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e-balance

Deliverable D2.1

Selection of representative use cases

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Abstract

This deliverable aims to identify a selection of the most representative use cases for Energy Management Systems to be adopted in smart city environments. We start by identifying the energy balancing system functionalities and perform an overview on related Energy Management Systems (EMS). Further we describe the use cases for each group of functionalities considering their impact within the e-balance eco-system.

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Impressum

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Executive Summary

This deliverable identifies a selection of the most representative use cases with regard for the energy efficiency and energy balancing e-balance system. These use cases highlight the most relevant scenarios and functionalities and define the representative stakeholders of such energy management systems.

In Section 2, an overview on representative use cases addressed in other environments is performed. The related work study focuses on adopted use cases in similar energy efficiency projects and on outcomes of the work done by international standard development organizations and other research & development projects.

Then, Section 3 describes the energy balancing use cases by specifying energy balancing schemes which fulfil e-balance objectives and allow the adoption of enhanced consumption and production management services inside each smart city.

Further, in Section 4 the use cases for neighbourhood monitoring in smart cities are identified, with a strong focus on energy distribution grids, considered in this deliverable as one of the main enablers for energy efficiency.

Finally, in Section 5 the use cases for the energy prediction and simulations of the influence of e-balance technology penetration are addressed. They allow the estimation of energy efficiency achievements and energy grid stability with different levels of penetration of the energy efficient technology (components, appliances) considered by the e-balance project.

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Abbreviations

AMI	Advanced Metering Infrastructure
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
DER	Distributed Energy Resource
DG	Distributed Generation
DR	Demand Response
DSM	Demand Side Management
DSO	Distribution System Operator
EMS	Energy Management System
ESO	European Standardization Organization
ETSI	European Telecommunications Standards Institute
EV	Electric Vehicle
GUI	Graphical User Interface
ICT	Information and communications technology
KPI	Key Performance Indicator
LV	Low Voltage
MV	Medium Voltage
PV	Photo Voltaic

1 Introduction

This section explains the context for the use cases that are defined further in the document. It introduces the e-balance project and defines the goals of this deliverable.

1.1 The e-balance Eco System

E-balance aims to develop an energy balancing framework providing interfaces for all the users and stakeholders of the energy grid. The main objective of the e-balance project is to improve the energy efficiency by performing rational consumption of available resources and by reducing energy losses in the energy grids, but also to reduce the CO2 emission by integrating renewable energy resources, as well as to increase the robustness of the energy grids, by monitoring their state. Besides previous objectives, the e-balance project will also consider non-technical aspects of the energy efficiency and will evaluate the adoption problem of smart energy control solutions, investigating their interdependencies within social, legal and economic aspects.

Existing energy management solutions only address energy efficiency in specific premises and such systems are closed, since they do not provide interfaces towards other energy players. Within the eco-system, e-balance will provide an energy management solution which will address energy efficiency, not only at the household level, but also in a smart neighbourhood and smart city global perspective, providing each user and stakeholder with a personalized interface.

The main body of the e-balance work is the definition and prototype of such enhanced Energy Management systems, focusing on each user requirements and concerns. This work will include an identification of devices and equipment that will interact within such management platform. The proposed energy management platform will be evaluated in real world scenarios as well as in an emulation/simulation environment.

1.2 Work Package 2 – Use cases and socio-economic aspects

The goal of Work Package 2 is to define the e-balance use cases and the main functionalities by analysing and defining technical, social, legal and economic requirements and constrains. The aim of such analysis is to ensure a proper architecture definition, taking into account a proper allocation of components and information flows. From the end-user perspective, WP2 performs social user studies in order to provide the input for system specification (WP3) and help during evaluation of the proposed architecture (WP6).

1.3 Deliverable D2.1 – Selection of representative use cases

Deliverable D2.1 identifies a selection of representative use cases for the energy balancing platform. The main results come from Task 2.1 (WP2) that defines the use cases within the context of the project. Deliverable D2.1 also provides input on the representative stakeholders and e-balance functionalities, which introduces the deliverable D2.4 – users and stakeholders' requirements. Figure 1 depicts the interdependencies between the tasks and deliverables in WP2.

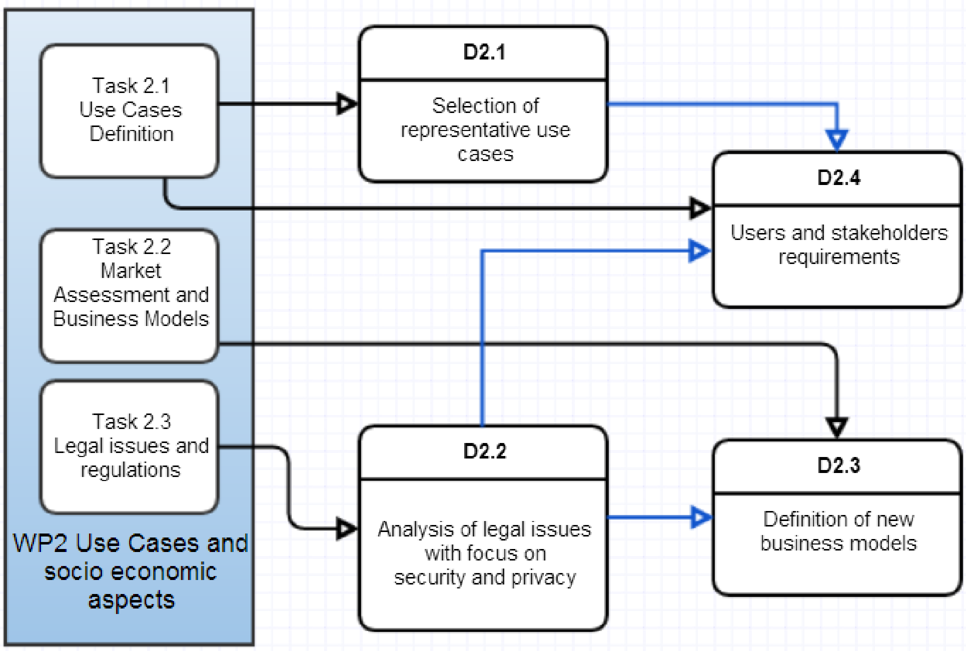

Figure 1. Interdependencies in WP2

1.3.1 The Structure of Deliverable D2.1

The deliverable is structured in four main parts. It starts by performing a survey of selected use cases for similar initiatives. Furthermore it addresses use cases by three main clusters of use cases, namely energy-balancing, neighbourhood monitoring and energy predictions and simulations.

The use case specification methodology is performed based on the filling of a template. For this deliverable we perform a brief use case description, followed by the identification of the involved actors, the identification of events and the flow that defines the behaviour in the use case. In order to identify assumptions and pre-conditions, each use case specifies the dependencies to other use cases and clarifies the assumptions which activate the specified use case. Table 1 presents the e-balance use case template, used for the specification of e-balance representative scenarios.

Table 1. e-balance use case template

Use Case identifier	E-balance use case name
Description	E-balance use case description
Actors	Identification of the related actors which interview within the use case.
Flow	Identification of system and use case flows which affect the use case.
Assumptions	(Optional) Identification of assumptions which influence the use case.
Pre-conditions	(Optional) Previous use cases which directly influence the occurrence of the specified use case.

1.4 Representative e-balance functionalities

This deliverable provides an overview of representative e-balance use cases. These use cases describe e-balance system scenarios and functionalities and are grouped in three main clusters:

- **Energy Balancing.** Energy balancing use cases include the promotion of energy efficiency in smart neighbourhoods, reducing energy generation produced by non-renewable sources. It also includes the management of loads and aims to reduce load diagrams instability, reducing the demand consumption peaks and promoting energy usage during excessive energy availability timetables.

- **Neighbourhood monitoring.** Neighbourhood monitoring use cases include the measurement of technical parameters from the energy distribution grid, which allow the assessment of energy delivery performance indicators and provide data towards enhanced monitoring applications, such as power flow and optimization of dispatching mode.
- **Energy prediction and simulation.** Energy forecast and simulation use cases address electrical grid modelling use cases. These functionalities focus on providing a simulation environment to simulate different levels of demand forecast and renewables generation, different levels of distributed generation and electric vehicles penetration and electrical grid behaviour assessment with different levels of energy storage penetration. Such functionalities aim to perform off-line studies which are expected to provide energy grid restrictions and limit operation scenarios.

Table 2 overviews representative e-balance use cases. Use cases were identified based in their related cluster: energy balancing, neighbourhood monitoring and energy prediction and simulation clusters.

Table 2. The e-balance main use cases overview

Use case cluster	E-balance use cases
Energy Balancing (Section 3)	Integration of renewables sources Integration of electric vehicles Integration of energy storage modules Integration of smart appliances Support of grid operation in isolated mode
Neighbourhood monitoring (Section 4)	Power flows measurement and recognition Energy delivery KPI measurement and calculation Fault detection and location Fault prevention and risk assessment Fraud detection and Losses calculation Energy delivery enhanced dispatch modes Neighbourhood energy efficiency calculation
Energy prediction and simulation (Section 5)	Demand prediction Renewables energy generation predictions Energy storage penetration predictions Electric vehicle penetration simulations Distributed generation penetration simulations

2 Related work

This section provides an overview on use cases and results of standardisation bodies as well as other research and development projects.

2.1 Related standardization initiatives

Energy efficiency and renewable energy represent the key goals to achieve by the 20-20-20 targets of reducing carbon emissions and increasing energy supply. The adopted European Commission policy has been promoting a paradigm change in the energy market, which also considers an alternative vehicle transportation eco-system.

Besides the well-known European mandates on smart energy meters (M441) and charging stations for electric vehicles (M468), which addressed specific challenges for the energy market, the European mandate M490 identified the electrical supply grids as key enablers for such innovations, demanding CEN/CENELEC/ETSI standardization bodies to investigate the status of smart grids standardization in Europe.

This section gives an overview of the standardization activities concerning the functionalities and the use cases which have been considered within international fora. Within the e-balance project, the smart grid is considered as a key enabler for smart city and smart neighbourhood environments.

2.1.1 Smart Grid Coordination Group CEN/CENELEC/ETSI

The European Standardization Organizations (ESOs) CEN, CENELEC and ETSI established the Smart Grid coordination group in order to accomplish the activities within the Mandate M/490 from the European Commission. Within this coordination group, the “Sustainable Processes” working group described the smart grid use cases in [1]. These use cases are considered a first step towards the definition of future developments and reference architectures.

Such approach outcomes from Mandate M/490 that defined as first activity the collection, analysis and harmonization of use cases. Although considering building, industry, appliances and home automation use cases out of scope, the ESOs were requested to consider such automation systems interfaces with the smart energy grid.

Besides the specification of methodology for collecting and grouping the use cases, the Sustainable Processes working group defined generic grid related use cases and demand and generation flexibility use cases. Table 3 gives an overview of the generic use cases.

Table 3. Generic use cases

Generic grid related use cases
Fault Location, Isolation and Restoration (FLIR)
Voltage Control and power flows optimization (VVO)
Short term load and generation forecasting
Microgrid management
Monitoring the distribution grid
Emergency signals
Electrical vehicles charging
Generic flexibility related use cases
Receiving consumption, price or environmental information for further action by consumer or a local energy manager
Direct load / generation management
Flexibility offerings
Auto Registration of participating devices and customers
Using Flexibility

The use case collection activities took into account the expertise from several institutions and technical working groups. Overall, they collected more than 500 use cases in the transmission grid management, microgrids, substation automation, distributed energy resources, advanced metering infrastructures, energy storage, electric transportation, asset management, bulk generation and market domains.

2.1.2 ITU-T Smart Grid Focus Group

The International Telecommunication Union (ITU) established a focus group on Smart Grid aiming to identify the potential impact on standards, investigate future studies and familiarize and encourage collaboration between telecommunications and smart grid communities. Considering the ICT perspective, the focus group reported in [2] a description of smart grid use cases also meeting requirements and architecture considerations.

The study considers high-level and detailed use cases. The high-level use cases are depicted in Figure 2. The study covered more than 400 detailed use cases for Demand Response, Wide-Area Situational Awareness, Energy Storage, Electric Vehicle to Grid Interaction, AMI systems, Distribution Grid Management, Market Operations, Existing User's Screens, Managing Appliances Through/By Energy Service Interface, Control of Electric Vehicle, Distributed Energy Generation/Injection and demand response.

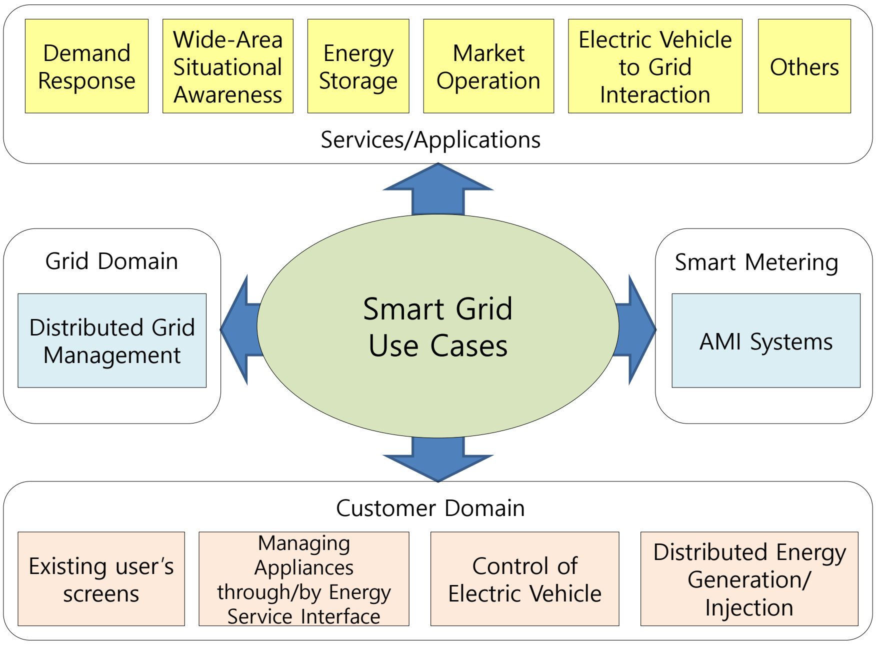

Figure 2. ITU-T High level smart grid use cases

Besides the high-level use-cases, the report considers additional energy consumer oriented use cases where the smart grid reference architecture is used for promoting life assistance, security and support. These use cases include senior care, home security monitoring, climate change monitoring on energy consumer premises.

2.1.3 ETSI M2M Communications impact on Smart Grids

The Machine-to-Machine working group from ETSI assessed in [3] the applicability of ETSI M2M architecture deployed in smart grid networks. The report focusses on the most representative use cases for smart grids and performs analysis on requirements and recommendations for future ETSI M2M work activities.

Use cases are classified according to the ETSI concept models: the energy layer, control and connectivity layer and service layer. Table 4 presents the smart grid use cases identified by ETSI M2M committee.

Table 4. ETSI M2M Smart Grid use cases

Smart Grid Energy Layer Use Case
Advanced Distribution Automation WAMS (Wide Area Measurement System)
DER control (Distributed Energy Resources)
DR control (Demand Response) for large scale application
DS supervision (Distribution System)
DER, DR/Microgrid control
Electric Vehicle (EV) charging and power feed
PV Generation (Photo Voltaic)
Control and Connectivity Layer Use Cases
Use Case for Service Providers Management
Service Layer Use Cases
Home-DR applications (Demand Response) for consumer appliances
Home Energy Management (HEM)
Submetering
Smart Grid/Metering Service Layer

The technical report has identified several requirements for the technical specifications inside the M2M technical committee and suggested the maintenance of coordination between different smart grid mandates and between ETSI and external organizations.

2.2 Related projects

This section provides an overview on the use cases of other research and development projects and initiatives.

2.2.1 SEEDS. Self-learning energy efficient buildings and open spaces

The goal of this project is to develop and validate the concept of Self learning Energy Efficient buildings and open Spaces (SEEDS) [8]. The SEEDS project defines, models and implements a Building Energy Management System (BEMS) and an architecture based on self-learning techniques which allow the system to anticipate energy uses for optimal performance. The project uses the combination of advances in wireless sensor technology and self-learning methods in order to give SEEDS a competitive advantage in future BEMS.

The project develops an open architecture and system for adaptive real-time energy management for buildings, surrounding areas and open spaces that integrate self-learning methods, advances in wireless sensor technology and building technologies to optimize the building's performance in terms of comfort, energy efficiency, resource efficiency, economic return, functionality and lifecycle value. The open architecture facilitates data acquisition from wireless sensors, adopts novel sensor validation methods and allows easy enlargement and integration with controls systems from different manufactures.

Wireless technologies allow its applications to a variety of building types and open spaces and make it suitable for new construction and retrofitting. The word "building" is used in a wide sense including not only the interior of a single building but also a group of buildings and their surrounding and open spaces (like a district, a university campus or a shopping center with its parking area).

Machine learning anticipates the energy demand and the behaviour of the different energy subsystems in the building in order to reach an optimal operation point that will aim to minimize energy consumption and CO2 emissions whilst maintaining user comfort. The developed adaptive building energy management system will allow integration of different energy production, consumption and storage sub-systems such as Renewable Energy Sources (RES), lighting, heating/cooling systems, etc. and be suitable for a wide range of buildings and spaces.

Figure 3 presents one of the applications developed in the project: a tool for sensors positioning:

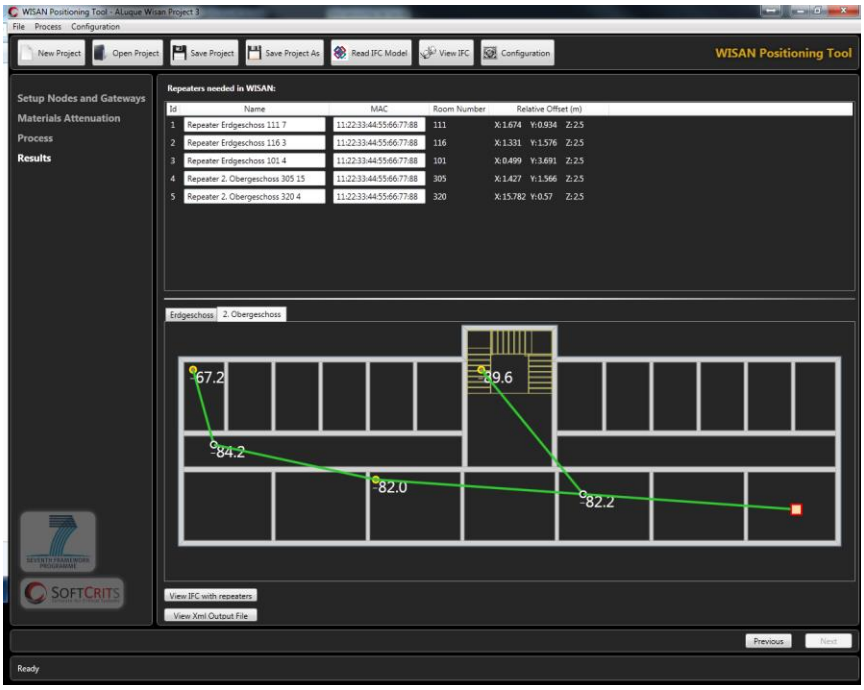

Figure 3. Sensors positioning tool in the SEEDS project

2.2.2 EnPROVE

The objective of EnPROVE (Energy consumption prediction with building usage measurements for software-based decision support) [4] is to develop a software model for predicting the energy consumption of a specific building, with different scenarios implementing energy-efficient technologies and control solutions based on actual measured performance and usage data of the building itself.

The key hypothesis of EnPROVE is that it is possible, from adequate gathering and assessing data on how a structure performs and is being used from an energy view point, to build highly accurate and specific energy consumption models relevant for prediction of alternative scenarios.

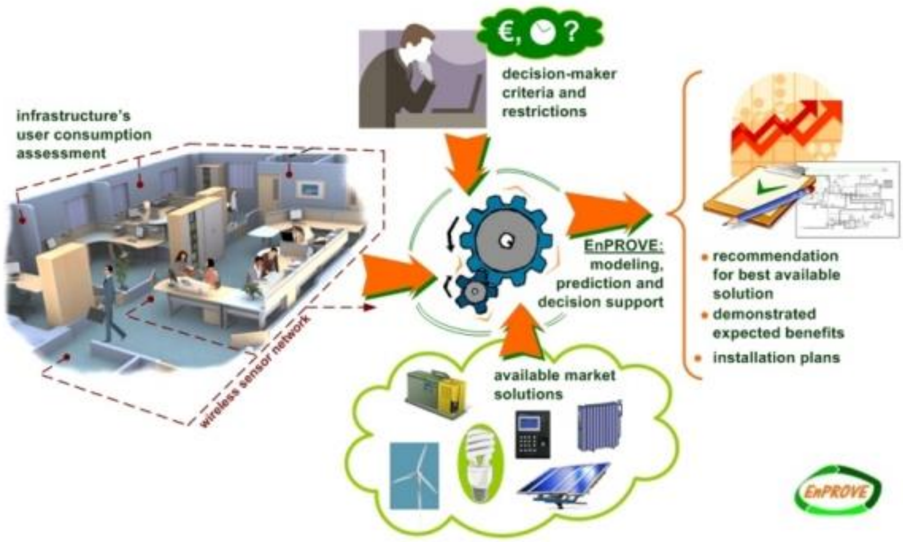

Figure 4. EnPROVE project overview

The EnPROVE software tools assess the energy-efficiency impact of alternative technologies for which available investment resources can be directed and, thus, support the decision maker finding the optimized set of energy-efficient solutions to be implemented. These results will be tailored to the actual building itself, through automated measurements of the building usage and energy efficiency. Technological solutions include energy reducing, generating and storing options, and with user-defined criteria on resources and restrictions, will identify through new prediction algorithms when the return on investment will be realized.

By solving these problems, EnPROVE has developed tools, interoperable with existing CAD or Facility Management tools, to model the energy consumption from monitored data, predict the performance of alternative scenarios and support the decision maker in finding the optimal point for the investment. Compared to current available energy auditing services and prediction tools, it is foreseen that EnPROVE could increase the cost-effectiveness of renovation investments by 15 to 30%. These services will open new business opportunities for both construction companies that work on building renovation, as well as building management companies on long-term contracts. The application of the tools has been validated in two real buildings.

2.2.3 IMPROSUME - The Impact of Prosumers in a Smart Grid based Energy Market

IMPROSUME project [5] tries to provide answers to several and timely issues highlighted by IEA the ERA-Net, regulators and the industry. It is a multi-disciplined effort that synthesizes research and business relating to consumer behavior, energy trading, distributed production, storage, renewable energies, energy business strategies etc.

The principal focus of the research is on prosumers (portmanteau formed by contracting either the word producer with the word consumer), their future role in the market and the collective influence they could muster. Consequently the studies of contingencies for consumer acceptance and adoption of the prosumer role are very important in this project.

By applying theories from system dynamics and advanced operation research, simulation models that can help us study a number of effects that can affect the future market have been created. Design criteria that can be applied both in the Nordic energy market, in Europe and beyond have been defined:

- To define and study the role of prosumers in the future power market.
- To develop strategies for securing consumer acceptance and active participation based on solid knowledge of prosumer behaviour given a set of constraints and stimuli.
- To analyze and develop possible business models for prosumers
- To develop simulation models and analyze technical and commercial impact from prosumers, given different constraints and stimuli, business models and various combinations of distributed energy resources
- To analyze different trading strategies covering inter- as well as intra-trading
- To analyze the relation between the prosumers and technical and commercial aggregators (TVPP and CVPP) including operational criteria
- To analyze the value chain prosumer-VPP-market
- To extract constraints, rules and relationships that can help design and optimize the Smart Grid of tomorrow, the definition of new market mechanisms, trading instruments and grid management facilities to achieve optimal use of resources, high regularity, acceptable price levels and stability of supply as well as sustainable growth for the European countries.

2.2.4 MIRABEL: Micro-Request-Based Aggregation, Forecasting and Scheduling of Energy Demand, Supply and Distribution

The MIRABEL project's [6] main goal is to develop a conceptual and infrastructural approach that allows energy distribution companies to efficiently manage higher amounts of renewable energy and balance supply and demand. Currently, most renewable energy sources (RES; e.g. windmills, solar panels) pose the challenge that the production depends on external factors, such as wind speed and direction, the amount of sunlight, etc. Hence, available power from RES can only be predicted but not planned, which makes it difficult for energy distributors to efficiently include RES into their daily schedules. As an unfortunate consequence, power from RES often has to be given away for free due to a lack of demand.

The objectives of the MIRABEL project are as follows:

- To develop a model of actors with certain roles in the energy market and specify data to be exchanged between these actors.
- To develop a concept of micro-requests to handle the energy demand and supply on a household level, together with methods - to forecast demand and supply based on historical and additional data, such as weather forecasts (both on a small scale, i.e. for households, and on a larger scale), and to update these predictions over time, - to aggregate and disaggregate the micro-requests on a regional level, and - to schedule energy production and consumption based on aggregated requests.
- To design a distributed, decentralised and scalable infrastructure to handle the high data load from the mass of households. Prototypical system architecture and its revision will be developed.
- In order to test and demonstrate this project, a demonstration system with the help of concrete trial scenarios and real-world data will be implemented. These include a Transmission System Operator trial, a Local Distributor of Energy trial, and a community consumer trial.
- Standardized data exchange is required between consumers and brokers; between producers and brokers; among brokers themselves; and between brokers, large producers/consumers and grid operators. Standardization is pursued throughout the project.

2.2.5 NOBEL - A Neighborhood Oriented Brokerage Electricity and Monitoring System

The NOBEL approach [7] targets to develop, integrate and validate ICT enabling a reduction of the currently spent energy, by providing a more efficient distributed monitoring and control system for local network operators and prosumers (as depicted in Figure 5). NOBEL will focus its efforts in designing a new Neighbourhood Oriented Energy Monitoring and Control System. This solution will help network operators to improve last mile energy distribution efficiency by integrating operators' requirements and by enabling bidirectional interaction between them.

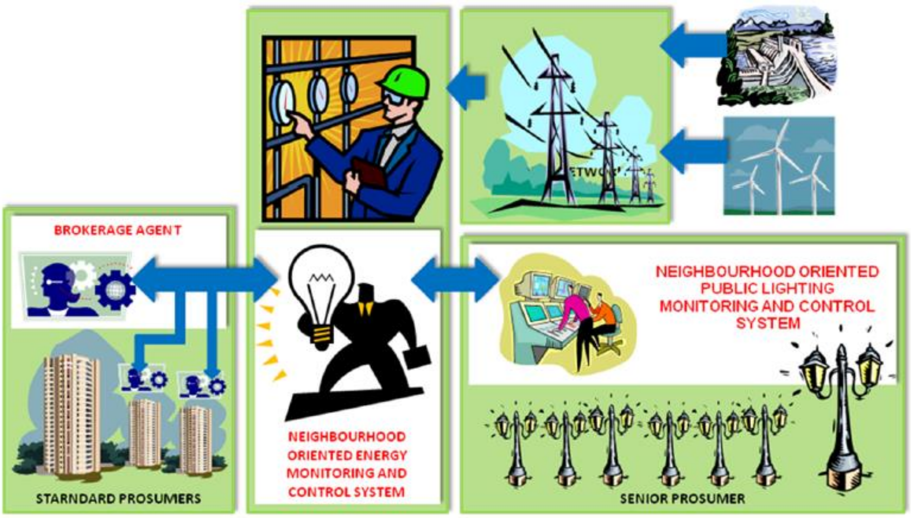

Figure 5. NOBEL overview: Energy Efficiency for the Neighbourhood

Two different prosumer profiles are considered for the proof of concept:

- A standard prosumer, represented via a Brokerage Agent. This Agent will be developed within the project to dynamically monitor the amount of energy that he has produced, and the amount that is not yet consumed. This energy can be traded and therefore made available to other users, improving in this way the overall efficiency of the system.

- A senior prosumer that extends the previous concept in the sense that it requires additional internal processes to not only dynamically monitor but additionally control the energy produced or consumed in a largely distributed local area. Examples of senior prosumers are sport centers, industrial parks, shopping centers, etc. NOBEL will use a real-world test bed i.e. the Neighbourhood Public Light System to validate and assess its concepts.

By improving monitoring efficiency, the NOBEL approach aims at reducing the required production of energy. In the short term, it is more important to improve the efficiency than trying to dramatically reduce the production, which would require a major social agreement and a major adjustment in the behaviour of citizens. The key to NOBELs efficiency improvement is that prosumers become sources of both energy and information. The information allows the energy system to better adapt the amount of electricity in the network to the real time demand. The performance of the entire system is enhanced by exploiting the locality of the processes in monitoring and control that normally do not consider the detailed behaviour of the actual consumers.

The ultimate objective is to achieve higher energy efficiency and optimize its usage. This will be achieved by analysing and continuously monitoring the components in the distribution network, gathering the appropriate data and, finally, identifying on-the-fly situations where energy can be saved. This will allow NOBEL to create a highly dynamic system where the amount of electricity in the network follows the current demand. Excess energy already bought or created is monitored and managed to make the energy available in other parts of the network (see Figure 6) or to intelligently make use of it via demand side controlling. To achieve this goal, the energy that comes from the local network operator as well as the prosumers will have to be monitored in a fine-grained way, analysed, and decisions will need to be made in a timely manner.

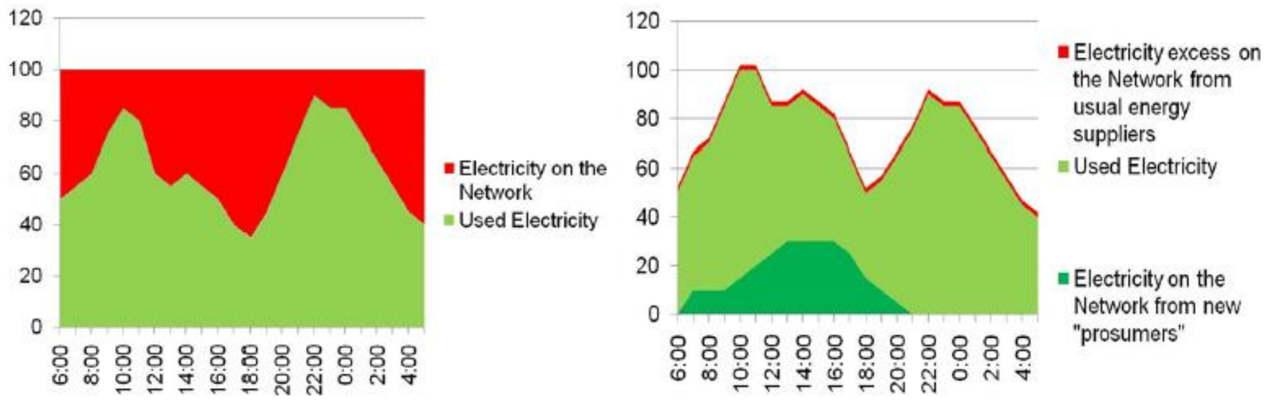

Figure 6. NOBEL approach: demand-driven production/energy-purchase

2.2.6 SmartCities Málaga

SmarCity Málaga [9] is a Spanish demonstrator of a SmartGrid whose goal is to improve electricity management by means of an integration of renewable energies in the electrical grid and also by allowing traditional consumers to become generators (prosumers). This constitutes a new electricity management model based on electricity microgeneration where different prosumers coordinate to share energy and use it in a more efficient way.

The following aspects have been tackled:

- Smart metering: this new intelligent devices will allow a transparent billing and real-time metering and will allow users to query electricity usage information and be notified in case disconnections in the grid occur.
- Grid automation: automation can be achieved by means of remote metering devices, diverse sensors, security cameras etc. Real-time information about the smart grid will result in shorter disconnection times due to failures of maintenance operations.
- Distributed electricity generation and storage: batteries will allow electricity from different sources to be store and used to

- Intelligent electric vehicle charging: diverse vehicle charging points have been installed throughout the city that uses the electricity of the smart grid to power non-contaminant vehicles and reduce the CO2 emissions.

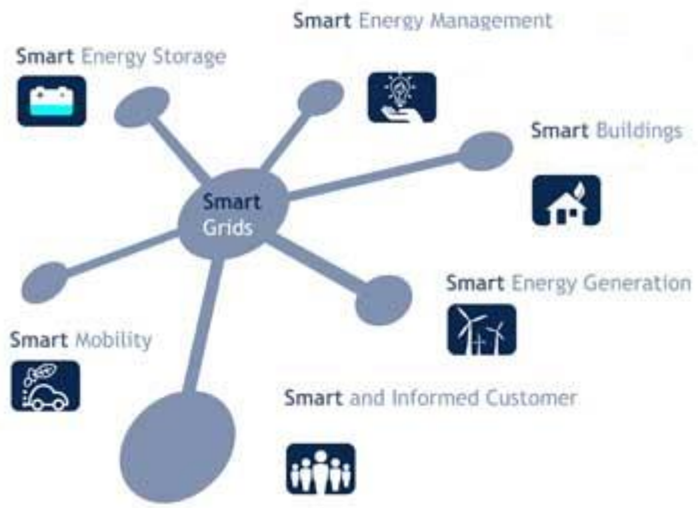

Figure 7. Challenges tackled in SmartGrid Málaga

All these measures will provide a better control of the whole electricity system, from high voltage networks to medium and low voltage ones (currently only 20% is monitored). This new concept of smart grid will transform the traditional electricity network to highly flexible and automated network that includes remote and centralized diagnose, repair and management of smart meters.

2.2.7 Twenties

Twenties project [10] aims to demonstrate new smart grid capabilities by means of a set of real demonstrator in several European cities. This demonstrator will bring answers to the following questions:

- What are the valuable contributions that intermittent generation and flexible load can bring to system services?
- What should the network operators implement to allow for off-shore wind development?
- How to give more flexibility to the transmission grid?
- Overall: how scalable and replicable are the results within the entire pan-European electricity system?

These questions will be answered by addressing the following different objectives:

- To demonstrate that active and reactive power control and voltage/reactive control in the system can be performed effectively by aggregated wind farms.
- To show at large scale that aggregating DER (Distributed Energy Resources), including wind production and flexible loads) can lead to a more secure and efficient electricity system.
- To provide the critical building blocks of DC grid control and protection strategies and DC breakers which will allow guaranteeing the security of future HVDC messed grids.
- To demonstrate that adequate coordination mechanisms between offshore wind farms management and available hydro power capacity in neighbouring systems brings viable
- Solutions to securely control the power balance during offshore storm passages.
- To demonstrate that adequate coordination mechanisms between Dynamic Line Rating, Power Flow Controlling Devices and Wide Area Monitoring Systems (WAMS) bring more flexibility to the power system within affordable capital and operational costs.

- To demonstrate that alternative operation parameters provided by Dynamic Line Rating and FACTS technology, do bring flexibility, do enhance security and do expand the capability of the network to evacuate more wind power on a regional basis.
- To assess the impact, barriers and solutions needed to upscale the demonstration results.
- To assess the benefits of replicating the obtained results throughout the entire panEuropean interconnected transmission system.
- To disseminate the obtained results widely enough for an early take-up of scaling and replication rules by the stakeholders.

These intertwined overarching goals have been split into 6 main high level demonstration objectives:

1. System services provided by wind farms (SYSERWIND): Tests to provide new active and reactive power control services to the system (EMS level), using improved systems, devices and tools, but keeping the current hardware at wind farm level.
2. Large scale VPP integration – (DERINT): Improve wind integration based on intelligent energy management of central CHPs, off-shore wind, and local generation and load units in the distribution grid.
3. Technical specifications towards offshore HVDC networks – (DC GRID): Assess main drivers for the development of off-shore HVDC networks.
4. Offshore wind farm management under stormy conditions – (Storm Management): Demonstrate shut down of wind farms under stormy conditions without jeopardizing safety of the system.
5. Network enhanced flexibility – (NETFLEX): Demonstrate at regional level (CWE) how much additional wind generation can be handled thanks to DLR (Dynamic Line Ratings), coordination of controllable devices (PSTs & HVDCs) and usage of WAMS.
6. Improving the flexibility of the transmission grid - (FLEXGRID): Demonstrating that current transmission network can meet demands of renewable energy by extending system operational limits, maintaining safety criteria.

3 Energy Balancing use cases

The smart grid of the future we consider in the e-balance project will have an ICT system/infrastructure in place that will allow a diversity of activities that can be regarded as energy balancing. The diversity of aspects that are to be supported provides a great flexibility and support for all possible deployment scenarios. Further, the comprehensive view on the energy system considering multi-aspect and multidimensional problem space allows better efficiency.

The scenarios or use cases presented in this section can be grouped into the following classes:

- Distributed generation
- Energy Storage
- Electrical Vehicle
- Demand Side Management
- Microgrid balancing

But, as already mentioned, these use cases only represent the individual aspects of the complete system and shall be considered together. Most of the use cases are cross-class scenarios..

Distributed Generation (DG) Distributed generation refers to the production of electricity from many small energy sources, e.g. photovoltaic panels, combined heat power plants (CHP) and windmills. Distributed generation based on renewable sources is influenced by several factors, e.g., the changes in weather and due to that the actual production capacity may not be easy to predict. The distributed generation includes all sources of energy smaller than some defined threshold (e.g., 50 MW for Portugal) that may be connected to the grid at any level, i.e., at the low voltage (LV), medium voltage (MV) or even high voltage (HV) distribution grid.

From the point of view of the **customer** that produces energy his energy produced as the distributed generation can be used in several ways:

- It can be consumed immediately at the place of production,
- It can be sold to an **energy supplier, aggregator** or another **customer,**
- It can be stored at the place of production, , and used or sold at a later point in time.

The actual possibilities are defined and/or limited by the legislative and market context that may be different in different countries, even across Europe.

In the worst case, the energy generation devices produce energy in an unpredictable or almost unpredictable way. For instance the solar panels generate energy only if sun is shining, the windmills produce energy only if wind is blowing and the combined heat power plant (CHP) generates energy only while heating the water. The latter case can be slightly influenced, if the heating activity can be shifted in time with some given flexibility.

Energy storage Energy storage allows the energy customer to perform a delayed release of accumulated energy. The energy storage can have different scales and can be connected to any layer of the distribution grid, i.e., high voltage (HV), medium voltage (MV) or low voltage (LV). There are different approaches for energy storage, like: batteries, flywheel, compressed air, hydroelectricity or thermal. These approaches use a diversity of basic principles to store energy, like: chemical, potential or kinetic.

The major parameters that describe the energy storage are; the capacity, energetic efficiency (including losses and battery degradation) and the maximum charge/discharge currents.

In order to use energy storage efficiently the **customer** needs the support of advanced energy management systems that supports the decision process concerning (a) when to store, (b) when to sell and (c) when to locally consume.

Further, for the **distribution system operator** or the **energy supplier** to use the energy storage efficiently it is necessary to provide the visibility of the storage units and their availability, in order to match the generation levels and demand needs through an advance energy management system.

Electrical Vehicles (EV) There are three types of electric vehicles that are important for smart energy systems:

– Pure electrical vehicles are equipped with electric motor powered by batteries that are charged by connecting the vehicle to the energy system.

– Plug-in hybrid electric vehicles (PHEVs) equipped with both – electric motor and combustion engine. In PHEVs both, the electric motor, as well as the combustion engine, are mechanically coupled to the wheels. In series PHEVs, though, the electric motor is directly coupled with the wheels and the combustion engine is only used to charge the batteries when needed.

– Hybrid electric vehicles (HEVs) with motor using gasoline and batteries that are always charged by the engine.

Besides its ecologic and social advantages, an electrical vehicle can be regarded as mobile energy storage. Similar, hybrid electric vehicle can be regarded as mobile energy generator. The mobility of the electrical vehicles as energy storage or generator implies that they can be connected to the distribution grid at different points. And thus, in order to allow correct accounting for consumed and produced energy, a mechanism for identifying the customers is necessary.

The mobility is the main difference between EV as energy storage and the classical energy storage. Further, the EV is a vehicle and thus, the customer's strategy for using the EV as storage will be most probably dominated by the EVs primary function.

Demand Side Management (DSM) The aim of demand side management is to modify the **customer** demand for energy using a diversity of methods, such as financial incentives or education. Usually, the goal of demand side management is to encourage the customer to use less energy during the peak hours, or to move the time of major energy use to off-peak times such as night time and weekends. Demand side management does not necessarily decrease the total energy consumption, but is usually expected to reduce the need for investments in networks and/or power plants.

Microgrid balancing A microgrid is an interconnection of generation and consumption that operate in a coordinated fashion. The microgrid may be a single customer, a group of several co-located or dispersed customers. While capable of operating in the islanding mode, independently of the grid, the microgrid usually functions interconnected, purchasing energy and other services from the grid and potentially selling energy back at times.

Table 5. Strategy-driven decision on the use of the produced energy

Use Case #1	Strategy-driven decision on the use of produced energy
Description	The **customer** that produces energy shall have a choice of the use of the energy in order to implement some defined strategy, e.g., to maximize the profit. The alternatives to selling the energy depend on the **customer** type and may include the storing and the consuming of the energy by her devices.
Actors	• **customer** that produces energy • **energy supplier** the **customer** has contract with or an **aggregator**
Flow	1. The **customer** specifies the strategy for using the energy he produces. The possible strategies depend on the available decision factors (e.g., dynamic energy price, local consumption, production obligations) and the possible ways for the **customer** to use the energy (sell, store, consume). 2. The energy is used according to the defined strategy and the decision parameters received from the grid (from the **energy supplier** or **aggregator**).

	3. The **customer** may redefine the strategy at any time and is informed about the current status.
Assumptions	• The **customer** has alternative choices to selling the energy, e.g. energy storage and/or energy consuming appliances. • The **customer** gets some input from the **energy supplier** that influences the decision process (e.g. the current energy price, contracts for energy production)
Pre-conditions	• The **customer** has means (e.g., a GUI) to specify his energy use strategy • The **customer** has means to monitor and control the energy flow and the energy producing and energy storing appliances • If the **customer** has an energy storage available the use case **strategy-driven decision on charging or discharging the energy storage** can be applied together in order to improve efficiency • If the **aggregator** is involved, the **customer's** strategy can allow the **aggregator** to control the **customer's** energy use
Use case class	Distributed generation, Demand side management

Table 6. Energy consumption priorities in case of energy delivery limitations

Use Case #2	Energy consumption priorities in case of delivery limitations
Description	The **customer** shall be able to specify the energy consumption priorities for his appliances. This is important in case of energy supply limitations. If the amount of energy available in the grid for the **customer**, including the energy produced locally by the **customer**, is not enough to cover all his consumption, e.g., due to grid outage, these priorities define the way the energy is consumed by the customer appliances in order to provide more critical appliances with energy first.
Actors	• **customer** that consumes and optionally produces energy • **distribution system operator** or **energy supplier** the **customer** has contract with
Flow	1. The **customer** specifies the consumption priorities for her energy consuming appliances. 2. The **energy supplier** or **distribution system operator** informs the **customer** about the grid status and in case of an outage or a limitation in energy supply the consumption priorities are applied for the **customer's** appliances. 3. If the limitation does no longer exist the **customer** appliances operate in normal mode, i.e., the energy consumption priorities are not applied. 4. The **customer** may redefine the priorities at any time and is informed about the current status.
Assumptions	• The **customer** is notified about grid status and energy supply changes by its corresponding **energy supplier** or **distribution system operator.**

Pre-conditions	• The **customer** has means (e.g., a GUI) to specify his energy consumption priorities and to get notifications • The **customer** has means to monitor and control the energy flow and to control the energy consuming appliances
Use case class	Demand side management

Table 7. Distributed generation balancing and resilience

Use Case #3	Distributed generation balancing and resilience
Description	Automatic controlling and monitoring of the distributed generation allows avoiding failures in the grid and thus, increases the quality of service.
Actors	• **customer** that produces and optionally consumes energy • **energy supplier** the **customer** has contract with or an **aggregator**
Flow	1. The **energy supplier** or **aggregator** defines the energy production limits and energy quality parameters for the **customer**. The energy production limits may be dynamic. 2. The **customer** is informed about the status and can access the information about the defined energy quality parameters as well as the energy production limits. The **customer** defines his strategy for reactions in case of failures. 3. The parameters of the energy generated by the **customer's** appliances are monitored. In case the quality parameters do not fit into the defined frame the reactions according to the strategy are applied and e.g., the energy generating appliance that failed is disconnected from the grid. If it is not possible to identify the source of the quality loss, the complete energy production is disconnected from the grid. 4. In case the energy production limit is exceeded, the energy production is adjusted according to the limit, e.g., the power of some of the energy generating appliances is adjusted or some of the appliances are disconnected from the grid.
Assumptions	• The **customer** is notified about energy quality parameters and the energy production limits by its corresponding **energy supplier** or **distribution system operator.**
Pre-conditions	• The **customer** has means (e.g., a GUI) to specify her reaction strategy in case of failures and to get notifications • The **customer** has means to monitor the energy quality and to control the energy producing appliances • If the **aggregator** is involved, the **customer's** strategy can allow the **aggregator** to control the **customer's** energy production
Use case class	Distributed generation

Table 8. Energy production and consumption agreement/contract

Use Case #4	Energy consumption and production agreement/contract
Description	The **customer** and the **energy supplier** (or **aggregator**) may agree on a

	fixed amount of energy to be produced and consumed by the **customer** in a specified period of time. This agreement defines the mutual obligations for both parties.
Actors	• **customer** that consumes and/or produces energy • **energy supplier** the **customer** has contract with or an **aggregator**
Flow	1. At some point in time, the **energy supplier** and the **customer** define their individual strategies for the procedure of energy production and consumption agreement/contract. 2. The **energy supplier** (or **aggregator**) and the **customer** are notified on the current state and may adjust their strategies. 3. A **forecast** of the energy consumption and production by the **customer** for a defined period of time is performed and forwarded to the **energy supplier** or **aggregator**. 4. The **energy supplier** or **aggregator** performs a prognosis on the overall energy production and consumption in the part of the grid**.** 5. The prognoses of the customer and energy supplier are compared. If the energy consumption predicted by the **customer** exceeds the amount of energy proposed by the **energy supplier** (or **aggregator**) for the **customer** or the **energy supplier** (or **aggregator**) asks the **customer** for more energy to be produced, the amounts are renegotiated. When the customer and **energy supplier** (or **aggregator**) agree on the energy to be produced and consumed the energy supplier. 6. If the agreed amount of energy made available for the **customer** does not cover all the actual consumption, the **energy consumption priorities** are applied. 7. The agreement/contract specifies the amount of energy to be produced and/or consumed by the **customer** and defines a mutual obligation. The **customer** is obligated to deliver the amount of energy she promised to produce and she is obligated to consume the amount of energy she ordered. The corresponding obligations apply to the **energy supplier** (or **aggregator**) as well.
Assumptions	The **customer** is able to make a forecast of the amount of energy each of its appliances can produce or will consume in the defined period of time. In order to do this he has to have additional data, e.g., a weather forecast data and/or historic information on energy production and consumption, available.
Pre-conditions	• The **energy supplier** (or **aggregator**) and the **customer** have means available (e.g., a GUI) to specify their strategies for the contract preparation procedure and to get notifications • The **customer** has means to monitor the energy flow and to control the energy producing, storing and consuming appliances • The **energy consumption priorities** use case is implemented • If the **aggregator** is involved, the **customer's** strategy can allow the **aggregator** to control the **customer's** energy production agreement procedure • If the customer has energy storage available, the use case **strategy-driven decision on charging or discharging the energy storage**

	can be applied to increase the efficiency
Use case class	Distributed generation, demand side management

Table 9. Strategy-driven decision on charging or discharging the energy storage

Use Case #5	Strategy-driven decision on charging or discharging the energy storage
Description	A **customer** may have energy storage modules installed. These are able to store energy either coming from local production by the **customer** or from the grid, e.g., from power plants or renewable sources. This energy can be further used by the customer or it can be sold as customer's own generation.
Actors	• **customer** that has an energy storage installed and may also consume and/or produce energy • **energy supplier** the **customer** has contract with or an **aggregator**
Flow	1. At some point in time, the **customer** defines the energy storage charging strategy. He is notified about the current status and storage mode and charge level. 2. The strategy defined by the customer is implemented; according to the defined parameters and conditions in the grid, like current energy price, demand or obligations, the energy is either stored or released from the energy storage.
Assumptions	• The **customer** gets some input from the **energy supplier** or **aggregator** that influences the decision process (e.g. the current energy price, contracts for energy production)
Pre-conditions	• The **customer** has means (e.g., a GUI) to specify his energy storage charging strategy and to get notifications • If the **aggregator** is involved, the **customer's** strategy can allow the **aggregator** to control the **customer's** energy storage
Use case class	Energy storage, distributed generation, demand side management

Table 10. Electrical vehicle as mobile energy storage or generator

Use Case #6	Electrical vehicle as mobile energy storage or generator
Description	Depending on its configuration an electrical vehicle can be regarded as a mobile energy storage or a mobile energy generator. Due to this mobility feature, the electrical vehicle can be connected to different points in the distribution grid at different times. These points may include the **customer** (vehicle owner) premises and in this case the electrical vehicle is regarded in similar way as a standard stationary energy storage or generator. But if the electrical vehicle is connected outside the **customer's** premises it is necessary to manage it differently. Usually, these cases include the situations where the vehicle is connected to the grid at a charging station (that may act as an **energy supplier** or **aggregator**) or at some other **customer's** premises.
Actors	• **customer** that owns an electrical vehicle and may also additionally consume and/or produce energy • **energy supplier** the **customer** has contract with or an **aggregator**

Flow	1. At some point in time, the **customer** defines the energy strategy for the electrical vehicle. The strategy includes the strategy for charging/discharging the car energy storage as well as the strategy for the use of produced energy, both considering the current usage strategy of the vehicle (defining for instance the maximum allowed discharge level). The **customer** is notified about the current status, working mode and charge level. 2. The strategies defined by the customer are implemented together.
Assumptions	• The **customer** gets some input from the **energy supplier** or **aggregator** that influences the decision process for charging and discharging the electrical vehicle, e.g. the current energy price, contracts for energy production.
Pre-conditions	• The **customer** has means, e.g., a GUI, to specify his electric vehicle strategy and to get notifications • If the **aggregator** is involved, the **customer's** strategy can allow the **aggregator** to control the **customer's** electrical vehicle working mode • The use case **strategy-driven decision on the use of produced energy** can be applied for the management of the energy production • If the **customer's** electrical vehicle has an energy storage available the use case **strategy-driven decision on charging or discharging the energy storage** can be applied
Use case class	Energy storage, distributed generation, demand side management

Table 11. Customer interfaces for better efficiency and interaction

Use Case #7	Customer interfaces for better efficiency and interaction
Description	In order to provide a better interaction with the customers and to achieve higher efficiency a diversity of user interfaces has to be provided with different range of data and interaction.
Actors	• **customers** • **energy supplier** the **customer** has contract with, an **aggregator** or a **distribution system operator** • **ICT service providers**
Flow	1. The **ICT service providers** provide means (interfaces) for the **customer** to interact with the energy system and other customers 2. The customer specifies the availability of his data, the intended use and sharing preferences 3. The **distribution system operator**, the **energy supplier** and the **aggregator** make the data collected about the **customer** available via the interfaces. These interfaces allow also **customer** input. This presented information may include „self-feedback" based on customer defined targets, efficiency data of other **customers** as well as suggestions for energy usage based on consumption and production prognosis.
Assumptions	

Pre-conditions	The customers defines the allowed use of their data – the use case **handling of current and historical customer data for improved safety and privacy** is implemented
Use case class	Demand side management, energy storage, distributed generation, microgrid balancing, electrical vehicles

Table 12. Handling of current and historical customer data for improved safety and privacy

Use Case #8	Handling of current and historical customer data for improved safety and privacy
Description	The **customer** shall have the influence on the way his data is collected, processed and stored. The **customer** can choose the frequency her consumption and production is sampled. In this case the choice may influence the achievable quality of the energy balancing. The collected data is used for accounting, but it is enough to store an aggregate for that purpose. Stored raw consumption and production data can be used for prediction of future **customer** behaviour. When the **customer** decides to sell or rent his premises, his privacy may be at risk. Thus, in order to assure privacy, the **consumer** should be also able to erase his private data from the system.
Actors	• **Customer** • **energy supplier** the **customer** has contract with, an **aggregator** or a **distribution system operator** • **ICT service providers**
Flow	1. The **customer** defines his data collection, processing and storage preferences. 2. The other parties in the energy grid perform the collection, processing and storage for the **customer** data according to his preferences. 3. At any time the **customer** may change his preferences as well as remove detailed data from the system (only aggregates necessary for accounting will remain).
Assumptions	• The **customer** has means to provide his data collection, processing and storage preferences (e.g., a GUI) • The other parties of the system respect the **customer** preferences with respect to his data
Pre-conditions	
Use case class	Demand side management, energy storage, distributed generation, microgrid balancing, electrical vehicles

Table 13. Intelligent home appliance energy consumption balancing

Use Case #9	Intelligent home appliance energy consumption balancing
Description	A typical home appliance consumes a given amount of energy to fulfil a defined task. The appliance is usually composed of several modules and for the fulfilment of the task it may be necessary to involve a set of them. Further, some of the components may also generate energy. And in order to

	provide fine grained energy control the logic of the appliance has to know the specific energy parameters and requirements of its components as well as the time necessary involve each component to fulfil the given task. Based on this data it is able to control the components, e.g., to keep the overall energy consumption (or production) within a specified range. In order to allow coordinated control of multiple appliances there is a need for an interface that allows influencing the energy profile of the appliance. Appliances not equipped with such an interface have to be controlled in coarse grained fashion, e.g., by controlling the connection to the power line.
Actors	• **customer** • **energy supplier** the **customer** has contract with or an **aggregator** • **home appliances vendor**
Flow	1. The **home appliances vendor** makes the intelligent appliances available for the **customer.** 2. The **customer** specifies the constraints for the appliance, e.g., maximum energy consumption or production. The constraints can be set manually or automatically based on the input from **energy supplier** or **aggregator**. The constraints may change dynamically. 3. At some point of time the **customer** specifies a task to be fulfilled. 4. The appliance fulfils the task within the defined (possibly dynamic) constraints and notifies the **customer**, if the constraints disallow fulfilling the task.
Assumptions	
Pre-conditions	
Use case class	Demand side management, energy storage, distributed generation, electrical vehicles

Table 14. Additional sensors for appliance energy consumption balancing

Use Case #10	Additional sensors for appliance energy consumption balancing
Description	In order to achieve even better energy efficiency the customer may define a strategy and dependences for the appliance control depending on the data from additional sensors, e.g., the light in the room shall be switched off as soon as all persons leave the room; or temperature and air humidity sensors to control the heating more efficiently.
Actors	• **customer** • **energy supplier** the **customer** has contract with or an **aggregator** • **home appliances vendor or ICT service provider**
Flow	1. The **home appliances vendor** and/or the **ICT service provider** make the sensor devices available for the **customer.** 2. The **customer** specifies the influence of the sensor data to the constraints for some appliance. The constraints can be set manually or automatically based on the input from **energy supplier** or **aggregator**. The constraints may change dynamically. 3. At some point of time the **customer** specifies a task to be fulfilled. The task can be also triggered by a sensor.

	4. The appliance fulfils the task within the defined (possibly dynamic) constraints and notifies the **customer**, if the constraints disallow fulfilling the task.
Assumptions	
Pre-conditions	• The use case **intelligent home appliance energy consumption balancing** is implemented.
Use case class	Demand side management, energy storage, distributed generation, electrical vehicles, microgrid balancing

Table 15. Microgrid energy balancing

Use Case #11	**Microgrid energy balancing**
Description	A Microgrid is an interconnection of small modular generations and consumptions that operate in a coordinated way and are connected to low-, medium- or even to high- voltage distribution grid. Micrograds can operate connected to the grid or be operating islanded. The microgrid can act as a single customer (e.g., operated by an aggregator) connected to the grid via a single connection. On the other hand, a hierarchy level in the distribution grid tree can also be seen as a microgrid if its generations and consumptions are controlled in a coordinated way. The energy balancing in a microgrid is similar to energy balancing for a single customer. The major differences are that in case of multiple customers their data may have to be handled differently due to potentially different data handling preferences and the accounting has to be realized for each customer individually.
Actors	• **customer** or **customers** • **energy supplier** the **customer(s)** has (have) contract with, an **aggregator** or a **distribution system operator** (or **balance responsible party**)
Flow	1. Each **customer** specifies his strategy for energy balancing. 2. Each **energy supplier** and **aggregator** operating a microgrid performs the energy balancing trying to satisfy each customer's energy consumption and production strategy. The **energy supplier** or **aggregator** performs the balancing similar as it is done by a customer, but on the microgrid level the customers are like appliances on the customer level. The **energy supplier** or **aggregator** agrees with its microgrid **customers** on the energy consumption and production levels in order to achieve the best efficiency of the microgrid. On the other hand, the **energy supplier** or **aggregator** uses the data from higher level – the context, and manages the data and energy exchange with **distribution system operator** or **balancing responsible party**. 3. The **distribution system operator** or the **balancing responsible party** collects the consumption and production data from **energy suppliers** or **aggregators** operating the microgrids in the grid and performs grid level energy balancing.
Assumptions	
Pre-conditions	• The use case **energy consumption and production agreement/contract** is implemented. • The use case **strategy-driven decision on the use of produced**

	energy is implemented. • The use case **energy consumption priorities in case of delivery limitations** is implemented. • The use case **customer interfaces for better efficiency and interaction** is implemented. • The use case **energy generation balancing and resilience** is implemented. • If the **aggregator** is involved, the **customer's** strategy can allow the **aggregator** to control the **customer's** strategy parameters and/or appliances
Use case class	Microgrid balancing, distributed generation, energy storage, demand side management, electrical vehicles

Table 16. Multiuser privacy management in energy grid

Use Case #12	Multiuser privacy management in energy grid
Description	The energy grid **stakeholders** often perform their tasks in parallel using the same infrastructure. Due to that the data sets (possibly business data) belonging to different **stakeholders** may be shared on the same ICT system components, different other **stakeholders** may have access to the data owned by others. It is of utmost importance that the data is protected from unauthorized access even if needed for common processing.
Actors	• All **stakeholders**
Flow	1. There is a need to specify the domains for different data used in the energy grid, their necessity for performing the grid basic functionality like accounting and balancing and the data ownership. 2. The stakeholders specify their data collection, processing and storage preferences for both, data they own (produce) as well as data they process. 3. Only cooperating stakeholders (directly or indirectly) have access to each other's data. The access limits are defined by their data preferences. 4. The cooperating stakeholders may agree on some relaxations of their data preferences, e.g., for some profit. 5. Each stakeholder can modify his data collection, processing and storage preferences at any time.
Assumptions	• All stakeholders must respect the defined data related preferences of other stakeholders
Pre-conditions	• Each stakeholder has the possibility to specify his data related preferences (e.g., using a GUI)
Use case class	Microgrid balancing, distributed generation, energy storage, demand side management, electrical vehicles

4 Neighbourhood monitoring use cases

Smart Cities of the future will include numerous Information and Communication Technologies (ICT) nodes with sensing and/or capabilities for monitoring energy distributions grids. Besides the Smart Meters (SMs) from Smart Energy Grids, which constitute the Advanced Metering Infrastructure (AMI), other ICT nodes will be deployed in strategic spots of the distribution infrastructure, including secondary substations, distribution cabinets, distribution lines and Distributed Energy Resources (DERs). These ICT nodes will monitor a set of selected metrics, providing input towards a Smart City advanced Energy Management System (EMS). The availability of these data at the EMS allows the implementation of services involving different actors, which will aim to jointly optimize the energy efficiency process, to maximize the Quality of Supply, in order to maximize the benefits and profits and/or to reduce the costs of all the involved actors. The following sets of neighbourhood area services were considered the most relevant in this project:

- **Power flow recognition**: These services are related to the detection and recognition of energy flows from centralized and distributed sources. This also allows the computation of optimized power flows that are then used to propose different electrical grid topologies and normal operation modes to interested stakeholders.
- **Distribution grid monitoring**: These services are related to the monitoring of the quality of supply, energy efficiency, losses and fraud detection.
- **Fault detection, location, isolation and restoration**: Energy faults such as broken or short-circuited lines, as well as malfunctioning field devices, usually result in total or partial outage in a distribution feeder, affecting energy delivery for a set of customers with direct impact on quality of supply performance indicators. Consequently, detection and repair of these occurrences must be performed as quickly as possible. Traditionally, fault detection and localization is time consuming, since it is based on customer complaints, followed by time consuming fault location search activities performed by repair teams. These use cases attend the implementation of services that significantly hasten these tasks.

4.1 Power flow recognition

This section presents the representative use cases for energy power flows in smart neighbourhood environments. The included use cases focus on the detection and recognition of energy flows from centralized and distributed sources and the calculation of different power flow modes, considering technical condition and cost savings estimations.

Table 17. Neighbourhood power flows use case

Use Case #13	**Neighbourhood power flows**
Description	The EMS enables the recognition of energy power flows within the Low Voltage electrical distribution grid. It provides insight in the capacity of distribution assets based on a real time analyses and allowing querying for historic specific timetable.
Actors	• Distribution System Operator • Energy Retailer
Flow	1. Electrical grid modelling. 2. Periodic data retrieval from distribution grid ICT devices. 3. Storage of retrieved data. 4. System actors request visualization for current or time specific power flows.
Assumptions	

Pre-conditions	

Table 18. Distributed generation power flows use case

Use Case #14	**Distributed generation power flows**
Description	The EMS enables the recognition of renewables generation related power flows within the Low Voltage electrical distribution grid. It allows understanding the capacity of distributed generation sources in real time and allows analysing for specific timetables.
Actors	• Distribution System Operator • Energy Retailer
Flow	1. Electrical grid modelling. 2. Periodic data retrieval from distribution grid ICT devices. 3. Storage of retrieved data. 4. System actors request visualization of current or time specific power flows.
Assumptions	
Pre-conditions	In order to correctly differentiate renewables power flows from power plant related power flows, this use case requires the implementation of use case identifier: 'Neighbourhood power flows'. This use case considers the recognition of renewables power flows and aims to increase monitoring capabilities which provide a differentiation within centralized power plant energy flows.

Table 19. Optimized power flow use case

Use Case #15	**Optimized power flow**
Description	The EMS calculates the optimal power flow topology based on electrical grid capacity, demand and distributed generation energy flows. Optimized power flow provides a GUI for the best distribution grid topology, considering technical data from distribution assets and consumers demand. Besides technical conditions, the optimal power flow aims to achieve the conditions which enable the lowest cost per delivered energy.
Actors	• Distribution System Operator
Flow	1. Electrical grid modelling. 2. Calculation of optimized power flow. 3. Identification of switching operations which need to be performed within the distribution grid.
Assumptions	
Pre-conditions	

Table 20. Economic dispatch use case

Use Case #16	Economic dispatch
Description	The EMS performs calculation of power levels with the objective of minimization of total generation cost. It considers the calculation of demand for a specific smart city for a specific period. Then the calculation of generation set points is achieved for all energy sources, the EMS identifies the operations and power levels expected at each power injector of the energy grid which solve demand-generation challenge, by minimizing energy losses due to over generation or lower consumption levels.
Actors	• Distribution System Operator • Energy Retailer
Flow	1. Electrical grid modelling. 2. Calculation of power set points in generation units which minimize generation costs. 3. Identification of operations and actions which minimize energy losses.
Assumptions	
Pre-conditions	

Table 21. Power flow state estimator use case

Use Case #17	Power flow state estimator
Description	The EMS calculates and estimates the technical condition of energy flows and electrical infrastructure assets when assessing different topology configurations for the energy distribution grid. The state estimator aims to validate the real-word applicability for topology modifications which consider non-normal operation modes in such smart city.
Actors	• Distribution System Operator
Flow	1. Electrical grid modelling. 2. Retrieval of current electrical grid configuration. 3. State estimation of technical grid condition assuming the assessment of a different energy grid topology.
Assumptions	
Pre-conditions	This use case complements Optimized power flow and Economic dispatch use case identifiers.

4.2 Electrical distribution grid monitoring

This section presents the selection of most representative electrical grid monitoring use cases. It considers measurement for quality of service, efficiency, losses and calculation of fraud probability within energy distribution grids.

Table 22. Quality of supply measurement use case

Use Case #18	Quality of supply measurement
Description	The EMS processes information from neighbourhood households and determines the quality of service Key Performance Indicators (KPIs) according to the data retrieved from ICT devices.
Actors	• Distribution System Operator • City municipality • Local country regulator
Flow	1. Periodic data retrieval from ICT devices considering technical quality of supply metrics; 2. Calculation of key performance indicators related to Quality of Service and Quality of Energy delivery.
Assumptions	
Pre-conditions	

Table 23. Energy efficiency measurement use case

Use Case #19	Energy efficiency measurement
Description	The EMS processes information from neighbourhood households and determines the energy efficiency of each energy customer.
Actors	• Distribution System Operator • City municipality • Local country regulator • Energy Customers
Flow	1. Periodic data retrieval from ICT devices considering technical energy efficiency metrics; 2. Calculation of energy efficiency level for each household and neighbourhood.
Assumptions	This use case assumes each actor is capable of retrieving energy efficiency indicators. Local household indicators are intended for local energy customer, while neighbourhood efficiency indicators will address neighbourhood efficiency indicators towards their inhabitants.
Pre-conditions	Quality of supply measurement.

Table 24. Fraud detection use case

Use Case #20	Fraud detection
Description	Energy management system processes information from neighbourhood households and determines fraud probability occurrences in each neighbourhood
Actors	• Distribution System Operator • Energy retailer
Flow	1. Periodic data retrieval from ICT devices considering technical energy consumption metrics;

	2. Calculation and detection of non-expected energy consumptions which were not subject to commercial billing.
Assumptions	This use case assumes the detection of fraud activities performed in energy distribution grids. Energy management platform algorithms correlate data from ICT devices and issue alerts on fraud events occurred in such neighbourhood. This use case must consider data sampling measurement errors performed by ICT devices in order to avoid false-positives energy fraud events.
Pre-conditions	

Table 25. Losses calculation use case

Use Case #21	**Losses calculation**
Description	The EMS processes information from ICT devices and determines energy losses within energy grid assets.
Actors	• Distribution System Operator • Local country regulator
Flow	1. Periodic data is retrieved from ICT nodes; 2. EMS calculates theoretical energy losses; 3. EMS calculates losses based on retrieved data;
Assumptions	This use case considers the calculation of energy losses within energy distribution grids. It considers energy waste due to lake of demand and higher distributed generation.
Pre-conditions	

4.3 Fault detection, location, isolation and restoration

This section contains the representative use cases for fault detection, location and restoration in smart neighbourhood environments. Energy delivery failures occur in distribution lines due to several factors, from weather to mechanical causes. Fault detection enables DSO operation and maintenance teams to initiate their repair activities right after fault occurrences. Therefore, this approach guarantees the reduction of outage time experience by all inhabitants of such affected neighbourhood.

Table 26. LV fault detection and location use case

Use Case #22	**LV fault detection and location**
Description	Detection and awareness of energy faults in electrical distribution grids in Low Voltage Networks.
Actors	• Distribution System Operator • Energy customers
Flow	1. Fault occurrence in Low Voltage distribution grid 2. Alarm trigger (event reported towards EMS system) 3. Calculation of affected households 4. Dispatch repair teams to affected area(s)

Assumptions	Fault detection assumes that one or several energy customers are affected by an energy fault / outage. DSO is able to detect failure before energy customers report complaints through the service unavailability call-centre. Fault location assumes that repair teams are assigned to the most probable faulty assets based on the information retrieved from ICT devices.
Pre-conditions	

Table 27. Fault detection on public lighting circuits use case

Use Case #23	**Fault detection on fused luminaires**
Description	The e-balance system retrieves information from ICT devices, detecting and identifying the fused or faulty luminaires. This use case considers two different types of energy faults: public lighting luminaires which are not consuming energy according to the expected timetable and circuit failure when a large number of luminaires are not consuming energy during the expected night period.
Actors	• Distribution system operator • City municipality
Flow	1. Enable retrieval of information according to public lighting timetable for each location; 2. Collecting and processing data retrieved from ICT devices; 3. Detection and location of faults in public light luminaires.
Assumptions	
Pre-conditions	

Table 28. Fault prevention use case

Use Case #24	**Fault prevention (LV)**
Description	The EMS calculates the loads for each distribution grid asset and determines the probability of fault occurrence. Fault prevention contemplates the retrieval of technical data from the distribution grid and the risk calculation based on assets characteristics. As final result, the EMS is expected to report assets which may cause energy faults.
Actors	• Distribution System Operator
Flow	1. Retrieval and calculation of energy load per asset; 2. Determination of probability failure (alert if higher than a specific threshold);
Assumptions	
Pre-conditions	

5 Energy forecast and simulation use cases

To be able to properly balance the energy consumption, some information on the demand and production must be known beforehand. Since this information is not available beforehand, the demand and production must be predicted using algorithms. The Building Energy Management system uses these predictions as input. The algorithms that are executed on the Building Energy Management system together with the predictions are simulated to evaluate energy storage, electrical vehicle and distributed generation use cases.

5.1 Demand prediction

The algorithms to be developed predict the energy demand of a household for one day ahead in time. This demand can be predicted on many levels of granularity. When possible a low level of granularity is used, and the demands of individual devices are predicted. Technically, this is not always possible, and then the total demand of the household is predicted.

To be able to make good predictions, measurement data or typical behaviour patterns are required.

Table 29. Demand prediction use case

Use Case #25	**Demand prediction**
Description	The prediction of demand is required as input for the demand side management algorithms that are used by the Building Energy Management system. These predictions are made both on device level when possible and for the entire household otherwise. For both cases, the predictions are made for one day ahead in the future. A planning is based on this prediction.
Actors	• The **customer** • Building Energy Management system provider (**ICT provider**)
Flow	1. The energy demand of the consumer is predicted for the next day. 2. The Building Energy Management system uses this prediction to make a planning for the next day.
Assumptions	Training data in the form of past energy demand is available. For algorithm design, data sets or behaviour patterns of many households are available.
Pre-conditions	

5.2 Renewables prediction

Predictions of the energy production from renewable energy sources (e.g., PV and wind energy) are required to make good demand-side management and energy storage decisions. To develop and verify prediction algorithms, measurements of PV and wind energy production is required.

Table 30. Prediction of renewable energy generation

Use Case #26	**Prediction of renewable energy generation**
Description	The generation of renewable energy is predicted for the next day. For this, the weather forecast is used as input.
Actors	• The **weather forecast agency**

	• The **customer** • Building Energy Management system provider (**ICT provider**)
Flow	1. The prediction strategy is determined using historical weather data, together with renewable energy generation data. 2. At each day, weather forecasts are used as input to predict the renewable energy generation for the next day. 3. The Building Energy Management system uses the predictions to make a planning for the next day.
Assumptions	Weather forecasts are available.
Pre-conditions	

5.3 Energy storage penetration simulations

Electrical energy can be stored using, for example, batteries. The placement of these batteries influences many quality parameters (e.g., power quality, peaks, etc.). The distribution of the batteries may influence how easy it is to control these parameters, costs, etc. At one hand, distributed storage is used (batteries are placed within houses), while at the other hand distributed energy storage is used (as in the Bronsbergen test site).

In e-balance, we evaluate the impact of the location and amount of batteries to using simulations. For these simulations, demand predictions and renewable predictions are used as input of the to be developed optimization and real-time control algorithms.

Table 31. Energy storage penetration simulations use case

Use Case #27	Energy storage penetration simulations
Description	The impact of the location and amount of energy storage is simulated. Both distributed and centralized energy storage are evaluated.
Actors	• User of the simulation software.
Flow	A neighbourhood of houses is simulated for different energy storage penetration scenarios. The computer simulation takes the following steps for each scenario: 1. For each day, a prediction of demand and renewable energy generation is available. 2. Based on this information, a planning is made. 3. Houses try to follow this planning and use real-time control when the predictions are incorrect. 4. Multiple days are simulated, and information on effectiveness of each scenario (e.g., peaks) are collected and presented to the user.
Assumptions	• Behaviour patterns or measurements for demand are available. • Weather forecasts are available.
Pre-conditions	• Demand prediction use case

	• Prediction of renewable energy generation use case

5.4 E-vehicle and D.G. penetration simulations

While with distributed generated renewable energy (e.g., PV and wind energy) consumption of fossil energy sources are avoided, they introduce new problems. Germany faced several black-outs the last few years because more energy was produced using PV and wind energy that could be consumed. This is due to the fact that the current German network is designed with flexibility at the production side in mind, while the current situation requires flexibility at the consumption side. This flexibility can be introduced using demand-side management. For demand-side management, the available flexibility in (for example) a household is used to schedule energy consumption at the times when energy is cheap, for example when there is a lot of production. One particular appliance that allows for a lot of flexibility is an electric car charger. The user configures when the car should be charged, such that the system can charge the car at times when the energy is cheap.

Table 32. Electrical vehicle and distributed generation penetration simulations use case

Use Case #28	Electrical vehicle and distributed generation penetration simulations
Description	The impact of the location and amount of distributed generation, together with the number of electrical vehicles is simulated.
Actors	• User of the simulation software.
Flow	A neighbourhood of houses is simulated for different electrical vehicle and distributed generation penetration scenarios. The computer simulation takes the following steps for each scenario: 1. For each day, a prediction of demand and renewable energy generation is available. 2. Based on this information, a planning is made. 3. Houses try to follow this planning and use real-time control when the predictions are incorrect. 4. Multiple days are simulated, and information on effectiveness of each scenario (e.g., peaks) are collected and presented to the user.
Assumptions	• Behaviour patterns or measurements for demand are available. • Weather forecasts are available.
Pre-conditions	• Demand prediction use case • Prediction of renewable energy generation use case

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