EEPOS - Energy management and decision support systems for energy positive neighbourhoods

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EEPOS validation strategy and application scenarios

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1. PUBLISHABLE EXECUTIVE SUMMARY

Future buildings and neighbourhoods are expected to combine a manifold of Energy using Products ranging from electrical lighting to HVAC with locally available renewable energies (e.g. solar, wind) and with locally available storages (e.g. car batteries). An intelligent management of energy in such a local grid would enable customers to participate in the energy market and even contribute to the stability of the power grid. As a consequence, we will have more and more stakeholders being consumers & producers (prosumers) at the same time. The purpose of EEPOS is to prove, that the effects of advanced energy management can be significantly improved by organizing single homes and local energy producers in "neighborhoods". The system to support this is called Neighbourhoud Energy Management System (NEMS).

This report specifies the targets and strategy for complementary neighbourhood demonstration and test cases. The scenarios will exemplify the roles of various stakeholders in the district level energy management.

In EEPOS we have planned the different environments to validate the specified scenarios, especially Laboratory Prototypes and two Real World Demonstrators in Finland and Germany. Each scenario description contains the specification, how and where it can be (partly) tested and validated.

The scenarios we developed as starting point for the further development of systems and services are devided according the level they occur: inside the building (B), at the interface between building and the neighbourhood (BN) or on the neighbourhoud level (N). Additionally they are classified according their complexity from simple (= C1) to complex (= C3). Depending on the validation target and the stakeholder needs the developed scenarios describe functionalities and give short stories of using them. The scenarios serve for different purposes, especially the illustration of the vision and benefits from users' point of view, the requirements of relevant stakeholders like the NEMS operator, energy brokers and energy supply companies. Each scenario consists of a description of the key functions, the criteria and environments how and where they will be validated and finally – as cross-reference – the possibilities to combine them with other scenarios.

Summing up this report covers eleven scenarios with different complexity which covers all relevant RTD tasks of this project. They provide a reliable baseline for the ongoing development on the EEPOS system which finally have to provide the evidence, that the results of EEPOS together and separately will have the potential to significantly contribute to EE impacts – especially energy saving, load shifting and RES integration.

2. INTRODUCTION

2.1 Purpose and target group

When building a new or renovating an existing home, the selection of energy sources is a key element of effective energy management. Along with incorporating access to traditional sources such as the local power grid and gas lines, the homeowner may also opt for the inclusion of a solar energy system or even a wind energy generator. The use of these alternative energy sources helps to minimize the use of traditional sources by using these easily renewable sources when and as possible. As a result, the homeowner saves money and also decreases the demand on traditional utilities. The costs of energy on the one hand and the possibilities to reduce this cost by using EEPOS on the other hand defines the general conditions to calculate the revenue models for the EEPOS related systems and services. If the required investments and costs are too high, the payback period will be too high and EEPOS will not succeed in the real world. Therefore this financial condition has to be taken seriously into account when the business models are defined.

The purpose of EEPOS is to prove, that the effects of advanced energy management can be significantly improved by organizing single homes and local energy producers in "neighborhoods". Consumers & producers (prosumers) within such a neighborhood will be connected with the main electrical and heating grids – not only on the physical layer but also on the communication layer based on a neighborhood energy management and decision support system.

This document specifies a range of different scenarios which will be used to specify the targets, the needed services and interfaces in EEPOS system. A focus is set on the roles of the various stakeholders (from the users to the energy brokers) in the district level energy management, therefore the scenarios describes on the one hand functionalities being requested by the stakeholders and on the other hand short stories of using them. Both type of descriptions results in the requested key functions, a description where and how the scenarios should be validated within the context of the available EEPOS test- and demonstration capabilities and also the targets of the project being covered by each scenario. Finally the possible combinations of the different scenarios are described. The general intention of this deliverable is that each EEPOS target is covered by at least one scenario.

2.2 Contributions of partners

The development of the scenarios is a crucial aspect to get a common understanding of the EEPOS project targets, therefore the work was carried out in co-operation.

While ENO as Task Leader was responsible for the general content (esp. chapter 1,2 and 5) each partner contributes at least one scenario to chapter 4. The structure and content of the document was discussed intensely in different meetings, telephone conferences and via email.

The partners being responsible for the virtual and real demonstration sites (DERlab, ENO, YIT) contributed the descriptions of the demonstrator capabilities in chapter 3 that can be used for the validation of the scenarios.

The following table gives a detailed overview:

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2.3 Baseline

This report is one of the first deliverables of EEPOS project, therefore the starting position for all contributors are experiences from previous projects like the 3e-Houses project ([3]) or SmartCoDe ([1]) as well as interviews and discussions with various (potential) stakeholders.

A lot of ideas and techniques concerning smart grids are already in use, all being quite isolated such as IEDs (Intelligent Electronic Devices), “supervisory control and data acquisition” (SCADA) and AMR (Automated Meter Reading) and thus can’t be considered a breakthrough.

Advanced energy management systems and services will be crucial for a stable energy supply in the future, therefore with the growing usage of decentralized energy production smart Grid projects take place on all levels:

- EU, national, regional, „private“ initiatives
- Network operators, academia, research centres, manufacturers, ICT companies
- Deployment as well as R&D and demonstration projects
- Various ICT levels: integration/standardization, security, reliability, forecasting

In the first phase of EEPOS, the scenarios, evaluation methods and criteria will be defined on the basis of existing standards, methodologies and experiences. For the residential buildings this will be based on the methodologies developed by the 3e-houses and the eSESH project, while for industrial processes (e.g. district heating plant) the existing methods of the IPMVP (International Performance Measurement and Verification Protocol) will be applied.

During the project the partners will have a close look on the developments in the market and in other research groups to share and discuss the ideas and concepts of EEPOS. Details will be described in the Deliverables of WP6 (Dissemination).

2.4 Relations to other activities

According the purpose of this document the developed scenarios are used to discuss and specify the data, services and overall architecture of the EEPOS system. Validation strategy and application scenario (T1) together with the resulting Stakeholder requirements (T1.2), the Business Models (T1.4) and the general architecture specification (T1.3) the results of WP1 forms the overall frame of the following work packages.

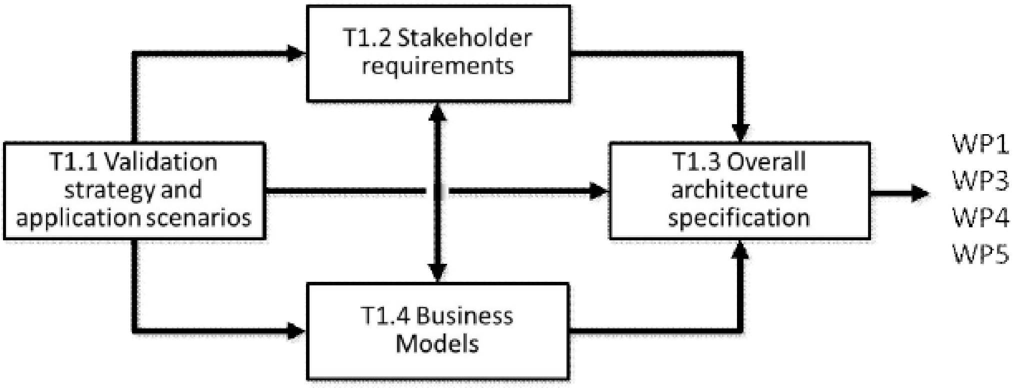

Figure 1. Relations of tasks and work packages (based on T1.1)

3. Description of the Environment

The following environments have been planned to validate the specified scenarios:

A. Laboratory prototypes

B. Real World Demonstrators (in Finland and Germany)

For each scenario in chapter 4 it is specified, how/where the scenario can be tested and validated. In the following a short description is given on the possibilities and general equipment, each environment can provide.

3.1 Possibilities of laboratory prototypes

In T4.2, laboratory tests of the EEPOS neighbourhood automation and management system developed in WP2 will be carried out in the laboratory testing facilities of Fraunhofer IWES. The testing of the EEPOS automation and energy management system will be carried out with respect to the use cases and according to the testing procedures developed and described in WP2.

The tested EEPOS-NEMS computer hardware and installed software (including the OGEMA framework, energy management, control and monitoring applications (T2.3), data models (T2.2) as well as drivers (T2.1) will be the same as employed in the real world demonstrators in Finland and Germany. Different Energy management systems (EMS) on the building level will be connected to the EEPOS neighbourhood automation and management platform. It is planned to connect several embedded computers, running an OGEMA energy management system on the household level and representing virtual houses, to the EEPOS NEMS computer. Also the interfaces between OGEMA and EMS employed in the real world demonstrations (Smartbox and Jace) will be tested.

Instead of the connection of real load and production units, devices as for instance heat pumps, wind turbines, pv panels or household devices will be modeled on both the neighbourhood and the building level. The type and number of simulated devices will be chosen in line with the real world demonstrators. Additional devices will be simulted to cover EEPOS scenarios, which cannot be validated in the field.

3.2 Possibilities of the Real World Demonstrators

3.2.1 The Finish Demonstrator

At the Finnish demonstrator there is a common ground source heat pump system and local district heating network that provides heating energy for all dwellings in neighbourhood. The same heat pump system can be used to remove extra heat during hot season and pump it down to the ground for seasonal storage.

Additionally solar heat collectors might be in use as well as PV-panels and small wind turbines for intermittent renewable power production. All local energy sources must be managed optimally giving priority to intermittent renewable energy production before geothermal energy utilisation with high COP heat pumps. Power purchased from the utility grid is the last resource for energy provision.

Locally produced renewable energy is distributed within the neighbourhood based on the demand or sold to market if the demand is low. The system should enable the addition and optimum management of extra renewable electricity generation capacity.

In the Finnish demonstrator, a building automation and monitoring system will be installed to ensure the applicability of advanced control and monitoring measures supporting the NEMS realisation.

3.2.2 The German Demonstrator

For the German Demonstrator the housing cooperative Bauverein Langenfeld eG (BVL) provided four of its residential buildings. These buildings are already equipped with a basic energy management system which was installed by ennovatis in 2008. Therefore, exact baseline data can be obtained from the existing measurements and energy bills for heating and water consumption as well as for the building gas consumptions. A radio based sub metering system for billing, installed and operated by the LAS GmbH, was previously connected to the energy management system of ennovatis (Smartboxes). The main heat meters of the buildings were also connected to the system and the obtained data of the last years can be used for the baseline calculations in the project.

The general subject of the ICT solution is the monitoring, energy management and control of the existing energy consumption systems of the buildings. The BEMS is designed to provide mainly the following functions:

- Provide measurement data of room temperature and -humidity, heating consumption, cold or/and hot water quantity and electric energy consumption to the tenants and the energy manager of the housing association (BVL) to change energy consumption behaviour and calculate energy savings with the measured data
- Installation of smart thermostats for the heating radiators in selected rooms of each dwelling, combined with information on window opening, which allow switching on and off the heating, if a windows will be opened.

The BEMS is designed to provide the following data via the web interface to the tenants:

- Weekly data of heat consumption and water(hot and cold) quantities
- Hourly electric energy consumption of every dwelling
- Costs of the above stated types of consumption
- CO_2 emissions for electric energy and heating energy consumption
- Room temperatures of certain heated rooms in the dwellings
- Relative humidity (indoor and outdoor)
- Outside temperature

In the last month the heating system was changed from central gas heating to a local district heating network powered by a thermal power station that provides heating energy for all buildings in the neighbourhood. The building “Martinstrasse 1” is additional equipped with a heat pump.

4. DESCRIPTION OF EXEMPLARY EEPOS SCENARIOS

The ENERGY PROSUMER model assumes that every household is a potential supplier and/or consumer. EEPOS addresses the systems and services being necessary to build up an infrastructure for business models that allows energy savings and also - and this might be the even more important functionality in the future – the local energy balancing.

The scenarios we developed as starting point for the further development of systems and services are devided according the level they occur:

- inside the building (B),
- at the interface between building and the neighbourhood (BN) or
- on the neighbourhoud level (N).

Additionally they are classified according their complexity from simple (= C1) to complex (= C3).

4.1 Scenarios on the Building Level

4.1.1 Scenario B-1 (C1): Integration of Consumers / non-automatized loads

Although the major loads in the proposed Neighbourhood Area Grid (NAG) can be integrated in the BEMS/NEMS, on the level of larger consumer goods may not be economically feasible, as the replacement by units which offer connectivity to the outside. Still especially so called "white goods" like dishwasher, washing machine and dryer significantly contribute to the electrical load of households. Therefore, a way to influence them via the consumer / end user is needed.

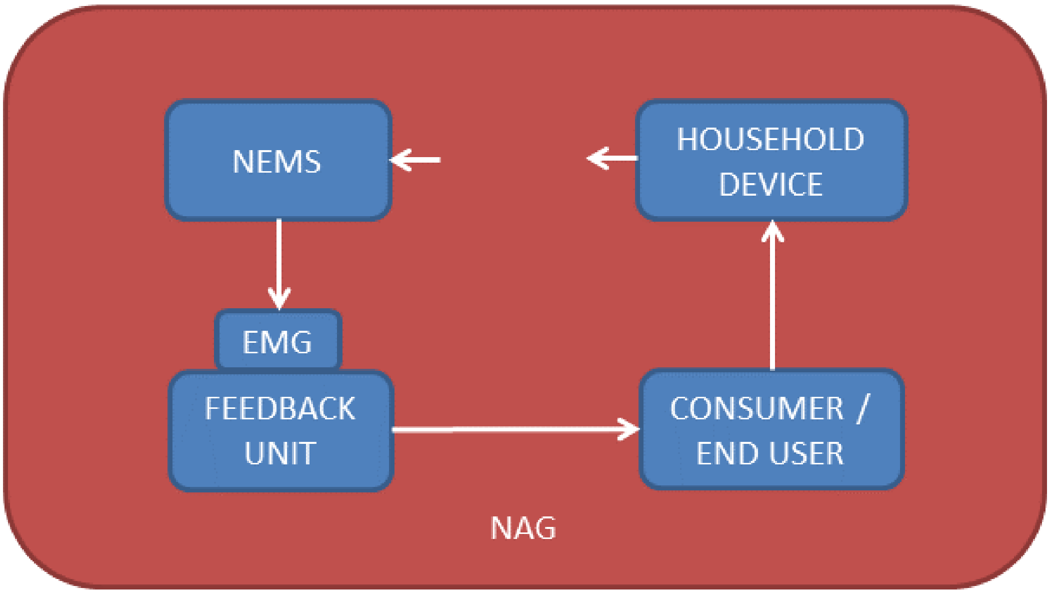

Figure 2. Direct Energy Feedback to the customer - an open loop control where the effect has to be estimated

This can be achieved by feedback to the consumer / end user about the current and especially predicted state of RES in the system. Depending on the billing model utilized, this can either be based on dynamic price signals for the end user, or simple indicators which would advise him at which time the use of electricity will be favorable with respect to NAG and the accompanying energy broker.

On the other hand the NEMS can track the change power consumption causes by the feedback, and adjust the forecast accordingly. This model can be both used for heat and power.

Key functions

- Forecast and actual of amount energy
    - Produced in the NAG
    - Consumed in the NAG (including storage)
    - Consumed by source not included in the NEMS
    - Change of behaviour of the sources not included in the NEMS

    and their equivalent in CO2
- Information to end user
    - Price or status

Validation of the scenario

The scenario will be implemented and tested in at the Laboratory prototype and implemented and validated at the Real World Demonstrator in Germany.

For the validation, impact of the behavioural changes induced by the system on the consumption profile will be quantified according to the methodology developed in D4.4. Furthermore, the usage of the system itself will be quantified by evaluation of interaction of the user and the systems itself, e.g. by applying descriptive statistics on the activity logs of the collaboration tool and correlating the results to the energy profile.

The scenario covers the following targets of EEPOS project: Information models for neighbourhood energy management (D2.2), Energy performance monitoring and operations planning tools (D3.3) and also the End-user collaboration tool (D3.4).

Combination with different scenarios

This scenario is best used as an add on with any other scenario described in this document, as it will not interfere with them.

4.1.2 Scenario B-2 (C1): Optimisation of heating grid

To get a complete picture of Energy Positive Neighbourhoods we don' only have to consider the power but also the heating (and cooling) aspects. Nearly every heating system also uses (or produces) power like combined heat and power systems. Therefore this scenario deals with the optimization of the heating grid in general and a heat-pump based system in the concrete case.

The heat-pump system will be planned considering all heating loads for Finnish demonstration case in Nupurinkartano. However the system is driven by electricity which may be limiting factor especially during peak load times. Therefore EEPOS neighbourhood energy management system should allow active configuration of the heating grid.

Key functions

In this scenario end-users can set suitable limits for indoor climate conditions to be compromised to cut the peak loads and thus contribute to optimum heating and power grid utilisation.

For example:

- The end-user might allow indoor temperature to drop from 22 to 20 ^{o}C during high market prices to reduce electricity costs and cut peak loads. The normal temperature conditions will recover automatically when power prices have come down to acceptable levels.
- The end-user can activate the 'away' mode, thus allowing indoor temperature to drop down to 16 ^{o}C until return time inclusive the consideration of a pre-heating period. The normal temperature is recovered within forecasted low market price/consumption hours.
- During hot season indoor temperature is allowed to rise until 28 ^{o}C and chilled mode is used outside of peak hours only.

Validation of the scenario

The scenario will be validated by the testing of the functionality in Finnish Real World Demonstrator; additionally the energy consumption will be monitored during the testing.

This scenario will contribute to

- EEPOS automation and energy management system platform (D2.1)
- Supervisory and predictive control methods and applications (D2.3)
- EEPOS ICT and decision support systems platform (D3.1)
- Energy performance monitoring and operations planning tools (D3.3)

Combination with different scenarios

This scenario can be combined with all Finnish test case scenarios.

4.1.3 Scenario B-3 (C2): Activities delayed by end-user

During peak demand the price of power is extremely high. In order to cut the peak load, all necessary information concerning real-time tariff, power consumption and generation and estimated price trends is provided to the end-user. Based on the information the end-user can choose to delay one or many energy consuming activities.

Key Functions

- Cut the consumption manually by switching off electrical equipment
- Enable to cut or delay the consumption automatically based on preset limits and rule-sets e.g. delay the operation of washing machine, sauna, turn off stand-by consumption, dimming of lights.
- Discharge the energy storages up to preset limits
- Boost power generation

To make EEPOS system work optimally it must have self-learning features and connection to weather forecast and spot power market to make reliable predictions about future consumption and price trends and to be able to make suggestions and set feasible operational limits based on past performance of the system.

Validation of the scenario

The scenario will be validated by the testing of the functionality in Finnish Real World Demonstrator. The validation of the scenario will be done by testing the availability of the information needed to make decisions. Additionally, the access to change some building automation settings and limits is provided and tested.

This scenario will contribute to:

- EEPOS automation and energy management system platform (D2.1)
- Information models for neighbourhood energy management (D2.2)
- Supervisory and predictive control methods and applications (D2.3)
- EEPOS ICT and decision support systems platform (D3.1)
- Energy performance monitoring and operations planning tools (D3.3)
- End-user collaboration tool (D3.4)

Combination with different scenarios

This scenario can be combined with all Finnish test case scenarios.

4.1.4 Scenario B-4 (C3): End-user collaboration tool

The main functions of the EEPOS end-user collaboration tool are to engage and motivate the end users in energy saving and shifting their energy consumption from peak hours to off-peak hours of the day. The load shifting depends for example on the available production status and the level of the storage capacity of the neighbourhood's renewable energy sources as well as SPOT market electricity price. The main functions are explained by the following example:

Heikki is a resident in the EEPOS neighbourhood. He is an average citizen who has some interest for energy saving issues but he does not know how to do that. Fortunately a new EEPOS end-user collaboration tool has been developed. After few short information sessions all EEPOS neighbourhood residents have been informed how to use the tool.

Heikki is just moved to his new apartment and he starts to use the tool. First he uses tool's energy reporting features including energy consumption (heat, electricity, gas etc.) reports, costs, RES part of the used energy and load shifting (moved demand from peak hours to off-peak hours of the day) relating year, month, day and hour level. The report includes also the comparison to the other end users consumptions. Using these reports Heikki has tried to save energy and do some manual load shifting. After two months later Heikki notices that he has been very successful in load shifting and he publish the result with few comments how to do that in end-user collaboration tool related forum. Later Heikki noticed that some load shifting could be done automatically and he order the work using the collaboration tool "work order" feature which send the order automatically first to the building owner (accept) and then to the NEMS operator (work order).

Heikki has also utilised the tool's feature "human as a sensor" based on Quick Response (QR) codes and/or GPS coordinates. Some QR codes are located in Heikki's apartment (temperature is cold, cool, neutral, warm, hot) and some of them in buildings and in the neighbourhood for feedback. It works as follows. If Heikki feels that there is too cold in his apartment he focuses smart phone camera to the QR code marked "cold" (placed in the bed room's wall) and the information is registered automatically in the right place in the end user collaboration tool's database. Then he goes out and finds out that the outdoor lights are turned on in the middle of the day. He starts end user feedback application and writes a short commend and push related application send button. The GPS coordinates are included automatically to the message. This message is then automatically added to the end user collaboration tool neighbour level BIM model supported map UI or 3D game engine based UI. After the problem is solved the message goes to the archive.

Later on Heikki uses the end-user collaboration tool forum to find out what other people have done to reduce the energy consumption. He also asks advice from the collaboration forum to some problems which are not clear in the tool's general energy saving instructions. In some cases the collaboration tool's crowdsourcing features will be utilized. All this is because he wants to save money and environment. He wants also to win this year the neighbourhood's energy saving competition.

Key functions

Possible key functions of the end-user collaboration tool are as follows: end user energy performance reporting, benchmarking and guidance; neighbourhood discussion forums; energy saving games/contents in the neighbourhood; targeted energy saving group actions trough crowd sourcing. The ultimate target is to engage and motivate the end users in energy and cost saving and shifting their energy consumption from peak hours to off-peak hours of the day.

Validation of the scenario

This scenario includes the vision how to utilise the end-user collaboration tool (D3.4). The tool is targeted to be used to improve the collaboration among the end-users related to energy saving. Some of the basic functions will be selected for use and validation in the Finnish demonstration. The aim of the validation is to show based on real measured results the impacts of end-user collaboration on the energy consumption and energy costs. For the assessment the impact assessment methodology of D4.4 will be applied. That validation wills tentative cover following energy performance indicators:

- shifted energy consumption from peak hours to off-peak hours of the day and related cutting percentage of the monthly energy bill and
- reduced CO_2 emissions.

Combination of different scenario cases

This scenario can be combined with all Finnish test case scenarios.

4.2 Scenarios on the Interface between Building and Neighbourhood

4.2.1 Scenario BN-1 (C2): End-user balance card

End-user or resident can purchase a balance card to enable simultaneous energy production and consumption (act as a prosumer). The card can be loaded with power credits that can later be used to purchase energy. All power consumed decreases credit according to real-time (buy) tariff.

Key Functions

There is two principal ways to load credit onto balance card.

- Purchase credit

- Produce power. Produced surplus power loads the balance card with power credit according to real-time (sell) tariff. In principle it does not matter how the power is generated – via solar panels, wind mills or diesel or gas engine-generator. In some cases, to stimulate renewable energy production more credit (better tariff) can be admitted for clean power production.

The balance card can be in two different modes

- Sell only – in this mode no power from outside is used. The end-user consumes only self-produced power and sells surplus power to local neighbourhood area grid. This mode is useful if the end-user is away.
- Buy & Sell – this is the normal mode. Surplus power is sold to local neighbourhood area grid and deficit power will be bought from the neighbourhood.

Validation of the scenario

The scenario will be validated by the testing of the functionality in Finnish Real World Demonstrator. The validation of the scenario will be done by simulating different options and operation schemes.

This scenario will contribute to:

- Information models for neighbourhood energy management (D2.2)
- Supervisory and predictive control methods and applications (D2.3)
- EEPOS ICT and decision support systems platform (D3.1)
- Energy Brokering Tool (EBT) (D3.2)
- End-user collaboration tool (D3.4)

Combination with different scenarios

This scenario can be combined with all Finnish test case scenarios.

4.2.2 Scenario BN-2 (C3): Energy Brokering Tool

The Energy Brokering Tool enables the real estate managers who manage the real estate with its own energy production (“NEMS operator”) to measure, calculate and monitor energy consumption and production. The Energy is stored in local storage (batteries etc.) and this enables NEMS operator to buy energy when prices are low and storage are low. When prices go up, the manager can use the battery reserves to optimise costs.

The normal case stores extra produced energy to batteries until they are full. Then the left over energy can be sold to the grid. Energy stored in the batteries is used first when consumption is higher than production and the missing energy is bought from the grid. However this kind of local storage and intelligent software enables real estate manager to take the next steps towards energy brokering. The operator can purchase energy from the grid for local storage if market prices are profitable, and sell it later when the prices goes up. Of course, the operator has to make sure his own real estate maintains its own energy consumption according to the plans. Intelligent software helps the operator to achieve this.

Key functions

The Software enables the NEMS operator:

- to manage the energy consumption data
- to monitor the energy consumption, peak loads and energy output

- to monitor competitive sales and purchasing prices of the energy
- to anticipate sales and purchasing activities according to consumption and forecast
- to monitor the activities realizations
- to transfer the anticipated supply requirements to sales and purchasing activities
- to perform sales and purchasing of energy
- to perform actual cost calculation

Validation of the scenario

The scenario will be implemented and validated at the Energy Brokering Tool (D3.2) and partly with the real world demonstration in Finland. How widely it can be implemented on the demonstration site, is not known yet.

The scenario covers the following targets of EEPOS project: EEPOS automation and energy management system platform (D2.1), Information models for neighborhood energy management (D2.2), ICT Platform (D3.1) and Energy Brokering Tool (D3.2)

Combination with different scenarios

This scenario is best used as an add-on with any other scenario described in this document, as it will not interfere with them.

4.3 Scenarios on the Neighbourhoud Level

4.3.1 Scenario N-1 (C2): Automatic consumption cut off

This scenario elaborates the potential of peak load cutting functionality without intruding the end-user comfort. The idea is to cut off such loads that do not necessarily affect the wellbeing of the end-user or limit their occupancy.

Key Functions

Local group of end-users or a housing company can preset allowed limits to cut off peak power consumption. The limits are set to the equipment that is in common use and outdoor areas (equipment that is not controlled by individual inhabitants) or to the equipment that longer operational buffer, e.g.

- Air handling units and ventilation system
- Heating and air conditioning system
- Electric car charge
- Outdoor lighting (dimming/switch-off)
- Lighting of common spaces (dimming, color adjustment, shorter delay of switch-off timer)
- De-icing applications

Validation of the scenario

The scenario will be validated by the testing of the functionality in Finnish Real World Demonstrator. The validation of the scenario will be done by testing the availability of the information needed to make decisions. Additionally, the access to change some building automation settings and limits is provided and tested. For the limit setting the access to the control panel is provided.

This scenario will contribute to:

- EEPOS automation and energy management system platform (D2.1)
- Information models for neighbourhood energy management (D2.2)
- Supervisory and predictive control methods and applications (D2.3)
- EEPOS ICT and decision support systems platform (D3.1)
- Energy performance monitoring and operations planning tools (D3.3)
- End-user collaboration tool (D3.4)

Combination with different scenarios

This scenario can be combined with all Finnish test case scenarios.

4.3.2 Scenario N-2 (C2): Utilising energy performance monitoring and planning tool

The main priority of the EEPOS NEMS operator is to guarantee the neighbourhood energy transmission system stability and balancing, energy storages and production, energy grid capacity & tariffs and power quality. The interest of the NEMS operator is also to optimise the energy production-procurement mix in the neighbourhood based on real time demand forecasts. The main functions are explained in the following:

The NEMS operator is utilising the new EEPOS energy performance monitoring and planning tools. The software utilises BIM and neighbourhood map based user interface for visualising the NEMS status including functions like historical data and trend based real-time monitoring, different kind of statistical data analysis, duration curves, dependencies between different monitored values, neighbourhood level benchmarking, monitoring value based automatic fault detection and related basic level fault diagnostics.

Using that tool NEMS operator has noticed that one building in EEPOS monitoring software related neighbourhood map based User Interface (UI) turns to red and begins to blink meaning that the building is in alarm state. The alarm related fault has been found out automatically by EEPOS monitoring software based fault detection algorithm. In this case the algorithm has noticed that outside compensated energy consumption of one building has changed a lot. This means most probably that something has broken in that building and a facility service company is needed. Depending on the used business model or common practise the NEMS operator informs the building owner or directly to the service company (they may have received the alarm automatically) about the problem. The facilities company assets the criticality of the problem and decides what immediate actions has to be taken. In this case the problem can be fixed tomorrow in normal working hours. The facilities service company use the same EEPOS monitoring software but more detailed features. They find out that the energy consumption related problems happens only when outside temperature is between -10 °C and -15 °C. After that the facility service company checks (using EEPOS monitoring software 3D BIM UI) the BAS related indoor temperatures and indoor quality and find out that there is no overheating problem but the indoor quality in one air handling unit’s serving area has same kind of dependency as energy consumption. This means that the problem must be in that air handling unit's heat recovery ice melting automatic. The facility service company fixes the problem and checks after two days special monitoring period that everything is ok and charges the building owner. In this case the early detection of too high energy consumption means 15 % saving in next month energy bill and much more if there will be big delay relating the fault detection.

Next day the status of another building in EEPOS neighbourhood monitoring map UI has changed. The NEMS operator selects the problematic building from UI by clicking it and finds out from monitoring trends that one building has problematic hourly electricity consumption profile related to spot market hourly electricity prices. The operator knows that these energy peaks means a lot of money and updated BAS / electric / HVAC systems integration (electric heating on/off control, air handling unit's volume flow and temperature control, outdoor lighting on/off control etc.) could solve this load shifting problem. NEMS operator informs the building owner about the problem. In this case the building owner decides to invest some money to solve the problem and the owner order the BAS system update from BAS contractor. After the update is done the BAS contractor puts two days special monitoring on and checks that load shifting works and charges the building owner. In this case the procurement of the load shifting controller means 10 % cutting of the monthly energy bill.

Next month the NEMS operator finds out from EEPOS neighbourhood monitoring map's benchmarking view that one of the buildings is using 15 % more energy than the others of the same kind in that area. They know that an ESCO company could solve the problem. The NEMS operator informs the building owner about the situation. In this case building owner decides to invest some money to solve the problem and the owner asks the ESCO company an offer about energy savings. The ESCO company review the situation using the EEPOS monitoring tool and based partly on that data and mainly on their own on-site energy audit they offers 18 % energy savings. The building owner and ESCO company make a deal that ESCO company makes all needed investments and takes care of all maintenance work and get every year 50 % of saved money.

In winter the NEMS operator finds out using EEPOS neighbourhood monitoring map UI that the local wind power station's weather compensated energy production varies a lot. This means that there is something wrong in that wind power station. According the business model used here the NEMS operator informs the facility service company about the problem. The facility service company use the same monitoring tool's more detailed features. They find out that the most probable reason is related to the wind turbine's rotation speed. The facility service company fixes the problem by changing a new gearbox to the wind turbine. After fixing the problem they do some extra checks in the next weeks from EEPOS monitoring software in order to assure the energy production works fine. Thereafter the work will be charged. In this case the wind power station's yearly energy production will be increased 40 %.

Key functions

The key functions of the energy performance monitoring and planning tool are historical and real-time trend data monitoring, different kinds of statistical data analysis, calculation of duration curves and dependencies between different monitored values, neighbourhood level benchmarking, value based automatic fault detection and related basic level fault diagnostics. In the user interface of the tool BIM and the neighbourhood map will be utilised for visualising the NEMS status.

Validation of the scenario

This scenario includes the vision how to utilise the energy performance monitoring and planning tool (D3.3). The tool will serve as an informative add-on tool related to the basic toolset of the system provider. Some of its functions will be selected and validated at the real Finnish demonstrator. The validation will be based on impact assessment methodology of D4.4 and its aim is to show through real measurements the impacts of using the tool on the energy consumption and energy costs. That validation will tentative cover following energy performance indicators

- energy and cost saving percentage in apartment, building and neighbourhood level,
- load shifting percentage and related cutting percentage of the monthly energy bill in apartment, building and neighbourhood level and
- neighbourhood level RES energy production and related CO2 emissions.

Combination of different scenario cases

This scenario can be combined with all Finnish test case scenarios.

4.3.3 Scenario N-3 (C3): The Trading (Agent-Based) Approach

With more and more PROSUMER try to deliver energy to the Main Grid (MAG) it is especially a critical task to consider the limited capacity of transmission lines. When these lines are overloaded, they may break down and cause, in the best case, damage to the system and a minor blackout or, in the worst case, a massive blackout. These significant challenges call for the need to build decentralized autonomous systems that are self-organizing and achieve high levels of efficiency. We call such a decentralized autonomous system a “Neighbourhood Area Grid” (NAG). The general target is an architecture with a high level of surplus which ensures that transmission lines are never overloaded.

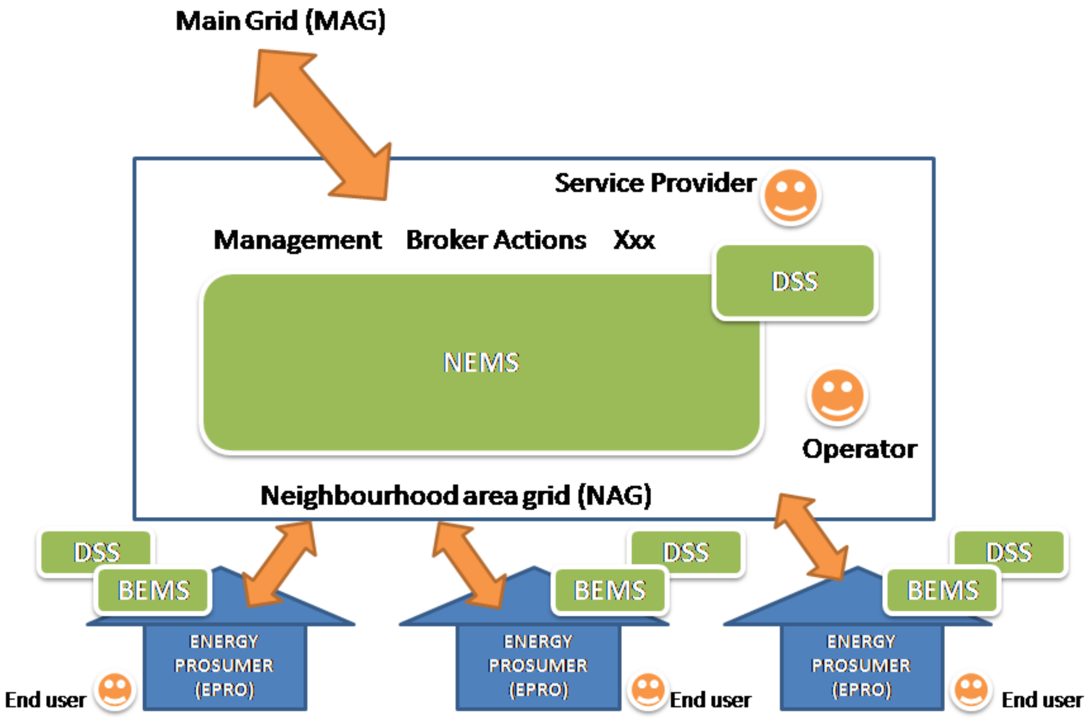

Figure 3. Overview on key functions and their relationship in neighbourhood area grids

A possible concept to deal with the challenge is to test agent-based trading strategies for the Smart Grid, where each Energy PROsumer (EPRO) is represented by an agent who manages the self-interested actions of the EPRO. In this context “self-interested” means, that the agent represents the individual interest of the EPRO and not the interests of the complete neighbourhood in general which can be quite different. The NAG offers a balancing mechanism in form of a market place, where buyers and sellers of energy do the trading. The trading is limited to a given trading period which is divided into time frames.

Key functions

In order to build a working marketplace and define its Key Functions, different components and their relationship has to be considered:

Transmission Lines (t) are for electric-power transmission, especially for the bulk transfer of electrical energy, from generating power plants to electrical substations located near demand centers. This is distinct from the local wiring between high-voltage substations and customers, which is typically referred to as electric power distribution. The capacity of t is a limiting factor for dealing with power. Transmission lines, when interconnected with each other, become transmission networks (T).

The amount of electricity required and delivered by the MAG and the EPRO are also an important factor in this scenario. We decide between buyers (B) and sellers (S) where each participant (b or s) can change his role in dependence of the market conditions.

Finally it is necessary to consider the possibility to store or to shift energy if required – dependent on the technical equipment - in order to find optimized trading strategies and to get the required energy for the best conditions.

The relationships of the ruling components in the scenario are:

- Transmission Lines – Capacity (t Є T), with
    - between NAG and MAG
    - between NAG and EPRO

  => Transmission Lines t Є T
- amount of electricity required by
    - MAG
    - EPRO

  => buyers b Є B at the market
- amount of electricity can be supplied by
    - MAG
    - EPRO

  => sellers s Є S at the market
- amount of electricity can be stored at
    - MAG
    - EPRO

  => in general also part of the buyers b Є B model – because it is not clear to the grid, whether a "buyer" use the electricity directly or stores it for further use (even to sell it later)
- prices that would be accepted to buy electricity by
    - MAG
    - EPRO

Validation of the scenario

The scenario depends on the relation between the ruling components in a given trading period. To validate the scenario we decide between (nearly) time independent variables and time dependent variables.

A time independent variable is for example the transmission line capacity: we can decide three different cases:

a) $CT_{MAG} >= CT_{EPRO}$
b) $CT_{MAG} = 1/2$ of CT_{EPRO}
c) $CT_{MAG} = 1/4$ of CT_{EPRO}

with CT_{MAG} = Capacity of Transmission Line between NAG and MAG and CT_{EPRO} = Sum of Capacity of Transmission Lines between NAG and EPROS

A typical time dependent variable is the amount of buyers and sellers on the market place in a given trading period and the amount of electricity they want to buy or have to sell, dependent on the individual possibilities (to produce and store) and needs (to consume).

Cases can be:

I. only buyers at the market place: B, !S
II. only sellers at the market place: S, !B
III. more electricity to sell: $E_S > E_B$ at a given time frame
IV. more electricity to buy: $E_S < E_B$ at a given time frame

with B is the group of current Buyers, S is the group of current Sellers, E_S is the Electricity to sell at a given time frame and E_B is the Electricity to buy at a given time frame.

For the validation we plan to use the laboratory prototype and – if the combination of the components and services succeeds in the simulation – also at the German Demonstrator.

This scenario will contribute to:

- EEPOS automation and energy management system platform (D2.1)
- Information models for neighbourhood energy management (D2.2)
- Supervisory and predictive control methods and applications (D2.3)
- Energy performance monitoring and operations planning tools (D3.3)
- End-user collaboration tool (D3.4)

Combination of different scenario cases

In general this scenario can be combined with all "B" and "NB" scenarios. In practice it will be validated especially in combination with N-5.

4.3.4 Scenario N-4 (C3): Considering Power and Heat

This scenario enhances the power-focussed scenario N-3 with the consideration of the heating aspects. The Combined Heat and Power (CHP) plant on site, as indicated in Figure 4, covers the heat demand (central heating and hot tap water) and the electricity demand of the district and delivers majority of the production of green electricity to the neighbourhood. Both electricity and heat are distributed with a direct supply line from CHP to end user (buildings).

The implementaation of the short term storage on district level, as a result of the scenario shall increase the supplied green heat.

To completely optimize the ecological and economic benefits of the energy concept, an intelligent "conversation" between producer and end user is necessary. The black points in Figure 4 is a multiple cross points with the multi commodity networks.

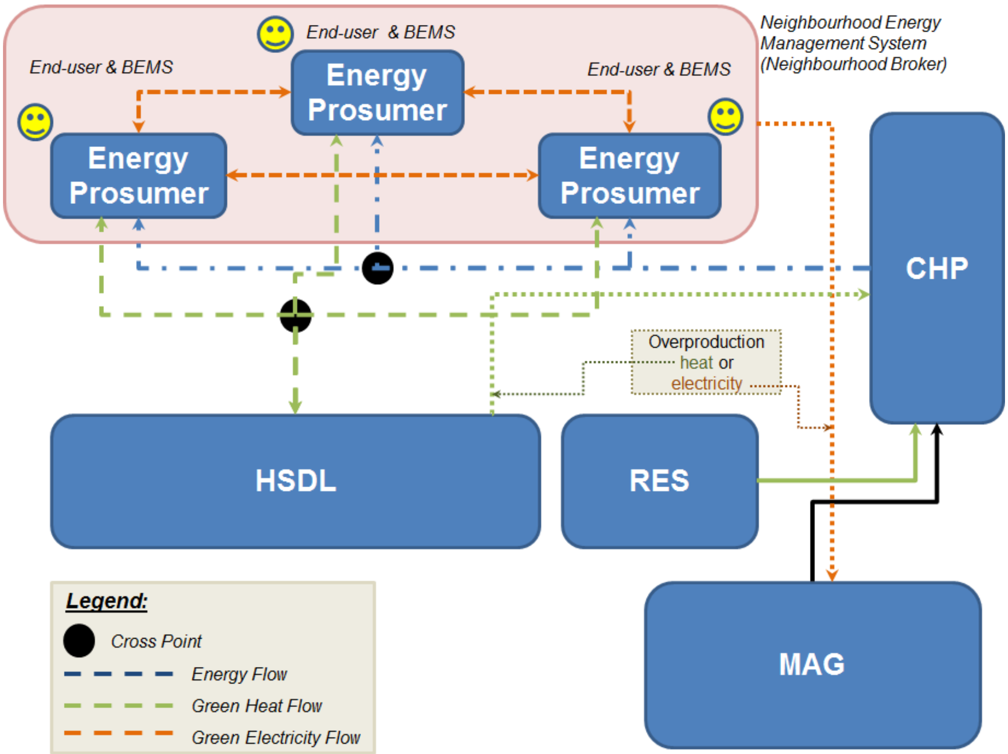

Figure 4. Overview of neighbourhood area grids and their relationship

The CHP knows at all times the actual consumption of the buildings and the dwellings (through BEMS) and is able to manage this information actively. The intelligent cross point at storage level leads the heat, at overproduction, to the storage and steers the heat from the storage back on the heating network when there is underproduction.

In case of the electricity, the overproduction is steers to the MAG, to sell them to the grid operator by the Neighbourhood broker.

This information stream is bi-directional:

- on one hand it is used for the multi commodity network,
- on the other hand it is used to communicate with the end user through the interface of the BEMS.

Key functions

This scenario is an enhancement of scenario N-3, therefore it deals with similar components. For a detailed description see chapter 4.3.3.

The relationships of the ruling components in the proposed scenario are:

- Transmission Lines – Capacity (t Є T, with
    - between CHP and NEMS (heat & electricity)
    - between HSDL and NEMS (heat)

  => Transmission Lines t Є T
- amount of heat and electricity required by
    - CHP
    - Energy Prosumers

  => buyers b Є B at the market
- amount of electricity can be supplied by
    - MAG
    - RES

=> sellers s Є S at the market

- Amount of heat can be supplied by
  - MAG
  - RES
  - HSDL

=> sellers s Є S at the market

- amount of electricity could be stored at
  - CHP
  - HSDL
- prices that would be accepted to buy heat & electricity by
  - MAG
  - Energy Prosumers
  - Neighbourhood Broker

Validation of the scenario

The scenario depend on the relation between the ruling components in a given trading period. To validate the scenario we decide between (nearly) time independent variables and time dependent variables.

A**time independent variable** are for example the transmission line capacity: we can decide two main different cases:

I. $CT_{MAG/CHP} = CT_{NEMS}$

II. $CT_{MAG/CHP} = CT_{NEMS} + CT_{RES/CHP}$ (for heat)

With:

- $CT_{MAG/CHP}$ - Capacity of Transmission Line between MAG and CHP
- CT_{NEMS} - Sum of Capacity of Transmission Lines between Energy Prosumers in Neighbourhood.
- $CT_{RES/CHP}$ - Capacity of Transmission Line between RES and CHP

A typical **time dependent variable** is the amount of buyers and sellers on the market place in a given trading period and the amount of heat and/or electricity they want to buy or have to sell, dependent on the individual possibilities (to produce and store) and needs (to consume).

Cases can be:

III. more heat and/or electricity to sell: $H\&E_S > H\&E_B$ at a given time period

IV. more heat and/or electricity to buy: $H\&E_S < H\&E_B$ at a given time period

with:

- $H\&E_S$ - is the Heat and/or Electricity to sell at a given time frame,
- $H\&E_B$ - is the Heat and/or Electricity to buy at a given time frame.

The proposed scenario will be implemented and validated at the (virtual) prototype (D4.3). The results of the scenario will in addition contribute to:

- Information models for neighbourhood energy management (D2.2)
- Supervisory and predictive control methods and applications (D2.3)
- Energy performance monitoring and operations planning tools (D3.3)

Combination of different scenario cases

This scenario will be implemented and tested at the virtual prototype, therefore a combination for the validation with other scenarios is not planned.

4.3.5 Scenario N-5 (C3): Automated Demand Side Management (DSM) within the Neighbourhood

In this scenario, the energy generation and consumption on the neighborhood level are automatically managed by the EEPOS system. Each unit (building, house, flat, ...) of the neighborhood is equipped with an Automation and Control System (ACS), which can control different loads (e.g. heating/cooling devices, washing machines, …). Thus, besides their role of monitoring, the ACSs play an active control/optimization role on the building level.

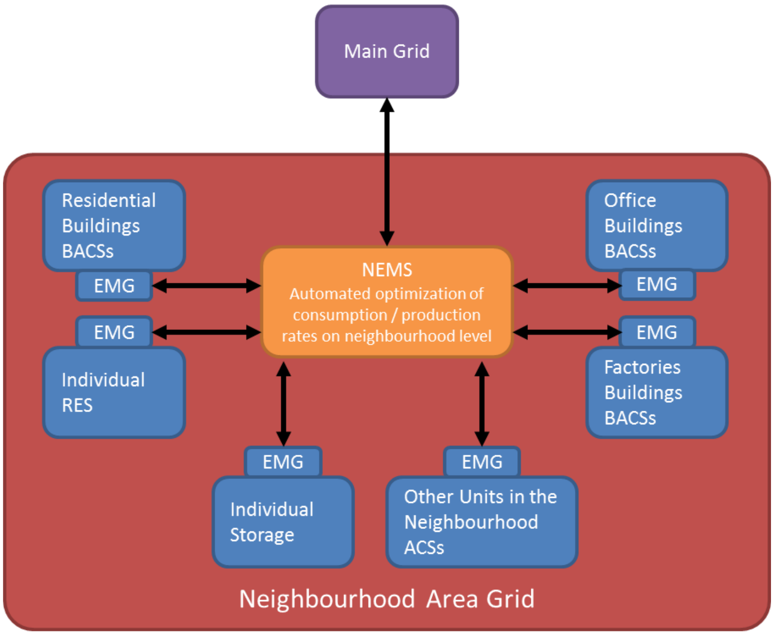

Figure 5. Schematic representation: Automated DSM within the neighborhood

All ACS as well as further individual RES and storages are connected to the Neighborhood Energy Management System (NEMS) using web based standardized protocols and can send offers as well as information on free resources (e.g. present energy production or peak load shifting potentials). The NEMS performs co-ordinated optimisation on the neighbourhood level and can actively take part in energy trading with external parties on behalf of the neighborhood members, who are not allowed for the direct participation in energy trading.

Key functions

The NEMS performs co-ordinated energy management and optimisation on the neighbourhood level. This includes monitoring and predictive control (e.g. by involvement of forecasts for production / consumption rates, calculation of forecasts for customer reactions), consideration of local diversity, automated load shifting and use of storages, and energy brokering.

The NEMS decides on the activation of the resources offered by the individual ACS (e.g. by sending switching signals or time dependant energy tariff signals).

Furthermore, the NEMS can provide metering and system services to the distribution system operator (DSO) or aggregate measurement data collected from the individual ACS.

Validation of the scenario

The scenario will be implemented and validated at least in the laboratory (T4.2). It is aimed to implement as many aspects as possible as well in the real world demonstrators in Germany and Finland.

The scenario covers the following targets of EEPOS project:

- EEPOS automation and energy management system platform (D2.1)
- Information models for neighbourhood energy management (D2.2)
- Supervisory and predictive control methods and applications (D2.3)
- EEPOS ICT and decision support systems platform (D3.1) (partly)

To be able to rate potential energy efficiency gains, and load and generation shifting potentials obtained by the neighbourhood level management, a reference scenario will be defined for the model neighbourhood represented in the laboratory. Among others, this scenario will comprise energy consumption and generation profiles for the modelled neighbourhood without management.

Combination with different scenarios

This scenario can be combined with all German test case scenarios.

5. Conclusions

5.1 Summary of achievements

The discussion and definition of the requirements of the stakeholders as well as the needed services and infrastructure for the validation finally leaded to a series of innovative and challenging scenarios which covers all main aspects of EEPOS development.

The following table shows the connection between the scenarios on the one hand and the RTD tasks of WP2-3 on the other hand:

Scenario / Project Target		EEPOS automation and energy management system platform (D2.1)	Information models for neighbourhood energy management (D2.2)	Supervisory and predictive control methods and applications (D2.3)	EEPOS ICT and decision support systems platform (D3.1)	Energy Brokering Tool (EBT) (D3.2)	Energy performance monitoring and operations planning tools (D3.3)	End-user collaboration tool (D3.4)
Scenarios on the Building Level								
B-1	Integration of Consumers / non-automatized loads		X				X	X
B-2	Optimization of heating grid	X		X	X		X	
B-3	Activities delayed by end-user	X	X	X	X		X	X
B-4	End-user collaboration tool							X
Scenarios at the Interface between Building and Neighborhood								
BN-1	End-user balance card		X	X	X	X		X
BN-2	Energy Brokering Tool	X	X		X	X		
Scenarios on the Neighborhood Level								
N-1	Automatic consumption cut off	X	X	X	X		X	X
N-2	Utilizing energy performance monitoring and planning tool						X	
N-3	The Trading (Agent-Based) approach	X	X	X			X	X
N-4	Considering Power and Heat		X	X			X	
N-5	Automated Demand Side Management (DSM) within the Neighborhood	X	X	X	(X)			

Depending on the validation target and the stakeholder needs the developed scenarios describe functionalities and give short stories of using them. The scenarios serve for different purposes, especially the illustration of the vision and benefits from users' point of view, the requirements of relevant stakeholders like the NEMS operator, energy brokers and energy supply companies.

The implementation and evaluation of the different scenarios in the different test environments will lead to valuable cognitions how to transfer the theoretical needs to the practice and how the end-user will act and react using the new technologies.

5.2 Relation to continued developments

With the scenarios in mind the smart control of demand for consumption and supply to enable balanced, energy positive buildings and neighbourhoods as anticipated in the EEPOS project requires a quite ambitious future NEMS with new approaches for data collection, data analysis and energy management actions.

An important task of the ongoing development on this new NEMS is to provide the evidence, that the results of EEPOS together and separately contribute to EE impacts – especially energy saving, load shifting and RES integration.

The application of the validation strategy in the prototypes and demonstrators (WP4-5) will have to consider a rational combination of measuring/observing under laboratory conditions and especially at the real world demonstrators and set the focus on the parts of the scenarios and their features that can be validated.

6. ACRONYMS AND TERMS

ACS .... Automation Control System
AMR........................... Automatic Meter Reading
BACS .... Building Automation Control System
BEMS .... Building Energy Management System
CHP .... Combined Heat and Power
DSM .... Demand Side Management
DSO .... Distribution System Operator
DSS............................. Distributed System Service
EMG .... Energy Management Gateway
EPRO.......................... Energy PROsumer
HSDL .... Heat Storage on District Level
IED .... Intelligent Electronic Devices
IPMVP......................... International Performance Measurement and Verification Protocol
MAG........................... Main Grid
NAG .... Neighbourhood Area Grid
NEMS......................... Neighbourhood Energy Management System
OGEMA .... Open Gateway Energy Management Alliance
PROSUMER .... PROducer and conSUMER
QR .... Quick Response
RES............................. Renewably Energy Sources
SCADA .... Supervisory Control and Data Acquisition
UI................................ User Interface

7. REFERENCES

[1] Cochrane R., Damm M., Freihofer H., Hajek J., Herndl Th., Holleis E., Kopetzky R., Mahlknecht S., Malbasa V., Neumann P., SmartCoDe - Evaluation Report, Project No.: ICT-2009-247473, December 2012

[2] R. Apel et.al., Demand Side Integration - Lastverschiebungspotenziale in Deutschland, VDE VERBAND DER ELEKTROTECHNIK ELEKTRONIK INFORMATIONS-TECHNIK e.V., Juni 2012

[3] R. Silvero, M. Rey, D. Hildebrandt, M. Hartung, A. Fuentes, Definition of methodologies - I. Methodology for Energy Efficiency Measurement, Draft of deliberable D 1.2.of the EU-project Energy Efficient e-Houses, July 2010