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D2.03: Sustainable Governance of the Federation

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Abstract	This deliverable presents the initial setup and operation of the governing body of the federation (the Federation Board), and initial plans for sustainability of the federation.
Keywords	Federation board, governance, sustainability

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

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EXECUTIVE SUMMARY

This document presents the work done so far in two related aspects: governance of the Fed4FIRE+ federation, and sustainability of the Federation beyond the end of the Fed4FIRE+ project. At this early stage, we can make interim recommendations regarding sustainability, and the key recommendations are described here along with the key conclusions. Subsequent deliverables will build on the work presented here.

Governance

We have defined the key concepts for the Federation Board, the primary decision-making body of the Federation, and environment in which it operates. The board sets *objectives* for the Federation, measures the Federation's performance by defining and observing *key performance indicators*, and steers the Federation via *strategy* comprising *policies* and *control instruments*. For each concept, we have defined initial elements, which will be evaluated and expanded / adjusted as necessary while the board operates.

We have determined the composition of the board and appointed board members, the appointment being based on roles, experience and skills. We have also determined the board's interactions with other aspects of the Fed4FIRE+ project, to establish working practices to be evaluated within the project and operated beyond its end.

Sustainability

We have established that there are two major federation stakeholders that need to be sustained: the Federation Core, and the Testbeds. The Federation Core comprises the Federator, which runs and manages the Federation, and the Federation Board, which sets the objectives, policies and practices of the Federation and provides steering guidance. The Federation Core is intrinsic to the Federation: the Federation Core is necessary for the Federation to operate, and the Federation Core's existence is tightly tied to the Federation - without the Federation, the Federation Core does not need to exist. The testbeds are key stakeholders in the Federation, but their lifetime is not tied to the Federation's – the Testbeds can (and often do) exist within and outside the Federation, and they choose to be part of the Federation because of the key benefits the Federation offers them.

All federation participants are likely to need to pursue more than one source of funding to generate adequate funding to support themselves and to insulate themselves from the risk of one funding source disappearing. Testbeds are often funded by national and local public funding, as well as any funding the Federation brings (e.g. in the form of the funding Fed4FIRE+ brings). Experiences from previous projects indicate that commercial funding of Testbeds is rare. The Federation Core is currently funded by public money (in the form of the Fed4FIRE+ grant) and needs to seek continuation funding, and to do this, it needs to demonstrate value to both experimenters and Testbeds.

The Federation Core and the Testbeds have separate but inter-dependent sustainability cases. The Federation supports the Testbeds' viabilities by bringing them access to greater numbers of experimenters inside the Federation. The Testbeds support the Federation's sustainability case by provision of a multitude of different resource types, offering experimenters a rich variety of testing options, and thereby providing an attractive offering for experimenters. Both value propositions are based on a critical mass of experimenters and testbeds, and the Federation's viability depends on this critical mass.

The key "customers" of the Federation are experimenters. These are typically academics (researchers, educators or students) or industry who want to use the Federation's resources for testing and scaling experiments, for example. Fed4FIRE+ has dedicated programmes of funding targeted at these user types. We have described how the Federation helps the different types of users, in terms of a value proposition canvas that describes how the Federation solves customers' problems and provides benefits to them.

The Federation Core provides services to both experimenters and Testbeds. For experimenters, the key services are access to a multitude of different experimentation facilities, recommendations and easy setup on the Testbeds. For testbeds, the Federation core provides assistance to become compliant with the Federation's user tools and single sign-on processes – the easier experimenters can access Testbeds, the more they are likely to use them.

The Testbeds in the Federation are widely distributed from a geographical viewpoint, and currently demand from SME users mainly comes from southern European countries. Market investigations are needed to determine if there is a need from other areas, what kinds and how much.

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In addition to each Testbed serving a wide audience, brought through the Federation, they also provide resources to its local community. As such, a Testbed can act as a local innovation hub that is a focal point for local users, facilitating support, introductions between users, providing collaboration opportunities etc. This will be mutually beneficial for the local users (through the support and the local community), the Testbed (through enhanced reputation and potential users) and the Federation (through "viral" marketing and the potential increase in users).

Fed4FIRE+ provides open calls, which contribute funding to experimenters' and testbeds time and operating costs. These are popular, but this is not surprising given that experimenters are paid for their time. The acid test of the Federation's value is the "Open Access" programme, where experimenters get resources at no charge, but do not get their time funded. This is a highly likely future sustainability situation after the end of the project. The existing Open Access programme is moderately successful, but needs to be promoted more, to evaluate the true worth of the Federation's offerings when experimenters' time is not funded.

Other federations are presented as case studies, and Fed4FIRE+ has many similarities with them, and all can learn from each other. The currently-identified key points worth investigating are the following.

- FED4FIRE+ should aim to federate with as many as possible new testbeds as well as other federations worldwide, which will improve its positive externality, scale of operation, and attract new experimenters creating an enhanced customer basis, and therefore satisfying the critical mass sustainability aspect.
- It is worth investigating whether the homogeneity of access is transferrable across federations – it may be possible to form partnerships with the Federations listed above so that users of one federation can use resources from another. Each federation is likely to be made stronger by these partnerships, and the result can become a rich interconnected network of experimentation facilities.
- Extending the 5TONIC model, by investigating funding from multiple future projects, where Fed4FIRE+ is offered as a ready-made infrastructure of multiple testbeds that can be used for experimentation within the projects. The projects get access to the heterogenous federation of testbeds and make a small contribution to the upkeep of the federation in return.
- Evangelizing Fed4FIRE+ as a contribution to the European Research Infrastructures community, learning lessons from the SILECS ongoing experience, specifically understanding the research infrastructure communities' requirements and accommodating them in proposals for RI funding.
- Different other types of funding should be investigated, for example private or crowdfunding. These may or may not be applicable depending on the application or use required, and multiple funding streams are likely to be needed at any one moment.

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2 INTRODUCTION

This document presents the work done so far in two major related aspects: governance of the Fed4FIRE+ federation, and sustainability of the Federation beyond the end of the Fed4FIRE+ project.

The governance of the Federation is achieved through the Federation Board (abbreviated to “FB”). This is a decision-making body modelled on a company board of directors, whose purpose is to determine the objectives of the Federation and the strategy in order to achieve them. This document presents the initial setup of the FB, its initial objectives, Key Performance Indicators (KPIs) to measure the performance of the Federation and strategy to steer the Federation in the form of policies and control instruments.

The Federation’s sustainability is addressed in a number of ways. Firstly we have defined what needs to be sustained, as the Federation contains a number of actors, each of which is highly likely to be sustained through multiple and different mechanisms. We evaluate the Federation’s value proposition to different stakeholders, describe the question of sustainability from the perspective of the origins of Fed4FIRE+, and present two case studies of related federations.

Finally, we conclude with key points raised by the discussion within the document and make recommendations for immediate next steps and longer term actions.

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3 FEDERATION BOARD: RESPONSIBILITIES, CONCEPTS AND SETUP

The Federation Board's is first and foremost a decision-making body whose responsibility is to determine the objectives and strategy for governance of the Fed4FIRE+ federation, firstly within the project and subsequently to determine a pattern for operational governance beyond. The Federation Board is modelled on the established pattern of a board of directors (e.g. for a company), and the overall remit, operational patterns and composition of the FB is derived from this pattern. Figure 1 shows the core concepts of the Federation Board's input and influence.

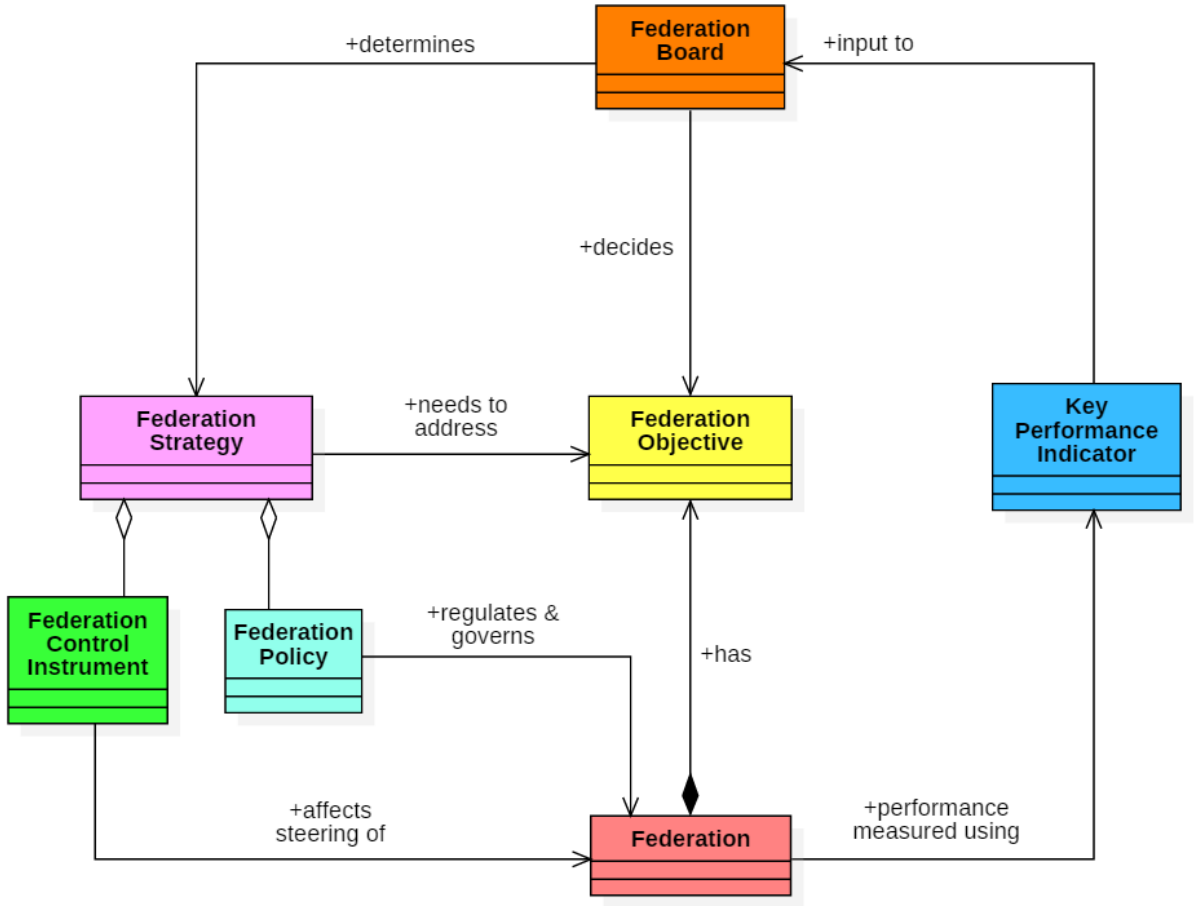

Figure 1: Federation Board Key Concepts

The board is responsible for setting federation objectives and to determine a strategy that meets these objectives. Within the strategy, there are policies, which are statements of key principles or regulations for the Federation (for example experimenter eligibility or terms and conditions); and control instruments, which are aspects of the Federation that may be adjusted to steer its overall direction (for example types of open call or testbed portfolio). Following the classical definition of strategy as *"a plan of action designed to achieve a long-term or overall aim"*[1], the Federation strategy is a collection of parameterised control instruments and policies that form a coherent plan to achieve the objectives of the Federation.

[1] https://en.oxforddictionaries.com/definition/strategy

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3.1 FEDERATION OBJECTIVES

Federation objectives are a primary concern of the FB and will be continually evaluated. The Federation objectives identified so far are shown in Figure 2[2].

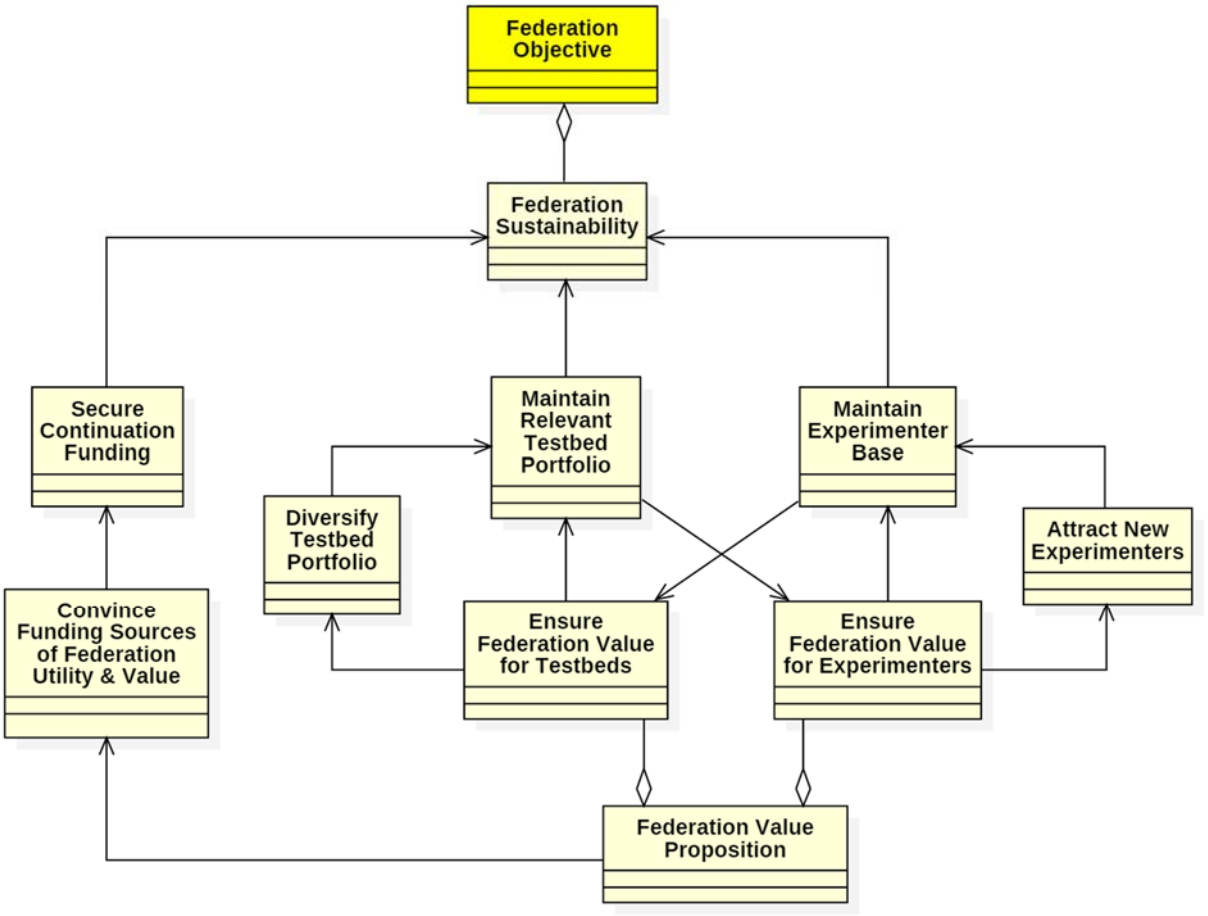

Figure 2: Initial Federation Objectives

The primary top-level objective identified so far is *"Federation Sustainability"*, reflecting the need to keep the Federation running beyond the end of the project's funding. Clearly, this is a critical objective, and other objectives identified at the current time all contribute to this.

"Federation Sustainability" is supported by three sub-objectives. The first, "Secure Continuation Funding" reflects the need to find sources of income that can pay for the continued operation of the Federation. The second, "Maintain Relevant Testbed Portfolio", describes the need to keep the portfolio of testbeds within the Federation up to date and relevant to the user community's needs. The third, "Maintain Experimenter Base" reflects the need to keep experimenters coming to the Federation.

There is inter-dependency between the two objectives that concern maintaining the experimenter base and the Testbed portfolio, and this is reflected in the next level down, where value propositions for both experimenters and testbeds are shown. In order to maintain a relevant testbed portfolio, we need to determine a value proposition for testbeds, and this (amongst other things) requires maintaining a critical mass of experimenters who want to use the Testbeds. Similarly, the value proposition for experimenters requires maintenance of a relevant portfolio of testbeds.

[2] An arrow in the figure indicates ***"contributes to"***, so "Secure Continuation Funding" contributes to "Federation Sustainability", for example.

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Relevancy of the Testbed portfolio is an important objective in its own right. The testbed portfolio in the Federation needs to be useful to the experimenter community, and therefore needs to be kept relevant to the needs of the community. Therefore, the "Diversify Testbed Portfolio" supports the "relevance" aspect of "Maintain Relevant Testbed Portfolio".

In order to maintain the experimenter base, the Federation needs to continually attract new experimenters. In many cases, experimenters come to the Federation only once, so there is a constant need to attract new experimenters.

Both experimenter and testbed value propositions are necessary for the overall *"Federation Value Proposition"*, which contributes to providing a convincing case describing the Federation's utility and value to potential funding sources, and thence to securing continuation funding. Potential funding sources could be public funding, e.g. in the form of grants from public bodies such as the funding for the Fed4FIRE+ project, payments from users, or subscriptions from testbeds (others are certainly possible). Funding sources need to be further investigated and cases for the Federation's value will need to be constructed based on which funding source is being targeted.

3.2 FEDERATION POLICIES

The Federation policies are statements of regulation or practice that govern the Federation. Figure 3 shows the initial set of candidate policies.

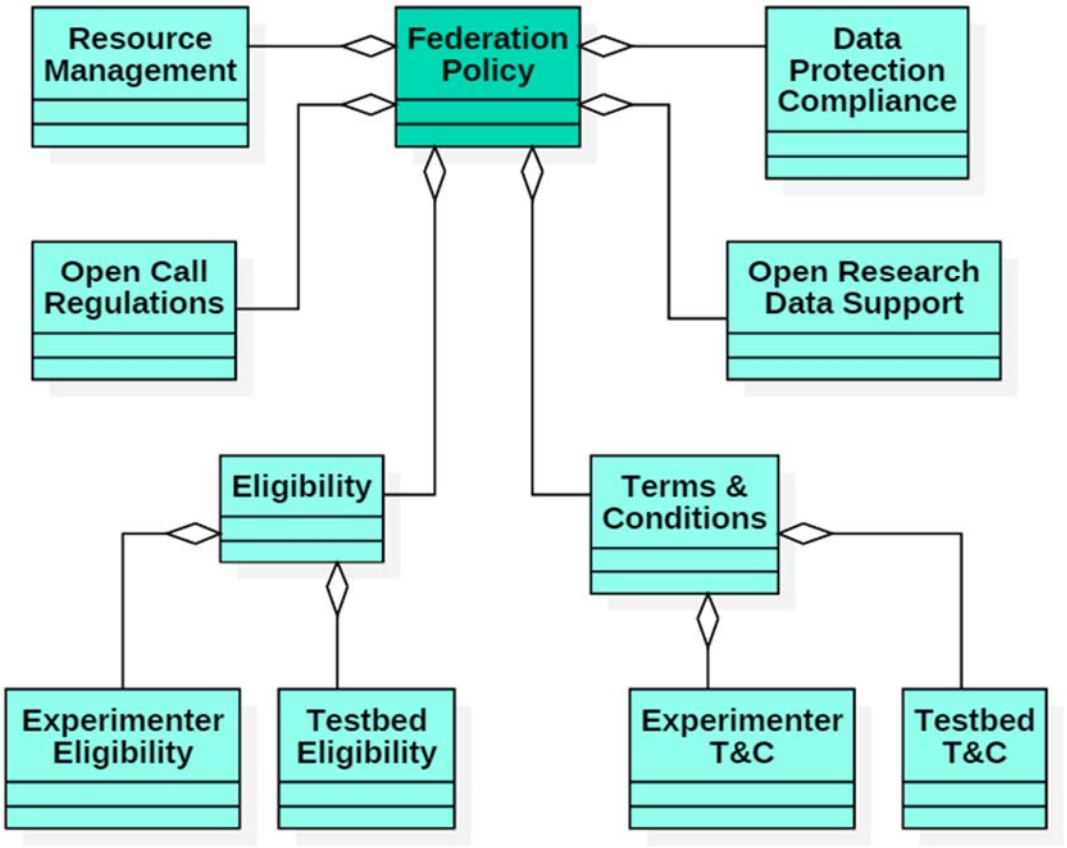

Figure 3: Federation Policy Candidates

A number of these policy candidates derive from the work done in the Fed4FIRE Federation Board and are reported in Fed4FIRE D2.15[3]. These policies have been augmented and updated as necessary for Fed4FIRE+. The status of each policy varies, as some are mature and others are new.

Resource Management. This policy determines the sharing of resources provided by testbeds to the Federation. It is intended to cover the minimum limits on contribution of testbeds' resources to the Federation (to ensure

[3] Taylor, Steve (2016) D2.15 Final Federation Board Specification. https://doi.org/10.5281/zenodo.1309324

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enough testbed resources are available to experimenters) and any quota limits on the resources used by for experimenters (to prevent some experimenters using more than their fair share). This policy is in its early stages, and observation of the usage of resources is needed to determine the limits needed in both cases.

Data Protection Compliance. This policy determines compliance with the GDPR. The board is officially responsible for all policies and takes input from expert parties when needed, and in the case of GDPR compliance, the experts in Fed4FIRE+ are Mandat International (MI), so the board will follow their recommendations. The current recommendations regarding GDPR compliance are recorded in Fed4FIRE+ D2.1, the Data Management Plan.

Open Call Regulations. This policy determines the regulations for open calls. The regulations in place are mature: they derive from EC regulations on cascade funding and have been in operation throughout Fed4FIRE and Fed4FIRE+. The regulations will be monitored by the board and adjusted as necessary. A recent case in point was an addition to the open call application process requiring prospective experimenters to observe Open Research Data (see next policy).

Open Research Data Support. This policy derives from the EC's policy to support open science through the creation and archival storage of Open Research Data (ORD). This is discussed at length in D2.1. Fed4FIRE+ follows the EC's mantra that research data should *"as open as possible, as closed as necessary"*, meaning that data can be closed if needed, but is encouraged to be open. A policy decision in Fed4FIRE+ is that each experimenter is the source of ORD and therefore each experimenter needs to determine whether that data should be open or closed. If they decide it is open, the experimenter needs to create a Data Management Plan (DMP) for it (there are templates in D2.1 and Fed4FIRE+ will aid them). If the data is closed, the experimenter needs to provide valid reasons why (e.g. commercial confidentiality).

Eligibility. This policy covers the criteria that experimenters and testbeds must satisfy to use or offer resources within the Federation. This policy is mature and uses the eligibility criteria from Fed4FIRE, which is specifically designed to be as accepting of all experimenters and testbeds. The main policy requirements are that the experimenters are European-based and comply with the Terms and Conditions, and testbeds are European-Based, comply with the Terms and Conditions, and are compatible with the Federation technical requirements.

Terms and Conditions. These policies cover separate Terms and Conditions (T+C) for the experimenter and the Testbed. The policies are mature and use the T+C from Fed4FIRE. The experimenter T+C contains elements such as limitation of liability, acceptable usage, fair usage and enforcement. The testbed T+C contains elements such as stability, security, resource provision and, audit. The T+C will be monitored and updated as necessary.

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3.3 CONTROL INSTRUMENTS

The Federation Board has several control instruments at its disposal. These may be adjusted or specified in different ways to steer the Federation to address the Federation's objectives. The initial set of control instruments is shown in Figure 4.

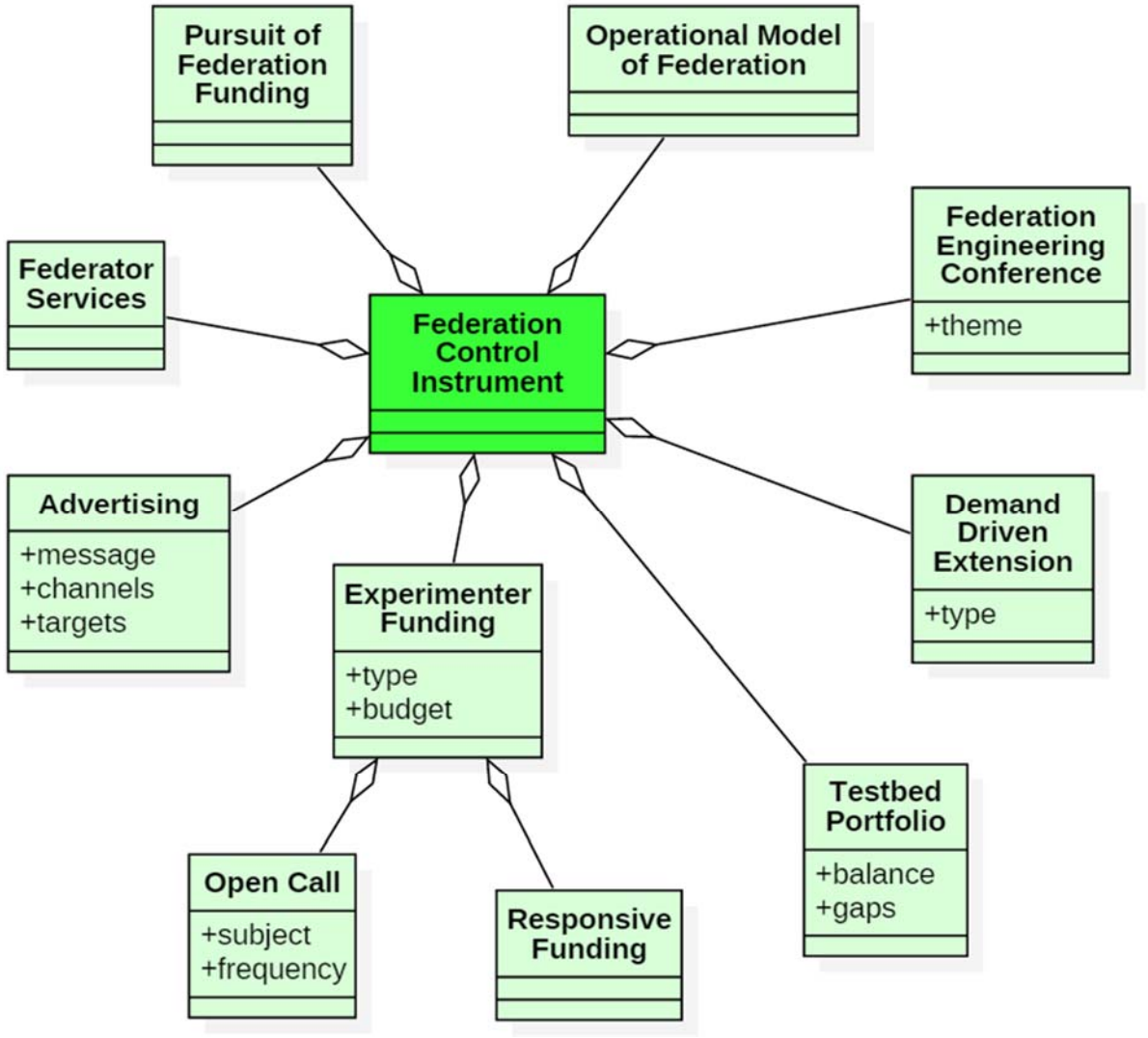

Figure 4: Federation Control Instruments

Pursuit of Funding. This instrument determines how continuation funding is sought. For example, we need to understand who the target funding providers are, how we approach them and how we build a case for continuation funding. This instrument is clearly linked to the sustainability objective and the value propositions but is in its early stages. It will be evolved as the work on Fed4FIRE+ sustainability progresses.

Operational Model of Federation. This instrument determines how the Federation operates, who the key stakeholders are, and what contributions each makes to the Federation. Fed4FIRE determined that its operation model was that of a "One Stop Shop", as defined by an earlier version of the FitSM standard[4]. The "One Stop Shop" is an operational pattern whereby the setup for an experiment is done by a prime contractor facing the user up to the point where the experiment is ready to run, but the execution of the experiment is handled by the experimenter. The prime contractor is called the "Federator" (which explains the name of WP2 in Fed4FIRE+). The Federator handles the execution of all operational aspects of the Federation, and therefore is the focus of

[4] https://fitsm.itemo.org/

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the sustainability question. This instrument is mature since it dates from Fed4FIRE and has been operated successfully for at least two years. It will be monitored but at the current time there are no plans to alter it.

Federator Services. This instrument determines the service portfolios offered by the Federator to experimenters and testbeds respectively. The services the Federator offers experimenters include: advice on selection of a testbed or testbeds based on the experimenter's requirements, single sign on to federated testbeds, automation or help to set up an experiment, funding for experiments and collaboration with other experimenters through Federation Engineering Conferences. The services the Federator offers the Testbeds include: assistance to become technically compliant with the Fed4FIRE+ infrastructure, advertising of testbeds' resources to all the Federations' users, matchmaking experimenters to testbeds and funding per experiment for testbed patrons. The services will be monitored, augmented and adjusted as necessary.

Federation Engineering Conferences (FECs). These conferences occur every six months and function as a gathering point and community building opportunity for the Federation users, management and resource providers. Each FEC has a theme, and it is the board's responsibility to determine the theme based on current trends and demand. As an example, the next FEC in October 2018 has Internet of Things as its major theme.

Advertising. The Federation disseminates its benefits, service and resources to existing and potential users. The board's task is to ensure that the advertising is consistent with the goals of the Federation (e.g. to increase the number of experimenters). The key control parameters at the disposal of the board are the message – what is said in the advertising, the target audience – who the advertising is intended to reach (and this may influence the message), and the channels used.

Demand-Driven Extensions. The Fed4FIRE+ project has capacity to fund extensions to the Federation, mainly in added functionality and additional testbeds (or new types of testbed). The board will determine the types of extensions that are most promising, as well as decide how they are funded.

Experimenter Funding. Up the current time, the main mechanism for experimenter funding has been open calls, managed by IMEC. IMEC has put in place a schedule of different types of open call, mainly differentiated by the size of experiments in terms of funding. The board reviews the schedule and make recommendations as appropriate for adjustments and whether there is the need for any specific calls on dedicated subjects. The board also has considered other mechanisms for experimenter funding, and a recent case in point has been the trial of a "responsive mode" funding scheme, which has no deadlines and experimenters can apply at any time and get a fast decision. This was in response to identification of SMEs' needs – they cannot wait three months for a decision on experimentation funding – the market may have moved on in that time, so the SMEs need a responsive and agile means of experimentation support.

Testbed Portfolio. This is the aggregation of testbeds in the Federation, and the board has a responsibility to ensure that the types of testbeds meet the needs of the experimenter base. These needs are likely to change over time, as new technologies come on line and new types of experiment need to be conducted, so the board needs to scan the horizon to determine new types of testbed to add. In some cases, testbeds become under-used and irrelevant because their resources are no longer in demand, and the board may recommend adjustments to their operators with the intention of keeping them relevant. The testbeds are under no obligation to heed this advice, but the intention is that it is given in the spirit of constructive assistance.

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3.4 KEY PERFORMANCE INDICATORS

The Key Performance Indicators (KPIs) measure the performance of the Federation. They are used as input so that the board can determine courses of action and steering decisions based on the values of the KPIs. The KPIs are in different categories, and the KPIs determined so far are shown in Figure 5.

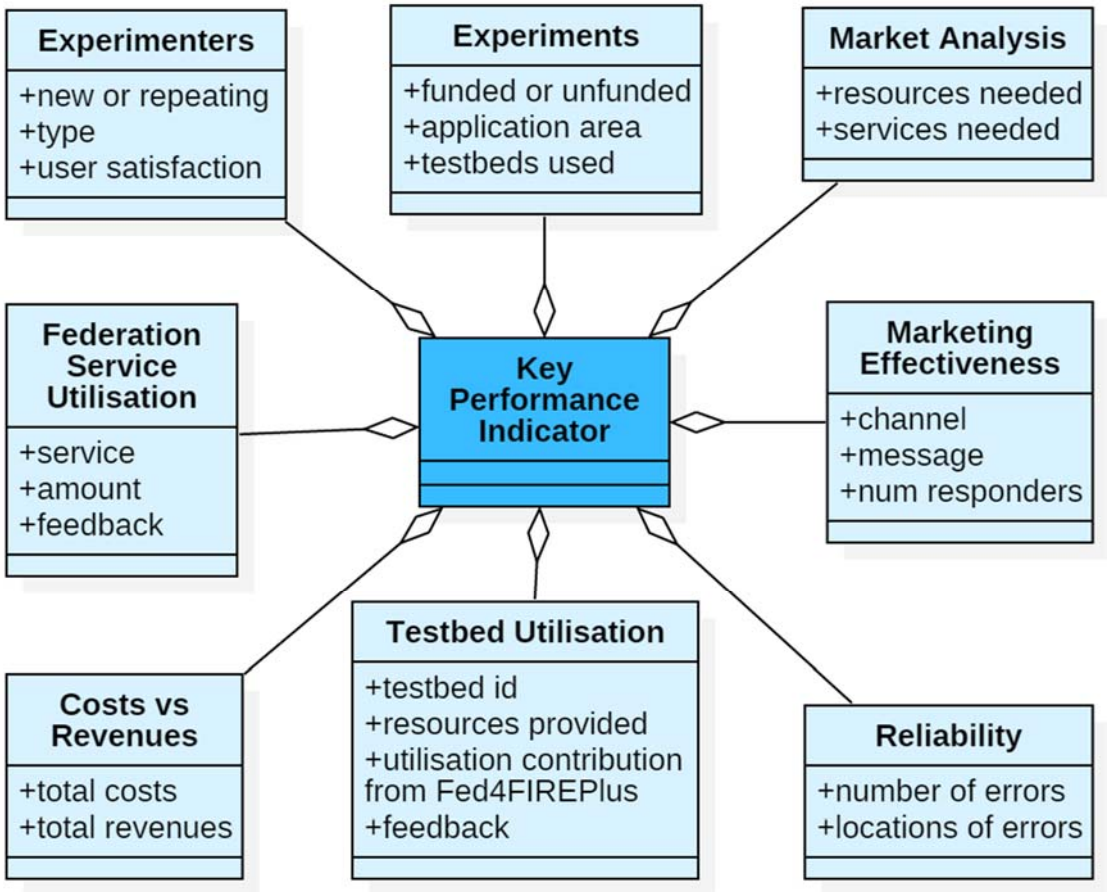

Figure 5: Key Performance Indicators

Number of Experimenters. This is how many experimenters are using the Federation actively using the Federation in any given moment. It is important to know that the users are active, and not just registered and inactive, as active users give an accurate picture of the utility of the Federation. Understanding time-based trends of active users is also important, as it is important to know whether the Federation continues to provide a useful and relevant service. Ideally, the number of active users will increase over time, and if they stand still or decrease, investigations can be triggered into the reasons why. It is also important to understand whether experimenters are new (new blood is being attracted) or are coming back having experimented previously (satisfied customers). The type of experimenter is also a useful indicator, e.g. academic, SME, corporation, public service department, as this will indicate the key sectors Fed4FIRE+ is successful and can guide future strategy in marketing the Federation. Finally, the experimenters' satisfaction will provide information about whether the Federation is doing the right things or how it can be improved in the eyes of its users.

Number of Experiments. Clearly, the number of experiments is important, as it is a basic indicator of the utility and popularity of the Federation. A key parameter is whether the experiments are funded by Fed4FIRE+'s open calls or whether the experimenter's costs are funded by themselves. The latter is a stronger indicator of Fed4FIRE+'s value to experimenters than the former and going forward beyond the end of the Fed4FIRE+ project, it is likely that an objective will be to increase the number of experimenters using resources provided through Fed4FIRE+ but funding their own effort. The application area (or vertical sector) of the experiments is also useful information, because it indicates where Fed4FIRE+ is making impact, and also can provide clues to new areas for expansion or diversification. A further key parameter is the types of testbed that the experiments utilise. Coupled with the number of experiments, this provides indications of which testbeds are popular.

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Market Analysis. This is not strictly a KPI as it is not a direct assessment of the performance of the Federation but is included here as it provides useful information that may be used to guide the Federation's steering. The market analysis comprises mainly investigation of resources and services needed by the current (and possible future) user community but not yet provided by Fed4FIRE+

Federation Service Utilisation. This indicates which services provided by the Federator are most used by experimenters and testbeds (the Federator provides services to both) together with feedback from the users on each service they use. This provides information to identify the popular services and less well-used services, and all can be improved by the feedback.

Marketing Effectiveness. The Federation is advertised through different channels (e.g. website, mailing lists), targets different types of user (both experimenters and testbeds) and has different messages (e.g. open calls, advertising the Federation's resources). These need to be evaluated, both individually and in combination, to determine their effect, i.e. how many users respond to the messages and come to use or provide resources in the Federation.

Costs vs Revenues. At a basic level, this is simply the total costs vs the total revenues, and the Federation's revenues must exceed its costs. There may be more detailed breakdowns; for example determination of the revenue-cost ratio of different actors in the Federation (notably the Federator).

Testbed Utilisation. This shows which testbeds are most used by experiments. The metric includes the types of resources offered by each testbed, so the resources in demand by federation can also be determined by aggregation. Most testbeds have additional users apart from those brought by the Federation, so their absolute utilisation is not interesting for Fed4FIRE+ (and testbeds may not wish to supply this information). Instead, any indication of utilisation should indicate the Federation's contribution to the Testbeds' utilisation as a proportion of the capacity the Testbed has offered to the Federation. This will indicate how relevant the Testbed is for Fed4FIRE+ users. Finally, aggregated feedback from users can provide clues as to how well the Testbeds are received and how they may improve.

Reliability. This is an overall measure of the reliability of the Federation, in terms of errors and problems experienced by users. Clearly the fewer errors, the better the user experience, so the Federation has an interest in locating and reducing errors, so this metric has an indication of the location of the error (e.g. in the Federator or in a testbed).

3.5 COMPOSITION & APPOINTMENT

The FB represents the key stakeholders in the Federation, namely the Federator and the Testbeds, and testbed representatives make up a large proportion of the board, but at the first FEC meeting it was decided that additional positions were needed in the FB, so it was decided that the composition of the board should include the following representation:

- Testbeds
- The Federator
- Federation tools
- Sustainability of the Federation
- External expertise

Each board member has one vote, and to prevent imbalances of power, a key principle of appointment to the board was that there cannot be more than one person from the same legal entity.

Board members were selected based on their expertise, role within the project and affiliation. The current board members are:

- Serge Fdida, Sorbonne University, Federator
- Symeon Papavassiliou, NTUA, NETMODE Testbed
- Thanasis Korakis, CERTH, NITOS Testbed
- Jerry Sobieski, DANTE, NORDUNET Testbed
- Brecht Vermeulen IMEC, Federation tools
- Steve Taylor, IT Innovation, Sustainability
- Ivan Seskar, Rutgers University, External expert

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3.6 BOARD OPERATION WITHIN FED4FIRE+

Within the Fed4FIRE+ project, the board operates inside WP2 and has numerous connections, as shown in Figure 6. The board's decisions are informed by inputs from multiple sources and its decisions are carried out within other tasks.

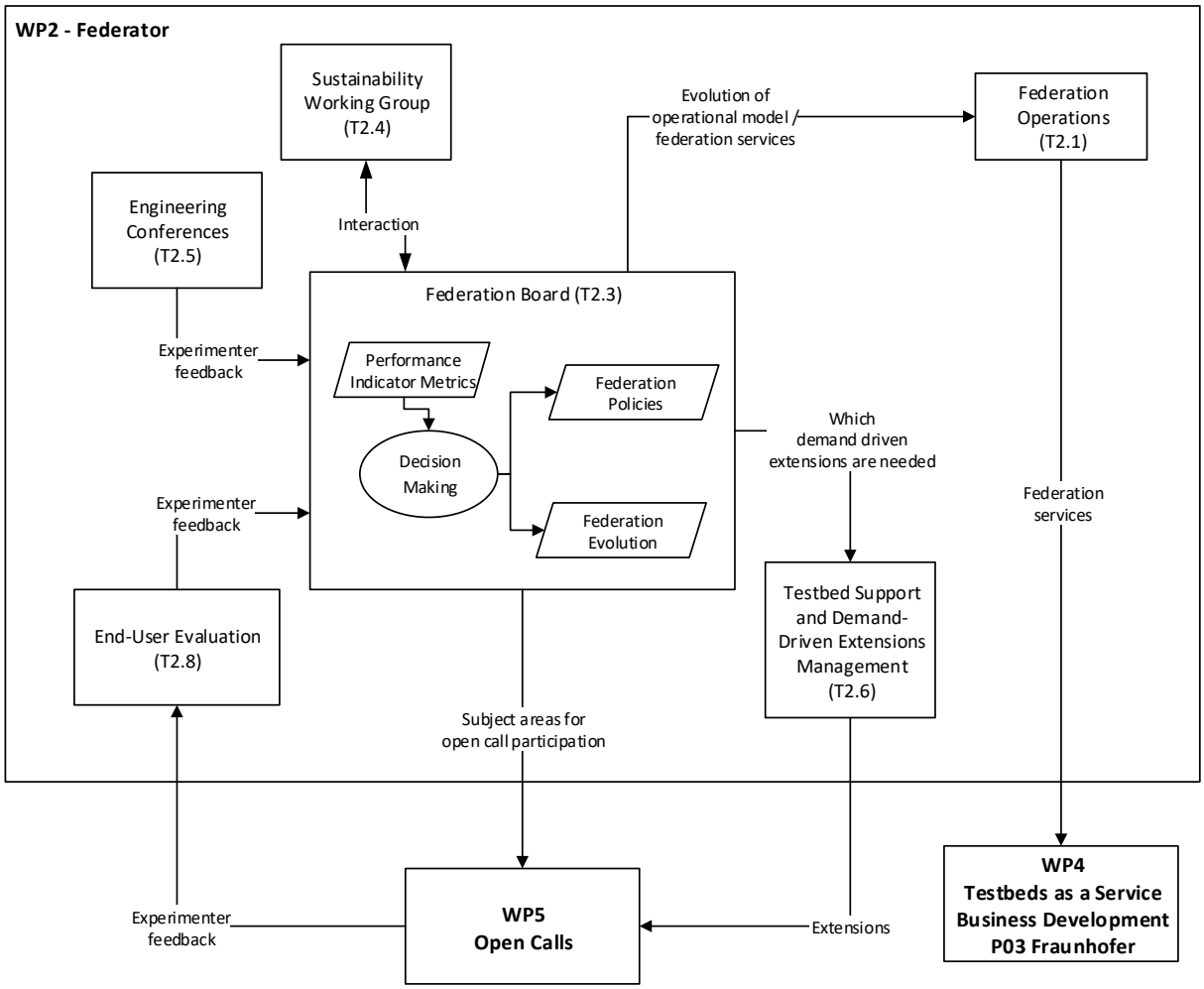

Figure 6: Federation Board's Position within Fed4FIRE+ Project Structure

The board takes input in the form of Key Performance Indicators (KPIs) from other tasks within WP2 and the wider project. Key sources are from the surveying conducted within T2.8, which polls end user feedback, and live feedback gathered at the 6-monthly Federation Engineering Conferences (FECs). Another significant source of KPI is via statistical information regarding the experiments run in the Federation. All this information is assimilated and presented to the board in compact format ahead of board meetings, so that the board can decide on courses of action that should be undertaken to further the Federation or to correct problematic behaviour.

The board's primary decisions are in two major categories: federation policies (expressions of principles and practice for governance of the Federation) and federation evolution (steering the direction of the Federation). Examples of key decisions are shown in the figure. The board decisions are not limited to these and have been discussed above in the "policies" and "control instruments" sections.

There is a tight relationship between the board and the sustainability task, and the reason for this is that sustainability is a key objective for the Federation, especially beyond the end of the Fed4FIRE+ project. Therefore, sustainability is at the heart of the objectives for the Federation, as described in section 3.1.

The interactions within the Fed4FIRE+ project are shown in Figure 7.

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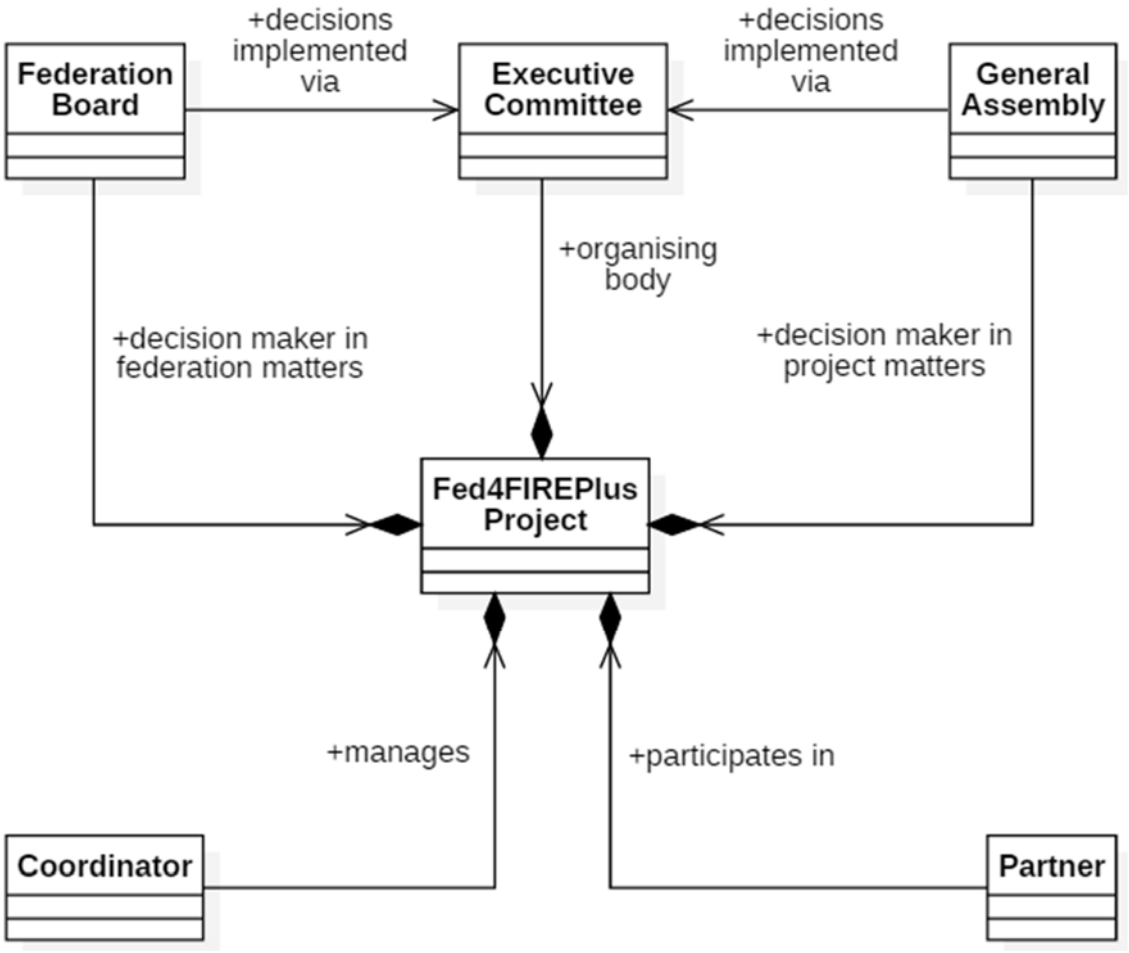

Figure 7: Communications within Fed4FIRE+ Project

The project has two governing bodies, the Federation Board, responsible for federation governance, and the General Assembly (GA), responsible for project governance. As its name suggests, the Executive Committee of the project is the body that actions decisions from the two governing bodies. The Exec Committee makes small management decisions regarding the running of the project, but major decisions are made by the Federation Board or the General Assembly. Any party in the project can request decisions of the Board or the GA, and issues or decision requests are communicated to the Board and the GA via the Exec Committee with the resulting decision communicated back to the Exec Committee.

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4 SUSTAINABILITY

The Federation needs to be sustainable beyond the end of the Fed4FIRE+ project, and T2.4 is responsible for investigation of options for sustainable continuation of the Federation. This section contains a number of perspectives on the subject of sustainability for Fed4FIRE+. As this is the first in a series of deliverables concerning sustainability, the approach chosen is divergent thinking, so as to capture as wide a diversity of options for sustainability as possible. Later deliverables will evaluate this work and converge towards a plan for Fed4FIRE+ sustainability.

Before deciding on a plan for sustainability, it must be determined *what* needs to be sustained, as the Federation is an aggregation of different entities. Figure 8 shows a possible future federation containing the key actors who need to be sustained.

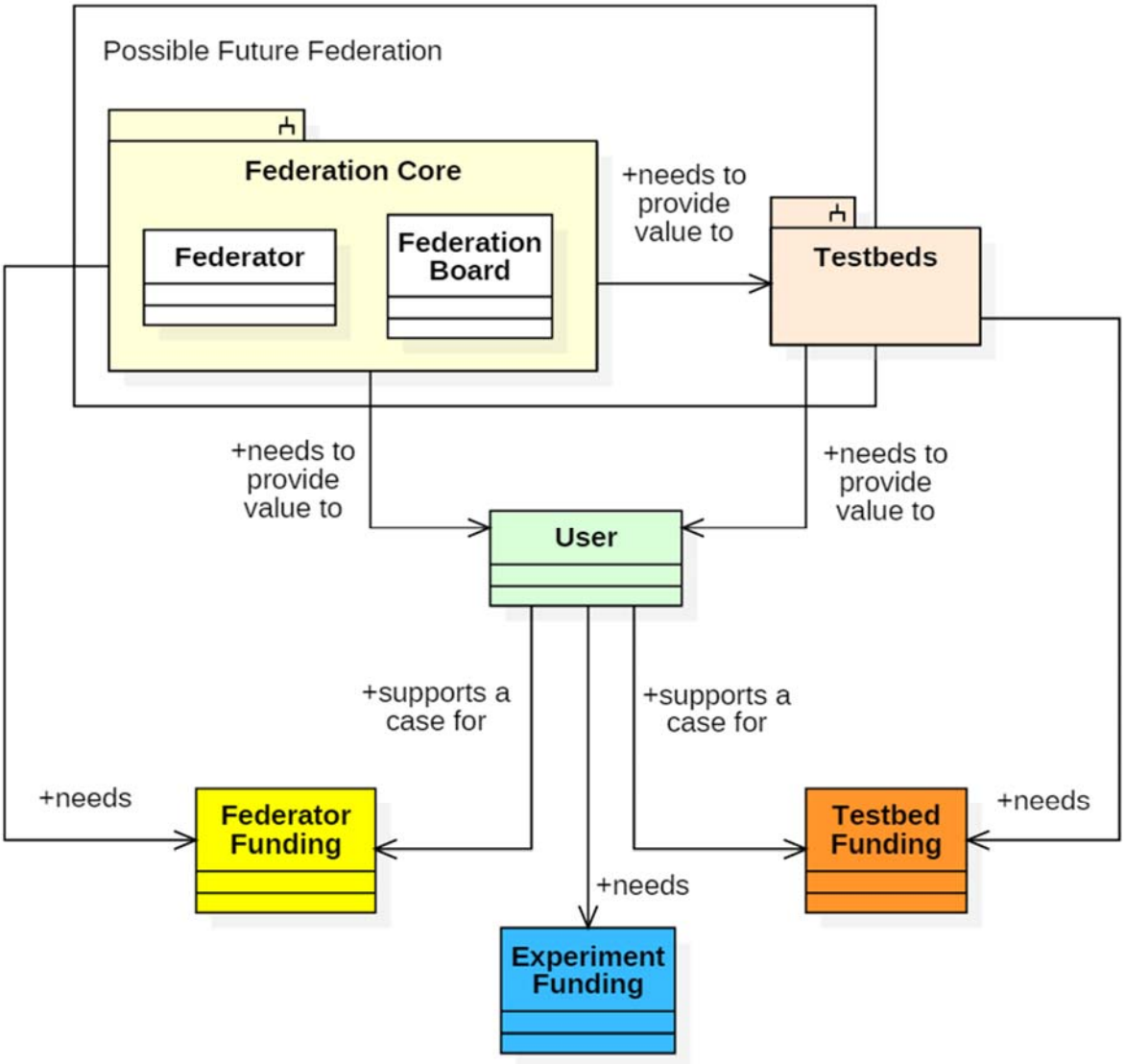

Figure 8: Possible Future Federation

There are two main aspects to this future federation.

- The Federation Core, comprising the Federator (the body that works to enable the running of the Federation), and the Federation Board (the body that governs and steers the Federation).
- The Testbeds, who provide the experimentation resources upon which experiments are executed.

The Federation Core is intrinsic to the Federation, meaning that the Federation cannot exist without the Federation Core, and the Federation Core has no purpose outside the Federation. The Testbeds, on the other

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hand, have a life outside the Federation, and contribute to the Federation because there are clear benefits (these benefits are actually part of the Federation's value proposition towards the Testbeds).

Both the Federation Core and the Testbeds need to be sustained. Each has sources of funding that may be employed individually or together.

The Testbeds' funding may come from multiple sources, for example:

- National or local funding programmes;
- Public Private Partnerships (PPP);
- European grant funding or research programmes;
- Users paying for resources or services; or
- The Federator, when the Testbed is used in support of a federation experiment.

The Federation Core's funding may come from multiple sources, for example:

- European grant funding;
- Subscriptions paid by testbeds; or
- Experimenters paying for access to federated testbed resources.

Within the Federation Core, the Federation Board's sustainability is tied tightly with the Federator's, as if the Federator does not exist, there is no need for the Federation Board, so the Federation Board's sustainability is considered together with the Federator, and both are collectively referred to as the Federation Core. The Federation Board has a few costs, e.g. the board members' time and expenses for board meetings and preparations, and these costs should come out of the Federator's revenues and be factored into the Federator's costs.

In future cycles of the project the costs will be specified and better quantified, and the consortium will investigate the different possible funding sources. As a general principle, a hybrid funding approach for continuance of operation is highly likely for each stakeholder in the Federation, where a Testbed or the Federation Core seeks multiple sources of funding at the same time, as reliance on one source of funding is risky. Diversification of funding is common practice for existing testbeds and broker-type organisations – they seek funding from all possible available sources to build up a fund that can sustain them and insulate them from one funding source disappearing.

Different options for payment methods will be investigated in future work along with the funding sources, for example an annual membership fee with priority access to the federated facilities, or a pay-as-you-go model for individual experiments for a certain period of time. Such charges can apply on-demand, according to the use of resources (expressed in terms of CPU, nodes, time, etc.). When direct payment is not a viable solution, alternative in-kind contributions may be available (on a per customer basis), so that e.g. SMEs can donate equipment time in agreement with the Testbed providers and the FED4FIREplus consortium. Academic institutions and non-for-profit research centers may be able to use these testbeds free of charge on a best effort basis service, provided that they provide some relevant in-kind contribution, e.g. contributing their produced data sources / files to a Fed4FIRE plus data repository, word-of-mouth advertising or testimonials, etc.

There is a third actor, the User. They are the "customers" of the Federation, who perform experiments using the resources and facilities of the Federation (and as such users are interchangeably known as "experimenters"). In a sustainability situation beyond the end of the Fed4FIRE+ project, experimenters typically they do not require funding from the Federation, but in the special case of the Fed4FIRE+ project, their funding may come from the cascade funding distributed by Fed4FIRE+ on behalf of the EC, so that the experimenters' time is paid through the open calls of Fed4FIRE+. For the purposes of sustainability, this special case of experimenters being paid by the Federation must be discounted, as the Federation must demonstrate enough intrinsic value to warrant its existence. The Federation's value proposition is critical to sustainability and is assessed in the next section.

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4.1 FED4FIRE+ VALUE PROPOSITION ASSESSMENT

This section describes an initial assessment of the value proposition of the Federation. It will be evolved and updated in later cycles of the project, as the experience of operating the Federation contributes to making the value proposition clearer.

4.1.1 VALUE PROPOSITION

FED4FIREplus core facilities consist of twenty testbeds spread in nine different European countries. Specifically, four wired, nine wireless, six OpenFlow and two cloud testbeds exist. In addition, the overall infrastructure is further complemented by approximately eighty internationally federated testbeds around the glove.

The following identified technical specifications and principles should be fulfilled in order to ensure the continued operation and the sustainability of the federated infrastructure, while supporting its cost-effective operation, smooth extensibility and positive externality. Note that these are "necessary" conditions, but certainly not sufficient for sustainability:

1. **Flexible components:** The individual testbeds should consist of flexible components so as to efficiently serve and support different configurations, software implementations and extensive measurements and experimentations, therefore supporting a plurality of different research and commercial objectives.
2. **Fast control connectivity and easy management:** The federated infrastructure should be an easily configurable and highly utilizable research and experimentation "tool". Researchers and/or experimenters need not have extensive systems implementation experience in order to perform experimentation.
3. **Extensibility:** Since technologies utilized in the Federation advance rapidly, one should provide for the evolution of the experimental infrastructure. This creates constraints both financial and technical, favoring software-based solutions. Component-based approaches allow for the inclusion of additional functionalities – without harming the operation of the existing ones – while also permitting the replacement of existing function realizations, with enhanced or alternatives implementations, supporting interoperability.
4. **Hardware Provisioning:** The overall architecture should generally account for non-expensive hardware, which however can address the performance requirements of the different technologies. Clearly, it would be rather inappropriate to purchase very cheap equipment with poor capabilities: extending such infrastructure with demanding hardware and software modules would be extremely difficult (if not impossible in most cases). On the other hand, even though expensive infrastructure (cost reaches the order of thousands of euros per node) can expand the research horizon further, they are rather difficult to replace in cases of theft or malfunction. Ideally, sustainability could be better served by moving away from an architecture based on multitude of black boxes equipped with specialized hardware and pre-loaded with specialized software, to a new architecture consisting of a "white box" running a multitude of specialized software. The later also appears to be the dominant choice and direction in current and future communication and computing infrastructures.
5. **Educational/Training Aspects:** Specific features and/or small parts of the infrastructure should be utilized to complement the teaching/training of elective courses emphasizing on the design, modelling, management and planning of future internet infrastructures.

However, as mentioned before, the aforementioned conditions do not suffice to ensure sustainability.

The current selling point of FED4FIREplus is the easy access to heterogeneous networking and computing resources spread worldwide, enabled by the use of homogeneous common basic software tools for accessing the Testbeds and providing a single point for authentication and authorization. Those are the critical features and benefits that must be advertised and strengthened by the future sustainability and marketing activities. This objective can be served by promoting the possible simultaneous usage of multiple (and perhaps more importantly) heterogeneous testbeds to realize experiments, services or products of a complete chain, that would be extremely difficult or even impossible to be completed in individual – even technologically advanced – testbeds or infrastructures. The key message is that the Fed4FIREplus federation supports not only scalability and experimentation diversity, but also heterogeneity in the technologies and testbeds used, which cannot be found or reproduced in any single testbed, no matter how advanced. This message certainly supports the uniqueness of our federated infrastructure, and therefore contributes to its sustainability as a federation. Under

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this assumption and consideration, it is clear that FED4FIREplus should (and actually does) allow for delivering an end-to-end experimentation service, while supporting both the principles of repeatability and reproducibility.

In our approach, the support services provided by the Federator determine the interaction between the experimenters and the providers of the federated testbeds. We believe that the Federator should act as a broker and interacts with both the experimenters and the Testbed facility providers. Following the experiment lifecycle of FED4FIREplus, the experimenters interact with the Federator to discover and request resources (e.g. resource reservation services). The Federator takes responsibility to interact directly with the individual testbed facilities to enact resources reservation. Once complete, the experimenters can perform their experiments on the facilities. The Federator should provide high level services for both stakeholders, such as collecting the monitoring data and provide Service Level Agreement (SLA) for the provided resources.

Full sustainability should support and be supported by two critical factors, closely interrelated – either implicitly or explicitly: a) critical mass sustainability and b) financial sustainability. Academic researchers, which form a large pool of experimenters, will be a major type of "customers" who should be invited for experimentation. The utilization of the federated facilities will be free of charge for academic institutions and not-for-profit research centers. The experimenters will be encouraged to make "in kind" contributions, such as new services or software extension in consultation with the Testbed owner and the FED4FIRE plus consortium or contributing their produced data sources/files to a Fed4FIREplus-approved data repository in support of Open Science, that could become available to the corresponding relevant community. The collaboration between FED4FIREplus consortium and academic partners from different research fields, such as agriculture and health, will help to create more real-life testbeds and living labs. Furthermore, a small (contained) portion of the facilities could be offered for educational/training purposes – which however is still important aspect for properly disseminating Fed4FIREplus activities, while creating a well-trained broad set of young researchers, engineers, scientists, students, etc., that will promote usage of the federated infrastructure in their future endeavors, careers and employers, and therefore contribute towards the critical mass sustainability. FED4FIREplus will also put effort to federate with as many as possible new testbeds worldwide, which will essentially improve its positive externality. It is clear that the benefit obtained by the Federation by including one additional facility should be multi-faceted and of multiplying factors, as its usage would become (and benefit) available to a large pool of users (customers).

Secondly the FED4FIREplus will be accessible to SMEs for experimentation. Similar to open calls, the Testbeds' providers will act as Patron. SMEs could pay a fee, which will vary according to the duration and complexity of the experiment. Alternatively, large industry (and some SMEs) will be able to contribute ''in kind'', by donating equipment, commercial software tools, etc. Due to the geographical disperse of the federated testbeds, FED4FIREplus partners can act as a local innovation hub that will support SMEs and help the creation of new ICT enterprises.

There are three different type of potential beneficiaries for Fed4FIREplus; academic researchers, SMEs and the Testbed providers themselves. In the following, we analyze the potential role of each actor and which are the key motivation and the gains from conducting experiments on FED4FIREplus facilities.

- Most academic researchers have access only to the facilities of their lab or institution and thus, the evaluation of their research under realistic conditions is not possible and it is based primarily on simulation tools. This further leads to limited dissemination value and visibility for these research group, while in several constraining questioning the validity and applicability of the obtained results. Having access to the federated infrastructure allows them to validate their research with added credibility and enables them to develop synergies with European and international partners. Also, the reputation of FED4FIREplus motivate the academic researchers to contribute new services and software tools in order to gain more visibility, therefore implicitly contributing to the sustainability, progress and evolution of the federated infrastructure.
- SME experimenters are mainly interested in either initial or even stress testing of their products and services under real- life scenarios. This is infeasible for the majority of the SMEs, which usually do not have a proprietary testbed. In addition, gaining access to other industrial or special purpose facilities could be either impossible or extremely costly for them. Therefore, a federation like FED4FIREplus possibly remains the only valid and still cost-feasible solution for a great majority of SMEs. FED4FIREplus consortium has learned many lessons from the process of the open calls during the project and can spot what the SMEs expect from the Federation in terms of tools and infrastructure. An interesting remark

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is that the most proposals of the open calls[5,6] are coming from academia and SMEs from southern European countries, i.e., Greece, Italy and Spain, which indicates the need of experimental facilities in this European region, and investigation is needed to determine needs in other regions. Thus, FED4FIREplus can become a leading player on the experimentation market and act as intermediary node between academia and SME.

- Finally, FED4FIREplus consortium will invite testbeds to join the Federation. This will help many small testbeds with limited resources, which are usually used by the researchers of a single academic entity, to connect with other testbeds worldwide and gain more visibility.

In order to organize better our sustainability plan, we have used the Value Proposition Canvas[7] by Stratygazer. The Value Proposition Canvas has two parts: the customer profile and the value map. The first one describes the jobs, the pains and the gains of the customers, while the second one illustrates the features of a specific service or product and is broken down into products and services, pain relievers and gain creators. Figure 1 illustrates a snapshot of the proposed tool.

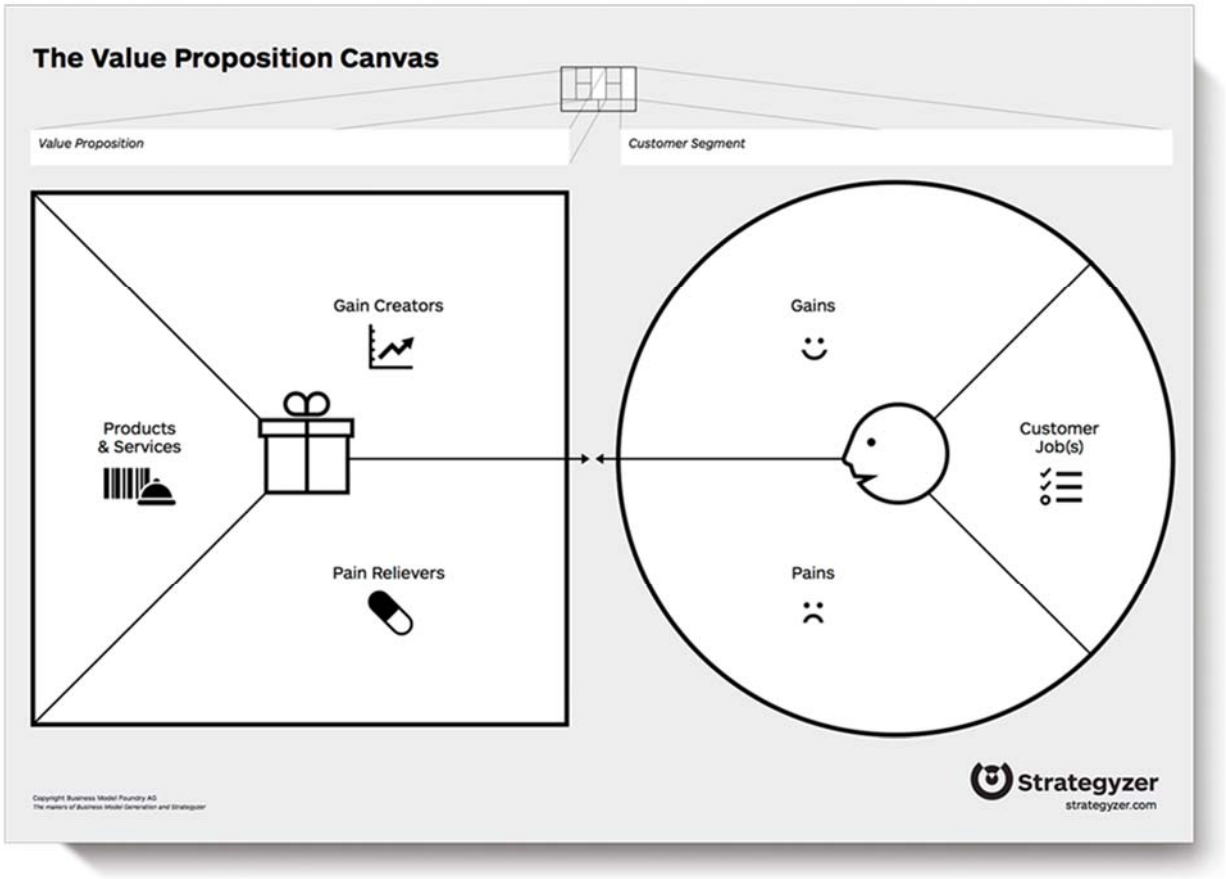

Figure 9 – Value Proposition Canvas by Strategyzer

Tables 1-3 show the fields of the Value Proposition Canvas for each type of the aforementioned users, who utilize the FED4FIREplus resources and software tools.

[5] https://www.fed4fire.eu/news/2nd-fed4fire-open-call/

[6] https://www.fed4fire.eu/news/3rd-fed4fire-open-call/

[7] https://strategyzer.com/canvas/value-proposition-canvas

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Table 1 - Value Proposition Canvas for Academic Experimenters

<table>
<tr><td colspan="2">Customer type: Academic Experimenters</td></tr>
<tr><td colspan="2">Customer JOBS
Develop novel services/applications.
Develop innovative network architectures and protocols.
Reduce the experimentation time.
Reach the planned results/objectives.
Attract international liaisons.</td></tr>
<tr><td>Pains
Difficulties in using new technologies.
Not fully understanding the implications of real-life environments on their work.
Difficulties in accessing realistic experimentation environments.
Difficulties in integrating different facilities for different purposes.
Analyzing the shortcomings of the experiment.
Waste time on ideas that do not work.</td><td>Gains
Experimentation under realistic conditions.
Reduce development cost.
Improve the tested idea.
Visibility among research community.
International liaisons.
Speed up publication process.
Create innovation.</td></tr>
<tr><td colspan="2">FED4FIREplus solution Value Map for Academic Experimenters</td></tr>
<tr><td colspan="2">Single sign on and easy access in heterogeneous resources.
Allows conducting traceable and reproducible experiments.
Enable small, medium, and large-scale experiments.
Access to experimental infrastructure outside Europe.
Provide realistic experimentation environments.
Provide support through the entire lifecycle of the experiment.</td></tr>
<tr><td>Pain Relievers
Available experimental infrastructure without need to set up from scratch.
Reduce uncertainty of the application/ service’s success.
Reduce time of the experimentation.
Single sign-on and unified access to all testbeds.</td><td>Gain Creators
Significantly reduce capital and operational expenditures for experimentation.
Access to heterogeneous infrastructure in terms of resources, scale and geographical dispersion.
Realistic demonstration and robust results.
Reduce time for conducting experiments.
Connect with experts in different domains or acquire new skills.</td></tr>
</table>

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Table 2 - Value Proposition Canvas for SME Experimenters

<table>
<tr><td colspan="2">Customer type: SME Experimenters</td></tr>
<tr><td colspan="2">Customer JOBS
Develop novel services/applications.
Reduce the time for publishing service/application to market.
Provide robust service/application.
Reduce the experimentation time.
Reach the planned results/objectives.
Attract potential customers.
Attract international liaisons.
Reduce risk of failures.</td></tr>
<tr><td>Pains
Difficulties in using new technologies.
Not fully understanding the implications of real-life environments on their work.
Difficulties in accessing realistic experimentation environments.
Difficulties in integrating different facilities for different purposes.
Analyzing the shortcomings of the experiment.
Testing applications/services can become costly and time-consuming.
Service/applications performance and features are not well understood by end-users.
Waste time on ideas that do not work.</td><td>Gains
Experimentation under realistic conditions.
Reduce development cost.
Improve the tested idea.
International liaisons.
Create innovation.
Connect with experts in domains or acquire new skills.
Develop application/services for a wide market.
Gain competitiveness over other enterprises.</td></tr>
<tr><td colspan="2">FED4FIREplus solution Value Map for SME Experimenters</td></tr>
<tr><td colspan="2">Single sign on and easy access in heterogeneous resources.
Allows conducting traceable and reproducible experiments.
Enable small, medium, and large-scale experiments.
Access to experimental infrastructure outside Europe.
Provide real world use cases.
Provide support through the entire lifecycle of the experiment.</td></tr>
<tr><td>Pain Relievers
Available experimental infrastructure without need to set up from scratch.
Reduce uncertainty of the application/ service’s success.
Reduce time of the experimentation.
Single sign-on and unified access to all testbeds.
Get feedback from the customer’s due to their involvement in experimentations.</td><td>Gain Creators
Reduce capital and operational expenditures for experimentation.
Access to heterogeneous infrastructure in terms of resources, scale and geographical disperse.
Realistic demonstration and robust results.
Reduce time for conducting experiments.</td></tr>
</table>

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Table 3 - Value Proposition Canvas for Academic Testbed Providers

<table>
<tr><td colspan="2">Customer type: Academic Testbed Providers</td></tr>
<tr><td colspan="2">Customer JOBS
Reach experimenters/customers.
Fund the Testbed.
Extend the facilities.
Find international partners.
Gain visibility.
Advertise the Testbed.</td></tr>
<tr><td>Pains
Difficulties in acquiring funding.
Difficulties in broaden liaisons.</td><td>Gains
Attract large number of academic and SME experimenters.
Maintain facilities with cutting-edge technology.</td></tr>
<tr><td colspan="2">FED4FIREplus solution Value Map for Academic Testbed Providers</td></tr>
<tr><td colspan="2">Reach experimenters from academia and SMEs.
Improve their facilities and combine them with software suite of the Federation.
Allow easy access to the Testbed.</td></tr>
<tr><td>Pain Relievers
Become member of a federation.
Offer a complete set of facilities collaborating with versatile testbeds.
Improve the Testbed visibility.
Provide easy access to the Testbed</td><td>Gain Creators
Reach large number of academic and SME experimenters.
Join forces with other testbed to satisfy the users' requirements.</td></tr>
</table>

4.1.2 COMPARISON TO OTHER FEDERATIONS

We believe that the proposed business model for FED4FIREplus facilities is different from other European federations of testbeds. Most of these existing federations are either pure commercial or solely academic oriented, and are focused on a particular technology or application area. In the following, we briefly describe the services and the business model of the most relevant testbed federations for experimentation on different research fields. Various business models have already been proposed by European projects and can be summarized by the categories included in Table 4.

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Table 4- Business Models for Federated Testbeds

Type	Funding	Customer Type	Risk Analysis
Project Planform	Incomes: Public Funding, Member Fee Costs: equipment (capital) expenditure, operational cost	Dedicated to project partners, members only	Funding continuous investment in new equipment.
R&D Platform	Incomes: Public Funding Costs: equipment (capital) expenditure, operational cost	Academic and non-profit organization researchers, project partners	Dependent on public funding, funding continuous investment in new equipment
Commercial Platform	Incomes: exclusive commercial services Costs: equipment (capital) expenditure, operational cost, market analysis, consulting	Private companies, project partners	Funding continuous investment in new equipment, market competition
Cluster Platform	Incomes: Member Fee, commercial services, project funding Costs: equipment (capital) expenditure, operational cost	Private companies	How to attract a wide range of customers, prioritize the access to infrastructure

Some examples of publicly-funded testbed federations are listed as follows.

- PlanetLab is a collection of connected machines spread worldwide and provides a testbed and deployment environment for future networking research experimentation. The key value proposition of PlanetLab is to conduct experiments under real world conditions and on a global scale. Funding comes from sponsorship and additional subsidies are generated from a US government research grant. Planetlab can be characterized as a R&D platform.
- Another European R&D platform is European Grid Infrastructure (EGI), a federation of over 350 resource centers coordinated by EGI.eu. EGI provides computational and data resources for high-performance computing and is mainly utilized by academic researchers, particularly in Physics, Biology and e-Sciences to process large-scale data and run computationally intensive models. EGI has a continuous public fund.
- Finally, GEANT is a European data network and testbed to support education and research activities. GEANT combines a high-bandwidth, high-capacity 50,000 km network with a growing range of services, which cannot be got from commercial alternatives. GEANT is sustained through a public funding model, thus it is included in the R&D platforms.

Next, we present some European commercial and cluster platforms.

- 5TONIC (https://www.5tonic.org/platform) is a key stakeholder in the 5G community. 5TONIC has been founded by TELEFONICA and IMDEA NETWORKS and is supported by members, such as Ericsson, INTEL, COMMSCOPE, Universidad Carlos III de Madrid, Cohere Technologies, Artesyn Embedded Technologies. 5TONIC focuses on NFV/SDN experimentation and its testbeds include hosting and switching capacity for NFV infrastructure. It does not yet include outdoor Radio Access Network. 5TONIC can be considered as a combination of Project Platform and cluster platform business model, with membership, cooperation between industrials and academics but also ecosystem openness with startups' contest. 5TONIC implements an interesting business model where the test platform is developed by the 5TONIC partners for the usage of the 5TONIC partners. Therefore, it is not an open test platform, although some external requests can be considered. The 5TONIC test platform is used and its usage charged in the numerous 5G projects where 5TONIC is involved. This is a model that performs well as long as the test

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platform is part of the 5TONIC offering and attached to the R&D part. The usage is indeed limited to the partners.

- EANTC is independent test lab based in Berlin, specialized on NFV technology. EANTC is building on-demand test environment for customers and few public documents with technical details are available. The selling point of EANTC is the skills in testing methodologies. EANTC business model seems to be a commercial platform, targeting Internet Service Providers (ISPs) and large private companies.
- BiO is a smart city experimental site established by the University of Bristol and Bristol City Council. Furthermore, it is supported by industrial companies, i.e., NEC, InterDigital and Nokia. BiO seems like a living lab including data collection from users, access to IoT and NFV/SDN infrastructure. The business model can be close to cluster platform.

The proposed business model for FED4FIREplus has common features with some of the above platforms, however it is not identical with any of them. The Fed4FIRE+ federation's strongest attributes are its heterogeneity of testbeds (lots of different testbed types) and homogeneity of access (consistent access and single sign on to all federated testbeds). This represents two inter-dependent value propositions: one to the experimenters and another to the Testbeds. The heterogeneity of the Testbed portfolio is a major value to experimenters, and in Fed4FIRE it was referred to as a "testbed supermarket", indicating that there is one place for experimenters to go to get easy access to a wide variety of testbeds. The testbed portfolio is clearly dependent on attracting and retaining a diverse set of testbed to the Federation, and so the value proposition to the Testbeds must be attractive. The homogeneity of access is attractive to the Testbeds because they gain access to a wider pool of potential experimenters. It is intrinsic to the Federation Core, as it is part of the service offered by the Federator to the experimenters. The inter-dependence between the two value propositions is based on a critical mass of both experimenters and testbeds:

- A diverse portfolio of testbeds and easy and consistent access to them is attractive to experimenters, so should bring experimenters to the Federation
- More experimenters (attracted by the Federation's diverse portfolio of testbeds and easy access to them) is attractive to testbeds because it means a greater potential user base.

FED4FIREplus should aim to federate with new testbeds worldwide that support the current needs of the user population, which will keep the federation relevant improve its positive externality, scale of operation, and attract new experimenters creating an enhanced customer basis, and therefore satisfying the critical mass sustainability aspect. It is worth investigating whether the homogeneity of access is transferrable across federations – it may be possible to form partnerships with the Federations listed above so that users of one federation can use resources from another. Each federation is likely to be made stronger by these partnerships, and the result can become a rich interconnected network of experimentation facilities.

4.2 SUSTAINABILITY FROM THE PERSPECTIVE OF FED4FIRE+ ORIGINS

IMEC is coordinator Fed4FIRE+ and was also coordinator of its predecessor, Fed4FIRE. In addition, IMEC has been offering access to its testbeds over many years through different channels. The unique case of IMEC might lie in the fact that IMEC is offering different testbeds with a wide range of possible applications, which makes it possible to offer access in the context of a wide range of projects over a wide range of research areas.

In the framework of the FP7-project "OSIRIS" (Towards an Open and Sustainable ICT Research Infrastructure Strategy) and the Fed4FIRE project, IMEC has been collaborating in studies for identifying possible paths to running large scale research facilities in a sustainable way. The Fed4FIRE+ project and the concept of a federation of testbeds is partly based on these experiences.

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

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

The funding has been discussed in depth with each of these types of infrastructures during interviews. The outcome of the funding discussion is presented in Figure 10 below.

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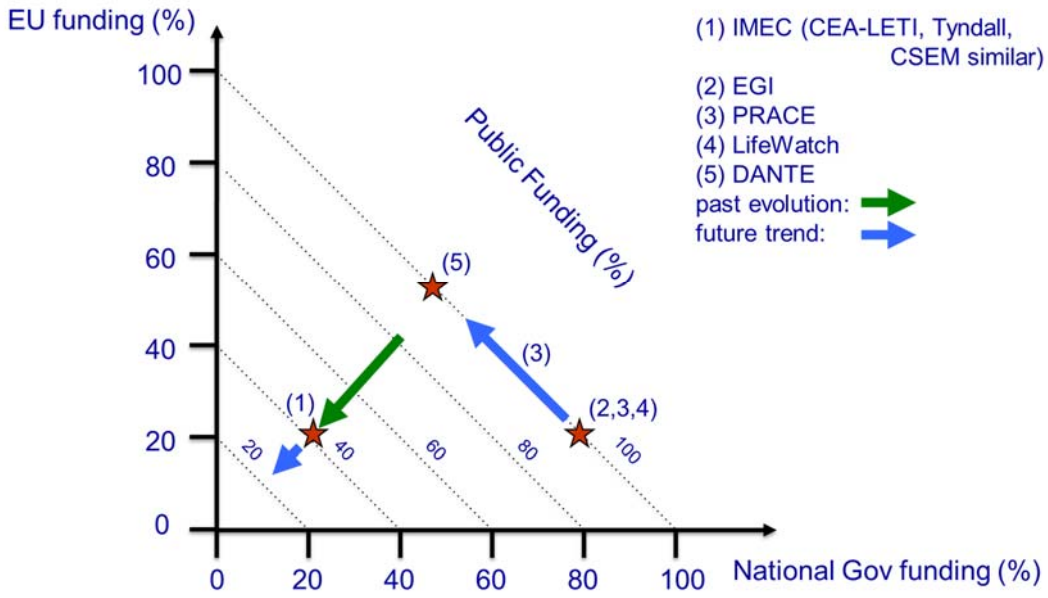

Figure 10: Testbed Infrastructure Funding

The graph shows the actual sources of funding and the direction that the key people in the RIs stated they wanted their funding to take. As can be seen from point (1) in Figure 10, MNT is the only type that is not nearly entirely funded by public money (CEA-LETI etc). Furthermore, PRACE stated their wish to increase the European proportion of their funding (indicated by the blue arrow).

This graph is taken from the OSIRIS-project and here IMEC is classified as a Micro- and Nano electronics research infrastructure as this analysis dates from before the merger with iMinds which covered at that time all the activities on the networks and NGI-related experimentation.

The testbeds involved in the Fed4FIRE-federation are physically located at the IDLab research group in Gent, which is both part of the Ghent University as well as IMEC as a research organization. Therefore, the industrial contracts providing funding for the micro- and nano- electronics research activities in IMEC, as depicted above, cannot be taken into account. In the remainder of the text we will just consider the NGI-related testbeds within IMEC as a separate unit.

This model and graph was used in the Fed4FIRE-project Deliverable D2.12[8] to map the Testbed facilities at that time. At that moment a "classification" of testbeds was made and a split between funding flows for infrastructures and funding for operational costs was made. From that research it is clear that the models used at different locations for different testbeds vary significantly.

4.2.1 Equipment costs –CAPEX

As is the case with a lot of testbed facilities, also the IMEC Fed4FIRE testbeds rely heavily on public funding for covering their initial and recurring investments. In the case of IMEC, this public funding originates mainly from long-term funding projects:

- grants from within the university;
- national funding agencies within Belgium; or
- regional funding agencies of Flanders.

It is clear that EU-funding is only used for a very small amount to cover investment costs for these facilities.

The main challenge in obtaining these resources lie in the increasing competition amongst a significant number of research groups applying for a steadily decreasing amount of available funding. The changing environment

[8] Van Ooteghem, Taylor, Vermeulen, Wauters, Demeester, Ahtes, Sawyer. (2015). *Fed4FIRE D2.12 – Third Sustainability Plan (Version 1.0)*. Zenodo. https://doi.org/10.5281/zenodo.1323477

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due to changes in the economic situation as well as political environment with changing focus points, makes it challenging to maintain a leading position in the field and keep research infrastructures up-to-date at a top level. Flexibility in changing focus, identifying new research topics and flexibility when defining and setting up testbeds is crucial to cope with these changing environments.

4.2.2 Operational costs - OPEX

Just as with CAPEX, research groups also rely heavily on public funding to cover their operational costs OPEX. Again reference is made to the deliverable D2-12 of the Fed4FIRE-project where this is listed for the Testbeds involved at that time. In the case of IMEC, operational costs are largely covered by EU-funding in contrast to the CAPEX as described above.

These testbeds are however used for different projects, of which Fed4FIRE is only a single project, for which different resources are used to cover the operational costs:

1. Students / educational purposes
2. PhD research work
3. Research in the framework of bilateral projects with industry
4. Research in the framework of national collaborative research projects
5. Research in the framework of EU-funded collaborative research projects

Fed4FIRE+ falls into the 5th scenario of the list above, and distributes the EC funding via a system of "Open Calls" that are used to attract experimenters. In the case of the Open Calls, operational costs need to be budgeted as "unallocated" funds. In all other scenarios, the experimenter is identified during the preparation and budgeting phase of the research work and the party providing the resources is identified.

At the start of the Fed4FIRE+ project, an experiment funding breakdown model was proposed, based on the experiences gained from Fed4FIRE and which model is followed by IMEC. This model is shown in Figure 11, and determines that the funding of an experiment consists of 4 parts:

1. Costs of Testbed resources and support (a contribution to the Testbed's operating costs);
2. Costs of Testbed provider consulting (covering the costs of testbed personnel in helping set up and run the experiment);
3. Experimenter funding (covering the costs of the experimenter in running the experiment); and
4. Experimenter self-funding (experimenter costs that are funded by the experimenter itself).

The open calls define the budget for the first 3 parts, but the size of each part is negotiated between the Testbeds and experimenters (its limiting range is defined by the open call definition). The flexibility to vary the size of each part makes it possible to have a more flexible market model (e.g. resources in one testbed may be more expensive, but more capable or more stable), to allow Experiment as a Service (where the consulting part by the Testbed is larger) and it allows experimenters to make the initial ramp up phase shorter by having some consultancy.

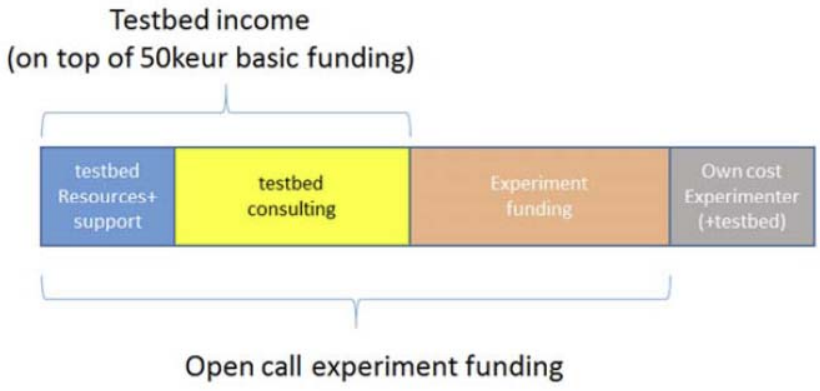

Figure 11: Experiment Funding Breakdown

The above model describes the split in resources when supporting experimenters which access the Testbeds through the Open Calls and the cascade funding scheme. However, an increasing amount of experimenters (but still limited) access the facilities through the Open Access model.

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4.2.3 Open Access model

Fed4FIRE+ also operates an "Open Access" model, where experimenters do not get funding for their own time, but get access to the Testbeds and run their experiments free of charge. In principle the facilities are free from the perspective of the experimenter (only subject to the general rules of use), but also no support is provided and experimenters need to rely on available documentation. However, in most cases basic support is provided as it also in the interest of the Testbeds' owners to have successful experiments run and completed on their facilities.

In practice, the experimenters use Open Access due to a number of reasons, including:

- a follow-up of previously (in most cases) funded experiments, which imply that experience is available to set up and run the experiments.
- as an initial test prior to submitting a more detailed proposal for an extended experiment in which case this extended proposal will be submitted through a funded project
- as a new contact in which case basic support is mostly provided to ensure successful completion of the experiment and to build a proper customer-relationship.

It is important to note that these Open Access experiments do not contribute at all in any way to the financial sustainability of the Testbeds. No income is generated for the Testbeds owners and in most cases, support has to be provided, which includes costs (mainly personnel costs). The main advantage is that the availability of the Open Access to the facilities is to be considered as an investment as in most cases these Open Access experimenters either continue through participation in Open Calls or set up bilateral projects. Another advantage to the Testbeds is that Open Access experiments contribute to the Testbeds' cases for funding – the more experimenters a testbed has, the more useful it is, and therefore the stronger its case to its funding bodies.

4.3 FEDERATION CASE STUDIES

4.3.1 IoT Lab Case Study

4.3.1.1 Description

IoT Lab was a FP7 European Research project which explored the potential of crowdsourcing and the IoT for multidisciplinary research and experiments with more end-user engagement. IoT Lab has delivered an online platform (http://www.iotlab.eu/) which encourages community members, including citizens, end-users and researchers to collectively participate in solving real societal challenges (see Figure 12).

IoT Lab is supported by a mobile application named "IoT Lab" available on Google Play and on Apple's App Store, as well as through a dedicated website accessing the Testbed as a Service (TBaaS). IoT Lab provides different resources across several testbeds in Europe. It combines into a common platform the crowdsourcing tools together with several testbeds on the Internet of Things. The European testbeds are provided by the following project partners: the Computer Technology Institute and Press "Diophantus" (CTI) in Greece, the University of Geneva (UNIGE) and Mandat International (MI) in Switzerland and finally, the University of Surrey (UNIS) in England. All these testbeds are based on FIRE-related research infrastructures developed in the frame of European projects like Hobnet, WISEBED and EAR-IT.

The voluntary participants can initiate, run or just take part in a selected experiment and thus contribute to the new research. The collection, the transmission and the processing of the data are compliant with data and privacy protection regulations.

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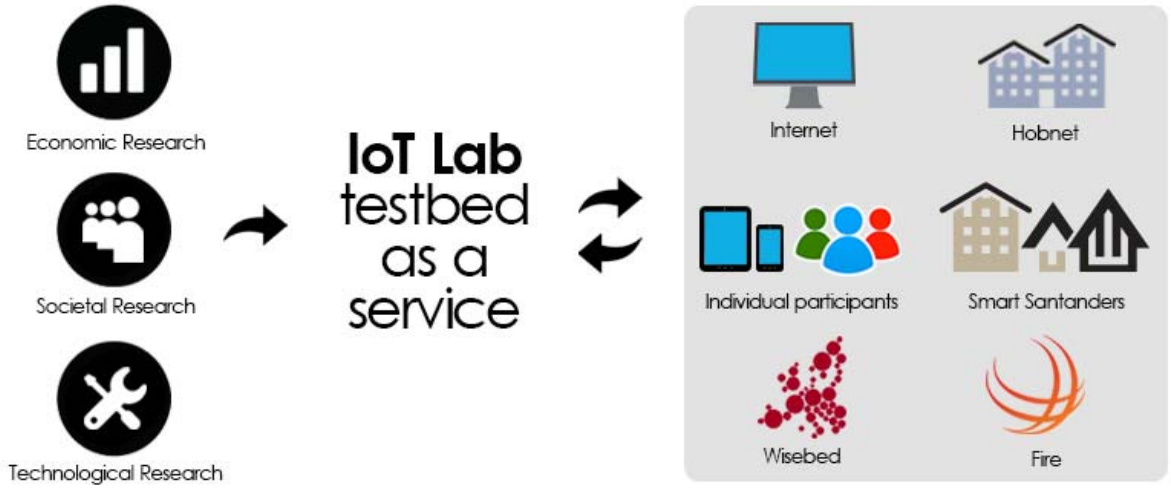

Figure 12: IoT Lab high level view

The IoT Lab project started in October 2013 and finished in October 2016. After the end of the European project, an association was created to continue to exploit the results of the FP7 research project. This association is composed of the former partners of the project consortium and new members can apply to join the IoT Lab Association. The platform composed of the website (including the TBaaS), the mobile application and the different European testbeds is managed, maintained and financed by the members of the association. The commitment, in terms of time and money, provided by members to support the association reflects their belief in the value proposition of the association.

Currently, the IoT Lab platform has around 450 registered researchers and 2500 participants. The current exact numbers of researchers and participants can be retrieved live here: http://www.iotlab.eu/JoinTheWisdomOfTheCrowd/PlatformScores

The researchers and the participants (participants are also named “end-users” and form the crowd that can be accessed by researchers), are the most important actors of the IoT Lab online platform. When a researcher needs to have the feedback of the community, they can create and freely submit a research project to the IoT Lab crowdsourcing platform. Afterwards, the end-users can vote and rank research ideas and take part in research projects by providing their inputs through mobile phone sensor data or/and by responding to surveys written by the researcher. In return, the IoT Lab provides results to the researcher who can finally obtain some scientific conclusions.

The testbeds federated into the IoT Lab platform and managed by the previous project partners are also an actor because they provide to the researchers resources under the form of IoT devices like sensors and actuators. Actually, the number of testbeds resources available through the IoT Lab Testbed as a Service (TBaaS) is around 500. By comparison, the number of crowd source sensors (which are in fact the sensors of the participants’ smart phones) is around 6250.

In summary, the key actors are the Testbeds themselves, the researchers and the end-users. The different owners of testbeds provide the resources in term of IoT devices, but also in terms of work to enable and to maintain the federation of the Testbeds. The owners of these testbeds are universities and research centres, all based in Europe. So, in the frame of the IoT Lab online platform, the researchers and the crowd (the end-users) are somehow the clients of the IoT Lab testbeds federation.

During the IoT Lab project, the partners explored some concrete ideas to get funds. For instance, the end-users can participate to some researches and experiments and are rewarded by a donation to selected charities that are well-known non-governmental organisations involved in the defence of the human rights or in the protection of the environment. Another implemented possibility to get some funds is the sponsorship of the IoT Lab platform. These two solutions to get more money to sustain the Federation of testbeds were not really successful.

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By the meantime, the IoT Lab crowdsourcing tools are currently updated and improved through the U4IoT project (https://u4iot.eu). This European project encourages the user engagement in the frame of the five Large Scale Pilots (LSP) for the Internet of Things. The end-user of the five LSPs can provide the feedback about the different implementations and propositions made by the researchers and developers working in the LSPs. A new version of the mobile application is now available for Android and iOS through the respective online app stores.

4.3.1.2 Relevance to Fed4FIRE+

IoT Lab and Fed4FIRE+ are quite similar. Both are a federation of several testbeds mainly located in Europe. IoT Lab's processes and tools to federate the Testbeds use the tools developed in the original Fed4FIRE project, so integration, interoperation and federation between Fed4FIRE+ and IoT Lab is possible and is being implemented. IoT Lab is more focused on Internet of Things (IoT) and to the user engagement through the crowdsourcing tools and the crowd sensing provided by the mobile application. So, there is no competition between Fed4FIRE+ and IoT Lab, but more a complementarity between the two federations of testbeds. So the knowledge and the experience acquired during and after the IoT Lab project can be reused in the Fed4FIRE+ project and particularly for the sustainability of the Federation.

4.3.1.3 Value proposition and sustainability prospects

A sustainability option that the IoT Lab Association would like to explore is a new path to guarantee the sustainability of the IoT Lab testbeds federation. Basically, IoT Lab could be in the next future a facilitator. This means that IoT Lab acts as a liaison agent between the researchers, the end-users and the appropriate stakeholders linked to the research. So, IoT Lab can become a co-creation platform offering some online services. This co-creation platform enriches the ideas and opportunities by connecting the partners interested in a particular domain of research like a network. The platform can provide organisational, legal, technical and academic support to bring the research project to fruition, taken into account the ideas and the feedback of the end-users who can be the final clients of a research project. IoT Lab would enhance the potential impact of new ideas by facilitating traditionally burdensome activities such as certifications, audits, tests and so more. Furthermore, the SMEs and start-ups can benefit of the infrastructure and services provided by the IoT Lab platform. Of course, the platform can bring together the inputs of the crowd with the inputs from other stakeholders as the governmental bodies, the international standards developing organisations (SDOs) and the decision makers.

Changing the process by involving the crowd at the beginning of the research can be a value proposition. Indeed, most companies consider end-user opinions when developing or validating the viability of a new product or service linked to the Internet of Things. This reduces the number of iterations in the research and development process and the time to market. Furthermore, the final service or product benefits by definition end-users and delivers societal added-value which will eventually increase its adoption by the crowd. Of course, this can be extended to other domains, as the IoT Lab platform has been designed to perform multidisciplinary experiments, not only for technical tests, but also for societal and economical evaluations.

As all the services and tools are available directly online, there is no need to the researchers to install them into their own infrastructure. This encourages the small-sized entities like the start-ups to take part in experiments involving a large panel of end-users reachable through the IoT Lab crowdsourcing tools.

In this context, the funds to run and maintain the federation of testbeds can be brought by the external stakeholders like the large companies, the governmental bodies and the standardisation developing organisations. So, IoT Lab and by extension Fed4FIRE+ can provide several online tools and services to them to ensure that the needs of the crowd are fully respected during the research and development process.

4.3.1.4 Proposed funding options for Fed4Fire+ sustainability

The sustainability of the project can be guaranteed through the securement of diverse financial streams of funds from a variety of sources. It is important to note that multiple funding solutions should be considered simultaneously for each research project.

In the context of this research, the following funding opportunities can be proposed:

4.3.1.4.1 Crowdfunding

As mentioned earlier, the originality of the IoT Lab consists in its community-based approach, which encourages researchers, citizens and end-users to collectively solve societal problems. A similar, community-oriented

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approach can be mirrored regarding the project's funding, particularly through the use of crowdfunding. Crowdfunding is a way of raising money to finance projects and businesses. It allows individuals to collect money from a large number of sources through online platforms. The future of the IoT Lab can be secured particularly through three types of crowdfunding, namely donation-based crowdfunding, rewards-based crowdfunding and revenue-sharing crowdfunding.

- In the first scenario, individuals or businesses supporting the mission of the research would make donations to reach larger funding targets while receiving no compensation of any kind in return.
- In the context of rewards-based crowdfunding, stakeholders would donate to a project with the expectation of later receiving a non-financial form of compensation in return, such as goods or services.
- In the context of revenue-sharing crowdfunding, the profit generated from the research would be shared in the future with the crowd, in exchange of financial donations now.

4.3.1.4.2 Public funding

Public funding represents another potential financial stream. Using public funds to finance innovation projects is a common practice, both at the national and European level. Grants are awarded on a highly competitive basis and require the preparation of a detailed proposal. The IoT Lab can support the researchers throughout the complex grant application process to maximize their chances of approval.

4.3.1.4.3 Private funding and special interest groups

The economic sustainability of projects like the IoT Lab and Fed4Fire+ can be also secured through a sound collaboration with private sponsors, including businesses and socio-economic actors, and special interest groups. The IoT Lab can put the researchers in contact with potential corporate funders to discuss possible sponsorship opportunities. Beyond financial sponsorships, partnership with the private sector can take multiple forms, including:

- research contracts,
- delivering analyses,
- providing consulting/training services,
- use of equipment and infrastructure, and
- granting licenses.

Viability of these funding options will greatly depend on the future capacities and intended roles of the Fed4Fire+ Federator.

4.3.2 SILECS Sustainability Plan – Case study for FED4FIRE+

SILECS - Infrastructure for Large-scale Experimental Computer Science - aims at providing a large instrument for research in distributed computing and networks, leveraging the strong expertise of successful communities in FIRE and the 5GPPP, which will enable us to tackle all the scientific challenges of Internet of Things, data centers, and the networks connecting them. This instrument will offer a multi-platform experimental infrastructure (HPC, Cloud, Big Data, Software Defined Storage, IoT, wireless, Software Defined Networking/Radio) capable of exploring future infrastructures.

The following SILECS Partners have already signed the SILECS MoU: INRIA, SU, CNRS, IMT, UTH, MI, IMDEA, EBOS, UCLAN, CNR. The following countries have already officially expressed their support to the SILECS RI within the ESFRI proposal and have included the RI in their National Roadmap: France, Greece, and Switzerland. The following countries have also officially expressed their support to the SILECS RI: Italy, and Cyprus. More than 50 research organizations, industrials and SMEs have expressed their support to the SILECS RI. GEANT and RENATER have also expressed their support.

The business principle of the SILECS facility is that the main costs are twofold:

- the infrastructure costs
- the running costs including development of new software components

The first should be covered by the fact that SILECS is grounded on existing testbeds and should benefit from ESFRI to provide reserved funding and therefore a large-scale facility that can directly face the competition and serve the constantly growing demand for such platforms. We expect that we will only need minor funding for the

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rejuvenating part as the federation concept will allow us to bring new cutting-edge technologies on board, and enhance the existing offering with more heterogeneous resources.

The second component is itself organized in two parts. The operation only accounts for the central services and we evaluate this need as 4 FTE engineers. The local testbeds are themselves supported by their own resources under a subsidiarity principle. The second component is related to the software development. As the components offered are open source, we expect that most will be delivered by the community that will contribute new components as need arose. We do not believe that industry will be engaged in a payed access per use, based on a resource consumption model (aka Amazon EC) but rather that we can access funding of projects that will require access to our facility as we already see today with some funded projects.

SILECS was proposed to be included in the ESFRI 2018 Roadmap (http://www.esfri.eu/). Although we did not succeed, we received very strong and positive feedback from the ESFRI panel that was build mostly to evaluate our proposal. This was the first time that ESFRI received a proposal dealing with a test platform to support the research in digital infrastructures. Clearly, entering ESFRI is a big challenge as we first need to evangelize the usual ESFRI communities (most of all other disciplines) as well as understand the framework and write a proposal that fits into their expectations. Second, this has also to be developed at the national level, as it is required that, an ESFRI proposal can be presented only if it received the support of at least 3 national representatives (at the level of their ministry in charge). In SILECS we had 4, which is notably insufficient and the effort at the national level should be pursued.

The investment plan of SILECS is summarized as follows:

Preparation and implementation costs:

- The ESFRI label will facilitate the requests for funding at national level (notably for equipment).
- The core partners have a strong in-kind involvement (notably personnel and premises)
- SILECS will also apply to a Preparatory Phase under Horizon 2020 if new calls for proposal are open in the coming month in order to include the SILECS preparation phase in this framework and to benefit from its funding.

Operational costs:

- Agreed national support in the countries of the core partners.
- The local testbeds are themselves supported by their own resources under a subsidiarity principle.
- As the software components offered are open source, we expect that most will be delivered by the community that will contribute new components as need arose.
- We expect in-kind funding from projects that will require access to the SILECS RI.
- We will also study how to involve sponsorship.

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5 CONCLUSIONS & RECOMMENDATIONS

This report has firstly described the setup and operation of the Federation Board, and secondly evaluated the question of sustainability of the Federation beyond the end of the project. This is the first in a number of deliverables on governance and sustainability. At this early stage, we can make interim recommendations regarding sustainability, and the key recommendations are described here along with the key conclusions. Subsequent deliverables will build on the work presented here.

Governance

We have defined the key concepts for the Federation Board, the primary decision making body of the Federation, and environment in which it operates. The board sets *objectives* for the Federation, measures the Federation's performance by defining and observing *key performance indicators*, and steers the Federation via *strategy* comprising *policies* and *control instruments*. For each concept, we have defined initial elements, which will be evaluated and expanded / adjusted as necessary while the board operates.

We have determined the composition of the board and appointed board members, the appointment being based on roles, experience and skills. We have also determined the board's interactions with other aspects of the Fed4FIRE+ project, so as to establish working practices to be evaluated within the project and operated beyond its end.

Sustainability

We have established that there are two major federation stakeholders that need to be sustained: the Federation Core, and the Testbeds. The Federation Core comprises the Federator, which runs and manages the Federation, and the Federation Board, which sets the objectives, policies and practices of the Federation and provides steering guidance. The Federation Core is intrinsic to the Federation: the Federation Core is necessary for the Federation to operate, and the Federation Core's existence is tightly tied to the Federation - without the Federation, the Federation Core does not need to exist. The testbeds are key stakeholders in the Federation, but their lifetime is not tied to the Federation's – the Testbeds can (and often do) exist within and outside the Federation, and they choose to be part of the Federation because of the key benefits the Federation offers them.

All federation participants are likely to need to pursue more than one source of funding to generate adequate funding to support themselves and to insulate themselves from the risk of one funding source disappearing. Testbeds are often funded by national and local public funding, as well as any funding the Federation brings (e.g. in the form of the funding Fed4FIRE+ brings). Experiences from previous projects indicate that commercial funding of Testbeds is rare. The Federation Core is currently funded by public money (in the form of the Fed4FIRE+ grant) and needs to seek continuation funding, and to do this, it needs to demonstrate value to both experimenters and Testbeds.

The Federation Core and the Testbeds have separate but inter-dependent sustainability cases. The Federation supports the Testbeds' viabilities by bringing them access to greater numbers of experimenters inside the Federation. The Testbeds support the Federation's sustainability case by provision of a multitude of different resource types, offering experimenters a rich variety of testing options, and thereby providing an attractive offering for experimenters. Both value propositions are based on a critical mass of experimenters and testbeds, and the Federation's viability depends on this critical mass.

The key "customers" of the Federation are experimenters. These are typically academics (researchers, educators or students) or industry who want to use the Federation's resources for testing and scaling experiments, for example. Fed4FIRE+ has dedicated programmes of funding targeted at these user types. We have described how the Federation helps the different types of users, in terms of a value proposition canvas that describes how the Federation solves customers' problems and provides benefits to them.

The Federation Core provides services to both experimenters and Testbeds. For experimenters, the key services are access to a multitude of different experimentation facilities, recommendations and easy setup on the Testbeds. For testbeds, the Federation core provides assistance to become compliant with the Federation's user tools and single sign-on processes – the easier experimenters can access Testbeds, the more they are likely to use them.

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The Testbeds in the Federation are widely distributed from a geographical viewpoint, and currently demand from SME users mainly comes from southern European countries. Market investigations are needed to determine if there is a need from other areas, what kinds and how much.

In addition to each Testbed serving a wide audience, brought through the Federation, they also provide resources to its local community. As such, a Testbed can act as a local innovation hub that is a focal point for local users, facilitating support, introductions between users, providing collaboration opportunities etc. This will be mutually beneficial for the local users (through the support and the local community), the Testbed (through enhanced reputation and potential users) and the Federation (through "viral" marketing and the potential increase in users).

Fed4FIRE+ provides open calls, which contribute funding to experimenters' and testbeds time and operating costs. These are popular, but this is not surprising given that experimenters are paid for their time. The acid test of the Federation's value is the "Open Access" programme, where experimenters get resources at no charge, but do not get their time funded. This is a highly likely future sustainability situation after the end of the project. The existing Open Access programme is moderately successful, but needs to be promoted more, so as to evaluate the true worth of the Federation's offerings when experimenters' time is not funded.

Other federations are presented as case studies, and Fed4FIRE+ has many similarities with them, and all can learn from each other. The currently-identified key points worth investigating are the following.

- FED4FIRE+ should aim to federate with as many as possible new testbeds as well as other federations worldwide, which will improve its positive externality, scale of operation, and attract new experimenters creating an enhanced customer basis, and therefore satisfying the critical mass sustainability aspect.
- It is worth investigating whether the homogeneity of access is transferrable across federations – it may be possible to form partnerships with the Federations listed above so that users of one federation can use resources from another. Each federation is likely to be made stronger by these partnerships, and the result can become a rich interconnected network of experimentation facilities.
- Extending the 5TONIC model, by investigating funding from multiple future projects, where Fed4FIRE+ is offered as a ready-made infrastructure of multiple testbeds that can be used for experimentation within the projects. The projects get access to the heterogenous federation of testbeds and make a small contribution to the upkeep of the federation in return.
- Evangelizing Fed4FIRE+ as a contribution to the European Research Infrastructures community, learning lessons from the SILECS ongoing experience, specifically understanding the research infrastructure communities' requirements and accommodating them in proposals for RI funding.
- Different other types of funding should be investigated, for example private or crowdfunding. These may or may not be applicable depending on the application or use required, and multiple funding streams are likely to be needed at any one moment.

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