



SAVE ENERGY  
Grant agreement no.: 238882

*Deliverable D 4.1*

# Open, service-oriented architecture for energy efficiency management system

*Covering period 1.03.09 – 31.05.09*

Document ID D4.1.17.07.09

Authors: CeTIM

Contributors: ISA, There, KYAB, CKIR, ALFAMICRO, Leiden

Workpackage: 04

Version: V01

Date: 29<sup>st</sup> of July 2009

Project Coordinator: ALFAMICRO

Contract Start Date: 01.03.2009

Duration: 30 months

Dissemination Level: Public



Project funded by the European Community  
under the Competitiveness and innovation framework  
programme 2007 – 2013





## Executive Summary

The SAVE ENERGY project aims at a validation experiment about how ICT, especially serious gaming, can lead to behaviour change of (public) building users and hence a reduction of energy consumption. To this end, the project will undertake five pilot validation experiments with public buildings. The results of these experiments shall be comparable and generalized into scientific conclusions and policy recommendations to use ICT for saving energy.

This document is positioned at the beginning of the SAVE ENERGY project (project month 3 of 30) and is among the first reports in the project. This first phase of the project is dedicated to establishing “concepts” (Description of Work, p. 45), which will later, after month 6, be detailed into “models and processes”. This architecture document contributes to collecting, structuring, and integrating the initial set of concepts to be further developed for experimentation in the project. Within the technical work package No. 4 of the SAVE ENERGY project, this is the first deliverable, which will be followed by a prototype of an essential SAVE ENERGY system (Del. 4.2) that demonstrates key features of an SAVE ENERGY system in a laboratory setting. The final report (Del 4.3) will be a business architecture chapter to be attached to the here represented report. It will collect experiment findings, discusses them and conclude on business issues of the European wide adoption of a SAVE ENERGY system.

This architecture document is not a technical design document but a structure to support the usability experiments and the later collection of data and findings. Guiding questions that we assume for the SAVE ENERGY architecture therefore are the following:

- How do SAVE ENERGY systems interact and change the energy consumption behaviour of individual users in public buildings? Do serious game interactions stimulate user behaviour to decrease energy usage?
- What organizational behaviour change is needed for public organisations for the adoption of SAVE ENERGY solutions?
- What is the business behaviour change associated with the adoption of SAVE ENERGY solutions by the supplying industry.

Like any architecture, this document makes choices about the fundamental elements of the system, their integration, design, and evolution principles. The SAVE ENERGY architecture follows a four-layer middleware structure. Given the heterogeneity of the pre-existing implementation at the five pilot sites this architecture document is to initiate and motivate cross-manufacture integration. Rather than defining yet another smart home standard, this architecture document shall serve for discussion and comparison of real existing modules, systems, and solutions. We therefore refer to it as “ideal” reference in contrast to the “real” pilots and the suppliers’ “real” intelligent building installations.

The deliverable is structured as follows. After a more detailed introduction architecture definitions from literature are introduced and reported examples are reviewed. Then the SAVE energy architecture is introduced and the relevant solutions available from technology partners in the consortium, and the pilots are described in more detail. The document closes with conclusions and indications for next steps in experimentation.

## Revision Table

Version	Date	Contributions from:
1.0 Initial draft	2009-03-21	E. Marges, B. Katzy, H. Uittenbogaard (CeTIM)
1.1 Consortium Discussion included	2009-05-28	E. Marges, B. Katzy, H. Uittenbogaard, A. Strube (CeTIM), A. Kippo (Helsinki Metropolia University of Applied Sciences), VP. Niitamo, S. Penttinen (Nokia), J.L. Malaquias, M.J. Benquerença (ISA), B. Cowley (CKIR)
2.0 Consolidation of consortium Input for Deliverable Finalization	2009-07-15	E. Marges, B. Katzy, H. Uittenbogaard, A. Strube (CeTIM)
2.1 Intermediate Consolidated version	2009-07-17	B. Cowley (CKIR), K. Kuusinen (Helsinki), M. Tommis (MCC), Á. de Oliveira (ALFAMICRO), Huub Schuurmans(Leiden)
3.0 WP submission to Coordinator	2009-07-31	Task 4.1 Members



## SAVE ENERGY Consortium

SAVE ENERGY Consortium			
Number	Partner	Partner Short Name	Country
1 (Coordinator)	ALFAMICRO - Sistemas de Computadores, Lda	ALFAMICRO	Portugal
2	Stichting CeTIM - Center for Technology and Innovation Management	CeTIM	Netherlands
3	GREEN NET Finland	GREEN NET	Finland
4	Helsingin kaupunki	HELSINKI	Finland
5	Helsingin kauppakorkeakoulu	HSE - CKIR	Finland
6	Intelligent Sensing Anywhere, S.A.	ISA	Portugal
7	Gemeente Leiden (Leiden Municipality)	LEIDEN Municipality	Netherlands
8	LISBOA E-Nova Agência Municipal de Energia-Ambiente de Lisboa	LISBOA E-Nova	Portugal
9	Luleå Tekniska Universitet	LTU – CDT	Sweden
10	Luleå Kommun (Luleå Municipality)	LULEA LKTF	Sweden
11	Manchester City Council	MCC	UK
12	Helsinki Metropolia University of Applied Sciences	METROPOLIA	Finland
13	NOKIA Corporation	NOKIA	Finland
14	RTS - Real Time Solutions, Lda	RTS	Portugal
15	Sociedade Portuguesa de Inovação Fomento da Inovação	SPI	Portugal
16	University of Salford	USAL	UK



## Table of Contents

Executive Summary .....	2
Revision Table.....	3
SAVE ENERGY Consortium.....	4
Table of Contents .....	5
Table of Figures .....	7
1 Introduction.....	8
1.1 What is a Software Architecture? .....	10
1.2 User-Centric SAVE ENERGY Pilots.....	11
1.2.1 Helsinki .....	11
1.2.2 Leiden .....	11
1.2.3 Lisbon.....	11
1.2.4 Luleå .....	12
1.2.5 Manchester.....	12
1.3 Living Lab Methodology .....	13
1.4 SAVE ENERGY Components.....	15
2 Software Architectures.....	16
2.1 Architecture Requirements .....	16
2.2 Data acquisition strategies and methods.....	17
2.3 Design Alternative 1: Direct-Data Architecture.....	18
2.4 Design Alternative 2: Middleware Layered Architecture .....	19
2.5 Design Alternative 2: Distributed Architecture .....	20
3 The Open SAVE ENERGY Architecture.....	22
3.1 The Open SAVE ENERGY Middleware Architecture .....	23
3.2 Local SAVE ENERGY Connector.....	25
3.3 SAVE ENERGY Serious Game Connector.....	26
3.4 Evolution.....	28
3.5 Business Architecture .....	28
4 Revision of Supplier Architectures For SAVE ENERGY.....	29
4.1 The ISA Middleware architecture.....	29
4.1.1 Architecture overview .....	29
4.1.2 General Architecture .....	30



4.1.3	Detailed architecture.....	32
	<i>Communications module</i> .....	32
	<i>Database module</i> .....	33
	<i>WCF module</i> .....	33
	<i>Client applications</i> .....	34
4.1.4	Online connections.....	34
4.1.5	Architecture advantages.....	35
4.2	Nokia/There corporation SAVE ENERGY Architecture.....	36
4.2.1	Home Automation Service Framework.....	36
4.3	The Saber architecture.....	38
4.3.1	Architecture overview.....	38
4.3.2	General architecture.....	38
4.3.3	Detailed architecture.....	39
4.3.4	Interoperation with other measurement systems such as the SAVE ENERGY Middleware.....	39
4.3.5	Summary of Saber Architecture.....	39
4.4	Plugwise Architecture.....	40
4.4.1	Plugwise Technology.....	40
4.4.2	Summary of the Plugwise Architecture.....	40
4.5	Discussion of SAVE ENERGY Supplier Architectures.....	41
4.6	Concept implementation plan for Leiden Pilot.....	<b>Error! Bookmark not defined.</b>
5	Conclusions.....	50
6	Next Steps in Living Lab Experimentation.....	41
6.1	Pre-studies.....	43
6.2	Experiment Implementation.....	44
6.3	Concept Experimental Setup for the Leiden Pilot.....	46
7	Glossary.....	51
8	References.....	52



## Table of Figures

Figure 1 Work Package 4 .....	8
Figure 2 Relevant Business Environment .....	9
Figure 3 Helsinki Pilot .....	11
Figure 4 Leiden Pilot .....	11
Figure 5 Lisbon Pilot .....	11
Figure 6 Luleå Pilot .....	12
Figure 7 Manchester Pilot .....	12
Figure 8 SAVE ENERGY Architecture from Project Proposal .....	15
Figure 9 Mesh network .....	20
Figure 10 Overview of main system components as presented in the project proposal .....	23
Figure 11 Overview of middleware architecture .....	24
Figure 12 Serious Game Architecture .....	26
Figure 13 ISA General Architecture .....	30
Figure 14 ISA Detailed Architecture .....	32
Figure 15 There Home Control Center Architecture .....	36
Figure 16 Plugwise Architecture Overview .....	40
Figure 17 Office Room in Leiden Pilot .....	47
Figure 18 Leiden Pilot Implementation Plan .....	49

## 1 Introduction and Methodology

This document is a deliverable for the SAVE ENERGY CIP Project. The SAVE ENERGY project is a validation project that experiments how innovative use of ICT can lead to energy savings in public buildings by using a serious game to change the users' energy behaviour.

The SAVE ENERGY project has selected 5 pilots in major cities across Europe where a simple model will be used to experiment with user behaviour transformation to decrease energy usage. Sensors will be installed in every pilot to measure and gather detailed information on energy usage. This energy usage will be presented to the user with a high update frequency and this data will also be fed into the serious game application.

The SAVE ENERGY project is a 30 month project and this is one of the first reports in this project, this means that this document is formed in the concept phase of the project where the key concepts are selected for further development into the "models and processes" report in the next phase.

This deliverable 4.1, the open, service-oriented architecture for energy efficiency management system, is the first deliverable for the technical work package number 4 of the SAVE ENERGY project. Work package 4 is structured into 5 tasks that result in 3 deliverables as visualized in the following diagram.

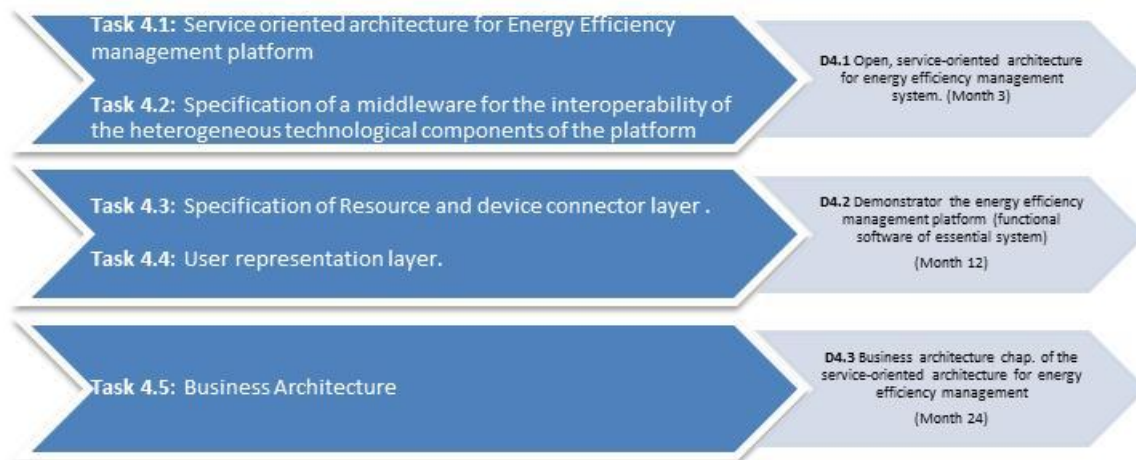


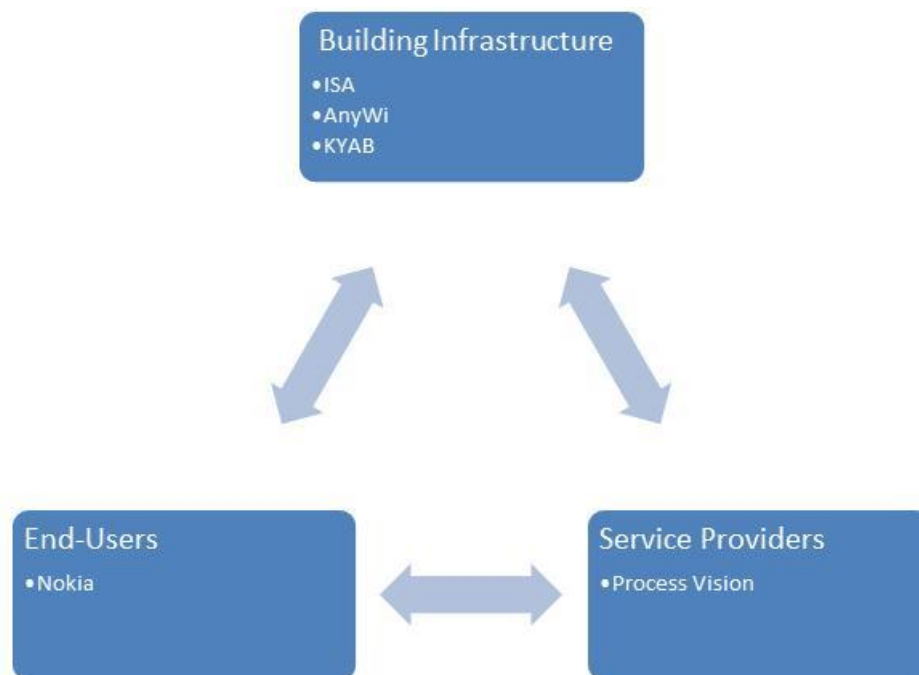
Figure 1 Work Package 4

This is a CIP project using a living lab methodology for user validation. The architecture document therefore is therefore not intended to be a technical design document within a software engineering process, but is designed to support the development of the experiments that test the behaviour change and to supports the later collection of data and consolidation of findings.

The work method of task 4.1, which led to the here presented deliverable has been three iterative cycles of 1/ extensive literature research, 2/ interviews and discussions with the pilots as early involvement and 3/ interviews and workshops amongst internal and external technology providers. The results have mature in each cycle from an explorative compendium of material available in the consortium, to initial ideas, and finally, to the here presented structured description of the consortium-wide shared understanding of this architecture.

All systems reflect to a certain level the environment in which they operate. Discussions in the project have shown that the industrial context of the convergence of former separate industries of building infrastructure, telecom service providers, and end user terminals, which clearly is a non-technical context of this architecture can be expected to have a dominant influence on the user validation results. Figure 1 shows the situation, which will later be detailed in the business architecture of task 4.5. The business architecture chapter is part of the technical work package since it is most likely that the industries that are involved in this technology will converge. The industry is fragmented in three stakeholders; Building Infrastructures, Service Providers, and End Users. Figure 2 shows an overview of the relevant business environment for this architecture.

A validation result of this industrial context is that the consortium partners well cover terminal manufacturers and building infrastructure providers. Cooperation with external partners has been established to cover the Service Provider perspective.



**Figure 2 Relevant Business Environment**

The document will now describe the concepts of software architectures and will then introduce the pilots and the living lab methodology that is used during this project. After that common software architectures from the literature are being introduced and discussed and compared to the solutions that the technical partners have available in this project.



## 1.1 The SAVE Energy architecture as a Software Architecture

The SAVE energy project is in the domain of the usage of information and communication technology, ICT, for energy efficiency. The decision therefore has been made to approach the architecture from a software architecture point of view. Compared to earlier standards, for the example the EIB/KNX European Integration Bus standard from 1962, which largely is a control system architecture on the basis of hardware components with some embedded software, this choice is modern and shall allow better usage of Internet technology and the stronger relevance of software.

In the late 1960ies it was already identified by scientists that the structure of a "software (computer) system matters" and that "getting the structure right is critical" (Origins of Software Architecture Study, 2006). Computer systems usually consist of different components and relationships between the components, all these components and concepts as relationships and complexity of a computer system are often defined in a software architecture. The SAVE ENERGY system will consist of fairly standard hardware with many software components what implies that the Software Architecture approach is an apparent choice. This chapter will introduce the concepts and definitions of the software architectures as they are commonly understood.

There are many definitions of software architecture, but the most widely used definition is the ANSI/IEEE standard 1471-2000. According to IEEE the organization software architecture is defined as

*"The fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution."* (Maier, Emery, & Hilliard, 2001)

The IEEE 1471 architecture definition standardizes the documents that define the architecture, not the process of designing one; it is therefore a blueprint standard (Maier, Emery, & Hilliard, 2001).

There are many different architecture description languages or architectural styles defined, but in order for the IEEE to create a blueprint standard, the concept of views and viewpoints was defined in the IEEE 1471 standard. A viewpoint is in fact a place from where you can look at the system; a view is what you see looking from that viewpoint. This can be compared with the different views that are used in architectural designs for buildings.

This deliverable already introduced two relevant view points: First, the industry viewpoint with the relevance of the ongoing conversion, and second, the technical viewpoint with a focus on software. When we look back at the IEEE standard definition for Software Architectures, the system should be *"organized to enable evolution and integration of all its components"*. As described in the introduction, the SAVE ENERGY project works in a complex business environment where several parties from different industries work together. The architecture therefore has to enable the integration of the industries and guide the evolution. Chapter 2 will describe the challenge of integration more.

Conform to the user centric approach of Living Lab experiments we will proceed by introducing the user view point on the architecture with an introduction of the 5 SAVE ENERGY pilots and then present the resulting overall architecture as presented in the SAVE ENERGY Project Proposal.

## 1.2 User-Centric View on the Architecture by the SAVE ENERGY Pilots

The SAVE ENERGY Pilots are located in 5 major cities over Europe, Helsinki (Finland), Leiden (The Netherlands), Lisbon (Portugal), Luleå (Sweden) and Manchester (United Kingdom). Due to the distribution of the pilots all over Europe, the climate for each of the pilots is quite different and this project can therefore address the different challenges that the climate types bring us regarding to energy saving. Besides the geographic distribution, the pilots also differ in building type and function. Although all buildings are publicly owned buildings, some host offices for the municipality, some are schools and others are the city hall.

The following paragraphs shortly present all the pilots of the SAVE ENERGY Project. More detailed description of the pilots will be given in the SAVE ENERGY project deliverable 2.1 and 2.2.

### 1.2.1 Helsinki



Figure 3 Helsinki Pilot

The Helsinki Pilot aims at changing the behaviour of pupils, teachers and other staff at 2 secondary schools. The pilot focuses in optimizing the usage of lighting, heating and other equipment together with user actions, which have impact on these systems. With help of the SAVE ENERGY project, Helsinki hopes to identify new ways to decrease the energy usage in their public schools and to arouse interest in energy efficiency issues and better consumer habits to households.

### 1.2.2 Leiden

The municipality of Leiden offers the SAVE ENERGY project to run a pilot in the City Hall providing Citizens Services. In this pilot we have selected eight almost identical office rooms that will all be equipped with sensors. Four of the eight rooms will get detailed information about their energy usage so that the employees are stimulated to change their usage behaviour. The other four rooms will be used as a reference, so that comparable results can be concluded at the end of the project.



Figure 4 Leiden Pilot

### 1.2.3 Lisbon

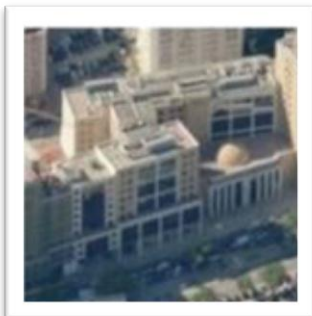


Figure 5 Lisbon Pilot

The Lisbon Pilot for the SAVE ENERGY Project is the Lisbon's Municipality main office building. This building was opened for use in 1998, serving both as administrative office and public attending services.

Key users of this building within the SAVE ENERGY Project therefore are the office employees.

### 1.2.4 Luleå

The Lulea pilot is owned by the municipality and provides cultural services to the Luleå Residents. Lulea Pilot intends to achieve energy efficiency performance through ICT applied to the Energy Management System and empowering the users of the building to take appropriate actions. Lulea Pilot intends to extend its energy efficiency practices beyond the building, by motivating the users of this very popular cultural space visited daily by an average of 3.000 people.



Figure 6 Luleå Pilot

### 1.2.5 Manchester

The Manchester SAVE ENERGY pilot will take place at the city's historic Town Hall.



Figure 7 Manchester Pilot

Completed in 1887, Manchester Town Hall was built in the neo-Gothic style at a cost one million pounds (£80m at 2009) in Albert Square. As a Grade 1 listed building, the Town Hall falls under the highest category of protection in the UK and is defined as “of exceptional interest”.

The Town Hall pre-dates the use of electricity and was originally constructed to be gas lit, hence all electrical installations are post construction. The building's design and heritage (Grade 1 listed) presents particular challenges in terms of energy efficiency and carbon emissions.



### 1.3 Living Lab Methodology

The SAVE ENERGY project is being implemented following a user-driven approach as provided by the Living Lab Methodology. The choice for this methodology is based on the fact that there are many technical solutions on the market to fulfil the needs that this project has, but so far there is little adoption of those solutions and user market penetration for these solutions remains low. By using a user-driven approach as the Living Lab Methodology, SAVE ENERGY project can experiment from a user perspective, what the problems and barrier towards adoption are.

The expected result of this study is a better understanding of the functionalities and services required by the users, how the technologies and services that need be customized to fulfil user and market request, and in a successful case to provide five successful pilot cases for demonstration. These requirements and specifications are being co-developed in close connexion with the users, the suppliers, the project facilitators and technology experts. The experience at individual Pilots is being exchanged with the other Pilots in close collaboration with the SAVE ENERGY system integrators and architecture experts. However in this industry do the technology providers have a challenge to include the users and generate user acceptance for their starting at “the early phases of context research and idea generation through the later phases of development and implementation” (Følstad, 2008). SAVE ENERGY is using the pilots as (best) practice cases on methodologies and improving them through field experimentation. The Living Lab methodology can be a way to solve the innovation challenges for ICT providers (Eriksson, Niitamo, & Kulkki, 2009). The living lab methodology represents a “user-centric research methodology to sensing, prototyping, validating and refining complex solutions in multiple and evolving real life contexts.” (Eriksson, Niitamo, & Kulkki, 2009).

Living labs have been gaining increased popularity and are used in the following fields according to the available research on Living Labs: Mobile ICT (De Leon, Eriksson, Balasubramaniam, & Donneley, 2006) (Lievens, Van den Broeck, & Pierson, 2006), ubiquitous computing (Abowd, 2000) (Intille, Larson, Beaudin, Nawyn, Munguia Tapia, & Kaushik, 2005), collaborative work (Katzy, Loeh, & Sung, 2005) and cognitive systems engineering (MacEachren, Cai, McNeese, Sharma, & Fuhrmann, 2006) (McNeese, An Ecological Perspective applied to Multi-Operator Systems., 1996) (McNeese, How video informs cognitive systems engineering: making experience count., 2004). The first Living Labs were in almost the same area as this research will be; the area of smart homes (Eriksson, Niitamo, & Kulkki, 2009). In the early Living Lab, the validation was setup with an experiment where homes where enhanced with new technologies, then people stayed in these homes for several time and the behaviour of the people was observed and measured.



The SAVE energy project, and with it this architecture document carries some methodological innovation on living lab methodologies because despite its current use “the current Living Lab research Literature indicates a lack of common understanding of how Living Labs can be used for ICT innovation and development” (Følstad, 2008). For sure is that “Living Labs mainly seem to be regarded as environments in which to present solutions to users” (Følstad, 2008) and papers argue about that Living Labs provide “insight into unexpected ICT uses and new service opportunities” (Følstad, 2008). As this project is not a development project, these observation from Asbjørn Følstad do not impact our use on the Living Lab methodology, but Asbjørn Følstad concluded a literature review in 2008 stating that “evaluation is a common purpose of the Living Lab methodology, in the sense that new ICT solutions are validated or evaluated together with users” (Følstad, 2008). Furthermore they are also used to co-create with the users new applications of existing technologies (Oliveira, Fradinho, Caires, Oliveira, & Barbosa, 2006).

SAVE ENERGY Project aims at validating the Intelligent Building Management systems thus the living lab methodology fits the SAVE ENERGY Project well.

## 1.4 SAVE ENERGY Architecture Components

The Description of Work of the SAVE ENERGY Project provides a first structure of the components in the architecture of this project.

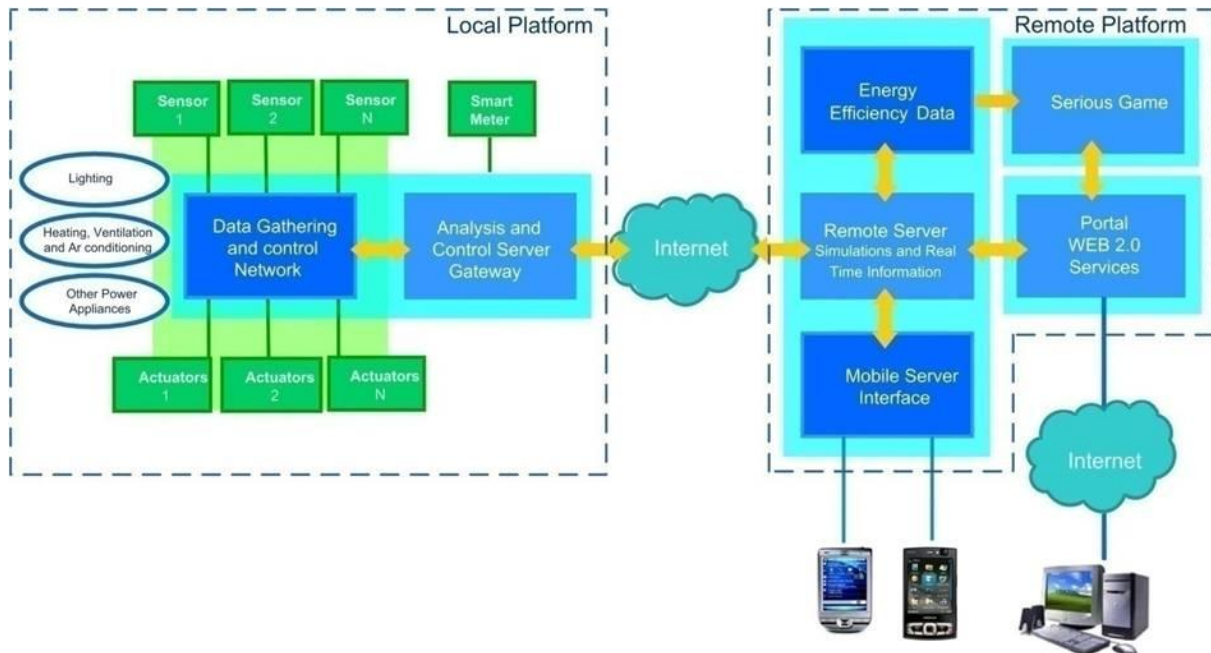


Figure 8 SAVE ENERGY Architecture from Project Proposal

From a user perspective, the most important components in this architecture are the sensors and the client applications. The sensors will be placed in the pilots and the data measured by these sensors will in the end be presented using a serious game, web-portal, mobile application or a screen on a wall to the users.

In order to get the data from the sensors being presented in any form, the data has to be collected, combined and analyzed and transferred to the presentation format. The SAVE ENERGY Project Proposal therefore proposes to split the architecture in three main parts: a local platform, a central platform and clients. The local platform consists of sensors and a gateway. The sensors measure energy usage, and other valuable data of the pilots and the local gateway gathers all data from the each of the sensors and provides this to the central platform. As all of the pilots use different integrators and suppliers, they will probably do not have equal hardware with interoperable communication protocols.

The central platform gathers the data from all the pilots in the project, analyses the energy usage data, and makes the data accessible in a format that the clients can read. The clients can either be a mobile telephone, a computer, or a screen on the wall. In all cases the SAVE ENERGY internet portal and its Serious Game module as software will carry the intelligence to show the energy consumption to the users.



## 2 The Save Energy Software Architecture

This chapter will present architecture alternatives that are available according to the literature, but in order to do so, some requirements have to be formed first.

### 2.1 The policy level - Architecture Requirements

The aim of the project is to generalize findings from five concrete pilot cases to recommendation, which can guide strategic business decisions and policy recommendation. The architecture can provide some structure and links to the challenge of bridging the concrete, but specific, with the general, but abstract. This work package, number 4, is positioned between the vision of WP 2 and the cases of Wp 6, from which we derive a first requirement. The requirements are numbered for better reference throughout the document.

**Architecture Requirement 1:** To be an “Ideal” reference for the comparison of the “real” implementations at the five pilot sites and generalize the conclusions.

The main goal of the project is the experimentation of behaviour change of humans, users of the buildings through a serious game, for which a seamless integration of sensors (and eventually examples of actuators) of different manufactures is needed. As already described in chapter 1, the definition of software architecture that we use in this project is, according to the IEEE standard 1471-2000:

*The fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution.” (Maier, Emery, & Hilliard, 2001)*

According to this IEEE standard definition for software architectures the system should be organized to enable evolution and integration of all its components. In this SAVE ENERGY project we already have identified the challenges that come forward when the users have different suppliers and integrators for their energy management systems. Each of the pilots seems to have different system integrators with different solutions at the pilots. To overcome this challenge we have

**Architecture Requirement 2:** to enable cross-manufacture integration.



Although there are many strategies to get to this cross-manufacture integration, many in the field of building automation have failed so far. In the past months our technical partners in the SAVE ENERGY Project have decided to aim at

**Design Principle 1:** using open, standard protocols

that all pilot integrators use between their sensor networks. This means that the equipment and protocols that are used by the pilot integrators can be from any brand, as long as their local gateway is able to communicate with the SAVE ENERGY platform following this standardized protocol; what means “the same message formats and sequences” (Bernstein, 1996).

## 2.2 Data acquisition strategies and methods

In order to be open in a world of uncountable sensors and devices, it is an advantage if the Save energy system can communicate with the least possible knowledge about the specifics of any given device, while making sure it can deliver and receive data from it. The software architecture of the Save Energy system therefore can further be typified as information / data architecture. Because the different manufacturers can have different data acquisition strategies and methods, it is required that the middleware

**Architecture Requirement 3:** Enables seamless integration with third party data acquisition strategies and methods.

Since the SAVE ENERGY middleware will receive and process the data that is gathered by the sensors the design of the middleware needs to match the ideas on the data acquisition strategies and methods. This implies that there is need for concrete plans for the data visualization to determine update rates of the sensor information as well what pre-processing of sensor data is required by the sensors before sending this data to the SAVE ENERGY middleware. Nevertheless, for the purpose of this project, the concrete data acquisition strategies should be aligned with the Serious Game and other data visualization methods for the SAVE ENERGY project.

Within the information / data oriented software architectures, will now review in more detail three remaining architecture alternatives that could be used for the SAVE ENERGY Open, service-oriented architecture for energy efficiency management system.

## 2.3 Design Alternative 1: Direct-Data Architecture

This first architecture is the most straightforward architecture that can be used in systems like in this project, but unfortunately due to their simplicity, they have some disadvantages. In this architecture components that require a data connection are directly connected. According to the Project Proposal, this would be the sensors in the pilot buildings on one side and the clients on the other side.

When we visualize this for the SAVE ENERGY Project, it would look like this:

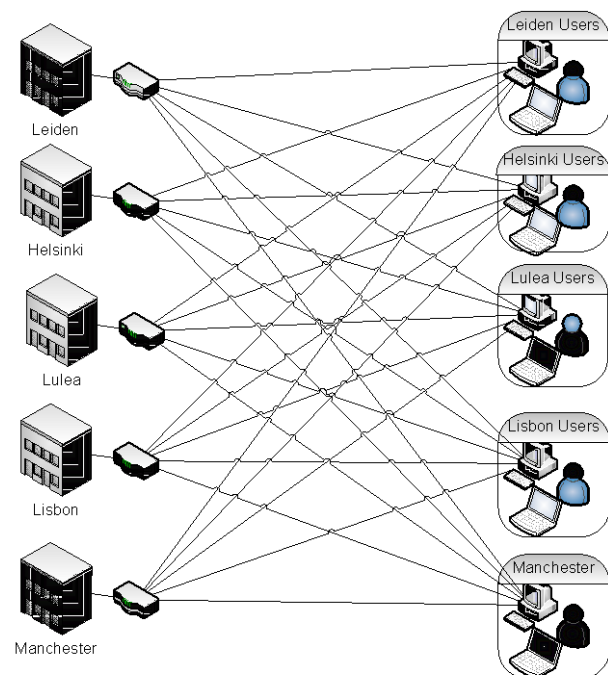
On the left side of the image, we see the pilot buildings in which sensors are placed that are connected to a router. On the right side we can see that all clients have an individual connection to each pilot to gather and compare data. Since there is no layer that provides guidance between the pilots' sensors and the clients, this system is not flexible, whenever a new pilot is added, or a pilot has changed, all clients need to be updated with this information.

The apparent advantages of this design alternative are:

- + Easy and quick installation on the very small scale

The disadvantages on the other hand are:

- Scalability challenges
- Many connections are required from every client to every pilot.



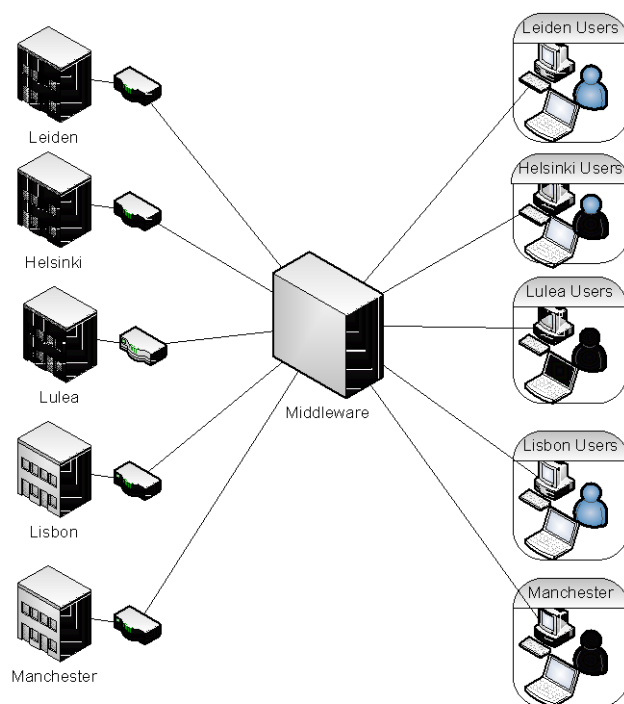
## 2.4 Design Alternative 2: Middleware Layered Architecture

This second design alternative is basically an update to the Direct Data Architecture where a centralized middleware connects with all the pilots and with all the clients. Serving as a broker this implies a shared point of access. When a system consists of multiple distributed applications the use of a middleware layer like this is very common. Bernstein describes the use of middleware layers in an architecture as following: *“To help solve customer’s heterogeneity and distribution problems, and thereby enable the implementation of an information utility, vendors are offering distributed system services that have standard programming interfaces and protocols. These services are called middleware services, because they sit “in the middle,” in a layer above the OS and networking software and below industry-specific applications”* (Bernstein, 1996)

In the scenario of the SAVE ENERGY project a middleware layer would be located in between of the pilot systems and the serious game.

The advantages of the middleware layer are:

- + Easy integration with the pilots for the serious game and other parties that request data that is measured by the sensors in the pilots.
- + The Business Logic algorithms can gather all pilot data accessing one central point.
- + If new pilots join, they can connect to the middleware layer and there is no need for change in the serious game or any other presentation method to gather the data.
- + Any vendor can connect to the middleware platform by using the open standard protocol.
- + Industry has accepted middleware architectures as a standard solution for complex management systems.



The disadvantages on the other hand are:

- Scalability challenges when the number of pilots gets very large.
- Traditional Middleware solutions are often too heavy-weight for smart environments (Coyle, et al., 2003)

## 2.5 Design Alternative 2: Distributed Architecture

Opposite to the middleware layered architecture is the distributed or meshed architecture. Many wireless sensor networks are already built using this kind of topology; a meshed network. This architecture avoids the need for a dedicated infrastructural support and the cost of services is distributed over the node population (Coyle, et al., 2003).

The roots of the Internet are in essence a meshed network, since all network nodes are in a way connected to each other and nodes can communicate with other nodes by determining a path using other nodes. These peer-to-peer (P2P) systems are researched significantly more recently and systems as Chord (Stoica, Morris, Karger, Kaashoek, & Balakrishnan, 2001) and Pastry (Rowstron & Druschel, 2001) show potential.

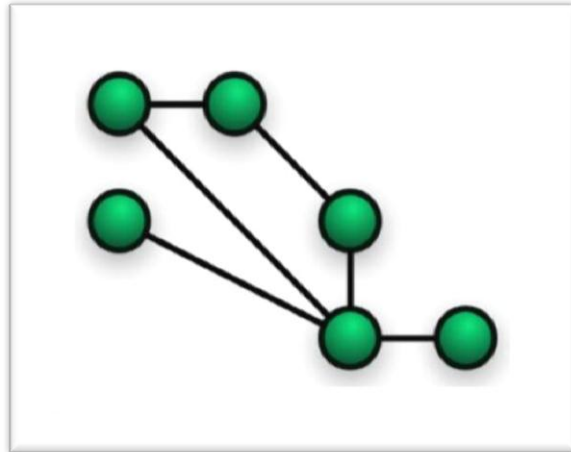
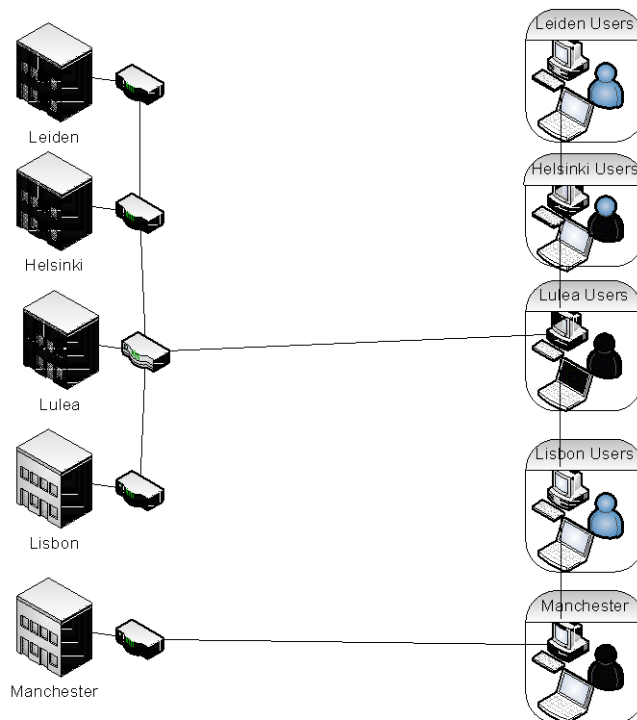


Figure 9 Mesh network



When we reflect this kind of topology to the SAVE ENERGY platform, we have each pilot as a node and the nodes are meshed using the existing internet network. Although all pilots are interconnected there must be at least one layer that informs the nodes on the ways to connect to each other. This is not equal to the middleware layers and the overhead of this much less than a complex middleware layer.



SAVE ENERGY EU CIP Grant agreement no.: 238882



The biggest advantages of a distributed architecture as this are:

- + Almost unlimited scalability due to distributed data storage
- + No single points of failure; this architecture is very robust

Unfortunately, the disadvantages of this architecture are:

- Difficult to achieve interoperability and openness without developing yet another standard.
- Firewall systems in place often makes incoming connections impossible.



### 3 The Open SAVE ENERGY Architecture

Discussing the three design alternatives as presented, we see that the direct data architecture would be too simple to handle the complex business systems we have in place and this would therefore not comply with the interoperability and openness that this project tries to achieve. Both the Middleware-Layered Architecture and the Distributed Architecture can handle this projects business system where the only differences exist when it comes to scalability and complexity.

The scalability issues of the middleware-layered architecture are only critical in systems where high volumes of data is transferred, unless that there are many sensors attached to this system and the number of communications will be relatively high, the amount of data transferred can be regarded low. The complexity of creating openness and interoperability in the distributed architecture would make this project focus on technical development more instead of the targeted behaviour change experiments.

Middleware layered architectures are also accepted by all involved industries which means that the such architecture for the Save energy architecture will make it more compatible with technical solutions already exist and enables to validate this technology instead of developing it.

From these observations it would be best to use a middleware-layered architecture in the SAVE ENERGY project. From an innovation point of view, middleware architectures are base technologies, while meshed architecture are more recent with a potential to become core technologies in the near future. In the frame of this project, which is geared at user behaviour change, it therefore seems appropriate to choose a middleware structure for faster adoption and hence stronger user experience. For research projects in the domain of networks, the choice might be different. The following chapter will now continue with describing a middleware layered architecture for the SAVE ENERGY project. We will proceed from an introductory architecture overview from the project contract to the concrete development results for the Save Energy architecture.

### 3.1 The Open SAVE ENERGY Middleware Architecture

The SAVE ENERGY Project proposal has a figure included that shows the main system components for this project. In this chapter this figure will be translated into a more technical representation the architecture with the use of an Open SAVE ENERGY Middleware Architecture. The figure with the overview of the main system components in the SAVE ENERGY project from the project proposal was as following:

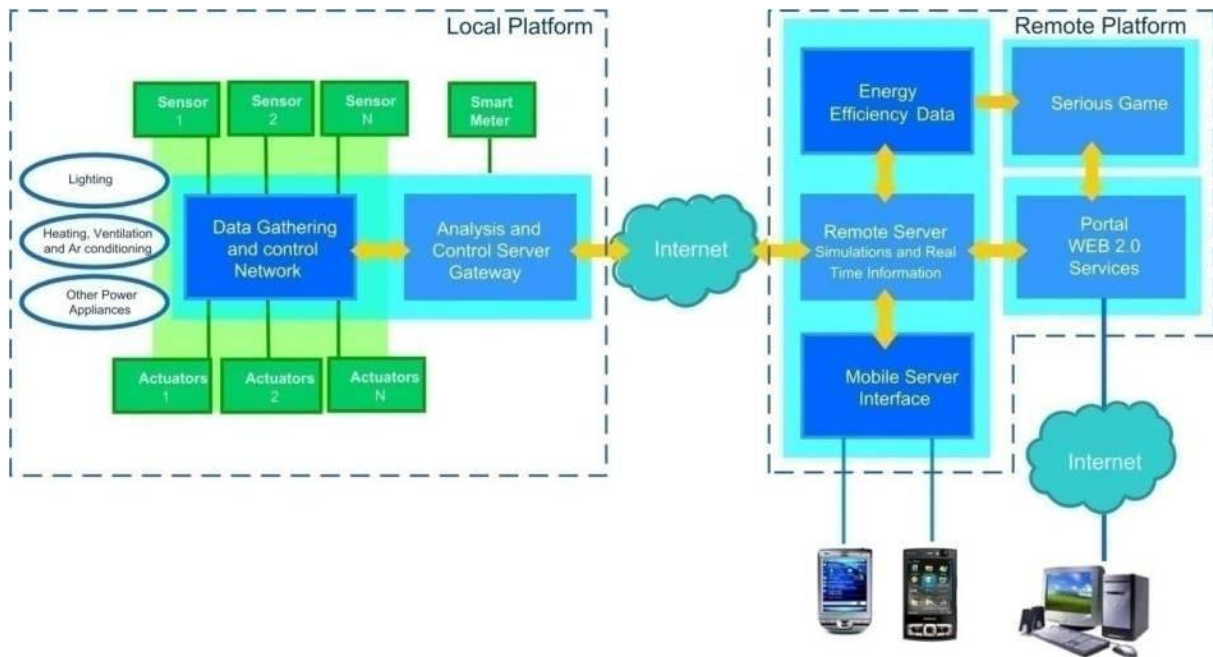


Figure 10 Overview of main system components as presented in the project proposal

This overview shows that the system consists of three parts, a local platform that runs at the pilot site, a central platform that receives and saves all the data from the pilots and the last part of this overview shows the clients that can either be mobile phones, web browsers that visit the SAVE ENERGY website or the Serious Game application.

When we translate these parts into a middleware architecture and include the architecture requirements as presented in chapter 3, we come to a commonly used 4 layer architecture as visualized in the following figure.

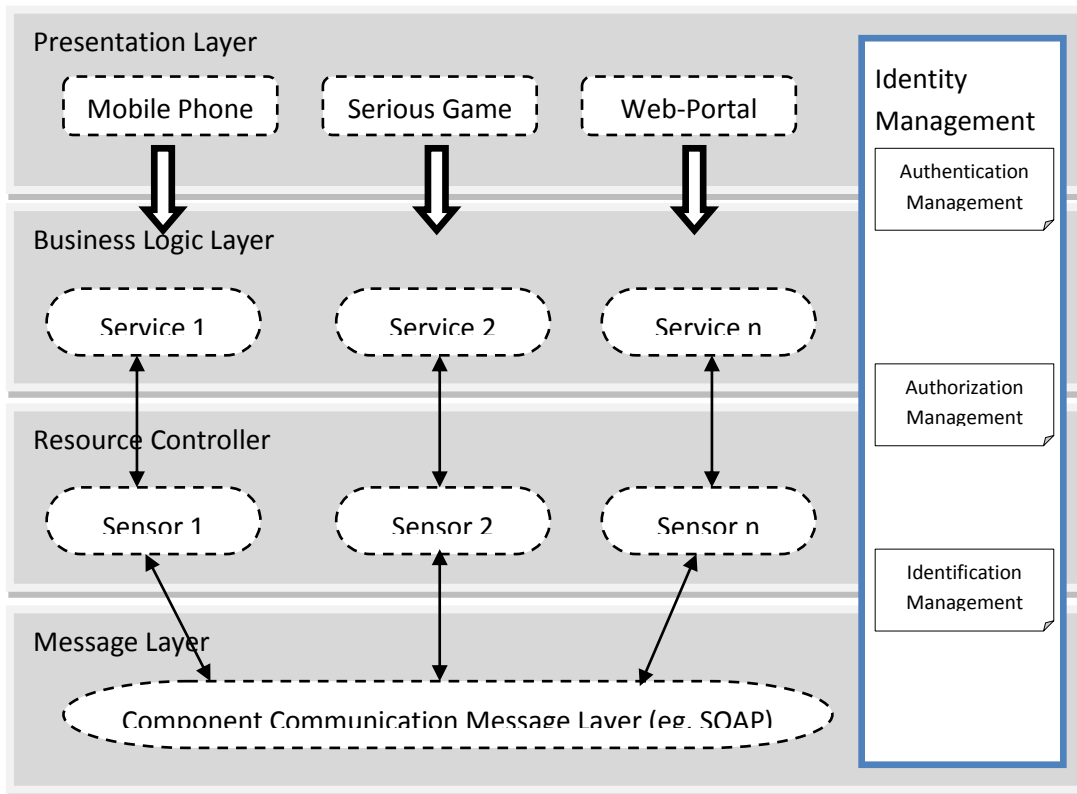


Figure 11 Overview of middleware architecture

As visualized in the figure, the four layers consist of a message layer, a resource controller, a business logic layer, and a presentation layer. The four layers are all protected by non-functional component, especially the identity management layer that handles security and authorization for the middleware.

The Presentation Layer allows the different applications, made by different manufacturers to connect to the same Business Logic Layer. In the Business Logic Layer the information received from the resources is processed and made ready to transform into human understandable format.

The Business Logic Layer connects with the Resource Controller, which manages the numerous sensors that are in place at the pilots. The data from the sensors is handled by the Message Layer before passing it on to the Resource Controller. By adding this extra layer, this middleware is ready for easy integration of the open protocol to enable the cross manufacturer integration.

When we look back at figure 10 we have a Local SAVE ENERGY Connector, a Central Platform and several clients. In the SAVE ENERGY Project, the Local SAVE ENERGY Connector will be supplied either by ISA, KYAB or There Corporation, the Central Platform will be supplied by ISA and several clients either by ISA, Nokia and CKIR.

### 3.2 Local SAVE ENERGY Connector

The required openness of the SAVE ENERGY architecture allows for different local connectors to be used at the pilots, this means that the pilots can use a broad range of sensors and that the supplier of the device is not fixed, although the only limitation is the protocols of the sensors, but the technical partners for the SAVE ENERGY Project have covered already a large number of commonly used protocols.

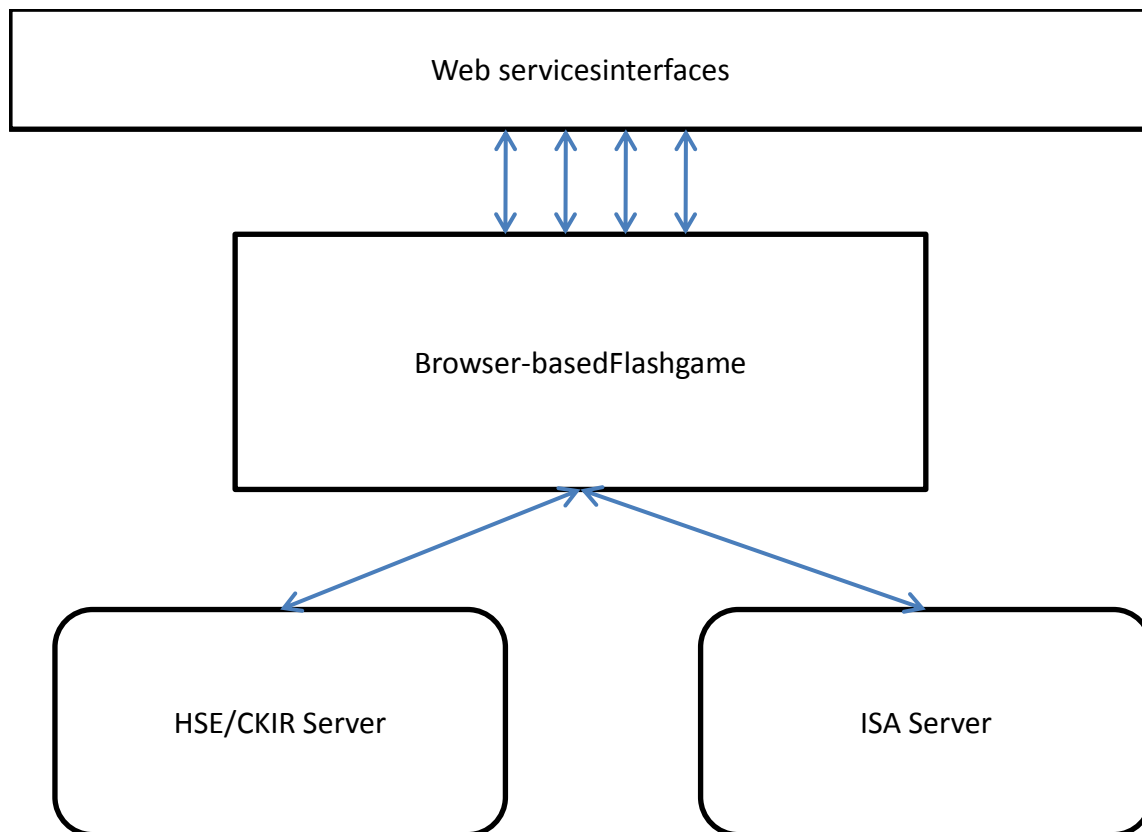
The following table shows the standard protocols that are supported by the technical project partners. Sensors that support any of these protocols can therefore be used in the project. Doing so in the pilot sites, will be one validation experiment.

<b>Protocol:</b>	<b>Supported by:</b>
<b>IPv4</b>	KYAB , ISA, There
<b>IPv6</b>	KYAB, ISA
<b>EIB/KNX</b>	There
<b>Modbus</b>	KYAB, ISA
<b>LonWorks</b>	KYAB, There
<b>C-Bus</b>	There
<b>DLMS</b>	ISA
<b>OBIX</b>	There
<b>WiFi</b>	KYAB, ISA, There
<b>ZigBee</b>	KYAB, ISA, There, Plugwise
<b>Z-Wave</b>	KYAB, ISA, There
<b>Bluetooth</b>	KYAB, ISA
<b>GPRS/UMTS</b>	KYAB, ISA
<b>Mbus</b>	KYAB
<b>X2D</b>	There
<b>ECOP</b>	There
<b>X10</b>	There
<b>Insteon</b>	There
<b>System Box</b>	There
<b>UPB</b>	There
<b>1Wire</b>	There
<b>XML</b>	Plugwise
<b>Proprietary protocols</b>	KYAB, ISA, Plugwise

### 3.3 SAVE ENERGY Serious Game Connector

User behaviour changes are stimulated by the Serious Game. The SAVE ENERGY Serious Game will be a Flash application that runs online, directly from the browser of a user. The game aims at presenting actual energy usage to create a competition among users. Since it presents the actual energy usage, a connection from the Serious Game to the SAVE ENERGY Middleware is required.

The architecture of the Serious Game is illustrated in the following image, which is provided by the game work package of the consortium.



**Figure 12 Serious Game Architecture**

The serious game will connect to a server that runs at the CKIR data centre. On this server runs the backend of this game where player accounts and feedback usage information is to be stored. Data from the sensors that are within the buildings are not stored on the backend server, but whenever data from the sensors is needed, a connection will be made to the SAVE ENERGY Middleware to retrieve the sensor data from the pilots.

The integration step for adding new buildings should be transparent to the game so that suitably qualified players can be given the option to connect their building. The game would therefore be able to cater for more users than the residents of the initial 5 pilot buildings.

Using Web 2.0 services the Serious Game results can be broadcasted to other websites, portals and applications, this happens through a direct connection to the Flash Game.



SAVE ENERGY EU CIP Grant agreement no.: 238882



Please refer to their work package, for more detail on the Serious Game development.



### 3.4 Save Energy Architecture Evolution

The open Middleware platform itself requires implementation effort. In the frame of the SAVE ENERGY project development budgets are limited, because it is not a technology development project. The consortium therefore brings together five system integrators, who do not directly compete but are willing to share developments.

**Evolution Principle 1:** Middleware evolution is based on the open source principles of specification & code sharing

After intensive negotiation amongst the partners, and in the frame of the SAVE ENERGY project this is implemented by partial opening of specifications and implementations into the shared open middleware through the technology partners. In doing so the integration partners convene to form the typical open source project steering board, where decisions are made on what to include. Membership is based on active contribution and therefore will be open beyond the boundaries of the project. During project life-span the WP 4 leader will assume the chairing function as set out in the description of work, because it is a research centre that does not act in the market and therefore does not face a conflict of interest. With this evolutionary approach and its organizational structuring a first contribution to post-project sustainability and the developed solution of the collaboration is intended.

This collaboration is a validation experiment about the viability of an open source business ecosystem in this domain. The results will be reflected in the business architecture chapters as specified in D 4.3. The next paragraph will introduce a start of the business architecture chapter.

### 3.5 Business Architecture

Deliverable 4.3 will describe the Business architecture chapter of the service-oriented architecture for energy efficiency management, which will be an addition to this report and will research a workspace for energy efficiency management from the business point of view. At this point we prepare the work of task 4.3 and provide a place holder for the scheduled contribution.

From the literature there is not really one shared vision on the definition of Business Architecture, but the Object Management Group has a Business Architecture Working group that tries to create a shared definition of a Business Architecture. Their draft definition is as follows: *"A blueprint of the enterprise that provides a common understanding of the organization and is used to align strategic objectives and tactical demands."* (Object Management Group, 2008)

Many researchers have studied the importance of alignment between the business architecture and IT, but the level of alignment has changed from just linking the business plan and the IT plan in the early studies (McLean & Soden, 1977) (Henderson & Sifonis, 1988) to sometimes revolutionary levels where IT redefines the business scope (Henderson & Venkatraman, 1992). A next step from that is that well-aligned IT can change industries (Chan & Reich, 2007), by increasing the scope and impact of IT in some example organizations, the industry structure was transformed causing significant market shifts (McKenny, Mason, & Copeland, 1995).



The business architecture that will be described in Deliverable 4.3 will therefore consist of business modelling, specification of a modelling approach and integration in the middleware to allow for the evolution of energy management systems by the change of energy management parameters.

## 4 Revision of Supplier Architectures for SAVE ENERGY

We have established the basic structure of the ideal SAVE ENERGY architecture based on literature research and user expectation that were voiced in the pilot sites. The aim of this chapter is to populate the architecture with the real existing solutions that are relevant for the execution of the project experiments. Since this project is a CIP project, which implies that we are not going to develop this proposed middleware, we are going to use and integrate existing solutions from project partners. In doing so, we provide a first validation test on the practical relevance of the general Save Energy architecture.

This chapter will first introduce the solutions for the SAVE ENERGY project that are available by the project partners and only then discuss them.

### 4.1 The ISA Middleware architecture

This solution aims to collect data from 5 different pilots and make it available in a uniform way for the different client applications.

#### 4.1.1 Architecture overview

The designed architecture was defined keeping in mind the following objectives:

- The possibility to have client applications that are completely independent of the communications with the equipments;
- The possibility to support different communication protocols that can change without any impact in the client applications;
- The possibility to have an abstraction level between the collection and the presentation of the data;
- The solution has to be scalable;
- The possibility to support a wide range of sensors;
- Flexible communications – currently we expect the equipments to communicate using GPRS but in the mean time we may need them to use other means of communication like SMS, etc. One of the main conditions for this architecture is that the inclusion of different means of communication will not compromise or induce any further development in the client applications.

### 4.1.2 General Architecture

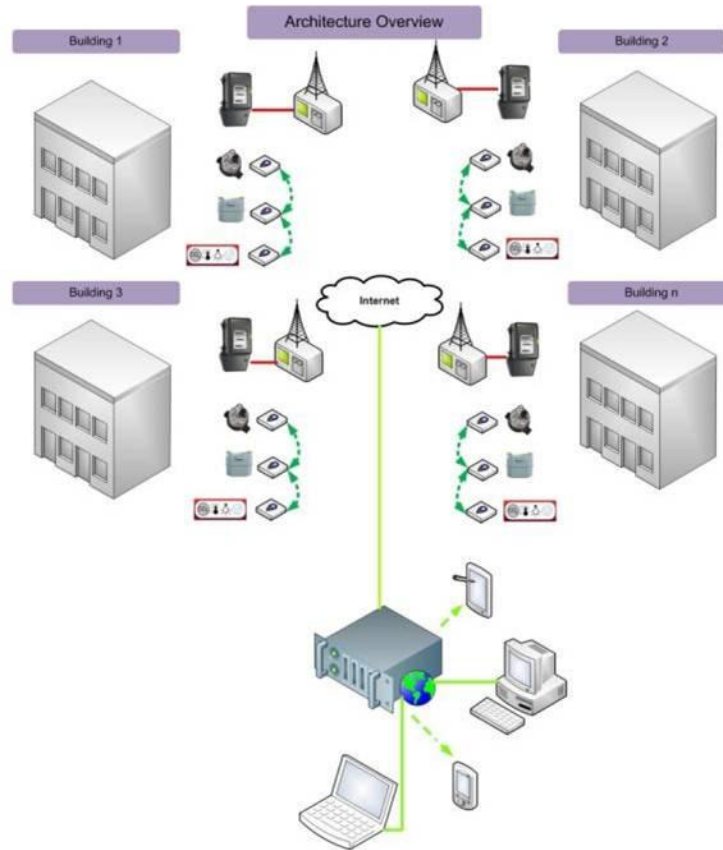


Figure 13 ISA General Architecture

The previous picture shows an architecture overview for the integration of different measuring equipments in different and distant buildings. We can see that the electricity, gas and water consumption are being monitored as well as several environmental conditions like temperature, humidity, concentration of CO<sub>2</sub> in the building and luminosity.

All the data is collected and sent to a central server where it can be seen by the management of the network of buildings (in this example) or by any other person with granted access to the information.

The system includes:

- Electricity meters;
- Radio communication modules that can be connected to the sensors;
- Modules to connect to the gas and water meters;
- Communication boxes that receive all the data and transmit it to the server;
- And a software application to process and display the data.



### 4.1.3 Detailed architecture

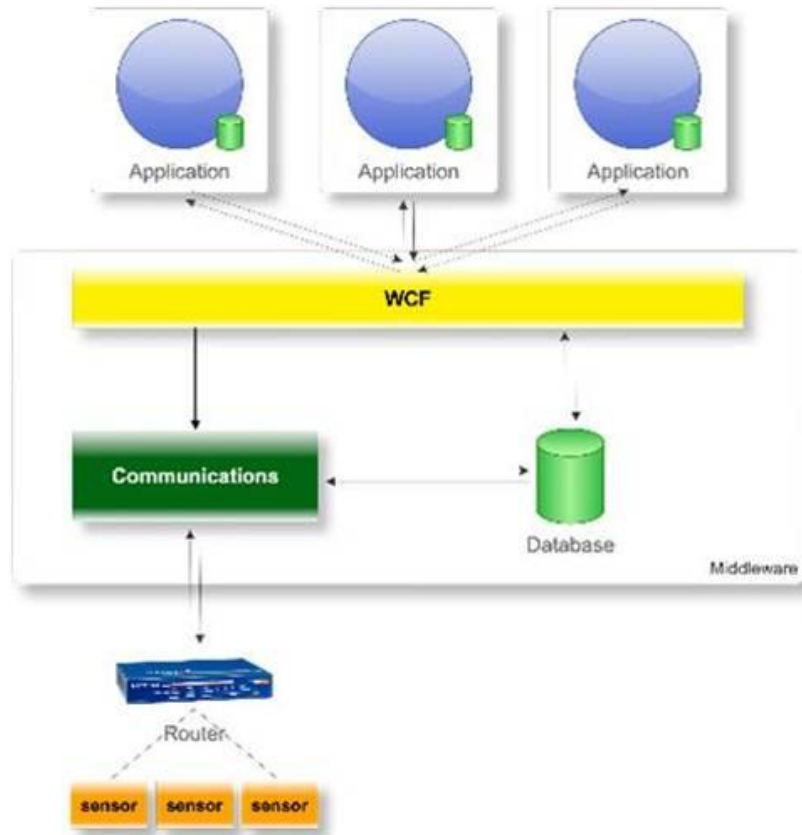


Figure 14 ISA Detailed Architecture

The Picture shows the generic modules of the *middleware* that support all the architecture.

The server that lodges the *middleware* will be in a network protected with a firewall (for example the ISA network), thus, in order for the equipments to be able to establish a connection with the server, the *firewall* that protects the server will have to have an open port specific for this solution.

#### Communications module

This module is responsible for the reception, sending and treatment of the data exchanged between the lodging server and the equipments.

The communications that are supported in the solutions will be TCP/IP based; nonetheless the module supports other types of connections, like GSM. Another demand to this module is that it will have to support different protocols.

In the scope of this project the communications established must be online, i.e., once the equipment establishes a communication them the server will not drop it. This concept has to predict the possibility that the connection may timeout in case there is no data exchanged between the server and the equipment; keeping this feature in mind we are predicting that the module will periodically send a package to the equipment or vice-versa, in such way that the connection timeout will be prevented.



The fact that the connections are online might add a limitation to the number of equipments that are connected to the server (equal to the number of available threads in the server). These limitations are secondary since the communication module will be constituted by a set of services that can be spread throughout different servers, providing the system with great scalability.

### Database module

The middleware database should implement the concept of tags, i.e., each unit can have several measuring and alarm channels configured that are always seen as simple measure point with an associated value.

It is not intended for this communication and database layers to know what is being measured or the units in which it is expressed. All those details will be defined either in the client applications or in the WCF service.

The proposed abstraction presented in this architecture allows the system to support different types of measures. In this level the middleware will not do any type of data treatment working only as a communication platform.

The middleware database will not support any measuring unit configurations and customizations, but only the creation and maintenance of equipments and associated tags.

### WCF module

This module will be the interface between the client application and the middleware. Is through this layer that the client applications access the data and do the maintenance of the equipments.

In this module we can have two different approaches:

- Option 1 – the client applications will be responsible to do the maintenance of the different measuring points and to configure the tags in the middleware (add, remove, edit) besides that they can periodically get data concerning their application.
- Option 2 – the client applications don't create units nor tags, thus the middleware responsible has to give a map of the tags of the system and the equipment channels.

In both options there will have to be a mechanism that allows the configuration of equipments without the clients having to know the protocol.

The communication between the WCF and the client applications can be made using TCP/IP or http, though this last one is slightly slower. Both modules share a contract that allows the client application to know, in the middleware, what can be invoked.

The data available in this layer is raw data, being all the treatment and manipulation in the side of the client.

The client applications will have private credentials that allow the middleware to know which client application is invoking it and return the information concerning that client. Nonetheless it will be possible to develop in the WCF a behaviour like “to the X client I will return data of Y and Z”.



### Client applications

In the proposed architecture the number of client applications will not constrain the working of the middleware. Each client can use the middleware to search for data or as an intermediate step between them and the equipments. In both cases the client can be a complete and autonomous system, using the WCF only as data collector, keeping the responsibility to store the data in a local system.

In this way it is possible to have several client applications containing each a database with different information and that only need to know the map of the middleware-client application.

Once the communication service between the middleware and the client application would use WCF technology then the applications can use whichever technology they want, open source or proprietary.

#### **4.1.4 Online connections**

In the SAVE ENERGY solution the connections with the equipments will have to be online so that a possible actuation on the devices can be immediate, for example the turning on or off of a lamp, the air conditioning, etc.

The online connections impose a limitation that can be summarized as the need to have available resources in the server where the middleware is running, because each connection will be an independent thread and an additional resource of the server. If we predict the existence of a high number of communicating devices that will exhaust the available threads one can divide the middleware in several servers remaining each one in charge of different connections.

As an alternative to the online connections we can define that the equipments have a fixed IP address (which they will have since they are connected to a router) and that such router is accessible through a specific port. In this scenario the connections between the equipments and the server would not be permanent, being established only when one of the parties needs to communicate. This alternative could bring some delay in the actuation of devices, but it is still viable since it gives the system greater scalability.

#### 4.1.5 Architecture advantages

The architecture presented here has features that give it a big attractiveness, some concerning the configuration of the system functioning and others concerning the adaptation potential in case the solution evolves to other equipments, protocols or communication means.

In the following table we present a set of advantages of the architecture concerning the global functioning of the system:

Advantage	Description
VF1	Possibility to allow the clients only to see data, preventing an incorrect configuration of devices.
VF2	It is possible for the clients to have systems that are truly autonomous both in architecture and technology used.
VF3	Possibility to create specific mechanisms to make the data available.

In the following table we present a set of advantages in the architecture concerning future developments:

Advantage	Description
VC1	Scalable – according to the number of equipments communicating it can distribute the load between the different servers.
VC2	Versatile – has the capacity to integrate GPRS communications at this stage, but in the future it can also have GSM or other communication type.
VC3	Capacity to include new protocols without interfering with the client applications.
VC4	Once the data storage is abstracted in the tag concept, the platform can support different sets of measuring data without the necessity to carry on core changes.

## 4.2 Nokia / There corporation SAVE ENERGY Architecture

This chapter describes the Nokia/There Corporation Architecture as used in their Home Control Center solution. Nokia is consortium member and There Corporation is a spin-out company from Nokia for the commercialization of SAVE ENERGY solutions. The heart of this solution is the There Home Control Center, which is built on top of a standard gateway / router architecture with specific requirements to enable secure home controls in the platform.

The two most important control nodes are the mobile phone and the web browser which are connected directly to the Home Control Center when in reach of the WLAN network or will be connected via the back-end server architecture that is provided by There Corporation whenever outside of reach of the home network.



Figure 15 There Home Control Center Architecture

The Home Control Center platform is designed for easy integration of different home automation protocols. Although several protocols are initially supported, a partner program with open API allows collaborators to integrate other technologies into this architecture, by the use of USB devices.

### 4.2.1 Home Automation Service Framework

The Home Automation Service Framework (HAS), runs on the Home Control Center router, is based on a Linux 2.6 platform and ties the different software components together. It consists of three components:

1. Technology Drivers

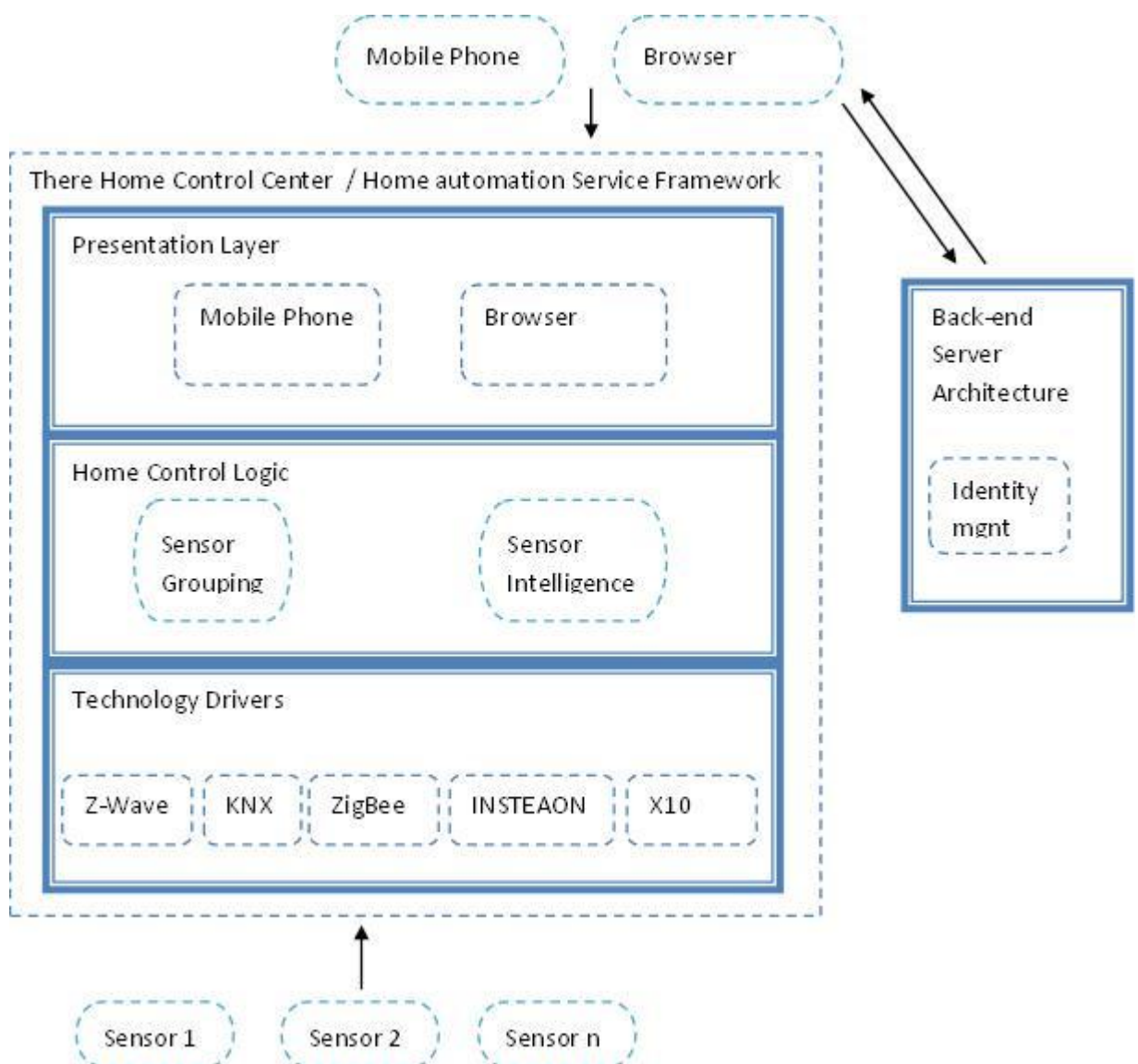
The technology driver is the component that translates any communication protocol to the language that the There framework understands. The need for this part comes from the fact that there is not a widespread standard in home control. A physical connection between a new wireless or wired technology and the Home Control Center platform can be implemented using the USB ports.

## 2. Home Control Logic

Home control logic is a set of features that anyone can use to command, get information and group their devices. The actual intelligence of devices can be interpreted here instead of within the devices.

## 3. Presentation Layer

The presentation layer, or bridge is the actual component that presents the actual or grouped devices to different control nodes. It can use, for example, UPNP language in S60 Mobile phones or HTTP language in a web browser. More protocols can be implemented if there is need for.



## 4.3 The Saber architecture

Saber is a start-up company from Lulea and for the commercialization of the solutions used in the Lulea pilot site.

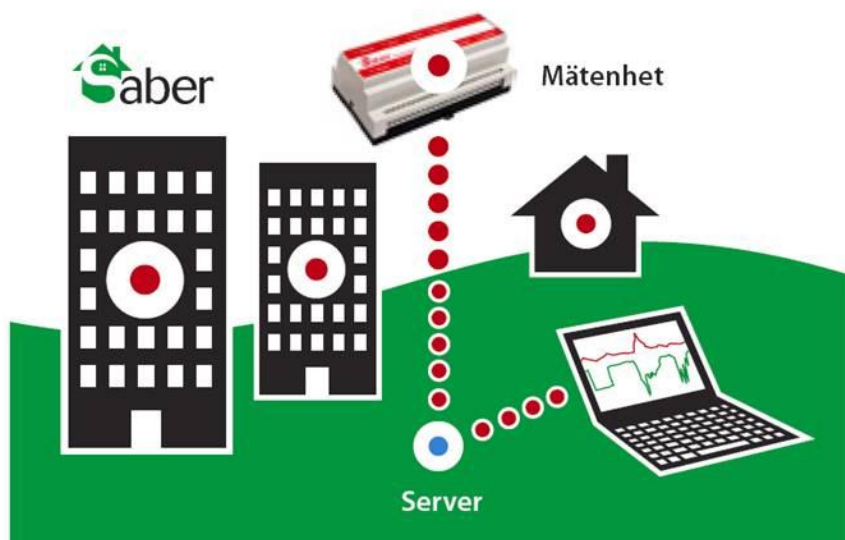
### 4.3.1 Architecture overview

The designed architecture was designed to meet the following criterias:

- Scalability
- Client applications on the server side independent of the protocols and communication means used on the Saber Pro.
- The possibility to support different types of communication protocols together with a wide range of sensors.
- Easy to implement support for new protocols without the need to change the client applications.
- Flexible communication, Saber supports a variety of different communication means. Such as Ethernet, SMS, GPRS, 1-wire etc.

### 4.3.2 General architecture

The Saber measurement system



The picture shows the general architecture. Every building can have one or many Sabers, each of them in turn connected to a number of sensors. The data is collected by the Saber and transferred to the Server using the desired protocol and communication means.



### 4.3.3 Detailed architecture

The saber measurement system consists basically of three major parts.

- The Saber Professional gateway, Linux based with mysql database for 30 days of measurement communicating directly with sensors and the SDS and/or SAVE ENERGY middleware.
- The Saber Database Server (SDS) where the Saber stores the data long-term. The data is displayed by the SWS and/or transferred to the SAVE ENERGY Middleware.
- The Saber Web portal Server (SWS) with applications for displaying and manipulating data. The web portal can be accessed by a standard browser or using a mobile unit such as a mobile phone or laptop. Through the web portal all measurement are available and attached actuators, switches etc can be manipulated online using simple commands.

When applicable the communication is protected by firewalls.

### 4.3.4 Interoperation with other measurement systems such as the SAVE ENERGY Middleware

In situations where interoperation with an existing measurement is required, Saber Professional can achieve this in several different ways depending on the target system. The communication can be achieved directly from the Saber Pro by LAN, RS-485, RS-232, SMS, GPRS or other means providing there is a standard for communication with the target system. Other means of communicating with the SAVE ENERGY Middleware is using an API and downloading or sending the measurements directly from the SDS to the middleware. This is the preferred solution.

### 4.3.5 Summary of Saber Architecture

The measurement system can be used as a one system and provide the user with a flexible environment capable of both, collecting and storing, and presenting information. The flexibility of the system also allows interoperation with a wide range of measurement systems on the market. The easy implementation and update of new protocols, through the web update functionality built in to the Saber, allows interoperation with new and future systems. Thus Saber is a versatile and stable platform for measurement and control applications in demanding environments.

## 4.4 Plugwise Architecture

Plugwise is a Dutch company and candidate to be involved in the Leiden pilot that developed an easy to install system to measure the electricity usage per power outlet (wall socket). They have developed a small plug that can be placed in between the power outlet and the electrical appliance. The plugs communicate using a meshed network.

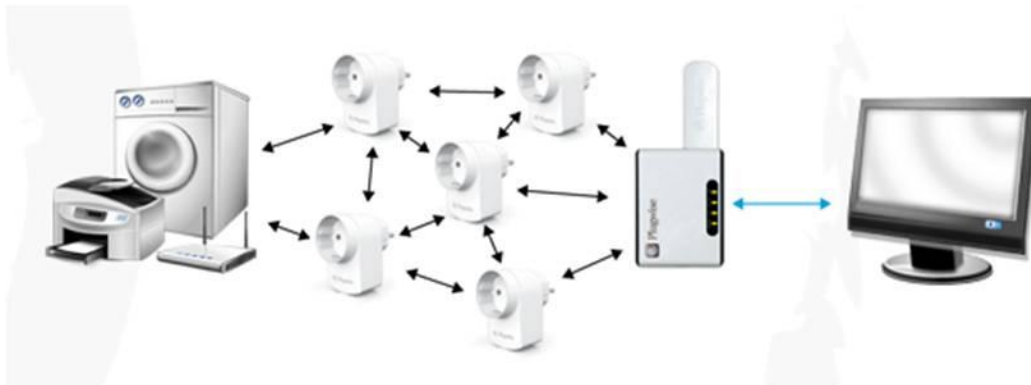


Figure 16 Plugwise Architecture Overview

### 4.4.1 Plugwise Technology

The Plugwise sensors use a meshed Zigbee network to communicate with the concentrator. Plugwise uses a proprietary protocol to overcome the weaknesses that exist in the standard Zigbee protocol. In this way the maximum number of nodes per network is limited to 65 in the Plugwise system, but the errors in transmission are much lower. In case 65 nodes is not enough for a building, then a concentrator can be used to interconnect more Plugwise Zigbee networks to expand the network to an unlimited number of nodes and therefore no scalability problems are known for this technology.

The Plugwise concentrator can work as a middleware layer between the clients and the sensors, but also has the possibility to act just as a network bridge between the Plugwise Sensors and third party devices. This means that seamless integration with third party systems can be handled by the Plugwise system using an open XML protocol for data distribution.

The Plugwise concentrators have memory available to save the energy usage in case the output can somehow not be transferred to a third party system like the Middleware Architecture in this document. This assures that no data is lost in case of a power drop or network outage.

### 4.4.2 Summary of the Plugwise Architecture

The brief introduction of the Plugwise system already shows that it is ready to be used in the SAVE ENERGY project because it is a flexible and reliable system that can handle the project requirements as openness, interoperability and does not require further development before the actual implementation of the pilots.



## 4.5 Compatibility of the SAVE ENERGY architecture with Supplier Architectures

This chapter explained the solution of several SAVE ENERGY project partners. As we can see, ISA, Plugwise and KYAB use a middleware layer in their architecture, Nokia on the other hand uses a distributed architecture that is not completely built as a meshed network, but uses a central server that is a broker for direct connections between users and home gateways.

Unless that the solutions above support open protocols for the sensors they all work with proprietary protocols between the gateway, middleware and users. For the SAVE ENERGY project, the companies have to open up their proprietary protocols and use some standard instead. Although this brought some challenges, the companies are now working together on integration and they all see the benefit of it.

The Middleware Layer that will be used in the SAVE ENERGY project will be the existing middleware of ISA; The gateways in the buildings can be of any of the technology providers since they can all communicate with the ISA middleware after the integration.

These important steps have in fact already shown the first validation of the project; the companies can change and collaborate towards integration of their systems. The next paragraphs introduce the concept implementation plan for the Leiden pilot, according to the described architecture as a theoretical validation of the proposed architecture.

On a paper base this pre-study let's assume that the supplier architectures seem to fit with the SAVE ENERGY architecture as it is developed in this deliverable. The next validation experiment will be practical experimenting with the different solutions in the user environment.

## 5 Living Lab Experimentation based on the SAVE ENERGY architecture

The Save Energy project is an EU CIP Project, which implies that it should validate a technology that is already available, but not yet on the market. A common way to perform a technology validation is using an experiment. The architecture developed in this document is an instrumental in defining the experiments, comparing results from different experiments and integrating the findings of the multiple experiments into one integrated description. This chapter therefore introduces the setup of the experiment, as an important source of requirements for the architecture description.

These experiments are specific because the project has chosen to use the Living Lab approach.

Using the **Living Lab** as experimental environment means that we use a natural environment which is not a specific set up for the experimental test. The Living Lab tests users live and work in their common environment. In conclusion to that a high quality of results can be recognized and simply transfused to a very general statement. To realize a Living Lab the following points have to be considered:

- Installation of test equipment has to be done carefully: normal behaviors must not be influenced or changed.
- Installation of the test equipment has to be done in a realistic, efficient and repeatable way. The complexity and costs should be limited in order to be worthy.
- The users should not feel like in a laboratory. The common life and work style must not be influenced (only by the test intention itself!).
- Documentation of problems and other troubles in order to improve for later adoption and to find out the best practice.

The overall **research hypothesis** of the validation experiments of the SAVE energy project is:

*The presentation of energy consumption measurements to a user will change his/her behavior so that energy consumption decreases.*

**Presentation** in this context is the independent variable which allows indicating quantitative measures to the user. There will be different types of forwarding measurements e.g.

- Computer screens
- Mobile devices
- Interactive, serious game
- Etc.

**Energy consumption measurements** in this context are sensor data collected from different energy-using devices. These measurements will be transformed from machine readable format to a human readable format for a better presentation. The different sensor data are at least, but not limited to:

- Temperature (room, window side, beside heating)
- Electricity, light, heating in kW

**Users** in this context will be the test persons who get the information about the energy consumption. The users differ in their demographical characteristics, behavior and modality to encounter the presentation of energy consumption, e.g.:

- Owner of the house
- Facility manager
- Every day users (employee respectively use for employment, students)
- Education
- Demographical factors: young/old, men/women...
- One-off, sporadic usage.

These different user structures have to be differentiated and stipulated clearly and precisely in the five pilots in order to interpret the monitoring in the right way.

**Behaviour** in this context is the individual way of handling energy and its consumption if it is presented in any kind of way.



**Energy consumption** in this context is the individual usage of energy in any kind of way. The consumption of electricity and heating has the main attention in the pilots.

## 5.1 Pre-studies

Pre-studies are important to get an overview about the experimental conditions and to assure a frictionless, standardised, comparable, repeatable and meaningful experiment with results based on facts.

### 1. Buildings

The buildings have to be analysed with regard to the following points:

#### **The technology:**

There has to be an inventory control about the installed energy system (heating, electricity and water system) before the tests start. Therefore the modernity is very important to interpret the test data in the right way. Furthermore it is very important to know if the building already has sensor controlled energy usage, e.g.

- Moving sensors for light, water and paper towels
- Water dispenser which turns off automatically
- Stand-by mode systems.

Moreover the building has to be checked on structural measures to implement sensors and presentation systems.

In order to assure a comparable test a standardised checklist should be prepared.

#### **The users:**

First of all the test group has to be defined clearly. It has to be chosen which persons should be involved.

The involved person has to be analysed on the individual kind of energy usage (light, electricity, heating or water). In conclusion to that the right sensors and focus for the test have to be identified. In addition it should be known how long the user plays an active role on an average in the regarded room/house (working hours) to interpret the behaviours, measurements and changes in the right way.

All involved users have to be informed about and taught in the test procedure and presentation systems.

The assignment of a reference group should be chosen carefully to make sure that the test data are comparable and to evaluate results based on facts. In order to make a comparison feasible the reference group acts nearly similar (same energy consumption, same activities, same room etc.).

In order to assure a comparable test a standardised checklist should be prepared.

## 2. Economic conditions

Different business organisations are involved in the SAVE ENERGY project. They develop different sensors and technical systems which are needed for the experiment. The organisations all have an overlap in their products, but also have their specialities. In order to optimize the solution for the SAVE ENERGY project and beyond, the organisations have to integrate their specialities and can probably all benefit of that.

Inside the buildings there are also economic conditions that need to be taken into account. In public organisations there are often strict procedures to be followed in order to change either the building infrastructure or install software applications on employees workstations. In the SAVE ENERGY project a challenge is to get the building owner, the facility department and the IT department working together towards integration of systems and energy saving. This might even imply a change in the working procedures and in the Leiden pilot this already led to the specification of a new position in the municipality: an Energy Manager. This therefore requires to be studied in the experiment to identify best ways to get the alignment between the different stakeholders in such projects.

## 3. The sensors

The sensors should be implemented easily and without any physical changes to the buildings required. The assembly has to be cost and complexity efficient so that it is acceptable for a later integration in private households and organisations. The sensors should be ready for implementation as there is no time for testing and development. A wireless assembly should be preferred.

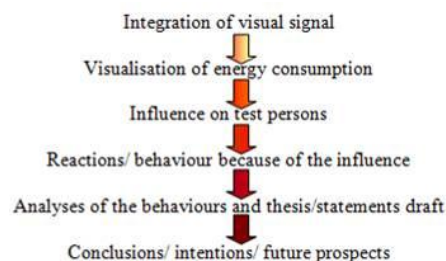
The sensors measures energy consumption (at least electricity, heating) in the easiest way in order to be efficient. The measures will be transformed in person readable format and the presentation runs via visualisation systems. Because of using different sensors from different organisations the documentation of the measurements has to be done in a standardised way to make it comparable.

## 4. Environmental conditions

The season, weather and light conditions have to be documented because these factors influence energy consumption.

## 5.2 Experiment Implementation

Each of the five pilots runs through the following experimental steps:





For all these steps a clearly defined outflow is arranged in order to assure a comparable evaluation. To guarantee such a standardisation the individual steps and the procedure are described in detail in the following chapter.

### **Step 1:** Visual signal integration

- Define the kind of signal which should be visualised:
  - Adherence and implementation of the pre-studies and their results
  - Typical [kW/h] for electricity and heating
  - [m<sup>3</sup>/h] for water
  - Possible [W/s] and [m<sup>3</sup>/s] to show it more clearly:
- Integrate the technology into the living lab area
  - Adherence of the special Living Lab conditions
- - Adherence of the challenges and overcoming of the challenges which appear because of the different operating business organisations
- Visualisation by data transfer system (hardware and software):
  - Internet, Ethernet, USB, wireless, Bluetooth, infrared...
  - Different technology will be installed but the transformation has to be standardised
- Visualisation on all display systems:
  - e.g.: PC, TV, cell phone...
- Setup documentation (order/approach, special conditions, problems and solutions)

### **Step 2:** Documentation of impact, behaviour and changes

- Define the test persons (user):
  - Adherence and implementation of the pre-studies and their results
- Interview/survey before, during, after the experiment (demographical factors, employment, Interest in/attitude towards energy topics, impact/influence by visualisation systems...).
- Documentation of the behaviours by means of energy consumption before and during the experiment respectively by means of the changes in energy consumption
- To specify and measure the impact/influence and behaviour changes a kind of checklist/documentation list will be developed in order to know how to measure and document the expected changes.



### **Step 3: Experiment Execution**

- Preferably no influence, no discontinuity, no artificial conditions
  - Adherence of special Living Lab conditions
- Define the duration of the experimentation
- Documentation of irregularity, problems and unexpected but also especial successful activities in order to improve and learn for later (find out the best practise)
- Assure that a contact person (reference to: energy manager) and a kind of handbook for the users are available if any problem occurs
- Data Acquisition in comparable way (reference to: middle ware platform)

### **Step 4: Experiment evaluation**

- Analyse and comparison of the collected data
- Analyse and interpretation of the survey/ interviews with the users
- The evaluation takes place on the basis of well-defined psychological evaluations processes
- Definition of a general experimental result and confirmation or correction of the overall research hypothesis
- Publication

Because of the little experimental experiences on this field of experimentation it is hard to forecast all influencing factors, the characteristic and development of the running experiment. That is why the pilots have to run for a certain time in order to document the first observations. During this time the first behaviours, changes and trends lead to the development of a well defined model to compare the data at the end of the running experiment and to evaluate a result.

### 5.3 Example for Experimental Setup - the Leiden Pilot

In order to validate the described architecture and its usage for living lab validation experimentation, we will present in this chapter an implementation plan for the Leiden Pilot using the proposed middleware architecture and commercially available equipment. The case is a choice of convenience as the editors of the deliverable are best acquainted with this case.

The pre study has been undertaken and the above mentioned dimensions were studied. As a result, the Leiden Pilot will be located in the Leiden City Hall. The municipality offers the Save Energy Project to use 8 almost identical office rooms for the experiment. In each room there will be two persons working at a desk. The rooms will have two windows that can be opened or closed by the employees and two radiators for heating that the employees can adjust themselves. The light in the rooms can be controlled by two switches that both switch two fluorescent tubes at the same time.



Figure 17 Office Room in Leiden Pilot

Experiment hypothesis:

The experiment hypothesis in the Leiden pilot case is that visualization of actual energy consumption at a central pace (the coffee machine), will motivate the building users to change their behavior, in that they manually switch off devices, where possible.

Several such awareness programs have been undertaken before with only temporary effect. Users changed behavior but after some time changed back again. The second hypothesis therefore is that computer displayed actual energy consumption data will have a longer lasting effect on user behavior change.



Experience in Leiden shows that technology alone did not create lasting impact. Actually an energy consumption display has already been installed in another Leiden building entrance, but it is out of order for a long time, because it is not organizationally assigned to anybody. The third experiment hypothesis on the organizational behavior change is that analysis of the cost reduction of energy consumption information will motivate the public administration to implement organizational routines to stay energy aware.

Experiment Implementation:

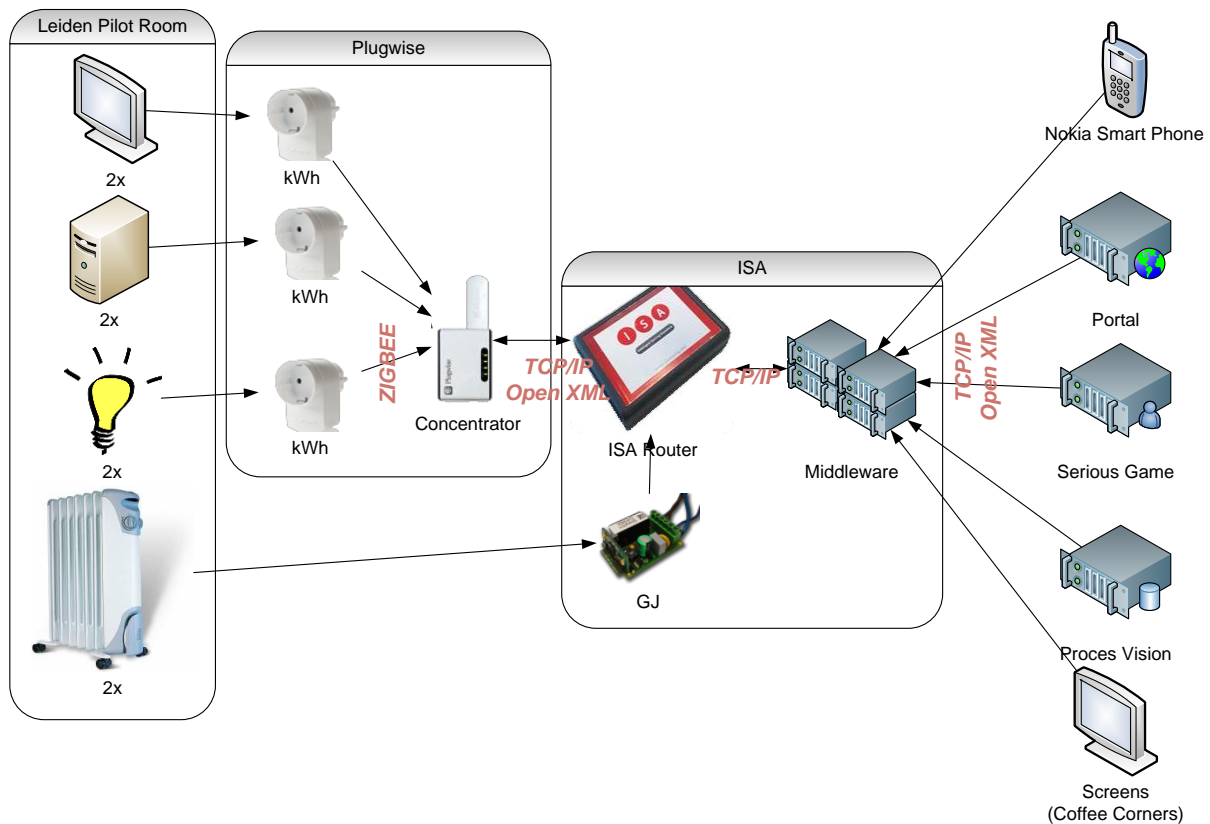
The initial setup of the Leiden Pilot therefore is to measure the electricity usage of the computers, screens, lighting and other room-specific devices like coffee machines or printers. Next to the electricity usage the hot water usage for the heating will be measured and the temperature and humidity will be measured. This initial setup measures all the energy usage of a room, but does not measure everything possible.

During the pilot it can be determined to place extra sensors to see if influencing the users with different information might help the user with saving more energy. It is for example possible to measure if a window is opened or closed using an extra sensor. In this way it is possible to communicate to a user of a room that the heating is on and the windows is open and that he or she would save a substantial amount of energy if he closes the window or shuts off the heating. The following table shows other possible sensors that can measure information to influence the behavior of the users.

Sensor:	Measures:	Information to users:
<b>Infrared Sensor</b>	Measure if someone is in the room	Light on or off?
<b>Door Sensor</b>	Measure if the door is open/closed	Your heating goes to the corridor.
<b>Window Sensor</b>	Measure if the window is open/closed	Your heating goes directly out the window
<b>Light Sensor</b>	Measure the light intensity	Should your light really be on?
<b>Remote Controller</b>	Easy interaction with appliances	Easily shut off all appliances when leaving the room with one button.

In the initial setup in the Leiden Pilot it is determined to install sensors for the computer screens, the computers, lighting, heating and temperature. If a room has some special equipment like a private coffee machine, then an extra sensor will be added to this room. There are many companies available that provide sensors that can measure this information, but at this moment is likely that sensors of the company Plugwise will be installed in the Leiden Pilot. The data that is measured by the sensors will be collected by a Plugwise concentrator that can communicate with the ISA router using an open protocol. The ISA router connects to the Middleware Layer where the Business Logic is applied to the measured data. Several clients as the Serious Game, Portal or ProcessVision can connect to the ISA middleware to download usage data from the pilot.

The following image shows a graphical presentation of the Leiden Pilot Setup.



**Figure 18 Leiden Pilot Implementation Plan**

As we can see from the image we use the ISA middleware layer that was described earlier in this document. This middleware layer allows for many clients and the local gateway at the pilot to connect. The local gateway at the pilot, or in the image, the ISA Router, is the central point at the pilot that has the knowledge of and connections to the sensors in the pilot. The sensors in this implementation plan are from both Plugwise (electrical energy sensors) and ISA (heating energy sensors). They are all seamlessly integrated in the pilot due to the open XML protocol that is used. This pilot implementation plan already shows that the proposed architecture, including the seamless integration, is feasible when studied from theory.



## 6 Conclusions

This deliverable develops the SAVE ENERGY architecture as the reference document for the solution that will be validated in the user experimentation.

In conclusion, this deliverable contributes, first, a methodological approach to using architectures not for software engineering, but as an instrument for guiding living lab experimentation in a project, starting from a user perspective, creating the architecture for altering user transformation behaviour, has showed potential of this methodology by looking at the end results.

Second, from the here presented evidence we conclude that it seems feasible to develop one open and interoperable SAVE ENERGY architecture, which could gain industry wide acceptance. There are (too) many technical architectures available meaning that the feasibility is not a technical but a business and market challenge. During this initial phase of the project the consortium also managed to co-create one architecture for many different users and stakeholders and the commitment to support this. Even with competitors in this project and thus pilots and suppliers work together with different targets and interests, the collaboration did work out well and resulted in a commonly shared vision on the architecture.



## 7 Glossary

API – Application Programming Interface; defines how an application can request services from other applications or libraries.

Firewall – Software or hardware part of a computer system that blocks unauthorized access.

HTTP – Hyper Text Transfer Protocol, protocol that could be used for communication on the application level in a network.

IP – Internet Protocol, enables communication in a packet-switched internetwork.

TCP/IP – Internet Protocol suite, the set of protocols used for communication on the Internet.

WCF – Windows Communication Foundation, an API for create service oriented applications.

Web Portal – Central place on the internet where information from various sources is presented in an unified manner.



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