Cognitive Radio Experimentation World

Project Deliverable D8.5
Sustainability model

Contractual date of delivery:	30-09-13
Actual date of delivery:	30-09-13
Beneficiaries:	iMinds, EADS, TCD, TCS, IMEC, TUB, TUD, JSI
Lead beneficiary:	iMinds
Authors:	Jan Van Ooteghem (iMinds), Daan Pareit (iMinds), Stefan Bouckaert (iMinds), Ingrid Moerman (iMinds) Christoph Heller (EADS), Luiz Silva (TCD), Thao Somsai (TCS), Lieven Hollevoet (IMEC), Mikolaj Chwalisz (TUB), Michael Mohorcis (JSI), Rohit Datta (TUD)
Reviewers:	Christoph Heller, Christian Blümm (EADS) Lieven Hollevoet (IMEC)
Work package:	WP8: Promotion and sustainability
Estimated person months:	5
Nature:	R
Dissemination level:	PU
Version	2.1

Abstract: This deliverable describes the business model for the CREW facility, indicating the different stakeholders, value proposition, access policy, cost model and tariffing plan, and the future scenarios after CREW. We also present some sustainability trends of the individual core partners' facilities.

Keywords:

Sustainability, business model, cost model, access policies, future scenarios, trends

Executive Summary

This deliverable is dedicated to the sustainability model of the project. Many testbed infrastructures have been set up from a technical perspective, mainly financed by EC, national or regional funds. However, the lifespan of technical innovation is not very long; hence additional investments must be made to keep the infrastructure up-to-date. Next to implementing updates the infrastructure must also be kept operational, maintained and supported, which also takes a lot of effort. Finding funding has been proven to be a problem for several projects in the past, and still today.

Therefore a sustainability model must be elaborated. This is a first requirement for keeping the CREW federation operational from year 3 onwards, guaranteeing a certain operational level and enabling maintenance support. New experimenters must be attracted during this period to make use of the available infrastructure, and to indicate the benefits of the testbed infrastructures of CREW. The Open Call 3 is focused on attracting new experimenters, but compared to Open Calls 1 and 2 no funding is provided in this call only support is offered. Additionally, the infrastructure is open to other experimenters at the same time as well outside the open calls. Most important is to convince all experimenters of the added value of the CREW infrastructure and services, as they are the key stakeholders for the facilities infrastructure.

Setting up a sustainability plan for the CREW facility is not an evident task and comprises various challenges. First we have to agree upon the definition of sustainability. It is defined now as *"Sustainability means usage (or usefulness) of the infrastructure beyond the end of the project"*.

A business model has been proposed. Different components have been investigated. First, we took a look at the stakeholders of the project. The core partners and FIRE users (via the open calls) are currently the most important actors. However, in the future the external experimenters will play a more important role. Next to these stakeholders also policy makers, funding bodies and other research projects play an important role. Interactions with Fed4FIRE, Acropolis, etc. are crucial for the further existence of the CREW facility and functionality.

Next, we presented the value proposition for CREW based upon the business canvas model of Osterwalder. This indicates what the project offers, its main activities, the key resources and partners, the customers and how to offer the service to them, and finally the underlying finances (costs & benefits).

A generic access policy framework has been proposed. Three models are presented: (1) CREW core and open call partners, (2) best effort experimenters and (3) premium external experimenters. All models have different rules concerning access to infrastructure, support, or other requirements such as feedback on the experiments, references in publications, etc.

A detailed cost model has been shown, indicating the different cost categories. In a next step, we focus on how to allocate the different costs in order to have a transparent cost model. This model can then be used to setup a tariffing plan. Only the premium use model is not for free. The cost should be based upon a transparent calculation of resource usage (infrastructure as well as personnel e.g. for support).

Two questionnaires were conducted, one in 2010 and one in 2013, requesting information concerning the core partner's testbed infrastructure (openness, usage, access policy and tariffing plan, financial availability), including some best practices learned during the project. Attracting new experimenters, knowledge gains, new research experience & facility improvements, good exposure and interactions with European researchers, better image & reputation are the main conclusions from the project.

When considering finally what to do after the CREW project, different options exist today. Either the project will be kept in its current form (such as is the case during year 5), or CREW functionality will move into Fed4FIRE, or the project structure dissolves and each partner will follow its own course. After this year in sustainability modus, a more clear insight on what the future will bring will be available.

List of Acronyms and Abbreviations

API	Application Programmer Interface
BRIC	Brasil, Russia, India, China
CapEx	Capital Expenditure
EC	European Commission
OC	Open Call
OpEx	Operational Expenditure
OS	Operating System
SLA	Service Level Agreement
WINNF	Wireless Innovation Forum

Table of contents

1 Introduction

This deliverable is dedicated to the sustainability model of the project. Many testbed infrastructures have been set up from a technical perspective, mainly financed by EC, national or regional funds. However, the lifespan of technical innovation is not very long; hence additional investments must be made to keep the infrastructure up-to-date. Next to implementing updates the infrastructure must also be kept operational, maintained and supported, which also takes a lot of effort. Finding funding has been proven to be a problem for several projects in the past, and still today.

Therefore a sustainability model must be elaborated. This is a first requirement for keeping the CREW federation operational from year 3 onwards, guaranteeing a certain operational level and enabling maintenance support (Figure 1). New experimenters must be attracted during this period to make use of the available infrastructure, and to indicate the benefits of the testbed infrastructures of CREW. The Open Call 3 is focused on attracting new experimenters, but compared to Open Calls 1 and 2 no funding is provided in this call only support is offered. Additionally, the infrastructure is open to other experimenters at the same time as well outside the open calls. Most important is to convince all experimenters of the added value of the CREW infrastructure and services, as they are the key stakeholders for the facilities infrastructure.

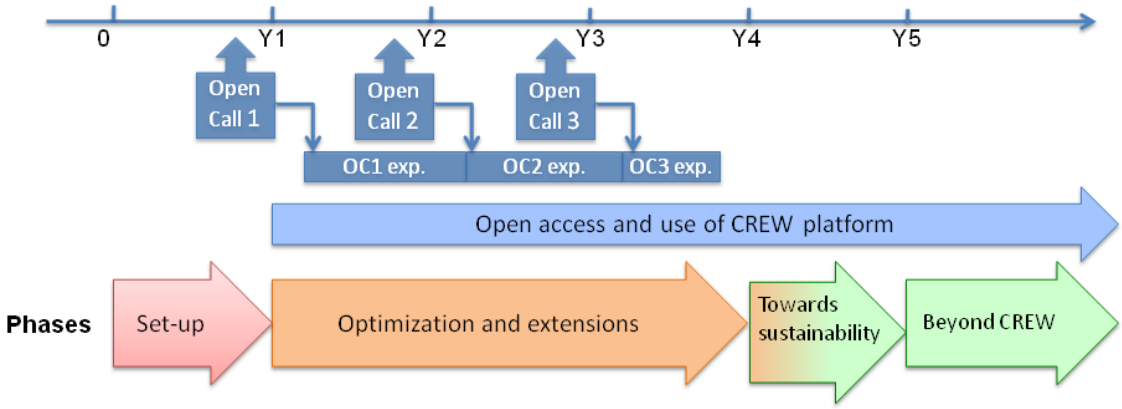

Figure 1: CREW roadmap

1.1 Purpose and structure of this deliverable

Within task 8.2, two main activities are considered: the operation and maintenance of the CREW facility during the sustainability mode of the project, and the business model.

As we will guarantee a minimal operation and maintenance support (including helpdesk) for keeping the CREW federation operational from year 3 on, external (preferably paying) researchers and research projects must be attracted. This is a very difficult task. An evaluation of the sustainability of the project must be made, which will be presented in D8.6 (after Y4) and D8.7 (end of the project Y5).

Within this deliverable, we focus on the second task, the business model. This activity focuses on investigating the economic viability of the federated testbed during the course of and beyond the project duration. Different aspects are considered and evaluated.

First, we present our definition of sustainability, based upon the different opinions from the project partners.

Next, we present the CREW business model. We indicate the different stakeholders involved in the project, ranging from the core partners and the experimenters to external parties, funding bodies, regulatory instances and other research projects. The CREW value proposition is presented, making use of the business canvas model. A generic access policy model is proposed, taking into

consideration all the currently available models implemented today in the individual facilities. A cost model indicates the different cost components and how they should be allocated. Combining the access and cost model, an overall tariffing scheme is proposed.

Furthermore, we present the results from a pre- and post project questionnaire of the different core partners of the CREW project about openness and use of the infrastructure, access policies, financial viability, and lessons learned from the project.

Finally, some possibilities are presented of what can happen after the CREW projects ends, thus after year 5 of the project.

1.2 Literature overview

A literature study has been conducted to analyse the other FIRE projects concerning their sustainability plan. A short list has been drawn up from the most interesting projects that also studied the sustainability of the testbeds.

- OSIRIS: This EU FP7 project (Open and Sustainable ICT Research Infrastructure Strategy) has identified a list of components of sustainability for setting up new ICT research infrastructures [1].
- BonFIRE: The BonFIRE consortium brings together industrial and academic organisations in cloud computing to deliver a robust, reliable and sustainable facility for large-scale experimentally driven cloud research. The project has created their own sustainability plan with special attention for the estimation of the real cost of experimentation. By far, this project has created the most detailed sustainability plan of all FIRE projects [2].
- MyFIRE: The MyFIRE Support Action gathers best practices for experimental facilities. D4.2 provides an overview of FIRE projects in Europe and the BRIC countries and an analysis of gaps in FIRE provision. Sustainability is stated as the weakest link of all testbeds in the European research framework. The recommendations on sustainability and business models have been taken into account throughout this document [3][4].
- The FIRESTATION Support Action has developed a FIRE Roadmap. The roadmap addresses lifecycle management, sustainability and services. In the FIRE roadmap, the components of the OSIRIS framework are used to sketch a first sustainability plan for a federation of FIRE testbeds [5].
- Fed4FIRE: Within this project, a sustainability plan for a new federation is constructed. A first sustainability plan was presented [6].

2 Defining sustainability

Sustainability of experimental facilities can be interpreted in different ways. Depending on the type and openness of the individual testbed infrastructure, each partner has a different definition of and opinion on the term "sustainability". In order to get an overview of all different points of view on sustainability within the CREW consortium an internal questionnaire was held. The outcome of this questionnaire leads to following conclusions.

First, multiple CREW core partners value their testbeds from a research point of view. In this context, sustainability means that having a testbed provides a competitive advantage for research activities. This advantage can also help in setting up new research collaborations. As the main purpose of the testbeds is to be able to conduct research, meaning (either internal research or external research driven by partners, it is of great importance to partners),keep the infrastructure up-to-date. Since being able to perform research is key to those partners, it is also logical that to uphold the testbed availability after the end of the CREW project.

Some of the answers received:

- The sustainability is a measurement of the levels of easiness/complexity to sustain the operation of an element/the testbed in the context of CREW.
- Sustainability is the capacity to endure where testbed activities shall be aligned with our research strategy and shall provide a competitive advantage for our research activities.
- Sustainability means usage (or usefulness) of the infrastructure beyond the end of the project.
- Capable of being supported and maintained with funding from ongoing research projects and collaboration with external users of the testbed.

In general we proposed the following definition of sustainability:

"Sustainability means usage (or usefulness) of the infrastructure beyond the end of the project."

This definition is in line with the definition of sustainability within the Fed4FIRE project [6]:

"Sustainability, at its most basic definition, is the ability to continue."

We must first determine *what* we wish to sustain. What are the key elements we wish to continue beyond the end of the project? Two major aspects to the answer to this question, are the following.

1. We must identify who the main (potential) stakeholders are: the actual organisations or people who may want to participate and the roles they could play within the federation, and the "customers". In general, the two main stakeholders defined are the facility providers and experimenters. This is discussed further in section 3.1. For them we must define a clear value proposition in order to attract them and keep them interested in participating in the federation and using the services offered.
2. We must enable the federation to operate. It is likely that enabling the federation will involve the provision of some support services and infrastructure. The degree of support will depend on the value proposition of the federation, and will differ depending on the access policy.

As there are different views on sustainability, and the testbed infrastructures are very heterogeneous in terms of usage, size, openness, operators (industry, academia), the current conclusion is that it is unlikely that one single sustainability model will be the outcome of the sustainability work package in the CREW project. A combination of models is a more likely outcome. An access policy and cost based model is proposed in sections 3.3 and 3.4. Some potential strategies after the end of the project are presented in section 5.1.

3 CREW business model

The business model of the CREW project is described below. The different sections are the stakeholders, value proposition, access policy, cost model and tariff plan and are described in more detail below.

3.1 Stakeholders

Figure 2 depicts the stakeholders and their relation to the CREW project. We will discuss these in more detail in the upcoming paragraphs. This listing has been based upon [7].

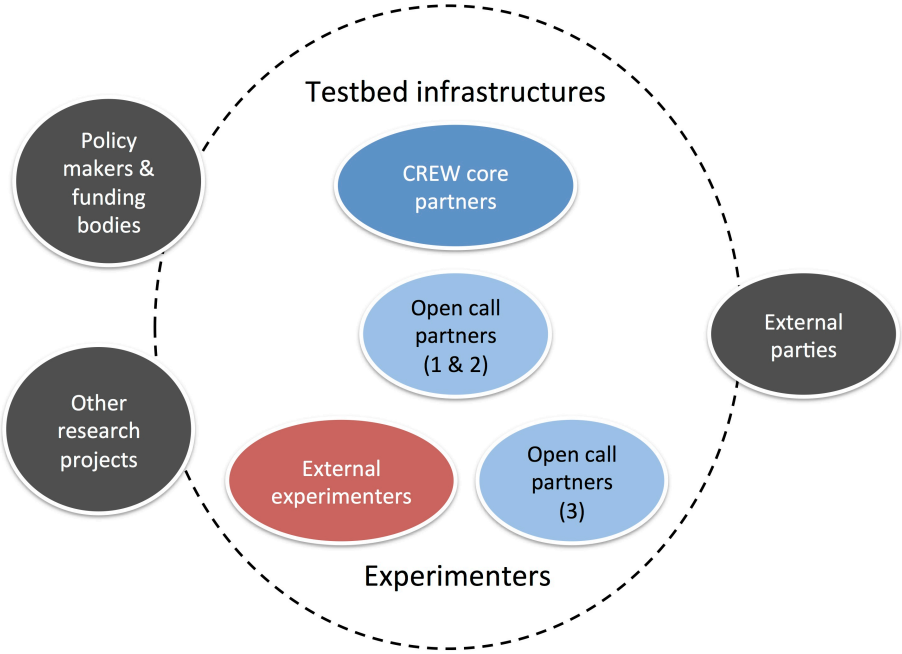

Figure 2: CREW stakeholders

3.1.1 Core partners

A core partner has been defined in [7] as *"a party having signed the CREW Consortium Agreement or a subsequent Declaration of Accession and that is not a FIRE user."*

In case of CREW, these partners are iMinds, IMEC, Trinity College Dublin (TCD), Technische Universität Berlin (TUB) Technische Universität Dresden (TUD), Thales Communications & Security France (TCS), EADS and Jožef Stefan Institute (JSI).

Each partner has brought its own assets and competences to the project. We have split these up in three categories: hardware assets, software assets and facility provisioning [7].

- *Hardware assets*: Different wireless and sensor hardware components are offered by the core partners within the project. A first type of hardware assets is the different hardware components that construct the isolated testbed islands of the CREW federated platform and that are owned by the individual facility owners. The second type of hardware components are owned to one party, but relocated in one or more of the individual testbed islands, owned by another party or other parties.
- *Software assets*: Different software components are developed and offered by the core partners such as control & management platforms, Iris software platform, WINNF transceiver API, IMEC sensing agent and the Connectivity broker. This software is

sometimes distributed over different testbed infrastructures, e.g. the TUB connectivity broker or TCD IRIS platform.

- *Facility provider*: Five individual testbed facilities are connected through the CREW platform, incorporating the above mentioned hardware and software components, either owned by facility provider itself or offered by one of the other partners. Besides, EADS offers its facility for specific use case testing.

3.1.2 FIRE users

FIRE users are defined in [7] as *"Experimenters that temporarily participate in the Project as a result of a successful proposal in one of the "Open Calls". The accession to the Consortium Agreement is acted by the signature of the Declaration of Accession by such external experimenter and the Coordinator."*

The FIRE users from the open calls can be split up in two categories:

- Open Call 1 & 2: 20 % of the project resources (with a maximum of 200 k€ and 120 k€ per experiment for OC 1 and 2, respectively) were reserved for running experiments by external researchers or research groups to validate innovative usage scenarios for cognitive radio & cognitive networking. Experimenters become partner of the CREW project (thus including the signing of the Grant Agreement & Consortium agreement) for the rest of the project, but are only active during 1 year and were fully funded for their experiments.
- Open Call 3: no funding from the EC for the experimenter is foreseen, but free access to the CREW facilities, and free and guaranteed support by CREW partners (covering training, technical assistance, extensions to experimentation tools…) is offered. Only a cooperation agreement through Memorandum of Understanding (MoU) is required, thus less administration and reporting is involved.

3.1.3 External experimenters

Next to the FIRE users attracted through the Open Call procedures, external experimenters can make use of the CREW facilities. These will become more important from year 3 on, when the project is in a sustainability mode, and after the project end.

3.1.4 External party

An external party is defined in [7] as *"A party having not signed the CREW Consortium Agreement or a subsequent Declaration of Accession"*. Two types of external parties have been defined: developers of facility software, and suppliers of infrastructure and services. They are supporting the federation through the facility providers.

- *Developers of facility software (tools):* Software developers will provide tools to operate and monitor the facilities, supporting the experimentation lifecycle process. The tools to be used can be community open source tools or other software provided by system integrators or any software developer (e.g. an SME or even a facility provider).
- *Suppliers of infrastructure and services:* This category includes network equipment manufacturers developing and providing networking devices, sensor manufacturers, IT equipment, etc. The federation provides a unique opportunity for them to evaluate their

products in a heterogeneous environment that anticipates technological trends.[1] Besides, manufacturers can leverage from such a complex environment to increase their expertise and reduce test cycle time, thanks to the feedback provided by experiments and facility providers. Service suppliers, such as commercial Internet providers (telecom operators) or developers of general purpose tools (Microsoft, Apple, Google, etc.), can also be included in this role.

3.1.5 Policy makers and funding bodies

As far as funding bodies are concerned, the European Commission is the main contributor as far as CREW is concerned[2], since it provides funds for Fed4FIRE project and many other FIRE activities. Other funding bodies for experimentation and infrastructure investment can be at national, regional or local levels.

The CREW project showed its importance to the EC in the competences of the different facilities and the potential of collaboration. The outcome of the project and the experimentation carried out within the project will guide and support European policy decision makers by contributing to the observation and analysis of the scientific, technical and technological trends and impact of spectrum sensing.

National regulators also play an important role, as many local wireless testbed infrastructures are used in this project, mostly related to granting licences for certain frequencies: e.g. 4G for TUD and licenced bands (TV white spaces) for JSI and TCD.

3.1.6 Other research projects

Other research projects and initiatives CREW interacts with are Firestation and its successor AmpliFIRE, Fed4FIRE, ACROPOLIS, OPENLAB, and other FIRE projects. Information was and will be exchanged with these projects. This will create synergies and contribute to develop a harmonised FIRE vision in preparation of the transition towards Horizon 2020.

3.2 Value proposition

Based upon the methodology presented by Osterwalder [8], we have described the value proposition of the CREW project (Table 1). The Business Model Canvas is a strategic management template for developing new business models or documenting existing ones. It is a visual chart with elements describing a project's value proposition, infrastructure, customers, and finances. It assists projects in aligning their activities by illustrating potential trade-offs.

- Infrastructure
  - *Key Activities*: The most important activities in executing a company's value proposition.
  - *Key Resources*: The resources necessary to create value for the customer. They are considered an asset to a project, which are needed in order to sustain and support the business.
  - *Partner Network*: Buyer-supplier relationships or business alliances.
- Offering

[1] In case new hardware is developed and early performance testing is executed making use of the experimentation services offered by the facilities, we can also consider them as experimenters.

[2] Not for funding equipment

- *Value Proposition*: The collection of products and services a business offers to meet the needs of its customers.

- Customers
  - *Customer Segments*: To build an effective business model, a company must identify which customers it tries to serve.
  - *Channels*: The way its value proposition is delivered to its targeted customers.
  - *Customer Relationship*: How to stay in contact with your customers
- Finances
  - *Cost Structure*: This describes the most important monetary consequences while operating under different business models.
  - *Revenue Streams*: The way a company makes income from each customer segment.

Table 1: Value proposition for CREW

<table>
<tr>
<td rowspan="2">Key partners
• Consortium partners e.g. EADS, IMEC, iMinds, JSI, TCD, TCS, TUB, TUD
• Facilities joined through the open calls</td>
<td>Key activities
• Facilitate experimentally-driven research</td>
<td rowspan="2">Value proposition
• Open federated test platform for Cognitive Radio experimentation
• Offering common strategies for wireless experimentation</td>
<td>Customer relationships
• Personal assistance and support
• Cooperation on conducting experiments</td>
<td rowspan="2">Customer segments
• Experimenters (research and industry)</td>
</tr>
<tr>
<td>Key resources
• Individual wireless testbeds incorporating diverse wireless technologies augmented with cognitive sensing platforms.
• Knowledge on experimentally-driven research</td>
<td>Channels
• Portal
• Open calls
• Conferences
• Newsletter
• FIRE activities
• Public demonstrations)</td>
</tr>
<tr>
<td colspan="3">Cost structure
• Experiment support
• Operations and maintenance
• Marketing and PR
• Open calls</td>
<td colspan="2">Revenue streams
• EC funding (during the project)
• Participation in new projects for the individual partners
• Revenues from supporting (consultancy) activities or premium use of testbed infrastructures</td>
</tr>
</table>

3.3 Access policies

We will present three types of access models: (1) CREW core open call partners, (2) best effort experimenters & (3) premium external experimenters. An overview is given in Table 2.

3.3.1 CREW core and open call partners during the sustainability year

This scenario is only for CREW core members and open call partners joining during the sustainability year. This is based upon the access policies granted during the project as well.

Access to infrastructure is based upon the use cases presented, either during the project between the different core partners as well as from proposals from the open calls. Based upon these use cases, resources were asked and granted for the different tests on the different testbed facilities. This is, thus, a case-by-case analysis. Currently, the actual resource consumption was not controlled or limited. However, availability is not always guaranteed; user quota can be given in function of the availability of resources. An additional rule was that the experiment had a non-commercial character.

During the sustainability mode of the project, the selected experimenters can make use of the CREW infrastructure; however, they will not receive any funding during Open Call 3. This was not the case during the previous open calls, where funding was provided for the experimenters by the EC. The different testbed providers, nevertheless, grant full technical support during the use case.

In return, the CREW project demands feedback on the experiment, requires that the project is be mentioned in publications that report results that are obtained on the testbed, and finally, the experimenters should also provide feedback on the user experience.

3.3.2 Experimenters

This category is based on experimenters attracted outside the Open Calls during the project and sustainability year of the project, and after the project ends. Two categories are defined: a free best effort service, or a paying premium services with guarantees.

a. Best effort service

This best effort service is for non-commercial experimentation only, such as personal use by PhD students, occasional use by academic institutes and ad-hoc use by research projects.

Access to infrastructure is constrained: limited resource usage (on peak, over a longer period), not all equipment might be accessible, no/limited advance reservation of resources, no guarantee on availability, lowest priority compared to other reservations, fair use policy.

Basic support is accessible for the experimenters: the CREW portal, guidelines and handbooks or other information (e.g. specific training sessions or public demonstrations) made available by the individual testbed infrastructures. More detailed or individual technical support is not included in this service.

For such usage scenario, the service is provided for free. However, in return, the CREW project demands some feedback on the experiment: the project should be mentioned in publications when results are obtained using the testbed, and feedback on the experience should be reported.

b. Premium use

The premium use service focuses on more advanced use of the testbed infrastructure with guarantees on resource usage and support. Either commercial and non-commercial experiments are targeted such as e.g. long term use by academic researcher, “fundamental” use in research projects or by academic partners and companies.

Compared to the best-effort service, access to infrastructure is now depending on the proposed experiment by a case-by-case analysis. This includes resource usage with the possibility of reservation in advance, higher priority for executing the experiment, the use of more advanced equipment and resources, possibility to integrate third-party hardware in the testbed, etc. are premium features.

Basic support is accessible for the experimenters: the CREW portal, guidelines and handbooks or other information made available by the individual testbed infrastructures. More detailed or individual technical support is available, but is offered as a consultancy service.

In this usage scenario the service is not for free. The tariff for this service should be based on a transparent cost-based model as proposed in 3.4. In terms of billing, two options are foreseen: either a bill is sent to the experimenter, or the testbed infrastructure provider is considered as partner e.g. in a research project, and thus funded.

Table 2: Access policies

	CREW core partners & open call partners during sustainability mode	Experimenters	
		Best effort service	Premium use
Who	CREW core partners & open call partners	Non-commercial use only e.g. personal use by PhD student, occasional use by academic institute, ad-hoc use by research projects	Commercial and non-commercial e.g. long term use by academic researcher, "fundamental" use in research project or by academic partners, companies
Access to infrastructure	Yes. Case by case analysis depending on the proposed experiment.	Best effort • limited resource usage • no/limited advance reservation • lowest priority • fair use policy	Case by case analysis depending on the proposed experiment. • resource usage • possibility of advance reservation • higher priority
Support	Yes, technical support	Basic available information for the experimenters: portal, guidelines, handbooks, No / very basic technical support	Basic available information for the experimenters Consultancy based technical support
Cost model	Free[3]	Free[4]	Cost-based model
Other	Provide basic info on experiment Mentioning CREW / testbeds in publications	Provide basic info on experiment Mentioning CREW / testbeds in publications	

[3] Totally free use for CREW core partners and best effort experimenters only in case of remote use; in case of experiments conducted physically at the facility, the 'compensation' for local support to be agreed on a case by case basis (can be anything from joint experiment execution and paper writing, to joint preparation of project proposals or even monetary compensation for person-hours spent for preparation and on-field support)

[4] cfr footnote 3

3.4 Cost model

First, an overview of the different cost categories is given. In the second section, we focus on how to allocate the different costs in order to have a transparent model.

3.4.1 Categorization of costs

The categorization of costs can often be a point of discussion; we, therefore, first define our classification of cost categories by splitting up CapEx and OpEx costs. An overview can be seen in Figure 3.

Capital expenditures (CapEx) contribute to the fixed infrastructure of the facility, and is depreciated over time. The yearly capital cost can be calculated as the initial purchase cost divided by the expected lifetime. This includes hardware as well as software. The cost of first time installation is also included in the CapEx. The initial development cost of custom software developed specifically for the federation will also be considered as CapEx. For open source software the initial purchase cost will often be zero (but not necessarily).

Operational expenditures (OpEx) group several categories for operating an existing, up and running service.

- *The continuous cost*: this is the cost of keeping the service operational in a failure-free situation. It includes the cost for floor space, power and cooling energy for the hardware infrastructure.
- *Software upgrades*: the cost of continuous software adaptations, and facility enhancements (e.g. towards an emerging technology).
- *Maintenance and repair cost*: the cost of preventative measures such as monitoring and maintaining the service against possible failures, but also the repair costs when a failure has occurred, is diagnosed, fixed and tested.
- *Provisioning and service management*: this includes all costs related to handling a service request from an experimenter. Many technical components are automated (and hence zero cost)
- *Pricing and billing*: all costs related to sending bills and ensuring payment, it also includes the application of penalties when an SLA is not fulfilled.
- *Marketing*: The cost related to acquiring of a new experimenters and facilities for a specific service, it involves promotion, providing information concerning pricing, etc.
- *General OpEx*: this relates to general overhead expenses every company has such as the costs for buildings to house personnel, energy for desktops, administration, etc.

The cost of human resources (personnel costs – wages) is in our view considered as a part of several operational expenses (e.g. part of repair cost, software upgrades, service management).

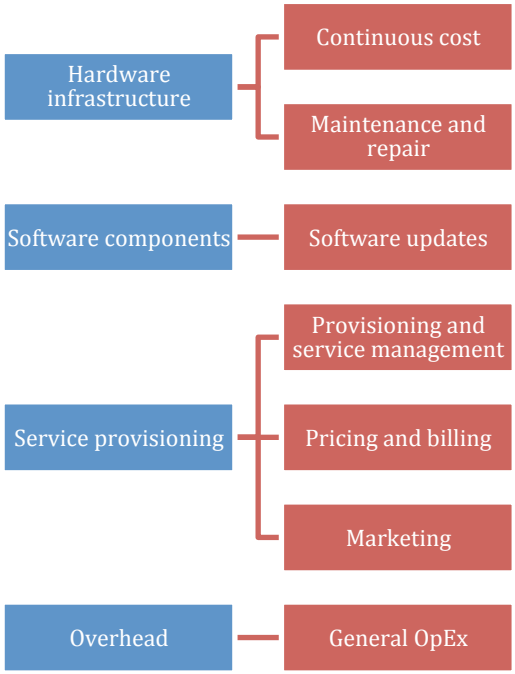

Figure 3: overview of cost figures

3.4.2 Cost allocation

Depending on the testbed infrastructure offered (within the CREW project), different considerations must be made. It also relates to the funding received for developing and acquiring the infrastructure and components.

a. Allocation depending on funding

The funding depicts the rules, whether the costs can be allocated to the tariff:

- *EC or national project funding*: no cost can be allocated for tariffing as this is already paid for. The operational expenses (for keeping the component up and running (e.g. electricity cost, housing, man power if required, etc.), maintenance and repair), if not comprised by the funding, could however be allocated.
- *Own funding:* this cost could be part of the tariff, taken into account the technical lifecycle (depreciation time) and operation expenses (for keeping the component up and running (e.g. electricity cost, housing, man power if required, etc.), maintenance and repair).

Depending on the type of component, funding is granted.

- *Hardware:* This comprises large upfront investment. Most likely the funding mechanism will be EC or national funding. Exceptionally own funding has been used, mostly related to upgrades or specific component development.
- *Software*: This can either be stand-alone (e.g. software library) or supporting the underlying infrastructure (OS for dedicated infrastructure). It requires an upfront investment and continuous development. The size of the investment depends on the type of software and is case dependent. Funding can either be covered by EC or national projects (large software components), or own funding / shared cost development with stakeholders (upgrades and additional components). Remark: if the software offered is open source, the cost can never be allocated.
- Added value services: These components are supporting the hardware and software components, and are most likely funded by the own testbed infrastructure provider or via shared cost development. These services can be software components, but are mostly human

resources for keeping the hardware and/or software infrastructure up and running, and up-to-date.

b. Cost driver

A cost driver should be used for each component.

- *Hardware and software:* The usage time of the component is most commonly used. All costs should then be gathered and added, and divided by the time the component is available for experimentation. This includes the depreciated cost (based upon the lifetime of the component) and operational costs. In the end, an hourly rate for the component use should be available.
- *Added value services:* As these comprise most of the time human resources (e.g. for support), an hourly or daily rate should be foreseen.

Several questions are still open for discussion and should be clarified per component.

- *What to do with shared resources (mix & match, IPR)?* A clear allocation rule should be worked out between the different parties owning or having rights to the component. Examples can either be percentage based upon the usage of the component or through licences.
- *How to allocate costs between different individual infrastructures?* This will depend on the amount of allocated costs, and the use of infrastructures in both directions.
- *How do you allocate costs for components not owned by your testbed infrastructure?* In some cases within the CREW project, hardware and software components were placed in testbed infrastructures of other parties. In case an experimenter wants to make use of these components in a premium use model, how should the cost of those components be allocated? This should be cost based as it was proposed before, and the amount should be remunerated to the concerned infrastructure owner.

3.5 Tariff model

Table 3 depicts our proposed tariff model. Again, the three different categories presented in section 3.3 were used.

For CREW core partners and open call partners during the sustainability year, and the experimenters making use of the best effort service, the cost for using the hardware infrastructure is free, of course taking into account the restrictions as proposed before. For premium users, the tariff should be cost based.

For software components, a division between open source and dedicated software components should be made. For open source, the only rule is that additional developed components should be published under open source licencing terms, and thus should be made public. For dedicated software components, they can be used for free / fair use (as indicated in [7]) for CREW core partners and open call partners during the sustainability year, and the experimenters making use of the best effort service (however upon discussion, case by case specific). For premium use experimenters a case-by-case evaluation should be made.

Operational costs are free for the first two access models (CREW and open call partners during sustainability year, and best effort service experimenters), and cost based for premium use experimenters.

Table 3: Tariff model overview

	CREW core partners & open call partners during sustainability mode	Experimenters	
		Best effort service	Premium use
Hardware (Including investment cost, continuous cost of operation, maintenance and repair)	Free	Free	Cost based model
Open source software (Including software updates)	Additional developed components to be published under open source licencing terms		
Dedicated software components (Including software updates)	Components can be used for free / fair use (as indicated in [7]) – upon discussion, case by case specific		Components can be used upon discussion, case by case specific
Operational costs (Including provisioning and management services, support, pricing and billing, marketing, other)	Free service provisioning and management		Cost based model

Several questions are still open for discussion and should be clarified.

- *Which tariff should be applied for making use of the infrastructure?* Different options are possible: at cost, cost+ (small profit margin) or at market price (high profit margin)? When we only bill at cost price, the testbed will never be sustainable, as the costs for the free users are not covered, and this is in the perception that the testbed is used during the entire time at maximum capacity. This might be the case for cost+, to run a break-even situation, but is not very likely. But what to do with costs for keeping the infrastructure up-to-date? Then a market price rating should be in place. The question then arises how much can be asked above cost price. This will probably depend per testbed facility on the ratio non-paying / paying experimenters and funding opportunities.
- *How can premium use be billed?* This is not always very straightforward, as some of the CREW testbed facilities are related to universities.
- *How to deal with (excessive) OpEx during experimentation for CREW core partners and best effort service?* Dedicated support by our personnel needs some sort of compensation also in the case of CREW core partner experimenters and best effort service; to be agreed on a case-by-case basis. It can range from joint experiment execution and paper writing, to joint preparation of project proposals or even monetary compensation for person-hours spent for preparation and on-field support. Also, any excessive additional costs with the operation of the testbed for an experiment by CREW core partners and best effort service are to be somehow compensated.

4 Sustainability trends of CREW core partners

Based upon two questionnaires, one in 2010 in the early start of the project, and one in 2013 near the end of year 3, we have asked the individual CREW core partners for information concerning their testbed infrastructure (openness, usage, access policy and tariffing plan, financial availability). A comparison of the results is presented in this section. We conclude with some best practices.

4.1 Openness

Not all test facilities in the CREW consortium are open today, but there is a trend towards making the testbeds publicly accessible (where possible). This can be seen in Table 4, shifting from sharing the infrastructure with researchers of the own institution and project partners within research projects to external research institutes and in some cases industry (e.g. iMinds). Although we should mention that some of the infrastructures stay a closed environment, such as TCS. In general, we can conclude that there is mainly a shift downwards, thus towards more openness, but in some cases also a shift upwards, protecting part of the testbed infrastructure for internal testing and further developments.

Table 4: General conclusion on openness of testbed infrastructures of CREW core partners

	2010	2013
Closed environment (for private use only - no sharing)		
Information sharing (web portal with information about the TI)		
Sharing with **researchers of the own institution**	■	
Sharing with **project partners** within research projects	■	■
Sharing with **external research institutes**		■
Sharing with **external industry firms**		
Installation of additional equipment/software in your TI by external firms or research institutes		

4.2 Usage

Next to openness, we asked the different core project partners for what reason their testbed infrastructure was used (Table 5). In 2010, the main focus was on (European) funded research projects. The latter was the case for all CREW core partners. Access was in nearly all cases granted to other project partners for making use of the testbed infrastructure. Only few had experience with attracting external users back then. In 2013 we see that more partners make offers towards external users. A concern to consider is that there is less interest from the external users to use the testbed when the facility/component owner is not involved in the project!

Table 5: Usage of your facility/components

	2010	2013
For **internal research** (knowledge perspective)	■	
To be used in (European) **research projects** (research funds) • Private use (or tests for other project partners) • Use by project partners	■	■
Attracting **external users** (pay per use/license/…)		■

All CREW core partners indicated that they have attracted more experimenters thanks to the CREW project. The main experimenter types are individual researchers, academic groups, research projects, SMEs and some large companies. Attracting the latter two to use the testbeds is one of the main goals of the CREW project so this is a positive conclusion.

4.3 Access policies and tariffing model

Below, some conclusions can be found concerning the access policy and tariffing model currently applied at the different facilities:

- The access policy and tariffing model proposed in section 3.3 are perceived very well by the different core partners and is in line with their current models.
- Not all testbed infrastructures have implemented an access policy. Some of them do not have the intention at all to implement such policy in the future. The main reason is to keep control of the situation or not wanting to have external experimenters using their facilities. In such situations, mostly only (external) research projects partners are intended to use the facilities.
- Not all partners are in favor of a premium access model. The first two access models (CREW core & open call partners, and best effort) are perceived as most "valuable" for attracting experimenters, mainly for being free of use, or easy to implement.
- Taking part in new research projects as testbed infrastructure provider, however, is very appealing for some partners. This relates to the premium use model, where guarantees are offered concerning availability of resources, advanced reservation, access to protected resources, etc.

4.4 Financial viability

The questionnaire results show that the testbed infrastructure owners are in a constant search for funds. While funding was available for the last years thanks to the CREW project, it is worrying to see that not a single partner is sure of future funding for investments in their facility. Furthermore, while funds may be available for operating the facilities as they exist today, there may not be room for significant expansion of functionality. This conflicts with a part of the definition of sustainability: the ability to keep testbeds up-to-date in such way that they will still be relevant tomorrow and form a solid base for further development and expansion.

Table 6: Financial viability

	2010	2013
Yes, **long term** financially viable (operations and investments)		
Yes, **short term** financially viable (I have to find funds for the upcoming years)		
Yes, **very short** term financially viable (funds to keep it operational at this moment but no funds for current of future investments)		
Constant search for funds and investors to keep it operational (possibly ad-hoc investments / cross-subsidizations)		

The status of the financial viability is presented in Table 6. The situation stays the same as in 2010, meaning (very) short term financial viability for the different individual facilities. Test facilities are highly dependent on research project funding; thus, the viability depends on the success rate of

projects, which is in the current economic situation not evident. The project partners seem to be pessimistic about success rate of project proposals in the pipeline and future. Conclusion is that there is definitely a need for sustainability models for sharing facilities/components against financial compensation and a need for well-defined policies for use for long term viability of the facilities.

4.5 Best practices

We asked the CREW core project partners what has changed the most compared to the start of the project. The results are presented below:

- They obtaining new research experience & facility improvements:
  - Efforts of core consortium resulted in better equipment integration (connectivity brokerage, IMEC SEs, etc.).
  - Open Call experiments often have an additional positive return (e.g. introduction of new components and services, new competences obtained)
- They have a nice integration and validation of hardware and software components in broader testbed infrastructure.
- They experienced, evaluated and implemented different experimental models.
- They reached good exposure and interactions with European researchers.
- The project contributed to a better image & reputation of the individual facilities: 18 submitted proposals for Open Call 1, 21 for Open Call 2.
- Testbeds are currently used in classroom demonstrations to increase the enthusiasm of students to pursue higher studies in wireless communications.
- They indicated that the CREW project has helped significantly with expanding and disseminating the capabilities of the testbed, and a number of external experiments have made use of the testbed as a result.
- They agreed that since CREW (and also under impulse of other projects), more technical information became available on the infrastructure. Furthermore the access policies are now a lot clearer.
- They promote the use of open software and remote access, benefiting all stakeholders. For example, TCD has made their software defined radio framework, Iris, open source. The software can now be downloaded by external users and used in their own testbeds. They also now allow remote access to our hardware, enabling researchers to remotely run full over-the-air experiments using our testbed.
- They could set up cooperation with commercial partners. For instance, IMEC implemented the sensing engine as proof of concept in the framework of our internal roadmap for cooperation with commercial partners. Now that the point has been proven and that the setup is available, it is an added value to offer the sensing setup to partners in research projects.
- Some of the partners indicated that the project has led them to new funding opportunities.

5 Future of CREW

A few different options can be proposed for the future of CREW. We have to consider first the results from the sustainability year before we will be able to discuss in detail the future of the test infrastructure.

5.1 Possible future strategies

Three options are possible when the CREW project ends: the project will be kept in its current form (thus even after the sustainability mode), CREW functionality will move into Fed4FIRE, or the testbeds will follow individual directions as implemented by the different partners.

5.1.1 CREW will be kept in its current form

In the last years of the project, the project will run in sustainability mode. Open Call 3 was launched, but without funding for the experimenters. The results must show, whether there is interest by experimenters to participate in this formula. If this is fruitful, the access model proposed could work nicely for attracting experimenters.

The main question that arises is what to do after the sustainability mode period. If the project should continue in its current form, several issues should be solved first:

- Will all current partners continue cooperating?
- How will it be managed?
- How will it be funded?

Lessons should also be learned from other projects, such as BonFIRE or Ofelia, which have to deal with the same issues in the upcoming months.

5.1.2 CREW functionality will move into Fed4FIRE

Fed4FIRE is delivering a common federation framework for Future Internet Research and Experimentation facilities that will:

- be widely adopted by different communities (experimentation facilities, experimenters, academia, industry)
- support powerful experiment lifecycle management (including tools for discovery and reservation, experiment control, measurements, etc.)
- support key aspects of trustworthiness (federated identity management and access control, accountability, SLA management)

This project would like to bring together a lot of experimentation facilities, in order to attract more experimenters and save costs (economies of scale). This IP project is now ending its first year, and several decisions concerning the structure and functionality should be taken. A first version of their sustainability plan has been published [6].

Several questions still arise when this path should be chosen:

- Which partners will join Fed4FIRE?
- Which functionality will move to Fed4FIRE? Are there any restrictions concerning IPR (e.g. when partners with IPR rights are not joining the project)?

5.1.3 Each partner follows its own individual course

When the CREW partnership will not be kept in its current form, each partner will go its individual course. It can either join Fed4FIRE, as mentioned above, or go its own way, e.g. by making liaisons with other partners or joining groups such as the Wireless Innovation Forum (WINNF). This is the least optimal solution as it would result in the individual testbeds to lose the gain that was built up during CREW.

5.2 Visions from the CREW core partners

Below we give an overview of the answers from the core project partners on following questions: How do you see the future after CREW? Will it all end after the sustainability mode of the project? Will the functionalities merge into Fed4FIRE? Will CREW stay independently?

- They see opportunities in cooperating with or being partner of Fed4FIRE. Fed4FIRE's main purpose is to attract new experimenters by combining different testbed infrastructures. Keeping projects such as CREW sustainable is very difficult. Each facility has its own competences and specific hardware and software infrastructure. The EC should protect this, and should discourage setting up new facilities with the same functionality as existing testbed infrastructures. New EC projects seeking experimentation resources should then be sent to existing facilities (e.g. CREW or the individual core partners) able to offer them the required infrastructure, rather than setting up new facilities.
- Some partners claim that, although they envision continuing to operate the testbed for the foreseeable future, they are a research center and the continued operation and expansion of the testbed depends on the continued availability of funded research projects. They hope that FIRE, within the framework of Horizon 2020, will play an important role in sustainable funding for testbed federations; this might enable them, for instance, to retain a full time person to provide support for testbed use by external researchers.
- They hope CREW will not all end after the sustainability mode of the project, looking forward to the non-funded OC3 results. It would be good to keep the CREW federation running for publicity reasons. Finding funding will be crucial. Otherwise it will be very difficult for CREW to stay independent.
- For some partners, it is not the purpose of CREW to stay independently. If needed, the functionalities could be merged into Fed4FIRE.
- Some partners will end the collaboration after the CREW project. For others their main technology challenges could be addressed and industry-ready prototypes could be showcased.

6 Conclusion

Setting up a sustainability plan for the CREW facility is not an evident task and comprises various challenges. First we have to agree upon the definition of sustainability. It is defined now as *"Sustainability means usage (or usefulness) of the infrastructure beyond the end of the project"*.

A business model has been proposed. Different components have been investigated. First, we took a look at the stakeholders of the project. The core partners and FIRE users (via the open calls) are currently the most important actors. However, in the future the external experimenters will play a more important role. Next to these stakeholders also policy makers, funding bodies and other research projects play an important role. Interactions with Fed4FIRE, Acropolis, etc. are crucial for the further existence of the CREW facility and functionality.

Next, we presented the value proposition for CREW based upon the business canvas model of Osterwalder. This indicates what the project offers, its main activities, the key resources and partners, the customers and how to offer the service to them, and finally the underlying finances (costs & benefits).

A generic access policy framework has been proposed. Three models are presented: (1) CREW core and open call partners, (2) best effort experimenters and (3) premium external experimenters. All models have different rules concerning access to infrastructure, support, or other requirements such as feedback on the experiments, references in publications, etc.

A detailed cost model has been shown, indicating the different cost categories. In a next step, we focus on how to allocate the different costs in order to have a transparent cost model. This model can then be used to setup a tariffing plan. Only the premium use model is not for free. The cost should be based upon a transparent calculation of resource usage (infrastructure as well as personnel e.g. for support).

Two questionnaires were conducted, one in 2010 and one in 2013, requesting information concerning the core partner's testbed infrastructure (openness, usage, access policy and tariffing plan, financial availability), including some best practices learned during the project. Attracting new experimenters, knowledge gains, new research experience & facility improvements, good exposure and interactions with European researchers, better image & reputation are the main conclusions from the project.

When considering finally what to do after the CREW project, different options exist today. Either the project will be kept in its current form (such as is the case during year 5), or CREW functionality will move into Fed4FIRE, or the project structure dissolves and each partner will follow its own course. After this year in sustainability modus, a more clear insight on what the future will bring will be available.

References

[1] OSIRIS, 2012, Arno Hoogerwerf et al., "Deliverable D4.1 - Model for Public Authority – Research Infrastructure Interaction", available online: http://www.osiris-online.eu/Public/248295_OSIRIS_Deliverable_D4-1%20vs%2012-06-04.pdf

[2] Michael Boniface, Philip Inglesant, Juri Papay, "Counting the Cost of FIRE", The Future Internet, Lecture Notes in Computer Science Volume 7858, 2013, pp 297-309,

[3] MyFire, 2012, "Deliverable D4.2 - Contribution to FIRE roadmap", available online: http://www.my-fire.eu/documents/11433/38630/D4.2+-+Contribution+to+FIRE+roadmap

[4] MyFire, 2012, "Deliverable D3.3d – Routes to Sustainability", available online: http://www.my-fire.eu/c/document_library/get_file?groupId=11433&folderId=38795&name=7508

[5] ICT-FIRE, 2012, Serge Fdida, "Deliverable 3.6 - FIRE Roadmap sharing, sustainability, federation and interoperability among FIRE testbeds", available online: http://www.ict-fire.eu/fileadmin/publications/deliverables/D3_6-pu-FIRE_Roadmap_Sharing_sustainability_federation_interoperability_v1.0.pdf

[6] Fed4FIRE, Deliverable D2.3, "First Sustainability Plan", 31/7/2013

[7] CREW, Project Deliverable D1.2, "IPR Management report", 30/9/2012

[8] A. Osterwalder, Yves Pigneur, Alan Smith, Business Model Generation, published in 2010, http://www.businessmodelgeneration.com/