FI.ICT-2011.1.8 FINESCE

D2.7

Trial Results

Contractual Date of Delivery to the CEC: *30.September 2015*	
Actual Date of Delivery to the CEC: 16.September 2015	
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Participant(s):	*ACCIONA*
Workpackage:	*WP2*
Estimated person months:	*25*
Security:	PU
Nature:	R = Report
Version:	1.0
Total number of pages:	12

Abstract:

This report summarizes the results obtained in the WP2 trial stream of Madrid, encompassing the experience of the adoption of FIWARE Generic Enablers and the development of Specific Enablers, results on energy optimization, and results on interaction with end-users/stakeholders.

Keyword list:

Building energy management, Smart metering, Generic Enablers, User interaction, FIWARE

Disclaimer:

All information provided reflects the current status of the WP2 Madrid trial at the time of writing and may be subject to change.

Executive Summary

The Madrid trial stream within WP2 aims to integrate and assess FIWARE components in the context of the smart building domain. More specifically, the Madrid trial stream focuses on an office building in which the purpose is to test different energy services which could be applicable in any tertiary building, and to some extent in industrial buildings as well.

The trial building is equipped with a Building Management System (BMS) which can be operated remotely, energy generation assets consisting of solar photovoltaic (PV) panels and simulated wind power, energy storage through electric batteries, and a wireless metering infrastructure for measuring electricity consumption.

In the initial stage of the trial (trial design), different evaluation criteria for assessing the success of the trial were defined. They have now been revised in order to evaluate the trial outcome. Although many evaluation criteria are more connected to the exploitation beyond the project timeline, they have been properly targeted within the trial, namely:

- Integration of a number of GEs coherent with the initial target.
- Implementation of testing applications (although not yet from third parties) on top of the trial infrastructure.
- Proper dissemination of the trial through innovation events and open days, including an open day hosted in the trial.
- Different energy service prototypes implemented in the trial.

The integration of FIWARE components in the trial has shown that Generic Enablers (GEs) constitute a good foundation for building innovative energy services and applications, although improvements are still needed in terms of platform reliability, technical support and communication policies.

Different applications have been tested on top of the GEs and Domain Specific Enablers (DSEs) integrated in the trial, namely: pre-processing the weather forecasts through the Temporal Consistency DSE, customization and management of alerts connected to the trial subsystems through the Scene Manager DSE, and a web interface for visualizing the monitored data.

Different energy service prototypes have been implemented and are being tested in the trial, including demand management services, energy auditing/monitoring/verifications services, and energy generation/storage management services.

The data generated by the trial building subsystems have been made available through the trial API and are therefore accessible to third parties willing to use the data for testing innovative energy-related applications in the smart building domain.

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Table of Contents

1. Introduction

Office buildings, as well as industrial and tertiary buildings in general, differentiate deeply from residential buildings in the degree of freedom that is given to end users for controlling the building equipment generating, storing or consuming energy. The control of all these devices, and particularly of the most energy-hungry ones, such as HVAC equipment, is normally centralized and implemented through a Building Management System (BMS) which integrates the operation of the different building subsystems. Therefore the optimization of these centralized control systems is crucial in order to achieve significant energy savings.

However, even if the larger portion of the energy savings will most frequently come from more optimized global control strategies, the influence of end users on the final consumption cannot be completely neglected, as they still retain certain degree of control over some of the energy consuming devices in the building. Therefore the promotion of energy awareness and energy efficient habits among end users, which has been deeply researched in the residential buildings domain, needs to be further developed in non-residential buildings in order to underpin the savings achieved through centralized control strategies.

Another factor to consider is the increasing integration of renewable energy technologies in buildings, which together with the promising prospects in the field of energy storage (e.g. the recent development of cheaper and more compact electricity storage batteries announced by Tesla[1]), and the new energy billing patterns which are being adopted by European utilities and Member States (e.g. the new regulated electricity price applied in Spain, which calculates a different tariff for each hour of the day[2]), call for more advanced control systems and algorithms which can optimize the matching of the building's energy demand with its own energy generation and storage capabilities, taking into account as well the dynamic prices and any demand management signals coming from the electricity grid.

The implementation of all these advanced control, energy awareness and energy efficiency strategies will normally be addressed by Energy Service Companies (ESCOs), utilities or other stakeholders who will need to be provided with the necessary technological foundations for supporting the delivery of these services to multiple buildings.

FIWARE can be one of these underlying technologies, and the objective of the Finesce Madrid trial has been to assess how this platform can meet the requirements for data handling, processing and exchange in the context of providing smart energy services for industrial and tertiary buildings.

In order to perform this assessment, the Madrid trial uses an office building equipped with a BMS which can be remotely operated through a software platform called Building Control Centre (BCC), this platform can control the BMS from multiple remote buildings. The building also has photovoltaic panels for electricity production, simulated wind power generation, and a battery for electricity storage, which supports the testing of strategies for the building to act as a "prosumer" of the electricity grid. Lastly, the building has also been equipped with a smart metering and sensing infrastructure, and a weather forecasting service has been developed to feed the building energy control algorithms.

This report presents the final results of the trial experiments which have been conducted in the Madrid office building, which are classified into three categories:

- Results with respect to the integration of FIWARE GEs and the developed Domain Specific Enablers (DSEs) with the trial infrastructure, and how they fulfil the requirements for which they were selected as trial components (Section 2 of this document).
- Results with respect to the building energy management and awareness services which have been enabled/enhanced through the integration of FIWARE components (Section 3 of this document).

[1] http://www.teslamotors.com/powerwall

[2] http://www.esios.ree.es/pvpc/

- Results with respect to the interaction with the end users of the building and the different stakeholders involved in the delivery of the building energy management services tested (Section 4 of this document).

The results and findings of the trial are assessed according to the main evaluation criteria which were defined in deliverable D2.1 Trial Design Document. They are included as a reminder in the table below:

Table 1 Trial evaluation criteria

KPI ID	Evaluation Criteria
1	Level of usage of GEs in service platforms implementations. Total number of GE used in ACCIONA trial.
2	Selected test applications (e.g. from third parties) implemented and successfully validated. Evaluation of the success of commercial products developed from FINESCE project results. Evaluation will be carried out through number of downloads.
3	Visibility of FINESCE. Level of dissemination and knowledge within potential application developers. This information will be evaluated by using surveys taking the different stakeholders into account.
4	Energy Innovation through ICT. Number of prototype services/products successfully implemented in the building.
5	Impact on the Energy Sector. Total data managed by FINESCE solutions

2. Trial Results on Usage of Generic Enablers and FIWARE

2.1 Integration of FIWARE Generic Enablers in the trial architecture

The architecture of the Madrid trial integrates three different Generic Enablers: two of them currently active in the FIWARE Catalogue (Big Data Analysis – Cosmos GE and Publish/Subscribe Context Broker – Orion GE), and an additional Generic Enabler (Publish/Subscribe Context Broker – Context Awareness Platform) which has been removed from the Catalogue but is still functional within the trial.

In addition to FIWARE Generic Enablers, the trial integrates two Domain Specific Enablers: Scene Manager and Temporal Consistency. The Scene Manager DSE has been devised as a generic module for managing subscriptions to alerts coming from the available buildings' subsystems, which are triggered based on different configurations/combinations of building parameters ("scenes"). Thus, the Scene Manager can be of help for any third party aiming to develop new applications which need to subscribe to data generated by buildings (e.g. a mobile app for facility managers).

On the other hand, the Temporal Consistency DSE allows applying pre-processing algorithms to data streams from building subsystems which need to be refined before feeding any energy optimization strategy. For instance, this is the case for weather forecasts: it is well known that the accuracy and correctness of these forecasts can determine the validity of any simulation model using these data as input, and based on which optimized building control strategies are calculated. The accuracy of these data can be improved through different mechanisms; the Temporal Consistency DSE applies an algorithm which compares the last data received from a stream with the historical evolution of the same stream in previous periods. Thus, it is possible to spot erroneous values and propose alternative ones which match better with the observed data patterns in time.

Another key component which has been integrated into the trial architecture is the trial API, which allows third parties to access the data from the trial in order to support any innovative development in the smart energy field, through the experimentation with the data generated by the building. The trial API functions have also been integrated in the FINESCE API.

2.2 Lessons learned using FIWARE Generic Enablers

The evaluated FIWARE Generic Enablers fulfil adequately most of the different trial functional requirements based on which they were selected to be integrated in the trial architecture. The detailed assessment of the compliance with requirements was done in a harmonized way together with other FINESCE trials using the same GEs, and the results of this assessment were presented in detail in deliverable D2.4 "Analysis of Generic and Specific Enablers Integration".

In spite of this fact, it shall be noted that the instance of the GEs running in FI-LAB platform has experienced frequent availability/stability issues, which questions the maturity and readiness of this platform for already hosting commercial applications and services. However, the stability problems seem not to be directly related to the GEs themselves, but rather to the capacity of the underlying IT infrastructure. Therefore it could be expected that once these infrastructure limitations get solved, FIWARE will be much closer to being able to offer the performance and reliability that commercial energy services will demand.

Another lesson learnt is the importance of having an adequate technical support to the GEs, both from the point of view of support to software developments integrating the GEs, and from the point of view of maintenance and problem solving of the running GE instances. While the support to the development process has been adequate and the interaction with the FIWARE GEs development teams has been fluent, maintenance and problem solving of the GE instances used by the Madrid trial has not always been quick enough, especially since the FIWARE Accelerator Programme started. Therefore this point shall be given high priority as well in order to increase the chance of FIWARE being adopted by companies and entrepreneurs.

A last lesson learnt is that communicating roadmaps and development strategies of FIWARE is fundamental. During the trial experimentation some GEs which were already integrated or planned to be integrated in the trial infrastructure have been deprecated. Although this fact did not have an impact on the working status of the trial, it is clear that using FIWARE in a commercial context needs an adequate communication of the development roadmaps planned in the FIWARE Catalogue, so that the impact of any change in the Catalogue can be assessed well in advance.

2.3 Advantages of using FIWARE in comparison to alternative technologies

During the evaluation of FIWARE Generic Enablers, an assessment was carried out for comparing the performance of one of the GEs integrated in the Madrid trial, the Big Data – Cosmos GE, and a commercial alternative, the BigQuery component of the Google Cloud Platform. The detailed description of this comparison process and of its results was included in deliverable 2.3.2 “Midterm Analysis of GEs and DSEs”. The comparison was made according to different common criteria agreed with the rest of FINESCE trials, namely: functional suitability, performance efficiency, compatibility, reliability, security, maintainability and portability.

It is remarkable that even at an early stage of this comparison, the evaluated FIWARE GEs did quite well when compared with commercial alternatives from a top competitor like Google. Nevertheless some issues were detected where Big Data – Cosmos GE lagged behind, particularly in terms of usability and ease of configuration. Other issues were more related to the fact that FIWARE is a platform that is still under development, while the evaluated alternative is an already stable commercial solution, which occasionally originated availability and maintainability problems. Nevertheless, it can be expected that these will be mostly solved once the FIWARE development is stabilized and its supporting IT infrastructure is dimensioned according to the demand that it will receive from multiple users.

The comparison which was performed with the Big Data – Cosmos GE could be further extended by comparing it with additional commercial alternatives from other vendors or by comparing other integrated FIWARE GEs with any commercial counterpart. However, this work has been already carried out by other trials (i.e. all the trials together give an overall picture of the performance of the different FIWARE GEs when compared with commercially available solutions), and therefore it is more interesting to look at the general advantages provided by the own concept of FIWARE platform, than at the individual technical performance or functional suitability of each of its components, namely:

- FIWARE platform relies on an open specification which can be implemented and maintained by any company/organization. This helps to avoid dependence on a single provider, one of the key features when evaluating the acquisition of a platform of this type.
- As a consequence of the previous point, very large organizations such as the main energy utilities may consider the option to deploy and maintain their own FIWARE instantiation in a private cloud.
- The fact that FIWARE is the result of a European research effort gives more confidence to customers in Europe and other world regions for storing and processing their energy data within this platform, rather than other platforms with which they may have privacy concerns.
- Furthermore, the FIWARE Accelerator Programme which is currently running supported by European funding is another opportunity to fine tune the performance of FIWARE platform and its GEs, as it will have to cope with the demanding requirements of an extensive base of entrepreneurs who want to use FIWARE as the technological foundation of their businesses.

3. Trial Results on Energy Services

It was already briefly explained in the introduction that the objective of the Madrid trial was to test how FIWARE GEs and DSEs could help enable/enhance innovative energy management and energy efficiency services to be provided by ESCOs to industrial and tertiary buildings. It was already mentioned in deliverable D2.5 “Trial Demonstration” that these services could be classified into three main categories:

- **Demand management services:** this category of service is the one from which higher energy savings in industrial and tertiary buildings can be expected to be achieved. It addresses the optimization of the day-to-day operation of the different building subsystems through an already existing or newly installed BMS.
- **Microgrid/prosumer services:** this category can be considered as a complement to the previous one for buildings that have energy generation and/or storage capabilities. In this case, in addition to optimizing the energy demand of the building, it is also necessary to provide services for optimizing the matching between energy demand, energy generation, energy storage and the energy prices offered by the grid. The aim is to optimize the costs of the energy purchased or sold to the grid, by deciding in each moment:
    - Whether the energy generated by the building has to be either consumed directly by the building, or stored for using it in other time period, or sold to the grid.
    - Whether the energy demand of the building has to be satisfied with its own generation, its own storage and/or energy purchased from the grid.
    - Whether the building shall purchase energy from the grid and store it for using it in periods when the prices are higher.
- **Monitoring/energy efficiency services:** this category targets energy efficiency services for diagnosing the energy use of a building, defining strategies for increasing the energy efficiency through different strategies (e.g. upgrade of equipment, improved management of the building installations, etc.), and measuring/verifying the energy savings obtained with the implementation of the previous strategies. This process must be supported by an appropriate metering and monitoring system for comparing the final and initial energy consumption of the building. Such systems must be cost effective, easy to deploy, accurate and appropriate for any type of building regardless of whether it is equipped with a BMS.

Demand management services are the main category of service from which larger energy savings can be expected to be achieved. This is due to the fact that it targets the optimization of the BMS’s daily operation, encompassing different building equipment which normally account for 40%-70% of the total energy consumption of tertiary buildings. Lack of BMS optimization frequently leads to excess of energy consumption of up to 20% in the energy bill. For instance, the application of optimization algorithms to the BMS of the trial building has achieved savings of up to 10-15% in the consumption associated to the HVAC systems.

The BCC, to which the trial BMS is connected, allows a remote operation of the latter. This is an interesting approach which enables new business models for operating multiple buildings using a centralized platform. Besides, the BCC addresses interoperability as it can integrate different standards used by BMS, such as BACnet, LONWorks, KNX-EIB, etc.

Future plans for improving the BCC include tuning the algorithms used for calculating the daily optimized operation plans which are passed to the BMS. These plans are calculated based on simulated models which are fed with the technical specifications of the building and of its installations, together with historical data and forecasts of weather and energy consumption. Therefore the optimization algorithms can be improved if the underlying simulation model of the building is made more accurate. This can be achieved for instance by refining the data sources feeding the model, something which has been already applied in the Madrid trial with satisfactory results, through the use of the Temporal Consistency DSE for filtering the weather forecasts used by the model. Another approach which can be researched in the future is the inclusion of new inputs to the model, such as precise estimations of building occupancy based on real data obtained from the building monitoring systems.

As mentioned above, demand management services can be complemented with micro-grid management services for buildings which are equipped with their own energy generation and storage capabilities. The service tested in the Madrid trial allows the simulation of different management profiles, in which the control system decides how to satisfy the energy demand of the building taking into account the prices from the grid, the energy generation forecasts and the available energy stored.

Finally, the experimentation of the monitoring/energy efficiency services has allowed defining a wireless metering and monitoring platform that is at the same time cost effective, easy to deploy and accurate. Besides, the specific case of the Madrid trial has been used to support the triple certification process of the building according to standards ISO 50001, 14001 and UNE 171330-3.

4. Trial Results on Interaction with Users/Stakeholders

In the introduction to this report it has already been mentioned that industrial and tertiary buildings usually leave much less control to end users over the energy consuming systems and devices when compared to residential buildings. In spite of this fact, end users still have an impact on the final energy consumption of this type of buildings, and therefore one of the objectives of the Madrid trial was to evaluate how FIWARE could support the development of innovating solutions targeting end users, both from the point of view of increasing awareness about energy efficiency, and of correcting/improving the operation of building systems which are still under the control of these users. The potential user interactions that were analysed for the Madrid trial were the following:

- **Awareness about global energy consumption:** the first interaction priority shall be to provide feedback to end-users about the global consumption and comfort of the building, also presenting the detailed breakdown of the different building areas, in order to increase their awareness about energy efficiency, and drive changes in their behaviours which can lead to energy savings associated to the portion of the building energy consumption over which they can have a direct influence.

  The building energy consumption and comfort data obtained in the Madrid trial through the deployed wireless metering/monitoring system are a valuable result which can be used to feed different applications for increasing energy awareness among the building's end users. One interesting application which has been identified in the Madrid trial is to take advantage of the TV displays which are enforced in public buildings by the Spanish Regulation of Thermal Installations in Buildings (RITE) for displaying building comfort data (temperature and relative humidity) to end users. A plan for a continuation of the trial activities beyond the Finesce project timeline is to complement the comfort data of these displays with energy consumption data as well as the evolution of this consumption over time (e.g. compare the energy consumption during a month with the previous month, or the same month of the previous year). Besides, the trial metering infrastructure provides a breakdown of electricity consumption per building floors/areas, therefore it would be possible to organize competitions among different end user "teams" aiming to decrease the energy consumption of the building area to which they are associated.

  Furthermore, the Madrid trial API, that has its functions integrated in the Finesce API as well, allows third parties to access the building data and experiment with innovative applications (e.g. mobile apps) for presenting energy data of industrial and tertiary building to its end-users, thus increasing energy consumption awareness and promoting energy efficient habits among them.

  A last result targeting user awareness, as well as supporting the monitoring activities in the trial, has been the integration of the data from the deployed wireless metering/monitoring system with a web interface which allows a visualization of data through customized charts and dashboards. One of the main advantages provided by this interface is that it allows the configuration of access permissions to the level of individual metering devices. This means that each user can be given a completely customized profile in terms of the parameters which can be visualized. Based on this feature, the web interface is valid both for facility managers/energy efficiency consultants who may need to access all the monitored building parameters, and for the building's end-users who just need the visualization of a small subset of key parameters. Further research is needed in order to simplify even more the visualization of data by building end users with no energy expertise, which could be done through appropriate mobile applications.

Working in this direction, the interface has been tested with a small group of 6 building end-users with different areas of expertise (ICT, energy efficiency, or other completely different areas), and it has also been checked with experts from the energy services business division of ACCIONA group. The feedback from all these stakeholders is currently being used in order to develop more simplified interfaces consisting of dashboards with customized widgets, as well as for defining the types of alerts which can be more useful for the different user profiles.

- **Direct control of energy consuming equipment/devices by end-users:** In the case of office buildings, IT equipment such as PCs, printers, etc. usually represent the largest percentage of energy consumption (up to 20% of the electricity consumption of the building) over which end users have direct control.

  Other equipment with potential interaction are lighting systems (in cases where the control of this system is not completely centralized and therefore luminaires can be switched on/off by end-users) and some independent heating/cooling units, e.g. in meeting rooms. For these cases end-users may be supported by additional monitoring and control systems which can help them optimize the use of the equipment they can directly manage, to the greatest possible extent.

  In the case of the Madrid trial no results have been achieved yet related to this type of user interaction, as no specific monitoring/control systems (e.g. smart plugs connected to controllable devices) were included for this purpose in the trial design. Nevertheless, the metering system deployed is a good basis which can be further enhanced with additional monitoring devices in order to obtain an even more detailed breakdown of the energy consumption of the building, thus helping end-users to identify which part of the building consumption can be directly allocated to their activities.

- **Detection of systems malfunction:** End-users can be key stakeholders in detecting malfunction of energy consuming equipment or inadequate equipment control set points, as these facts frequently lead to situations of discomfort which they suffer directly (e.g. too high/low temperatures in certain building areas). Therefore, their feedback is a valuable input for building/facility managers. The latter can also react quicker to any abnormal situation if they are given immediate, near real time updates of the working status of the building installations.

  A key result of the trial experimentation has been the integration of the BCC data with GEs and DSEs, as this allows the subscription to the data and customized alerts coming from the different energy consuming devices of the building (e.g. HVAC units, boilers, etc.), thus enabling future development of dedicated applications for building managers, through which they can receive and visualize the most critical information and alerts, facilitating the daily operation of the facility. A point for further research beyond the project timeline is how to integrate the available data from the building with the mentioned feedback from the end-users. Adequate processing algorithms are needed for instance in order to combine the feedback about comfort (which could be provided through a mobile application) coming from different users, in order to calculate the most comfortable temperature set point which shall be configured for each building area.

5. Conclusion

The activities carried out in the Madrid trial within WP2 have led to very positive results, both in terms of the foundations which have been laid for further development of innovative energy services for industrial and tertiary buildings, and of the research which has been done regarding the possibilities of interaction of end users with the energy related installations in this type of buildings, which is an area with great potential for the development of innovative services targeting such interaction.

The trial has allowed testing how Future Internet technologies can facilitate and empower the development of three different typologies of energy services which can be commercialized by ESCOs, these are:

- Auditing, monitoring and verification services, through an appropriate metering/monitoring system, targeting the improvement of the energy management global strategies and the update of the energy consuming devices of a building.
- Demand management services addressing the optimization of the day-to-day operation of a BMS, including remote visualization.
- Services for management of energy generation and storage integrated in buildings and their interconnection with the energy grid.

The interaction with industrial and tertiary building end-users' still needs to be further researched, as it has been usually given less attention compared to other contexts, e.g. residential buildings, due to the limitations that these buildings normally have for interacting with its installations. In spite of these limitations, end-users need to be more aware of their capabilities to influence on the energy consumption of buildings, and they can give valuable feedback to improve the energy maintenance and management routines.

FIWARE has proven to provide adequate components for supporting the delivery of all these services, in particular with regard to the capacity of processing huge datasets and for managing subscriptions to the different data sources of the trial. Together with the trial API, the trial infrastructure constitutes an excellent basis for building additional applications providing innovative services, which can be developed by third parties who can access the trial data. Nevertheless, the reliability of FIWARE platform and its development and support strategies need still to be improved in order to make its use adequate in the context of delivering commercial services.

6. List of Abbreviations

API	Application Programming Interface
BCC	Building Control Centre
BMS	Building Management System
DSE	Domain Specific Enabler
ESCO	Energy Service Company
GE	Generic Enabler
HVAC	Heating, Ventilation, Air Conditioning
ICT	Information and Communication Technologies
RITE	Reglamento de Instalaciones Térmicas en Edificios (Spanish Regulation of Thermal Installations in Buildings)