an IT service management approach for exploring sustainability within the project as Fed4FIRE is building a federation based on IT solutions. Moreover, IT service management is a recognized solution for the delivery of high quality IT services that meet the demands and expectations of users. After all, Fed4FIRE will deliver services that rely on IT solutions thus such an approach is very convenient to define the procedures required to carry out these services.

We therefore adopted the FitSM model [13], a lightweight standards family aimed at facilitating service management in IT service provision, including federated scenarios. This standard has been provided by the FedSM project, an initiative co-funded by the European Commission Seventh Framework Programme to improve service management federated ICT infrastructures and to bring experience from this improvement to a broad community of (federated) communities.

We adopted their vocabulary and templates to define a service, service component and configuration items.

- A *service* is defined as a way to provide value to a user/*customer* through bringing about results that they want to achieve.
- A service is composed of *service components* (SC), which are technical or non-technical elements helping to make up a service. It is any component, which underlies a service, but does not create value for a customer/user alone and is therefore not a service by itself.
- *Configuration items* (CI) are elements that contribute to the delivery of one or more services or service components, and therefore needs to be controlled. CIs vary widely and can be anything from technical components (switches, cables, software), effort (human resources) to documents (SLAs, contracts, procedures).

In the next sections, we will go deeper into the different core and supplementary services offered by the federation, their service components and configuration items.

4.2 Service portfolio

Services are 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 an expected capability by the end users. Additional or supplementary services are considered as nice to have.

The federation focuses on the provisioning of the core services but could also implement certain supplementary services. 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. Some services may have a large benefit 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 goal of the next section is to identify, classify and describe the possible services and to identify their components and configuration items in order to define the Fed4FIRE portfolio. This analysis started from the currently proposed and implemented architecture [14][15].

The left side of Figure 4 gathers core and supplementary services offered by the federation. All of these services rely on specific service components, which are described in the following section.

4.3 Service components

This section describes service components for core and supplementary services. Our core service towards experimenters is the ability to experiment using multiple federated experimentation facilities. The service can furthermore be split up in different main categories: i) resource description, discovery, reservation and provisioning, ii) resource management, iii) experiment control and iv) monitoring. The supplementary services consist of experiment extensions (e.g. permanent storage), experimenter support, incident management and service level management. Towards testbeds, the main service consists of providing the possibility to promote the facilities as part of a wider federation and providing the tools and APIs for the different facilities in order to become compliant, as well as the necessary support from the federation.

Figure 4 provides a graphical overview of the services that could be offered by the federation and the service components they rely on.

In the remainder of this section we provide a more detailed description of each service and service component. For each of these, we try to provide answers to the following questions:

- Description: what is the component functionality?
- Cost to offer[1]: what is the cost of offering this component
    - In a federated way (cost for the federator to offer this feature)?
    - To new facilities joining the federation when the feature is offered by the federation?
- Added value: what is the added value[2] for experimenters and facilities of doing this in a federated way?
- Recommendation: is this an essential component for the federation?

In order to compare the cost and value of each service component independently, we use the following quantifiers for evaluating each component the federation could offer:

[1] The cost to offer considered here includes only maintenance costs in case Fed4FIRE is already providing this component to the federation as part of the work done in the framework of the project.

[2] The real added value for each component will be realized in combination with other service components, offered within a service.

- 0 = None (does not apply)
- L = Low
- M = Medium
- H = High

In case a service component requires some additional development and support in the future, the federator may prefer to rely on a service provider (tool developer) in order to carry out the required functional evolutions of each tool, instead of doing it by itself. The development of such evolutions might be provided by a commercial partner (e.g. an SME specialised in that particular domain), other research projects or by one of the software communities producing open source software. The federator has to make sure the software is compliant with its set requirements. For each component a choice has thus to be made which software to use, and who will deliver and support this.

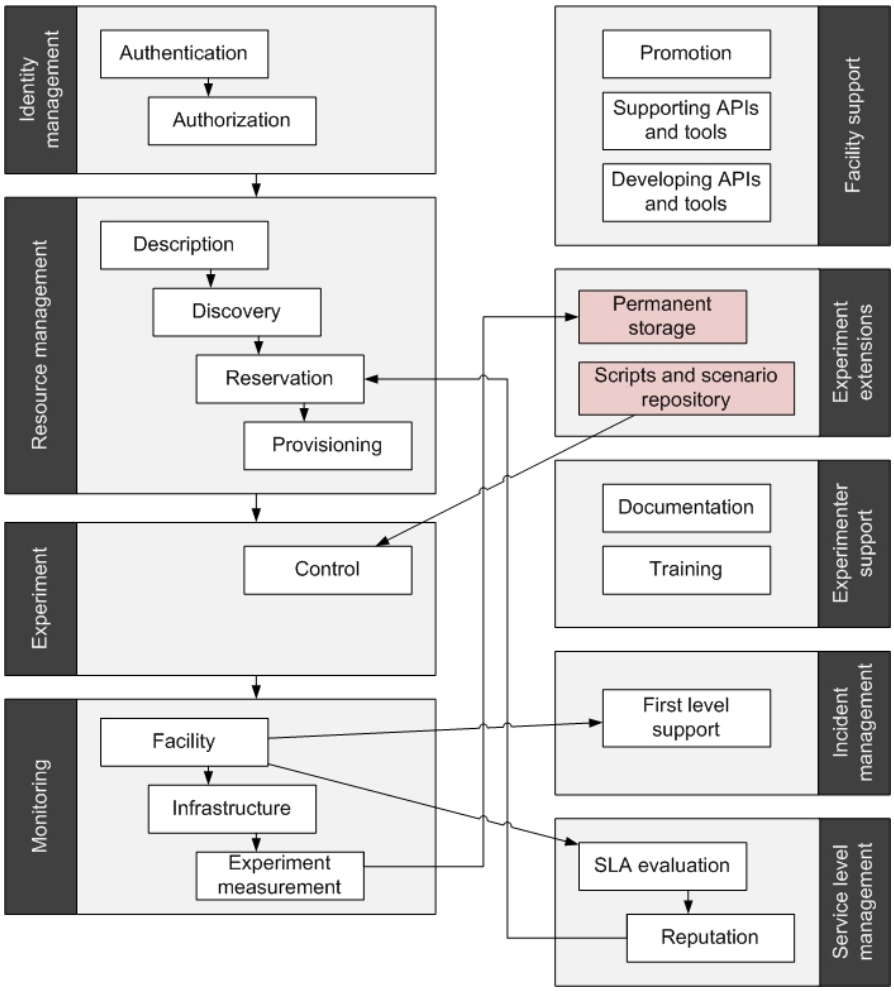

Figure 4: Overview service components

4.3.1 Service components for experimentation services

4.3.1.1 Core services

Identity management

We start with the first steps within the experiment lifecycle, namely the authentication (the processes for establishing roots of trust and issuing identities within a federation) and authorization (capabilities to protect access to data and other resources), resource description and discovery (finding the resources and applications), resource reservation (allocation) and provisioning (instantiation).

Table 1: Identity management: authentication and authorisation

Authentication and authorization			
Description		Authentication includes the processes for establishing roots of trust and issuing identities within a federation. Authorization includes the capabilities to protect access to data and other resources for only authorized individual including mechanisms for delegation and revocation of rights to experimenters and services operated within an organization of 3rd party organizations.	
Cost to offer	by the federator	L	This component is provided by Fed4FIRE. The only cost is related to to update slice and member authority software yearly
	by the facilities	L	Most facilities already have their own identity management systems. Only updates would be required
Added value	for the experimenter	H	Central login – ease of use – one account – directly linked to what he can use depending on his type of account, ...
	for the facilities	M	Reduced operational activity Centralized administration, increased customer base when linked with other authentication registries, ... (qualitative evaluation)
Recommendation		H	The value exceeds the cost for offering this. This component is vital for the federation

Resource management

Table 2: Resource management: resource description, discovery, reservation and provisioning

Resource description and discovery			
Description		Finding available resources and applications across all testbeds, and acquiring the necessary information to match required specifications, including the guarantees offered by the provider in terms of how the service will be delivered (e.g. availability of resources). Resource discovery can also provide information concerning the reputation of the facilities (trust). This concept also includes connectivity services offered by each facility.	
Cost to offer	by the federator	L	This component is provided by Fed4FIRE (ontologies). Unified resource description and methodology for resource discovery for heterogeneous resources. The ontology should be as universal as possible in order to support new resource types not existing today. As far as connectivity is concerned, the federator's role would be to coordinate standardization of technology/tools/policies frameworks, etc. Moreover, there has to be a central component required to determine the routes among testbeds called SCS (stitching computation engine), which currently runs at iMinds.
	by the facilities	M	Adaptation of own resource description.
Added value	for the experimenter	L	Discovering all resources in a centralised manner is easy and I a benefit to the end user (instead of fragmenting resources across different facilities that the experimenter has to visit independently). However, this feature is expected by the experimenter, so the value is only low.
	for the facilities	M	The supermarket effect can promote the usage of certain facilities that were not initially planned for an experiment.
Recommendation		H	This component is vital for finding the resources required for experimentation over different facilities. The value for the experimenter is low, as he sees it as a necessity rather than an added value.

Resource reservation			
Description		Allocation of a time slot in which exclusive access and control of particular resources are granted We can see 2 dimensions: - Type: soft (best effort) versus hard (guaranteed) reservations - Timing: now, sometime (waiting until resources become available), scheduled (at predefined moment in time) – all for a certain duration	
Cost to offer	by the federator	L	This component is provided by Fed4FIRE (central reservation broker).
	by the facilities	M	Adoption of reservation implies internal mechanisms to control access to reserved resources or even to penalise mis-usage, e.g. reserved resources are not finally used, especially when no billing is applied
Added value	for the experimenter	M	Reservation is useful when demand is very high. Most facilities have no capacity issues currently. However, reservation can be crucial when facilities are used for training purposes involving a large number of interested experimenters.
	for the facilities	M	Reservation is useful when demand is very high. Most facilities have no capacity issues currently. An increased usage of the testbeds can also be an added value for them.
Recommendation		M	This component can be vital for some experimenters e.g. academic or SMEs. It will depend whether hard reservation is required by experimenters, and on the availability of capacity of the different facilities. The actual reservation system deployed will depend on the cost for implementation centrally and at each facility and the requirements from their experimenters

Resource provisioning			
Description		Instantiation of specific reserved resources directly through the testbed API, responsibility of the experimenter to select individual resources.	
Cost to offer	by the federator	H	It implies orchestration procedures. Will depend on the reservation and orchestration tool implemented. It needs to orchestrate the availability of requested resources with the demanded time constraint. At the time of writing this deliverable, the federation has not implemented orchestration features yet.
	by the facilities	L	Already existing provisioning mechanisms will be used. The orchestration operates at a higher level and the testbed only receives requests and provides some result to the central tool.
Added value	for the experimenter	L	The experimenter might consider this a basic procedure, as provisioning of the requested resources is fundamental for experimentation. It gains more value as it is more sophisticated (e.g. orchestrated provisioning across different facilities).
	for the facilities	L	Facilities have their own provisioning mechanisms.
Recommendation		H	This component is vital when reserving resources required for experimentation over different facilities. The value for the experimenter is low / non-existing, as he sees it as a necessity rather than an added value.

Experiment control

Experiment control deals with control of the testbed resources and experimenter scripts during experiment execution.

Table 3: Experiment lifecycle: experiment control

Experiment control			
Description		Control of the testbed resources and experimenter scripts during experiment execution. This could imply predefined interactions and commands to be executed on resources (events at start-up or during experiment workflow). Examples are: start-up or shutdown of compute nodes, change in wireless transmission frequency, instantiation of software components during the experiment and breaking a link at a certain time in the experiment. Real-time interactions that depend on unpredictable events during the execution of the experiment are also considered.	
Cost to offer	by the federator	L	This component is provided by Fed4FIRE (e.g. NEPI).
	by the facilities	L	Adopt existing tools (in most cases available)
Added value	for the experimenter	L	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 would become very valuable.
	for the facilities	L	There is no especial benefit in providing this information as far as testbeds are concerned, besides trust aspects that might affect reputation.
Recommendation		M	This can be a value-added functionality when offering centralized experiment control. The level this should be automated e.g. one script that command nodes in different testbeds, or a tool in which you can visually change your experiment (directly through OMF, which is not currently supported by NEPI) has not yet been determined.

Monitoring & measurement

Two types of monitoring are considered: facility (supervise the behaviour and performance of the testbeds) and infrastructure (collecting data by the testbed itself on the behaviour and performance of services, technologies, and protocols). Experimenters want to monitor whether the service delivered to them is according to the agreed SLAs. Experimental data can also be collected for further evaluation. More details can be found in Table 4.

Table 4: Experiment lifecycle: monitoring and measurement

Facility monitoring			
Description		Instrumentation of resources to supervise the behaviour and performance of testbeds, allowing system administrators or first level support operators to verify that testbeds are performing correctly. This is absolute basic monitoring.	
Cost to offer	by the federator	L	Centralisation and visualisation of facility monitoring information. Central facility monitoring is provided by Fed4FIRE.
	by the facilities	L	Mechanisms already in place on in progress among different testbeds (Nagios or Zabix on each machine)
Added value	for the experimenter	M	Experimenters need to know when a testbed is not running, it is more a necessity than a value. One centralized point for all information, rather than distributed among the test-beds.
	for the facilities	L	There is no especial benefit in providing this information as far as testbeds are concerned, besides trust aspects that might affect reputation. Reputation might increase when delivering this information to a centralized point.
Recommendation		H	This component is vital for a federation as monitoring the status of your partners within the federation is of important in terms of service reliability. It is a required input for first level support. Experimenters do see this more as a necessity rather than an added value.

Infrastructure monitoring			
Description		Instrumentation by the testbed itself of resources to collect data on the behaviour and performance of services, technologies and protocols. This allows the experimenter to obtain monitoring information about the used resources that the experimenter could not collect himself. An example of infrastructure monitoring is the provisioning by the testbed of information regarding the CPU load and NIC (network interface card) congestion on the physical host of a virtual machine resource. The experimenter can only collect monitoring data on the level of the virtual machines (VM), but the testbed provides infrastructure monitoring capabilities that make this data available to the experimenter.	
Cost to offer	by the federator	M	Centralisation and uniform formatting of infrastructure monitoring information. Fed4FIRE provides the means for each testbed to provide the data in the same format (OML streams), but the data schemas differ depending on the tool used by the experimenter. Visualisation of measurements is not provided as a central service in the federation.
	by the facilities	L	Mechanisms already in place. (setting up OML server, need to foresee/configure metrics to send data to the server). The cost can depend on the degree of metrics in place.
Added value	for the experimenter	L-H	Low if they want to know the information on the nodes High if they want all the details when for instance programming a new system
	for the facilities	L-M	There is no especial benefit in providing this information as far as testbeds are concerned, besides trust aspects that might affect reputation. Can be an added value feature for the facility to offer more detailed information towards the experimenter.
Recommendation		M	This component can be an added value for the federation when doing this centrally. Experimenters do see this more as a necessity when something is wrong, rather than an added value service.

Experiment measuring			
Description		Collection of experimental data generated by frameworks or services that the experimenter can deploy on his own, in order to read the output of the experiment. Possibility to install a loop function (control & measurement) throughout the experiment: change setup of the experiment, real time monitoring of changes, adapting the setup of the experiment, ...	
Cost to offer	by the federator	M	Centralisation and uniform formatting of information, including multiple applications, technologies and vertical domains. Fed4FIRE provides the means for each measurement tool to provide the data in the same format (OML streams), but the data schemas differ depending on the tool used by the experimenter. Visualisation of measurements is not provided as a central service in the federation either. Manifold is offered to allow experimenters to query their data from their OML collection resources
	by the facilities	L	If mechanisms are already in place, this cost can be low. There is no generic approach to define metrics, but different standards/tools can be used (e.g. Zabbix). Most of the testbeds provide such tools anyway as it is the case in BonFIRE and FUSECO. Experimenters can create their custom metrics to instrument their experiments in Zabbix that provides GUI, graphs, screens, and dashboard, etc.
Added value	for the experimenter	L	The level of detail can depend on type of experiment(er). If this information is gathered centrally, and timing information is gathered, a more detailed and quicker view on test results and correlations between effects on different testbeds could be detected.
	for the facilities	L	There is no especial benefit in providing this information as far as testbeds are concerned, besides trust aspects that might affect reputation. Can be an added value feature for the facility to offer more detailed information towards the experimenter.
Recommendation		L	This component can be an added value for the federation when doing this centrally. Experimenters do see this more as a necessity when something is wrong, rather than an added value service. Different technologies could have different OML streams. Centralizing this would be beneficial for the experimenters as correlations could be made between effects on different testbeds. At the end, experimenters have differing demands. Most of the experimenters are researchers who will collect their data and reuse or analyse it but not really interested in tracking the behaviour through graphs. In case they wish to have the data visualised, no need to export the data into OML, but rather use whatever tool that support such (e.g. LabWiki)

4.3.1.2 Supplementary services

Experiment extensions

This service includes additional components to ease the life of the experimenter, such as enabling storage as a service for experiment results and/or scripts.

Table 5: Experiment extensions: permanent storage and repository

Permanent storage			
Description		Systems and mechanisms allowing experimenters store experiment related information beyond the experiment lifetime, such as experiment description, disk images and measurements.	
Cost to offer	by the federator	L	Implementation of a centralised storage service. This is most likely to be implemented by Fed4FIRE.
	by the facilities	L	Integration with that centralised component
Added value	for the experimenter	M	This depends on the experimenter's requirements and own storage means.
	for the facilities	L	Facilities do not gain a great value from this central component.
Recommendation		M	This could be an added value service if experimenters were interested in this.

Repository of experimenter scripts			
Description		Repository of Experimenter Scripts clustered for example into OMF-based, NEPI-based, jFed-based, etc. This could be used in relation to the experiment control service component.	
Cost to offer	by the federator	M	Implementation of a centralised storage service for scripts and experiment scenarios (utility in progress within Fed4FIRE)
	by the facilities	0	Testbeds do not need to integrate with this component. It is the experimenter who will be in charge of uploading his own information.
Value	for the experimenter	H	Reuse of existing experiment settings, scripts, etc. Reproducibility of experiments
	for the facilities	L	There is no special benefit for facilities in case this service is offered, unless the experimenters allow facilities to share these pieces of development with other experimenters. In that case, testbeds would increase in popularity as these tools are made available.
Recommendation		M	Interesting added value service

Experimenter support

For supplementary services the main service components are training for experimenters and documentation about the elements of the federation

Table 6: Training, documentation and support

Training			
Description		Allows experimenters to contact the federation for training requests according to their needs. This could also be considered for new testbeds, when they join, to help them become compliant to the federator's minimal set of requirements.	
Cost to offer	by the federator	M	Acquisition of the overall vision of federation tools. Most probably some amount of work for setting up a course, in latter stages minimal effort to keep the training material up to date. Most effort will thus be manpower.
	by the facilities	L	Testbeds are well aware of their capabilities.
Added value	for the experimenter	H	This eases the life of the experimenter and helps him be familiar with federation concepts, resources and tools as well as inspiration for experiments.
	for the facilities	H	This helps promote facilities.
Recommendation		L-M	This could be an added value service for the federator. For new customer bases, this could be valuable. The question is also whether experimenters would invest time, travel expenses and/ore registration fees for such a service.

Documentation			
Description		Keeping up-to-date and rigorous documentation concerning the elements of the federation (user manuals, installation guides, etc.) complements direct support	
Cost to offer	by the federator	L	Establishment and update of documentation centre
	by the facilities	L	Contribution to establishment and update of documentation centre for own facility
Added value	for the experimenter	H	Documentation is very important in order to guide the experimenter through the interaction with the federation resources and tools
	for the facilities	H	This helps promote facilities and contributes to reputation aspects.
Recommendation		H	This component is very important to guide current and future experimenters in discovering the benefits of using the federation and its facilities. This should include an overview of the facilities, as well as documentation on how to set up an experiment and the tools available.

Incident management

Incident management deals with managing interaction with experimenters whenever a problem occurs during experimentation.

Table 7: First level support

First Level Support			
Description		Interaction with customers for support request, incident communication, consultation, etc. This service component is strongly linked, among others, with facility (and infrastructure) monitoring, and up to date information from the facilities e.g. on maintenance, updates, etc.	
Cost to offer	by the federator	L	Fed4FIRE implements a centralised ticketing system for FLS.
	by the facilities	L	Provide single point of contact, as well as information on (scheduled) maintenance and updates.
Added value	for the experimenter	H	FLS is an important support tool that eases the interaction of the experimenter with the federation.
	for the facilities	M	Facilities can benefit from the federated first level support and reduce their own support effort.
Recommendation		H	This is very valuable component in a federation. Of course its implementation should be evaluated towards the cost of providing the service (e.g. is a centralized forum enough, or should be provide a call centre functionality?). This will depend on what this service task will contain regarding information and competences (e.g. just redirecting towards specialist, or does this FSL centre also provide technical feedback?).

Service level management

Service level management deals with monitoring whether the delivered service met the proposed expectations.

Table 8: SLA management and reputation service

SLA management			
Description		Experimenter can also monitor the service delivered to them vs. expectations gathered in a Service Level Agreement (SLA) between providers and himself.	
Cost to offer	by the federator	M-H	It depends on the degree of centralisation. For the moment, the only centralisation Fed4FIRE has implemented is visualisation of all the SLAs provided by each facility (at the portal). The most complete case of centralisation would be that the federator acts as a prime contractor and agrees the SLAs with the experimenter on behalf of the testbeds.
	by the facilities	L	The tool is easily adopted. This is based upon information gathered from the facility (and infrastructure) monitoring service component, which also have to be adopted by new facilities.
Added value	for the experimenter	L-H	Experimenters can benefit from service guarantees, above all if compensation is applied in case of failure. (If an SLA is important for experimenter, this is valued as high, otherwise low or medium)
	for the facilities	L	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.
Recommendation		M	This component can be an added value for the federation when doing this centrally. This can be beneficial for the different facilities to delegate the agreements to a central service provider (less involvement required if SLAs are met), and for the experimenter in order to have a unique service provider that responds in the name of the facilities.

Reputation service			
Description		The federator contributes to trust and user experience by providing the mechanisms and tools towards building trustworthy services based on the combination of reputation and monitoring data. For building reputation-based trust on a testbed two aspects are taken into consideration and compared: the user/experimenter feedback regarding their Quality of Experience (QoE) and service received, and monitoring data.	
Cost to offer	by the federator	L	The federation is implementing this feature. Setting up the mechanisms for reputation, linking this to existing service components e.g. SLA evaluation, the reservation system where for instance users could see the reputation of testbeds when defining the final setup for their experiment
	by the facilities	L	Integration of existing monitoring with a central component
Added value	for the experimenter	H	The experimenter may receive very valuable information concerning the testbeds' performance and could give feedback to facilities and federation about this.
	for the facilities	H	This tool contributes to trust. Based upon QoE information of the experimenter, the facility could furthermore adapt its service delivery depending on the experimenters' expectations. On the other hand, if the facility is trusted, it has a positive effect on its usage by experimenters.
Recommendation		M	This component contributes to trust with the experimenter, which is important from federator's point of view as he would like to offer a community of facilities with a reliable, trusted set of services.

4.3.2 Supporting facilities

Besides the services offered directly in support of the experimenters, dedicated services can be offered to the facilities.

Promotion and attraction of potential new experimenters

Table 9: Promotion

Promoting experimentation (and facilities)			
Description		The main service a federator offers to facility providers is promotion, which provides the ability to improve the attractiveness of the facility by embedding it into a broader community (e.g. by the use of common interfaces and best practices), increasing the usage of the facility and enhancing its reputation. The federator can provide the means for facility providers to advertise their infrastructure, the services and tools that will be made available to the experimenter, including comments from experimenters who share their experiences. This can contribute to increasing the visibility and reputation of a facility.	
Cost to offer	by the federator	L-M	Setting up the mechanisms for advertisement, attending events, business development, building contacts with potential experimenter bases, etc. This task should be aligned with the different facilities within the testbed.
	by the facilities	L-M	Support towards the federator on promotional material, manpower for co-attending events, giving presentations on behalf of the federation, etc.
Added value	for the experimenter	H	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 within the proposed boundaries.
	for the facilities	H	This contributes to self-promotion and trust. The federator can increase the exposure of 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.
Recommendation		H	The federation could set up a business development team, in cooperation with the joined facilities. Collective business development can include activities such as promotion, additional to the activities taken up by the individual facilities. The service of training is linked to this service.

Development and support of tools and APIs

Table 10: Development and support of tools and APIs

Support of existing tools and APIs			
Description		Selected tools and APIs from the federation could be supported by a team of experts towards the different facilities when updates are required, integration problems occur, etc.	
Cost to offer	by the federator	L-H	This will depend on the evolution rate of the tools adopted. These are related to the adopted service components described above.
	by the facilities	L	Testbeds take advantage of a centralised service and only need to adopt the updates (when already compliant with the current version of the standards).
Added value	for the experimenter	L	This is expected by the experimenter and must be transparent for him (described in the documentation).
	for the facilities	H	This lowers the effort required by facilities when adopting new versions of the tools.
Recommendation		H	When the federation sets a minimum requirement for implementing some service components and related standards, some sort of support will be required. This could either be done by the federator itself, or agreed upon by the organization who developed the tool or API.

Development and support of new tools and APIs			
Description		When new opportunities arise (e.g. new component demanded by experimenters and no solutions are available on the market or lack the required functionality) the federator could develop this centrally and distribute this amongst its partners, or sell it / licence it to other non-federated partners.	
Cost to offer	by the federator	L-H	This will depend on the demand of experimenters and the lack of available tools on the market, or additional functionality required within existing tools.
	by the facilities	L	Testbeds take advantage of a centralised service offering new functionality. Depending on whether the component will be required by the federator, the testbed facilities will have the choice of adopting this new tool or API.
Added value	for the experimenter	M	Adding new functionality and tools will increase the value of the federation and its facilities.
	for the facilities	H	This lowers the effort required by facilities when new tools, and API standards are developed centrally. Depending on the functionality (and whether the facility will adopt this), this could benefit the facilities, but this might be case specific.
Recommendation		M	Depending on the component and functionality, this could be an added value service. This way new innovations and changes in requirements by experimenters can be offered and supported by the (whole) federation.

4.4 Configuration items

Configuration items are elements that contribute to the delivery of one or more services or service components. Examples can be manpower (effort by people for installing and operating the service component), hardware (e.g. servers, switches, cables, etc.) and software components (e.g. GUIs, standard APIs, software libraries, etc.), documentation (e.g. training material, manuals, procedures), etc.

In a first iteration, we have estimated, for a number of service components, the required configuration items. This is based on knowledge gained during the development and installation of the different components within the project. We made a distinction between federator and testbed dedicated costs, and general tool development, where the latter can be done by either one of them, or an external party. We considered the following resource categories: hardware and software components, support and content provisioning, split up between purchase, development, installation, updates and maintenance, of which the operational costs are expressed in required full time equivalents (FTE). This is furthermore elaborated in the following section.

Different service component offerings are considered, as some components can be offered in a minimum up to an advanced setting (e.g. for first level support this can be a very basic website or forum, up to a full service call center functionality). For each business scenario, depending on the value proposition offered, a list of service components with their specific settings will be selected. A first potential business scenario has been worked out in section 6.

5. Cost / benefit model

We have determined in the previous section a list of potential service components that can be offered by the federation. Some services will certainly be sustained by the federation beyond the end of the project (core services), others might be adopted depending on the business model (evaluation of cost of implementation and operation at federated and testbed level versus overall benefits for experimenters and testbed facilities). To support that decision we wish to have a good view of the cost of operating a service component during and beyond the end of the project for the federation as well as the cost for the facilities, and the benefits for all stakeholders involved.

Cost model

The approach to technical federation is to reuse as much as possible from previous projects and to only do dedicated development where no other alternative is possible. It would be unfair to allocate the cost of those (past) developments to the federation. We will only focus on what is needed in terms of dedicated adaptations to (open source) software or new (dedicated) software development, maintenance cost and purchase cost of federation hardware to offer each service. We will thus only look at the incremental costs.

Each service component offered to the experimenter has been divided into a set of processes and activities. In order to estimate the cost of each component, the following list of points needed to be answered:

1. Define the process/activity by describing who is using it and the problem it solves.
2. Describe how the process/activity operates in terms of capital expenditures (CapEx) and operational expenditures (OpEx).
3. Estimate the yearly CapEx related to the purchase of infrastructure (e.g. a server, a rack, office equipment).
4. Estimate the yearly OpEx (expressed in FTE) for keeping the service operational and include costs of technical and commercial operations, administration, etc.

An initial spreadsheet based model has been built incorporating the above-mentioned factors, in order to estimate the costs for each service components. Costs for each service component have been split up between generic tool development, federator and facilities. This is described in Table 11.

Table 11: Cost parameters for evaluating the different service components

Generic tool development			
Development	Initial development	CapEx	If the tool is not yet available, the cost for implementation needs to be considered (expressed in FTE).
	Updates of the tools	OpEx	Expressed in number per year, FTE required
Support towards facilities		OpEx	Driver based (e.g. number of updates, interventions, etc.) multiplied by the number of testbeds, expressed in FTE required
Federator			
Hardware	Requirements	CapEx	Hardware costs
	First installation time	OpEx	Required FTE
Software	Purchase	OpEx	Depend on type of licence e.g. open source, yearly fee, …
	First installation time	OpEx	Required FTE
Specific development	Initial development	CapEx / OpEx	Required FTE (depending on the size of the development)
	Updates / maintenance	OpEx	Expressed in number per year, FTE
Content	First time	OpEx	Required FTE
	Updates	OpEx	Expressed in number per year, FTE required
Testbed infrastructures			
Hardware	Requirements	CapEx	Hardware costs
	First installation time	OpEx	Required FTE
Software	Purchase	OpEx	Depend on type of licence e.g. open source, yearly fee, …
	First installation time	OpEx	Required FTE
Specific development	Initial development	CapEx / OpEx	Required FTE (depending on the size of the development)
	Updates / maintenance	OpEx	Expressed in number per year, FTE
Content	First time	OpEx	Required FTE
	Updates	OpEx	Expressed in number per year, FTE required

The cost accounting model template will be used to evaluate the overall Total Cost of Operation (TCO) for each of the service components (including its activities/processes) that could be operated by the federator. The cost data should give insight in the cost of running an operation on the one hand and the cost for a facility when joining the federation on the other. Economies of scale could be determined as several services are using shared resources.

A first estimation of costs has been gathered based upon information from project partners. This information will be furthermore verified and updated with the current project partners and newly joined testbeds. More information will also become available throughout the remainder of the project when more insight is gained in the actual implementations of the technical components and services. A more detailed version of the cost model will be presented in the next deliverables including additional information such as function of personnel required (e.g. sysadmin, administrator, helpdesk, etc.), level of economies of scale, more detailed operational processes information, etc.

Value and benefits

Next to the costs, a qualitative estimation of the benefits has already been included in the previous section. An indication of optimization in operations and economies of scale could be calculated, based upon the selected list of supported service components and given the situation at each the different testbed infrastructures. Interviews with experimenters and joined testbeds will be conducted to obtain a broader view on the (more qualitative) values and benefits.

Evaluation

A cost allocation model has been created to set up and analyse different constellations of service components offered by the federator. A first evaluation is presented in the following section.

6. Different business scenarios for federation

In the previous section we introduced the service management model we will follow within the project. This methodology and information will now be used for defining business scenarios with a specific service offering from federator point of view, considering, of course, the interaction with and potential benefits for the different testbeds, as shown in Figure 5. One specific case will be elaborated with an initial qualitative and quantitative evaluation.

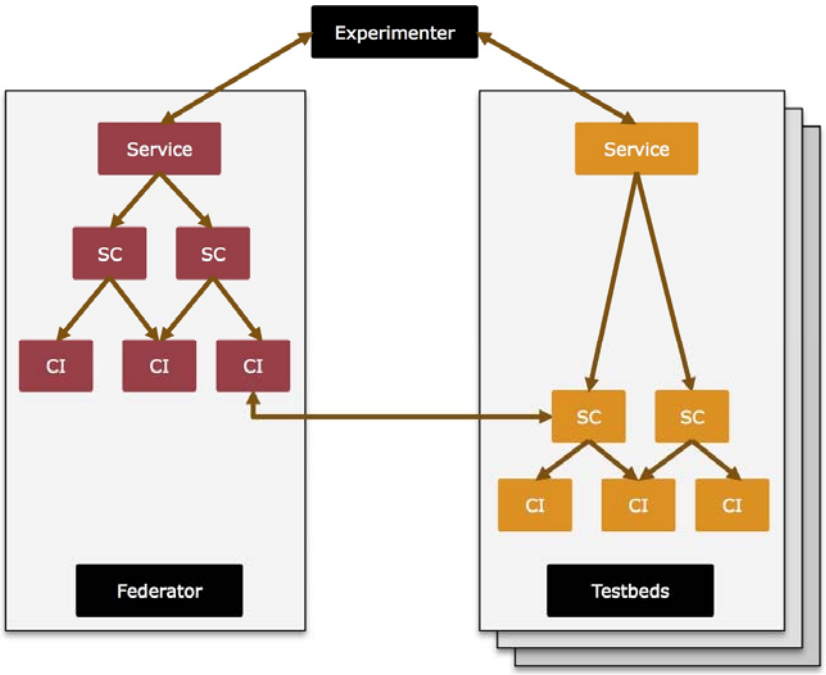

Figure 5: Service management structure

6.1 Federation scenarios

The FedSM project identifies a set of scenarios for the operation of federated IT facilities; these provide a useful analysis tool to consider how Fed4FIRE can be operated most effectively to optimize service delivery and minimize the federation's delivery costs [16]. Essentially these scenarios identify core services and determine whether they are provided in a coordinated manner by a central federator, or are delivered by each federation member (testbed) in an un-coordinated fashion. The spectrum of scenarios ranges from "Invisible coordinator" to "Integrator" (Figure 6). In the Invisible coordinator scenario, the federator may provide functions like: i) Interaction & communication protocols, ii) APIs & interface specifications, iii) certification authority. All these enable the federation to take place, without the federator needing to get involved at runtime - the federation participants can use these functions to interact directly with each other. The primary value added by the federator is thus in the definition of the protocols and standards, and the other stakeholders benefit by using them to understand how to cooperate together.

Integrator is very different from Invisible Co-ordinator. In the Integrator scenario the federator coordinates all of the services. A real-world analogy of this model is that of a prime (or general) contractor. The term comes from the construction industry and a prime contractor is the manager of a building project. The prime contractor bears full responsibility for the delivery of the completed project to the customer; the prime contractor is likely to employ subcontractors to carry out specialist tasks (e.g. building construction, plumbing, carpentry, electrical installation etc.); and the

prime contractor is the sole party that deals with the customer. The benefit to the customer is that they have a single point of contact, who is responsible for managing a complex project. The customer also benefits through having one party who is responsible for the project as a whole. The subcontractors typically benefit through the promise of significant amounts of work (most managed building projects involve significant amounts of work for subcontractors). We can see that in the Integrator model, the prime contractor is the federator, and the subcontractors are the testbeds, so the benefits to the experimenters are similar to those of a prime contractor's customers – the experimenter gets a complete managed service for a possibly complex experiment involving many testbeds. The more complex the experiment is, the greater the benefit of the federator in this scenario, because it saves the experimenter significant work in the overheads of dealing with multiple testbeds.

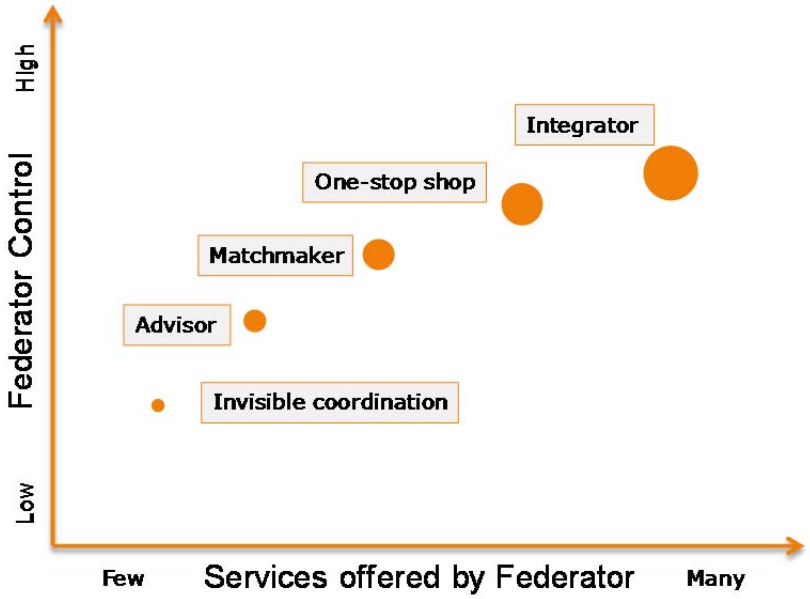

Figure 6: FedSM business models - Federator services offered versus control

6.2 Plausible federation scenario for Fed4FIRE

The federation scenarios represent differing ways that different stakeholders can interact to get useful value from their interaction in a federation. But which is the right scenario for Fed4FIRE? This role analysis method allows us to consider plausible options; here we take each of the core services identified in the previous section and determine whether that service should be provided by the federator in a coordinated manner to the experimenter; or whether the service should be provided in an uncoordinated manner by the testbed direct to the experimenter. This decision will result in a trade-off between the cost of implementation at federator and individual testbed level and the overall benefits for each actor involved. More service components with advanced functionality offered by the federator can/will lead to additional implementation effort at testbed level, which might lead to a marginal added value for the stakeholders. This window of opportunity can be seen in (Figure 7).

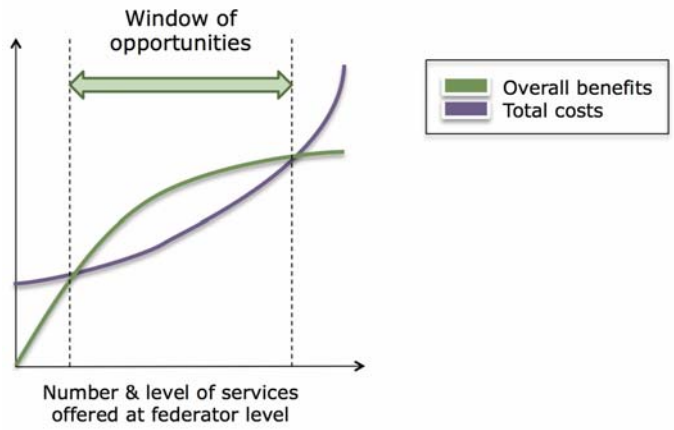

Figure 7: Window of opportunity for the federator

Table 12 identifies a plausible scenario for Fed4FIRE that is similar to the "one-stop-shop" FedSM scenario [16]. The federator provides all the support to find and acquire the right to use the facilities' resources e.g. discovery and reservation. Beyond this, the experimenter invokes services on the infrastructures directly. Also, as with the "Matchmaker" scenario, contracts or SLAs between the federator and the facility providers may be necessary, so as to determine what the federator can and cannot do; centralised monitoring is co-ordinated to underpin SLA Management.

In addition with this scenario, the federator provides added value services to the facility providers (e.g. handling payments and monitoring of SLAs), so these need to be described in contracts or SLAs, as well as information provided to the federator. Hence, an important relationship in this scenario is the provisioning of usage information to the federator that can be used to determine the bill for the experimenters.

Table 12: Role analysis of Fed4FIRE federation scenario

Service component	Co-ordination by the federator	Reasoning
Authentication & Authorization	Yes	Central authentication services can minimize the management of security across the federation and simplify the access to protected resources for the experimenter
Resource Description and Discovery	Yes	A central directory of resources offers significant value to help experimenter discovery what is both possible and available across the entire federation
Resource Reservation and Provisioning	Yes	Federator can observe available resources across federation that match requirements and allocate reservations accordingly. Optimize the service for both experimenter and testbeds
Facility monitoring (SLAs)	Yes	The federator collects usage information from the testbeds, which can be used to build systems to manage SLAs at the federation level (reputation system) and be used for first level support.
Documentation and First level support	Yes	Centralized up-to-date data collection of procedures is an important role for the federator towards experimenters, with basic support.
Experimental control and measurement	No	Once reserved experimenters can access the testbeds directly, there is little need to centralize this activity, which would increase the complexity and management of the federation with few benefits.

Based upon the description above, an evaluation was made of the required effort to operate the above mentioned service components. The results show a split up between costs for the federator and each testbed, and indication of initial investment and yearly required manpower (expressed in FTE). Note that the figures indicated are first estimations, and will be updated when more detailed information will become available.

Considering the proposed federation model above, we have made a first estimation of the costs allocated with the offering of the different service components. This can be seen in Figure 8. The federation is responsible for the initial implementations and updates of a number of service components such as SFA wrapper, portal, authority, documentation, first level support. Some components can be offered in a minimal or more advance offering, depending on what is included e.g. the portal could include account creation and basic reference to documentation, but could also be extended with integrated experimentation functionalities. Note that these figures are first estimations and some components are still missing (SLA, reputation, advanced monitoring, etc.). This information will be updated in the upcoming months. We see from the initial results that at least 3 FTE should be allocated centrally to the technical operations of the federation (software support and development, with very basic FLS incorporated), and a small amount of effort per facility provider. Note that an FTE is not necessarily a single employed person. An FTE could perfectly consist of marginal contributions of several persons from diverse organisations contributing to the different components.

When we compare the required resources for each testbed infrastructures when not participating in a federation with the effort required in the federation model, a reduction of about 0,86 FTE for each facility could be gained (under the hypothesis that each facility should start from scratch implementing the required APIs and tools). When the federation has at least 4 testbeds included, the effort of centrally managing the proposed service components will smaller than the combined benefits for the different stakeholders. The cost of hardware for a federator is manageable (some dedicated servers), as the biggest infrastructure lies with the facility providers to offer the resources for experimentation.

Type	Components / scenario	Included	Generic tool development	Federator		Facilities	
		0 = No 1 = Yes	By Whom	First time instal FTE	Yearly updates & support FTE	Initial instal FTE	Yearly updates & support FTE
				0,05	**3,04**	**0,38**	**0,11**
Provisioning	Slice & member authority	0	Federator	0,00	0,00	0,00	0,00
	Portal (min functionality)	1	Federator	0,02	0,54	0,00	0,00
	Portal (max functionality)	0	Federator	0,00	0,00	0,00	0,00
	SFA wrapper for testbeds	1	Federator	0,00	1,18	0,36	0,04
	SFA client (stand alone client)	1	Federator	0,00	0,80	0,00	0,00
	SFA client (if combined)	1	Federator	0,00	0,20	0,00	0,00
	AM directory	1	Federator	0,00	0,03	0,00	0,00
	Authority directory	1	Federator	0,00	0,03	0,00	0,00
	Service directory	0	Federator	0,00	0,00	0,00	0,00
Experiment support	Documentation	1	Federator	0,03	0,01	0,03	0,07
First Level Support for testbeds	Testbed monitoring, API testing and API support to testbeds	0	Federator	0,00	0,00	0,00	0,00
First level support for experimenters	Current monitoring service	1	Federator	0,00	0,25	0,00	0,00
	Full monitoring service	0	Federator	0,00	0,00	0,00	0,00

Figure 8: First cost estimation of the proposed federation model

Considering how to keep this sustainable, a way has to be found to keep this all organized and financed (e.g. by a financial contribution from the testbeds, offering software components or personnel in kind for keeping the components up and running, and updated, requesting subsidies from (European or national) funding agencies, request experimenters to contribute, etc. A clear governance structure must be formed in order to sustain the federation in the long run and responsibilities should be clear. This is part of ongoing work within the project.

In our previous deliverable D2.3 and in Figure 6 we provided a summary of the potential models presented by FedSM. An increasing provision of federation services, i.e. invisible co-ordination is the lightweight federation, whereas integrator is a complete service offering, will have a different operational model (for federator and federation authority) and thus also a different cost and benefit structure. Initially it would appear that the integrator is the most useful, simply because of the completeness. However, we have already discussed how lighter federation structures can bring value (lower overhead, greater control, etc.). Hence, an important next step is to further analyse the cost and value of these scenarios. This may in turn lead to the identification of new scenarios that capture value in different ways without directly falling into one of the five identified scenarios. This will be furthermore elaborated in future deliverables.

7. First recommendations

Based upon the work presented before, an initial list of recommendations has been formulated. This list will be furthermore examined and defined in detail in upcoming deliverables:

1. *Promote a consistent and compatible value proposition to both experimenters and testbeds*. There needs to have a value proposition that addresses the needs of the experimenter, and also another value proposition that addresses the objectives of testbeds, and these two value propositions needs to be compatible, in that they cannot be contradictory. The recommendation is to investigate benefits to both experimenters and testbeds, and how they may be achieved without compromising one another.
2. *Define the role of the Fed4FIRE operator*. In order to be sustainable, we need to address the question about what needs to be sustained. We have already identified the role of the operator to enable testbeds and experimenters to work together (the so-called "Federator"), and the recommendation is to investigate the services it needs to provide to both experimenters and testbeds, confirm that these services are valuable to the target audience and determine how they may be provided viably.
3. *Ensure that sustaining need is the driver of sustaining capability.* Where there is need, there are opportunities to generate revenue. It is necessary to realise that the needs may change over time, and this may mean changing the value proposition over time so that it keeps pace with the need. Hence we recommend further analysis of the experimenter and testbeds markets throughout the Fed4FIRE project lifetime and beyond to assess the extent to which these are changing, and how research trends are changing.
4. *Investigate how industry can be attracted as Fed4FIRE users*. Industry is often an important supporter of initiatives, i.e. they are the members with revenue to support value through sponsorship and membership — but they only participate where there is reduced risk and significant gain for the costs. We therefore recommend the investigation of potential industry involvement in Fed4FIRE and analysis of their requirements, plus necessary services required to support them (e.g. security and minimum SLAs).
5. *Promote Fed4FIRE as an experimental tool*. Work programme 1 of H2020 already highlights the importance of experiment-as-a-service. The research community is Fed4FIRE's primary customer and they rely on credible tools. Hence, Fed4FIRE's value proposition backed up by the necessary tools should be leveraged to attract a wider market share of future Internet experimenters.
6. *Consider wider users.* With the rise in online education, a new community of learners wishing to learn about experimental methodology may provide more users and new revenue streams. Call 10 of framework 7 has funded a STREP (named FORGE [11]) to examine how e-learning and FIRE facilities can be combined. Hence Fed4FIRE should investigate the opportunity of providing e-learning services as well as experiment-as-a-service.
7. Finally, we recommend the *consideration of multiple funding models*: Funding to sustain Fed4FIRE beyond the end of the project may come from different sources, so as many as possible should be investigated during the course of the project to assess their viability. Current candidates include i) public funding—which should be underpinned by a unique and needed value proposition that minimises funding costs elsewhere; ii) a subscription model for dedicated access to resources; iii) a community model of Fed4FIRE developers contributing to the maintenance of tools and the creation of new and novel services. Other funding sources should be identified and investigated.

8. Conclusions and future work

This deliverable explored insights in the differing values experimenters and testbeds see from the Fed4FIRE federation, a list of services and service components that the federation could offer with cost/benefit indication, and a first evaluation of a potential federation business scenario.

First we described our methodology to determine an initial value proposition for Fed4FIRE. 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. On the other hand facilities mostly value the potential access to new users, promotion and advertisement of their facilities, and tools and assistances. This analysis will be further extended in the upcoming months with feedback from open call participants.

Next we presented the different services our federation could offer. We made use the FitSM service IT methodology in order to describe the service components, the cost of provision for the federator and facilities, and their added value towards experimenters and facilities. This information will be the basis for describing different business scenarios, where cost/benefit trade-offs will be 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.

More models will be analysed and evaluated, based upon more accurate information that can be retrieved from open call experimenters and newly added testbed infrastructures. 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 9 presents the plans for the upcoming deliverables for this task 2.3 on sustainability. In the next deliverable (due M28) we will present the evaluation of more potential business scenarios, backed with more detailed insights on how to offer value to experimenter and testbeds.

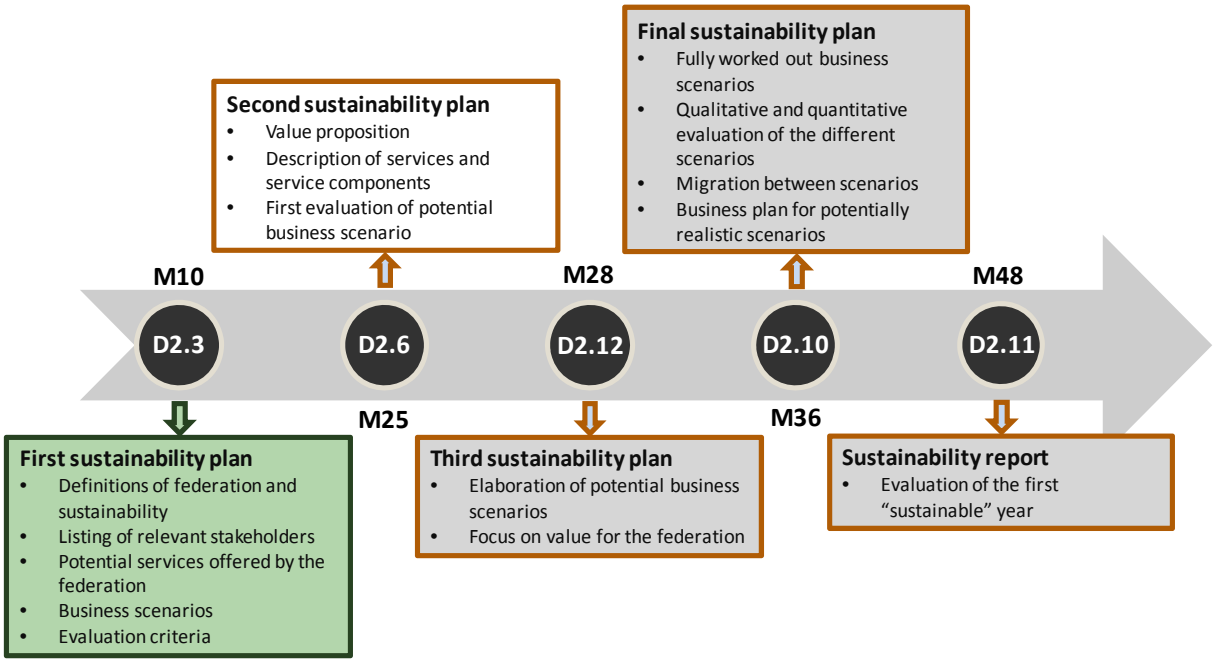

Figure 9: Steps towards the upcoming deliverables

This task will furthermore interact with the following tasks during the remainder of the project:

- We will contribute input to Task 8.3 “Sustainable standardization”.
- Results of this subtask will contribute to Task 8.2 “Establish and operate federation authority”.
- Input and feedback will be provided to the architecture task (T2.1) in order to take into account technical constraints that are derived from sustainability requirements.

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