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# Revised Demonstrator Test Plan

SmartCoDe

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## Table of Contents

1 Summary .....	5
2 Introduction .....	6
3 Demonstrator concept .....	6
3.1 Aims and objectives .....	6
3.2 Low additional costs .....	7
3.3 Communication infrastructure and security .....	7
3.4 Improvement of energy management by using SmartCoDe results .....	7
4 Demonstrator locations .....	10
4.1 Rationale for demonstrator locations .....	10
4.2 Almersberg location .....	11
4.2.1 Description .....	11
4.2.2 Consumption of energy .....	12
4.2.3 Demonstrator structure .....	13
4.3 Buchberg location .....	15
4.3.1 Description .....	15
4.3.2 Consumption of energy .....	16
4.3.3 Demonstrator structure .....	18
4.4 Demonstrator equipment .....	19
4.5 Equipment donated by Associated Partner .....	20
4.6 Role and responsibilities of the partners in demonstrator building .....	21
4.6.1 edacentrum .....	21
4.6.2 Infineon .....	21
4.6.3 TUW .....	21
4.6.4 Ennovatis .....	21
4.6.5 Tridonic .....	21
4.6.6 Ardaco .....	22
4.6.7 Quiet Revolution .....	22
4.6.8 University of Novi Sad, Faculty of Technical Sciences .....	22
4.7 Work schedule .....	22
5 Measurements at the demonstrator .....	23
5.1 Measurements at the Almersberg demonstrator site .....	23
5.2 Baseline data at Almersberg site .....	24
5.3 Measurements at the Buchberg demonstrator site .....	25
5.4 Baseline data at Buchberg site .....	26
6 Strategy of demonstrator testing .....	26
6.1 Relationship between test plan and implementation .....	26
6.2 General assumptions .....	28
6.3 Testing approach .....	28
6.4 Types of test .....	28
6.5 Requirements for testing environment .....	28

6.6 Requirements for human resources .....	29
6.7 Requirements for equipment .....	29
6.8 Procedures applied for testing .....	29
6.9 Procedure for retesting of fixed defects .....	30
6.10 Procedure for signing-off testing activities .....	30
6.11 Procedure for signing-off total testing .....	30
6.12 Testing inputs and outputs.....	30
6.13 Required support .....	30
6.14 Situations to be tested .....	30
6.15 Safety issues.....	31
6.16 Additional issues .....	31
7 Plan of demonstrator testing .....	31
7.1 Addressed types of tests .....	31
7.2 Unit tests .....	31
7.3 Functionality tests .....	31
7.4 Performance tests.....	32
7.5 Integration tests .....	32
7.6 Security tests .....	32
7.7 Safety tests .....	33
7.8 Test scenarios.....	33
7.9 Test scripts.....	34
7.9.1 Test Suite: Network Management.....	34
7.9.2 Test Suite: Dynamic discovery.....	36
7.9.3 Test Suite: Binding .....	37
7.9.4 Test Suite: Grouping .....	38
7.9.5 Test Suite: Routing.....	41
7.9.6 Test Suite: Security .....	42
7.10 Test Suite: Performance .....	45
7.11 Test Suite: Smart energy management.....	47
7.12 Test Suite: Other.....	47
7.13 Testing the communication between demonstrator nodes.....	48
7.14 Testing of demonstrator installation.....	49
7.14.1 Test strategy.....	49
7.14.2 Test plan.....	49
8 Analysis of the measured data .....	51
8.1 Definitions and abbreviations.....	51
8.2 Methodologies to determine and adjust the baseline .....	52
Technical ratios .....	53
Environmental ratios.....	54
Social ratios.....	54
Economical ratios.....	54

8.3 Options to determine the baseline and the energy savings.....	54
Option A: Measurement of Key Parameters of ECM-affected systems.....	54
Option B : Measurement of Consumption of Whole Facility .....	55
Option C: Calibrated Simulation .....	58
8.4 Selection Criteria for the measurement and verification.....	64
8.5 Proposed methodology to calculate energy savings in the SmartCoDe demonstrator .....	64
Establish baseline and reporting period .....	67
Baseline periods.....	68
Baseline - routine adjustments.....	69
Baseline - non-routine adjustments.....	70
8.6 Determination of other parameters .....	70
Persistence through Continuous commissioning .....	70
Statistic data analysis.....	71
Methodology Demand Response .....	72
Load factor .....	72
8.6.1 Baseline Profile Models.....	72
8.7 Methodology to calculate reduction of CO2 emission .....	73
9 Assessment of the project impact .....	74
9.1 Impacts of the project.....	74
9.2 Independent reviewers/consultants .....	74
9.3 Economic feasibility .....	74
9.4 Applicability and usability issues.....	75
10 Conclusions .....	75
11 References .....	76

# 1 Summary

SmartCoDe demonstrator's test plan, completed in June 2010 as a deliverable D-4.1, describes the test strategy and plan for testing the individual components and the overall demonstrator installation. Revision of the demonstrator's test plan is needed to cover ongoing work on the demonstrator and, even more important, to make necessary adjustments to the test plan which are necessary because of the decision made by the consortium to implement the demonstrator at a new location at Buchberg and complement it with the original location in Almersberg.

Originally, feasibility of SmartCoDe approach was planned to be tested at the demonstration site at Almersberg, near Vienna, Austria. The decision means that the overall demonstrator is enlarged to a two-site approach, as the original demonstrator site at Almersberg (where several installations are already available) will be kept in addition to the new site in Buchberg where the wind turbine will be installed.

The two demonstrator sites will be used to get practical experience on the usability of the approach in a "real-world scenario" that embraces regenerative energies (solar panel, wind turbine) and local energy management, and to measure and validate the estimated impact of the SmartCoDe concept.

Strategy of SmartCoDe demonstrator testing will be based on the bottom-up approach: components, units and subsystems will be tested first, followed by test of the overall demonstrator installation. Acceptance test of the individual components, units and subsystems will be followed by the acceptance test of the demonstrator installation.

Testing of the components will be managed by the respective task leaders and performed by the researchers or technicians appointed by the task leader. In general, testing will be performed by the consortium partners, so that each component will be tested by the people from the consortium partner who is responsible for its development. For each component to be tested, task leaders define type of testing, testing environment, people, equipment, dedicated test classes, test scenarios, procedures and safety issues.

Demonstrator test plan provides details of the tests which will be performed, especially what will be tested in terms of component functionality, performance, integration, security and/or safety. Details are given on unit testing (for example, power up, shut down, power down), functionality (responses to the user keys, test of each functionality, test of options / modes of operation, expected responses, test of ranges and limits), performance/stress tests (distance of communications, bandwidth, speed, response time), integration tests (communication to the other demonstrator units, functional integration into the demonstrator system), security tests (does the authorization work as expected, is the security at the expected level), safety tests (what happens in case of power down, what happens if some other demonstrator unit malfunctions, what if there is communication malfunction, what if there is an attempt to break security of the demonstrator).

For each of the above the test scenarios (situations) and test scripts (detailed step-by-step test instructions) for each scenario are developed and specified.

This document provides revised Demonstrator Test Plan and covers the following additional issues, which complement the original text delivered in June 2010 as D-4.1:

1. Rationale for selecting the demonstrator locations (Section 4.1),
2. Description of demonstrator location at Almersberg (Section 4.2) and at Buchberg (Section 4.3),
3. Description of the equipment which is installed at both of the locations, including the equipment which has been purchased and installed at Almersberg site and the equipment which will be moved to the Buchberg site (Section 4.4 ),
4. Description of the architectural characteristics and inhabitation status of both buildings (Sections 4.2.1 and 4.3.1).
5. Explanation of measurements which are taken at the demonstrator and how they are taken (Chapter 5),
6. How the measured data is analysed (Chapter 8),
7. How the project impact will be assessed (Chapter 9),
8. Rationale for recommendation to include an independent reviewer of the methods and analysis data (Section **Error! Reference source not found.**).

## 2 Introduction

The objective of SmartCoDe is to enable the application of advanced techniques for efficient energy management in private and small commercial buildings and neighbourhoods. To achieve this objective, SmartCoDe will develop new methods for automated energy management that specifically considers the requirements of Energy using Products (EuP) in homes / offices and local renewable energy providers, considering the required information security and dependability, develop an inexpensive hardware/software implementation that can be integrated into arbitrary EuP, providing them with the ability to communicate and to remotely control its use of power and demonstrate technical and economic feasibility and benefit of intelligent energy management in buildings and neighbourhoods with an initial focus on electric lighting.

In order to show the feasibility of SmartCoDe approach and to measure and validate the estimated impact, a demonstrator will be installed at the Almersberg site which will be complemented with Buchberg site, near Vienna, Austria. The demonstrator will be used to get practical experience on the usability of the approach in a “real-world scenario” that embraces regenerative energies (solar panel, wind turbine) and local energy management.

SmartCoDe demonstrator’s test plan describes the test strategy and plans for testing the individual components and the overall demonstrator installation, as well as how we will analyse the data collected from the demonstrator and assess the impact of the project.

In Section 3 we give overview of the demonstrator, including aims and objectives, description of the demonstrator sites and demonstrator structure, metering and the roles and responsibilities of the individual partners in building demonstrator. The rationale for selection of the demonstrator locations and the description of the Almersberg and Buchberg locations including the list of purchased and installed equipment and measurement channels are given in Chapter 4 and 5.

Section 6 covers the strategy and Section 7 plan of demonstrator testing. The strategy defines testing approach, types of testing, requirements and procedures. Testing plan describes the unit, functionality, performance, integration and security tests. It also gives test scenarios and scripts for demonstrator testing.

Chapter 8 present the methodology for calculation of energy production, consumption and savings, based on the data measured at the demonstrator. The last Chapter explains how the impact of the project will be assessed.

## 3 Demonstrator concept

### 3.1 Aims and objectives

The objective of the WP4 is to set up a demonstrator that allows to show the outcome of the project to a broad community. The demonstrator is needed to get practical experience on the usability of the approach in a “real-world scenario” that embraces regenerative energies (wind turbine, solar panel) and local energy management.

Demonstrator will allow the consortium to evaluate the outcomes under realistic conditions at two locations near Vienna, Austria. Demonstrator will be a proof-of-concept, in other words it shall prove that all the theoretical assumptions and models produced in SmartCoDe are correct. The demonstrator will provide a feedback (loop) to the models developed so that real-world data can be integrated to finalize the models.

The experiences to be gained from the demonstrator include evaluation of dependability of communication between nodes in wireless network, validation of models and simulation results from WP1 and WP2 and use of feedback for future improvements. The demonstrator will combine basic energy management and control functionalities with Local Energy Production (LEP) by renewable energies and EuP as for example household appliances including various lighting systems.

Besides the objectives mentioned above the demonstrator will be used to show to the public that the concept and implementation of SmartCoDe is feasible and thus provide a proof that the budgets of the project are spent for the benefit of the public society.

The demonstrator will be used to prove the SmartCoDe concept in real world settlement, more specifically:

- prove that newly developed methods for automated energy management are efficient,
- show the benefits of SmartCoDe high resolution energy management,
- show the communication and to remote control EuPs using the SmartCoDe devices
- demonstrate technical and economic feasibility and benefit of SmartCoDe intelligent energy management
- quantify possible energy savings due to:
  - Classical energy management,
  - High resolution energy management,
  - Coordination of supply systems,
  - Coordination of energy using products, and
  - Reduction of peak load.

SmartCoDe demonstrator will embrace locally available Energy using Products (EuP) and Local Energy Production (LEP) objects into a local energy grid with nodes such as electric lighting, heating, ventilation, air conditioning, and solar and wind power producers. The central energy management unit will use developed methods to efficiently control the local grid. The demonstrator will allow for the systematic monitoring, collection, analysis and presentation of all the available data to prove the SmartCoDe concept and provide a feedback for the future improvement.

The demonstrator will be used to prove the following results of the SmartCoDe project.

### **3.2 Low additional costs**

Cost of a full demonstrator installation will be calculated and compared with respect to the cost of installation with same EuPs and LEPs but without SmartCoDe components. Cost of each additional data channel will be calculated.

Cost of energy savings will be summarized and used to calculate payback time of the SmartCoDe installation. The expected payback time is less than 3 years.

The demonstrator will use the newly developed chips where ever possible. Experience on how to integrate the chips and how it will influence the various appliances will be collected and analyzed.

### **3.3 Communication infrastructure and security**

Communication infrastructure will be installed to prove that the individual demonstrator components communicate in an efficient and secure way. Security tests will be conducted to prove the level of the demonstrator security in various real world scenarios and show cases. The trials of security attacks will be run to search for security weak points.

### **3.4 Improvement of energy management by using SmartCoDe results**

The newly developed technologies of the SmartCoDe project will be applied in most profitable connection with an intelligent and cost-effective energy management system. We will perform the following steps to demonstrate SmartCoDe advantages.

#### **Show the benefits of EM before SmartCoDe**

- Show the benefits of classical EM
- Show the benefits of high resolution EM (intelligent metering)
- Control with the impact of various energy supplying systems (open building automation system)

The impact of the production profiles of photovoltaic and wind power plant as well as energy rates from the public supply will guide to an optimized load management with load shifting, dimming and frequency control.

The core functionality of the EMS will keep the building climate within a specified range, provide lighting based on an occupancy schedule, monitor system performance and device failures and provide email and/or text notifications to a responsible staff. The EMS functionality will reduce building energy and maintenance costs when compared to a non-controlled building for different daytime energy rates for energy consumption and exporting local produced energy to the public grid.

- Quantify possible energy savings due to:
  - Classical energy management
  - High resolution energy management

### **Show the benefits of SmartCoDe energy management**

- Show the implementation of newly developed methods for automated energy management.
- Show the communication to remotely controlled EUPs using the SmartCoDe devices and developed protocols.
- Demonstrate technical and economic feasibility and benefit of intelligent energy management. Technical feasibility will be demonstrated by implementing an efficient demonstrator installation with developed and off-the-shelf components. Economic feasibility will be demonstrated by the energy savings calculation (see Section 5).
- Quantify possible energy savings due to
  - Coordination of supply systems
  - Coordination of energy using products
  - Reduction of peak load

This will be done by producing semi annual energy reports which describe the various stages of the demonstrator.

As a result of this R&D project we will be able to trace the consumption of the EUPs in real time intervals and to develop typical usage profiles. This is the basic information necessary for Smart automated EMS.

Also it will be possible to analyze the performance of the EUP in dependence of events. (E.g. the person is sitting down on the chair in front of the computer, the PC screen is switching on – or the tariff for energy is changing at 2 pm and the EUP xy will be switched on [or off] or the light will be dimmed)

### **Impact of various energy supplying systems**

For the energy supply companies it is a standard to observe and control production and distribution of energy. For household and small neighbourhood solutions the use of EUP will be in dependence of the LEP, of rates (tariffs), may be of the CO<sub>2</sub> emissions of the supplier and so on.

The demonstrator will be used to show the influence of locally produced renewable energy in the household:

- dependence of increase and decrease of wind,
- dependence of increase and decrease of global radiation,
- changes of energy rates from the supplier,
- changes of energy selling rates to the public grid.

The EUPs being time flexible in a certain range of time for the performance time will be shifted to optimize EMS Solutions. (e.g. the trash holds value of the production of solar- or wind power is reached – the electric car will be charged).

According to the goals of the optimization model different benefits are the follow up effect – e.g.:

- Cost reduction for buying energy from the public grid
- Load reduction for energy out of the public grid
- Peak load reduction for energy out of the public grid
- CO<sub>2</sub> reduction of the public production (e.g. in peak load situations)

For solutions with storages the local “access production” will be used in an optimized way in the own storage system.

The measure to evaluate the results will be the increase of the efficiency of energy use of the LEPs

### **Automated control of EUPs using the SmartCoDe devices**

The automated control of the EUPs will be performed with the Smartbox and later with the Smartcenter. The Smartcenter is a taylorable form of the Smartbox. It contains modules for EUP control (rule and tariff based) and wireless communication. The communication with the Integrated Circuit Solution of SmartCoDe will be possible. (Smart **EUP Control** with Integrated Circuit Solution: “SEC”).



The test will include 3 functions of the SEC:

1. Switching on and off
2. Dimming (e.g. Illumination)
3. Frequency control (e.g. heating Pump)

The automated control will include for the basic decisions 3 functions of the SEC:

- Manual interaction of the user
- Rule based control
- Tariff based control

### **Automated energy management**

For the automated energy management we will investigate 2 optimization scenarios:

1. Maximize of the local use of the local produced energy
2. Maximize the benefit by selling the LEP to the public grid.

### **Demonstration of technical and economic feasibility and benefits of intelligent energy management**

We will demonstrate the technical and economic feasibility by providing

- Monitoring via Web interface
- User interface with TouchScreen interaction

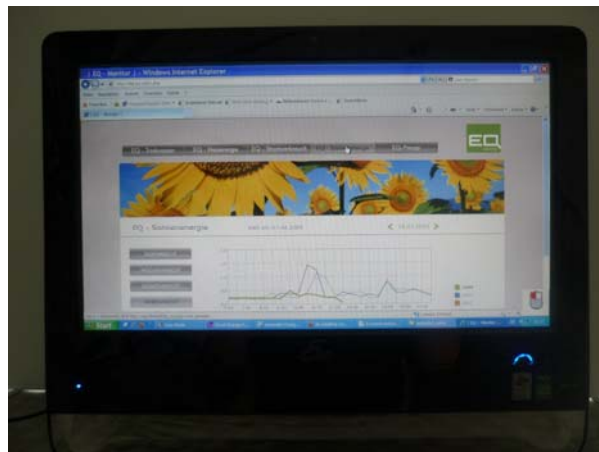


Figure 1: User interface with Touch Screen interaction

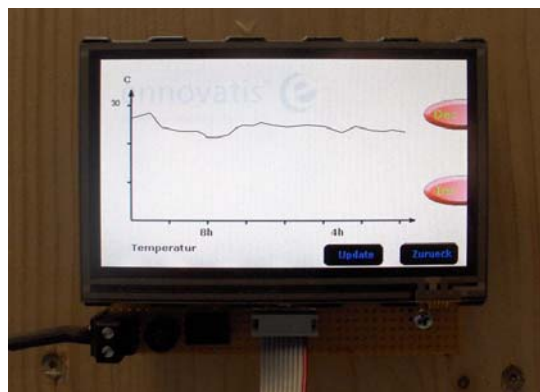


Figure 2: User interface with Touch Screen interaction Details

We will demonstrate the technical and economic benefits by providing energy reports which include

- Calculations of energy savings
- List of technical features
- Summary of advantages

## Quantification of possible energy savings

Finally we will try to quantify the possible energy savings due to

- Classical energy management
- High resolution energy management
- Coordination of supply systems
- Coordination of energy using products
- Reduction of peak load

## 4 Demonstrator locations

### 4.1 Rationale for demonstrator locations

Project work plan indicated that the demonstrator would be implemented at the domestic home of Mr. Christian Wysodil, in Almersberg, Neulengbach, near Vienna, Austria. The following advantages prevailed in proposing the Almersberg location for the demonstrator:

- Building at Almersberg location already contains equipment which will be part of the demonstrator installation, including photovoltaic power panel, sensors, and energy management unit.
- There is an extensive and valuable record of the energy usage at the Almersberg location, including manual logbook of energy using products, which would be used to establish a valid baseline data for the assessment of energy savings and overall impact of the project implementation.
- Almersberg location is a home to two people who live and perform everyday activities there, thus it is a representative location to demonstrate project results. Moreover, being the active participant in the project implementation, the owner of the building and the premises decided to voluntarily participate in demonstrator and play a role of a 'living lab' – an inhabited building with SmartCoDe energy management functionality installed together with a local energy generation. The owner also accepted the requirements such as installation of wind turbine, sensor metering and energy using products and agreed to operate the complete demonstrator installation.

During the first project year, the building preparations at the Almersberg have been executed, including the installation of a small weather station and measurement of the weather data. A wind speed analysis conducted during this phase of project implementation, revealed that the originally planned wind turbine installation site at Almersberg was not adequate due to limited average wind speed.

The new demonstrator site was found at Buchberg, but it was agreed to keep the original Almersberg site in addition, because it is very close to Buchberg and already has some of the needed equipment available. The arrangement essentially amounts to enlarge the overall demonstrator to a two-site approach. The average wind speed at Buchberg site is about 6.6 m/s, with expected power of about 5000 W.

Buchberg location includes a building which is used as restaurant as well as home for the restaurant tenant with a family of five (three adults and two children). The building will be equipped with a small wind turbine, energy using products and energy management system, which will ensure that all technical aspects can be fulfilled as defined in the SmartCoDe Grant Agreement.

For the new (public) location at Buchberg, Austria, additional contract negotiations have become necessary and at the time of delivering this report, the contract was close to final, expected it to be signed by all parties in May 2011.

Additional costs due to the location change for contract (notary), contract translation, etc. have been covered by partners QR, IFAT and ECN.

## 4.2 Almersberg location

### 4.2.1 Description

The building at A- 3040 Almersberg 9, near Vienna, Austria, was designated as the original site of the SmartCoDe demonstrator installation. Mr. Christian Wysoudil, the property owner, who is employed at *ennovatis*, uses the building as the home for his family of two, and as an office. The whole house including the surrounding garden is a part of SmartCoDe demonstrator site.

Building, already installed photovoltaic and a detail of heating system at Almersberg are given in Figure 3 to Figure 5. The basic information on the building and the area is listed in Table 1.



Figure 3: Building at Almersberg



Figure 4 Building with photovoltaic



Figure 5: Heating system

location:	A- 3040 Almersberg, Austria
Altitude	48.20°
Longitude	15.92°
Sea Level	250 m
weather data: average outdoor temperature	11 °C
year of construction, refurbishment:	1901 / 1928 / 1993
net base area:	718 m <sup>2</sup>
gross floor area:	836 m <sup>2</sup>
Net base area (thermal)	537 m <sup>2</sup>
Ve (thermal gross volume)	1.266 m <sup>3</sup>
A (surface area)	2.840 m <sup>2</sup>
A/V	2,24 m <sup>-1</sup>
BRI (gross volume)	1.955 m <sup>3</sup>

Table 1: Basic information on Almersberg location

## 4.2.2 Consumption of energy

Consumption and production is measured by the main gas meters, main electric meter and two water meters. Table 2 gives an overview of the consumption of energy and water during the last 5 years. All data are extrapolated for a period of 365 days.

medium	period	PE factor	2005	2006	2007	2008	2009	2010
<b>electricity</b> pub supply [kWh] 04 - 03		2,97	10.609	10.776	10.030	5.755	4.863	5.211
<b>electricity</b> sold to pub grid [kWh]		-2,97	0	0	0	0	2.874	2.387
<b>electricity</b> production PV [kWh]			0	0	0	0	4.510	4.286
<b>consumption electric</b> [kWh]			10.609	10.776	10.030	5.755	6.499	7.110
<b>solar thermal water heating</b> [kWh]		0	No data	No data	No data	No data	No data	No data
<b>warm water</b> [m <sup>3</sup> ]			No data	No data	No data	98	82	77
<b>room heating gas</b> [kWh]		1,12	2.306	823	321	339	494	0
<b>room heating wood</b> [kWh]		0,2	18.240	16.416	14.592	12.768	14.592	14.592
<b>consumption room heating</b> [kWh]			20.546	17.239	14.913	13.107	15.086	14.592
Heat Degree Days average		2.705	2.834	2.784	2.385	2.360	2.683	2.705
heat consumption HDD corrected [kWh]			19.611	16.750	16.914	15.023	15.210	14.592
<b>consumption total</b> [kWh]			30.220	27.526	26.944	20.778	21.708	21.702
Primary Energy Balance [kWh]			38.037	36.333	32.679	19.652	9.350	11.304

<b>consumption electric</b> [kWh/m <sup>2</sup> ]		20	20	19	11	12	13
<b>consumption room heating</b> [kWh/m <sup>2</sup> ]		37	31	31	28	28	27

consumption total [kWh/ m2]	56	51	50	39	46	45
Primary Energy Balance [kWh/ m2]	71	68	61	37	17	21
CO2 emissions [kg]		7.420	7.129	6.495	3.782	4.320
CO2 emissions [kg/m²]		14	13	12	7	8
						9

Table 2: Consumption of energy and CO2 emissions at Almersberg over the last 5 years

## Remarks

**General:** The measuring period is fixed from April to March of the next year. The values for the heat degree days in 2010 will have to be verified (at the moment only the average value of 20 years is available).

**Increase in 2009:** Due to private reasons people stayed longer in the rooms (building) as in the year before.

**Gas consumption:** Gas is only used in winter period for an anti frost strategy during holiday's app. 4 to 5 weeks and was installed first time in 2005. The increase in 2009 is due to the different usage conditions mentioned above (the ant frost heating with gas in January 2009 is here represented)

**Electricity consumption:** in 2008 the heating pumps where switched off after April, the e-Boiler was renewed and the temp reduced and the 3 PCs where switched of when not in use – also the old deep freezer was changed to a high efficient working deep freezer. In 2010 additional IT equipment was installed for wind measuring

**Electricity production:** the photovoltaic was installed in the year 2009. Only 65% of the electricity produced could be used directly. The increase of about 20% in electricity consumption is due to different reasons which could be explained by more detailed measurements

**Warm Water:** the water counter was installed at the entry for the solar boiler in 2008.

**Heating:** 4 circles with floor heating and radiators are used – main source hardwood 0,5 meter pieces. This leads to heat consumption in the year 2009 of 28 kWh/m²/a and an electricity consumption of 12 kWh/m²/a.

The running costs over the last 6 years for heating, electrical energy, water and waste water are listed in

Table 3: Energy costs for the demonstrator in Almersberg

	2005	2006	2007	2008	2009	2010
gas, water, wood, electricity [Euro]	2.365	2.344	2.305	1.359	1.375	1.303
variable cost reduction based on 2005 [%]	0	1%	3%	43%	42%	45%
cost [€/m²]	4,4	4,4	4,3	2,5	2,6	2,4

Table 3: Energy costs for the demonstrator in Almersberg

The costs are basically due to the electricity consumption. The reductions are due to the described analyses of consumption and user behaviour. The first attempted started as seen above in the year 2008 with the energy cost reduction based on the year 2005 of 52%.

## 4.2.3 Demonstrator structure

The demonstrator at Almersberg site will consist of:

- a solar panel (already available at the site)

- energy management unit from ENO, the currently available unit is:
  - enhanced with software developed in WP2,
  - networked with solar panel and wind turbine,
  - connected with SmartCoDe prototype network
  - connected with SmartCoDe dissemination web platform to allow real-time analysis (ECN)
- electric lightings and HVAC "upgraded" by SmartCoDe prototype (TA)
- a web interface that gives information on the consumption/generation of power and allows controlling power management and can "simulate" interactions of the local grid with the global grid, considering different ancillary services.

The different cases of interaction of the global grid with the local grid shall not be implemented physically, but it shall be possible to analyze the behaviour of the local grid in different scenarios of the advanced energy management. The analysis itself is part of WP1, task 1.6.

Task leader is UNS-FTS with contributions from ENO (site), QR (setup of wind turbine in Vienna), TA (electric lighting with SmartCoDe prototype integrated), ADO (security), TUV and IFAT (setup of SmartCoDe network), and ECN (real-time web integration).

Figure 6 and

Table 4 give an overview of the structure and power of LEPs and EUPs at the Almersberg site.

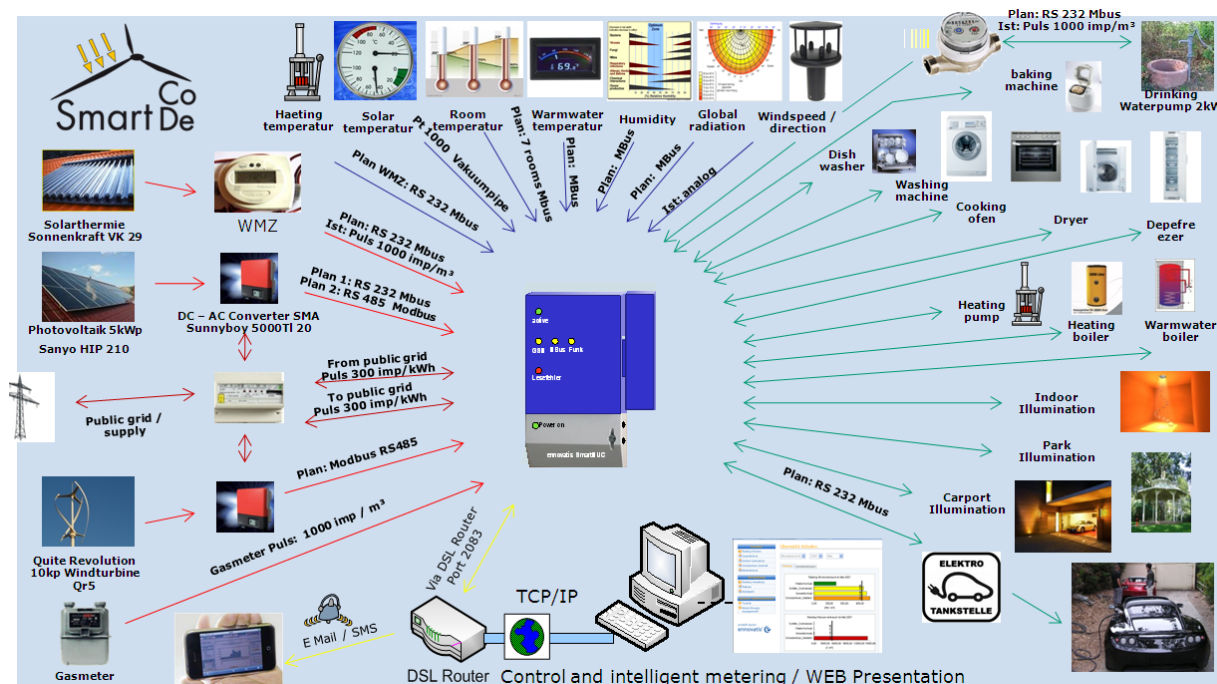


Figure 6: Demonstrator overview of available combinations of LEP and EUP

Local energy production (LEP)	kW	Energy using products (EUP)	kW
Solar Heating Vacuum tubes	1,2	Fridge	0,05
Wind power generator	10	Deep Freezer	0,12
Photovoltaic	4	Water pump Gardening	0,22
		Heating pump	0,045
<b>Supply from public grids</b>		Illumination	4,5
public grid supply gas	35	Indoor	
public grid supply Electric Power	25	Car Parking	
local water supply	2	Outdoor (Park,Terasse)	



		Water heater electrical	2
		Washing machine	2
<b>Energy storage</b>		Dishwasher	2
Battery 24V / e car supply		Waters ply pump	2
Room Heating Water tank 1 800l	2	Circulation pumps	0,25
WW Water tank 2 400l		Cooking	3,6
WW Water tank 3 100l	2	Baking machine	2
Water tank 4 500l	2		
Additional measurements			
Temperatures (see Tab )		Metrological data (see Tab.)	

Figure 7 gives the structure plan of the Almersberg demonstrator installation.

Figure 7: Almersberg Demonstrator Structure Plan

### 4.3.1 Description

The building and property at A- 3034 Buchbergstrasse 12 is owned by 3 municipalities: Neulengbach (40%), Maria Anzbach (40%) and Aspernhofen (20%). The building is rented to the restaurant operator who uses the building as a home to himself, his wife, 2 children and sometimes a cook in the upper floor of the building. The restaurant is opened Thursday to Monday from 9 am to 22 pm.

Table 5 gives the basic information on the building and the area at Buchberg.

location:	A- 3034, Austria
Owner	Tourismusverband Buchberg (Maria Anzbach, Aspernhofen, Neulengbach)
Altitude	48.xx°
Longitude	15.xx°
Sea Level at the cross	469 m
weather data: average outdoor temp.	Ca 8°C (not enough Data)
year of construction, refurbishment:	1945 / 1990 / 2006
net base area:	311 m <sup>2</sup>
gross floor area:	Will follow m <sup>2</sup>
Net base area (thermal)	249 m <sup>2</sup>
Ve (thermal gross volume)	681 m <sup>3</sup>
A (surface area)	635 m <sup>2</sup>
A/V	0,93 m <sup>-1</sup>
BRI (gross volume)	791 m <sup>3</sup>

Table 5 Basic Information on the Demonstrator (Schutzhaus Buchberg)

Remark: BRI is without cellar = technical room & storage.

### 4.3.2 Consumption of energy

The following table gives an overview of the consumption of energy of the last 4 years.

Consumption Buchberg	PE factor	2006	2007	2008	2009
Oil Litre (room heating)	1,17	4.003	7.360	5.003	10.003
Oil kWh		42.312	77.795	52.882	105.732
Oil weather Corrected		43.539	68.615	46.113	104.886
heating average 06-09 =65788kWh+weather cor		63.991	58.973	59.695	60.801
Electric energy kWh	2,96	45.873	51.159	54.802	59.260
Propane Gas kg (cooking)	1,11	1.517	2.196	600	
Earth Gas m <sup>3</sup> (cooking)	1,12			1.442	2.911
Gas kWh (cooking)		19.524	28.263	23.423	31.768
Water m <sup>3</sup> Oct - Sept	0,00	no data	private well	577	524
Total kWh absolute		107.709	157.217	131.107	196.760



total kWh Primary energy	206.961	273.822	250.085	334.379
--------------------------	---------	---------	---------	---------

KPI kWh tot / m²		158	231	193	289
Diff to 2006		100%	146%	122%	183%
KPI PE kWh tot / m²		304	402	367	491
Diff to 2006		100%	254%	232%	310%

KPI kWh electric / m²		67	75	80	87
Diff to 2006		100%	112%	51%	55%

KPI kWh heating abs./ m²		62	114	78	155
Diff to 2006		100%	184%	125%	250%

Heat Degree Days		3252	2997	3033	3090
Heat Degree Days dif to average = 3343		2,9%	-11,8%	-12,8%	-0,8%
kWh heating weather-cor./m²		64	101	68	154
Heating / m² diff. to 2006		100%	158%	106%	241%

Co2 emission [kg]		46.951	63.311	56.522	77.194
Diff to 2006		100%	135%	120%	164%

Table 6: Consumption data at demonstrator side (Schutzhaus Buchberg)

## Remarks:

**General:** The measuring period is fixed from Feb to Jan of the next year. For Oil we have only bills but no metering or filling information.

**Gas consumption:** Gas is only used in the kitchen for cooking food.

**Warm Water:** heated up with a oil burning system. The solar thermal system for Warm water is not working at the moment.

**Room Heating:** One circle with radiators is used – source: Oil.

**Heat Degree Days :** We are using as a base the average for Lower Austria, where the average for 20 years was 3343.

The focus for our Project will be in the Key Performance Indicator for Primary Energy per m<sup>2</sup> for the overall consumption which was 491 kWh/m<sup>2</sup> in 2009.

The running costs during the last 4 years for heating and electrical energy:

<b>Cost</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>
<b>Current € brutto</b>	5.817	8.286	9.125	9.609
<b>Gas €</b>	1.787	2778,08	1.866	1.838
<b>Oil €</b>	2.982	4.554	4.309	5.213
<b>Water €</b>			1.177	1.069
<b>Total € including VAT</b>	10.586	15.619	16.478	17.729

KPI € / m <sup>2</sup>	16	23	24	26
Diff to 2006	100%	148%	156%	167%

Table 7: Running energy costs on the demonstrator at Buchberg

### 4.3.3 Demonstrator structure

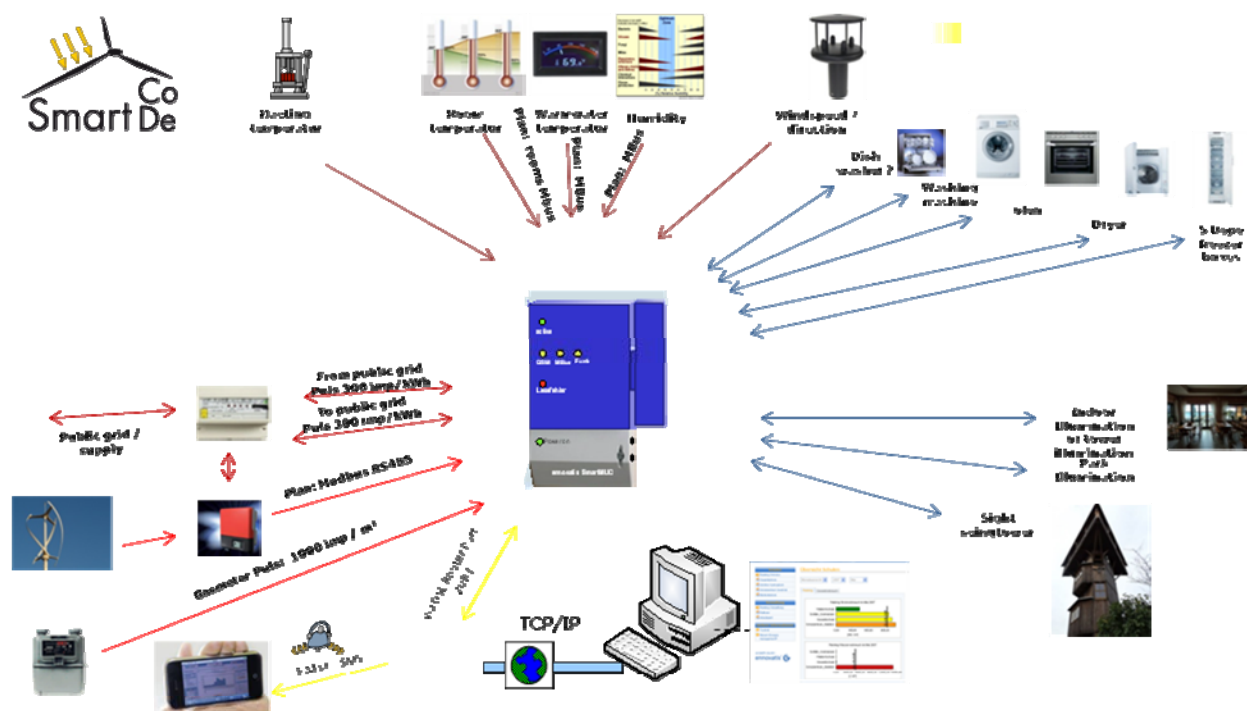


Figure 8: Demonstrator overview at Buchberg location

Local energy production (LEP)	kW	Energy using products (EUP)	kW
Wind power generator	6,5	5 Deep Freezer	0,12
<b>Supply from public grids</b>		Illumination	6
	35	Sightseeing tower	
public grid supply Electric Power	35		
		Washing machine	2,1
<b>Energy storage</b>		Dishwasher	2,4
		Dryer	0,25
		Oven	3,6
Additional measurements			
Temperatures (see next table )			

Table 8: Overview of connected power on the demonstrator

Figure 9 gives the structure of the demonstrator at the Buchberg site.

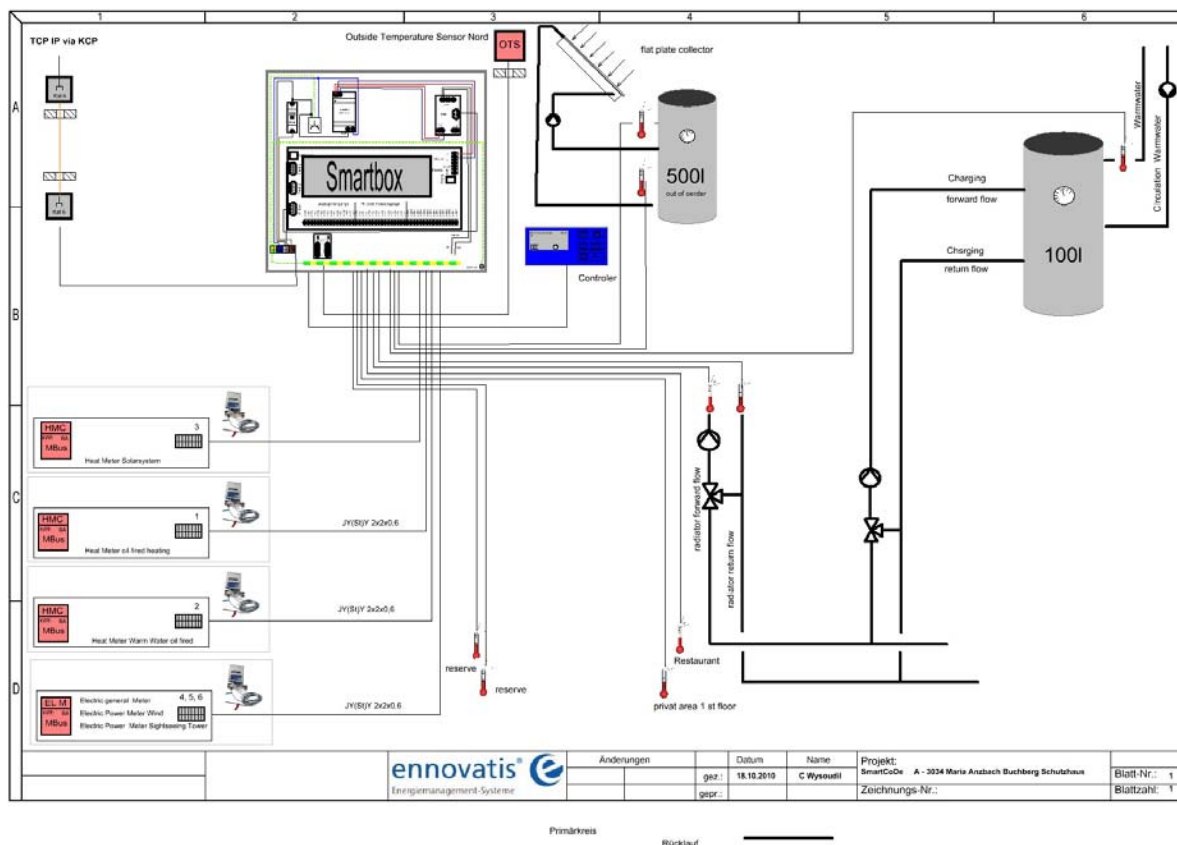


Figure 9: Demonstrator structure at the Buchberg site

## 4.4 Demonstrator equipment

According to the Grant Agreement, equipment has been purchased to complement the existing demonstrator installation at the Almersberg. After the decision to move the demonstrator to the Buchberg site and complement it with Almersberg site, some of the equipment purchased for the Almersberg will be moved to the Buchberg site, and yet some equipment will be purchased and installed at the Buchberg site.

The table below lists the equipment (purchased and planned to be obtained), classified according to the following categories:

- i0: equipment purchased in 2010 and installed at Almersberg site in 2010,
- i1: equipment purchased in 2010 and installed at Almersberg site in 2011,
- e: equipment purchased in 2010 and will be used at both demonstrator sites (for the purpose of programming the programmable equipment),
- B0: equipment purchased in 2010, which will be installed at Buchberg site in 2011,
- B1: equipment which will be purchased and installed at Buchberg in 2011.

ind	description	item
B0	control Warm water circulation	Heat meter SensoStar 1/2 Zoll el. WW
B0	Forecast check	Weather station P03/3-Modbus
B0	Presence control	Movement detector
B1	metering supply, Production and Tower	Industry meter M-Bus
B1	metering Eups	Mini Industry meter M-Bus
B1	room control	THI Sensor

B1	installation of meters	Distribution box
B1	230 V Connection EuP	230 V Connection EuP
B1	Level converter for 60 Mbus Connection	Level converter 60
B1	Level converter for 3 Mbus Connection	Level converter 3
B1	Temp sensor	Temp sensor
B1	Connecting Weather station and sensors	J-Y(ST)Y 6x2x0,8 cable
B1	getting Access to the Freezers outside the house	radio transceiver and transmitter
B1	Connection to Internet	Connection cable TCP IP
B1	Connection to Internet	Connection cable TCP IP
B1	Voltage supply for radio signal	Voltage supply
B1	Power supply cable	Power supply cable
e	configuration of Mbus	MBUs Micro-Master
e	development Web suite	Main board, Storage, CPU
i0	TCP IP Connection	Patchable Cat 5
i0	heat pump control	Temperature sensor room
i0	Pt 1000 Connection	4 Channel PT1000/M-Bus Converter
i0	PV and thermo dependence	Global radiation sensor
i0	TCP IP Connection	Mounting box
i0	consumption correction	Outdoor Temperature Sensor
i0	TCP IP Connection	Cat 6 Box
i0	room ventilation	CO2 Sensor
i0	electric pump switching	Gas Sensor
i0	electric pump switching	Base for Gas Sensor
i0	for Mbus Connection	M-Bus Level Converter
i0	EMU	Smartbox IP 65
i0	consumption correction	Temperature sensor Outdoor
i0	eg control for pumps	Temperature sensor pipe
i0	consumption object	Industry counter M-Bus
i0	connection of sensors	Cable J-Y(ST)Y
i0	Eup consump. metering	Mini Industry counter M-Bus
i0	Heat meter	Multi ball tap
i0	IP Connection Tecroom	Patchable Cat. 30m
i0	room control	THI Sensor
i0	Heating main supply	Heat meter SensoStar Type MSH 25mm Cu
i1	for Weather forecast check	Rainwater detector
i1	Switching devices	Fieldbus module
i1	heat pipe control	Pressure transmitter
i1	Heating, Solar and e Boiler	Heat meter SensoStar 19mm Cu

Table 9: Demonstrator equipment, already purchased and to be purchased

#### 4.5 Equipment donated by Associated Partner

Bosch-Siemens Hausgeräte (BSH), which is one of the global leaders in white goods and the member of the project Associated Partners, agreed to contribute to SmartCoDe demonstrator with high end research white goods, planned for delivery is 2011.

Table 10 lists the equipment which Associated Partner Bosch-Siemens Hausgeräte GmbH (BSH) has already provided and which have been installed at the Almersberg and Buchberg locations.

	equipment	type	location	status
1	Dishwasher	SD6P1S	Almersberg	installed
2	Oven	HTSHBP7	Almersberg	installed
3	Wash machine	WM 16S750	Almersberg	installed

4	Dryer	WDT60	Almersberg	installed
5	Dishwasher	SD6P1S	Buchberg	installed
6	Oven	HTSHBP7	Buchberg	installed
7	Wash machine	WM 16S750	Buchberg	installed
8	Dryer	WDT60	Buchberg	installed

Table 10: Demonstrator equipment donated by Associated Partner Bosch - Siemens

## **4.6 Role and responsibilities of the partners in demonstrator building**

### **4.6.1 edacentrum**

*edacentrum* will provide a mechanism to display near-real time analysis data from the demonstrator (data transmission and format to be discussed) on the web page, probably together with a web-cam. The goal is to demonstrate user awareness of energy consumption / generation data. *Edacentrum* will nominate person who will be responsible for the participation of *edacentrum* in building the demonstrator.

### **4.6.2 Infineon**

*Infineon* will contribute by ASIC implementation of the components needed for implementation of the nodes as well as providing SiP integration and packaging of integrated high voltage components which will be developed in WP3 and built into the SmartCoDe demonstrator. Mr. Thomas Herndl will be responsible for the *Infineon's* participation to the demonstrator

### **4.6.3 TUW**

*Vienna University of Technology* (TUW) will design, develop and provide discrete nodes which will implement SmartCoDe functionalities to the demonstrator Local Energy Provider (LEP) and Energy using Products (EuP).

TUW will need about a week time to install the nodes at the demonstrator site. As a prerequisite to install the nodes, the demonstrator will have to provide a solution for outdoor locations (for example IP65 /- a splash water proof solution for outdoor illumination and similar applications) and the interface to the EUP / LEP / Smartbox.

Dr Stefan Mahlknecht will be responsible for the TUW participation to building the demonstrator.

### **4.6.4 Ennovatis**

*Ennovatis* will provide a separate document which contains a detailed description of planned and installed Local Energy Provider (LEP) and Energy using Products (EUP) at the demonstrator site.

*Ennovatis* will provide energy management unit which will be enhanced with software developed in WP2, networked with solar panel and wind turbine, connected with SmartCoDe prototype network and connected with SmartCoDe dissemination web platform to allow real-time analysis (which *edacentrum* will provide). *Ennovatis* will also contribute the equipment to measure and analyze energy consumption and to improve the applicability of the methods developed for the demonstrator.

ENO provides the infrastructure to design, install and operate energy management systems. This will be provided in the form of the *ennovatis* Visual Energy Centre (VEC) and the component based Development Framework. The VEC is *ennovatis's* energy management software framework. It includes components for auditing, analyzing, simulation, visualization, storage / archiving of energy management data. *ennovatis* further provides the location and infrastructure for the SmartCoDe demonstrator.

Mr. Christian Wysodil will be responsible for the *Ennovatis* participation in building the Demonstrator.

### 4.6.5 Tridonic

Tridonic will provide and set up electric lightings and HVAC upgraded by SmartCoDe prototype to provide energy management. Mr. Reinhold Juen will be responsible for the implementation of the Tridonic's equipment to the Demonstrator.

### 4.6.6 Ardaco

Ardaco will be responsible mainly for demonstrator software implementation and security. For testing purposes, Ardaco requires a device which is able to dump network communication and send commands to network to simulate attack. Most likely it will be a notebook computer with attached RF transceiver, which means that this piece of equipment is not required to have it as a fixed part of demonstration site.

Ardaco recommends that the demonstrator site should be large enough to require communication paths longer than transmission range of a single node to demonstrate multihop routing and that we should have some devices ready to be added/removed dynamically to demonstrate network configurability.

Mr. Juraj Hájek will be responsible for the Ardaco's participation to the SmartCoDe demonstrator.

### 4.6.7 Quiet Revolution

Quiet Revolution (QR) will contribute the following facilities and specialist resources:

- access to the specially-instrumented energy yield test-turbine development systems which will allow for detailed measurements of fluctuating, grid-delivered, variable power output and wind resource data
- access to summarized results from the installed fleet-wide data set of turbine performance and urban wind resource history (> 70 years accumulated data from real-world installations)
- in-house software tools for analyzing turbine performance logs
- expertise in grid-connected small-scale energy generation issues
- access to technology and expertise behind the remote monitoring systems of the turbines
- installation / support of the turbine which will be part of the technology demonstration effort
- access to electrical and mechanical workshops and tools for supporting custom elements of demonstrator project

QR will provide knowledge and experience from renewable energies. QR's expertise in turbine energy generation will be utilized in the development of the energy management profiles for the SmartCoDe energy management unit. Quiet Revolution will assist in setting up the demonstration site by providing a small urban wind turbine. Quiet Revolution's involvement with the demonstrator two dimensions:

Turbine Installation: up to now Quiet Revolution supplied Ennovatis with all the documentation, including planning permissions and so forth, and support for helping prepare demonstrator site for the installation of the wind turbine.

Demonstrator Interface: there will be a measure of custom software and hardware that Quiet Revolution will need to implement with the turbine system to enable it to properly interface with the rest of the SmartCoDe demonstrator system.

Dr Tamas Bertenyi will be responsible for the Quiet Revolution's participation to the SmartCoDe demonstrator, but he soon he will hand it over to one of their dedicated Installation Managers. Most likely, Mr. Tom Young will be responsible for developing custom software to make the turbine system communicate with the Smartbox.

### 4.6.8 University of Novi Sad, Faculty of Technical Sciences

UNS-FTS together with Ennovatis will be responsible to coordinate development of a test strategy for the demonstrator together. With contributions from ENO, QR, TA, ADO, TUV and IFAT, UNS-FTS and Ennovatis will produce the SmartCoDe demonstrator's test plan which describes the test strategy, dedicated test classes and maps these to actual test cases. The Test Plan further defines how the results of the energy management optimizations are verified. The test plan will be continuously updated throughout the project's life-time.

Prof. Veljko Malbasa will coordinate the activities related to the development of the SmartCoDe Demonstrator test plan.

## 4.7 Work schedule

The work on the demonstrator will be organized according to the following time schedule:

	Task	Deliverable	Activity	Deadline
1	4.1	D4.1	SmartCoDe Demonstrator Test Plan	30. 06. 2010.
2	4.2-a		SmartCoDe Demonstrator, set-up	30. 06. 2011.
3	4.2-b		SmartCoDe Demonstrator, analysis	28. 06. 2012.
4	4.2-c		SmartCoDe Demonstrator, refinement	31. 12. 2012.

Table 11: Schedule of the work on demonstrator implementation

## 5 Measurements at the demonstrator

### 5.1 Measurements at the Almersberg demonstrator site

The following measures will be performed at the Almersberg site to collect data which will be analysed to assess the energy consumption and production as well as to assess the user behaviour and weather impact on the energy production/consumption:

- main power supply from the public power grid,
- electric power returned to the public grid,
- photovoltaic and solar power production,
- power consumption of the energy using products,
- outside and inside temperatures,
- wind speed and global radiation,
- indoor humidity and CO<sub>2</sub> concentration (to assess user comfort).

The following table lists the already activated measurement channels at the Almersberg demonstrator site. The abbreviations are:

A, channel number,

M, medium

TE, technical entity

MC, measuring cycle

U, measuring cycle units

SC, storage cycle units

ID, channel D

Item	A	M	TE	MC	U	SC	ID
Energy supply							
Gas counter	5	Gas	m <sup>3</sup>	15	Min	0	1
Electricity from public grid	3	el. Cur 3 phase	kWh	2	Min	0	2
Electricity to public grid	2	el. Cur 1 phase	kWh	2	Min	0	3
Photovoltaic LEP		electricity	kWh	2	Min		
Solar thermo LEP		Water	kWh	2	Min		
Warm Water 100l (WW)		electricity	kWh	2	Min	0	

		heat	kWh	2			
Biomass		heater	kWh	5			
Warm Water counter	6	water	l	2	Min	10	9
Solar counter	7	heat	l	2	Min	0	10
T Temperatures							
T Outdoor north	0	Air	°C	15	Min	5	6
T Solar RL	4	solar water	°C	15	Min	15	11
T Solar VL	5	solar water	°C	15	Min	15	12
T Warm Water	6	freshwater	°C	15	Min	15	13
T Solar Thermo roof	2	solar water	°C	15	Min	5	5
T Cold Water	3	freshwater	°C	15	Min	5	7
T Solar water tank up 400l	7	freshwater	°C	15	Min	15	14
<b>Other sensors</b>							
Wind speed m/s	4	wind	m/s	10	Min	60	8
Global radiation		sun	w/m2	2	Min	60	
Temperature PV Surface		Temperature	°C	15	Min	60	
Temperature WW El.tank 100l		Temperature	°C	15	Min	15	
Energy using Products (EUP)		electricity	kWh	2	Min		
Washing machine							
Dishwasher		electricity	kWh	2	Min		
Water supply pump well		electricity	kWh	2	Min		
Oven Kitchen (cooking)		Electricity	kWh	2	Min		
Technician room (pumps, IT)		Electricity	kWh	2	Min		

Table 12: Activated measurement channels at the Almersberg

The following table lists the measurement channels which are planned to be activated at the Almersberg demonstrator site.

	A	M	TE	MC	U	SC	ID
Fridge		electricity	kWh				
Deep Freezer		electricity	kWh				

Table 13: Measurement channels to be activated at the Almersberg

## 5.2 Baseline data at Almersberg site

The following table lists baseline data collected at the Almersberg site, which will be used for the benchmarking of the energy consumption..

key features		2005	2006	2007	2008	2009	2010
consumption total [kWh]	0	30.220	27.526	26.944	20.778	21.708	21.702
consumption total [kWh/ m2]	0	56	51	50	39	46	45
Primary Energy Balance [kWh]	0	38.037	36.333	32.679	19.652	9.350	11.304



Primary Energy Balance [kWh/ m2]	0	71	68	61	37	17	21
CO2 emissions [kg]	0	7.420	7.129	6.495	3.782	4.320	4.588
CO2 emissions [kg/m <sup>2</sup> ]	0	14	13	12	7	8	9
running cost [Euro]		2.365	2.344	2.305	1.359	1.375	1.303
cost [€/m <sup>2</sup> ]		4,4	4,4	4,3	2,5	2,6	2,4

Table 14: Different quantities for benchmarking the energy consumption

### 5.3 Measurements at the Buchberg demonstrator site

The following measurements will be performed at the Buchberg site to collect data which will be analysed to assess the energy consumption and production as well as to assess the user behaviour and weather impact on the energy production/consumption:

- main power supply from the public power grid,
- electric power returned to the public grid,
- wind turbine power production,
- power consumption of the energy using products,
- outside and inside temperatures,
- wind speed and global radiation,
- indoor humidity and CO2 concentration (to assess user comfort).

Table 15 lists planned measurements at the Buchberg demonstrator site.

Planned channels							
Name	A	M	TE	MC	U	SC	ID
Energy supply							
Gas Meter		Gas	m <sup>3</sup>	15	Min	0	
Electricity from public grid		el. cur 3phase	kWh	15	Min	0	
Electricity to public grid		el. cur 1phase	kWh	15	Min	0	
T Temperatures							
T Outdoor north		Air	°C	15	Min	5	
T Warm Water		freshwater	°C	15	Min	15	
Other sensors							
Wind m/s		wind	m/s	10	Min	60	
<b>further planning (depending on the available budget)</b>							
<i>Energy using Products (EUP)</i>							
Deep Freezer		electricity	kWh				
BSH Washing machine		electricity	kWh				
BSH Dishwasher ?		electricity	kWh				
Illumination in the Sightseeing tower							
BSH Dryer		Electricity	kWh				

BSH Oven							
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Table 15: Planned measurements at the Buchberg location

The following abbreviations are used in Table 15:

- A, channel number,
- M, medium.
- TE, technical entity,
- MC, measuring cycle,
- U, measuring cycle units,
- SC, storage cycle units ,
- ID, channel ID.

## 5.4 Baseline data at Buchberg site

The following table lists baseline data collected at the Buchberg site, which will be used for the benchmarking of the energy consumption..

key features	2006	2007	2008	2009
consumption total absolute [kWh]	107.709	157.217	131.107	196.760
consumption total [kWh/ m <sup>2</sup> ]	158	231	193	289
Primary Energy Balance [kWh]	206.961	273.822	250.085	334.379
Primary Energy Balance [kWh/ m <sup>2</sup> ]	304	402	367	491
Co2 emission [kg]	46.951	63.311	56.522	77.194
Co2 emission [kg/m <sup>2</sup> ]	69	93	83	113
running cost including VAT [€]	10.586	15.619	16.478	17.729
running cost [€ / m <sup>2</sup> ]	15,5	22,9	24,2	26,0

Table 16: Different quantities for benchmarking the energy consumption

## 6 Strategy of demonstrator testing

Strategy of SmartCoDe demonstrator testing is based on the bottom-up approach: first the components will be tested, than the subsystems, and finally test of the overall demonstrator installation will be performed. Acceptance tests of the individual components will be followed by the acceptance tests of the subsystems and eventually test of the overall demonstrator installation.

Testing of the components and subsystems will be managed by the respective task leaders and performed by the researchers or technicians appointed by the task leader. In general, testing will be performed by the consortium partners, so that each component will be tested by the people from the consortium partner who are responsible for its development.

In order to make the on-site testing more efficient, whenever possible each component will be extensively tested in the laboratory environment. For example, each component which communicates to Energy Management Unit ('*Smartbox*') will have to be tested to show that the communication works as expected.

As the most important aspect of the demonstrator testing are the interface and communication between the components, the focus of this section is on testing of the communication.

## 6.1 Relationship between test plan and implementation

The two project tasks, Demonstrator Test Plan (Task 4.1) and Demonstrator (Task 4.2) are closely related and have to be developed and coordinated closely. The following table describes the relationships between the implementation and testing tasks.

Task 4.2 SmartCoDe demonstrator	Task 4.1 Test plan
Installation of the required metrology (electric counters for PV, wind turbine, several dif. Circuits will be monitored), heat flow counters, wind probe, temperature probes (indoor, outdoor), humidity probes, etc	Testing of the functionality (hardware), checking plausibility of values
Setup of equipment inventory list (designation, physical location, measured media, assigned input of SmartBox, ..)	Prepare plan for testing, setup of a test plan documentation
Installation of information infrastructure (M-bus, RS485, Ethernet (TCP/IP))	Testing of communication to all devices
Insert bus-addresses of all installed devices into the inventory list	Check completeness of the inventory list, verification of connectivity
Integrate all devices into ennovatis controlling system	
Establish database (ev. FTP-space on ennovatis homepage)	
Set EM system into operation	Periodical, repetitive plausibility checks of data base entries
Setup of hardware to control appliances (prototype of the final chip solution)	Test classes: 1. manual verification of remote control of controllable devices like dish washer, fridge, alliances which are allowed to be switched to standby, etc. 2. Setup of rules for energy management system for controlling the devices in the demonstrator 3. Test the automated remote control of the devices 4. Monitoring of all EM system actions – automatic report generation
Creation of project plan for the erection of the qr5 wind turbine	Setup of metering, remote control, monitoring of all relevant data
System running on the demonstrator	Monitoring the system under quasi normal conditions.
Simulation of communication between global and local grid – the communication could be based on PLC (power line carrier) or ripple control systems which are currently in use by the utilities	Development of a command structure, communication protocols, a user interface for clearly showing the efficiency of the EM to the end-user.  For scientific approach the efficiency shall be calculated according to IPMVP proposals.  See <a href="http://www.evo-world.org">www.evo-world.org</a> for details concerning

	methodology, statistical and mathematical principles to calculate the “avoided energy use”.
coverage	Measuring distances reachable with different barriers

Table 17: Relationships between the implementation and testing tasks

## 6.2 General assumptions

The goal of project is to demonstrate feasibility of solution and not to develop final ready-to-market device. Defects without direct impact on evaluation of feasibility could be potentially accepted.

Existing hardware and software components from 3rd party vendors will be reused. Detailed testing of these components is out of project scope, especially:

- 3rd party hardware platform with ZigBee support in the case that ZigBee standard is adopted and extended. This includes also ZigBee protocol stack if it is available for used hardware.
- 3rd party hardware (smart card, crypto memory, etc) providing elementary cryptographic algorithms (e.g. ECC, AES, etc), especially if it is already certified by trusted authority.
- Full ZigBee compatibility testing as required for ZigBee certification.

## 6.3 Testing approach

Testing will be based on standardized software method like Rational Unified Process (RUP)<sup>1</sup>. Testing will be integral part of development process continuously verifying quality. Iterative approach will be used with high risk items implemented and tested at first wherever possible.

## 6.4 Types of test

The project will have several levels of testing, Unit, Integration, Functional, System and Acceptance.

- Unit Tests at the level of a line of code (performed internally by developers).
- Integration Tests at the level of low level modules aggregated to larger parts.
- Function Tests at the level of distinct business events or functional process.
- System Tests at the level of the system (Stress, Performance, Security, Recovery, etc). It is not expected that full testing of scalability will be possible, because of limited size of demonstrator
- Acceptance Tests at the level of operational processes.

## 6.5 Requirements for testing environment

Testing requires following parts of the demonstrator

Deliverable	Requirements
<b>D-2.4, M18:</b> Protocol SW of a SmartCoDe node, initial version	<ul style="list-style-type: none"> <li>• Virtual prototype of SmartCoDe Node and SmartCoDe network</li> </ul>
<b>D-2.6, M30:</b> Protocol SW of a SmartCoDe node, revised	<ul style="list-style-type: none"> <li>• Hardware implementation of SmartCoDe Node integrated into devices on demonstrator site</li> <li>• At least one device from each class of devices supporting smart energy as will be defined in Task 2.2, "Optimization and adaptation of the ZigBee standard",</li> <li>• The size of SmartCoDe network should be large enough for testing of multi-hop</li> </ul>

<sup>1</sup> <http://www-01.ibm.com/software/awdtools/rup/>

	routing
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Table 18: Requirements for testing environments

## 6.6 Requirements for human resources

Project role	Skills	Responsibilities in testing process
Project manager/Test Manager (Aggregated role)	General project and test management skills	<ul style="list-style-type: none"> <li>Ensuring the appropriate planning and management of the test resources</li> <li>Assessing the progress and effectiveness of the test effort</li> <li>Advocating the appropriate level of quality by the resolution of important Defects</li> <li>Advocating an appropriate level of testability focus in the software development process</li> </ul>
Security analyst	Knowledge of network protocols and security mechanisms and application area	<ul style="list-style-type: none"> <li>Preparing risk analysis</li> <li>Participation on preparation of test plan</li> </ul>
Test Analyst/Test Designer/Tester (Aggregated role)	Knowledge of testing methodologies, testing approaches and tools	<ul style="list-style-type: none"> <li>Designs and documents test cases</li> <li>Executes test case,</li> <li>Records test case results</li> <li>Documents and tracks defect.</li> </ul>
Developer	C++, knowledge of application area	Implementation of unit tests

Table 19: Requirements for human resources

## 6.7 Requirements for equipment

A tool for sniffing, analyzing and injecting network communication (hardware and software). The tool could be based on customized SmartCoDe node attached to notebook or 3<sup>rd</sup> party tool.

## 6.8 Procedures applied for testing

Procedure applied for testing

1. Define test mission
2. Verify test approach
3. Validate build stability (smoke test)
4. Test and evaluate
5. Achieve acceptable mission
6. Improve test assets

The detailed content of activities is defined in RUP. These activities are done at least once per iteration.

Procedure applied after error or defect is found:

1. Register defect.
2. Execute remaining test cases.
3. Evaluate test results.
4. Prioritize issue list and prepare plan for next iteration
5. Improve development process
6. Improve test assets and define new test mission

## ***6.9 Procedure for retesting of fixed defects***

1. Basic testing is executed by developer.
2. Build stability is verified on buildserver. This includes automatic execution of regression unit tests.
3. Development iteration is finished when the goal of iteration is achieved.
4. New test mission is defined and test plan is prepared for the next testing iteration. Test cases selection criteria are based on:
  - character of changes
  - potentially affected functionality
  - project phase.

Full regression testing is performed if important milestone has been achieved or it is required due to nature of changes.

5. Test plan is executed.

## ***6.10 Procedure for signing-off testing activities***

Each of our testing activities is based on a test plan that defines when and how to run test cases. Each test case defines a purpose, pre-conditions, test data, steps and the most important the expected results (success criteria). Decision to sign-off a testing activity is always based on the success criteria which must be unambiguous and measurable.

## ***6.11 Procedure for signing-off total testing***

The final sign off is based on evaluation of test report as a summary output from test execution process. The test report should match unambiguous and measurable criteria defined in test planning phase (test coverage, number of failed test cases for high, medium and low priority, etc)

## ***6.12 Testing inputs and outputs***

Inputs:

- Requirement specification
- Risk analysis
- Output artefacts from development (virtual prototype of SmartCoDe node in early phases of projects, hardware and software in final phase)

Outputs:

- Test report (list of executed test cases and their results)

Other outputs of testing activities in wider content

- Test plan
- Test scripts
- Test cases

## ***6.13 Required support***

The coordination with other project partners is required for integration and acceptance testing.

### **6.14 Situations to be tested**

- Initial network establishment and configuration
- Network maintenance, replacement of nodes
- Network extension
- Node and network functionality oriented on smart energy
- Interference with most popular wireless networks
- Vulnerabilities against well known security attacks

### **6.15 Safety issues**

The safety tests are not addressed yet. Testing is primary focused on network layer and security in the meaning of cryptographic mechanisms.

### **6.16 Additional issues**

- The demonstration site should be large enough to require communication paths longer than transmission range of single node (demonstration of multihop routing)
- Testing of commissioning requires some nodes ready to be added/removed dynamically.
- Testing of scalability and performance cannot be fully performed, because of limited size of the demonstrator.

## **7 Plan of demonstrator testing**

### **7.1 Addressed types of tests**

- Unit
- Functionality
- Performance
- Security

### **7.2 Unit tests**

It is hard to define scope of unit testing at this phase of project, because it is not clear yet which existing components will be reused and which will be developed from the scratch. The scope of adaptation and optimization of ZigBee standard also has not been defined yet at current phase of project.

In general, we will implement unit tests for any functionality which is implemented as an output of our tasks wherever possible.

### **7.3 Functionality tests**

The functionality tests will cover the following features:

- Network management
  - Create new network
  - Configure network parameters (network ID, channels, root trust for PKI, etc)
  - Add new device
  - Remove existing device
- Dynamic discovery
  - Dynamic device discovery
  - Dynamic service discovery (detect capabilities of devices)
- Binding
  - Create binding between devices (e.g. switch/light)
  - Remove binding
- Grouping
  - Add group (e.g. several lights controlled by one switch)

- Remove group
  - Add device to group
  - Remove device from group
- Security management
  - Establish Key
  - Transport Key
  - Request Key
  - Switch Key
  - Authenticate Device
  - Encrypt transported data
- SmartCoDe smart energy management functions. The list of functions will be defined in Task 2.2, "Optimization and adaptation of the ZigBee standard".

## **7.4 Performance tests**

The performance tests will cover the following scenarios:

- Time required for registration/unregistration of new device in network
- Time required to add/remove binding between devices
- Time required to add/remove group of devices
- Time required to discover new routing path
- Speed and response time of network with several security profiles (e.g. without security vs. with encryption and authentication)
- Time required to recover network after reset of central node.
- Behaviour of network in interfering environment (e.g. presence of other SmartCoDe network, interference with other devices on the same channel)

Each test will be repeated for different number of nodes and network architecture within scope of demonstration site.

## **7.5 Integration tests**

The integration tests will cover the following scenarios:

- Interaction between software and hardware layer
- Execution of logical commands delivered to smart energy devices
- If some existing ZigBee protocol stack is reused and extended/optimized:
  - Interface compatibility
  - Unexpected parameter values or state interaction
  - Handling of run-time exceptions.

## **7.6 Security tests**

The security tests are focused mainly on:

- Infrastructure security
  - Network access control
  - Integrity of packet routing
  - Prevent unauthorized use of packet
- Application data security
  - Message integrity
  - Authentication
  - Freshness (reply attacks)
  - Privacy

Several tools for exploiting security in ZigBee network will be evaluated and potentially used, for example:

- Daintree Sensor Network Analyzer, <http://www.daintree.net/sna/sna.php>
- KillerBee (ZigBee Hacking Framework), <http://www.willhackforsushi.com/?p=400>



- or other tools listed on ZigBee Alliance site,  
<http://www.zigbee.org/Products/TestDevelopmentSolutions.aspx>

The list of security tests will be extended based on Task 2.2, "Optimization and adaptation of the ZigBee standard".

If cryptographic algorithms (RNG, AES, ECDSA, etc) are provided by generic 3<sup>rd</sup> party modules, detailed testing of these components is not in scope of project, because quality of their implementation does not have strategic impact on feasibility of solution or system architecture. However, security evaluation is possible based on standardized validation suites, e.g. NIST tests (<http://csrc.nist.gov/groups/ST/toolkit>).

## 7.7 Safety tests

The expected behaviour in safety critical situations has not been defined yet.

## 7.8 Test scenarios

Detailed description of test cases will be based on the following scenarios:

- Network Management
  - Create new network
  - Join
  - Leave
  - Rejoin
  - Network status
- Dynamic discovery
  - Device discovery - IEEE address request
  - Device discovery - network address request
  - Service discovery
- Binding
  - Add new binding
  - Add new binding - fails for different clusters
  - Remove binding
- Grouping
  - Add new group
  - Remove group
  - Add device to group
  - Add device to group - fails for different clusters
  - Remove device from group
  - Correct addressing of groups
- Routing
  - Routing - single hop
  - Routing - dynamic discovery of path
  - Routing - multi hop
- Security
  - Cryptographic algorithm validation
  - Application data security
    - Authentication
    - Authentication - smoke test, valid authentication data
    - Authentication - smoke test, invalid authentication data
    - Message integrity
    - Modifications in payload are detected
    - Freshness (reply attack)
    - Record and reply network communication
    - Privacy
    - Network data are encrypted
    - End to end data are encrypted
  - Infrastructure security
    - Secure key exchange
- Performance
  - Transmission speed, single hop, happy day
  - Transmission speed - multihop, happy day
  - Transmission speed - single hop, interference

- Required time - network initialization
  - Required time - route discovery
  - Required time - add/remove new group
  - Required time - add/remove binding
  - Required time - join/leave device
- Smart energy management
  - Smart energy features
- Other
  - Customized ZigBee profile validation

## 7.9 Test scripts

### 7.9.1 Test Suite: Network Management

#### Test Case SCD-3: Create new network

##### Summary:

##### Prerequisites:

- Network coordinator device
- Network analyzer tool

##### Steps:

1. Turn on network coordinator
2. Start commissioning/configuration tool (it could be build-in part of coordinator or external)
3. Enter new network ID
4. Enter network parameters (channel, expected level of security, etc)
5. Apply configuration

##### Expected Results:

- New network should be created
- Network analyzer tool should detect new network with expected parameters

#### Test Case SCD-17: Join

##### Summary:

##### Prerequisites:

- End device to join network
- Debugging node as a parent device

##### Steps:

1. Permit join to network on network coordinator

2. Send join request from end device
3. Accept join on network coordinator (if required by design of network coordinator)
4. Perform smoke test if device can participate on network communication (e.g. send some commands)

Expected Results:

- Device should successfully join network and should be able to participate on network communication
- Parent device should update its routing tables

### Test Case SCD-18: Leave

Summary:

Prerequisites:

- End device to leave network
- Debugging node as a parent device

Steps:

1. Perform operation invoking "leave network" for end device, e.g. turn it off.

Expected Results:

- Parent not should receive information about leaving network and update its routing tables

### Test Case SCD-19: Rejoin

Steps:

1. Join end device to network
2. Cause lost of communication, e.g. by shielding device
3. Remove obstacle causing lost of communication

Expected Results:

- Device should automatically rejoin network and continue in working

### Test Case SCD-14: Network status

Steps:

1. Start network sniffer/analyzer
2. Invoke every situation defined in ZigBee Specification, section 3.4.3.3.1 Status Code (e.g. address non existing target)
3. Check logs on analyzer

Expected Results:

- Correct network status command should be send over the network in the each situation

## 7.9.2 Test Suite: Dynamic discovery

### Test Case SCD-21: Device discovery - IEEE address request

Summary:

Device should be able to discover other devices in network.

Prerequisites:

- Debugging node injecting network commands

Steps:

1. Enable detailed logging on debugging node
2. Address other device by debugging node using its target IEEE address

Expected Results:

- Debugging node should successfully discover target device (check logs)

### Test Case SCD-22: Device discovery - network address request

Summary:

Device should be able to discover other devices in network.

Prerequisites:

- Debugging node injecting network commands

Steps:

1. Enable detailed logging on debugging node
2. Address other device by debugging node using its target IEEE address

Expected Results:

- Debugging node should successfully discover target device (check logs)

#### Test Case SCD-23: Service discovery

##### Summary:

Device should be able to discover capabilities of other devices on network.

##### Prerequisites:

- Debugging node injecting network commands and logging network communication
- Several other devices supporting different profiles/application clusters

##### Steps:

1. Use debugging node to send request for information about capabilities of other devices

##### Expected Results:

- Capabilities should be correctly detected and they should match with real profile of each target device and supported clusters.

### 7.9.3 Test Suite: Binding

#### Test Case SCD-4: Add new binding

##### Summary:

##### Prerequisites:

- Two types of devices belonging to the same cluster - source and target, e.g. switch and light.

##### Steps:

1. Enable binding on source device
2. Enable binding on destination device

##### Expected Results:

- New binding relationship should be detected
- Binding tables should be updated
- Destination device should receive commands from source device and reacts on them (e.g. lights are turned on)

#### Test Case SCD-5: Add new binding - fails for different clusters

##### Summary:

##### Prerequisites:

- Two device which do not belong to the same application cluster (e.g. dimmer and smart meter - dimmer cannot send dimming commands to smart meter)

##### Steps:

1. Enable binding on source device
2. Enable binding on destination device

##### Expected Results:

Binding will be refused.

#### Test Case SCD-12: Remove binding

##### Summary:

##### Prerequisites:

- Source and destination device with existing binding relationship

##### Steps:

1. Apply "remove binding" *on device where binding table is stored*

TODO: Need more research where binding relationship is stored. In ZigBee binding table is stored on coordinator; ZigBee Pro stores it on end device(s).

##### Expected Results:

- Binding should be removed and source device should not be able to send commands (e.g. turn off) to destination device

### 7.9.4 Test Suite: Grouping

#### Test Case SCD-10: Add new group

##### Steps:

1. Create new group (send "add group" from device")

##### Expected Results:

New group should be discovered on network

#### **Test Case SCD-11: Remove group**

##### Summary:

##### Prerequisites:

- Existing group

##### Steps:

1. Send "Remove group" command

##### Expected Results:

Group should not be visible on network anymore and group addressing is not possible.

#### **Test Case SCD-6: Add device to group**

##### Summary:

##### Prerequisites:

- at least 2 devices which forms group (e.g. lights)
- at least one device which will address group (e.g. dimmer)

All devices belongs to the same application cluster

##### Steps:

1. Create new group
2. Create binding between source and destination group
3. Add new device to group (enable "allow add to group" for group and send "add to group" from added device)

##### Expected Results:

- New device should be added to group
- Source device (e.g. dimmer) should be able address group (e.g. dimming of all lights in group)

#### **Test Case SCD-7: Add device to group - fails for different clusters**

##### Summary:

**Prerequisites:**

- Two devices belonging to different application clusters (they do not support the same set of commands)

**Steps:**

1. Create new group with first device
2. Allow join to group
3. Send "join to group" request from second device

**Expected Results:**

- Join should be refused because devices does not support same cluster

### **Test Case SCD-8: Remove device from group**

**Summary:**

**Prerequisites:**

- Source device addressing existing group (e.g. dimmer)
- Target group with at least 2 devices (e.g. lights)

**Steps:**

1. Allow "remove from group" for group
2. Send "remove from group" from device which should be removed
3. Send command from source device to group (e.g. turn off)

**Expected Results:**

- Removed device should not belong to group
- Only remaining devices in group should respond to commands

### **Test Case SCD-9: Correct addressing of groups**

**Summary:**

**Prerequisites:**

- Two independent target groups addressed by two independent source devices (e.g. 2 sets of lights each regulated by independent switch)

**Steps:**

1. Send command from the first source device to the first destination group



2. Send command from the second source device to the second destination group

Expected Results:

- The first destination group responds only to commands from the first source
- The second destination group responds only to commands from the second source

## 7.9.5 Test Suite: Routing

### Test Case SCD-13: Routing - single hop

Summary:

Prerequisites:

- Two devices within transmission range (e.g. switch and lights)

Steps:

1. Send any command from the first device to the second, just to test communication, e.g. turn on lights.

Expected Results:

- Devices should be able to communicate together and react on commands sent

### Test Case SCD-16: Routing - dynamic discovery of path

Summary:

Prerequisites:

- Two devices out of single-hop transmission range (e.g. switch and light)
- Physical distribution of nodes allowing several multi-hop routing paths

Steps:

1. Run network analyzer tool
2. Send command from source to destination device (e.g., turn on lights)
3. Use analyzer to track routing path
4. Remove/disable intermediate nodes on routing path
5. Send command again

Expected Results:

- New routing path is discovered
- Source and destination devices are still able to communicate together

#### Test Case SCD-15: Routing - multi hop

##### Summary:

##### Prerequisites:

- Two devices out of transmission range (e.g. switch and light).
- Physical distribution of nodes allowing several multi-hop routing paths.

##### Steps:

1. Send any command from the first device to the second, just to test communication

##### Expected Results:

- Devices should be able to communicate together and react on commands sent

### 7.9.6 Test Suite: Security

It is assumed that suspicious behaviour of nodes or attempts to break security are recorded and reported.

Details about reporting will be specified during project analysis and network/protocol design.

#### Test Case SCD-24: Cryptographic algorithm validation

##### Summary:

Validate implementation of cryptographic algorithms using standardized validation test suites (e.g. NIST tests).

A list of concrete tests will be dependent on algorithms selected during project elaboration phase. We can assume usage of AES referenced in ZigBee Specification and potentially ECDSA referenced in ZigBee Smart Energy Profile Specification. The related test suites could be found here:

- <http://csrc.nist.gov/groups/STM/cavp/documents/aes/AESAVS.pdf>
- <http://csrc.nist.gov/groups/STM/cavp/documents/dss/ECDSAVS.pdf>

As part of the algorithm validation, additional algorithms implemented by the main algorithm must be validated. For example, for the Key Pair Generation function, this includes the underlying RNG/ DRBG algorithm. For the Signature Generation function, the underlying SHA and the RNG/DRBG algorithms must be validated. For the Signature Verification function, the underlying SHA algorithm must be validated, etc.

Higher level algorithms (e.g. key exchange protocols) are tested similar way.

The scope of performed tests is dependent on certified security level of cryptographic device.

## 7.9.6.1 Test Suite: Application data security

### Test Suite: Authentication

#### Test Case SCD-1: Authentication - smoke test, valid authentication data

##### Summary:

Note: Strength of algorithms is addressed by separate test.

##### Steps:

1. Attach device with valid authentication data to network
2. Invoke communication between attached device and other devices in network (e.g. send "turn on" command from remote control switch to lights)

##### Expected Results:

- The target device should accept command.

#### Test Case SCD-2: Authentication - smoke test, invalid authentication data

##### Summary:

Prerequisites:

1. Tool supporting custom packet injection to network

Note: Strength of algorithms is addressed by separate test.

##### Steps:

1. Use injecting tool to inject command with invalid authentication data (e.g. turn on lights)

##### Expected Results:

- Target device should refuse commands
- Target devices should report problem in defined way, e.g. red blinking LED, notification of trust centre, local log (TODO: define expected behaviour)

### Test Suite: Message integrity

#### Test Case SCD-26: Modifications in payload are detected

##### Summary:

Prerequisites:

- Two end devices communicating each other (e.g. switch and light) through malicious device
- Malicious device (emulated by debugging node) in between two end devices

Note: Strength of algorithms is addressed by separate test.

Steps:

1. Invoke command between source and target device, e.g. turn on lights
2. Use malicious node to change transported payload

Expected Results:

- Modified packets should be refused
- Inconsistency/attempt to break security is reported

## Test Suite: Freshness (reply attack)

### Test Case SCD-25: Record and reply network communication

Summary:

Prerequisites:

- Network sniffer/injecting tool
- Two devices communicating each other (e.g. switch and light)

Note: Strength of algorithms is addressed by separate test.

Steps:

1. Start network sniffer to record network communication
2. Execute some command between source and target device - e.g. use switch to turn on lights
3. Replay network communication

Expected Results:

- Replayed communication does not invoke execution of commands (e.g., lights are not turned on)
- Attempt to use old packets is recorded

## Test Suite: Privacy

### Test Case SCD-27: Network data are encrypted

Summary:

Prerequisites:

- Network sniffer/analyzer

Note: Strength of algorithms is addressed by separate test.

Steps:

1. Start network sniffer
2. Invoke communication between network devices, e.g. create binding between devices
3. Check if data are encrypted by network key

Expected Results:

- All transmitted data are encrypted by network key

**Test Case SCD-28: End to end data are encrypted**

Summary:

Prerequisites:

- Network sniffer/analyzer

Note: Strength of algorithms is addressed by separate test.

Steps:

1. Start network sniffer
2. Invoke end-to-end communication between network devices. (To-do: specify when end-to-end encryption is used and provide more details about steps in this test case)
3. Check if data are encrypted by network key

Expected Results:

- End-to-end communication is encrypted with keys dedicated for this scenario (= not with general network key)

**Test Suite: Infrastructure security**

**Test Case SCD-29: Secure key exchange**

Summary:

Infrastructure should support secure key exchange.

Note: Strength of algorithms is addressed by separate test.

Steps:

TODO: Protocol for secure key exchange is not specified yet at this phase of project. Describe concrete steps after it will be specified.

**7.10 Test Suite: Performance**

**Test Case SCD-30: Transmission speed, single hop, happy day**

Summary:

Transmission speed should fulfil criteria from specification. Measurement will be done in non-interfering environment.

TODO: Exact values are not specified yet.

**Test Case SCD-31: Transmission speed - multihop, happy day**

Summary:

Transmission speed for multihop should fulfil criteria from specification. Measurement will be done in non-interfering environment.

TODO: Exact values are not specified yet.

**Test Case SCD-32: Transmission speed - single hop, interference**

Summary:

Transmission speed should fulfil criteria from specification at defined interference level.

TODO: Exact values are not specified yet.

**Test Case SCD-33: Required time - network initialization**

Summary:

Network initialization (e.g. after restart of devices) should fulfil performance criteria from specification for defined network size and configuration.

TODO: Exact values are not specified yet.

**Test Case SCD-34: Required time - route discovery**

Summary:

Time required for new route discovery should fulfil performance criteria from specification for defined network size and configuration.

TODO: Exact values are not specified yet.

**Test Case SCD-35: Required time - add/remove new group**

Summary:

Time required for adding/removing group should fulfil performance criteria from specification for defined network size and configuration.

TODO: Exact values are not specified yet.

#### **Test Case SCD-36: Required time - add/remove binding**

##### Summary:

Time required for adding/removing group should fulfil performance criteria from specification for defined network size and configuration.

TODO: Exact values are not specified yet.

#### **Test Case SCD-37: Required time - join/leave device**

##### Summary:

Time required for join/leave device should fulfil performance criteria from specification for defined network size and configuration.

TODO: Exact values are not specified yet.

### ***7.11 Test Suite: Smart energy management***

#### **Test Case SCD-38: Smart energy features**

##### Summary:

Description of custom smart energy features is not defined yet in specification.

TODO: Extend test cases based on output from Task 2.2, "Optimization and adaptation of the ZigBee standard",

### ***7.12 Test Suite: Other***

#### **Test Case SCD-39: Customized ZigBee profile validation**

##### Summary:

ZigBee standard will be adopted and optimized in Task 2.2, "Optimization and adaptation of the ZigBee standard".

(Potential) new profile should be compliant with existing standard. It is possible to evaluate compatibility with tools provided by several ZigBee Alliance member

<http://www.zigbee.org/Products/TestDevelopmentSolutions.aspx>

#### Steps:

1. Run validation tool against SmartCoDe node

#### Expected Results:

- Validation tool should confirm expected compatibility level with ZigBee requirements

- **Additional issues which may be relevant for the test plan of your WP/task.**  
None.

## **7.13 Testing the communication between demonstrator nodes**

In Task 2.2 the requirements identified in task 2.1 will be used for the optimization and adaptation of the ZigBee standard. The ZigBee standard in itself is a very general standard which allows for a very broad range of solutions. Despite the different profiles offered by the ZigBee Alliance such as the Home Control Lighting or Demand Side Management Profiles, the special security, transmission requirements, but also resource/cost restrictions which we have in this project need some adaptations/optimizations resulting in a new ZigBee Profile. Task 2.2 also considers transmission requirements and possible restrictions due to interferences with WLAN or Bluetooth clients for example. Depending on the results from task 2.1 it might also occur that some adaptations are necessary to allow for the combination with the DALI and DSI standard. Especially the timing could become a critical factor, since for example in the DALI specification the response time until a forward telegram has to be acknowledged is below 9.17 ms. Using Encryption makes this point even more critical and lead to appropriate formulation of a new profile.

The security aspect is a major concern in SmartCoDe, it will be based on two principles: shared key (every unit in this system stores a private key for establishing a secure channel) and RSA key pair (+ certificate). This approach will ensure the security of a communication channel against tapping or misuse. It protects the grid against intrusion (unauthorized communication) and can guarantee the authenticity of data provided.

### **Test strategy**

The Demonstrator will include a network of the wireless nodes which will communicate through low-power ZigBee modules. The network will be debugged either by using a dedicated hardware or some of-the-shelf IEEE 802.15.4 modules together with open source software.

Typical low-power ZigBee modules have transmit power between 0 and 8 dBm and receiver sensitivity between -90 and -100 dBm. (See for example

[http://freaklabs.org/images/stories/blog/zigbee\\_chip\\_comparison.pdf](http://freaklabs.org/images/stories/blog/zigbee_chip_comparison.pdf) )

Under ideal conditions (negligible interference, free space) that will give:

$$0 \text{ dBm} + 2,14 \text{ dB} - 20 \cdot \log(4 \cdot \pi \cdot d \cdot f / c) \text{ dB} + 2,14 \text{ dB} = -90 \text{ dBm}$$

(TX pwr) (TX antenna) (path loss) (RX antenna) (RX sensitivity)

This calculation results with the distance of  $d = 514 \text{ m}$  at frequency  $f = 2,4 \text{ GHz}$ . It is realistic to expect for the signal to traverse one wall using typical IEEE 802.14.5 equipment at 2,4 GHz and two walls at 800 and 900 MHz.

The commissioning will be determined when the consortium reaches a consensus about the security architecture will be used. ZigBee specifies simple binding (described in Home Automation Profile) and system level binding and SmartCoDe will need to support both. A rational approach would be to demonstrate just one or the other binding.

Wireless network will be designed, debugged and tested by simulating the network and monitoring the quality of the simulation with relatively small-scale laboratory tests.



An issue will be to prove that the enhanced security and commissioning methods do not interfere with the expected network performance. To this end we plan to use the TLM-model which will be created. It may include an instruction set simulator in order to run the same code in the simulation as in the real world.

The test application will include energy management, lighting and HVAC as test applications as well as commissioning (binding & security). The test plan is as follow:

1. Form network
2. Commission a number of devices to accept energy management control from energy management controller, test functionality (data interchange, commands, sensor values)
3. Move one device to different part of the network, test functionality
4. Commission a single lamp and switch, test functionality
5. Commission a group of lamps, test functionality
6. Commission a presence sensor to control group, test functionality
7. Commission a scene setting and a scene selector, test functionality
8. Commission a temperature sensor, temperature setter, meter and pump, test functionality
9. Commission additional sensor and setter at a different part of the network, test functionality

We do not have to prove that ZigBee will always travel at least through one wall, because IEEE 802.15.4 has put considerable effort into finding a trade-off between cost and reliability of the RF interface. We can either use their results or develop our own physical layer.

## 7.14 Testing of demonstrator installation

The test strategy will be based on performing a sequence of the functionally dependent steps. We will start from testing functional units and proceed to subsystems and finally to the test of the overall demonstrator functionality.

### 7.14.1 Test strategy

Strategy of SmartCoDe demonstrator testing is based on the bottom-up approach, meaning that first individual components and units will be tested, then the subsystems and finally testing of the overall demonstrator installation. The strategy is illustrated in the following diagram.

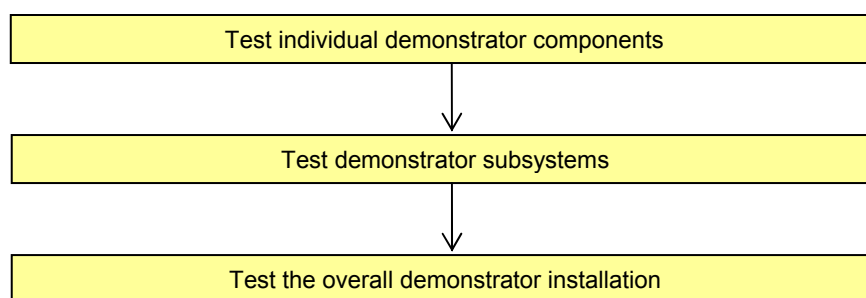


Figure 10: Strategy of femonstrator testing

Testing of the components will be managed by the respective task leaders and performed by the researchers or technicians appointed by the task leaders. Testing of the subsystems will be managed by the respective WP leaders and performed by the researchers or technicians appointed by the WP leaders. For each component and subsystem, task/WP leaders will define type of testing, testing environment, people, equipment, dedicated test classes, test scenarios, procedures and safety issues.

Testing of the demonstrator installation will be managed by the ennovatis in cooperation with the partners who will participate in setting the demonstrator.

## 7.14.2 Test plan

Demonstrator test plan provides details of the tests which will be performed, especially what will be tested in terms of component functionality, performance, integration, security and/or safety. For each component it is specified what kind of unit test are performed (for example, power up, shut down, power down), functionality (responses to the user keys, test of each functionality, test of options / modes of operation, expected responses, test of ranges and limits), performance/stress tests (distance of communications, bandwidth, speed, response time), integration tests (communication to the other demonstrator units, functional integration into the demonstrator system), security tests (does the authorization work as expected, is the security at the expected level), safety tests (what happens in case of power down, what happens if some other demonstrator unit malfunctions, what if there is a communication malfunction, what if there is an attempt to break security of the demonstrator).

For each of the above the test scenarios (situations) and test scripts (detailed step-by-step test instructions) for each scenario are developed and specified.

The tests will address the integration of a local energy provider (LEP) and energy-using products (EuP) with a specific focus on energy management optimization strategies and the verification of the optimized results.

Test of the demonstrator installation will be performed in the following sequence of steps:

1. Installation of the required measuring devices: electric counters for PV, wind turbine, (several different circuits will be monitored), heat flow counters, wind probe, temperature probes (indoor, outdoor), humidity probes, etc.
2. Testing of the functionality of hardware, checking plausibility of values and if the installation was correctly done.
3. Setup of equipment inventory list (designation, physical location, measured media, assigned inputs to Smartbox...)
4. Prepare systematic for testing, setup of a test plan documentation
5. Installation of information infrastructure (M-bus, RS485, Ethernet (TCP/IP))
6. Testing of communication to all devices
7. Insert bus-addresses of all installed devices into the inventory list
8. Check completeness of the inventory list, verification of connectivity
9. Integrate all devices into ennovatis controlling system
10. Select the devices which will be removed and the devices which will stay in the system
11. Establish database (Web space, Server space, FTP-space on ennovatis, ENC, QR platforms)
12. Data secure check, data space check and data mirroring check
13. Set EM system into operation
14. Periodical, repetitive plausibility checks of data base entries
15. Channel Check
16. Threshold checks
17. Metering check
18. Responding check
19. Setup of hardware to control appliances (prototype of the final chip solution)
20. Creation of project plan for the erection of the qr5 wind turbine
21. Check of Setup of metering, remote control, monitoring of all relevant data, check of Energy efficiency key
22. System running on the demonstrator
23. Monitoring the system under quasi normal conditions with observation of reasonable results
24. Simulation of communication between global and local grid – the communication could be based on PLC (power line carrier) or ripple control systems which are currently in use by the utilities

25. Development of a command structure, communication protocols, a user interface for clearly showing the efficiency of the EM to the end-user.

The following test classes will be used:

1. Manual verification of remote control of controllable devices like dish washer, fridge, alliances which are allowed to be switched to standby.
2. Check of the setup of rules for energy management system for controlling the devices in the demonstrator.
3. Test the automated remote control of the devices
4. Monitoring of all EM system actions – automatic report and monitoring generation.

## 8 Analysis of the measured data

Demonstrator will be used to:

- Calculate energy production by local energy production (wind generator and photovoltaic),
- Calculate energy consumption by local energy using products,
- Calculate energy savings compared to the pre-demonstrator energy consumption at the demonstrator site.

One of the important objectives of the demonstrator is to quantify possible energy savings due to:

- classical energy management,
- high resolution energy management,
- coordination of supply systems,
- coordination of energy using products, and
- reduction of peak load.

The methodology which be applied to achieve this objective is to calculate energy or demand savings and evaluate demand response. These are determined by comparing measured energy use or demand at the demonstrator site before and after implementation of the SmartCoDe demonstrator.

The methods which will be used to calculate energy savings are based on the IPMVP protocol, see document „International Performance Measurement & Verification Protocol (IPMVP)“, March 2002, [www.ipmvp.org](http://www.ipmvp.org). The IPMVP has been widely adopted by national and regional government agencies and by industry and trade organizations to help determine energy savings in energy performance contracting.

This Chapter provides methodologies to analyse the collected data, determine and document energy savings achieved in the SmartCoDe demonstrator by applying SmartCoDe nodes and SmartCoDe energy management.

To reach this goal we modified the Methodology for Energy Efficiency Measurement (EEM) developed in the 3e-HOUSES project (see <http://www.3ehouses.eu/>), on grounds of Energy Savings, avoided CO<sub>2</sub> emissions and load curve shifting (demand response) measurements This will enable the SmartCoDe project to meet one of the objectives of the project and, more generally speaking, of the European Union on Energy efficiency, the replicability and standardization of the results achieved in the demonstrator.

The methodology described has been drawn up bearing in mind this goal. It is an objective, proven methodology to measure and subsequently assess the technical, economic and environmental results and impacts of the implementation of the ICT solution, which are aimed to be disseminated and extrapolated out of the scope of the project, and broadly, at international level, to meet the European Union 20-20-20 target.

### 8.1 Definitions and abbreviations

Definitions:

**Independent Variable:** Characteristics of a facility's use or the environment which govern energy consumption: weather ( $T^a$ , humidity) and occupancy

**Degree Day:** is the measurement of the heating or cooling load on a facility created by outdoor T. It's defined relative to a base temperature - the outside temperature above which a building needs no heating

**Measurement & Verification:** The process of using measurements to reliably determine actual savings created by energy efficiency measures in facility

**Routine adjustments:** Adjustments for changes in selected independent variables that can be expected to happen throughout the baseline period

**Non-Routine adjustments:** (baseline adjustments): Adjustments for changes in parameters which cannot be predicted and that affect to demand

#### Abbreviations

b	Baseline Power	FEMP	Federal Energy Program
BPM	Baseline Profile Model	HDD	heating degree day
CDD	cooling degree day	IPMVP	International Performance Measurement & Verification Protocol
DHW	Domestic Hot Water	LEP	local energy production
ECM	energy conserving measure	Q	Heat
EEM	energy efficiency measure	SEC	Smart EUP Control with integrated circuit solution
EPBD	Energy Performance of heating Directive	W	electric auxiliary Energy
EuP	energy using product		

## 8.2 Methodologies to determine and adjust the baseline

Energy savings can't be measured directly, it's necessary to compare always different situations, because the sceneries are different in time. More practical is a calculation of the energy savings with a standardized calculation methodology. This chapter gives an overview about different types of methodology to calculate these savings. Generally said, the saving is the difference among the consumption according to the energy efficiency measures (EEM) and measured during the reporting period and the consumption prior the implantation (baseline period), (see Figure 11). Consumption however is influenced by different variables like weather, usage or occupancies. If the differences are small in absolute values, as it is the case in the SmartCoDe demonstrator, it is necessary to eliminate as much as possible of these influences. This means it is necessary to have consumption and conditions data prior the implantation of EEM in similar conditions than after the implantation. Also it is necessary to make suitable adjustments for changes in conditions and independent variables.

Engineering calculation of baseline and reporting period energy can originate from:

- short-term or continuous measurements of key operating parameter(s) (sub-metering ECM affected system)
- consumption measurements of the whole building.
- Calibrated simulations.

The method which has to be chosen to describe the baseline and to make the necessary adjustments should meet the criteria:

1. Is the method easy to implement?
2. Are the results accurate?
3. Are the results useful and transparent?
4. Is the method adaptable on this type of projects?

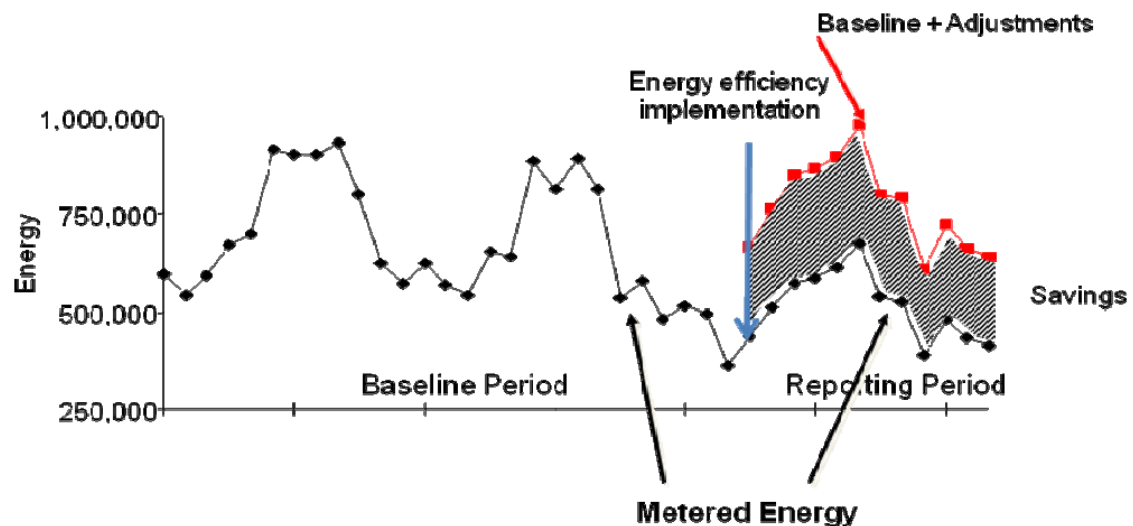


Figure 11: Definitions of Baseline, Reporting and Saving periods

### Quantities to formulate ratios to the baseline – Key Performance Indicators

Generally, there are different ratios which can be measured and monitored to calculate energy savings (technical, environmental, economical) but there are also ratios existing, which can be only rated in a specific way (social) or only indicators to relate to this ratios can be measured. The following list shows existing ratios in relation to energy efficiency:

#### Technical ratios

Technical ratios are important to calculate the energy savings and therefore measure the energy efficiency. With technical ratios it is possible to visualize the results in diagrams to analyze them and show inconsistency clearly.

##### Heating:

Heating consumptions per person (kWh/person)

Consumptions per square meter (kWh/m<sup>2</sup>) or kWh/HDD, HDD stands for "heating degree day"

Primary Energy consumptions per square meter (kWhPE/m<sup>2</sup>)

##### Cooling:

Cooling consumptions per person (kWh/person)

Consumptions per square meter (kWh/m<sup>2</sup>) kWh/CDD, CDD stands for "cooling degree day"

Primary Energy consumptions per square meter (kWhPE/m<sup>2</sup>)

##### Lighting:

Lighting consumption per person (kWh/person)

Lighting consumption per square meter (kWh/m<sup>2</sup>)

Primary Energy consumptions per square meter (kWhPE/m<sup>2</sup>)

##### Cooking:

Cooking consumption per person (kWh/person)

Primary Energy consumptions per person (kWhPE/person)

##### Water ratios:

Consumptions per person (litre /person)

##### Pumping:

Solar pumping consumption per person (kWh/person): the solar contribution is for domestic hot water (DHW), therefore the ratio should be by person that uses the DHW in the facility.

Primary Energy consumptions per person (kWhPE/person)

**Other appliances:**

Other consumption per person (kWh/person)

Other consumption per square meter (kWh/m<sup>2</sup>)

Renewable energy share in energy and electricity [%] - The share of renewable energy in e. g. total primary energy consumption, total end energy consumption or electricity generation

**Environmental ratios**

The level of this ratio is depending on the previous known technical ratios, the higher are the energy savings, the lower are the emissions caused by the energy generation.

HVAC, lighting:	CO <sub>2</sub> emissions per m <sup>2</sup>
Cooking, pumping:	CO <sub>2</sub> emissions per person

**Social ratios**

An important ratio is the “comfort” which is directly influenced by the general condition of the building and the installed technical systems. A very important factor to regulate the comfort is the behaviour of the tenant. With the knowledge of the use of the technical systems the tenant can influence the comfort level directly. Ratios to measure the comfort are room temperatures and relative humidity in the dwellings.

**Economical ratios**

These ratios are directly related to the energy consumption and their costs. Economical ratios shall be provided e.g. in a web interface to have a direct overview of the costs and savings generated by the measured energy consumptions.

- €/person or €/m<sup>2</sup>: Total consumption/ key factor
- €/person/per annual income: total consumption per person taking into account his capita income
- Cent/saved kWh: Costs per saved kWh of end energy on the level of a building or dwelling
- Profitability [€]: Net present value of the investment (additional cost approach)
- Profitability (full cost approach) [€]
- Public funding [%]: Share of public funding on the energy saving investment

### ***8.3 Options to determine the baseline and the energy savings***

Baseline and energy savings can be determined either by measurements or calibrated simulations. In the case of SmartCoDe measurements are primarily for monitoring and therefore performed with high time resolution. Thus we are able to identify the key parameters energy consumption and operating hours by simply looking at the consumption data.

Depending on the adjustments, there are 3 options:

- Specific measurements of Key Parameters of ECM-affected systems
- Measurements of the consumptions of the whole system using utility meters
- Calibrated simulations based on the EPBD assessment of the building

**Option A: Measurement of Key Parameters of ECM-affected systems**

**Measurements**

Savings are determined by field measurement of the key performance parameter(s) which define the energy use of the ECM's affected system(s) and/or the success of the project.

Measurement frequency ranges from short-term to continuous, depending on the expected variations in the measured parameter, and the length of the reporting period.

**Baseline and Adjustments**

Short-term or continuous measurements of baseline and reporting period energy and/or engineering computations using measurements of proxies of energy use.

Routine and non-routine adjustments as required.

### Energy savings calculation

For each ECM

Saving = Baseline Period – Reporting Period ± Adjustments

### Areas of application

New behaviour or/and new equipment + sub metering

### Examples of application

1. A lighting retrofit where power draw is the key performance parameter that is measured periodically. Operating hours of the lights based on building schedules and occupant behaviour.
  - Before: Power = 60 W operation hours: 10 h/week
  - After EEM: Power = 15 W operation hours: 10 h/week
  - Savings:  $(60-15)*10=450\text{Wh}$  /Saving year:  $450\text{Wh}*52\text{weeks}/\text{year}=23,4\text{ kWh/year}$
2. Application of a variable speed drive and controls to a motor to adjust pump flow; measure electric power with a kW meter installed on the electrical supply to the motor, which reads the power every minute. In the baseline period this meter is in place for a week to verify constant loading. The meter is in place throughout the reporting period to track variations in power use.

## Option B : Measurement of Consumption of Whole Facility

### Measurements

Savings are determined by measuring energy use (utility meter) at the whole facility or sub-facility level. Continuous measurements of the entire facility's energy use are taken throughout the reporting period. One or more ECMs might be included.

Applicable for Energy savings > 10%\* due to measuring the whole facility

### Baseline and Adjustments

Analysis of whole facility baseline and reporting period (utility) meter data. Routine adjustments as required, using techniques such as simple comparison or regression analysis. Non-routine adjustments as required.

Multifaceted energy management program affecting many systems in a facility. Measure energy use with the gas and electric utility meters for a twelve month baseline period and throughout the reporting period.

It is possible to explain the residential consumption with the next formulation:

Electricity consumption = constant + X \* number people + Y \* HDD + Z \* CDD

Combustible consumption = constant + X \* number people + Y \* HDD + Z \* CDD

Water consumption = constant + X \* number people

If the energy savings are less than 10% and there are no possibilities to use option A or B. It will be consider uncertainty analysis to identify energy savings.

It is possible to reduce the previous formulation:

- No heating: constant + X \* number people + Y \* HDD + Z \* CDD
- No cooling: constant + X \* number people + Y \* HDD + Z \* CDD
- Occupancy constant: constant + X \* number people + Y \* HDD + Z \* CDD
- No cooling & heating: constant + X \* number people + Y \* HDD + Z \* CDD
- No cooling & heating & occupancy constant: constant + X \* number people + Y \* HDD + Z \* CDD

### Energy savings calculation

Saving = Baseline Energy – Reporting Period Energy ± Adjustments

### Example of application

Heating consumption of university building

In Figure 12 we show the measured heating energy consumption for the years 2001 to 2007. the data are degree day corrected. Samples of the correction coefficients are given in Tab. 2 During the years 2001 to 2004 the consumption was almost constant, but almost 50% higher than predicted. Therefore at the end of 2005 recommissioning took place and measures were proposed to reduce energy consumption.

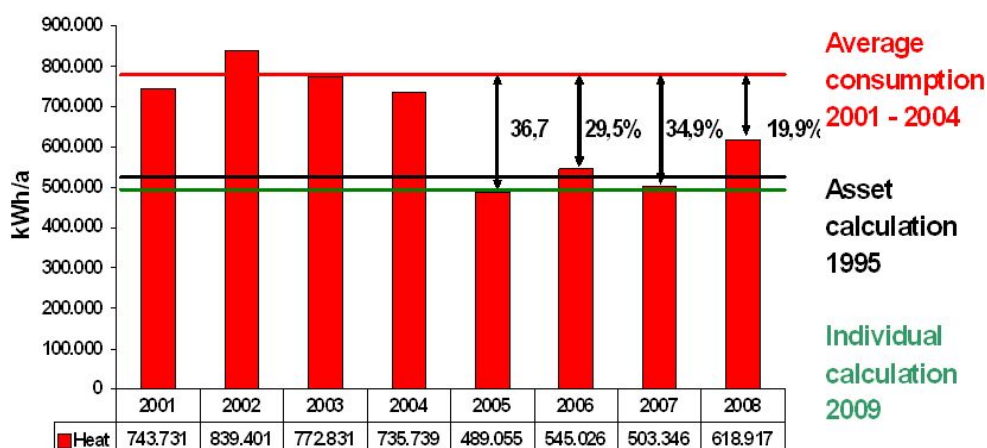


Figure 12: Heating energy consumption during the years 2001 and 2008 (degree day corrected)

This was described in more detail in a German report to be downloaded from the Energy management demo portal. Figure 13 gives the monthly data for heating energy consumption.

From this we take that the energy conserving measures went in operation only at the end of January 2005. Everything worked well. However starting in February 2006 the heating energy consumption increased by 10% to 20 % and later by up to 50%. In July 2006 the faulty behaviour became obvious. However it took till October 2006 to correct the faults. No serious errors occurred in 2007 as can be seen from the correlation between outdoor temperature and heating energy consumption as shown in Figure 14. However another unexpected increase occurred at the beginning of 2008. This again confirms that it is not enough to monitor consumption but also necessary to perform an ongoing commissioning. The University therefore decided to employ an energy manager at the beginning of 2009. He started working on implementing a monitoring system for the whole university to allow ongoing commissioning. At the end of 2009 12 buildings were online as can be seen from the screenshots in Figure 15 and Figure 16. It can easily be seen that is a helpful tool which animates energy managers to interpret the consumption on an actual basis.



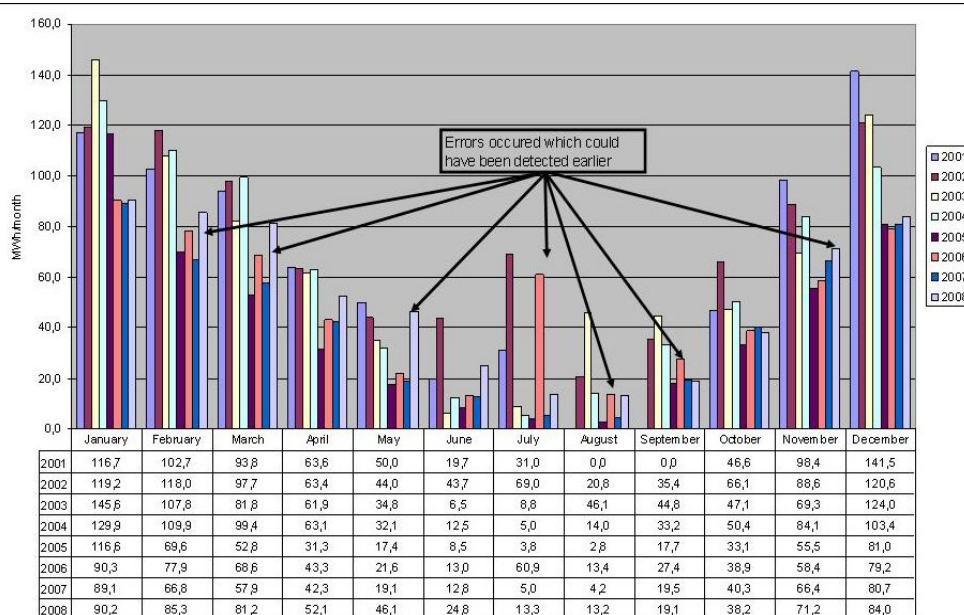


Figure 13: Monthly heating energy consumption during the years 2001 and 2008 (degree day corrected)

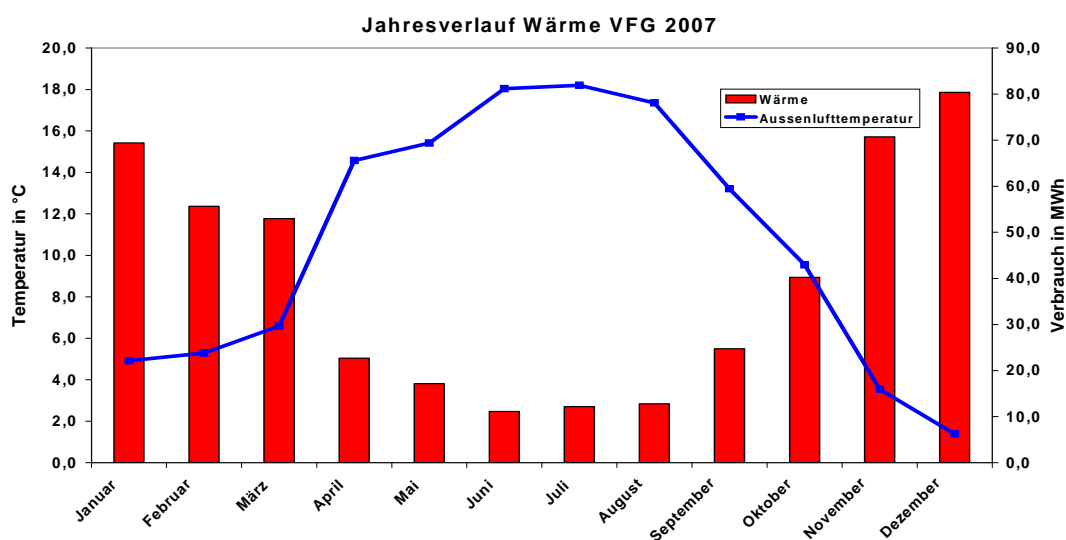


Figure 14: Monthly heating energy consumption during the year 2007 compared to outdoor temperature

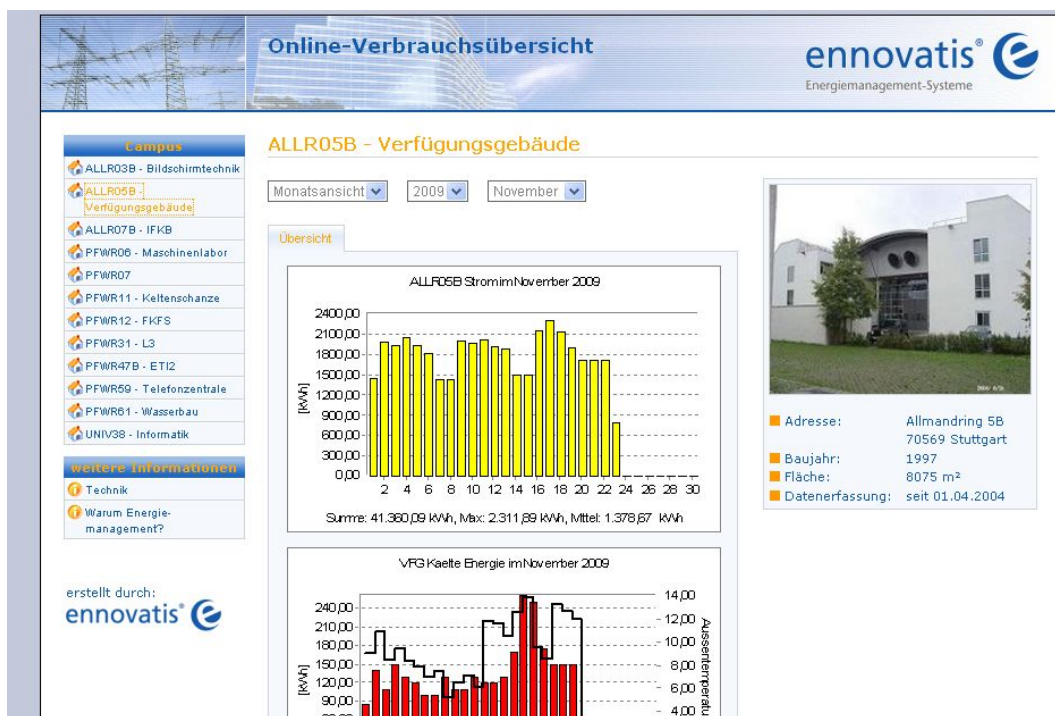


Figure 15: Screenshot of the ongoing commissioning system of the University of Stuttgart



Figure 16 : Screenshot of the ongoing commissioning system of the University of Stuttgart with ongoing commissioning comments from the energy manager

### Option C: Calibrated Simulation

Savings are determined through simulation of the energy use of the whole facility, or of a sub-facility. Simulation routines are demonstrated to adequately model actual energy performance measured in the facility. This option requires considerable skill in calibrated simulation if applied or the whole facility.

Energy use simulation, calibrated with hourly or monthly utility billing data. (Energy end use metering may be used to help refine input data.)

Multifunctional energy management program affecting many systems in a facility but where no meter existed in the baseline period. Energy use measurements, after installation of gas and electric meters, are used to calibrate a simulation. Baseline energy use, determined using the calibrated simulation, is compared to a simulation of reporting period energy use.

## Whole building calculation

Whole building calculations can be performed in the basis of the EPBD. This was done for the university building shown in the previous chapter.

The results of the different asset calculations are compared in Figure 17. Some comments and interpretations seem to be necessary:

1. The total area of the building was calculated incorrectly in 1995
2. The calculation from 1995 does not account for an extra volume of about 900m<sup>3</sup> in the roof
3. Six zones were considered in the calculations from 2008 using the German implementation of the EPBD:
  - Office (area 624 m<sup>2</sup>)
  - Laboratory (area 2107 m<sup>2</sup>)
  - Auxiliary rooms (area 1630 m<sup>2</sup>)
  - Technical rooms (area 1830 m<sup>2</sup>)
  - Experimental hall (area 1222 m<sup>2</sup>)
  - Stairs and floors (area 3780 m<sup>2</sup>)
4. The air change rate in the DIN V 18599 are systematically too high
5. The Internal loads in the 1995 calculations were calculated on the basis of 8 kWh/m<sup>3</sup>/a

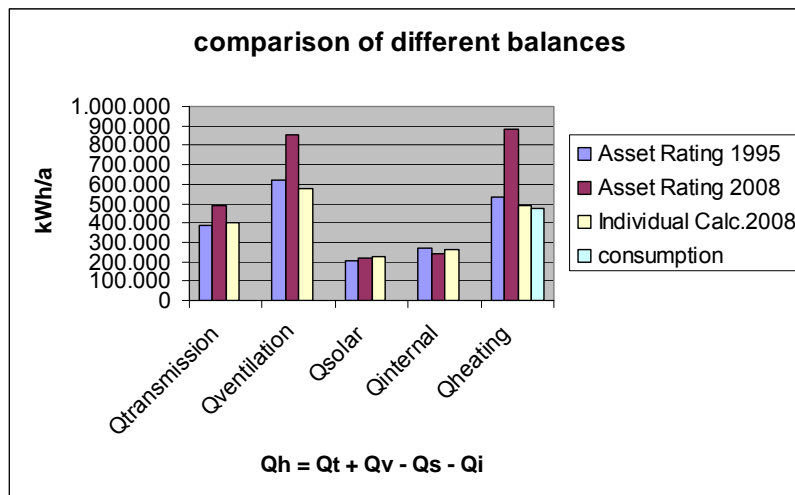


Figure 17: Comparison of different asset calculations with actual consumption

The results of the 1995 asset calculation and the individual calculation are quite similar. They also are in reasonable agreement with the actual consumption for 2007. Major uncertainties are due to the assumption on ventilation. They have to be checked for the individual calculations routinely.

Once more nice agreement could be found between the individual calculation and the actual consumption. Therefore we compare in Figure 18 also monthly values for asset and consumption. Again we can see a fairly good agreement between both types of values. Typically for district heating consumption is too high during the months when only little heating is required. A better control during this period could contribute to an additional reduction of the consumption of about 5% to 10 % (25000kWh to 50000kWh)

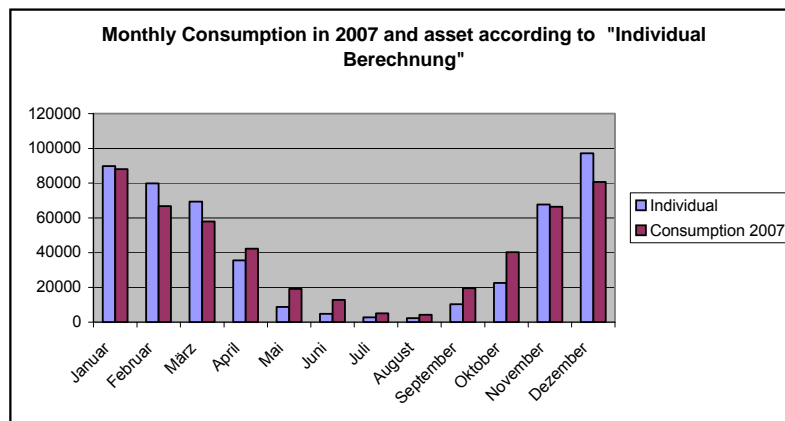


Figure 18: Comparison of monthly consumption and demand data for 2007

From these and similar calculations we concluded that the following accuracies in predicting heating consumption should be reachable:

- Yearly values Individual calculation 5%
- Monthly values Individual calculation 10%
- Daily values regressions 10 %

This might become even better if we use more calibration as allowed for the individual calculations

### Models for specific EuPs

According to CEN 13790 each component of the system is modelled as an efficiency box which models the efficiency of a component in dependence of the operation mode. Generally an efficiency box could be an emitter, a distribution circuit, a hot/cold storage or a generator of some service. Among the generators there are boilers, chillers, CHP units, etc. The same approach is made for heating, cooling, domestic hot water and ventilation systems. But also other appliances could be modelled in a similar way.

Each box can in principle be implemented with different level of complexity. The simplest one is to assign a constant efficiency (e.g. efficiency of the distribution circuit), whereas the sub-model for a boiler or a cooler could be more complex.

Figure 19 illustrates the principle input and output data as well as the calculation for a given sub-system (box) through the box characteristic equation. The output (service) of the box is characterized by  $Q_{\text{required to}}$ . Each sub-system considers an input of energy (electrical or thermal energy)  $Q_{\text{required from}}$  and auxiliary electricity (W). The auxiliary electricity is converted to thermal energy and partially added to the system output.

The outputs are the energy (electrical or thermal) that is delivered to the next connected component  $Q_{\text{required to}}$  and the thermal losses  $Q_{\text{lost}}$ .

## ➤ CEN Approach

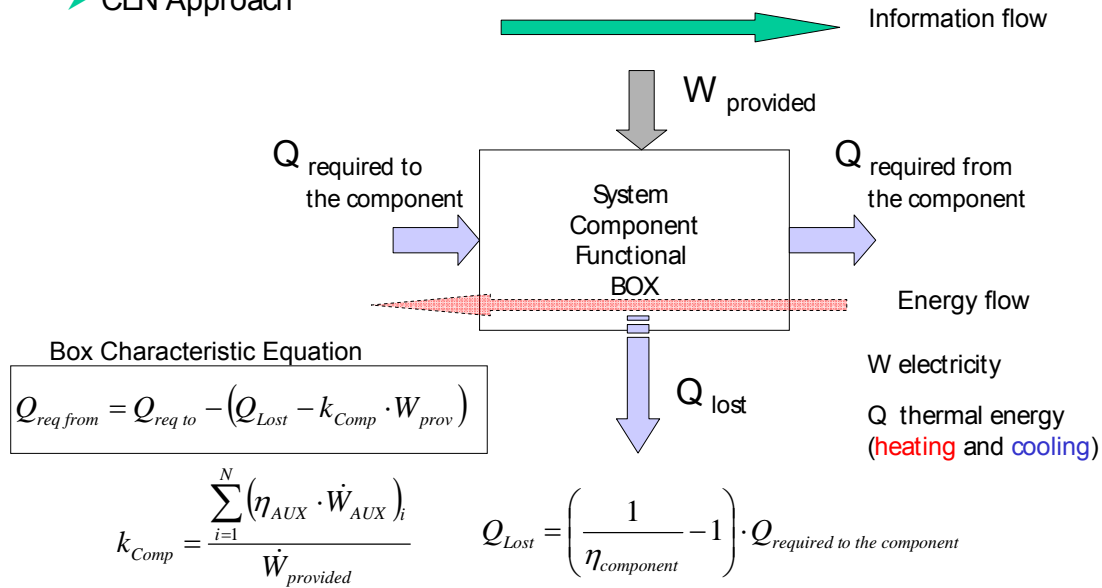


Figure 19: Simplified box model according to CEN 13790 (from Building EQ18)

Similar models will be developed in the frame of SmartCoDe and applied to optimize operation strategies.

The model allows calculating loads and to determine points to switch on or off certain devices. This is shown for the heating and cooling load that is necessary to maintain a set-point temperature. The heat transfer by ventilation is directly connected to the air node temperature. The heat transfer by transmission is split in two main parts: the transmission through window and the transmission through opaque wall. The flux due to internal and solar sources is divided among the three nodes (air node, central node, mass node).

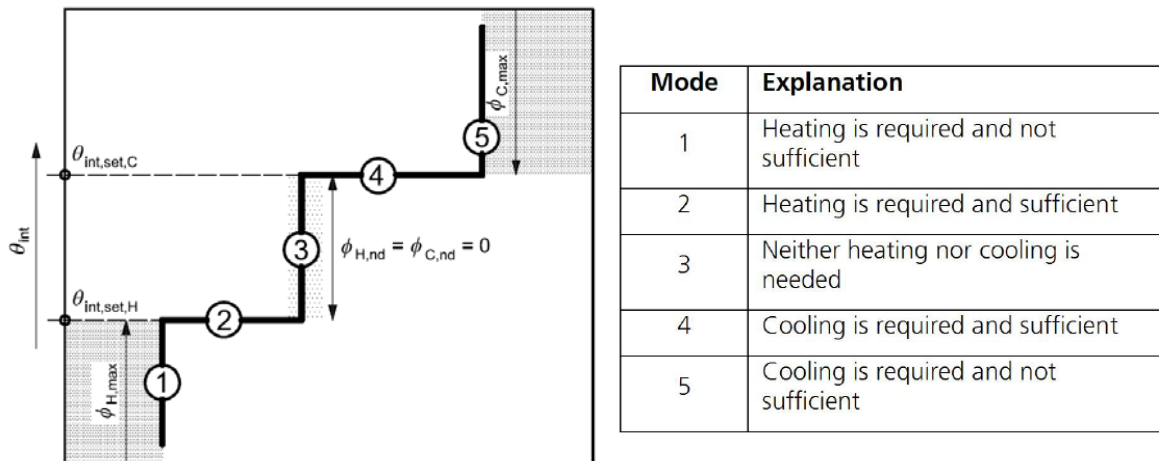


Figure 20 Building zone temperature behaviour versus system behaviour

Table 20 shows possible operation modes using the hourly method considering a maximum power for heating and/or cooling emitters. Mode 1 and 5 are considered when the maximum power of the heating or cooling emitters is not sufficient to meet the load (and thus to reach the set-point temperature). Mode 2 and 4 are considered when the building zone is at part load and only a part of the maximum power is released to the air node. Mode 3 considers the free-floating operation.

Models for typical EuPs and LEPs are also developed in SmartCoDe.

The simulation option is primarily used to analyse special effects using these models

	Class	SKDSVC	CONSVc	VARsVC	ETOSVC	COMCON	CHACON	CUSCON
	Abbrev. from	schedulable service	constant service	variable service	event-timeout controlled service	complete control	charge control	custom control
	Description	The EuP provides a service which runs for a certain time and can be scheduled within a certain time span.	The EuP provides or maintains/supports a constant service within certain bounds.	The EuP provides a service which might vary due to user interaction and/or daytime	device is switched on and kept on by sensor events, and switched off in absence of sensor event	charging and using up power decoupled; latter only restricted w.r.t. time slots & minimal service	charging and using up power decoupled; latter is mostly (or solely) user-dependent	device does not fit into other classes, therefore custom control by user and/or EMS
Parameters	subclass	none	virtual storage (true/false)	virtual storage (true/false)	none	none	none	none
	Configuration	none	interval defining upper & lower bounds, comfort level?	interval defining upper & lower tolerance bounds, comfort level?	absence time span for switching off	minimal runtime per time span, time slots	minimal charging per time, maybe charging policy	none
	Sensor input	none	value describing the current state of the service, e.g. temperature, illuminance	value describing the current state of the service, e.g. temperature	event, e.g. presence detection	current charge status	current charge status, device presence	none
	Online user input	runtime earliest start time latest stop time	none	value describing the current user demand	none (indirectly through sensor input)	none	device removal and/or usage	user demand / EMS demand
	Action	On input of runtime, earliest start time and latest stop time, SmartCoDe has to find a start time within the given bounds which minimizes costs.	SmartCoDe has to keep the state of the service within the threshold values such that costs are minimized.	SmartCoDe has to keep the state of the service within the threshold values (determined by the current user demand and the tolerance bounds) such that costs are minimized.	SmartCoDe switches device on if event is detected, and switches it off after the time span set if event is not detected any more.	SmartCoDe charges the device and runs the device within the given time slots such that costs are minimized.	SmartCoDe charges the device according to the minimal charging setting and a possible charging policy such that costs are minimized.	SmartCoDe does not control the device except through direct user-input or EMS control
	Examples	washing machine, dryer, dishwasher, baking machine	Fridge, Freezer, lighting controlled by illuminance level (e.g. in garden, at entrance)	HVAC, Water-boiler, dimmable lighting, blinds	lighting controlled by presence detector (e.g. on corridor)	robot vacuum, robot lawn-mower	battery & cell phone chargers, cordless vacuum	HiFi, PC, Oven, user controlled lighting

Table 20: SmartCoDe models to describe EuPs

Class	Abbrev. from	Description	Parameters			Examples
			installation	from EP	to EP	
ENGRID	energy grid	conventional energy provider	feed-in possible (true/false)	pricing forecast, supply forecast	feed-in to grid	local electrical power provider long-distance heating
VOLAEP	volatile energy provider	energy source which depends on weather, daytime etc.	switchable (true/false)	supply forecast	on/off if switchable, weather forecast?	wind turbine, water turbine, solar, geothermal
ENSTOR	energy storage	energy source which has to be charged	storage capacity	charging level	charge / provide	batteries, concrete heat storage
LENGEN	local energy generator	energy source which transforms some kind of fuel to energy	fuel capacity	fill level	on / off	block power generator, diesel generator

Table 21: SmartCoDe models to describe LEPs

### Baseline and Adjustments

Develop model for component where ECM is applied

Determine level of comfort and associated  $Q_{req\ from\ before}$

Calibrate model to measured consumption

Apply ECM to component and model

Recalculate  $Q_{req\ from\ after}$

### Energy savings Calculation

$$\text{Saving} = Q_{req\ from\ before} - Q_{req\ from\ after}$$

The following baseline data will have been collected for at least one year before the demonstrator installation:

- demonstrator site equipment and conditions,
- site energy consumption and demand profiles,
- site occupancy type, density and periods,
- space conditions for each operating period and season, including light level, space temperature, humidity and ventilation,
- site equipment operating practices (schedules and set point, actual temperatures),
- significant equipment problems or outages.

Ennovatis will manage the demonstrator installation, operations and maintenance. Ennovatis will specify the metering points, periods of metering, meter characteristics, meter reading, calibration process, method of dealing with lost data, quantification of the expected accuracy associated with the measurement, data capture and analysis, and specification of how results will be reported and documented.

The energy use quantities will be measured by separate measurements of parameters which will be used in computing energy consumption. For example, equipment operating parameters of energy using products and operating hours will be measured separately and factored together to compute the EuP's energy use.

## **8.4 Selection Criteria for the measurement and verification**

The IPMVP Protocol gives different options to measure the achieved savings after the introduction of a energy management solution.

Depending on the project, energy efficiency savings potential and measurement capabilities it is possible use different possibilities.

### **Option A**

- Indicated for equipment renovation with the same behaviour or behaviour change in the use of equipments
- It is necessary sub metering systems inside house
- It is necessary to know (estimate) hours of use of the equipment
- Savings for each parameter = Baseline Energy – Reporting Period Energy ± Adjustments

### **Option B**

- for energy efficiency measurements application with total energy savings Indicated potential higher 10%
- At utility meter level
- Savings = Baseline Energy – Reporting Period Energy ± Adjustments

### **Option C**

- Indicated for equipment renovation with change in behaviour or for modifications in the operation in special equipment
- Sub metering measurements to calibrate models desirable
- Estimation of model characteristics from manufacturer data
- Savings for each parameter simulation of original operation- simulation of new operation  
$$\text{Saving} = Q_{\text{req from before}} - Q_{\text{req from after}}$$

Depending on the project, energy efficiency savings potential and measurement capabilities it is possible use different possibilities.

## **8.5 Proposed methodology to calculate energy savings in the SmartCoDe demonstrator**

The following steps will be applied to determine energy savings at the demonstrator site:

- Measure and collect relevant energy and operating data before that demonstrator installation (*baseline data*) and record it in a way that is suitable to access for analysis, calculation of energy savings and visualization. Make sure that all data which will be needed for energy savings calculation is measured and collected in a systematic way.
- Install and test the components and the demonstrator as a whole and verify that the demonstrator installation works properly (*commissioning*).
- Measure and collect energy and operating data after the demonstrator is installed in a systematic way which is consistent with the baseline period (prior to the demonstrator installation).
- Calculate the energy savings, report and present all the collected and computed data in a way which is suitable to demonstrate the effect of the demonstrator on the energy savings.

The energy savings will be the difference between consumption of energy at the demonstrator site after demonstrator will have been installed (this period of time is called „*reporting period*“) and the



energy which there would have been prior to the installation (this period of time is called „*baseline period*“). The baseline period will be representative of the operation of the site before implementation of the demonstrator.

Ideally, we should have energy consumption data measured at exactly identical conditions at the demonstrator site prior to the demonstrator installation and after the installation. Of course, it would be impossible to have identical conditions at the two distinct time periods due to the uncontrollable weather and other site parameters. Therefore, adjustments should be included in the energy savings calculation to compensate for the change in the site conditions.

Energy savings will be calculated as:

$$E_s = E_b - E_d \pm A$$

where:

- $E_s$ , energy savings,
- $E_b$ , baseline energy use,
- $E_d$ , energy use after demonstrator installation,
- $A$ , adjustments.

The calculation of the energy savings will be with respect to the total energy consumption of the demonstrator site.

The energy calculation will be based on the energy consumption at the demonstrator site as a whole. Energy savings will be calculated based on the continuous measurements throughout the baseline and reporting periods. The utility meters for the whole demonstrator site will be used to measure the energy performance of the site.

Periodic inspections should be made of all equipment and operations in the demonstrator after its installation to identify changes from baseline conditions or intended operations.

### Energy Data

Each energy flow into the site will be measured separately. Separate meters will be used to measure the flow of one energy type into a building. Savings will be determined separately for each meter or sub-meter serving the site so that performance changes can be assessed for separately metered parts of the facility.

If energy data are missing from the post-retrofit period, a post-retrofit model will be created to fill in missing data. However the reported savings for the period should identify the report as "estimated."

The time of utility meter peaking will be recorded for each month to calculate savings due to electrical demand. The minimum time step for any demand recording meter will have to match the utility's demand time interval.

For additional evidence of energy use, energy data will be collected from utility meters, either through direct reading of the meter, or from utility invoices.

If energy is supplied indirectly to the site, for example through on-site storage facilities for oil, propane or coal, a meter downstream of the storage facility will be used to measure energy use.

### Independent Variables

Independent variables, such as weather and occupancy will be recorded as they represent characteristics of a site's use and the environment which governs energy consumption. For the energy consumption analysis outdoor temperature and humidity will be measured and recorded. Occupancy will be recorded in terms of the number of residents in the site, daily occupancy hours and number of occupied days.

Independent variables will be measured and recorded at the same time as the energy meters. For example, weather data should be recorded daily so it can be totalled to correspond with the exact monthly energy metering period which may be different from the calendar month.

### Data Analysis and Models

The adjustment term of equation for energy savings will be calculated by developing a valid model of each meter's base year energy use and/or demand. A model may be as simple as an ordered list of twelve actual base year monthly electrical demands without any adjustment factors. However they can often be a set of factors derived from regression analysis correlating energy use to one or more parameters such as degree days, metering period length, occupancy, and building operating mode summer/winter.

Statistical validity of the selected model will be assessed and demonstrated by reference to published statistical literature. Selected models can involve several sets of regression parameters each valid over a defined range of conditions such as ambient temperature. One full year of continuous base year daily energy data will be recorded and used to reduce statistical bias of the regression.

Hourly metered data should be aggregated at least to the daily level to control the number of independent variables required to produce a reasonable model of the base year, without significant impact on the uncertainty in computed savings.

### **Computation of Routine Adjustments**

The following steps will be applied to calculate the adjustments term (A) in equation for energy savings.

- Develop the appropriate model for the base year energy data and selected significant driving conditions.
- Insert the post-retrofit period's independent variables (e.g. ambient temperature, metering period length) into the base year model from above. This process derives the energy use that would have happened under post retrofit conditions if the demonstrator had not been installed.
- Subtract the base year's energy use from the result of 2, above, for each month.

### **Evaluating Savings Uncertainty**

Calculations of energy production, consumption and savings at the demonstrator site will be affected by inevitable errors and uncertainties, introduced through

- instrumentation error
- modelling error
- sampling error
- planned and unplanned assumptions.

Methods of quantifying the first three errors are discussed in the available literature. The last category of error takes into account all the unquantifiable errors associated with stipulations, and the assumptions necessary for measurement and savings determination. During the detailed planning of demonstrator measurements, special attention will be paid to the factors which create uncertainty, either qualitatively or quantitatively.

Quantified uncertainty will be expressed in a statistically meaningful way, by declaring both accuracy and confidence levels.

For the demonstrator site, at least one year of energy use and weather data will be used to construct regression models.

If the energy consumption of the metered equipment varies by more than ten percent from month to month, additional measurements will be taken at sufficient detail and over a long enough period of time to identify and document the source of the variances. Any major energy consumption variances due to seasonal production increases or periodic fluctuations in occupancy or use will also be tracked and recorded.

### **Baseline Adjustments (Non- Routine)**

Conditions which vary in a predictable fashion will be included within the basic mathematical model used for routine adjustments. Where unexpected or one-time changes occur they may require non-routine adjustments, normally called simply Baseline Adjustments.

For example, baseline adjustments will be needed in case of changes in the amount of space being heated or air conditioned, changes in the amount or use of equipment, changes in environmental conditions (lighting levels, set-point temperatures, etc.) and changes in occupancy, schedule or throughput.

Base year conditions will be well documented so that proper adjustments can be made. It is also important to have a method of tracking and reporting changes to these conditions. This tracking of conditions may be performed by the site operator and management (ennovatis). Non-routine Baseline Adjustments are determined from actual or assumed physical changes in equipment or operations.

### **Weather Data**

Weather data will be recorded daily and matched to the actual energy metering period. For monthly or daily analysis, government published weather data will be used as well as site monitored weather

data. When analyzing the response of energy use to weather in mathematical modelling, daily mean temperature data or degree days may be used.

## **Measurement Issues**

### **Electric Demand**

The method which be used to calculate electric demand will replicate the method the power company uses for the relevant billing meter. For example, if the local power company is calculating peak demand using a 15 minute "fixed window," then the recording equipment will be set to record data every 15 minutes. After processing the data for the demand analysis, the 15 minute data can then be converted to hourly data for archiving and further analysis against hourly weather data.

### **Instrumentation and Measurement Techniques**

Special meters will be used to measure physical quantities or to sub meter an energy flow. To determine energy savings with reasonable accuracy and repeatability, good measurement practices will be followed for these quantities.

Instrumentation will be calibrated with respect to standard calibration procedures.

### **Data Collection Errors and Lost Data**

A plan will be developed to address (1) maximum acceptable rate of data loss and how it will be measured and (2) establish a methodology by which missing or erroneous data will be interpolated for final analysis. For example, base year and post-retrofit models may be used to calculate savings.

### **Use of Energy Management Systems for Data Collection**

Smartbox unit will provide most of the monitoring necessary for data collection and storage.

## **Energy savings**

Energy Savings = Baseline Energy Use – Energy use after ECMs ± Adjustments

In order to calculate the energy savings, it is necessary to know the baseline consumptions, the consumption after the ECM solution implementation and the necessary adjustments to do.

1. Establish baseline: through
  - Energetic audits
  - Measurement campaign
2. MEASUREMENT & VERIFICATION Savings
  - Establish baseline
  - Establish adjustments

### **Establish baseline and reporting period**

In order to know the energy consumptions prior to the implementation of the ECM solution, it is necessary to develop energy audits and a measurement campaign, if we don't obtain all consumption data from the energy audits. The necessary information is:

- Equipment in the facility
- State and operation of the equipment
- Operation detail to calculate the energy distribution consumption of the facility
- Registered consumptions
- Distribution of the energy consumption
- Energy saving potential for each EEM
- Know the behaviour of the energy consumption in the facility. This way would be possible to make routine and non routine adjustments during the reporting period

We have to know also the energy consumptions after the implementation of ICT solution and apply the adjustments necessary to adequate the conditions of this period to the previous period.

## Baseline periods

The definition of a baseline period is a very important point to calculate energy savings. With a fixed baseline value it is possible to compare energy consumptions before and after the implementation of an energy management solution. Depending on the type of consumption which shall be compared it is possible to have different time ranges (weekly, monthly, yearly) to define a baseline period. For example, the DHW consumption is quite similar during the whole year, therefore a baseline of a week is enough. On the other hand the HVAC consumption varies monthly, therefore we need consumption data of a whole year in order to establish the baseline.

In the following a definition of baseline periods for different types of consumption is given:

### Fuel/Gas/biomass:

Without HVAC:

Baseline period: a week

Information to register:

- Week consumption (daily average)
- Independent variables (routine adjustments):
  - o HDD or CDD
  - o Occupancy level
- Static factors (non-routine adjustments): environmental, operational and maintenance characteristics

With HVAC:

Baseline period: a year

Information to register:

- Hourly consumption
- Independent variables (routine adjustments):
  - o HDD or CDD
  - o Occupancy level
- Static factors (non-routine adjustments): environmental, operational and maintenance characteristics

### Electricity:

Without HVAC:

Baseline period: a week

Information to register:

- Week consumption (daily average)
- Independent variables (routine adjustments):
  - o HDD or CDD
  - o Occupancy level
- Static factors (non-routine adjustments): environmental, operational and maintenance characteristics

With HVAC:

Baseline period: a year

Information to register:

- Hourly consumption
- Independent variables (routine adjustments):
  - o HDD or CDD

- Occupancy level
- Static factors (non-routine adjustments): environmental, operational and maintenance characteristics

#### Water:

Baseline period: a week

Information to register:

- Week consumption (daily average)
- Independent variables:
  - Occupancy level
- Static factors (non-routine adjustments): environmental, operational and maintenance characteristics.

#### Baseline - routine adjustments

Routine adjustments are used for changes in selected independent variables that can be expected to happen throughout the baseline period. This adjustments are often seasonal or cyclical (weather or occupancy variations).

Therefore heating degree (HDD) days or cooling degree days (CDD) are used for these reasons as the climatic changes are the main reason of variability in the residential consumption profiles.

The main objective is to develop a formulation and regression models that represent the energy consumption depending on the independent variables. For regression models is necessary to get  $R^2 > 0,7$ .

	Baseline (kWh)	HDD
January	3.746,80	299
February	3.033,87	189
March	2.666,27	206
April	1.778,29	118
May	1.396,91	62
June	471,53	19
July	366,56	3
August	109,28	5
September	571,41	18
October	1.269,90	80
November	2.158,28	249
December	4.066,22	318
	<b>21.635</b>	<b>1.566</b>

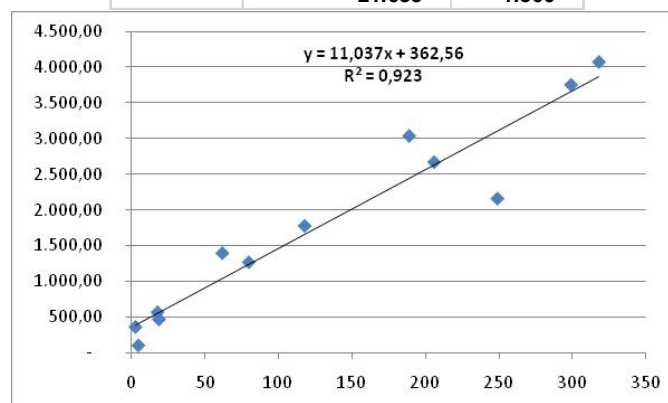


Figure 21: Table and graph of energy consumption related to HDD

In this graphic we observe the correlation between the monthly consumption versus the HDD. There is a  $R^2 > 0,9$ , therefore it is possible to do routine adjustments regarding HDD.

### **Baseline - non-routine adjustments**

Non- Routine adjustments are Adjustments for changes in parameters which cannot be predicted and for which a significant impact on energy use/demand is expected. Non-routine adjustments should be based on known and agreed changes to the facility:

- i) changes in the amount of space being heated or air conditioned,
- ii) changes in the amount or use of equipment
- iii) changes in environmental conditions (lighting levels, set-point temperatures, etc.)
- iv) changes in occupancy, schedule or throughput.

## **8.6 Determination of other parameters**

### **Persistence through Continuous commissioning**

After the implementation of the energy management solution and a following period with improvements/adjustments the energy savings should remain stabilized. To monitor the persistence of energy savings it is necessary to roll out the following steps:

- Persistence (increase or decrease) of energy savings in the time:
- It is possible to compare each week, month or year to analyze if the energy savings are continuous in the time after measurement implementation (see Figure 12 or Figure 13).
- In a short term is relevant in "behaviour measures". For equipment renovations (option A) is very important in long-term too

In the SmartCoDe project this is achieved by continuous commissioning ("Continuous Commissioning" and "CC" are registered trademarks of the Texas Engineering Experiment Station) methods as developed in the BuildingEQ project.

The "Continuous Commissioning Guidebook" of the FEMP gives the following definition for continuous commissioning:

"Continuous Commissioning is an ongoing process to resolve operating problems, improve comfort, optimize energy use and identify retrofits for existing commercial and institutional buildings and central plant facilities."

A more detailed definition of continuous commissioning from Annex 40 stresses the aspect of quality assurance which strives to meet the requirements of the owner:

"CC = Clarifying Owner's Project Requirements (OPR) from viewpoints of environment, energy and facility usage, and auditing and verifying different judgments, actions and documentations in the Commissioning Process (CxP) in order to realize a performance of building system requested in the OPR through the life of the building."

Typically, the commissioning process is described as a multi-level process. The "Continuous Commissioning Guidebook" of the FEMP describes the general phases for CC as follows:

#### **1 - Develop the CC plan**

- Develop a detailed work plan (description of task, definition of targets, specification of monitoring, etc.)
- Identify the entire project team
- Clarify the duties of each team member

#### **2 - Develop performance baselines**

- Document existing comfort conditions / problems
- Document existing system conditions / problems
- Document existing energy performance

#### **3 - Conduct system measurements and develop CC measures**

- Identify current operating schedules, set points and problems
- Develop solutions to existing problems

- Develop improved operation and control schedules and set points
  - Identify potential cost effective energy retrofit measures
- 4 - Implement CC measures
- Obtain approval for measures from building owner's representative before implementation
  - Implement solutions to existing operational and comfort problems
  - Implement and refine improved operation and control schedules
- 5 - Document comfort improvements and energy savings
- Document improved comfort conditions
  - Document improved system conditions
  - Document improved energy performance
- 6 - Keep commissioning continuous
- Maintain improved comfort and energy performance
  - Provide measured annual energy savings

### Statistic data analysis

There are a lot of variability in the consumption data, therefore it's necessary to develop a statistic analysis in order to know the dispersion of data and their liability.

**Mean (Y):** The most widely used measure of the central tendency of a series of observations. Mean is determined by adding up the individual data points ( $Y_i$ ) and dividing by the total number of these data points ( $n$ ).

**Variance (S<sup>2</sup>):** Variance measures the extent to which observed values differ from each other, i.e., variability or dispersion.

**Standard Deviation (s):** This is simply the square root of the variance. This brings the variability measure back to the units of the data (e.g., while the variance units are in kWh<sup>2</sup>, the standard deviation units are kWh).

It's necessary to define a method to estimate values with a given confidence level when we don't have any direct measurement. We recommend the t Test: Range = main  $\pm$  t\* SE

**Standard Error (SE):** This is the standard deviation divided by  $n$ . This measure is used to estimate precision.

**Precision:** Precision is the measure of the absolute or relative range within which the true value is expected to occur with some specified level of confidence. Confidence level refers to the probability that the quoted range contains the estimated parameter.

Absolute precision is computed from standard error using a "t" value from the "t-distribution"

Relative precision is the absolute precision divided by the estimate or main:

In general the true value of any statistical estimate is expected, with a given confidence level, to be in the range defined by

	Consumption (kWh)
January	3.055,50
February	2.003,00
March	1.895,00
April	1.609,00
May	1.505,00
June	1.344,00
July	1.453,00
August	1.254,00
September	1.222,00
October	1.100,00
November	2.978,00
December	3.345,00

<u>Mean - Estimate</u>	<u>Standard error</u>	The previous table shows that "t" is 1,80 for 12 data points and a 90% confidence level
$\bar{Y} = \frac{\sum Y_i}{n} \quad 1.897 \text{ kWh}$	$SE = \frac{s}{\sqrt{n}} \quad 228 \text{ kWh}$	
<u>Variance</u>		<u>Absolute precision</u>
$S^2 = \frac{\sum (Y_i - \bar{Y})^2}{n-1} \quad 623.860 \text{ (kWh)}^2$		$t \times SE \quad 410 \text{ kWh}$
<u>Standard Deviation</u>		<u>Relative precision</u>
$s = \sqrt{S^2} \quad 789,85 \text{ kWh}$		$\frac{t * SE}{Estimate} \quad 21,64\%$

Figure 22: Monthly consumption and relevant statistic parameters

### Methodology Demand Response

Generally it is possible to shift the energy demand to other periods with less PE consumption. The benefits & impacts of this methodology are similar to the energy savings determination.

Savings: baseline – consumption after demand response program ± Adjustments

Attention should be paid on the baseline, which has to be established in a different way for this case. To do this we define the load factor

#### Load factor

The **Load factor** (LF) calculation is advised to improve the accuracy of demand response. The load factor is defined as the value obtained by dividing the minimum power demand over the maximum power demand of a facility.

$$LF = (\text{Min. power demand})/(\text{Max. power demand})$$

Following the ideas of the 3E-HOUSES project we propose the procedure described in Figure 23

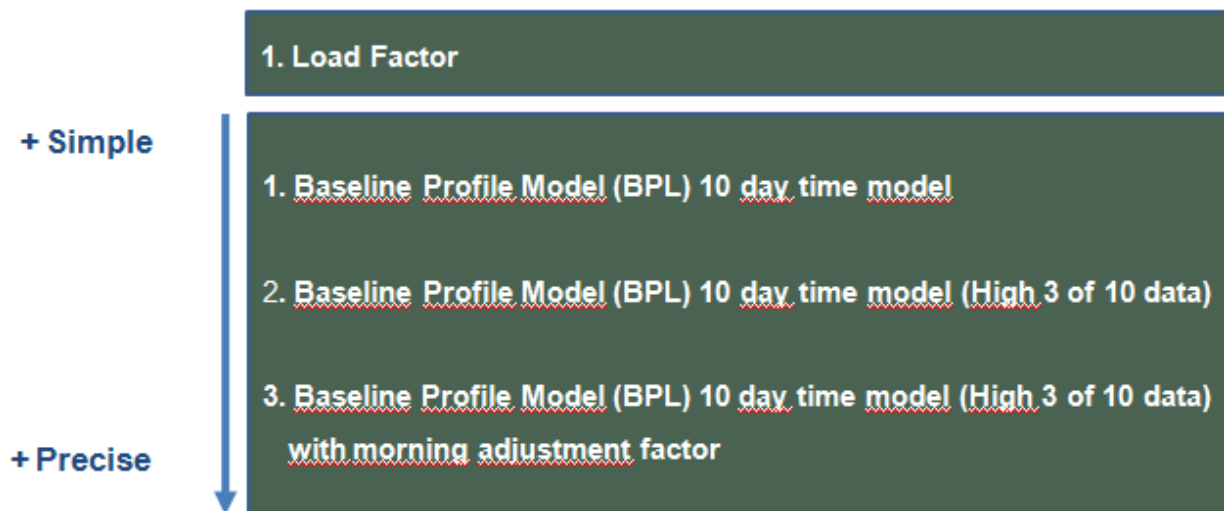


Figure 23: Demand response baseline methodology

## 8.6.1 Baseline Profile Models

### 1. Baseline Profile Model (BPL) 10 day time model

It is generally accepted that a period of approximately 10 (non-event) business days reasonably represents consumption for normal operations and therefore makes up a preferred baseline window for resource adequacy and demand programs. Using a 10 day time window provides an



appropriate balance – short enough to account for near – term trends and long enough to limit opportunities for manipulation

- Average calculation method for a 10 day period
- $b: (d1(t,h)+d2(t,h)+d3(t,h)+d4(t,h)+d5(t,h)+d6(t,h)+d7(t,h)+d8(t,h)+d9(t,h)+d10(t,h))/10$   
(=average power demand for the number of the events of 10 days of the event)

## 2. Baseline Profile Model (BPL) 10 day time model (high 3 of 10 data)

High 3 of 10 exclusion rules among the previous 10 days, excluding event days and holidays

- $b: \max(1,3) (\sum d_n(t,h))/3$

## 3. Baseline Profile Model (BPL) 10 day time model (high 3 of 10 data) with morning adjustment factor

- Customer demand is often heaviest on event days, capturing day-of realities in a customer load profile is essential to delivering accurate performance calculations.
- A simple way to address this need is through an adjustment based on day-of event conditions.
- $b': \max(1,3) (\sum d_n(t,h))/3$
- $P: (d(t,h-1) - b(t,h-1) + d(t,h-2) - b(t,h-2))/2$

## 8.7 Methodology to calculate reduction of CO2 emission

The total Avoided CO2 emissions

= Avoided CO2 emissions related energy savings + Avoided CO2 emissions related demand response

### 1. Avoided emissions related to energy savings

If the energy savings are known which are obtained by ICT's implementation the CO2 avoided emissions can be calculated:

CO2 avoided emissions (kgCO2/a) = energy savings (kWh/a) \* emission factor (kgCO2/kWh)

The emission factor depends on the type of energy saving:

- electricity: depending the composition of the electricity generation mix of each country
- natural gas: 0,201 (kg CO2/kWh)
- gasoil: 0,287 (kg CO2/kWh)

### 2. Avoided CO2 emissions related to demand response

If a shifting of the demand curve is achieved, emissions will be avoided because the electricity produced in off-peak hours has a bigger contribution of renewable, therefore the CO2 emissions associated to this consumption are lower.

On the contrary, the emission factor during the peak hours is higher, because the contribution of fossil fuels to the generation mix is higher.

The CO2 emissions avoided, related to demand response, are calculated as:

CO2 avoided emissions (kgCO2/a) = consumption energy displaced (kWh/a) \* ( emission factor peak hours (kgCO2/kWh) - emission factor off- peak hours (kgCO2/kWh) )

These peak and off-peak hours emission factors are different each day but we can calculate a medium value for each country.

## **9 Assessment of the project impact**

### **9.1 Impacts of the project**

The goal of the SmartCoDe project is to provide a solution which will allow manufacturers of energy using products to add energy management functionality, with additional features such as remote control, safety and security, for very little additional cost, and thus enable local entities to participate in the energy market as an intelligent, managed “sub-grid” that can even contribute to a demand side management. Having this in mind, in this section we explain how we will evaluate project's objectives and approaches, and thereby assess the overall impact of the project with respect to:

- Enomomic feasibility,
- Applicability and
- Usability.

### **9.2 Independent reviewers/consultants**

For the SmartCoDe project it is most important to evaluate the project's objectives and approaches on the basis of economic and technical feasibility as well as on usability aspects. The SmartCoDe project therefore intends to install independent reviewer / consultants from the rich pool of SmartCoDe Associated Partners for three specific areas of research:

- Interface to Energy using Products (EuP),
- Interface to global grid / net operator and
- Energy Management aspects.

For the EuP area SmartCoDe Associated Partner Bosch Siemens Hausgeräte (BSH) agreed to act as reviewer, Non Disclosure Agreements have already been signed between BSH and SmartCoDe partners Vienna Technical University, ennovatis GmbH, Infineon Austria AG, edacentrum GmbH.

For the global grid / net operator area the SmartCoDe coordinator is currently in discussion with two candidates, RWE Innogy and Stadtwerke Hannover.

We still have no appointed reviewer for the Energy Management aspects, but we are in a process of selecting one from the pool of the project Associated Partners.

### **9.3 Economic feasibility**

To assess the economic feasibility of the project we will address several aspects:

- What costs are involved for the different kind of groups (user, equipment provider, energy provider),
- How can invested cost be refund for the different kinds of groups, for example lesser energy costs, market penetration, lesser net load (i.e. lesser peaks probably mean that the maximum net load with which nets are built can be reduced),
- What actually are the benefits apart from energy cost reduction, for example what are community benefits as related to the CO2 reduction.

We will compare the baseline data with the data collected during the demonstrator operation at the two demonstrator locations, and calculate energy savings due to the local energy production and intelligent energy management.

Energy cost savings will be classified as relative to:

- Cost reduction for buying energy from third Party (egg the public grid)
- Load reduction for energy out of the public grid
- Peak load reduction for energy out of the public grid

We will quantify the possible energy savings due to:

- Classical energy management,
- High resolution energy management,
- Coordination of supply systems,
- Coordination of energy using products,
- Reduction of peak load.

To estimate the economic feasibility, we will calculate installation cost of the SmartCoDe solution, savings in energy, labour and maintenance, projected for expected life time of the system (for example, 10 years). To compensate for the increased energy costs and cost of maintenance, we will assume that the values of annual energy savings and savings in maintenance increase by some percent (for example 5 %).

Based on the previous analysis we will calculate the simple payback as the time required to return the investments in accumulated savings. It would be simple to calculate internal rate of return as the time value of the net annual savings for the equipment investment that is comparable to the interest rate one might earn by investing the same amount of money in bank account.

The overall economic impact of the project will result from the large number of houses to be considered. Standardisation of both hardware and installation will result in a significant reduction in production and installation costs and allow to provide energy management for smaller buildings more effectively. The cost of initial investment will be estimated with a factor of 10 with respect to the cost of equipment and labor for demonstrator installation, excluding the cost of wind turbine.

The results of the previous analysis will be inputs for calculation of the reduction of the net load. We will take baseline profiles with all the peaks and compare them against profiles after implementing energy management with load shifting and switching off of the energy using products, enhanced with the local energy production. The calculation will be extrapolated to a large number of building, say 100.000, to estimate the reduction of the net load, and further on to the reduction of the Co2 emission. The estimate of the benefits will be conservative, because the number of 100.000 buildings represents just a fraction of the overall number of the residential buildings without energy management (over 15 million such building in Germany).

## **9.4 Applicability and usability issues**

We will the external reviewer inputs to prepare, conduct and analyse the applicability and usability of the SmartCoDe solution. The analysis will be based on monitoring the behaviour of the inhabitants of demonstrator locations to get an understanding how they used the demonstrator equipment and if they are using the suggested methods in an appropriate way.

The choice of the two demonstrator location is valuable, because we have households with opposite technical background and experience. In case of Almersberg site, the member of the household is an experienced user with technical skills, and at the inhabitants at Buchberg are average users without technical education and (possibly) with no time to read manuals and actively participate in energy management.

We will discuss with external reviewers the methods of collecting the data on the demonstrator usage at the two locations, and a form a questionnaire to the inhabitants to assess their experience with demonstrator installation, seems to be in place.

## **10 Conclusions**

The revised demonstrator test plan, presented in this document, describes the test strategy and plans for testing the individual components and the overall demonstrator installation, as well as how we will analyse the data collected from the demonstrator and assess the impact of the project.

The document gives detailed overview of the demonstrator, including aims and objectives, description of the demonstrator locations and demonstrator structure, metering and the roles and responsibilities of the individual partners in building demonstrator. Rationale for selection of the demonstrator locations is explained and the Almersberg and Buchberg locations are described. We also give lists of purchased and installed equipment, the equipment donated by the Associated Partner and measurement channels.

The document defines test strategy, types of testing, requirements and procedures. Testing plan describes the unit, functionality, performance, integration and security tests, including It also gives test scenarios and scripts for demonstrator testing.

Detailed methodology for calculation of energy production, consumption and savings, based on the data measured at the demonstrator is presented together with explanation of how the impact of the project will be assessed.

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