

# RESULTS & FINDINGS

FROM THE SMART GRIDS MODEL REGION SALZBURG

MAY 2013

Connecting **ENERGY** intelligently.  
We're working on it!

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**SMARTGRIDS**  
*Model Region Salzburg*

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## Preface

Salzburg is one of the pioneers in Europe in developing intelligent energy networks. This is why it was chosen by the Austrian Climate and Energy Fund to be the first Smart Grids Model Region in Austria.

The Smart Grids Model Region Salzburg (SGMS) comprises a total of 23 projects, of which a majority received funding from the Federal Ministry for Transport, Innovation and Technology as well as the Climate and Energy Fund. Without this financial support and the great cooperation with the Ministry, this Model Region would have never been possible.

Applying the philosophy that “the whole is more than the sum of its parts”, the SGMS consortium has pursued the goal of connecting projects to create synergies: The different smart grid applications will be combined into an integrated system. Based on a diverse body of research, the concepts that have been developed will be bundled together in flagship projects to be implemented in communities so that they are concrete, demonstrable and evaluable. In addition to demonstrating technological solutions to real problems, the acceptance and user-friendliness of the system for customers plays a central role.

This report aims to answer the following questions across the different projects from the perspective of the Model Region Salzburg:

- Which overriding lessons learnt or key conclusions can be derived from the experiences with the Model Region so far?
- Are there still open questions?
- Which barriers towards implementation did the project reveal?
- Which demands do the smart grid applications used here make on the institutional framework?<sup>1</sup>
- What are the perspectives for further development?

This report also aims to offer a comprehensive picture of the conclusions from SGMS across the different projects. The detailed results of the different projects are not contained within this report and will instead be offered in individual final reports. Upon completion, all final reports will be made available at [www.smartgridssalzburg.at/downloads](http://www.smartgridssalzburg.at/downloads).

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<sup>1</sup> This question aims to show the adjustments that need to be made without having to anticipate a certain solution based on a one-sided position. The adjustments in the institutional framework need to take different groups of interest into account. Therefore an individual position paper is planned that will present a concrete plan for action based on the results of the projects and the findings listed in this report.

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## Executive Summary

Smart grids play an important role in making a successful transition to sustainable energy. The Smart Grids Model Region Salzburg (SGMS) shows how intelligent electricity networks can look in practice through comprehensive research activities and demonstrations. In applying the philosophy that “the whole is more than the sum of its parts”, SGMS has endeavoured to combine the findings of the numerous individual projects into a systematic whole: Smart Infrastructure Salzburg. This report describes how it arrived at this point. To provide a structured overview, the results of the project have been divided up into five areas of application.

### *Smart grid areas of application*

Integrating renewable energy sources into the distribution network requires intelligent network control solutions that involve producers and consumers to use the existing infrastructure more efficiently and to increase the hosting capacity of the network to handle energy flow from decentralised renewable sources. For this purpose, an internationally premiered prototype was developed for medium voltage networks, out of which a product that is suitable for general use can be created. The prototype has shown that an increase in generating capacity in the critical section of the network in the Demo Region by approximately 20 % is realistic. A functional solution for voltage control in low voltage networks was also developed and implemented in the Model Community of Köstendorf. Due to the numerous stakeholders and applications that must be taken into consideration at this level, it is extremely important to develop rules for how they will interact.

Smart Infrastructure Salzburg also includes intelligent system integration for electromobility. In this area of application, the effects of a high concentration of electric vehicles on the power grid were examined and a concept for interaction between the power system and its users was developed. Since widespread congestion on the low voltage distribution grid is to be expected when market penetration reaches 25 % to 40 % depending on the charging strategy, the development and implementation of adaptive charging is recommended. Until this concept can be put into place, three-phase charging with low charging capacities can prevent grid overloads. Vehicle-to-grid delivery of electricity is not economically feasible due to current market conditions since present costs are around twice as high as the economic benefits.

The third area of applications concerns the intelligent integration of residential customers into the power grid. In a field test, various energy feedback methods produced average electricity savings of 6.7 %, which because of the level of variance is of uncertain statistical significance and cannot be directly attributed to a particular feedback method. On the whole, feedback on electricity consumption is a valuable source of information for residential customers despite them losing interest. Generating an added value by integrating other services would offer a potential improvement. The same can be said for recommendations for shifting time of consumption in order to decrease electricity costs (a further value-added feature). A decentralised solution for real-time feedback is recommended due to its lower costs. Data would be transferred from the smart meter to a gateway or a local computer and then visualised.

In contrast to a conscious change in behaviour among residential customers, systems that condition buildings can be automated and therefore manage loads without being noticed by the user. This approach particularly uses thermal inertia combined with thermoelectric coupling in buildings, and takes into account existing technologies but also examines and develops new solutions. The former comprises systems that can be managed using ripple controls. Its load shifting potential has been shown to be approximately 10 % of peak load in a select test area with a high penetration of electric space heaters. Due to its limited applicability and its neglect of processes within buildings, it can be seen as a transitional technology.

The second, more forward-looking approach is based on expanding building automation systems, for example, by incorporating the current condition of the network into the optimisation process. A newly developed Building Energy Agent bundles all the shiftable loads in the building, in particular those of heating and cooling units, and communicates with the electricity system. If buildings are well insulated, electricity use from the heating system can be shifted by up to twelve hours without resulting in a loss of comfort.

Other load shifting potentials are examined in a fifth area of application: load management in commercial and industrial enterprises. In a single industrial production company, more than four megawatts in capacity could be shifted with comparably little effort. A storage system is required in the production process in order to be able to continue production despite the shutdown of machines. Currently, commercial customers create a financial advantage primarily by optimising the purchase of electricity on the market.

### ***Cross-application findings***

There are three types of synergies stemming from an integrated view of the areas of application which facilitate the economic expansion of the requisite information and communication technology (ICT) infrastructure: synergies in the area of communication and IT infrastructure as well as in the cooperative use of hardware. In order to use these (especially the first point), the smart grid applications should be embedded in a reference architecture that will form the basis for devising and applying standards. For the applications that were observed here, there was a potential saving of over 30 % when the ICT infrastructure was optimised in comparison to the worst case.

In order to benefit from the synergies between the applications, it will be necessary to bundle the specifications of the individual technologies rather than viewing them separately. This will enable the creation of an efficient, generic and easy-to-extend basic infrastructure. New challenges are, for example, the integration of residential customers, the processing of dramatically increasing data volumes and user-specific security. For all applications including smart metering, the transport protocol IP should be used as a convergence layer.

Within the smart-grid context, smart metering can be used to provide timely consumption data and billing in shorter intervals but also timely billing of incentive rates as well as measurements for grid operation. Currently, these measurements are barely covered by offerings from manufactures. Besides the statutory minimum requirements should be specified further in this context. Uncoordinated implementation with a too narrow focus would not allow for all functions to be utilised and would therefore jeopardise the opportunity to use the system as a building block to create an intelligent power system.

In order to ensure the trust and acceptance of both the consumer and the producer in ICT-based applications, it is essential to provide for security and privacy on a consistent basis. A holistic view comprises the three pillars of technological security, data protection and trust. For each of these fields, recommendations for action for current and future projects will be devised and implemented.

In addition to considering the technological aspects, there is also the question involving the relationship between the cost and benefit of an application and how this can be adequately evaluated. For example, different applications lead to a more efficient use of existing infrastructure and this, in turn, to deferred investments in the power grid. This benefit is however difficult to quantify. Using a cost rollup process, however, ranges for evaluating load peaks that have been successfully avoided on different network levels of the grid can be calculated. In the medium voltage network, there will be, for example, a benefit in the range of € 22-104 per kilowatt of successfully reduced demand.

Based on the areas of application and the findings across the applications, open questions concerning further development of technologies, cost effectiveness, risk minimisation and development of a market model will be analysed.

In addition to these open questions, a majority of which can be answered as part of further projects within the consortium or in cooperation with other companies and institutions, it will also be necessary to modify the institutional framework. In order to offer a differentiated overview, five key areas have been identified: politics, legislation, governmental agencies, market model and acceptance. The barriers that were identified in SGMS have been classified according to these areas. The findings show, for example, that regulatory incentives to invest in intelligent technologies are necessary.

In bringing together all the applications within an integrated smart grid system, it will be helpful to use a reference architecture. The Smart Grid Architecture Model from the M/490 Mandate will serve as a model. This will provide answers as to how the different electricity market and grid interests can be taken into account and aligned when flexibilities are used.

### **Conclusion and outlook**

On the whole, numerous valuable findings were made as a part of SGMS. The cooperation within the consortium made it possible to integrate different perspectives and competences. The flagship projects that were realised across the applications prove that the findings from SGMS conform to the motto that “the whole is more than the sum of its parts”. Building on the evaluation of the findings, the next steps will lie in developing feasible solutions for widespread use and in integration the individual applications in a reference architecture. This could also help manage the amount and complexity of the data. Furthermore, the advantages of smart meters must be established, providing a foundation on which high-level privacy and security standards can be used to ensure the trust of consumers and concepts to shore up and expand expertise can be developed.

In the further developments that will lead to the creation of Smart Infrastructure Salzburg, the international exchange of knowledge with other decision-makers, stakeholders and institutions will play a decisive role. The productive cooperation between SGMS and other national and international smart grid initiatives provides a useful starting point.

# 1 Connecting energy intelligently: We're working on it!

## 1.1 Why are we focussing on smart grids?

Since the 1980s, topics such as sustainability, climate change and the limited availability of resources have played an increasingly important role in politics and society.<sup>2</sup> The EU in particular set ambitious energy and climate targets (see Figure 1). These targets extend from the well-known 20-20-20 targets<sup>3</sup> to the goal of reducing carbon emissions by at least 80 % of 1990 levels by the year 2050.<sup>4</sup>

Although reaching these targets requires changes in all economic sectors, it assumes a pivotal role in bringing about the necessary increase in energy efficiency and the integration of renewable energies in redesigning the entire energy system.

The transition to renewable energy that will be taking place in the coming years will mean the realisation of a sustainable system of energy generation and includes much more than simply substituting fossil fuels for renewable energies. The massive expansion of renewable energy sources like solar, biomass, wind and hydropower is leading to a decentralisation of energy generation – lots of small scale generation units feeding power into the grid from geographically disparate locations. The task of balancing the supply and demand of power is made much more complex by weather-related fluctuations in the supply of renewable energies. Furthermore, increased requirements for energy efficiency as well as consumer-generated electricity and changing electricity demands on the part of consumers require improved monitoring of consumption and the use of energy-efficient alternative technologies such as electromobility.

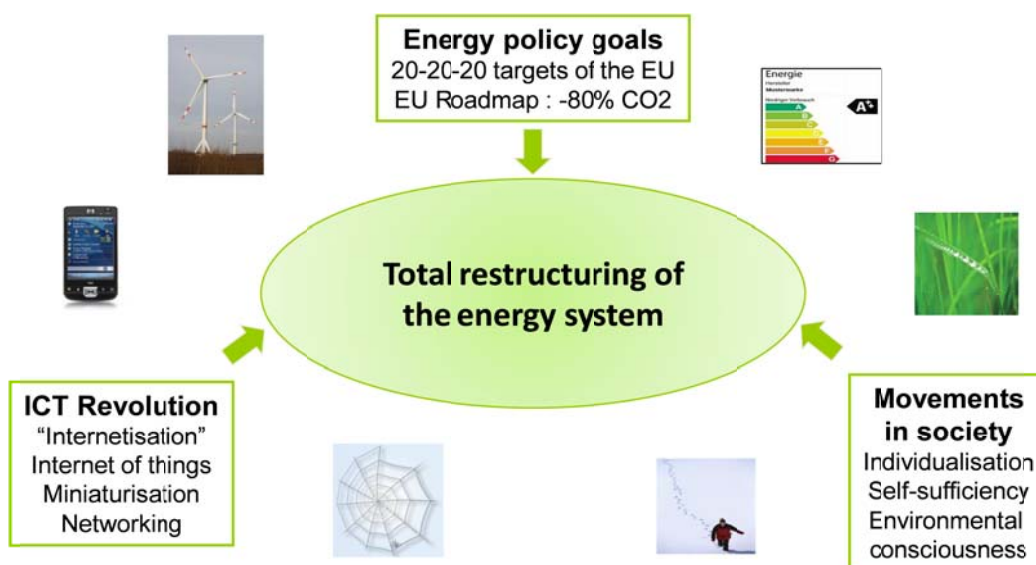
These developments are strengthened by changes within society such as an increased environmental consciousness, individualisation and the desire for a larger degree of energy independence (see Figure 1). More and more commercial and residential consumers are operating their own generation unit, thereby turning them from consumers to producers or “prosumers”.

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<sup>2</sup> Cf. Volker Hauff (Ed.) (1987): "Unsere gemeinsame Zukunft. Der Brundtland-Bericht der Weltkommission für Umwelt und Entwicklung." Eggenkamp Verlag. This report (in German) offers the first definition of the concept of sustainable development.

<sup>3</sup> The EU climate and energy package, passed by the European Council in March 2007, aims to meet the following goals by 2020: a 20 % reduction in greenhouse gas emissions from 1990 levels, a 20% improvement in the EU's energy efficiency, (compared to business as usual), raising the share of EU energy consumption produced from renewable resources to 20%.

<sup>4</sup> cf. European Commission (2012): EU Energy Roadmap 2050. Publications Office of the European Union, Luxembourg.



**Figure 1: Driving forces behind a paradigm change in the energy sector**

In addition, there are new opportunities made possible by the ever-increasing digitalisation and development of information and communication technology (ICT). In the last twenty years we've seen a revolution in interpersonal communication through the "Internetisation" of society. The next step in this development over the coming years will see the expansion of the internet to other things<sup>5</sup> (see Figure 1). Parts and components of electronic devices, cars, etc. will be connected to the internet, allowing them to communicate with each other and to be communicated with directly. If this concept is applied to the energy system, we can speak of the energy internet. This technology will experience a breakthrough when revolutionary services for producer and consumer can be offered using these technological means to increase our level of comfort while functioning almost exclusively automatically.

All these new challenges and opportunities affect not only the power grid but also other energy infrastructures such as the district heating and natural gas networks and will therefore require a paradigm change in the energy sector.

Using ICT and the flexible components of smart energy networks, smart grids can play a key role in overcoming these challenges.<sup>6</sup> They provide for the (cost-)efficient integration of renewable energies, contribute an increase in energy efficiency and help to fulfil new consumer demands.

The future will focus on connecting energy intelligently!

<sup>5</sup> This expansion of the internet will combine physical objects with one another. In the technology sector, this is also called machine-to-machine communication (M2M).

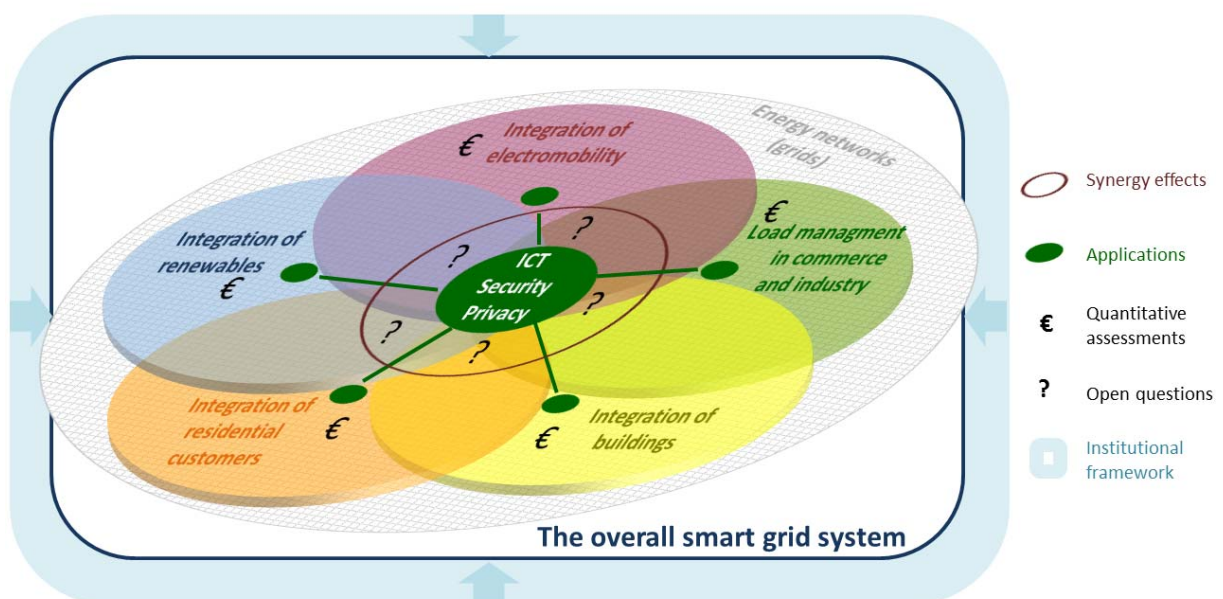
<sup>6</sup> This does not, however, mean that a future expansion of the grid to cover the growing need for energy and to integrate renewables can be avoided altogether. The goal is to utilise the infrastructure in the most economical manner possible.

## 1.2 Smart Grids Model Region Salzburg

Salzburg is one of the pioneers in Europe in developing smart energy networks. This is why it was chosen by the Austrian Climate and Energy Fund to be the first Smart Grids Model Region in Austria.

Smart Grids Model Region Salzburg is supported by an interdisciplinary team from the energy sector (Salzburg AG, Salzburg Netz GmbH), a property developer (Salzburg Wohnbau), a technology vendor (Siemens), consulting services (Fichtner) and renowned research institutions (Austrian Institute of Technology, Vienna University of Technology, CURE). The goal is to create an holistic smart grid system called Smart Infrastructure Salzburg.

Smart Infrastructure Salzburg is an intelligent energy system that creates a regionally differentiated balance between production and consumption, leading to the use of a high percentage of volatile renewable energies while preventing network congestion. Making this possible requires intelligent voltage control, as well as a more flexible and energy-efficient consumption structure on the part of companies, buildings, electric vehicles and residential customers. Only as a last resort is the active power of renewable energy generators limited. In implementing these applications, synergies are used across the whole of the network to reduce costs. The coupling of different energy networks creates more opportunities to balance generation and consumption.



**Figure 2: One vision of a smart grid system**

The five areas of application that are part of SGMS are colour coded in Figure 2.<sup>7</sup> They represent the starting points from different directions. At their intersections synergies are creat-

<sup>7</sup> No claim can be made to completeness. The areas of application that are a part of SGMS are listed here. In the context of smart grids there are also other areas of application, such as the integration of storage units., etc.

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ed, allowing for example different applications in the area of ICT infrastructure to have multiple uses. Along with other overarching topics such as the role of smart metering and the open questions that result, these synergies help make Smart Infrastructure Salzburg a reality. The ensemble is determined to a large extent by the institutional framework in which it is embedded.

The areas of application and overarching topics specified in Figure 2 constitute the basis for the outline of this report. The colours that are used correspond with those in Figure 3 and Table 1.

To allow for a better understanding of the material, the five areas of application and their contribution to the system as a whole are described briefly:

### **The integration of renewable energies in distribution networks**

The development of renewable energies is leading to a high share of decentralised and fluctuating generators who are predominantly feeding into the distribution network. This brings about enormous challenges for the infrastructure, which was originally designed mainly to deliver electricity to consumers. The goal of applications in this area is to increase the hosting capacity of the grid through intelligent planning, management, monitoring and voltage control approaches in order to take full advantage of the existing distribution network.

### **The integration of electromobility**

The increasing availability of electromobility creates great potential for increasing energy efficiency and decreasing CO<sub>2</sub> emissions in the transport sector. For the electric power system, electric vehicles are on the one hand flexible consumers that could potentially also be used as storage capacity. On the other hand, the simultaneous charging of numerous electric vehicles – as they respond, for example, to pricing signals from the wholesale market – can lead to localised congestions in the electricity network. In this area of application, solutions are needed that ensure the intelligent integration of electromobility into the electric power system and at the same time meet market requirements and use the existing network infrastructure efficiently. The focus, here, is on charging and ICT infrastructure, user interfaces and the development of business models.

### **The integration of residential customers**

The first and highest-order goal in integrating residential customers into the energy system is to maximise energy efficient behaviour and therefore the conservation of energy. Intelligent technologies offer residential customers the opportunity to play a more active role – in particular in the electric power system – and to contribute to its optimisation. Applications in this area extend from feedback on electricity use to the automated cycling on and off of household appliances, for example, with the goal of better synchronising demand with a supply of renewable or avoiding load peaks in the electricity grid.

### **The integration of buildings**

Buildings are responsible for approximately 40 % of energy demand and CO<sub>2</sub> emissions worldwide. The integration of buildings in the smart grids of the future is therefore a decisive factor contributing to the goal of creating a comfortable, intelligent, conservation-

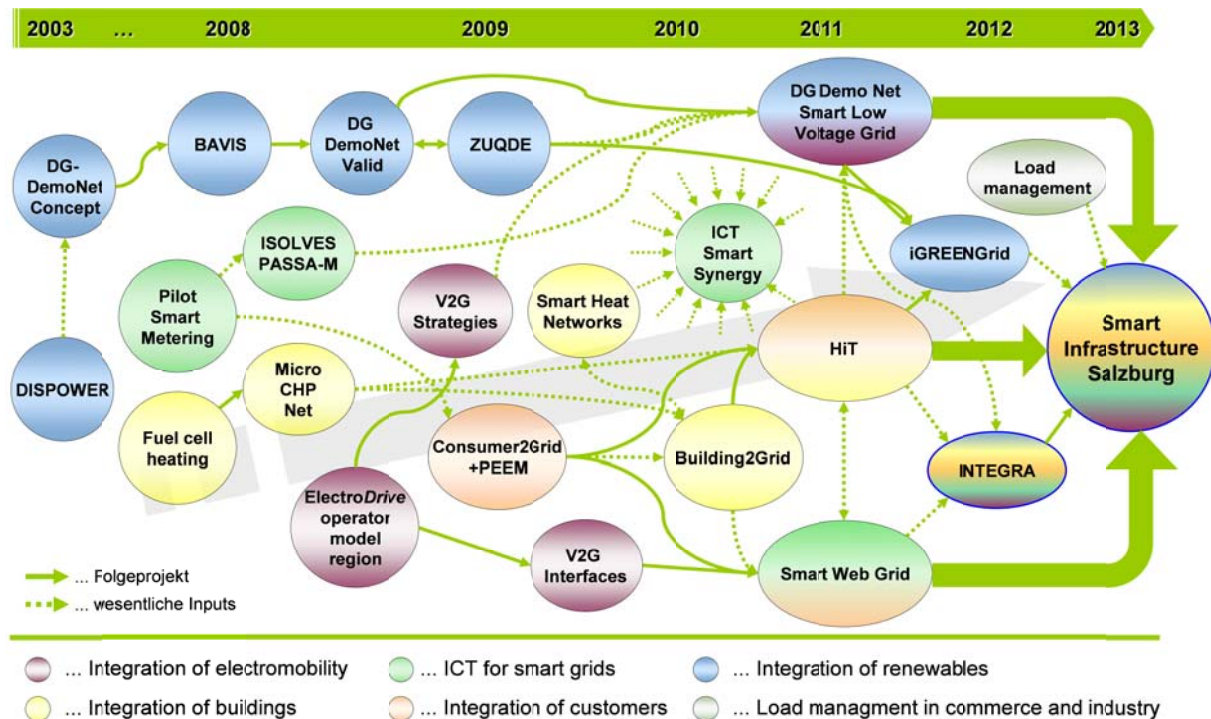
oriented and integrated smart infrastructure. The buildings of the future will play a combined role as consumers with intelligent storage systems and will increasingly produce energy themselves.

This can be facilitated through the use of thermal inertia, which makes it possible to shift energy use off peak periods without causing a loss of comfort. When energy use is shifted, we speak of flexible load management or demand response and demand-side management. In buildings, load-shifting potential can be accessed and put to use with the help of building automation systems.

### Load management in commercial and industrial enterprises

In addition to research in the area of residential customers and buildings, this area of application examines the load shifting potential of commercial and industrial enterprises.

The individual SGMS projects will be classified according to the five areas of application. In order to provide an overview, the following section will offer insight into these areas. The “big picture” shown in Figure 3 comprises all 23 individual projects. The relation of the projects to one another is illustrated through the use of arrows.



**Figure 3: The “big picture” of SGMS projects**

SGMS was launched with a project bundle that was submitted as part of an application for a grant from the research funding programme New Energies 2020. This built on several pre-

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ceding projects and was complemented by other projects responding to later calls for submissions.<sup>8</sup>

Building on a comprehensive body of research, the collected findings from several pilot projects, such as the Model Region Lungau (ZUQDE and DG Demo Net Validation Project), a block of flats on Rosa-Hoffmann-Straße (HiT Project) and the Smart Grids Model Community of Köstendorf (DG Demo Net Smart Low Voltage Grid) were combined and implemented in the real world in order to make them concrete, demonstrable and evaluable. In addition to demonstrating technological solutions to real problems, the acceptance and user-friendliness of the system for customers plays a central role.

**Fehler! Verweisquelle konnte nicht gefunden werden.** provides an overview of the individual projects, their central questions and their classification in the areas of application. A brief summary of the (preliminary) results and key conclusions from the individual projects can be found in the appendix.

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<sup>8</sup> Later calls for submissions were part of the New Energies 2020 programme as well as the first submission call.

**Table 1: Overview of the projects (colours correspond to Figure 2 and Figure 3; projects that have two or more areas of application are shown in white in this table)**

Project name	Central question
<b>DISPOWER*</b>	What are the fundamental effects of a high share of distributed generators on electricity distribution networks?
<b>DG Demo Net Concept*</b>	How can innovative active network control concepts be modelled and designed in a holistic manner?
<b>BAVIS*</b>	In concrete terms, what can the contribution to active distribution system operation through innovative voltage regulation look like?
<b>ISOLVES*</b>	Based on smart metering systems, how can a monitoring and analysis method of low voltage networks be built and the resulting control actions be derived?
<b>Smart metering pilot*</b>	<p>What needs to be done at Salzburg AG in order to prepare technically for the implementation of comprehensive, cross-discipline smart-metering systems (for electricity, gas, water, district heating) in Salzburg?</p> <p>Laboratory evaluation and field test with approx. 500 meters.</p>
<b>Fuel cell heating</b>	<p>How might an operating system for fuel-cell heaters be designed so that is able to generate decentralised electricity for use in in the central-heating systems of buildings?</p> <p>Field test in a block of flats.</p>
<b>Micro CHP Net</b>	<p>What are the implications of the implementation of a virtual power plant consisting of four small combined heat &amp; power (CHP) units that can be operated (heat-, power- and network-driven) by a control centre?</p> <p>Technical and economic analysis.</p>

<b>ElectroDrive Model Region*</b>	<p>Salzburg AG has been offering electric mobility since early 2009, titled "ElectroDrive Salzburg". In December 2009, Salzburg was awarded by the Climate and Energy Fund (KLIEN) as Model Region for Electromobility in Austria. ElectroDrive Salzburg GmbH, a 100% subsidiary of Salzburg AG, was founded in early 2010. The company distributes charging infrastructure for electric car owners in close cooperation with the automobile trade. In addition, public charging stations in the province of Salzburg are being constructed.</p> <p>As of January 2013 approx. 170 electric cars are on the road in Salzburg within the framework of the model region. They form an important basis for the analyses of SGMS.</p>
<b>Building to Grid (B2G)</b>	<p>How can load peaks be reduced, energy delivery optimised and energy efficiency improved by intelligently incorporating buildings into the electricity network?</p> <p>Field test with 10 actual buildings.</p>
<b>Consumer to Grid (C2G)</b>	<p>Is it possible to motivate residential customers to reduce their electricity consumption sustainably by providing feedback based on smart metering?</p> <p>Field test with 288 households.</p>
<b>PEEM – Persuasive End-User Energy Management</b>	<p>Which new strategies and tools can motivate residential customers to shift power consumption in the electrical energy system to more favourable times without sacrificing any comfort?</p> <p>Field test with 24 households</p>
<b>Smart Heat Net</b>	<p>Which intelligent operating and control strategies can be used to reduce peak loads in district heating networks and thus minimise the use of oil- or gas-fired peak load boilers?</p>
<b>SmartSynergy</b>	<p>What ICT infrastructure is necessary to optimally fulfil the requirements of diverse smart-grid and electromobility applications and how can this be used to create synergies?</p>
<b>Vehicle to Grid (V2G) – Interfaces</b>	<p>Which business models and interfaces need to be developed in order to intelligently integrate electric vehicles into the electricity system?</p>

<b>Vehicle to Grid (V2G) – Strategies**</b>	Which technical, economic and environmental consequences can be expected for the Austrian energy system from the extensive market penetration of electric vehicles?
<b>ZUQDE</b>	<p>How might the implementation of an automated, central-control-based voltage and reactive power control of transformers and small hydropower plants look? The goal is to increase the capacity of the distribution network to handle energy flow from decentralised renewable generation.</p> <p>Piloted in a medium voltage network in the Lungau region of the Salzburg province.</p>
<b>DG Demo Net Validation**</b>	<p>How can the active operation of the distribution network using innovative voltage control concepts in a medium voltage network be validated?</p> <p>Implementation of a coordinated regional voltage and reactive power control of transformers and small hydropower plants with the goal of significantly increasing the capacity of the distribution network to handle energy flow from decentralised renewable generation.</p> <p>Piloted in the same medium voltage network as ZUQDE.</p> <p>Evaluation and comparison using the ZUQDE approach.</p>
<b>Load management in commercial and industrial enterprises</b>	<p>How high is the load shifting potential in 30 small and medium enterprises and one industrial production facility in Salzburg?</p> <p>Identification, qualification, quantification of potential and the possible measures to be taken to activate and use this potential.</p>
<b>HiT project – Buildings as interactive smart grid participants</b>	<p>How can various smart grid applications in the context of buildings be grouped together in an innovative housing community?</p> <p>Optimised planning, construction and operation of the Rosa Zukunft (engl. “rosy future”) block of flats in Rosa-Hoffmann-Straße, Salzburg Taxham.</p>
<b>Smart Web Grid</b>	How can data exchange between the different smart-grid participants be designed so that it is universal, interoperable, and effective, creating a boon for users such as residential customers through services that link different data sets together?

<b>DG Demo Net Smart Low Voltage Grid**</b>	<p>How can a high share of photovoltaic systems and electric vehicles be optimally integrated in low voltage networks using intelligent planning, real-time monitoring and active network management?</p> <p>Field testing in the Smart Grids Model Community Köstendorf.</p>
<b>iGREENGrid</b>	<p>How can guidelines and recommendations for the intelligent integration of renewable energies in electric distribution networks be developed through the comparison and evaluation of international projects?</p> <p>Funding through the EU's Framework Programme FP7.</p> <p>Project to implement the European Electricity Grid Initiative (EEGI) roadmap in the framework of the Strategic Energy Technology (SET) Plan.</p>
<b>INTEGRA</b>	<p>How can low- and medium voltage networks be operated in a stable and secure manner in the presence of numerous interrelated and interdependent smart-grid services within the European energy markets?</p>

\* Projects in which Salzburg AG and sometimes additional partners have participated or are participating and around whose results the SGMS projects are built but which are not a formal part of SGMS.

\*\* Projects which are being conducted in close cooperation with SGMS, but ones with additional partners from outside SGMS.

### 1.3 Assumptions in the Model Region projects

The Model Region research projects proceed from a set of assumptions on the basis of which the project teams conduct their work. It is essential to establish certain assumptions to be able to develop focussed and solution-oriented results. The concretisation of technological concepts and solutions for dealing with smart grids that have been made possible through these assumptions is one of the most important contributions of the Model Region.

The establishment of a development framework does not however preclude exogenous development pathways.

Some of the assumptions made in the individual projects within the Model Region are as follows:

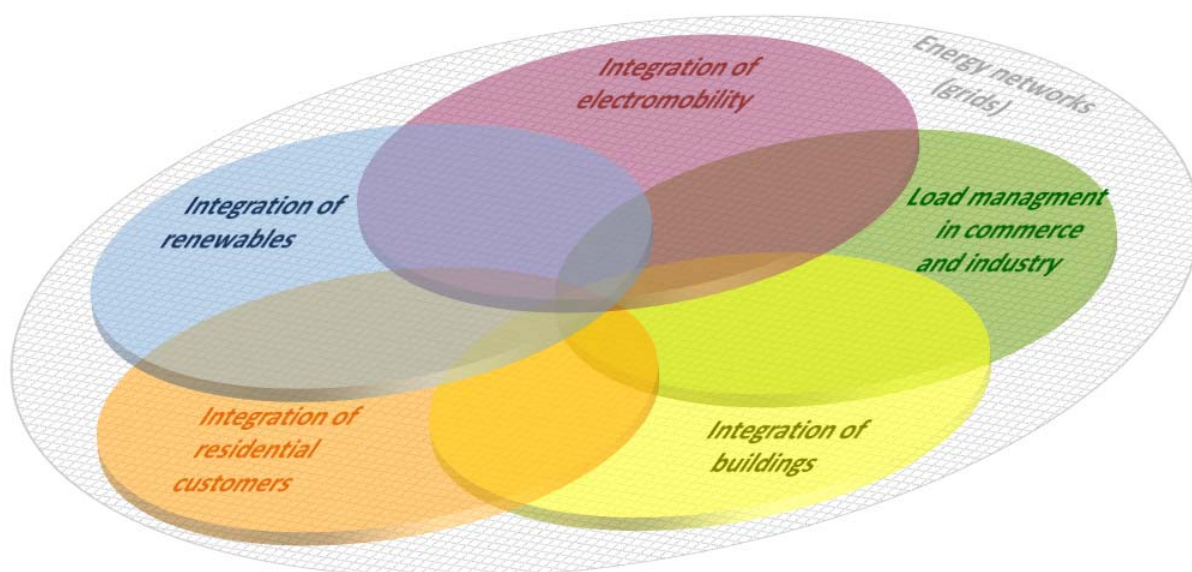
- In the next several years there will be a significant increase in the share of renewable energy sources in the electric power sector.
- A large part of this increase will comprise small units in the distribution network.
- In the foreseeable future no economically feasible small-scale storage technology will be able to store significant amounts of energy from renewable energy sources.
- For this reason, the distribution network will have to balance this increased power flow in the grid.

- As a consequence of the sharp increase in the price of oil, higher taxes on fossil fuels and tax incentives for the purchase of efficient vehicles will lead to the proliferation of plug-in hybrids and electric vehicles.
- Due to the partial reduction in the control over generation on the part of energy producers, demand response measures will be necessary over the medium term.

Based on these assumptions, it can be surmised, for example, that economically feasible small-scale storage technology would make the development of control methods in the distribution network as well as a series of demand-response approaches less necessary. Such an alternative technology is however not on the horizon. Nonetheless, the Model Region consortium points out that this report should be interpreted in light of the aforementioned assumptions.

## 2 Smart grid areas of application

The findings from the SGMS projects will be summarised in this chapter according to the five areas of application, which are shown schematically in Figure 4. It should be noted that these areas cannot be viewed independently because they show overlaps. It therefore makes sense to combine different approaches for example the integration of residential customers through energy feedback with a building automation scheme from the Integration of Buildings area of application. In designing the necessary information- and communication-technology network, it will be particularly necessary to view the areas of application as an overlapping whole in order to use existing synergies in the most efficient manner possible.



**Figure 4: Areas of application in SGMS**

One focus in the areas of application below is the need to create flexibility in consumption and in generation to be able to balance out the additional volatilities in the energy system brought about by the transition to renewable energy sources. This flexibility will make it possible to temporarily balance out the not exactly predictable electricity generation from wind and solar energy by switching on or off other generators or by flexible load management. This will enable the transmission capacity of existing lines and generating units to be used for as long as possible without reinforcing the grid.

It is therefore important that all flexibility providers be controllable and be made to conform to the requirements of the system as a whole. This must be the case for generators as well as for as many flexible loads as possible, including charging systems for electric vehicles, air-conditioning, heating and buffer-storage systems for buildings.

The speed with which the developments in the individual areas of application take place depends on both internal and external factors. A few examples include:

- Developments in the transition to renewable energy sources or the assumptions laid out in Chapter 1.3,

- The attractiveness of technology, especially in the area of residential customers, which these customers would want to pay for,
- The economic feasibility of implementing tested technologies, which might be increased by a greater willingness on the part of customers to pay for them.

The influence of these factors is however different in each area of application. These factors are therefore shown below with the corresponding findings and results.

## 2.1 The integration of renewables in distribution networks

In the electric power system the balance between generation and consumption must be exact at all times. The integration of a high concentration of fluctuating renewable energy sources such as wind and solar therefore plays an important role. In order to ensure proper integration, there are two methods currently in use: first, price signals on the wholesale market<sup>9</sup> to provide rough balancing and second, the control power at transmission system and control area level respectively is procured uniformly through control power markets<sup>10</sup>.

This kind of balancing based on market mechanisms throughout the whole marketplace or within a particular zone creates pricing incentives, promotes good frequency control and manages the operational requirements in transmission networks, but not in distribution networks. In distribution networks the problems are local. In urban distribution networks the primary need is monitoring of network asset utilisation, and in rural networks it is maintaining the permissible voltage bands<sup>11</sup> at each network node. These demands require different operation and control concepts which cannot exclusively be optimised by using just price signals. Since capacity utilisation and voltage band management are strongly driven by local network and load conditions, regional differences must be taken into account. While in one section of the network there might be enough reserves available, another section might be about to reach the allowable limit, thus a reaction to price signals may effect security of supply. In these critical areas of the network it is therefore necessary to strive for a reaction time of 30 seconds to one minute.

The DG Demo Net Validation, ZUQDE and DG Demo Net Smart Low Voltage Grid projects as well as V2G strategies offer ways to manage voltage bands and provide reactive power control in low- and medium voltage networks<sup>12</sup> in different applications. The network control based on price signals will be enhanced with regional and timely differentiated approaches for voltage band and asset utilization management. Regulating reactive power locally and

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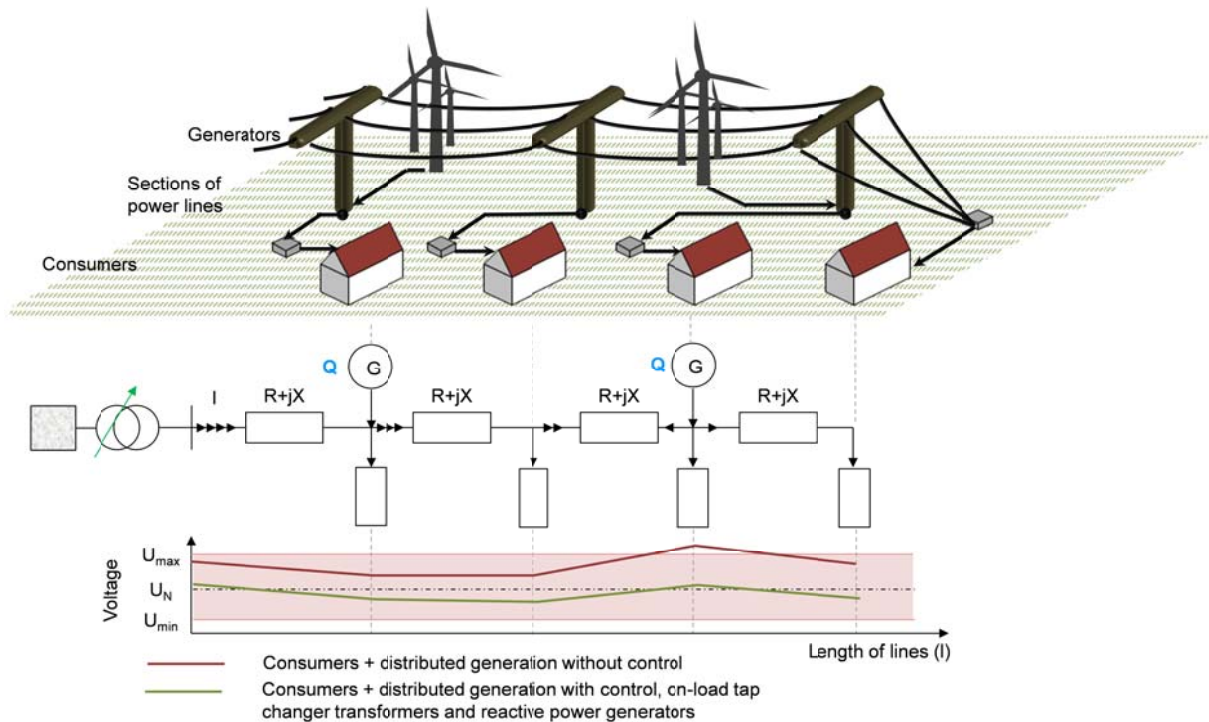
<sup>9</sup> This includes day-ahead and intraday trading.

<sup>10</sup> Among the control markets are primary, secondary and tertiary control. Further information is available at <http://www.apg.at/en/market/balancing>.

<sup>11</sup> In order for machinery and appliances that are connected to the grid to be able to operate trouble free, grid operators have to maintain particular voltage characteristics at all connection locations (according to EN 50160: Voltage characteristics of electricity supplied by public distribution systems). One example of the range of variation of the r.m.s. magnitude of the supply voltage in  $U_n \pm 10\%$ , which corresponds to a value of between 207 V and 253 V. at low voltage level.

<sup>12</sup> The ZUQDE system can be expanded and used in a high-voltage network (110 kV) as well.

using on-load tap changing transformer at individual substations significantly improves voltage band management and utilisation of the existing grid structure (see Figure 5).



**Figure 5: Improved voltage band utilisation through new network control**

### *Control of medium voltage networks*

Pilot projects up to now have produced a method<sup>13</sup> whose implementation in medium voltage networks works well on a technological, operational and economic level.

In the 30 kV grid in Lungau, the ZUQDE system showed that an additional increase in generating capacity of around 20 % in critical network sections / branches is realistic. Based on the assumption that this amount of energy can replace direct electricity generation by fossil-fuel power plants, around 24,300 MWh of thermal energy and therefore approx. 2,200,000 litres of crude oil as a primary source of energy could be replaced. Not burning this much crude oil would lower CO<sub>2</sub> emissions by approx. 5,000 tonnes per year.

The more "flexibility", which means controllable generation units as well as flexible loads or consumers available for network operation, and the more evenly distributed these are along the distribution lines in a network section, the better the voltage and reactive power in a medium voltage network can be controlled. Because of these findings, the goal should be to maximise the distributed generation in the existing electricity network and to integrate them into future control approaches.

<sup>13</sup> Further information is available in the ZUQDE project's final report at [www.smartgridssalzburg.at/downloads](http://www.smartgridssalzburg.at/downloads)

Of course, the limits of physics will determine the boundaries to integrating decentralised generators. Once the maximum transmission capacity in the grid has been reached, investments to strengthen or to replace existing units will be unavoidable.

With regard to cost effectiveness, in particular to the question of whether this solution is cheaper than expanding the grid. It must be noted that these calculations are based on individual cases on which the following factors depend:

- Investments in reinforcing the grid cannot generally be avoided, but rather only deferred.
- How long depends on the existing structure of the grid, the structure of consumers and generators and especially their development over time.

One example of the economic advantage that can result is the Turrach power plant. Without the power plant's contribution to voltage control, it would have been necessary to lay a 14-km-long cable<sup>14</sup> to the next suitable connection point. Using the new voltage control concept (ZUQDE or DG Demo Net) reduced the length of the cable to 50 m, thereby significantly reducing the cost to the power plant. In total, the power plant saved 1.67m euros against connection and adaptation costs of between 30,000 and 50,000 euros.<sup>15</sup>

This type of solution is a benefit for new generators connecting to the grid since the connection costs can be significantly reduced. The better maintenance of voltage bands and the improved security of supply, the increased share of renewable energy and the aforementioned reduction in emissions that result from this solution constitute an intangible advantage for society as a whole.

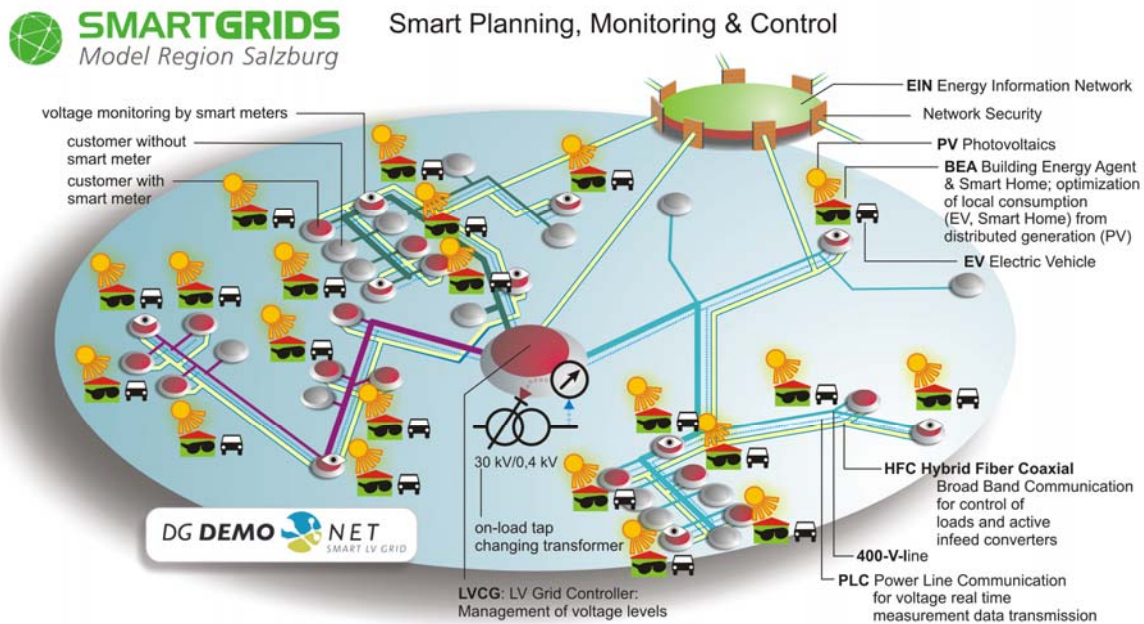
### **Control of low-voltage networks**

The control concepts for medium voltage networks described here can in principle also be used in low voltage networks, as field tested in the flagship project DG Demo Net Smart Low Voltage Grid in Köstendorf. However, this method is much more complex in low voltage networks because of the greater number of electricity producers and consumers, which are also often prosumers, and the additional technical challenges (see Figure 6).

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<sup>14</sup> This cable length already requires local voltage dependent reactive power and active power controls in power plants. Without these an even longer connecting cable would be necessary.

<sup>15</sup> This calculation is based on the 2011 price for cabling across different areas (fields, residential areas, streets, etc. and without offsets from the grid operator for implementing the ZUQDE system.



**Figure 6: Schematic illustration of the control concept in the field test in the low voltage network in Köstendorf<sup>16</sup>**

The challenge lies in answering the question of how specific or complex the control concepts need to be in order to ensure voltage band management in unbalanced 4-wire low voltage networks with strongly varying loads. Simulation based investigations have shown that the number of metering points necessary to characterise a low voltage network is extremely high in comparison to a medium voltage networks. Within only a few seconds, the voltage in the grid can change significantly. Since load conditions are complex to measure,<sup>17</sup> critical nodes or feeders are difficult to identify. They also vary from one moment to the next. This is why central or aggregate measurements such as the total current of feeders or low voltage network sections deliver almost no information about conditions in the network. But the problem of maintaining voltage also becomes more severe under unbalanced conditions. The effectiveness of the voltage control concepts implemented in the PV inverters depends on the conditions in the network. The individual control of every single unit<sup>18</sup> affords the greatest flexibility, but it is very expensive. On the one hand, it would require extremely complex planning and on the other, each individual controller would need to be configured (either on site or remotely). The alternative would be to connect with network users in bundled groups using broadcast commands. It is also always necessary to place an aggregator or flexibility opera-

<sup>16</sup> Source: Andreas Abart, Energie AG OÖ Netz GmbH.

<sup>17</sup> The ISOLVES project focuses on monitoring the condition of the grid using power snapshots taken by smart meters.

<sup>18</sup> Among the controllable units in low-voltage networks are generation units such as photovoltaic or charging stations for electric vehicles, heat pumps, electric heating systems, chillers as well as residential units with home automation.

tor<sup>19</sup> between the units and the network to check the conditions on the network and act on this basis.

With higher-level communication, the effectiveness of these regulation mechanisms can be improved. As a consequence of the challenges in the planning of electricity networks with a high number of generators with smart-grid functions, the economic evaluation of different approaches is very complex.

In general, the objective should be to use automation and the opportunities offered by the market to achieve a maximum level of energy efficiency from residential units as well as the highest load flexibility potential.

### *Aspects across different voltage levels*

On the whole, there are promising solutions both in low- and medium voltage networks. The biggest difference is in the different stages of research. In the medium voltage network, the solutions which have been tested are practicable. For the further development of prototype products and solutions, there are concrete agreements with delivery companies. In workshops with grid operators in Austria and Germany, results and solutions have been presented and discussed. There is real interest in seeing them implemented.

In low voltage networks, the first prototypes are currently being set up and will be tested until early 2014. For this reason, results are not as valid as in medium voltage networks. It can however be assumed that the solutions tested in the low voltage network will be similarly promising and will be able to be implemented as a purely network drive controller in the near future.

Due to the numerous applications for residential customers, it will be necessary to bring the control of the power grid into line with the electricity market system. The optimisation of consumption in residential units, for example, has to be connected with generation from photovoltaic units and charging strategies for electric vehicles. In addition, everything has to be harmonised with the offers on the electricity market and correspond to the vicissitudes of time and region that will occur. For this reason, it is a greater necessity that the open questions at the system level be answered in order to design products for low voltage networks (see Chapter 3.8). Only after these questions are answered can the technological solutions, the devices, the communication and the data exchange be devised in a way that the products address both the needs of residential customers and the demands of the market.

In the flagship projects, realistic assumptions were made in order to be able to put the right technology in place.

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<sup>19</sup> This term was defined by the Smart Grid Coordination Group of the M/490 standardisation mandate as follows: The flexibility operator is a general role that pools small flexibilities of customers / network users in order to make use of them in the grid or on energy markets. The concept is often referred to as aggregator, but in this case the name should underline the general role concept of "Using flexibility". According to the description of the role concept the roles of the flexibility operator might be performed by existing market roles like energy suppliers, aggregators, DSOs etc

It should also be noted for all voltage levels that the solutions were implemented in typical applications used by a rural distribution network operator in order to be able to apply the findings to other distribution networks. This will, however, not rolled out all at once but rather implemented network area for network area based on actual situations and needs. The determination whether to use intelligent network control concepts or to reinforce the grid is influenced by the following criteria and conditions:

- Do investments in existing lines have to be made anyway due to age or condition?
- How should the cost of network control concepts be allocated in the future? Although the generators reap the largest profit, especially in medium voltage networks, the operator will continue to shoulder the investment and operating costs of the new control systems, as will its consumers down the line in the form of system usage fees (network tariff). This question is important especially from an macroeconomic perspective, particularly since too high of an economic burden on generators could undermine targets for renewable energy use.
- Which power plants or consumers should be incorporated in this scheme? For new generators coming on to the grid, active medium voltage network control is an attractive alternative to high connection costs and can easily be integrated in new network connection contracts. Existing units, which may not be suited for new control capabilities, would however cost a lot to retrofit without creating a direct advantage. They could only be integrated into this scheme on a voluntary basis, through financial incentives or by being required to do so by law. An additional question is whether applying control exclusively to new power plants coming onto the grid constitutes unequal treatment<sup>20</sup> among network users.
- Does equal treatment mean that the grid operator always has to call upon a different participant or can it work with participants who are able to solve the technical problem the most effectively? Due to the electricity network and generating structure, some would be called upon more than others.

In essence, all of the different variations of market rules are possible. It is important for overall grid operation that rules are set to answer these questions so that distribution network operators can institute these operating solutions within the appropriate legal framework.

Independent of the voltage network, the question arises how to best integrate ICT to use the synergies with other smart-grid applications as well as the technical and organisational connection of the individual functions on the market.

An integrated view of the aforementioned methodologies for medium- and low voltage networks will be taken in the INTEGRA project (see Chapter 3.8).

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<sup>20</sup> The equal treatment of all grid users is enshrined in the Electricity Act [EiWOG (*Elektrizitätswirtschafts- und -organisationsgesetz*)] and provides an important legal foundation for grid operators (see for example EiWOG 2010, BGBl. I No. 110/2010, §5 and 9).

## 2.2 The integration of electromobility

In the framework of SGMS, concepts for interaction portals, visualisations and user interfaces for electromobility customers were established (V2G Interfaces project), and the technological and economic effects of grid-to-vehicle and vehicle-to-grid implementation<sup>21</sup> on the electricity network were evaluated (V2G Strategies and ElectroDrive Model Region projects). These make it possible to better assess future options for the systems-level integration of electromobility in urban and rural regions and to perform field tests (Model Community Köstendorf / DG Demo Net Smart Low Voltage Grid project).

Experiences from the project show that the intelligent integration of electric vehicles into the electricity network is strongly dependant on the individual patterns of mobility for each user, specific vehicle characteristics and the communications infrastructure that is used. V2G Interfaces came to the conclusion that the cost of interfaces, for example, for smartphones or tablet computers, make up around 2 % of the total cost, which includes the vehicle, infrastructure and electricity, from the perspective of residential customers, when these interfaces are purchased by the customers themselves. If the interface is offered by the mobility operator as part of a bonus package, this results in a significant reduction in cash value of up to 30 % of the business model “Monthly Electromobility Subscription”. For this reason, the use of existing devices is to be preferred.

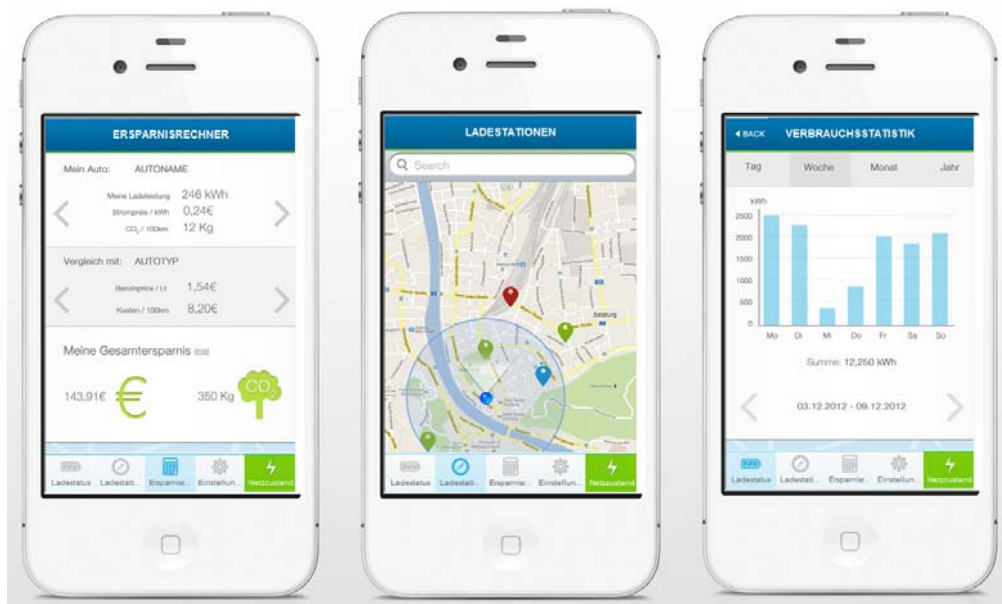


Figure 7: Example of a residential customer interface for electromobility

<sup>21</sup> Grid-to-Vehicle involves the charging of a vehicle based on the requirements of the electricity system (controlled or adaptive charging), Vehicle-to-Grid additionally involves feeding electricity from the vehicle battery back into the grid.

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The interface should be easy to use and should have the following functions:

- Charge now,
- Charge at lower tariff or eco charge,
  - Enter departure time,
  - Enter distance to travel.

An example of how an interface of the future might look was developed in the Smart Web Grid project and is in use in the Model Community Köstendorf (see Figure 7). In the future, integrating the interface in the vehicle is a possible alternative.

A further result from the Model Regions VLOTTE and *ElectroDrive* Salzburg is that charging is usually done at home and at work; because of the amount of time the car spends sitting in both of these situations, a charging station between 3.5 kW (single-phase) and a maximum of 10.5 kW (three-phase) is sufficient. Mode 2 (IEC 61851) charging using a household electrical socket is only possible to a limited degree due to a risk of overheating the socket an installation. Mode 3 (IEC 61851) charging using a charging station and a mandatory installation check is therefore recommended. This however contravenes, quite understandably, the preference of residential customers and electromobility service providers,<sup>22</sup> namely to be able to charge cheaply and quickly. An information campaign is therefore necessary to point out that slower charging at low loads meets the mobility needs of customers sufficiently, uses the infrastructure much more efficiently and keeps down charging costs.

In the V2G Strategies project, the technological and economic effects of integrating electromobility into the power grid and the electricity market were evaluated. First important result of the project was to identify, outline and define a framework for integrating electromobility into the electric power system from uncontrolled charging and controlled charging to adaptive charging.

The term “uncontrolled charging” refers to the charging of vehicle batteries immediately after reaching a defined location equipped with charging infrastructure. With this type of charging, the charging process begins immediately after the vehicle is plugged in and ends when it has a full charge or is unplugged prematurely.

The strategy of “controlled charging or discharging” is based on scheduled charging or discharging. These schedules help to fulfil individual target functions for controlled charging that is defined by the V2G Strategies project as market oriented, load oriented or generator oriented. Real-time measurements of the condition of the grid or the charging level of the vehicle, for example, cannot be used in scheduling with this strategy but they are implicitly included based on empirical data in the scheduling process and therefore facilitate a significantly more efficient integration into the system than with uncontrolled charging.

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<sup>22</sup> In this report an electromobility service provider is a business that offers electromobility as a service (in the form of car sharing, for example) so that products and services can be optimised for customers connecting their vehicle to the grid (charging stations incl. installation check, electricity purchasing, etc.).

Using real-time information,<sup>23</sup> “adaptive charging” offers the possibility to achieve the optimum level of system integration for electromobility using different target functions based on the condition of the system as a whole. The monitoring of this multi-dimensional strategy can, for example, be performed comparing predefined schedules to the condition of the grid or be fully automated using suitable control units. In general, it should be noted that adaptive charging would be based on data collected from users in conformity with the Data Protection Act of Austria. Best practices are discussed in detail in Chapter 3.4 “Security and Privacy”.

Based on this definition, the project examined the three strategies in real medium and low voltage networks and conducted economic analyses on market integration. The results of the project quantified that the effects of different charging strategies are greatest in low voltage networks, where there were congestions, necessitating further action at this level of the network.

In general, uncontrolled charging is generally more favourable for grid operation than market-oriented controlled charging since the latter means a large number of vehicles charging at once. Beginning at a density of 40 %<sup>24</sup> for electromobility, however, uncontrolled charging leads to congestions throughout a low voltage network. Projections indicate that this may be the case starting around 2030. Using suitable measures such as slower charging and symmetrical distribution of charging through three-phase chargers, the widespread use of electromobility can and should however be optimised from the start in order to make the system efficient; otherwise, a huge amount of existing reserves will be consumed. In addition, it must be noted that in parts of the network stretching over many kilometres that have a high utilisation and network nodes at the end of long feeders, network congestions could potentially be experienced earlier. Depending on the charging power that is used, this is the case in 7 % (for 3.5 kW) and 35 % (for 10.5 kW) of low voltage lines in Salzburg.

These network congestions are made more severe by quite understandable attempts on the part of electromobility service providers to offer market-oriented charging in order to optimise the purchase of electricity. Since so many vehicles are charging at once, this causes congestions to begin appearing at a concentration of 25 % and uses additional reserves from the existing infrastructure that were for future fluctuations in load and generation.

Controlled charging can reduce this consumption of reserves by 15 % for load-oriented controlled charging in a low voltage network with high utilisation, but it does not offer an optimal

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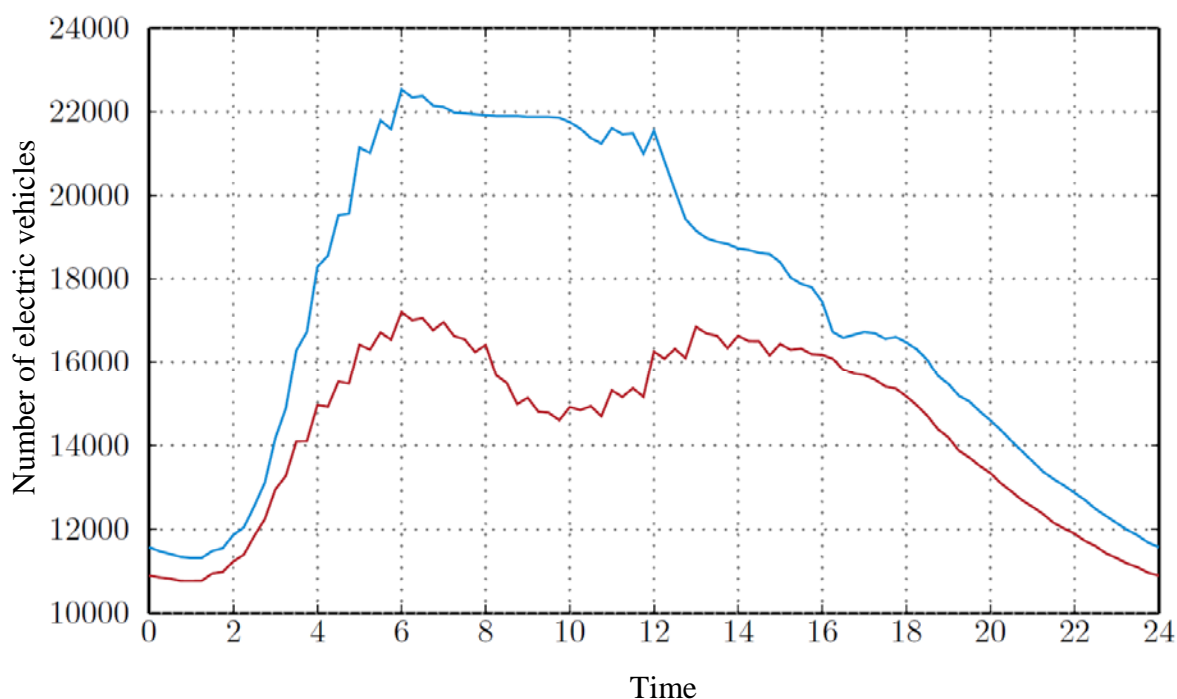
<sup>23</sup> This information could be measurements from the grid, changes in the price of electricity on the market and changes in the supply from photovoltaic units, for example.

<sup>24</sup> In the V2G Strategies project a scenario was chosen in which the widespread adoption of plug-in hybrids and electric vehicles is the consequence of a sharp increase in the oil price, higher taxes on fossil fuels and tax incentives for the purchase of efficient vehicles. Technological learning is taken into account.

The grid analysis were based on this ambitious scenario which foresees an electromobility adoption rate of approx. 40 % in 2030 and approx. 100 % including hybrids and range extender for 2050 and integrated these into the low- and medium-voltage networks.

solution for the system as a whole. Hence, controlled charging can reduce the negative effect of consuming reserves over the short term, but this problem can really only be solved through adaptive charging.

A further type of market-oriented controlled charging and discharging strategy would be allowing electric vehicles to participate in the control energy market. **Fehler! Verweisquelle konnte nicht gefunden werden.** Figure 8 shows the number of electric vehicles needed throughout the day to be able to deliver a constant level of 30 MW of tertiary control power. This would require the highest number of electric vehicles between 4 and 8 am. A maximum of 22,500 electric cars would be needed for the “charge and discharge at home” scenario and approximately 17,000 cars for the “charge and discharge at home and at work” scenario. This corresponds to between 6 and 8 % of the total number of cars in the province of Salzburg.



**Figure 8: Number of electric cars needed for 30 MW of tertiary control power over the course of 240 minutes; charging and discharging at a maximum of 3.5 kW at home (blue) or at home and at work (red)**

Accordingly, the consortium of the V2G Strategies project recommends that in order to efficiently integrate a high concentration of electric vehicles into the electric power system, the needs of residential customers, of vehicles, of the electricity market and of the grid must equally be taken into account, necessitating the development of adaptive charging. Only adaptive charging can achieve the optimum amount of system integration from a technological and economic standpoint. This requires the creation of a suitable infrastructure such as a smart grid to calculate the input parameters for an adaptive charging system that can implement the different pricing strategies on the electricity market and take the restrictions of the grid into account.

At a higher level, adaptive charging supports the key recommendations of the V2G Strategies projects, which can be subsumed as follows:

- In order to be able to use the existing grid as long and as efficiently as possible, slow charging (3.5 kW) is to be preferred. Symmetrical load distribution via three-phase charging should be adopted.
- Purely market-oriented controlled charging with a high number of cars charging at once should be avoided. Market-, load-, and generator-oriented controlled charging should therefore be conducted with fewer cars charging at once in order to be able to apply aspects of the market and to use existing network infrastructure efficiently. In order to make the system as efficient as possible, a scheme for adaptive charging should be developed at the same time. Adaptive charging should be introduced as soon as the necessary functionality in the power grid is present or, as anticipated in the V2G Strategies project, when the level of controlled charging has reached the critical point at which the energy system can no longer adequately handle the integration of electromobility.
- Vehicle-to-grid delivery of electricity is not feasible based on current market conditions and in the cases examined here, since the current costs exceed the achievable benefits by a factor of two.

Also, in the V2G Strategies project, the following open research questions were identified as key to preparations for an adaptive charging scheme:

- It must be established whether the chargeable costs for putting a system for controlled charging in place are less over the long term than the benefits achieved. While the former may contain a share of charging and control infrastructure and higher charging costs for residential customers, the benefits would include additional profit for electromobility service providers, savings in the power grid and fewer backup power plants. In this context, a macroeconomic evaluation should be performed to estimate whether optimising the system will mean more effort in installing the socket and charging infrastructure or whether the effects of unbalanced charging that have been demonstrated should be overcome by greater investment in expanding the grid. This discussion should be carried out by those responsible for developing standards and not solely based on the individual business considerations of the different stakeholders involved.
- There is a need to clarify how a flexibility operator will be constructed in order to efficiently combine the different target functions of individual stakeholders such as electromobility service providers, grid operators, balance group representatives, etc. into a systematic whole. To do this, a data model has to be developed which regulates access to the necessary input values for adaptive charging and the corresponding commands for the charging infrastructure.

The next steps to be taken to efficiently integrate electromobility as a system are therefore:

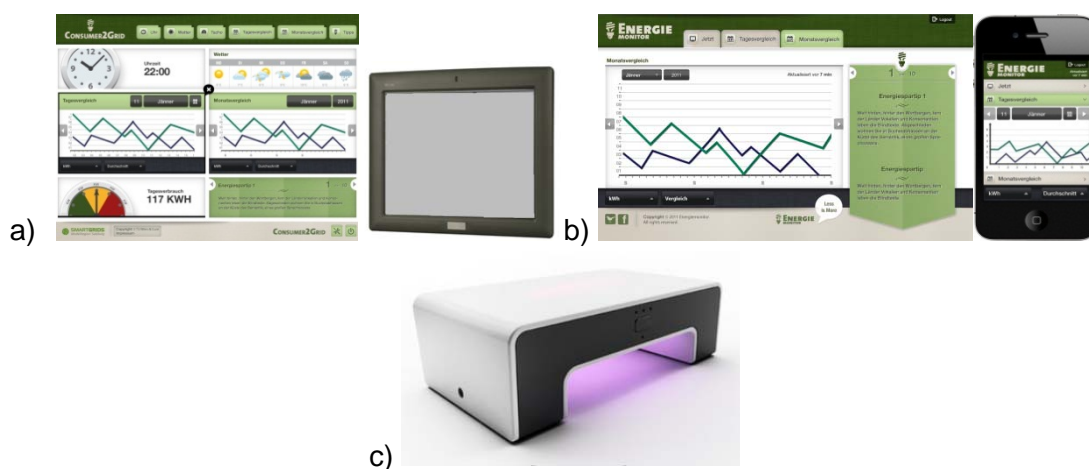
- In order to implement three-phase charging at low loads, coordinated decision-making between the stakeholders involved (grid operator, vehicle charging station manufacturers, electromobility service providers) should be carried out and the appropriate technical and organisational regulations should be agreed.
- When the benefits of adaptive charging exceeds the costs, the charging infrastructure will have to support adaptive charging. The deliberative bodies that will have to define the necessary standards (IEC 151118, for example) are to be informed.

## 2.3 The integration of residential customers

In the framework of different projects (in particular C2G, PEEM and Smart Web Grid), the role of residential customers and their integration into the electric power system was examined. These projects focused on feedback on patterns of electricity use and on recommendations for ways to shift electricity use to times that are favourable for the system as a whole. The following findings and theses were derived from the projects.

### Energy-use feedback

In the C2G project, different methods for providing feedback on electricity use were examined. Among these were the so called Wattson,<sup>25</sup> the monthly electricity bill, home displays and a web portal<sup>26</sup> (see Figure 9) and a control group with a yearly bill. In a year-long field trial, no significant differences in the reduction of electricity consumption could be discovered between the different feedback methods.



**Figure 9: Three of the five energy-use feedback methods examined a) C2G home display, b) C2G web portal, c) Wattson**

<sup>25</sup> A commercial product that delivers real-time feedback based on current-transformer measurements. Corresponding picture in figure 9 taken from: <http://inhabitat.com/2006/04/02/diy-kyotos-wattson/>.

<sup>26</sup> The home display and web portal methods were developed and implemented as part of the C2G project.

Compared with the previous year, the average reduction in electricity consumption across all groups in the trial (including the control group with a standard yearly bill) was 6.7 %, with a minimum value of 2.5 % and a maximum value of 10.9 %. Due to the high level of variance, these savings are however not sufficiently separable from each other statistically. Between the different feedback methods, there were no significant differences in electricity consumption. A comparable reference group with 68 households that did not take part in the trial and was therefore not at all influenced by any of the measures in the trial, showed a reduction in consumption during the time of the trial of 2.7 % in comparison to the previous year.<sup>27</sup>

The test subjects nonetheless frequently reported experiencing an increase in the level of awareness about the subject of household electricity use and found energy-use feedback to contain valuable information. At the beginning, test subjects question their own behaviour, which leads them to change their patterns of consumption. Even related subject areas such as sustainable mobility, which wasn't a direct target of the feedback, were reflected on by the trial participants. Over the course of time, however, the intensive concentration on the information in the feedback decreases. This is in large part due to the fact that after the introductory phase, residential customers experience very little increase in knowledge and cost savings, for example, which would increase the value of what they were doing.

In order to maintain the attention level of customers, it would seem beneficial to provide immediate real-time feedback for individual consumers. On the whole, detailed information on consumption (down to the level of household appliances) is of great significance to consumers.

In general, it can be said that electricity-use feedback was studied in detail by the test subjects at the beginning, but over the long term in a stable environment such as one's home it was only used sporadically to check individual levels. Between the different feedback methods, there were no significant differences in electricity consumption. Electricity-use feedback methods should therefore accompany users through different phases of their use. Customers are also only ready to pay for feedback if the cost does not exceed the savings.

A comparison of the effectiveness of the five feedback methods produced two clusters. The first cluster comprises state-of-the-art methods which are easy to implement, carry little information and few functions, and spring into action when triggered. In the C2G project monthly bills were used, which were extremely easy to implement. A further study could examine whether a monthly bill is necessary (similar to a monthly telephone bill) or whether monthly information on electricity consumption is sufficient.

The other cluster encompasses innovative methods which are much more difficult to implement but also have a higher level of functionality and make more information available to the consumer.

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<sup>27</sup> It should be pointed out that most of the test households were small flats in council estates with relatively few options to reduce their consumption.

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Based on the quantitative results of the C2G project, there are two different strategies for designing energy-use feedback methods:

1. Easy implementation combined with minimal implementation cost for the method that is adapted to the savings potential.
2. Use synergies derived from more innovated methods that balance out the advantages and disadvantages of the individual methods (such as constantly available home display with simple real-time feedback + monthly information on electricity consumption) and meet the newest technological standards.

It can be concluded that the constant presence of feedback methods (in the form of hardware, for example, as is the case with home displays) serves as a reminder to use the feedback, making this method advantageous. In addition to this constant availability, regular (monthly) information pushed to users is important so that the user doesn't have to request this information him/herself. This reduces any extra effort required to access electricity-use feedback from a cognitive standpoint (no need to remember) but also from a logistics standpoint (no need to turn on the computer).

Furthermore, it is important to offer residential customers additional functionality besides electricity-use feedback in order to maintain their interest over the long term. This could be in the form of prognoses or concrete recommendations for steps to take, as was the case with FORE-Watch in the PEEM project.

#### *Electricity consumption at different times*

In the PEEM project, the electricity-use feedback method FORE<sup>28</sup>-Watch (see Figure 10) was developed. In addition to simple feedback on electricity consumption, it uses colours to inform users when the "good" (green), "average" (yellow) and "bad" (red) times for the power system are to use electricity. This technology helps to provide residential customers with the support they need to change their behaviour and their attitude toward a more sustainable use of electricity.

FORE-Watch was seen by trial participants as a good means of reaching the goal of changing their electricity-use behaviour. An analysis showed only a loose connection between consumer behaviour and FORE-Watch recommendations. This is however not statistically significant.<sup>29</sup> Trial participants adjust some of their electricity consumption based on recommendations about times. The time of use especially for washing machines, dryers and dish washers were shifted. Barriers for residential customers to change their patterns of consumption, however, are convenience and old habits. In order to overcome the feeling of a loss of convenience, consumers have to experience a clear benefit or advantage.

The expected benefit stated by a majority of trial participants was a monetary one. Trial participants said they would adjust their behaviour to the clock if it enabled them to save money.

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<sup>28</sup> FORE stands for "Forecast Of Renewable Energy"

<sup>29</sup> In this context it should be pointed out that only twelve test participants per group were available and that a sample this small can hardly be expected to produce a statistically significant result.

A possible approach to achieve this adjustment in patterns of use would be to offer a pricing / tariff<sup>30</sup> models based on time of use. Still, the introduction of variable pricing according to time would probably mean little saving for residential customers.



**Figure 9: Newly developed feedback method: FORE-Watch**

Aside from the financial factor, altruistic motives also play a considerable role. For several participants, the fact that they were making a contribution to saving the environment and therefore contributing something positive to the good of society was enough of an incentive for them to adjust their consumption to the FORE-Watch recommendations. This factor is even more important to residential customers who are also producers, since FORE-Watch allows them to adjust their consumption to their generation.

The effort required of consumers should be kept as little as possible, for example by automated cycling on and off of household appliances control according to the times recommended by FORE-Watch. The user should, however, always be able to intervene in all of the relevant processes.

#### **Combination with other services**

Due to the findings from the C2G and PEEM projects, focussing solely on providing feedback on electricity use is only of marginal interest to residential customers. It seems therefore necessary to combine information and services from additional sources. It would be worthwhile to integrate feedback on heating, gas and water use, since they are often a greater source of cost to consumers than electricity.

<sup>30</sup> As far as not specified explicitly the term “tariff” refers to both energy and network tariffs.

Furthermore, it would be useful to develop new services like monitoring conditions within the home (Has everything been turned off?), alert functions (information on what to do when something goes wrong) as well as services that are independent of energy efficiency (security, ambient assisted living<sup>31</sup>).



**Figure 10: A design for a modified FORE-Watch with additional services**

Based on results from C2G and PEEM, the HiT project will use interaction technology to combine electricity-use feedback with other services. The FORE-Watch from the PEEM project is shown in modified form on the start screen of a tablet computer. Figure 10 shows how this might look. In addition to recommendations for basing electricity use on the time of day, clicking the My Home [*Meine Zuhause*] button calls up the home automation web application. This web app makes it possible for people with flats or houses which are suitably equipped to access data about the technology in the building and to change the settings. The My Energy [*Meine Energie*] button provides user access to the energy-use web portal, which shows electricity, heating and water use. With the Car Sharing button, users can reserve an electric vehicle.

This combination of approaches, solutions and demands from the smart grid with those from home automation offers numerous advantages. It allows the following aspects and needs to be covered:

- Relevant tasks such as the load balancing, optimisation of one's own energy use, etc. can be automated instead of requiring the constant attention of the user, with no loss of comfort.

<sup>31</sup> The term ambient assisted living involves innovative technologies to support the daily routines of older or disadvantaged people.

- Additional services (like alert functions) that offer further benefits to residential customers can be developed using the available data and sources.
- The integration of home automation has additional potential to offer secure solutions at the local level, therefore keeping the control over data "nearer" to the user.
- Cost synergies may also be created since the investment will be spread out over different parts of the system and are therefore easier to make.
- Automation also makes it easier for customers to make permanent changes in their households.

Whether the additional advantages of integrating home automation will lead to prolonged interest in energy-use feedback methods on the part of residential customers and therefore to improved energy efficiency is a question further research will have to answer.

### ***Privacy & acceptance***

It became apparent that consumers are wary of the collection, storage and transmission of detailed energy data (i.e. extremely exact with regard to usage times). For this reason, it is absolutely necessary that customers have the possibility to have control and to intervene in order to willingly participate in demand-response programmes, for example.

Furthermore, mechanisms to protect privacy must be taken into account in designing a smart-grid information and communication technology from the very beginning. In general, the benefit for consumers derived from providing their data must be clearly visible; otherwise, they will have difficulty accepting this technology.

### ***Centralised vs. decentralised data transfer***

C2G field trials used real-time feedback methods with decentralised data transfer (Wattson) and with centralised transfer (home display), which collected data from a smart metering system, processed it and sent it back to the display using the internet. The initial investment in the centralised version was disproportionately high in comparison to the low energy savings potential. The decentralised version on the other hand was much more economical to implement and, because data is processed on-site, also operates in accordance with the data minimisation principle of the Data Protection Act of Austria (DSG). Moreover, the decentralised version delivered energy-use feedback in real time, while the centralised version (i.e. the home display method) provided feedback almost in real time with a delay of 2-3 minutes. Since real-time information is used by residential customers to monitor the energy use of household devices, a longer delay doesn't deliver the desired benefit.

In addition, the data minimising approach of the decentralised version fulfils the regulations set out in the Data Protection Act because only the data used in billing or to provide legally mandated information (depending on the model, a load profile or daily usage statistics, for example) are transferred to the grid operator. The real-time data remains in the household, is processed there and transmitted to the consumer in the form of feedback. Wattson uses independent current-transformer measurements instead of a smart meter. In the future it would make sense to make use of smart meters with the decentralised version too, by transferring real-time measurements using a unidirectional communication interface, which is also pro-

vided for in the 2011 law outlining requirements for intelligent meters [*IMA-Verordnung*]<sup>32</sup>, directly to the display or another local gateway.

## 2.4 The integration of buildings

The optimisation of building operations to shift loads on the grid can be carried out using numerous flexible electrical aggregates and units assisted by different ICT solutions. Of particular importance are systems with thermal-electrical coupling such as heat pumps, chillers and co-generation power stations which use thermal inertia as virtual storage. In SGMS, two primary approaches were used: Optimised control of interruptible consumers using ripple-control units and the flexibility of buildings with the help of building automation systems. The latter are assisted by a Building Energy Agent, which acts as the communication interface to the electric power system (B2G approach). The power grid communicates using a smart grid controller.

### *Optimised control of interruptible consumers via ripple control*

The first approach to using existing, easily accessible flexible loads was to identify electric heating and hot water systems that are outfitted with ripple controls. These units are already being switched on and off by the grid operator according to predetermined times which are strictly regulated. These flexible electric loads currently account for a total of approx. 80 MW (around 10 % of peak load) in the network managed by Salzburg Netz GmbH. Using optimised triggering, a total of 10-15 MW (approx. 1.5 % of peak load) can be shifted within the existing legal framework.

This kind of highly variable method for controlling the usage times of ripple-controlled loads is currently being analysed and tested. In addition to analysing the potential as well as the technical feasibility, the legal and regulatory framework for this kind of demand response management is being examined closely since the legally mandated control and time-of-use network tariffs<sup>33</sup> partly pose a barrier to the maximal utilisation of the potential of ripple controlled load management. An area served by a primary substation with an above-average saturation of flexible loads was chosen as a test area. Here, depending on the weather, from 0.5 to 2 MW of load (up to 10 % of peak load in the area) could be shifted. Customers were informed about the test in a letter, and there were no negative responses. The control actions take place according to economic criteria.

Being able to rely on existing control infrastructure significantly reduced the investment that had to be made in the test.

A disadvantage is the strong seasonally fluctuation of consumption. Furthermore conditions within the individual households are not taken into account in the control of the units. If, for example, a central heating system had been turned off for several hours prior to a planned shut-down, comfort would dictate that the system would forgo the jettisoning of this load. The use of electric heaters and hot water systems with ripple control should therefore be viewed

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<sup>32</sup> These requirements issued by E-Control are based on: BGBl II No. 339/2011.

<sup>33</sup> The tariffs are currently divided into low (from 10pm to 6am) and high (from 6am to 10pm).

as a temporary solution that can be quickly implemented and less as an intelligent technology of the future.

In addition, the percentage of electric space heaters is on the decline.<sup>34</sup> On the other hand, the number of heat pumps is on the rise and seems set to continue. Many factors indicate that a system of the future would be able to take the processes within the building and therefore also the needs of residents into account but would also be able to be set up in all types of buildings regardless of the type of heating or hot water system. Still, the fundamental approach using the thermal inertia of a building to flexibly manage its load will remain.

### *The Building to Grid approach*

With the help of thermal simulation, it could be shown that even old buildings possess thermal characteristics that make it possible to shift heating loads over a period of several hours. The comfort of users is never in jeopardy since building materials react extremely slowly and most buildings also have storage units in the heating system of the building to act as a buffer.

The investment needed to configure a building for thermal modelling is normally considerable but has fallen drastically with a newly developed model that only needs the data available from an Energy Performance Certificate. The validation of these models was undertaken as part of a field trial. Adaptive systems that use sensors to conform to the conditions in a building were able to further reduce the cost and effort necessary to calibrate a model and therefore constitute a promising solution for future building systems.

Such a system can be integrated in building automation. It recognises the processes of the operator and optimises the operation and energy of a building in light of the operator's wishes. In order to make communication and harmonisation with the electric power system possible, an additional interface is necessary.

In the Building to Grid project, building automation systems in ten existing buildings were extended to include a Building Energy Agent (BEA) which communicates with the electric power system, which is represented by a smart grid controller, fulfilling the following tasks:

- Creating energy prognoses for the components used for the thermal conditioning of the building;<sup>35</sup>
- Dispensing the load-shifting potential, having taken into account warm-up or cool-down phases and compensation for the rebound effect<sup>36</sup> within a defined period of time;

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<sup>34</sup> According to guideline 6 of the Austrian Institute of Construction Engineering (OIB) electric resistance heating systems are not permissible in new buildings if they are the primary system. When buildings are renovated these heaters are partly replaced by heating systems that use other sources of energy.

<sup>35</sup> In the field trials, different heating systems such as combined heat and power plants (CHP), heat pumps, electric storage heaters, and electric space heaters, were utilised. These concepts are in principle also applicable to chillers and air conditioners.

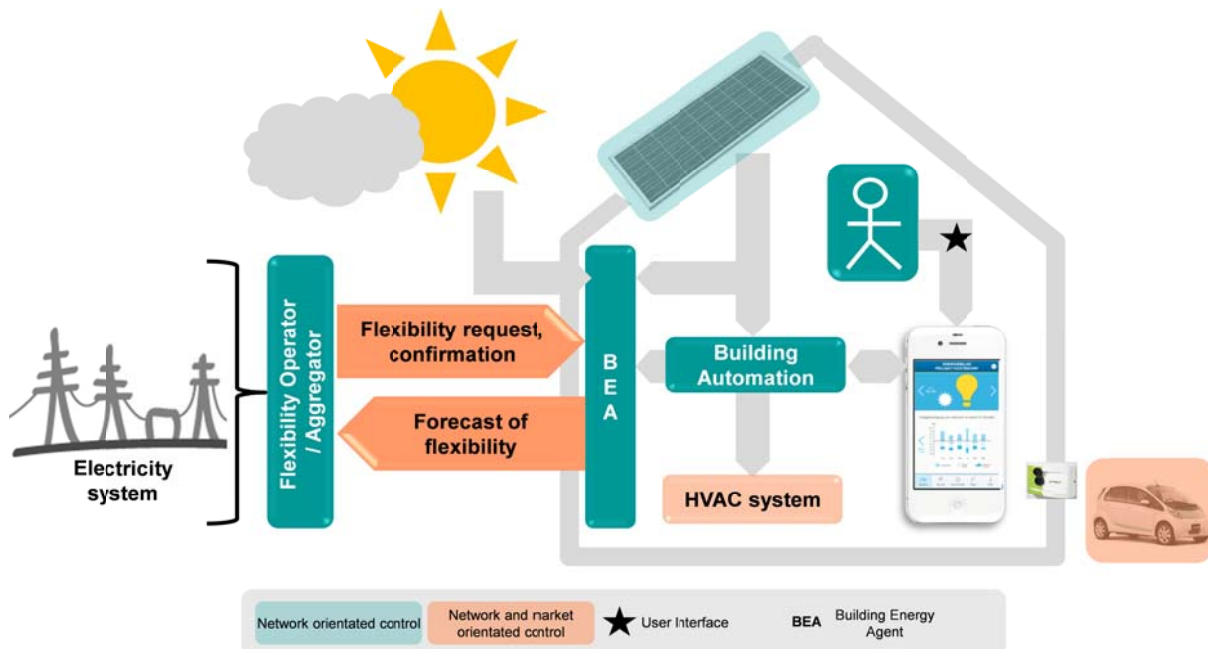
<sup>36</sup> In this context the rebound effect describes the simultaneous re-charging of storage units which had been switched off simultaneously during a period of high demand.

- Optimising the utilisation of on-site generated energy from e.g. photovoltaic units using electromobility and other flexible loads.<sup>37</sup>

In order to supply more flexibility, thermal storage units such as hot water buffer-storage systems and the building itself are used. In total, there was a maximum flexible load potential of approx. 350 kW in the ten buildings of the field trial.

It makes sense to use a building energy agent when a building is automated or when there are several smart-grid applications. The former is however much more prevalent in commercial and industrial buildings than in residential ones at the moment. There is however predicted to be a rise in the number of home automation systems in use in households.<sup>38</sup>

In order to use the potential of buildings as part of a smart infrastructure, it will be necessary in the future to include outside information in the local optimisation of the building. The types of information will extend from weather data to time-sensitive information on pricing all the way to the condition of the grid and will facilitate more exact and longer-distance prognoses. The integration of different information as well as possibilities for residents to intervene in the system are shown in Figure 11.



**Figure 11: Approach in the Building to Grid project (B2G)**

There is a need for additional research and development in the interface between the electric power system and the building. On the one hand, the interests of grid operator, who has to

<sup>37</sup> This functionality of a building energy agent is primarily used in the DG Demo Net Smart Low Voltage Grid project.

<sup>38</sup> For further information see (in German): VDI/VDE Innovation + Technik GmbH (2011): Technologische und wirtschaftliche Perspektiven Deutschlands durch die Konvergenz der elektronischen Medien. Commissioned by the Federal Ministry of Economics and Technology, Berlin.

guarantee security of supply and maintain voltage at all times in addition to monitoring the utilisation of the network infrastructure, conflict with those of the building operator, who wants to secure the best price on the electricity market by offering flexibility. Hence, market models or market rules need to be created that take both sides into account and are satisfactory to both. One approach is the traffic-light model<sup>39</sup> in which market demands are taken into account as long as critical threshold values on the power grid haven't been reached. If these are exceeded, then the grid operator can act to stabilise the grid without taking the market into account.

On the other hand, technical details like bringing protocol standards in the interface into agreement and developing security standards for data transfer between components of the grid operator (smart grid controller) and the devices and appliances in the building (BEA).

## **2.5 Load management in commercial & industrial enterprises**

The integration of buildings and electromobility in the electric power system already makes it possible to shift loads flexibly, but the total scope of this undertaking is still being examined. Further possibilities to manage loads that haven't yet been tapped lie with commercial and industrial enterprises.

It must first be ascertained to what extent load management in these enterprises can contribute to the optimisation of current grid operation. One question, for example, is how great their total flexibility is in relation to the total load. The larger it is, the better it is for the grid operator, who becomes able to balance out load peaks on the power grid.

On the other hand, the focus is on the economic advantages of load shifting for industrial and commercial customers who receive financial compensation if a load is shifted or if a system has to go offline. It remains to be determined how extensive the compensation must be in order to balance out a possible production stoppage or overtime on weekends.

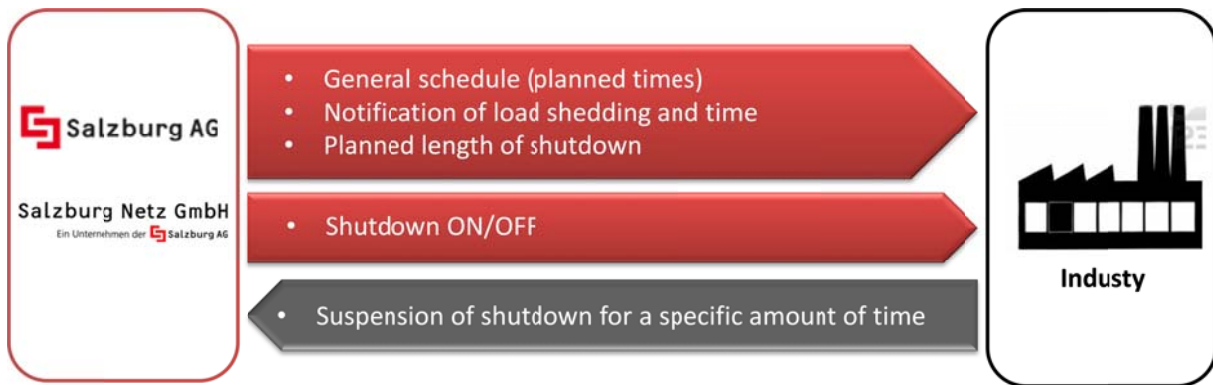
### ***Industrial customers***

Due to the great amount of electricity they use compared to residential customers, industrial customers have a high load-shifting potential, though the exact level must be determined by each individual company. The first cooperation with an industrial enterprise took place during SGMS with a company that can deal with up to 4.7 MW of flexible load by controlling the operation of mills. This corresponds to a potential that is much larger than the buildings examined in the Building to Grid project and can be put to use with comparably little investment.

In this pilot project, Salzburg Netz GmbH installed the controller components locally and handled the data transfer and the integration of the units into the control centre.

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<sup>39</sup> A more detailed description of this model can be found in Chapter 3.8.

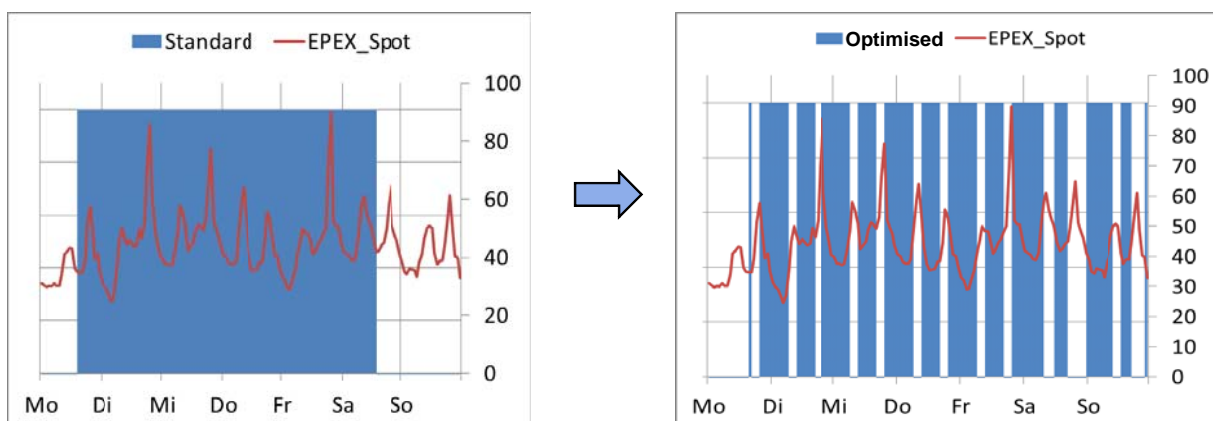


**Figure 12: Communication for load management for industrial customers**

The necessary programming in the local control system was carried out by the company. Finally, the energy supplier (Salzburg AG) and the grid operator (Salzburg Netz GmbH) created a schedule with the planned shutdown times for the mills and transmitted the automated control commands to the company. Since it won't be possible for industrial customers to go without the machines used in production, they should always have the possibility to stop planned shutdowns. The scope of communication is described in Figure 12.

The possible consequences for industrial enterprises are significant wear and tear on machines and the creation of additional costs by shifting production times and therefore working hours. Thus, the financial benefit for industrial customers is the most important factor.

Furthermore, flexible load management is not possible in every company. It is necessary that the facility has a storage system that can act as a buffer for a temporary shutdown. A second point is minimum quantity of goods produced that would ensure that the implementation of flexible load management would make sense.



**Figure 13: Optimisation of load management in the pilot project based on spot market prices**

This allows loads to be shifted using the current market mechanisms at the time – as shown in Figure 13 – and the benefits that are derived to be shared with the companies. The present fixed-price system for interruptible service gives grid operators very few options to create financial incentives using network tariffs to shift loads. In the future, a detailed examination should be conducted of the type of incentives in the network tariff that would be necessary to prompt industrial customers to shift their loads to such an extent that this would be beneficial to the grid operator.

### **Commercial customers**

In contrast to the individual approach necessary for industrial customers, the load-shifting potential of a commercial enterprise has been found to be applicable to other companies in this sector. One example is the retail sector, where a large number of chain shops together would also offer great opportunities for load management.

For this reason, the Load Management Potential in Businesses<sup>40</sup> research project is analysing the electricity consumption of 30 individual businesses in Salzburg along with the load they actually need over the course of a day. The goal of the analysis is to identify which electricity loads can be managed over the short and the long term without limiting any part of the work that is being done in the company. It also aims to determine the amount of possible savings on electricity costs different types of businesses and sectors can achieve, but also which incentives are necessary to implement demand response management through suitable business models. In addition, a projection of the sectors examined in the project will be used to estimate the total potential in SGMS.

## **2.6 Excursus: Applicability for other energy systems**

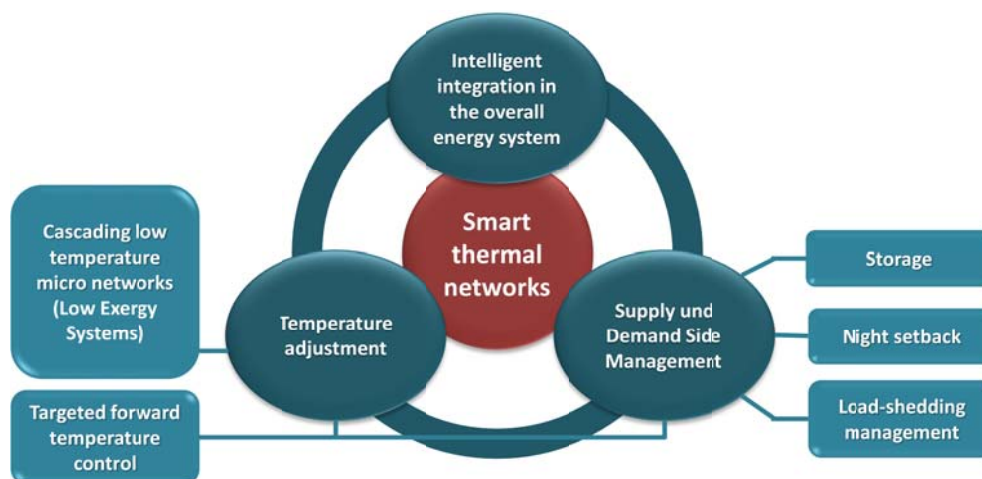
Up to now, the examination of smart grids focused almost exclusively on electric power systems. This is due especially to the challenge created by the need to have a balance between production and consumption at all times on the power grid. In gas and district-heating networks, on the other hand, the network uses changes in pressure or temperature to regulate flow so that balancing does not have to occur in real time. Nevertheless, there are several promising smart-grid approaches in these supply systems. Furthermore, there are numerous potentials for synergies in the interface between different energy systems, for example, using the optimised operation of hybrid systems that employ cogeneration units and heat pumps that combine electricity and gas and/or district heating networks.

The Smart Heat Net project expands the focus on smart grids to district heating networks, offering a cross-system perspective that conforms to the smart infrastructure approach of SGMS.

The project elaborated on the aspects of intelligent thermal networks shown in Figure 14. The issues that received particular attention appear in the rectangles to both sides.

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<sup>40</sup> Project management for this project is carried out by B.A.U.M. Consult GmbH. It is sponsored by the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT) through the Austrian Research Promotion Agency (FFG). Salzburg AG is a co-operation partner.



**Figure 14: Aspects of smart district heating and cooling networks**

### *Optimising operations through supply and demand side management*

This type of management includes measures that aim at reducing load peaks in district heating networks in the morning and evening and therefore constitutes the main focus of the Smart Heat Net project. Load peaks in heating networks – like in the power grid – lead to the creation of largely unused line capacity as well as the need to use backup power plants, which have higher carbon emissions than base load power plants. The project also examined the following topics: "the use of storage units", "night setback", and "load shedding power management". The results appear below.

- Using storage units can effect a reduction in peak loads. There is however a difference between decentralised and centralised storage. The latter offers a greater reduction in peak loads in relationship to investment costs. In a concrete case examined in the project, € 12,500 in fuel costs was saved, and at a price of € 300 per cubic metre the storage units paid for themselves in 17 years. CO<sub>2</sub> emissions would be cut in half by reducing the use of peak-demand boilers.<sup>41</sup> Decentralised storage units on the other hand cost more while producing the same effect, doubling the payback period. Moreover, incentives would be necessary to prompt residential customers to use these storage units.
- Night setback systems lower the room temperature at night. When a lot of buildings switch from night setback to the normal day set point, this causes demand peaks in the district heating network. Research has shown that reduced or disabled night setback can reduce demand peaks by up to 30 % for individual buildings. This also generally leads to a higher energy expenditure, making it necessary to perform a cost-benefit analysis for each area of the district heating network.
- Load shedding power management: This uses demand-control algorithms to carry out targeted load shedding or load control within a particular period of time. On the one hand, this takes advantage of the ability of the central control system to regulate the boiler and uses this to shed loads. These type of systems account for around half of all the systems in the rural test area of the project. They are, however, often so small that they have to be

<sup>41</sup> The calculations are from the Altenmarkt area.

heated back up several times a day, making it more difficult to make capacity utilisation plans for the district heating network. Secondary controllers that are not regulated by the district heating network pose an additional problem in that they have their own control logic, therefore rendering them unusable.

In the district heating network in the City of Salzburg, this load shifting method can only rarely be used since there are no data connections to most of the residential units.

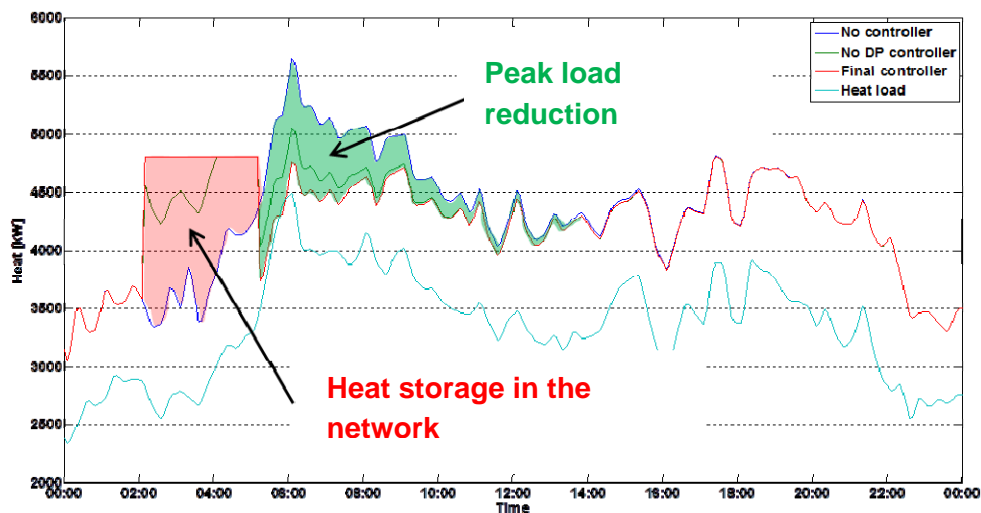
On the other hand, a controlled approach to regulating the turn-on time can be used. A sample of the 30 largest customers in the city network of Salzburg showed that the theoretical demand side management potential was 11 % of the maximum load, which would be sufficient to completely smooth morning load peaks over the course of a typical day. The question of whether this potential can be utilised in the future remains to be answered.

### *Adjusting the temperature level*

Targeted control of the forward temperature can utilise the storage capacity of the district heating network. Lower forward and return temperatures lead to a reduction in heat loss and demand peaks as well as to an increased potential for renewables and industrial waste heat.

- Control of forward temperature: The volume in a district heating network can to a certain extent be used to store energy through temperature control, thereby enabling load peaks to be reduced. One method is to raise the forward temperature in the network even before peak demand to store energy in the network. This potential, however, cannot always be utilised due to technical restrictions such as predetermined maximum network temperatures. In the rural area in which the trial was carried out, peak demand could only be reduced by 2 % because of hydraulic limitations. Theoretically, models predict a maximum saving in this area of 15 % (see Figure 15). It can be assumed that it is not possible to independently control the flow temperature in order to improve efficiency in numerous district heating networks.

The advantage of this method is, however, that adjusting the forward temperature costs almost nothing and still has a positive effect on energy use and emission control. Especially in urban areas in which there are no central storage units, this method would be an inexpensive way to reduce peak demand.



**Figure 15: Reducing peak demand using heat storage in network lines: the results of a simulation in the district heating network in Altenmarkt**

- A reduction in energy loss in the network can be achieved using micro networks. New buildings or new-build schemes often consume so little energy that utility providers often find it uneconomical to offer connection under standard conditions.

Reducing the temperature of the system is therefore an important step to raising energy efficiency. In a case study lowering the flow temperature in by 5 °C leads to a reduction in energy loss by approx. 10 % and a reduction in the electricity needed to run the pumps by 35 %.<sup>42</sup> All the variations tested – all comprised smart control and operation strategies of a sort – led to a reduction of heat loss and therefore to a decrease in operating costs. If the cost savings achieved are compared with the investments necessary to implement this method, the additional expenses caused by regular maintenance and repairs will need to be taken into consideration. A careful examination of the level of savings and additional investment showed that the highest standards for line insulation are preferable to complicated hydraulics and control systems.

### *Intelligent integration into the whole (urban) energy system*

This aspect encompasses the optimisation of interfaces with other energy grids and is therefore an integral part of smart city concepts. Since it has not been extensively examined as part of the SGMS projects, questions regarding the use of these kinds of interfaces to optimise power and district heating grids together remain to be answered.

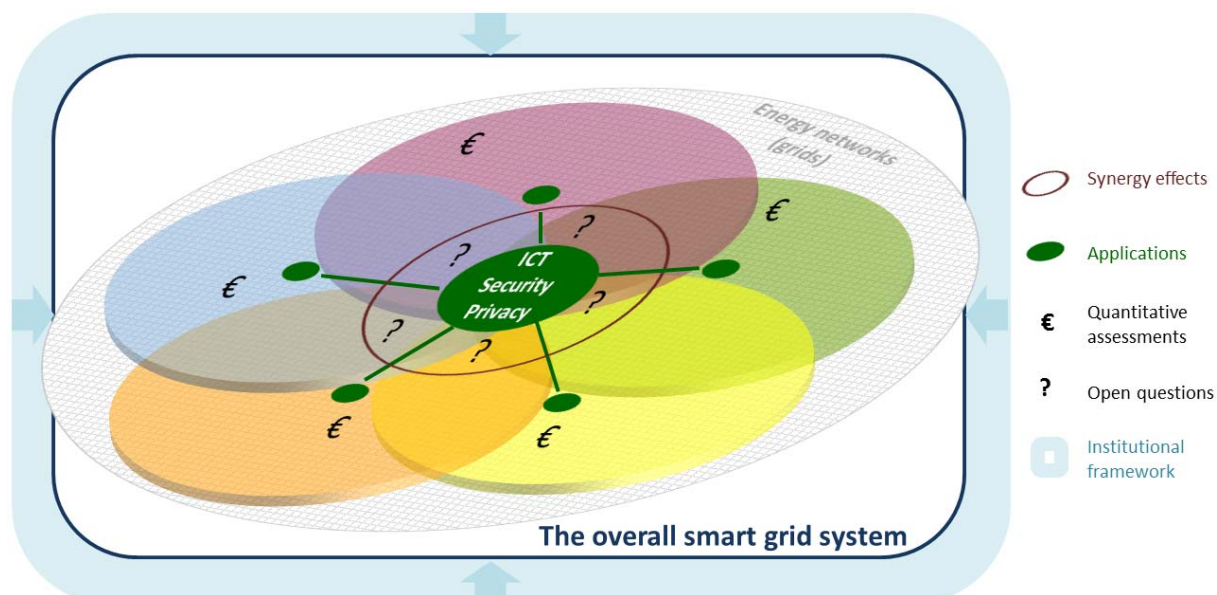
Visions and theoretical concepts for smart gas grids were developed in a separate project by Energy Research Austria<sup>43</sup> and the Austrian Association for Gas and Water<sup>44</sup>. In the future,

<sup>42</sup> This calculation was based on a beginning temperature of 70 °C in the forward line and 40 °C in the return line with a decrease to 65 °C and 35 °C respectively.

<sup>43</sup> For further information see (in German): Hinterberger R.(2011): Intelligente Gasnetze der Zukunft – Smart Gas Grids. BMVIT (Ed.), Berichte aus Energie- und Umweltforschung 57a/2011, Wien.

the aim is to optimise the transport and storage of hydrogen or methane from excess electricity (power to gas technology) as well as the decentralised generation of bio-methane. Although none of the projects in the framework of SGMS concentrated on intelligent gas grids, the aforementioned initiatives are being observed with great interest. In SGMS, smart grids are viewed and handled as an all-encompassing concept of smart infrastructure.

### 3 Consolidated findings



**Figure 1: Cross-application topics**

When looking at the five areas of application, it becomes clear that SGMS emphasises management of consumption and production. However, the use of flexible generation must be supported in the best possible way through appropriate framework conditions. These can include, for example, the creation of appropriate incentives for residential customers to integrate their equipment and facilities via corresponding time-variable tariffs, or the definition of standards while taking a future overall system into account.

The overall system must be designed to facilitate the most flexible energy market possible and allow implementation in a series of scalable and extensible steps towards the targeted system. This chapter provides a step-by-step outline of the overall smart grid system. After summarising the findings of the five areas of application, cross-application topics will be addressed – as schematically illustrated in Figure 1. First, the overlap between the areas of application will be compiled and summarised in three major areas of synergy. Subsequently, the chapter will focus on information and communication technologies (ICT) as essential components of a smart grid, as well as the role of smart metering and data privacy and secu-

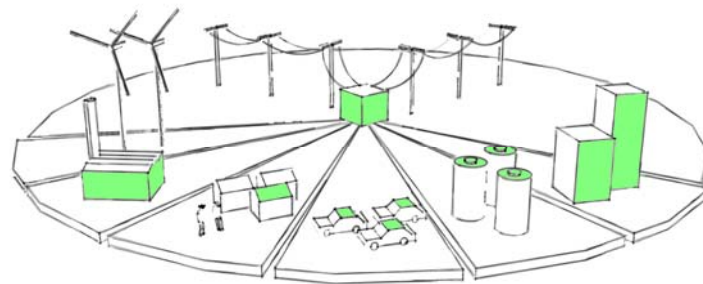
<sup>44</sup> Further information see (in German): Austrian Association for Gas and Water (ÖVGW) (2011): Positions Papier: Smart Gas Grids in Österreich. Final report of the project of the same name conducted in co-operation with DBI Gas- und Umwelttechnik GmbH, Leipzig, Germany.

rity requirements. Furthermore, the costs and benefits of applications will be quantitatively evaluated by way of example.

After presenting the open questions and demands placed on the institutional framework, the chapter will outline an overall smart grid system, taking into account all of the abovementioned aspects.

### 3.1 Synergy effects

In light of the fact that a wide demand-oriented implementation of smart grid applications in itself will entail considerable infrastructure costs, SGMS has analysed developable synergy potential. In this regard, it is important to minimise the overhead generated by the creation of the infrastructure by multiple use. From a macroeconomic point of view, it makes sense, for example, to combine, jointly consider and optimise the development of suitable ICT for power system automation and control with the necessary smart metering, as well as with other smart grid applications and also with broadband initiatives in the field of telecommunications, and to obtain maximum synergy in doing so. A joint use of the infrastructure by multiple applications – as symbolically illustrated in Figure 2 – is an important prerequisite for their macroeconomic viability.



**Figure 2: Synergetic use of infrastructure by various smart grid applications<sup>45</sup>**

Synergy potential is generally found in three areas that can each be considered individually.

1. Synergies in the use of communication infrastructure: an intelligent expansion is necessary, taking advantage of location and application synergies. This issue was treated in the SmartSynergy project. The main findings are presented within the scope of this chapter.
2. Synergies in the area of IT infrastructure: not only the efficient use of IT resources (servers, software, etc.), e.g. as made possible thanks to virtualisation concepts, is essential here, but also the synergetic use of information from various sources while taking data protection and privacy into account. The latter issue is discussed in the Smart Web Grid project, among others.

<sup>45</sup> Source of figure: Vienna University of Technology, Institute of Computer Technology.

3. Synergistic use of hardware: the area of physically required hardware for smart grids also contains significant synergy potential. Examples include the smartphone as a user interface, e.g. for energy feedback and electric mobility applications (see Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**) and the Building Energy Agent, bringing together the communication interfaces of various smart grid applications in a household or a company (see Figure 3 and Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**).

When considering the communication properties and requirements respectively, it becomes clear that various kinds of data and information must be comprehensively recorded and distributed for all smart grid and electric mobility applications. Each application has different technical requirements such as data volume, real-time capability, data security, availability and redundancy, significantly affecting the technical characteristics and thus the cost of ICT infrastructure. The cost-efficient establishment of ICT infrastructure through synergetic use for multiple applications at the same time, including validation of the actually realisable synergy potential, were key objectives of the SmartSynergy project, a case study for the Lungau region. On the basis of representative sites and a detailed survey of the ICT requirements of five applications<sup>46</sup>, the project estimated the ICT development costs in intelligent electricity networks, which currently constitute a difficult to estimate variable.

The compiled costs of exemplary, representative ICT sites are used as reference values for the calculation of location synergy factors, whereby distinctions are made according to the type of connectivity. First of all, it becomes clear that there are significant synergies even in rural areas such as the Lungau region due to the geographic proximity of the sites of various applications. For each of the smart grid applications considered, it was thus possible to determine the location synergy potential to the other applications. Thus, in 99 % of cases, an energy feedback site is also located at an electric mobility site and two of three DG Demo Net sites are also ZUQDE sites.

The application synergies were identified on the basis of the respective communications requirements. This makes it possible to measure to what extent various smart grid applications can harmonise and best complement each other in their specific technology requirements, allowing a holistic assessment together with the determined location synergies. On the basis of the requirements, two clusters can now be created: on the one hand, applications for residential customers such as energy-use feedback, electric mobility, building to grid, as well as smart meter-based billing and, on the other hand, applications located at network operator sites such as DG Demo Net, ZUQDE, smart metering data concentrators.

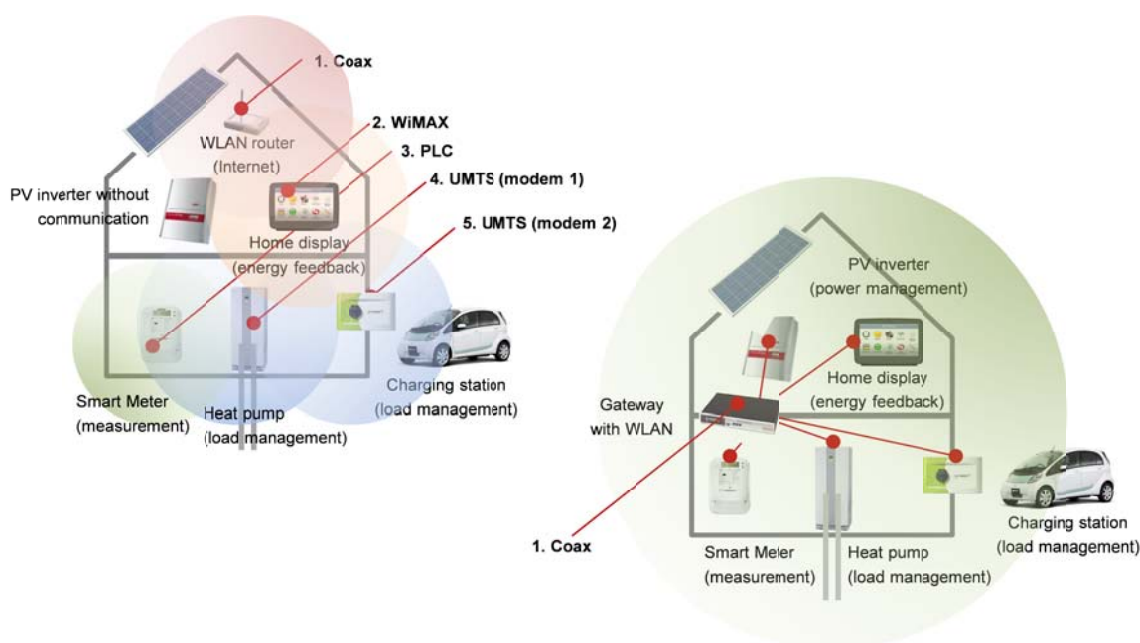
Another important finding is the fact that, within the minimum legal requirements, smart metering has few synergies with the other smart grid applications, which have much more demanding ICT requirements. In the area of last mile connectivity to households, frequently

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<sup>46</sup> These include energy feedback according to C2G, intelligent charging of electric vehicles according to V2G, the active involvement of buildings according to B2G, voltage control in the medium voltage network according to ZUQDE and DG Demo Net Validation and smart metering according to the prescribed minimum requirements for comparison.

used smart metering based on narrowband power line communication (PLC)- exhibits location synergies, but hardly any application synergies with the other smart grid applications. For synergetic use of smart grid applications, broadband PLC on the basis of the IEEE 1901-2010 standard could be examined, or an alternative type of connection could be selected. The connection of the network operator assets (e.g. local secondary substations) to the communications network can be realised by turning on various virtual networks (VLANs).

Furthermore, cost comparisons of different technologies such as WiMAX, PLC, fibre optics (FO), coax, UMTS and microwave, reveal potential savings of over 30 % when utilising all synergies compared to the worst case scenario (see Figure 3). Multiple use of an ICT connection, a relatively easy-to-influence synergy factor, contributes especially to this.



**Figure 3: Worst case (above) and best case (below) example of smart grid connection of a household**

Figure 3 illustrates how, instead of having five different ICT connections in the above part of the figure, only one is required in the bottom case via bundling with the help of a gateway. An photovoltaic inverter is also connected.

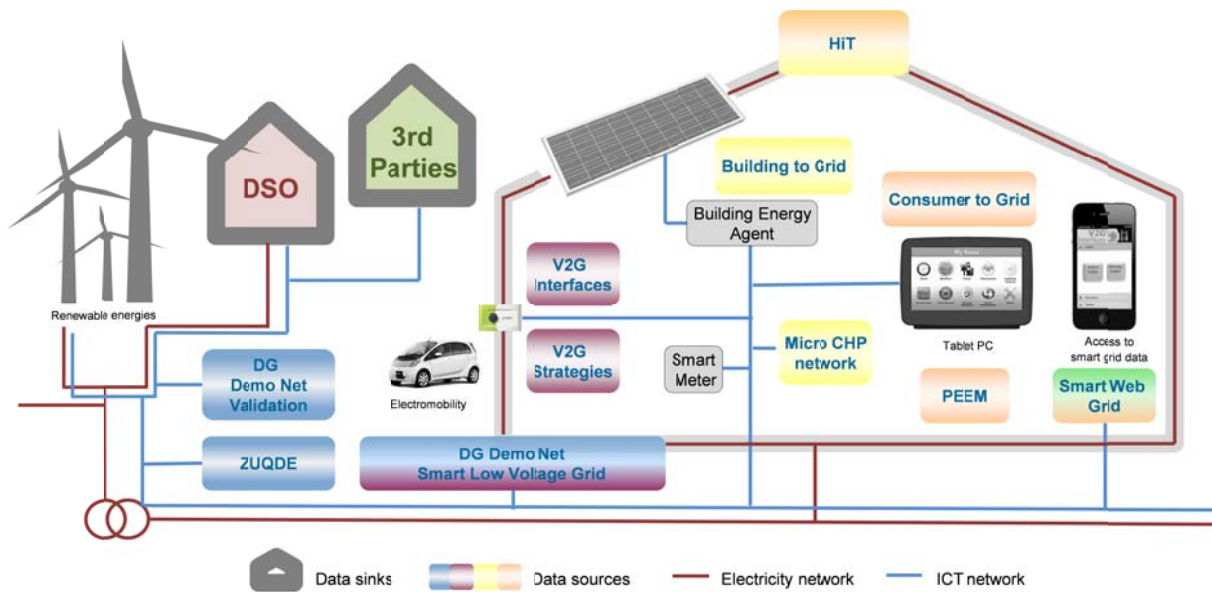
Furthermore, it is particularly evident in this example that the use of synergies, as well as their sustainability, is dependent on the use of unified standards. It is therefore recommended to drive forward the development and standardisation of communication and reference architectures for the entire system in general. Clear rules on the concurrent use of a communication channel of smart grid applications and external applications are also required with regard to security, safety and privacy.

The basic recommendation of the SmartSynergy project is to promote synergy-conscious development of communication infrastructure according to the methodologies described in the project in order to realise the savings potential. However, to efficiently enable and support this, the following recommendations must be implemented:

- Mandatory standards must be created to ensure general security and safety, security of supply, as well as stability of the electricity grid in synergistic use of communications infrastructure by smart grid applications together with third-party applications.
- The development of a common secure smart grid reference architecture should be encouraged on the part of the state in order to maximise the use of synergies and thus the economic benefits in addition to interoperability and security.
- Unified communication architecture and abstraction layers must be created for the various smart grid applications in the context of the reference architecture in order to promote standardisation in this area and thus develop additional synergy potential.
- Authentication and authorisation concepts within such a smart grid reference architecture should be given particular consideration in order to be able to formulate and implement unified and universally valid safety and security standards.
- To set up an intelligent energy network, all stakeholders should orientate themselves using this reference architecture. On the one hand, it applies to the operator responsible for the planning and development of the communications infrastructure. The realisation of the communication infrastructure can be carried out by third parties. On the other hand, it affects the industry with regard to the development of smart grid components and technologies.
- Smart grid components should be equipped with diverse, flexible communication modules or options in order to ensure the necessary flexibility in the selection of the most synergetic, cost-efficient method of development.
- When granting licenses for the use of the frequency spectrum on the basis of the respective legal framework, the creation of barriers that impede a synergetic use of wireless technologies such as WiMAX for smart grid applications should be avoided.
- Most of the required components are connected via telecommunications. The interaction of the telecommunications link and the power grid, as well as their potential impact, should be investigated further.

### **3.2 ICT for Smart Grids**

ICT is a key technology in SGMS projects and their applications. ICT is responsible for the transmission of information and processing between various smart grid components. Figure 4 and the subsequent elaborations depict projects in the model region that require ICT.



**Figure 4: ICT applications in the smart grid**

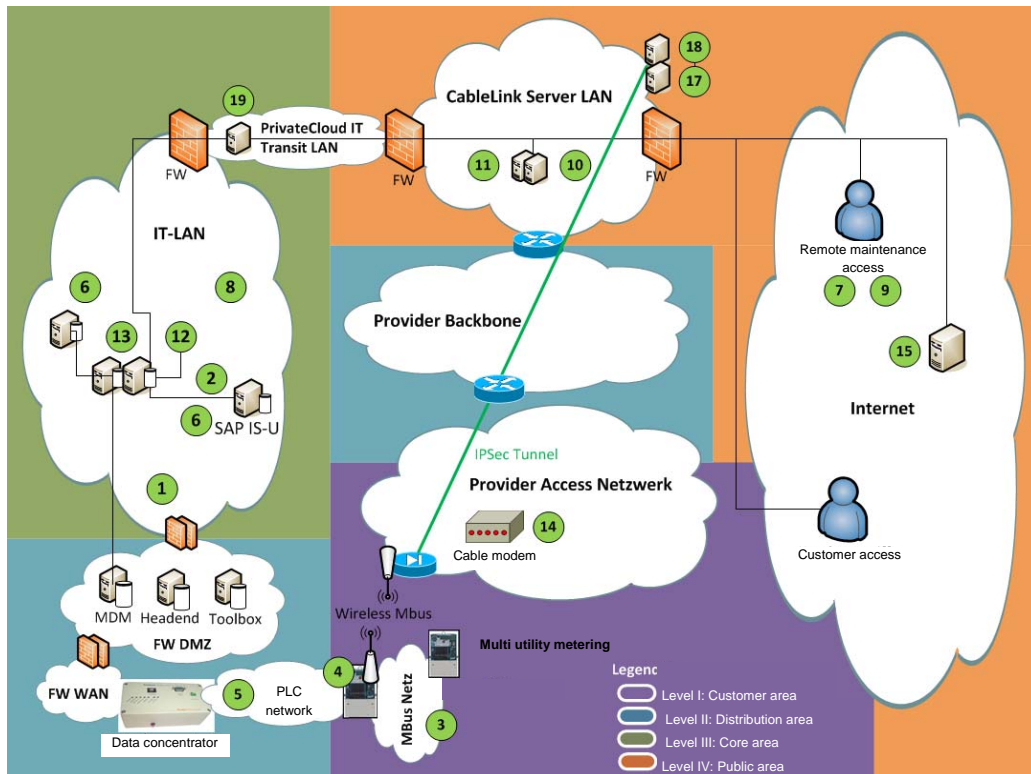
Despite the different ICT requirements, there are commonalities and synergies which should be taken advantage of in the future.

In many cases, an independent ICT solution is developed for smart grid applications in order to connect the data sink to the data source (see Figure 4) optimised for the particular task. For example, the residential customer's device (tablet computer, see Figure 5) in the C2G project got data over a private VPN (virtual private network) in the conventional public mobile data network. In the ZUQDE project, the connection of distributed generation takes place over VPNs of their own (telecom networks for control purposes). These are based on another infrastructure such as, for example, wireless technologies, which are independent of the power supply. Overall, in-depth consideration of the individual SGMS projects has revealed the ICT transport network, denoting the connection from the data source to the data sink, to be facing the following challenges:

- complexity of integration
- system security,
- compliance with data protection regulations and data minimisation,
- integration into the underlying backend systems (e.g. meter data management) and their operation.

In the next step, these different requirements and solutions must be merged and optimised into an overall solution. These challenges can only be counteracted by creating an efficient, generic, easily extensible basic ICT infrastructure – a so-called convergence layer. Standardised transmission, standardised logs as well as standardised interfaces are necessary to this end.

To illustrate this challenge, the levels of the basic ICT infrastructure are explained below in more detail and illustrated with an example.



- |   |   |    |   |    |                                     |
|---|---|----|---|----|-------------------------------------|
| 1 | Interface: Database to application server                           | 7  | Remote maintenance access from Internet to backend system | 14 | Ethernet interface at meter gateway |
| 2 | Interface: Application server for product and login data management | 8  | Remote maintenance access from intranet to backend system | 15 | ZAMG weather data from Internet     |
| 3 | Local BUS network   | 9  | Remote maintenance to web server                          | 16 | Web access for energy monitoring    |
| 4 | Optical interface at the AMIS smart meter                           | 10 | Web server energy feedback                                | 17 | Real-time database smart meter      |
| 5 | Power line carrier network  | 11 | Interface: Web server backend system                      | 18 | JAVA message BUS server             |
| 6 | Interface: ERP system to application server                         | 12 | Database server   | 19 | Interface server                    |
|   |   | 13 | Application server  |    |                                     |

Figure 5: The ICT infrastructure in the C2G project<sup>47</sup>

<sup>47</sup> Abbreviations:

TC WAN    Telecontrol - Wide Area Network  
 TC DMZ    Telecontrol - Demilitarised zone  
 PLC Net    Powerline Carrier Network  
 FW         Firewall

MDM        Meter Data Management  
 SAP IS-U    Billing system (ERP System)  
 IT LAN     Salzburg AG internal information and communications network

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### Overview of the basic ICT infrastructure

In each of the above projects, technical components for the deployment of the smart grid application are necessary. For the creation of the basic ICT infrastructure, these ICT components were initially listed for each project and then assigned to the ICT network levels.

The following classification applies to the ICT network levels:

- Level I: Customer area - devices and networks in the household of the user, e.g. smart meters, energy feedback tablet computers, charging stations for electric vehicles, etc.
- Level II: Distribution network - ICT transmission networks, e.g. 3G<sup>48</sup>, LTE<sup>49</sup>, WiMAX<sup>50</sup>, microwave<sup>51</sup>, etc.
- Level III: Core area - Data backend systems that collect data, e.g. smart meter head-ends, charging station management in electric mobility, etc.
- Level IV: Public area - most Web servers providing applications, e.g. central servers for energy feedback services, APP for controlled / adaptive charging, etc.

As an example, Figure 5 shows the ICT infrastructure for energy feedback in the Consumer to Grid project.

In comparison to “classic” telecontrol applications in the power system that focus on levels II and III, this example already makes clear that smart grid applications will enter the customer area, level I, but also the public sector, level IV.

It follows that a basic ICT infrastructure in the electrical energy system must be created, which develops away from the current “offline” world shielded by isolated network operation into an integrated “online” world.

This includes, for example, bi-directional communication and interaction with residential consumers, who will play an active role within the smart grid. Therefore, user-friendliness of the interaction application must be considered as an essential requirement, much more so than thus far. Thus the energy feedback offered on tablet computers, for example, should be designed to hold the greatest possible appeal for the user. In addition, it is important to take the needs of a broad residential customer base into account, which entails manifold requirements.

Furthermore, security, integrity and data privacy should already be included in the basic concept (“Security and privacy by design”, see Chapter 3.4).

Data collection and measurement is often carried out on the system of the user, making the data particularly worth protecting. The connection of hardware address of the customer installation with customer data is carried out in downstream in backend systems. The princi-

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<sup>48</sup> 3G – Mobile data network.

<sup>49</sup> LTE – next-generation mobile data network with higher bandwidth.

<sup>50</sup> WiMAX – broadcast radio technology for data exchange.

<sup>51</sup> Directional radio – point to point radio technology for data exchange.

ples of data privacy and data minimisation must be applied. This entails reducing the data transport to a minimum as well as ensuring that users have control of their own data.

The data sources or devices to be controlled, e.g., a smart meter or a charging station, are no longer located in the facilities of the operator, but mostly in the customer or public area. Thus, the security of the overall system can no longer be ensured by access security of the system operator facilities, but in the future must be guaranteed through application-specific security or device security.

Another challenge lies in the provision of user data collected by the grid operator via the public area for service providers such as, e.g., electric mobility providers and independent energy consultants on the free market. The ICT architecture must also ensure this potential future function of the distribution system operator (DSO) as a neutral “data hub” or “market facilitator”<sup>52</sup>.

The switch to the “online” world tends to result in higher operating expenses for ICT systems because it is necessary to establish higher service levels and availability for residential customers and users. To what extent this higher expenses are leveraged by synergies in other areas is an open question.

### *Future developments and outlook*

In the future, the technical implementation of smart grid applications could be planned and carried out transparently on the Internet Protocol (IP) convergence layer in order to comply with the standardisation requirements concerning data transmission.

Already today all smart grid applications can be implemented on the convergence layer IP, whereas in accordance with present technology smart meters are often connected via non-IP-compatible power line carrier (PLC) technology. To close this gap, the standardisation bodies IEEE<sup>53</sup> and IETF<sup>54</sup> are developing a possible future standard for communication based on PLC using IP as the transport protocol.<sup>55</sup>

To describe all applications of the projects via an ICT network, an integrated smart grid reference architecture is required. The architecture should be as homogeneous as possible and meet the following objectives, amongst others:

- ensuring the most uniform data transport possible,
- ensuring a high degree of flexibility,
- ensuring security, data protection and data authenticity as well as data integrity.

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<sup>52</sup> For further information, see: Smart Grid Task Force of the European Commission (2013): EG3 First Year Report: Options on handling Smart Grids Data.

<sup>53</sup> IEEE: Institute of Electrical and Electronics Engineers.

<sup>54</sup> IETF: The Internet Engineering Task Force (P1901.2).

<sup>55</sup> For further information see: Rob Kopmeiners et al. (2011): A Standardized and Flexible IPv6 Architecture for Field Area Networks. [http://www.cisco.com/web/strategy/docs/energy/ip\\_arch\\_sg\\_wp.pdf](http://www.cisco.com/web/strategy/docs/energy/ip_arch_sg_wp.pdf) [12.04.2013].

### *Comparison with ICT systems in other industries*

When designing appropriate security architectures, it is possible to draw on a wealth of experience from other industries. The banking sector in particular has many years of experience through million-fold use of secure data transmission over IP. Parallels can be drawn, especially with regard to the securing of the transport layer, but also partly to the encryption of the data to be transferred. Furthermore, smart grid users must be authenticated and authorised, just as banking clients during online banking.

Despite these parallels, additional challenges crop up, including variability of components participating in the smart grid on the one hand and, on the other hand, the fact that dynamic M2M communication is used in the majority of cases. Specifically, it is not possible to use additional security checks (e.g. pin, SMS TAN, chip card, etc.) for the authorisation of particular services. Instead, the components must be assessed as “trusted” via certificates, which makes it necessary to set up a resource-intensive public key infrastructure. Further challenges result from the complexity of the signal chain as well as the increase in data volume as a result of the encryption. This negatively impacts performance and latency.

### **3.3 The role of smart metering in the smart grid**

Smart meters constitute digital, so-called “intelligent measuring devices” that are connected to a central IT system by two-way communication link. Using this system, it is possible to, for example, remotely read all of the data recorded by the smart meter, remotely adjust the meter parameters and lock them, as well as release the meter for use by the consumer. In contrast to conventional electronic meters, it is therefore possible, for example, to read energy consumption values in high temporal resolution and set a wide range of tariffs and power limits. Smart metering denotes the entire ICT system – consisting of smart meters, communication links and central IT systems. In Austria, the appropriate functional minimum requirements for electricity meters are regulated by the IMA regulation.<sup>56</sup>

When considering the various smart grid applications, it becomes clear that a smart metering system is not a necessary precondition for an intelligent energy system. On the other hand, with the exception of network control of the medium voltage networks and flexible load management in the industrial sector, all implemented applications make use of smart meters because their advantages can support the functionality of smart grids well. This section should therefore demonstrate the role smart metering can play within a smart grid.

Within the scope of SGMS, smart meters are partly used as instruments within the building in order to provide data directly to a local component. In the B2G project, for example, smart meters represent a measuring point that passes data to the Building Energy Agent. In theory, it would also be possible to use other electronic meters with a one-way interface but without a two-way communication link for this purpose.

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<sup>56</sup> However, it must be noted that although the IMA regulation defines the minimum functional requirements, it merely requires “state of the art technology” with regard to protection and encryption (security) as well as data protection (privacy), without defining this technology more precisely and establishing the standards and norms to be applied.

Furthermore in the context of smart grids, smart metering systems can take on different tasks that place various demands on the overall architecture of the system:

- Timely consumption data and billing:  
Providing timely data on consumption (see C2G electricity consumption feedback methods) and monthly billing with the aim of increasing consumer awareness of energy consumption are often cited as reason for the introduction of smart metering. However, the results of the C2G project show no significant reduction in energy consumption that can be clearly mapped to one of the tested methods of feedback including monthly invoices (see Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**). It is likely that the increased awareness of energy consumption reported by the study participants could also be achieved even without a smart metering system, i.e. with less effort. A possible variant could involve, e.g., voluntary monthly collection of consumption data on the part of consumers by entering it into an online tool with an energy log.<sup>57</sup>
- Timely billing of incentive tariffs:  
A basic idea of the smart grid approach is to develop flexible production and consumption and to contribute to balancing by intelligently linking the flexibilities in a regionally differentiated manner. Energy and network tariffs with a suitable incentive for load shifting are expected to contribute to this optimisation of the overall system and thus to play an important role.<sup>58</sup> The possibilities range from time-variable rates to progressive volume- and load-based rates.<sup>59</sup> Such incentive tariffs are particularly relevant as input variables for the optimisation of operations at the object level such as, e.g., the individual optimisation of a building's energy consumption by a Building Energy Agent. Here, smart metering takes on an important function as a billing instrument. Such tariffs can neither be settled nor offered without remote reading of load profiles. This function is covered to the prescribed minimum degree by the ability of storing and once-daily remote reading of 15 minute load profiles. Due to the importance for a flexible electricity system this task can be stated as major argument for smart metering.
- Smart meters as offline or online measuring devices for network operations:

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<sup>57</sup> This approach is common in the Baltic states, e.g. Esti Energia (see: <https://www.energia.ee/en/naidud>): Residential electricity customers can report their meter reading between the last day of the month and the third day of the following month online and receive a monthly invoice. If no reading is reported, the monthly consumption is extrapolated using historical data. The meter reading must be reported at least once per year.

<sup>58</sup> It must be noted that no concrete experiences from SGMS field tests are presently available in this context.

<sup>59</sup> A time-variable tariff varies depending on the time of day in two or more stages and is set and announced in advance (typically for the following day). – „day ahead“).

A volume-progressive tariff depends on the amount consumed per unit of time (e.g. month) and is higher the greater the consumption.

A load-progressive tariff is dependent on the maximum consumption power in a certain unit of time (e.g. day or month) and is higher the greater the maximum consumption power.

According to the current state of the art, hardly any readings on actual voltages, active and reactive power, phase angles, etc. are available due to a lack of comprehensive implementation of measuring devices in low voltage networks. The integration of a large number of distributed generators increases both the need for measurements for improved planning (offline) as well as for operative monitoring systems (online) as a basis for intelligent control approaches. On the one hand, new instruments built for this purpose only could be implemented feeder by feeder, for example. On the other hand, it stands to reason to equip smart meters already installed for other tasks with additional functionality at specific points within the network and to use them as "eyes within the network".

So that the latter is possible, the relevant smart meters must capture the network-relevant parameters, i.e. voltage, currents, power and power-quality parameters and, e.g., send them to a data concentrator or router in the transformer station. Should these values be used for controlling purposes, it is necessary to transfer them within a minute range. This requires a corresponding bandwidth and a secure, bi-directional communication link, e.g. based on the IEEE standards P1901. The pilot projects ISOLVES and DG Demonetz Smart Low voltage Grid show that smart meters can be useful for these tasks. Currently, however, the appropriate functionality is supported by very few manufacturers. Also, the currently available smart meter communication links frequently do not comply with the described requirements for smart metering as online measuring devices for network operations. Besides the statutory minimum requirements should be specified further in this context.

- Other possible uses for smart metering systems include first-time accurate determination of power losses, as well as timely isolation of mains interference and outages.

In sum, smart metering tasks must exceed the provision of timely consumption data and billing. Only an integrated view of smart metering within the entire smart grid context can ensure that the technology provides clear added value and synergies (see Chapter 3.1) are utilised. In addition, on this basis it can be ensured that the overall architecture of the smart metering system is adapted to all requirements. This includes, for example, the dimensioning of bandwidth and the speed of the communication link as well as data storage, processing and management.

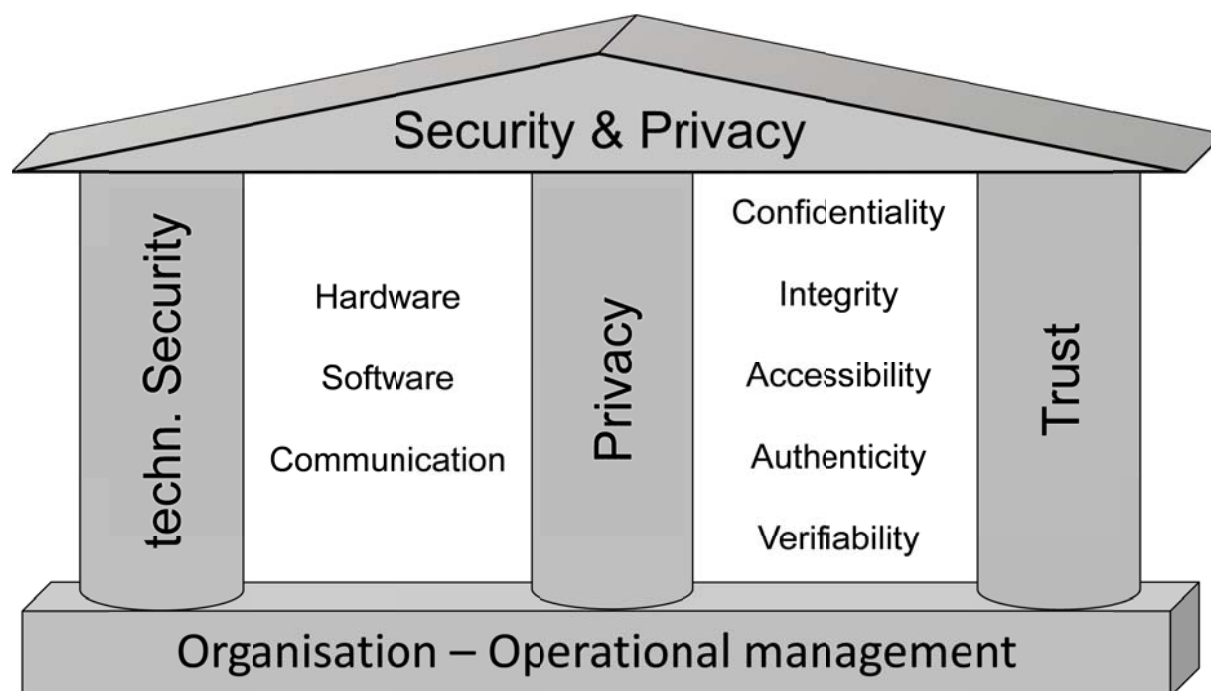
In this regard, it is crucial to formulate the requirements of the various currently foreseeable smart grid applications before a roll-out and take them into account in the specification of the smart metering system. Smart metering should be viewed as an integrated component of the overall smart grid system and the ICT architecture. As far as possible, standards such as IEEE P1901 should be used so as to not obstruct future functionality, to utilise possible synergies and to ensure investment security by preventing technological dead ends.

Uncoordinated implementation with a too narrow focus would not allow for all functions to be utilised and would therefore jeopardise the opportunity to use the system as a building block to create an intelligent power system.

### **3.4 Security & privacy within the smart grid**

The increased need for the use of ICT in smart grids makes this issue particularly important. Data security, data protection and protection of privacy (summarised as privacy) are of vital importance to safely operate these systems and gain participants' trust. Against this back-

ground, the SGMS projects were proactively examined with regard to security and privacy. To this end, a task force of employees of SGMS partners was deployed with the aim of analysing the prevailing or planned ICT architectures, identifying potential vulnerabilities and risks as well as inferring potential countermeasures.



**Figure 6: The Security & Privacy building in the smart grid**

The provision of a total system of security and privacy in the smart grid is based on the following three pillars (see Figure 6):

- “Technical security” includes the security of the technical components based on the ICT architecture, ranging from hardware (e.g. smart meters) to data transfer (e.g. IP networks) to software systems (e.g., SCADA systems, meter data management system).
- The second pillar, “data protection”, comprises the legal framework and defines the permissibility of data applications and data transmission in order to protect against misuse of personal data (see Data Protection Act,<sup>60</sup> DSG 2000).
- The third pillar, “trust”, deals with the acceptance of the user or subscriber whose data is being processed, and possible measures to promote trust.

Uninterrupted assurance of these three pillars during operations requires a “foundation” of precisely defined and documented operational management of the ICT systems.

<sup>60</sup> This is based on the Federal Act on the Protection of Personal Data (Data Protection Act 2000 - DSG 2000) BGBl. I no. 165/1999 in the currently valid version.

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### *Technical security*

As a first step, current and planned ICT systems are to be depicted in order to simulate possible threats and identify vulnerabilities. This is based on a unified representation and grouping of the network topologies. Countermeasures must be defined for the threats and their effectiveness is to be assessed. On the basis of this analysis it is possible to derive measures covering the main technical security risks, such as:

- ensuring a centrally manageable locking system and key management,
- securing all interfaces or wireless connection (e.g. through encryption, authentication or certificates) and shrinking the affected area (e.g. through formation of isolated networks or Virtual Private Networks),
- meaningful grouping (clustering) and hardening of servers (timely updates and change management),
- backing up servers (e.g. via firewalls) and applications (e.g. through policy enforcement/decision points).

### *Data protection*

In terms of data protection, relevant laws and decrees were analysed, with the defining the fundamental requirements. The results of the analysis of the data used in the SGMS projects and the discussion a leading privacy expert can summarised as follows:

- Personal data such as the energy consumption profile of residential customers does not constitute sensitive data within the scope of the DSGVO, which encompasses, for example, racial or ethnic origin, political opinions, trade union membership, religious and philosophical conviction, health and sex life.
- Explicit written consent of the person concerned is required for use of such personal data in compliance with the relevant supervisory laws (e.g. EIWOG) due to a lack of regulations. For research projects in which people voluntarily participate, it is necessary to obtain written consent, revocable at any time. This was done in the relevant SGMS projects. If use of the data is required for a particular product or service, the consent to the use of personal data may be also part of the contract with the consumer.
- With regard to the relevant data protection applications, it is necessary to file a report with the Data Processing Register (DVR<sup>61</sup>) because they are not standard applications according to the DSGVO. The Data Protection Commission (DSK<sup>60</sup>) will conduct a review of the report. The relevant data applications of the SGMS projects were registered with the DVR.
- The exact operation of the smart grid applications and the required data were not defined conclusively in the research projects of SGMS. The principles of the least invasive means (data minimisation principle) and earmarking are therefore observed.

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<sup>61</sup> German abbreviations; Data Processing Register – Datenverarbeitungsregister (DVR) and Data Protection Commission – Datenschutzkommission (DSK)

## *Trust*

For residential customers as participants and players in the intelligent energy system, the primary need for protection consists of high confidentiality and, above all, in the accuracy of the data used. It is therefore necessary to ensure trust from the user's point of view as a third pillar, going beyond the data protection regulations. Based on experiences and insights from SGMS and similar projects, the following recommendations were derived for the creation of user-side trust and acceptance:

- Start an open dialogue,
- Strengthen acceptance through freedom of choice,
- Ensure informational self-determination of residential customers, respect fundamental rights,
- Inform consumers without overwhelming them,
- Enable goal-oriented feedback,
- Privacy by design: consider data protection and data security in all phases of the introduction,
- Investigate behaviour of residential customers, make use of opportunities,
- Involve operators, regulatory authorities, energy agencies, data and consumer protection bodies, IT security institutions, etc.,
- Create and communicate a cost-benefit analysis based on robust data.

These recommendations serve as a guide for dealing with participants in the SGMS projects and in particular for the design of new data applications.

## *Organisation and operational management*

To ensure that the issue was addressed in a structured manner, it was recommended that an internal Security & Privacy Advisory Board advise the project teams at Salzburg AG and also all relevant applications in the core business on matters of data security and protection. The advisory board should already be integrated in the design phase. Furthermore, the board should take up the following tasks:

- Review of privacy and security for all relevant projects before they are handed over to operational management,
- Periodic review of privacy and security during operational management,
- Implementation of a process for passing from test operations to productive operations.

## *Privacy & security by design*

When the principles outlined here are followed from the outset in the design and development of prototypes, this is called privacy & security by design. This has already been implemented in the Smart Web Grid project during planning and prototypical implementation of the information platform and should serve as a benchmark for future projects and applications.

## **3.5 Quantitative assessment**

Quantification denotes the expression of facts or benefits in the form of numbers, serving as the basis for evaluation and decision-making. The use of smart grid applications often entails benefits that cannot be clearly quantified or assessed monetarily. This frequently significantly

complicates comparisons and cost benefit analyses (CBA). Examples include the quantification of avoided electricity network reinforcement, the environmental benefits of the reduction of CO<sub>2</sub> emissions or the increase in comfort due to automation in the residential customer segment.

In the context of SGMS, quantitative assessment plays an increasingly important role because the detailed inventory and assessment of benefits and costs represents essential information for further activities. As an example, the results of the quantitative assessment of three technologies or projects are briefly summarised below. The results refer to different application areas, respectively:

- electric mobility within the V2G Interfaces project,
- network control in relation to the ZUQDE project,
- load flexibility based on the example of B2G.

Because the electric mobility approach is vastly different from those of grid control and load flexibility, the approach and its results are dealt with separately.

### *Electric mobility*

In the context of the V2G Interfaces project, possible business models and customer integration strategies were identified and analysed with regard to feasibility.

These mainly differ on the issue of the players involved, as well as their offers. In general, a distinction is made between electric mobility customers, mobility service providers and grid operators. Cost-benefit calculations are used as the main method, as the prepared business models can be monetarily compared with their help. The approach quantifies only the material costs and revenues and neglects the intangible factors important from a macroeconomic perspective such as, for example, the environmental benefits.

On the one hand, these calculations show that feeding back of the electricity from electric vehicles into the electricity network (vehicle to grid) is not economically viable. On the other hand, from a business perspective, they give rise to the recommendation that interfaces such as smart phones be provided by the customers themselves rather than the electric mobility provider.

### *Approaches in the field of grid control and load flexibility*

To facilitate the quantification of benefits and an macroeconomically-oriented approach as well as a unified approach to the CBA of smart grid projects, EURELECTRIC<sup>62</sup> and JRC<sup>63</sup> published the so-called ‘Smartness Barometer’ in early 2012.

The methodology divided into seven steps not only resulted in a quantitative outcome, but also in focal points for the projects using a uniform nomenclature.

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<sup>62</sup> EURELECTRIC is a trade group of the European electricity industry.

<sup>63</sup> JRC denotes the Joint Research Centre of the European Commission.

The ZUQDE project was selected for the initial trials of the Smartness Barometer. The focus determined using the methodology, which also corresponds to the stated goal of the project, is the integration of additional distributed generators in the distribution network.

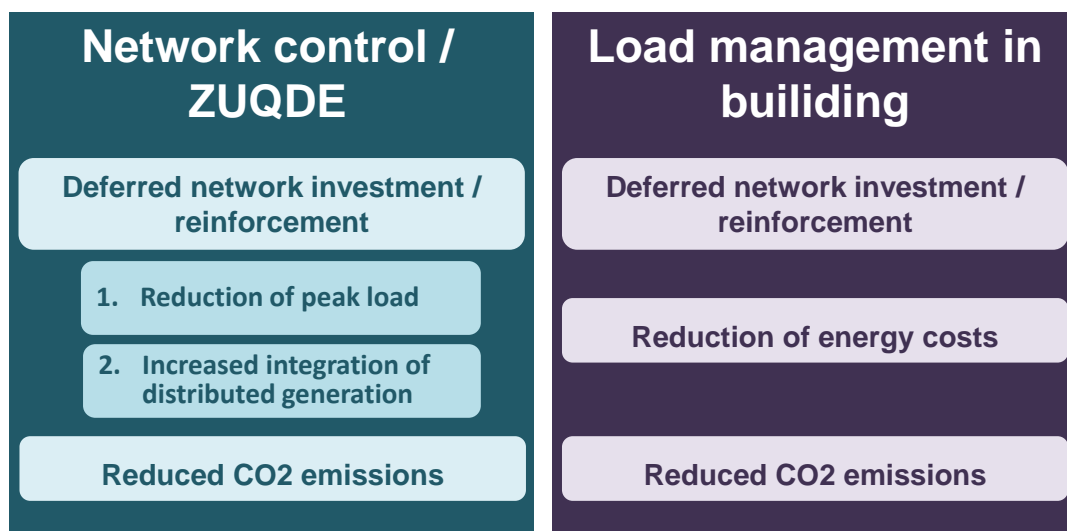
The implementation resulted in the realisation that the methodology is very helpful for a consistent comparison of costs and benefits of smart grid projects as long as one does not expect precise, absolute values as a result of the assessment.

Therefore, the Smartness Barometer was no longer used comprehensively and in detail for the assessment of load flexibility within the framework of the B2G project, but above all to determine benefits. In this project, the quantification of benefits by shiftable loads represents the greatest difficulty. Once an invoice has been issued, it is applicable to applications with the same benefits as, for example, load shifting in the commerce and industry sectors. For this reason, the following passages only use the more general term “load flexibility”.

Furthermore, in contrast to the CBA of ZUQDE, no costs are considered yet due to the current uncertainty of the information. Thus, the question, “How much can the solution cost?”, represents the focus in the considered case on increasing load flexibility.

### *Results on grid control and load flexibility*

The first steps of the CBA determined the functionality and benefits of ZUQDE network control and load flexibility by applying the Smartness Barometer. Similarities and differences exist, as depicted in Figure 7.



**Figure 7: Comparison of grid control and load flexibility benefits**

Both active network control as well as load flexibility allow deferred network reinforcement. The former causes a reduction of the maximum load through a decrease of voltage using on-load tap changer transformers in the substation, which can ensure network stability in critical situations. Furthermore, the co-ordinated control of transformers in the substation and reactive power management of generators enable an increased integration of distributed genera-

tors in the respective network section.<sup>64</sup> This benefit also implies the reduction of CO<sub>2</sub> emissions because the existing energy mix can be replaced by renewable energies.

Load shifting can also lead to deferred network reinforcement. However, this arises from the fact that, at peak times, the load and thus energy consumption is reduced and shifted to other times. The operation of peak-load power plants is thus avoided, implying savings of greenhouse gas emissions. In contrast to active network control, however, this type of flexibility comes with the potential benefits of a reduction in electricity costs for the provider. The provider can thus achieve an optimised procurement on the electricity market through load shifting.

If these benefits are to be calculated or quantified, the following question must be raised, both for active network control as well as increased load flexibility: How can the deferred network reinforcement caused by reduced maximum power / capacity need be represented in monetary terms? It must be calculated how much a kilowatt of network capacity costs in each network level and how much an assured kilowatt in power reduction is worth to the operator. A cost rollup allocation was carried out to solve this problem. It was based purely on power values on the basis of the methodology described in EIWOG<sup>65</sup>, resulting in values of euros per kW for the different network levels.<sup>66</sup> However, the results vary depending on the power calculation approach used. To obtain a representative range, three different types of power calculation were used:

- Total network capacity per network level,
- Total network capacity per network level plus installed maximum capacity of all generators connected,
- Total billed power actually rendered, based on average of the yearly peak load (total of the peak loads for each month divided by 12).

Due to coincidence, the power values of the last method are lower, resulting in a higher euro per kW value. The first two variants represent more source-related approaches. In network level 5, for example, values of approximately 22 euros per kW (2<sup>nd</sup> option) to approximately 104 euros per kW (last option) thus arise.

With the help of the values obtained from this cost rollup allocation, the cost-benefit balance in the ZUQDE project could be completed. The results show that the total benefits exceed total costs (see Figure 8). Furthermore, the solution represents a good alternative to conventional network reinforcement, especially in newer network sections. However, when looking at the individual market participants, it becomes clear that costs and benefits are not evenly divided across participants. Accordingly, the DSO bears the largest part of the cost which are

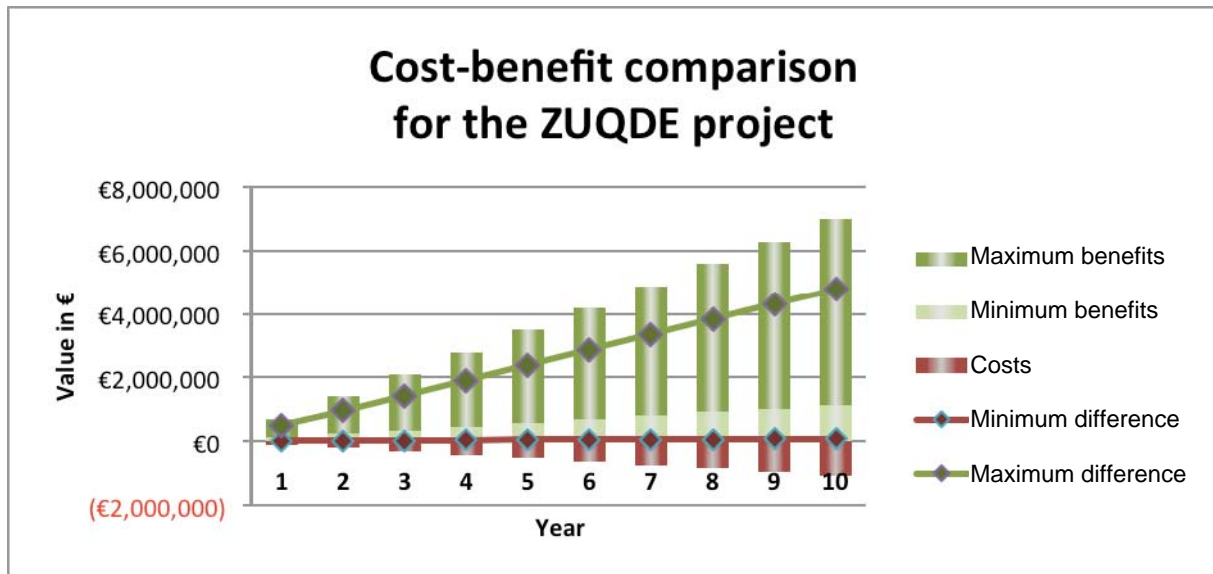
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<sup>64</sup> These two benefits can overlap depending on the network segment so that a simple addition is not possible. This fact was taken into account using a factor.

<sup>65</sup> The cost-rollup allocation is described in §62 EIWOG 2010, BGBl. I no. 110/2010.

<sup>66</sup> This static calculation assumes that required services will not lead to a jump in fixed costs.

ultimately transferred predominantly to consumers, while generators significantly benefit from the ZUQDE system.



**Figure 8: Comparison of costs and benefits for the ZUQDE project**

In the field of load flexibility the benefits due to the delay of network reinforcement can also be shown using the abovementioned cost rollup approach. For example, an assured power reduction of 50 kW per building at network level 6 over a period of 20 years results in benefits in the range of € 15,981 to € 80,128. This provides initial orientation with regard to the legitimate capital and operating costs for the development of flexibility.

In addition to the deferred network reinforcement, it is also necessary to consider the reduction of energy costs that can be achieved through the optimisation of energy consumption with regard to the energy market. It makes use of price fluctuations in the electricity market so that energy is consumed at times when it is cheaper.

Thus, this results in two interests with regard to load shifting: on the one hand, the point of view of the DSO that instates network operating limits in the event of an overload or violation. On the other hand, the perspective of the electricity market, which aims to balance supply and demand with help of varying prices. Often, both interests occur at the same time. This means that in times when the demand, and therefore the price of the energy market, is high, the network is under heavier strain. In this case, both benefits would add up.

When the interests of distribution system operation and market conflict, it is necessary to find a way to take both into account sufficiently and to not neglect the welfare of the general public. The question of how the electricity market and network requirements can be optimised together and depicted in a market model is the focus of Chapter 3.8.

As long as this is not regulated or specified, an accurate calculation of the benefits of increased load flexibility is difficult. The next steps therefore consider, and if necessary calculate, the following aspects:

- Frequency of conflicts of interest between electricity market and network,
- Any resulting limitations of the benefit of reduced electricity costs,

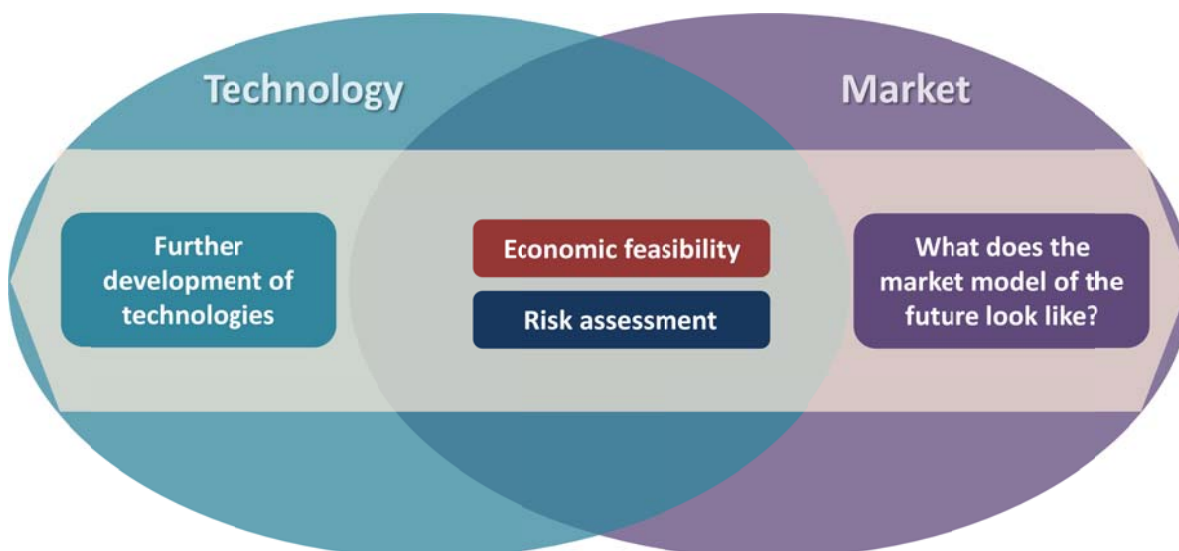
- Identification of network tariff models, e.g., to compensate these benefit limitations.

In addition, it is important to determine the actual cost of the flexibilisation of one kilowatt. The previously available costs come from research projects and cannot be transferred directly to commercial, standardised applications. A reduction in costs is expected in the future, however.

In summary, fundamental insights regarding their future viability can be extracted from quantitative assessments of projects and technologies. Therefore, the issue will be expanded to other applications when the examination of load flexibility is complete.

### 3.6 Open questions

As the individual projects mainly focused on the development and improvement of technical applications, the future will focus more on the question of how everyday solutions and products can be developed from prototypes. This means that in addition to the focus on technology, the consideration of markets will play a very important role. Figure 9 is divided into the two fields of technology and market, which have a common intersection.

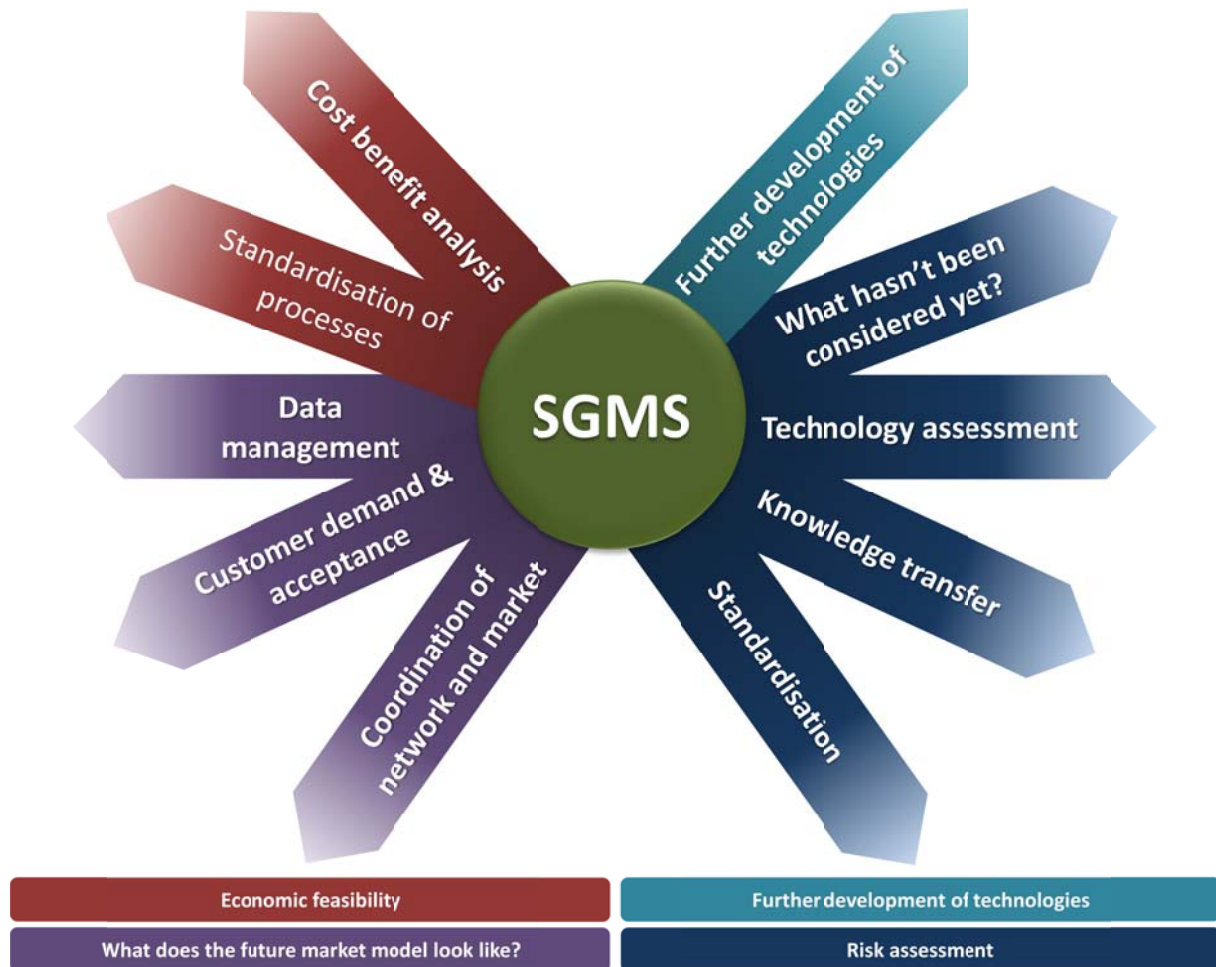


**Figure 9: From prototypes to everyday solutions and products**

When a company faces the question of whether it should invest in a product or its development, two questions are important: on the one hand, the expected cost-benefit relations must be known. On the other hand, the associated probability of success and the associated risk should be assessed.

However, as a basis for the calculation of profitability and risk, the market model and the demand should be known. In smart grids, many applications still lack a market, so that the relationships and roles of the market players can so far only be estimated vaguely. Often, it is not even known whether a demand for various applications exists at all and whether sufficient acceptance can be expected on the part of potential users. Therefore, the question of what the market model and demand will be like needs to be answered in the future. The assumptions made in this regard will in turn influence the investment risk.

The open questions involving cross-application aspects of the SGMS projects were allocated to the four blocks depicted in Figure 9 and grouped into clusters or directions (see Figure 10).



**Figure 10: Focal points of the open questions in the model region**

### *Further development of technologies*

In addition to the goal of developing everyday solutions and market-ready products, technological development must not stagnate. Especially in a rapidly changing environment such as the telecommunications sector, for example, it is particularly important to take into account the rapidly changing state of technology. The prototypes developed and tested in the smart grid projects are thus to be developed further into marketable products and solutions, without neglecting the current state of the art.

The physical and logical interface for communication between the electricity network and the individual applications is an example of the need for further development. Thus, for example, the charging stations of electric vehicles or the building energy agent require information on the current – and therefore regionally and temporally differentiated – network status. To minimise the burden, this communication interface needs to be standardised and implemented in such a way that it can be used by as many applications as possible.

To facilitate the convergence of different applications into an overall smart grid system, it was found within the scope of SGMS that IP technology can be used as a common basis of communication. Today, all smart grid applications can already be implemented over IP. Thus, a cost effective solution should be found to incorporate smart meters into this convergence layer in order to utilise further synergies.

Complexity increases when viewing and comparing various smart grid applications at the same time. It is therefore recommended to implement a structured representation by using consistent descriptions of the individual applications and functionalities and their integration into a reference architecture. This also allows one to recognise similarities and uncover “gaps” or other application combinations.<sup>67</sup>

### *Economic feasibility*

The issue of economy feasibility includes all open questions dealing with costs and benefits, as well as with future business models and their optimisation. This is related to the resulting activities such as a more equitable allocation of costs and benefits and putting necessary incentives through flexible tariffs or fees.

- **Cost benefit analysis**

Investment in a product or application must be economically feasible at least in the medium-to-long term so that they can be offered on the market. If this is not possible for individual applications, combinations of multiple applications should be considered wherever synergies can be utilised at their interfaces. If a positive result is obtained, the next step lies in finding out whether costs and benefits are balanced reasonably for each stakeholder. This is not the case with the ZUQDE project, for example, so an appropriate allocation of costs and benefits must be considered. Their implementation should be decided and defined politically and secured by laws or market rules.

- **Standardisation of processes**

The result of the cost-benefit balance may also lead to the realisation that the internal costs, from the order to the delivered of the finished product, are too high under current conditions. In this case, it can be necessary to consider potential economies of scale or scope, or to unify and standardise certain internal processes. The question of whether the individual engineering efforts can be reduced, for example, through a modular offer or a consistent service process is to be answered, if possible.

### *Risk assessment*

Under the condition that SGMS produces marketable or beneficial products or services, it is also vital to know the probability or risk of the occurrence of these market scenarios.

- **Technology assessment**

This could include a technology assessment which can critically question uncertain assumptions or have an in-depth look at the emergence of other hitherto completely underservedly ignored technologies. Sensitivity analyses and the structured creation of scenar-

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<sup>67</sup> This question is addressed in the INTEGRA project.

ios based on them are beneficial tools. An exemplary question could be, for example, how energy self-sufficient buildings can be made compatible with the development of the smart grid.

- **Knowledge transfer and standardisation**

The risk of neglecting important aspects and technologies can be reduced by a targeted exchange with other companies and institutions researching in the field of smart grids. One can attempt to have one's own activities and assumptions follow the general trend, including the current state of knowledge and therefore remaining transferable to other conditions, energy networks and markets. Furthermore, participation in standardisation committees enables national or international establishment of technologies already in use by the consortium. This increases the likelihood of market success for products based on this technology or standard. With regard to both measures, the following questions must be clarified on both a corporate as well as at national level:

- What can participation in the process of knowledge transfer or standardisation entail?
- Who should be the driver and coordinator of such processes?
- How can a national unified strategy incorporating all relevant aspects<sup>68</sup> be created?

In addition, it is also important that the insights previously gained from different national projects are collected, jointly analysed and evaluated. Based on these insights, “lessons learnt” and “next steps” can be derived. Such processes could be initiated and coordinated by joint initiatives such as the National Technology Platform Smart Grids Austria.

A further point concerning the issue of knowledge transfer is the need to train future skilled workers in the relevant smart grid areas. Through the close relationship between communication and power engineering solutions, for example, more cross-trained experts will be necessary in the future. Corresponding training programmes at all levels of expertise are required in order to design according to needs and develop in a timely manner.

- **What hasn't been considered yet?**

A comparison with the activities and findings of other enterprises and institutions also uncovers one's own gaps. These gaps can include a particular technology that has not yet been taken into account or even an idea for an alternative design of a business model.

Within the framework of SGMS, for example, the topics of (decentralised) storage of electricity and whether it can become economically significant through sensible combination with other technologies as well as more effective use of interfaces of the electricity grid with other energy networks such as district heating and gas have thus far not been considered. The Smart Heat Net project focuses mainly on methods for reducing the peak load in the district heating network. However, the potentially emerging synergies from the

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<sup>68</sup> These include the electric mobility strategy, Smart Grids Roadmap Austria, etc.

joining of both networks were not included in the project framework for resource-related reasons.

Furthermore, questions arise regarding additional services for residential customer applications that can be enabled and provided by smart grid technologies. They need not be directly related to the electricity system, but employ a thus far unused party. Examples include ambient assisted living or (mobile) security services for the home.

### *What can the future market model and demand look like?*

The risks concerning smart grids are additionally increased by a yet unknown future market model<sup>69</sup>. In addition to the assessment of the product, it is therefore recommended to deal more comprehensively and across stakeholders with the issue of the future market. This includes fundamental issues such as the roles and activities of the future market players and as well as the question of how they will relate to each other:

- **Information and data management**

For example, the accountability and organisation of the comprehensive information and data management<sup>70</sup> in the smart grid environment represents an unsolved issue. Due to the amount of data and information that is collected with the help of all applications, it is necessary to define players that manage this data and make it available to and usable by all market participants. At EU level different organisational models are under discussion. From the perspective of SGMS, the model “DSO as market facilitator” is preferable, since DSOs are already obliged to provide their infrastructure without discrimination. As a neutral data hub, they could provide the basis for innovative services in the market area while ensuring security and quality of supply in the distribution network through direct and rapid access to all relevant data and network operation figures.

An alternative would be a so-called “third party market facilitator” that allows authorised players to send and use data in the form of a regulated communications platform. The cost of establishing such a platform is, however, very high.

- **Coordination of electricity market and networks**

Furthermore, it is necessary to find and establish a model for balancing the electricity market and network requirements (see Chapter 3.8). Third-party services, i.e. providing flexibilities through a flexibility operator, should only be considered if safe network operation is ensured.

The next step must clarify in detail how the role of flexibility operator must be designed in order to optimally combine the different target functions of the market and transmission and distribution networks. The traffic light model (see Chapter 3.8) represents a possible approach, to be detailed further here.

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<sup>69</sup> It must be noted at this point that the market model should be adapted to optimally support the transition to renewable energy, instead of enforcing the implementation of smart grids. Smart grids are a means to an end, but not an end in itself.

<sup>70</sup> For further information, see: Smart Grid Task Force of the European Commission (2013): EG3 First Year Report: Options on handling Smart Grids Data.

- **Customer demand and acceptance**

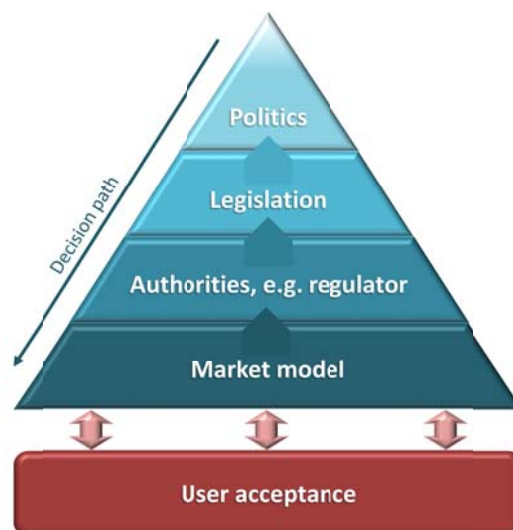
In order to provide a product at all in the future, sufficient demand and acceptance must be ensured.

Consequently, it should be kept in mind to create a clear added value through the applications so that residential customers' willingness to pay for these products is encouraged. Many of the requirements for energy efficiency and smart grid controls are seen as the "obligation of energy utilities", whereby the willingness to pay for coverage of the considerable expenses is insufficient. The question of whether and how this behaviour will change in the future needs to be looked at.

In this context, it might also be necessary to train users. This can be done on a broad basis, or via image campaigns aimed at an improved acceptance especially in the area of residential customers.

### 3.7 Requirements for the institutional framework

During the implementation of projects, the SGMS team often came across barriers whose causes were often attributed to the current market model – frequently across the board. A differentiated look reveals that the causes of such barriers are located at different levels of the institutional framework in energy sector (see Figure 11).

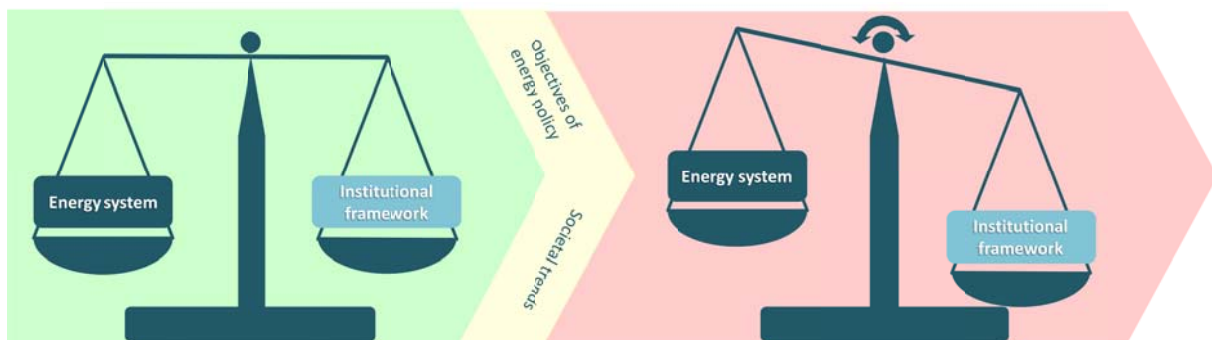


**Figure 11: Levels of the institutional framework**

The reasons for significant changes in the market model are often located at the top level, i.e., the politics that specify (energy) policy objectives. There, laws are passed that are interpreted and implemented by the authorities. This resulting market model links together individual players or defines their relationship with each other. To enable effective cooperation, standardisation processes will be necessary at technical interfaces or in the case of data transport or data transfer, resulting in the development of and adherence to a standard. Since standardisation processes are mostly driven by the various market players or by corresponding associations, they are not included in the pyramid of the institutional framework (see Figure 11). The authorities and legislators should however consider these national and international processes, standards and mandates in their elaborations.

Users of smart grid applications form the base of this pyramid. Without their willingness to accept a decision, a law or a product, activities at all other levels are difficult and cannot be implemented sustainably. The market model as a result of the implementation of political decisions should naturally and ideally be supported by the broadest possible user acceptance.

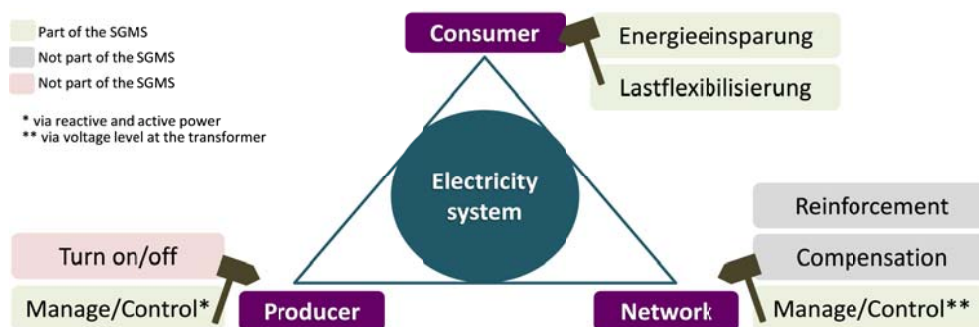
In the wake of increased orientation towards sustainability in energy policy, policy decisions resulted in an imbalance between the market model of the energy system and the institutional framework, as illustrated by Figure 12. The scales serve to symbolically illustrate the matching of the energy system with its institutional framework. Prior to the positioning towards the energy transition (Energiewende), the institutional framework facilitated proper operation of the market model in the energy sector. Today, new market players, processes, interfaces, technologies and applications have been developed to implement the policies, for example, ensuring the increased integration of renewable energy in the system. These innovations require adjustment of the institutional framework that cannot yet be foreseen in detail for all facets of the transition to renewable energy.



**Figure 12: Consequences of the energy transition on the balance between the energy system and institutional framework**

Fine-tuning is made easier when the barriers and problems of pilot and demonstration projects become known and can be mapped to the appropriate levels. To create this chapter, the project managers of the individual SGMS projects were interviewed on this subject and asked to incorporate issues and barriers into the levels of the institutional framework. All results were summarised and priorities were identified. They are reflected in the following tables (see Table 2 and Table 3) as well as in the following points.

The common objective of all SGMS projects lies in the optimised use of the energy network infrastructure as well as increasing flexibility of production and consumption in order to balance the power in the grid and specific sections of the network at the distribution network level. Producers, consumers and the electricity network are the key players in the energy system. They cannot be viewed as completely detached from each other, but rather occur in combination – as in the case of prosumers. Various tools can be used with any player to adjust consumption, supply and transmission to future challenges (see Figure 13).



**Figure 13: Tools to promote greater flexibility of the energy system**

The variety of the described approaches and tools in the electricity system which entail new interactions with stakeholders require a definition and specification of adapted rules to promote cooperation. Based on the current rules and laws,<sup>71</sup> they must be expanded and adapted with regard to the requirements of the transition to renewable energy. This includes, for example, intervention in residential customer equipment in order to shift heating power or control reactive power management of generators. In both cases, barriers have occurred that are defined below.

#### *Measures on the consumer side*

To increase energy efficiency and flexibility in power consumption, it is possible to use energy savings with the help of energy feedback methods on the one hand, and load flexibility on the other hand. The latter includes deliberate load shifting based on recommended actions (see FORE-Watch, Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**), management of consumers via building automation and controlled or adaptive charging of electric vehicles.

Apart from the question of cost allocation<sup>72</sup>, there are hardly any problems with the existing institutional framework regarding energy savings. Possible barriers in relation to data protection and privacy could arise due to processing, collection or storage of real-time data.<sup>73</sup> However, the tools for load shifting require various adjustments, as presented in Table 2. This is due to the different areas and technologies that are analysed for load flexibility.

**Table 2: Overview of adaptations to the institutional framework for the inclusion of consumers**

<sup>71</sup> The provisions of EIWOG 2010 (Elektrizitätswirtschafts- und -organisationsgesetz) constitute the basis of the current market model.

<sup>72</sup> In the field trials, the project partners covered development costs and Salzburg AG provided the service to the testers free of charge. In the future, it will be necessary to find a model that also includes residential customers in the costs, as long as the feedback exceeds the minimum standards specified by law.

<sup>73</sup> Explicit, written consent of the person concerned is required for use of personal data in compliance with the relevant supervisory laws (e.g. EIWOG) due to a lack of regulations.

<b>Politics</b>	<ul style="list-style-type: none"> <li>• Whose task is the implementation of “behind-the-meter” solutions?</li> <li>• Smart incentive schemes to promote electric mobility</li> </ul>
<b>Legislation</b>	<ul style="list-style-type: none"> <li>• Integration of building automation into the Energy Performance Certificate</li> <li>• Definition of a flexibility operator</li> <li>• Future obligation to connect charging stations for electric cars to a flexibility operator in order to enable controlled and adaptive charging</li> <li>• Clarification of data privacy provisions when using smart metering</li> <li>• Adjustments to the measurement and calibration laws relating to smart meters, e.g. in order to extend service life and thus exchange periods</li> </ul>
<b>Authorities</b>	<ul style="list-style-type: none"> <li>• Definition of standard requirements for the charging stations of electric vehicles</li> <li>• Type and structure of flexible tariffs</li> <li>• Specification and design of flexible tariffs<sup>74</sup></li> <li>• Coordination of requirements in the electricity and telecommunications market with regard to the use of synergies during comprehensive expansion</li> </ul>
<b>Market model</b>	<ul style="list-style-type: none"> <li>• Creation of market-based incentives for residential and industrial customers (e.g. flexible tariff structures, power and capacity orientated network tariffs)</li> <li>• Design principles for equal treatment of consumers and prosumers during integration into network control</li> </ul>
<b>Acceptance</b>	<ul style="list-style-type: none"> <li>• To overcome privacy concerns: <ul style="list-style-type: none"> <li>○ Transmission of aggregated data</li> <li>○ Reduction of temporal resolution</li> <li>○ Incentive systems for the transmission of energy data</li> <li>○ Allow intervention of residential consumers in the forecasts on load shifting</li> </ul> </li> </ul>

<sup>74</sup> This refers to more flexible energy as well as network tariff items. The flexibilisation of the network tariff structure should be thought over and adapted, from network access and network use, to optional network tariff elements. The optimisation of the overall tariff structure (network and energy tariff) must also incorporate the expansion of renewable energy and energy efficiency objectives as well as the necessary network infrastructure for integration of renewables and the characteristic consumption pattern as decisive parameters. EIWOG 2010 (§52(1)) enables the regulatory authority to design time and capacity dependent network tariffs while ensuring a consistent tariff structure.

### Measures on the producer side

The producer can be incorporated either through active network control or by increasing or reducing the fed-in active power production.

For network control with the aim of voltage band management, distributed generators in medium voltage networks were incorporated particularly, but also residential consumers as prosumers in low voltage networks. The methods include the control of generated reactive and active power production. However, the focus lies on reactive power because it is possible to control without financial losses on the part of the producer.

Restriction of active power production has not been applied so far. However, it would be the logical next step, since a significant reduction of the required network capacity can be achieved by curtailing the absolute peak loads of photovoltaic and wind power plants, for example. If this is done, however, compensation for lost revenue on the part of the producer must be clarified.

A summary of relevant barriers to the integration of producers is shown in Table 3.

**Table 3: Overview of adaptations to the institutional framework for the inclusion of producers**

<b>Politics</b>	<ul style="list-style-type: none"> <li>• In case of an emergency, can the DSO also influence active power supply or is this an excessive restriction of the generator?<sup>75</sup></li> <li>• Discussion and allocation of costs and benefits of smart grid solutions; cost allocation and recognition of measures; source-related feed-in tariffs vs. promotion of renewable energies</li> </ul>
<b>Legislation</b>	<ul style="list-style-type: none"> <li>• Obligation to participate in the network control actions when connecting a generating plant</li> <li>• Equal treatment of all network users, taking into account regionally differentiated requirements such as integration into the network control as necessary</li> <li>• Definition of conditions for the restriction of active power</li> <li>• Allowing more flexible contractual elements<sup>76</sup></li> </ul>

<sup>75</sup> In Germany, within the scope of the German Renewable Energy Sources Act (EEG), operators of plants from 100 kW upwards were obliged to technically enable remote-controlled limiting of the feed line feed-in (see EEG §6(1)).

<sup>76</sup> Due to statutory equality of all grid users in connection with the obligation to bill cost-causing grid connection costs, the DSO is forced to charge the direct network access costs to producers. However, this can make projects uneconomical for producers so they cannot be implemented. Through flexible contractual elements (in terms of technology, tariffs, time, location, load, type of production, etc.) it would be possible to make the integration of producers more flexible in relation to existing network structure and the requirements of producers.

<b>Authorities</b>	<ul style="list-style-type: none"> <li>• Obligation of the generator to prepare an ICT connection or to share the cost of laying data cables</li> <li>• Allocation models for reactive power</li> </ul>
<b>Market model</b>	<ul style="list-style-type: none"> <li>• Incentives for the integration of existing generation units into the new control and market mechanisms</li> </ul>
<b>Acceptance</b>	<ul style="list-style-type: none"> <li>• Network control as interference in the internal affairs of producers</li> </ul>

All in all, due to the use of tools for greater flexibility of the power grid, adjustments at all levels are necessary to bring the future market model in the electricity system into balance with the institutional framework.

In addition to the previously mentioned topics, the following aspects have resulted from the SGMS projects, which should be taken into account in the course of an adjustment of the institutional framework:

#### *Limited incentives for smart investments*

The current incentive regulation system in Austria ensures that investments will be refunded to the network operator with a maximum delay of two years and without efficiency reductions within a regulatory period. Although EIWOG 2010 §59(1) allows for the adequate consideration of costs for the efficient implementation of new technologies, grid operators have few incentives to make “smart” investments instead of conventional ones.<sup>77</sup>

If a grid operator invests in smart grid solutions such as new control solutions which then improve the cost efficiency of the network connection of distributed generation units, this is useful and worthy of support from an macroeconomic point of view, but from a business perspective, costs are moved to other market participants and business disadvantages arise for the DSO concerned, at least within the current regulatory period. This is expressed, for example, in the form of higher system utilisation fees for producers and consumers, or a poorer positioning in the benchmarking within the framework of the incentive regulation for DSOs. The manner in which potential economic benefits in the context of the regulatory system could be taken into account and promoted must be defined in the regulatory framework. There is no question that the rigid separation of the individual market players does not support optimal solutions for efficient network investment, at least from an macroeconomic point of view. Thus, the tasks of DSOs currently do not foresee investing in storage instead of network reinforcement, since the operator would then take on the role of an energy trader instead.<sup>78</sup>

<sup>77</sup> This includes investments in smart grids, which can delay more expensive conventional methods such as network reinforcement with the help of newer management and control methods and the use of ICT.

<sup>78</sup> See §26 EIWOG 2010, BGBl. I no. 110/2010.

Furthermore, it should be discussed whether and how DSO's investments in intelligent technology are to be split among the various market players and beneficiaries. An efficient transition to renewable energy is only possible when optimal economic conditions are created for each player.

### *Lack of incentives for additional services in the regulated area of the DSO*

If DSO can successfully put additional services such as energy consulting or home automation on the market and make a profit, these profits are offset against the regulated network costs. This is due to the monopoly position of the DSO. In this context, the regulation rules regarding the consideration of not marketable costs can be viewed as barriers inhibition to innovation.

The DSO should therefore be allowed to generate additional profit or losses beyond monopoly returns from services that are necessary from an macroeconomic perspective to deal with the energy transition. It should be therefore ensured that the return on the invested capital will be at least as high as the monopoly return. These potential gains would provide an incentive to implement research topics. It is conceivable to provide, for example, a percentage of the total costs in the form of a research budget. The resulting activities and possible services are to be approved and monitored. Nevertheless, the regulatory authority should ensure that cross-subsidies and discriminatory behaviour continue to be excluded.

Another possibility would be to extend the tasks of DSOs, e.g. with regard to residential customer installations. However, this would lead to unfair competition with other providers of such solutions and promote the emergence of an additional DSO monopoly.

Currently, the Federal Network Agency in Germany has chosen another path. The Agency is of the opinion that network operators should retreat to a serving role and generally leave services to the markets.

Thus far, neither path is free of disadvantages. In the future, it will therefore be necessary to work on joining these two approaches or achieving a compromise between them.

### *Establishment of an expert body*

In Austria, there is a neutral authority in the energy sector called E-Control that focuses on the interpretation of laws in the electricity and gas markets. To achieve a cost-optimised transition to renewable energy for everyone, it makes sense to bring together experts from various fields such as economics and the energy economy, energy technology, telecommunications technology, etc., and create an expert group devoted to Smart Energy. The group's tasks would include the development of recommendations for the design of overarching frameworks, as well as the verification of support measures from an macroeconomic point of view. For example, a possible question could be whether and up to which point the promotion of environmentally friendly generators is macro-economically advantageous, seeing as the additional costs for network expansion are apportioned to consumers.

An independent and neutral panel of experts involving different disciplines and interests could provide answers to such questions in the future.

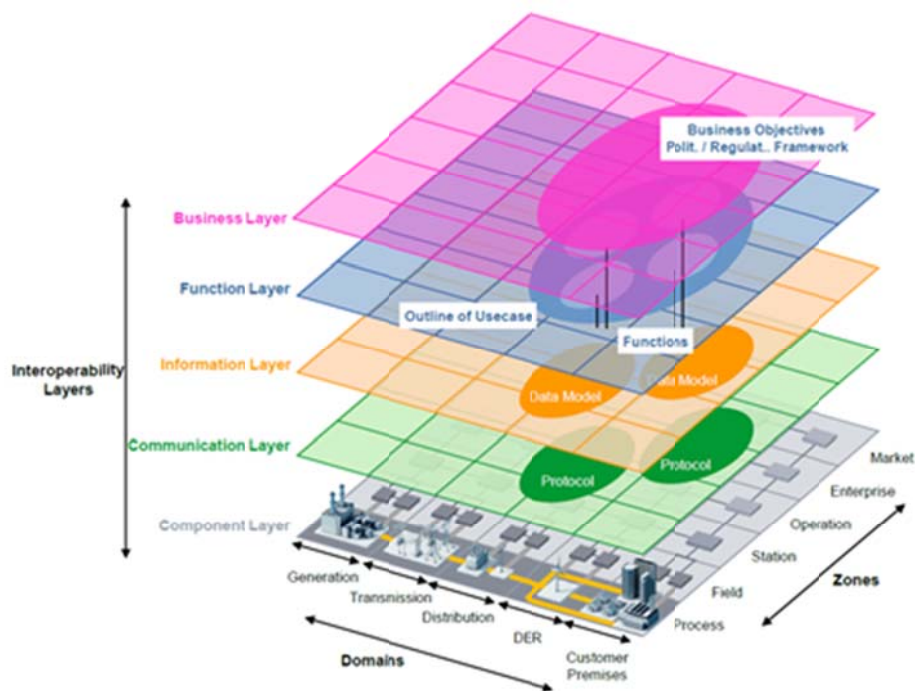
### 3.8 The overall smart grid system

Starting with the five underlying application areas, then considering overarching thematic areas and continuing on to the open questions and requirements placed on the institutional framework, a vision of an overall smart grid system will emerge. In this system, synergies are utilised and combined applications created.

In doing so, the following challenges will arise in the future:

- adjustment of the institutional framework,
- answering of open questions,
- integration of all technologies and applications into one internationally standardised reference architecture.

The INTEGRA project was initiated to address these challenges. The hitherto isolated examination of the applications is insufficient to assess the required system interoperability. This manifests in the ICT sector in the form of different, usually proprietary protocols and interfaces competing with each other. With the project findings of SGMS and the transnational partner project In2VPP<sup>79</sup>, INTEGRA aims to process similarities and determine hitherto untreated aspects in the form of an overall architecture.



**Figure 14: Smart grid architecture model**

<sup>79</sup> The In2VPP project (“Integration technisch und ökonomisch optimierter Virtueller Kraftwerke”) has been submitted in Germany within the scope of the 6th Energy Research Programme of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and builds on the e-energy projects “RegModHarz” and “eTelligence” (see [www.e-energy.de/de/modellregionen.php](http://www.e-energy.de/de/modellregionen.php)).

This will be carried out on the basis of the smart grid architecture model (SGAM) proposed in the European standardisation mandate M/490, which encompasses the dimensions shown in

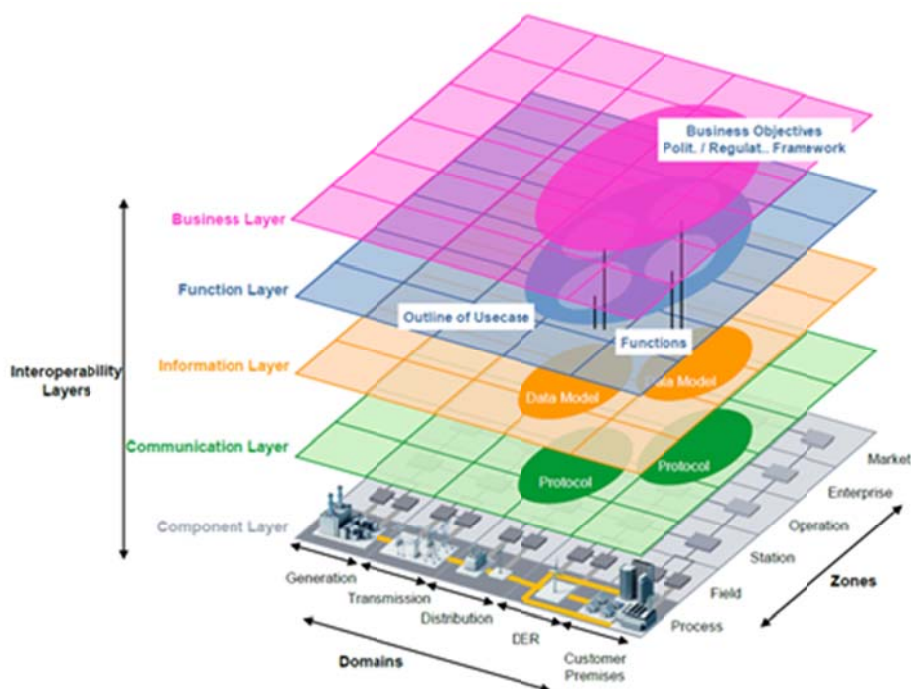


Figure 14.<sup>80</sup>

SGAM employs a multidimensional approach in order to take the various aspects of smart grids into account. The dimensions located on the bottom level constitute domains representing the physical grouping of the entire energy supply chain in a future energy network, and the zones that reflect the automation concept of the electricity system in a hierarchically ordered manner. The different layers represent interoperability, i.e. the ability to collaborate between different systems or applications.<sup>81</sup>

Business and operational aspects such as business models, product and service portfolios are represented at the highest level, the business layer. In order to achieve the objective of a smart infrastructure, it is now necessary to bring the market requirements in alignment with the network requirements. This is another of INTEGRA's goals that will answer many open questions about the model region.

The following example should better explain the problem:

*An energy supplier is interested in unrestricted marketing of electricity at any time and any place. However, for technical and operational reasons, this is only possible so long as it is possible on-site within the framework of safe network operations. For the specific network sections, where this is no longer the case at certain times, regional and temporal restrictions*

<sup>80</sup> The "layer model" is a similar model developed by the National Technology Platform (NTP) Smart Grids Austria.

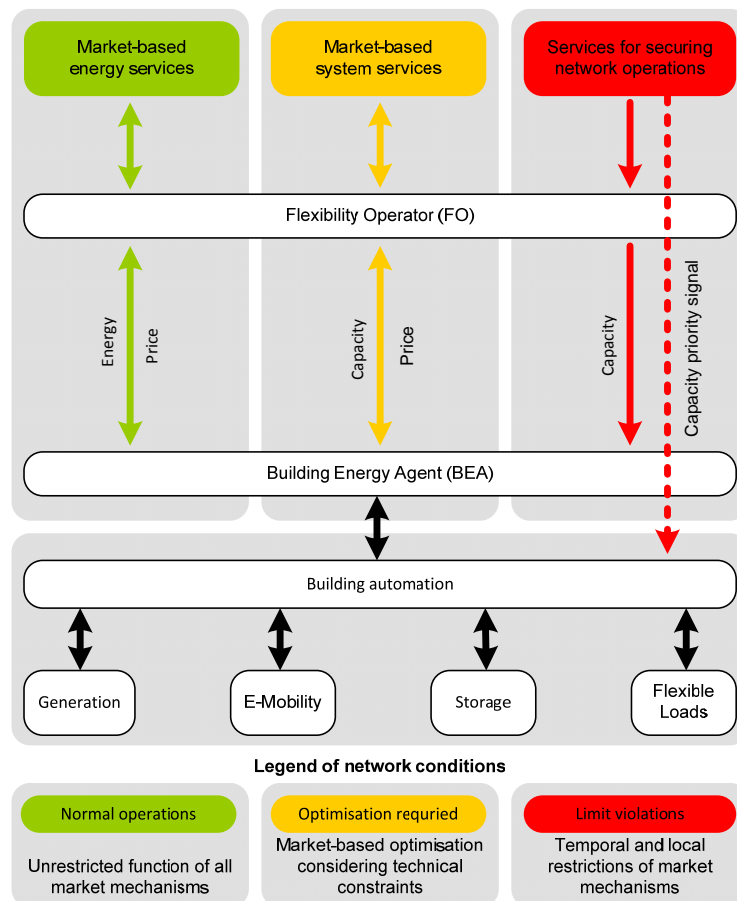
<sup>81</sup> For source of figure 29 and further information, see: M/490 Reference Architecture WG 2011 Framework for Smart Grid Architecture Models (<http://www.pointview.com/data/files/1/473/2185.pdf>).

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*or measures must be in place in order to resolve the physical problem on-site in a timely manner. In the worst case, the entire system or the market threatens to come to a complete standstill due to the cascading failures.*

Therefore, it must be ensured in the future that all market participants within the framework of the given market can adhere to their rules as unrestrictedly as possible without harming others. The so-called “traffic light model” denotes an approach aimed at controlling the system. The traffic light model assigns a regionally differentiated state to the electricity network or the market at any given time. This “operating point of the smart grid” can vary between red, yellow and green, depending on whether thresholds are met or exceeded, as shown in Figure 15.

Within these system states, different energy services and ancillary services are required in order to keep the overall system within the desired normal operations (green area), where the market can function fully. Possible services in this area include optimisation of energy consumption and production by means of price signals in order to synchronise a high proportion of renewable energy with the energy consumption and thus make it usable.



**Figure 15: Traffic Light Model: Network and market conditions in the electrical energy system, example of a building<sup>82</sup>**

In the yellow area, system services available on the market are called on, e.g. the use of power plants for frequency control and retrieval of offered flexible generation potential to avoid expected network congestions. Control commands pass directly from the transmission or distribution system operators to affected facilities.

Market requirements are temporarily not taken into account when the allowable limits (red light) are reached or exceeded. Leaving the area of “disrupted network operations” takes precedence.

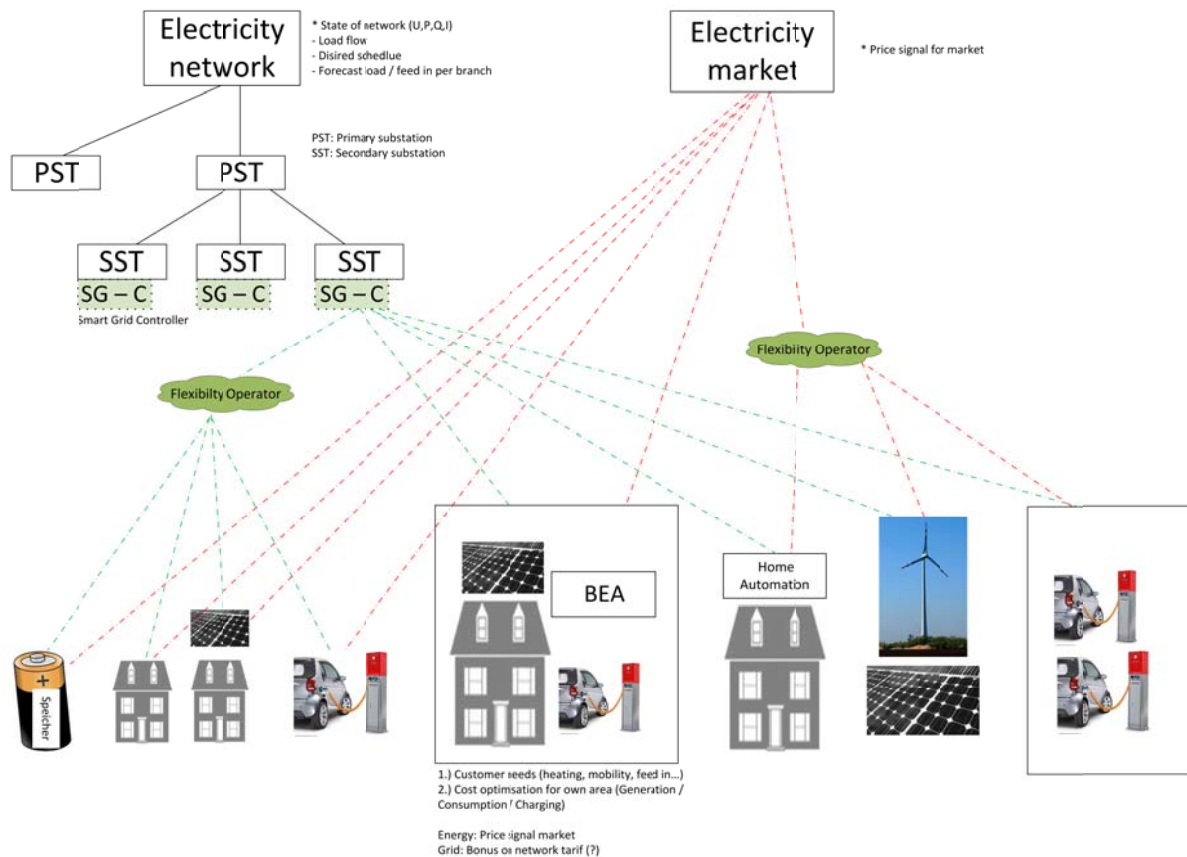
The “agents” and “operators” planned for the overall architecture should be conceived in such a manner that the appropriate coordination between the technical systems of market participants can take place according to the established market rules (ideally, with as much automation as possible).

<sup>82</sup> This graphic resulted from a discussion process within the NTP Smart Grids Austria, based on the traffic light model used by the E-Energy Programme in Germany.

As appropriate communication links and technical infrastructure are necessary for the information and data exchange, the interplay of market participants has immediate effect on the necessary technical design of the smart grid reference architecture.

### *Clash of interests between power supply and market*

An example of this clash of interests of the electricity market and the network raises the question of how to consider load flexibility in the electrical energy system.



**Figure 16: Exemplary depiction of market mechanisms in the smart grid**

Figure 16 illustrates this connection. Consumers and producers are generally tied to two types of contracts: the network connection and system usage agreement DSO and the energy procurement or supply contract with a supplier.

These reflect the different interests in the use of flexible loads. Flexible loads comprise all objects that in principle are able to effectuate a shift in consumption or generation. As shown in the lowest level of Figure 16, they include buildings, electric mobility, storage, distributed generation and flexibility aggregated to blocks of flats and building complexes. The bundling and provision of this comparatively small shift potential can be carried out by a flexibility operator.

Generally, the needs of flexibility providers can be described as follows:

- Consumption of energy services,
- Optimal costs and comfort in one's own range, which can also comprise the optimisation of one's own power consumption using self-owned generation units such as photovoltaic plants.

These needs should be taken into account in the smart grid as broadly and fully as possible. There are two ways to optimise the utilisation of flexibility: optimised for the electricity market the or for the electricity network / system operation.

### *Electricity market*

The optimisation of the electricity market takes place to balance generation and demand via price signals with scheduled values. The focus always lies on the entire market, regardless of network areas and regional operating restrictions. The price signals are passed through to the flexibility providers. On the basis of their own needs and the offered price, they can then decide whether or not they accept the market offer. This can lead to financial benefit for consumers and producers.

### *Electricity network*

DSOs aim to avoid critical or unstable network conditions by controlling or managing flexible loads.

Controlling or addressing via a price signal is inadequate here, because sending a real-time branch and voltage level based signal cannot ensure that a sufficient number of market participants will engage their flexible generating potential and solve the network problem in a suitable manner. Therefore, other incentive systems must be found that guarantee better handling and benefits for the provider.

First, however, the following requirements must be met in order to efficiently implement load shifts in the electricity network:

- Knowledge of the current state of the network, including reactive and active power, voltage and current in each network branch,
- Current power and electricity measurements for consumption and generation,
- Early provision of the requested schedules of consumers and producers,
- Forecasting of load and generation feed-in per branch.

As long as the electricity market and electricity network pursue the same interests by encouraging load shifts in same time periods, the system will work with the abovementioned mechanisms. But there will also be periods in which the requirements of market and network contradict. This may be more or less limited with regard to time and location.

To employ the possibilities of flexible generating potential with regard to both load shifting and generation control in a better and market-oriented manner, suitably designed network load forecasting is increasingly gaining importance in the network sector. The different possibilities of load shifting and their influencing factors must be considered. When charging electric vehicles, for example, the current state of charge and the available charging time determine whether and how long the load capacity can be shifted.

The order (referred to as “merit order” in the energy sector) in which these flexibilities will be used depends on one's point of view. Table 4 compares the merit order from the point of view of network operation to influence the operating voltage with the requirements of the electricity market. The latter gives priority to costs, so that cheap measures are employed first. From the point of view of the network operator, speed and availability play an important role, so flexible and fast-acting measures are given preference.

**Table 4: Comparison of flexibility merit order lists from the point of view of the network operator and the electricity market**

DSO / network operation requirements	Electricity market requirements <sup>83</sup>
<ol style="list-style-type: none"> <li>1. Very flexible loads such as hydroelectric power plants, inverters in photovoltaic plants, storage</li> <li>2. Influenced by “customer demand”, flexible loads, e.g. charging of electric vehicles, hot water boilers, demand side management in industry and commerce</li> <li>3. Slow flexibilities such as heat storage systems in buildings</li> </ol>	<ol style="list-style-type: none"> <li>1. Fast and preferred generation management</li> <li>2. Industrial and commercial demand side management</li> <li>3. Residential demand side management</li> <li>4. Storage</li> </ol>

Thus, the use of flexibilities from the perspective of the electricity network need not necessarily match the requirements of the electricity market. The question of who can enforce one's interests and control the available flexibilities in a specific case must be answered.

#### *Approaches to coordination of electricity market and electricity network interests*

Proposals for variants to solve this possible contradiction were extracted from the results of previous project findings and should be discussed with market participants and decision-makers. The following points should be considered as best possible:

- Advantages and disadvantages for individual market participants including a consideration of costs and benefits,
- Assessment of the issue from an macroeconomic perspective reflected in all layers of the SGAM model,
- International developments and spreading the solution on the European market,
- Creation of a flexible overall architecture that enables the migration of future complex solutions.

Different scenarios are possible on the basis of these requirements. On the one hand, controlling can take place via variable energy and network tariffs. For situations in the yellow or red area, the bonus in the network tariff must be securely higher than the bonus in the ener-

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<sup>83</sup> The merit order from the point of view of the electricity market is based on result from the e-energy programme.

gy tariff. This could be accomplished via a yearly fixed bonus on the energy tariff, if a certain number of exceptions are regularly provided with flexible generation for network control.<sup>84</sup> A contract is the more elaborate, but fairer variant in which flexibilities are available. If the DSO takes advantage of them, a subsequent settlement based on a suitable network tariff is carried out. The drawback of this approach is that the positive difference between the network tariff and the energy tariff is difficult to ensure via dynamic market pricing.

On the other hand, mandatory requirements in the market regulations can determine when and with which applications the provider must participate in order to troubleshoot network restrictions. This is neither market- nor provider-friendly. Due to the necessary reserves, not all potential is used on the market in special cases.

In the future, it would be good to strive for a combination of both approaches that allows broad market mechanisms (in the yellow section of the traffic light model) and assures grid operators mandatory participation of market players in the red area.

The overall architecture and market rules should always ensure that all information and data, suitable for e.g. for the planning of schedules and operational management, is made available to all relevant partners in a timely manner and in a suitable or standardised form.

The data required by both the electricity network and the electricity market includes:

- load profile and smart meter data for consumption and production billing,
- data interchange for clearing<sup>85</sup>,
- weather forecast data,
- knowledge of the flexibilisation potential of the individual providers.

For the implementation of the HiT and DG Demonet Smart Low Voltage Grid projects, a realistic market concept is assumed from the point of view of SGMS. To this end, the necessary general conditions (“market rules”) are coordinated and the necessary systems and technical solutions are designed and built. The subsequent trial operation represents a foundation for acquiring further knowledge and building more complex systems and market models.

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<sup>84</sup> This corresponds to the currently prevailing system in the USA.

<sup>85</sup> Clearing denotes coordinating and resolving conflicts between different interests.

## 4 Conclusion

The motto of the Smart Grids Model Region Salzburg is “Connecting energy intelligently”. The aim is to achieve balance between generation and demand in the energy system. Fundamental insights can already be obtained from the individual projects and applications, as well as the overarching subject areas. On the one hand, it is possible to integrate much more generation from renewable energy resources through smart network control. On the other hand, a range of possibilities and applications for increasing flexibility of demand is available to make energy consumption more flexible. These range from individual load shifting of residential customers, to buildings and electromobility, to involvement of industry and commerce.

Compared with the level of knowledge before SGMS, findings on synergies can be used to ensure a cost-effective design and build the necessary ICT. In the future, it is necessary to systematically look for further synergies with similar telecom initiatives and to implement them in consultation with the regulatory authorities.

All projects and applications have in common the objective to make more efficient use of the given resources so that a large contribution is being made to the climate and energy targets of the European Union and the Austrian Government, in particular with regard to the reduction of greenhouse gases.

These findings from the model regions and countries shall now be merged. An overall market model supporting the energy transition should be determined with the participation of relevant decision-makers and stakeholders.



**Figure 17: The steps on the way to Smart Infrastructure Salzburg**

Figure 17 shows the progress and future priorities on the way to making the energy transition - from the first project to the vision of Smart Infrastructure Salzburg. In logically consecutive steps, taking into account the current findings, individual applications were considered first. Technological development was not the main focus, but rather system integration and connection to available technologies. Therefore, they were subsequently combined, merged and developed synergistically.

The next step will entail an examination of the potential market on the basis of the technologies developed and the further development of applications into products suited to everyday life. Assessment and reduction of uncertainties and calculation of cost-effectiveness are therefore essential.

Although the existing institutional framework does not constitute a fundamental obstacle on the whole, concrete proposals can be derived from the findings of the flagship projects regarding further development of the existing institutional framework. Thus, new smart grid

requirements are to be supported better and in a more concrete manner as an element of the transition toward a renewable energy system.

In particular limited incentives for smart investments from DSO perspective or the lack of clarity concerning the drafting of the future market model are some of the current main obstacles. In many cases, the allocation of the costs and benefits of the solutions is divided among various market participants so that possible allocations need to be discussed and specified.

Many of the measures examined in SGMS require a rethinking of the tasks and benefits of market participants, also at the political level. For example, regionally and technically undifferentiated treatment in the context of smart network control or the unlimited availability of network capacity for private households must be re-discussed in these terms among all network users.

To further expand and introduce the know-how accumulated in SGMS, national and international exchange with other decision-makers, stakeholders and institutions is an essential next step. At the decision-making level an overall initiator or driver of such a consolidation process must be specified who takes the interests of all market participants into account, thereby bringing together national or international objectives. For this purpose, members of staff with appropriate credentials from affected ministries, regulators, or market participants are eligible. The D-A-CH Region<sup>86</sup> could be taken into consideration as the first international level.

Next, all knowledge is to be compared in a structured process and the existing policies such as the electro-mobility strategy, eco-power policies, or the Smart Grids Roadmap Austria are to be merged into a common roadmap. Various discussions regarding the socialisation of costs, the market model or flexible tariffs can also be integrated in such a process. Overall, a joint work plan for the next steps of the implementation should be developed.

The cooperation between partners from different fields will continue to be necessary for the development of these topics. Interest groups that have not yet been integrated are to be integrated into the discussion at an appropriate time.

In SGMS, bringing together different points of view and expertise from the energy industry, the housing industry, technology industry, as well as research and consulting, has produced many insights thus far and led SGMS away from the development of individual applications to the development of combined applications. The goal of creating something more than the sum of the individual parts has thus been achieved. Now it is time to expand this approach at a national and international level by involving further stakeholders so that the development of the overall system can be driven forward. The course is set so that each model region can no longer make progress alone within its individual radius.

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<sup>86</sup> The D-A-CH acronym stands for Germany, Austria and Switzerland.

## 5 SGMS in the national and international context

Smart Grids Model Region Salzburg is the first endeavour in Austria in which various projects on the future requirements in the energy system (such as integration of renewable energies in distribution networks, integration of buildings, electric mobility and residential customers in the smart grid, as well as load flexibility in commerce and industry) have been systematically combined within a region. By summarising the issues and findings from various smart grid application areas, it is now possible for the first time to optimise the effects of the individual applications, to analyse interactions and to utilise synergy potential. Furthermore, the visibility of projects on a European and international scale was significantly increased by strategic bundling of individual projects and generating a critical mass.

In the overall Austrian positioning in the field of smart grids, the model region Salzburg complements other regional projects such as:

- Smart Grids Pioneer Region of Upper Austria, focusing on smart metering and the future operation of low voltage networks with a high density of photovoltaics;
  - Smart Distribution Grid Biosphere Park Großes Walsertal (Vorarlberg), focusing on new control approaches for the active integration of distributed generation in medium voltage distribution networks;
- These two projects are being carried out within the framework of the project chain DG Demo Net in synergistic cooperation with the model region Salzburg.
- Smart Community Großschönau, focusing on energy efficiency in local energy systems, the integration of passive houses and the role of local authorities as energy distributors;
  - And other project initiatives, e.g. the Smart City initiatives in Villach and Vienna.

The fact that several of the individual projects from SGMS are also being carried out across model and pioneer regions<sup>87</sup> with the participation of other grid operators<sup>88</sup> guarantees a transferability of the results beyond SGMS.

The same is being implemented on a national level in the bodies of the national technology platform Smart Grids Austria<sup>89</sup>, the “Smart Grids” platform of Austria’s energy sector and in various ministry working groups for the creation of strategies in the areas of electro-mobility, smart grids or energy strategies.

Through transnational cooperation of the INTEGRA project from SGMS on the Austrian and In2VPP on the German side, the results from the model region Salzburg are undergoing a critical examination with regard to scalability and replicability in and to Germany. Findings from the German e-energy initiative on the RegModHarz and eTelligence projects are taken

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<sup>87</sup> This includes e.g. the DG Demo Net Validation project, the DG Demo Net Smart Low-voltage Grid and ISOLVES.

<sup>88</sup> The participating grid operators include Energie AG Oberösterreich Netz, Linz Strom Netz, Wien Energie Stromnetz and Vorarlberger Energienetze.

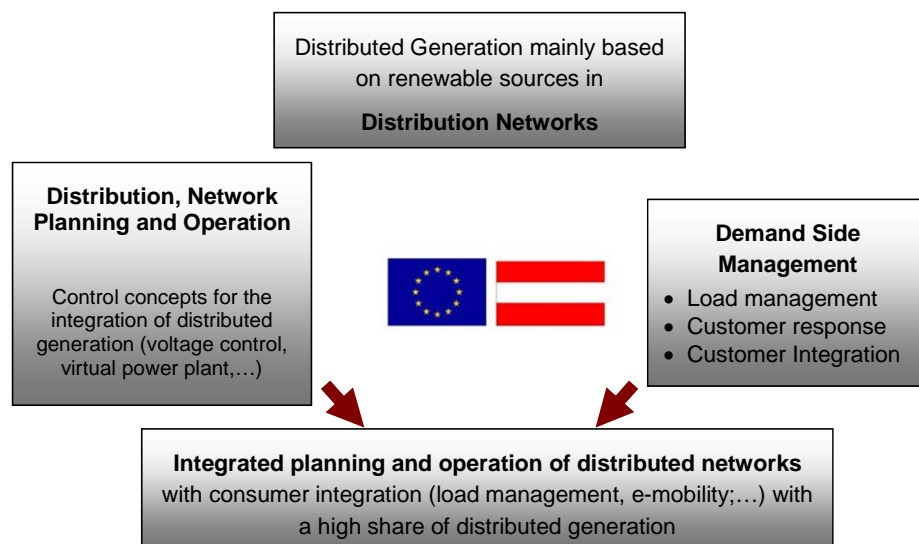
<sup>89</sup> For further information, see [www.smartgrids.at](http://www.smartgrids.at).

into account in the In2VPP project. The project investigates the question, how the economic operations emerging today and using renewable energies in virtual power plants can be combined with a technically sustainable operation of the regional network infrastructure. The aim of the project is to develop applicable system approaches, as well as a practical tool box for the coupling of regionally-driven networks as well as trans-regionally operated virtual power plants. Due to the different conditions for the implementation of combined electricity network and market-led operations in Austria and Germany, this exchange is viewed as an important element to secure the replicability of results from the model region Salzburg to other regions (at least in the D-A-CH region). Last but not least, the integration of renewable energy sources into the market and networks is one of the key issues in the model region.

At the level of D-A-CH cooperation, team members of SGMS have already participated in the various working groups within the scope of the cooperation of the responsible ministries in Germany, Austria and Switzerland. The content-related work of the D-A-CH cooperation includes development and testing of implementation strategies for smart grids.

Together with other schemes, SGMS thus supplies a major driver and contribution within the framework of the Austrian position in the implementation of the Strategic Energy Technology Plan (SET Plan) of the European Commission. The focus clearly lies on an integrated approach to the planning and operation of distribution networks featuring the following two partial aspects (see Figure 18):

- Distribution system planning, design and operation for optimised integration of distributed generation,
- Integration of customers in smart grids through intelligent load management.

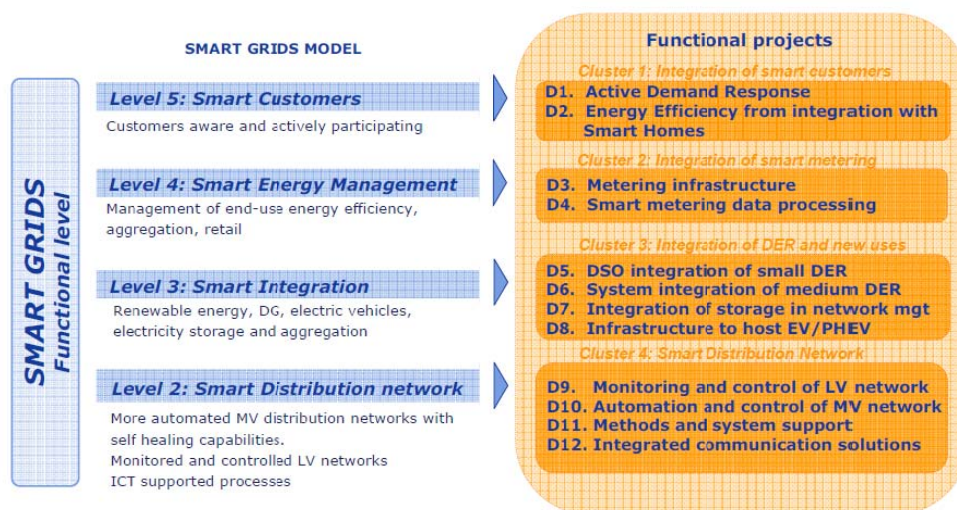


**Figure 18: Austrian position within the EU SET Plan**

The European Electricity Grid Initiative (EEGI) represents a key pillar for the implementation of European objectives in the field of smart grids. As an industry initiative of the European electricity industry, the EEGI published a roadmap and an implementation plan for Smart Grids in Europe in 2010. In the course of the integration of national initiatives of individual member states, SGMS was positioned as a major European demonstration project.

Figure 19 shows the EEGI Smart Grid Model at the distribution level. The strategic contributions of the Smart Grids Model Region Salzburg essentially address:

- Level 5: integration of smart customers,
- Level 3: integration of decentralised energy resources and new applications,
- Level 2: smart distribution networks.



**Figure 19: European Electricity Grid Initiative – Smart Grids Model at the distribution level**

The goal of the EEGI and the European Commission was and is to bring together national projects with pan-European relevance and to evaluate the replicability and scalability of the individual solutions. Thanks to the successful positioning within the EEGI Initiative, essential sub-projects of SGMS are part of the first “family of projects” (equivalent to a “functional project” in Figure 19) funded by the European Commission.



**Figure 20: EU iGREENGrid project partners**

Within the scope of the iGREENGrid project (see Figure 20), which was launched in January 2013, Salzburg AG will examine the replicability and scalability of the individual Austrian projects and solutions for the integration of distributed energy resources in medium and low voltage networks throughout Europe, together with Energie AG Oberösterreich and the Austrian Institute of Technology, and with major European companies such as ENEL and RSE (Italy), RWE (Germany), ERDF (France), Gas Natural Fenosa, IBERDROLA, Tecnalia (Spain) and HEDNO (Greece). As a result of the project, suggestions and recommendations for the European Commission on the further course of action will be defined.

The project thus enables the international positioning of the SGMS insights and sustainably strengthens Austria as a business and research site in the field of smart grids.

On the initiative of the BMVIT, Austria has already positioned itself as a leading and successful participant in implementing the ENARD (Electricity Networks Analysis, Research and Development) agreement via leading Annex 2<sup>90</sup> within the International Energy Agency (IEA).

The follow-up initiative was titled IEA ISGAN (International Smart Grid Action Network), aiming to promote the exchange of technological know-how between international experts and define best practice examples and recommendations for policy makers. In this initiative, SGMS was also positioned and established as an exemplary model from Austria. In autumn 2012, at the IEA ISGAN workshop on the topic, "Why smarter grids? – Regional drivers for smart grid deployment and lessons learned from current projects", in Nice, SGMS was presented as a "key demonstration project". Building on the previous contributions and within the scope of Smart Grids Week held in Salzburg in May 2013, IEA workshops will be held on topics related to SGMS. This will continue to ensure that the design of international technical, economic and regulatory framework conditions can be actively co-created from Austria, based on the activities in SGMS.

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<sup>90</sup> The topic was the integration of decentralised energy generation in the distribution network.

## 6 Outlook for SGMS

The rapidly increasing number of distributed renewable energy generation units on or in residential and business premises is but one indication that the energy transition is picking up and the sustainable use of energy is increasingly coming to the fore among decision-makers and the general public. The timely further development of intelligent energy systems as building blocks for this transition is now even more significant.

Topics that are relevant to the entire market system were defined in the previous chapters. However, not all open issues can be investigated within the scope of SGMS. Against this background, the specific course in the coming years can be summed up as follows:

- **Evaluate results and derive priorities for further development**

Thus far, the focus lay on the development and practical testing of technical solutions and applications. The next step involves evaluating the project results (cost-benefit analyses, examination of replicability and scalability, e.g. in the iGREENGrid project) and deriving priorities for further development and implementation. This must be driven forward particularly at a national and European level.

- **Getting from pilot projects to everyday solutions and products**

Based on the results of the evaluation, the aim is to develop tried-and-tested technologies and applications from the pilot projects into everyday solutions for network operation on the one hand, and to develop them further into specific products or services for potential users on the other hand. The focus lies on solutions and services that address the problems of the new energy system, but for which users and stakeholders are also willing to bear the corresponding costs. In this context, it is necessary to develop business models that are relevant and interesting for as many market participants as possible through creativity and interaction with the future users. Various concrete examples have been described in detail in the previous chapter.

To this end, it should be noted that classic “roll-out scenarios” are not to be assumed for such solutions and their implementation in general. The “operationalisation” will be carried out in a needs-based manner, with priority given to networks and systems where concrete action is required, and gradually extended to other areas of the network and systems.

- **Promote convergence of individual applications into a smart grid system**

In order to utilise synergy potential and safely carry out operations, it is crucial to embed the various smart grid applications into an overall system in the sense of a unified reference architecture and to bring it into line with market and network requirements. Specific rules for the interaction of market participants as well as new processes and interfaces required for the energy transition are to be voted on and specified. This is already being pursued in the INTEGRA project.

- **Master data volumes & complexity**

Due to the development of ICT and the diffusion of communication components such as smart meters and IP-enabled devices, the amount and complexity of data to be processed is increasing dramatically. Therefore, it is necessary to limit the amount of data by using an appropriate architecture, which may include decentralised intelligence and regional aggregation. On the other hand, it is necessary to adjust and prepare the ICT systems – in particular the backend systems. In this regard, the consistent use of IP as a convergence layer can also help to cope with the growing complexity.

- **Create trust via security & privacy standards**

In order to ensure trust and acceptance on the part of consumers and producers, consistent consideration of data protection and security is an essential prerequisite. The techniques that make this possible are explored in the new Josef Ressel Centre for User-oriented Smart Grid Control, Privacy & Security at the Salzburg University of Applied Sciences<sup>91</sup> since January 2013. Concrete problems arising in SGMS are incorporated here, thus coordinating and adjusting research work with the current requirements of the market and the industry.

- **Ensure added value of smart metering in smart grids**

The installation of smart meters in the majority of households and businesses, to be ensured in accordance with regulations, represents by far the largest single investment for DSOs in the next few years. For this reason, it is an essential requirement for Salzburg Netz GmbH and an indispensable one from a business perspective, that all synergies with other initiatives are utilised during the installation. This implies that an implementation of smart metering is carried out not only in the electricity and gas sector, but in all relevant networks – including water and district heating. However, the technologies offered are still not geared toward these requirements. Regarding the operation of smart metering systems in the planned smart grid solutions, it is thus important to assess which requirements are necessary and economically feasible. Next, a “target image for smart metering” will be derived from these requirements, making a holistic implementation possible.

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<sup>91</sup> The Centre is supported by Salzburg AG and Salzburg Wohnbau as corporate partners.

- **Secure and expand know-how**

Sufficient personnel resources with appropriate expertise are required to implement the abovementioned points. An increased demand for well-trained technicians is to be expected particularly in the area of integration of ICT and energy technology and the energy sector. On the one hand, this need will be met through internal training measures such as training electrical engineers in the field of ICT and vice versa at Salzburg AG. On the other hand, it will be met by training opportunities in cooperation with universities.

For this reason, together with the Salzburg University of Applied Sciences, Salzburg AG has initiated the study course “Future energy systems” starting in the academic year 2012/13. Experts at SMGS partner AIT are partly teaching the course. The Institute of Computer Technology at the Vienna University of Technology is offering a lecture course on smart grids starting in 2013.

SGMS has already produced numerous promising applications and technologies in order to make more efficient use of resources in the energy system. The consistent implementation and further development in relation to the issues mentioned above will mark a substantial contribution to turning smart grids into reality as building blocks for a sustainable energy system – in Salzburg and beyond.

## List of abbreviations

B2G	Building to Grid
BAVIS	Contribution to an active operation of the distribution network via innovative voltage control [Beitrag zum Aktiven Verteilnetzbetrieb durch Innovative Spannungsregelung]
BEA	Building Energy Agent
CHP	Combined heat and power
BMVIT	Austrian Federal Ministry for Transport, Innovation and Technology
C2G	Consumer to Grid (SGMS project)
D-A-CH	Germany-Austria-Switzerland
DG	Distributed Generation
DSO	Distribution System Operator
DVR	Austrian Data Processing Register [Österreichisches Datenverarbeitungsregister]
EEGI	European Electricity Grid Initiative
EIWOOG	Austrian Electricity Industry and Organisation Act [Elektrizitätswirtschafts- und -organisationsgesetz]
ENARD	Electricity Networks Analysis, Research and Development, IEA Implementation Agreement
FFG	Austrian Research Promotion Agency
HiT	Buildings as interactive participants in the smart grid [Häuser als interaktive Teilnehmer im Smart Grid] (SGMS project)
IEA	International Energy Agency
ICT	Information and Communication Technology
IMA-VO	Requirements for Smart Meters Ordinance [Intelligente Messgeräte-Anforderungsverordnung]
In2VPP	Integration of technologically and environmentally optimised virtual power plants [Integration technisch und ökonomisch optimierter Virtueller Kraftwerke] (an INTEGA sister project)
IP	Internet Protocol
ISGAN	International Smart Grid Action Network
ISOLVES	Innovative Solutions to Optimise Low Voltage Electricity Systems

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KLIEN	Austrian Climate and Energy Fund [Klima- und Energiefonds]
LV	Low voltage
NTP	Austrian National Technology Platform
PLC	Power Line Carrier
OIB	Austrian Institute of Construction Engineering [Österreichisches Institut für Bautechnik]
ÖVGW	Austrian Association for Gas and Water [Österreichische Vereinigung für das Gas- und Wasserfach]
SGAM	Smart Grid Architecture Model
SGMS	Smart Grids Model Region Salzburg
V2G	Vehicle to Grid (SGMS project)
ZUQDE	Central Voltage and Reactive Power Control with Distributed Generation [Zentrale Spannungs- (U) und Blindleistungsregelung (Q) mit dezentralen Einspeisungen] (SGMS project)

## Appendix

### A1 Fact Sheet

The Smart Grids Model Region Salzburg in figures*	
<b>Length of the affected line sections</b>	414 km in the medium voltage grid 6 branches up to 1000 m in length in the low voltage grid
<b>Renewable energy in the distribution grids of the demo regions</b>	18 small hydro power stations with ca. 24 MW, thereof 4 MW involved in network control 263 photovoltaic systems with ca. 3.100 kWp, thereof 41 systems with ca. 280 kWp involved in network control
<b>Participants</b>	1 industrial customer 30 small and medium enterprises 474 residential customers 58 buildings Approx. 22,000 not actively involved customers in the demo areas
<b>Smart meters installed</b>	approx. 1100
<b>Maximum load flexibility potential developed</b>	5.05 MW
<b>Electric vehicles</b>	Ca. 170 e-cars thereof 41 directly involved in smart grid demo projects.

\* Status May 2013 including facilities currently being implemented in the HiT project

## A2 Project results and key statements

(colours correspond to Figure 2, Figure 3 and table 1; projects that have two or more areas of application are shown in white in this table)

Project name	Central question Results / Key statements (for running projects: expected results)
<b>DG Demo Net Concept</b>	<p>How can innovative active network control concepts be modelled and designed in a holistic manner?</p> <hr/> <ul style="list-style-type: none"> <li>• Four innovative control approaches were developed, in which voltage limits in existing network infrastructure are adhered to and a reliable supply is ensured.</li> <li>• Numeric network simulations based on three real-world medium voltage networks demonstrated technical feasibility and economic efficiency.</li> <li>• A quantitative study of the installable capacity of distributed generation was conducted.</li> </ul> <p>In the simulations, the two control concepts “coordinated voltage control” and “distributed voltage control” have proven very effective.</p> <p>Final report available at <a href="http://www.smartgridssalzburg.at">www.smartgridssalzburg.at</a>.</p>
<b>BAVIS</b>	<p>In concrete terms, what can the contribution to active distribution system operation through innovative voltage control look like?</p> <hr/> <ul style="list-style-type: none"> <li>• In accordance with the objectives, two essential goals could be achieved in the course of the BAVIS project:               <ol style="list-style-type: none"> <li>1. A set of sophisticated measures for an active voltage control.</li> <li>2. A method for the planning of an active voltage control.</li> </ol> </li> <li>• A controller was developed that factored in operation-relevant requirements such as switching and replacement supplies on the network, reactive and active power management or monitoring of voltage at critical nodes and sets appropriate values for the control systems of transformers and generators.</li> </ul> <p>The EasyCheck procedure developed in the project is used to simplify planning and analysis of the use of the developed voltage control concepts.</p> <p>Final report available at <a href="http://www.smartgridssalzburg.at">www.smartgridssalzburg.at</a>.</p>

**ISOLVES**

Based on smart metering systems, how can a monitoring and analysis method of low voltage networks be built and the resulting control actions be derived?

On the basis of:

- Method and tool development for the measurement and analysis of conditions in urban and rural low voltage networks,
- Data collection in approx. 100 representative networks in the urban and rural area (power snapshots), characterisation of the network state and development of suitable network models in the four-wire system with unbalanced loads,
- Analysis of the potential for smart grid concepts in low voltage distribution networks and development of methods for planning and operation of active low voltage distribution networks.

On the basis of the above points and real-life conditions, new assessment procedures were developed for the connection of distributed generation.

Final report available from October 2013 at [www.smartgridssalzburg.at](http://www.smartgridssalzburg.at).

**Smart Metering Pilot**

What needs to be done at Salzburg AG in order to prepare technically for the implementation of comprehensive, cross-discipline smart-metering systems (for electricity, gas, water, district heating) in Salzburg?

Laboratory evaluation and field test with approx. 500 meters.

- The Siemens smart metering system employed in the project exhibits a high system performance in terms of the available functionalities as well as their availability, reliability and duration of the daily readout of the tariff and load profile data.
- The currently missing standards lead to a lack of interoperability between different smart metering systems.
- The integration of different non-electricity meters, e.g. for gas, water and heat, is linked to high costs due to the still missing mass-grade technology. The use of the smart meter as a communication gateway and connection to the field meter via M-bus radio or M-bus wire is limited.
- Integration into the existing IT system environment is complex, with a high overhead. It requires not only an appropriate meter data management system, but also the adaptation of additional IT-systems to be connected. Also, a corresponding monitoring tool needs to be developed to ensure the con-

sistency of the processes throughout the entire system chain.

- An operation management system with troubleshooting is currently unavailable. This includes largely automated fault containment and alarm correlation, as well as an automated assignment of troubleshooting.
- From the perspective of the network operator and on the basis of the current measurement rates as well as achievable increase in process efficiency, a smart metering system is currently not economically feasible so additional benefits need to be created.

### Micro CHP Net

What are the implications of the implementation of a virtual power plant consisting of four small combined heat & power (CHP) units that can be operated (heat, power- and network-driven) by a control centre?

Technical and economic analysis.

- Peak load of secondary substation: Taking into account technical availability, it is possible to reduce the peak load by up to 20%.
- Losses are reduced by 100% in the high and medium voltage grid and by approx. 50% in the low voltage grid.
- Even at a maximum possible CHP penetration (interpreted as 15% - 30% of the heat requirement) the impact on voltage band management in the low voltage grid is very low.

Micro-CHP units have a lowering effect on the peak-load at the secondary substation and on network losses. However, the economy still needs to be improved because the operation of micro-CHP units does not pay off under 30 kW<sub>el</sub> due to the poor underlying conditions

Final report available at [www.smartgridssalzburg.at](http://www.smartgridssalzburg.at).

### ElectroDrive Model Region

Salzburg AG has been offering electric mobility since early 2009, titled "ElectroDrive Salzburg". In December 2009, Salzburg was awarded by the Climate and Energy Fund (KLIEN) as Model Region for Electromobility in Austria. ElectroDrive Salzburg GmbH, a 100% subsidiary of Salzburg AG, was founded in early 2010. The company distributes charging infrastructure for electric car owners in close cooperation with the automobile trade. In addition, public charging stations in the province of Salzburg are being constructed.

As of January 2013 approx. 170 electric cars are on the road in Salzburg within the framework of the model region. They form an important basis for the analyses of SGMS.

- The reservations about leasing products led to only purchase products being offered. In contrast to the electric car, which is often perceived as too expensive, the market for electric-powered two-wheeled vehicles is growing strongly.
- Co-operations with automotive suppliers are used for the sale of electric cars and a total package is being offered.
- Via data collection within the pilot region, it is possible to create sum charge profiles as well as distributions to charging start times and charging energy snapshots so that demand and distribution of the charging infrastructure can be estimated.
- The components of electric cars are improved through evaluation of the current vehicle fleet.

### **Building to Grid (B2G)**

How can load peaks be reduced, energy delivery optimised and energy efficiency improved by intelligently incorporating buildings into the electricity network?

Field test with 10 actual buildings.

- Development of a method for the simplified parameter configuration of a building model based on data from the Energy Performance Certificate.
- Development of a building energy agent representing the interface between the electricity system and the building
- In buildings with a good thermal envelope, there is enough freedom to move the operation timetable of e.g. heat pumps to more favourable times for the entire system. In a case study in St. Johann, a load shift of 12 hours was easily possible without major impact on room temperature.
- The maximum load shift potential of 350 kW could be exploited fully for short time periods (30 min.).
- The unannounced load shifts and shutdowns in the field tests did not result in complaints on the part of the residents / users.

Final report available from August 2013.

**Consumer to Grid (C2G)** Is it possible to motivate residential customers to reduce their electricity consumption sustainably by providing feedback based on smart metering?

Field test with 288 households.

The reduction in power consumption compared to the previous year was in the range of 2.5% to 10.9% and amounted to 6.7% on average over all groups (including the control group with standard annual billing). Due to the high variability, these savings cannot be separated in a statistically significant manner.

Nevertheless, the subjects frequently reported a fundamental increase in awareness of the issue of energy consumption in the household and felt energy feedback to be valuable information.

Final report available at [www.smartgridssalzburg.at](http://www.smartgridssalzburg.at).

**PEEM – Persuasive End-User Energy Management**

Which new strategies and tools can motivate residential customers to shift power consumption in the electricity system to more favourable times without sacrificing any comfort?

Field test with 24 households

The newly developed energy feedback mechanism, FORE-Watch, is considered suitable by the study participants to achieve the goal of “changing energy consumption patterns”.

The results suggest that there is a low correlation between the consumption of residential consumers and the FORE-Watch forecast. However, this is not statistically significant. In the future, more added-value is to be created through flexible tariffs and combination with automation solutions in the household.

Final report available at [www.smartgridssalzburg.at](http://www.smartgridssalzburg.at).

**Smart Heat Net**

Which intelligent operating and control strategies can be used to reduce peak loads in district heating networks and thus minimise the use of oil- or gas-fired peak load boilers?

- Selective forward temperature control can reduce the peak load on the studied area by up to 2%. The theoretical maximum value without hydraulic limitations is 15%.
- The use of central storage has an ROI of 17 years in the calculated case and reduces CO<sub>2</sub> emissions by half.
- For the district heating network in the City of Salzburg, the demand side

management potential amounts to up to 11% based on the 30 largest consumers. This would be sufficient to completely balance the morning peak in an exemplary day load gradient.

- The lowering of system temperatures reduces power losses by approximately 10%, if forward and return temperatures are reduced by 5°C each.

The fundamentals of all cited calculations are described in the final report.

Final report available from July 2013 at [www.smartgridssalzburg.at](http://www.smartgridssalzburg.at).

### SmartSynergy

What ICT infrastructure is necessary to optimally fulfil the requirements of diverse smart-grid and electromobility applications and how can this be used to create synergies?

- The probability of encountering two applications in one place (location synergies) is very high, even in rural areas.
  - Application synergies describe how different applications harmonise in their technology requirements. They can be divided into two basic clusters: applications in the area of residential customers and in the area of the distribution system operators. Thus far, smart metering exhibits only limited synergies with the other assessed applications within the statutory minimum framework.
- Given synergetic use for the expansion of infrastructure, the most savings potential is present in the access technologies fibre optic cable and cable TV.

Final report available at [www.smartgridssalzburg.at](http://www.smartgridssalzburg.at).

### Vehicle to Grid (V2G) – Interfaces

Which business models and interfaces need to be developed in order to intelligently integrate electric vehicles into the electricity system?

**Interface:** The interfaces must be low in complexity and be able to factor in the charging needs of electric vehicle owners. The technical integration of the interfaces into the existing infrastructure (accounting, charging infrastructure, etc.) represents a challenge that shouldn't be taken lightly.

**Business model:** If the hardware for the interface is provided by the electromobility service provider, this has a highly negative impact on the provider's revenue model. The utilisation of existing hardware (e.g. via mobile phones or tablet computers) is therefore preferable. Corresponding applications need to be developed.

Final report available at [www.smartgridssalzburg.at](http://www.smartgridssalzburg.at).

### Vehicle to Grid (V2G) – Strategies

Which technical, economic and environmental consequences can be expected for the Austrian energy system from the extensive market penetration of electric vehicles?

**Technical:** Charging processes with high coincidence consume unnecessarily high network reserves in the examined medium and low voltage networks. Charging with low load, a balanced load distribution (e.g. using three-phase connections) as well as the influencing of load profile-controlled charging (e.g. manual itinerary specification) is least burdensome on the networks.

**Economic:** Feeding back of the electricity from electric vehicles into the electricity network (vehicle to grid) does not make sense under current market conditions and for the investigated cases, since current costs are higher than the achievable benefits by a factor of 2.

Final report available from September 2013 at [www.smartgridssalzburg.at](http://www.smartgridssalzburg.at).

### ZUQDE

How might the implementation of an automated, central-control-based voltage and reactive power control of transformers and small hydropower plants look? The goal is to increase the hosting capacity of the distribution network to handle energy flow from decentralised renewable generation.

Piloted in a medium voltage network in the Lungau region of the Salzburg province.

- The existing SCADA system was equipped with an automated, centrally controlled voltage and reactive power control of transformers, generators and loads. Its mode of action was tested and evaluated in a 30 kV grid in Salzburg and in actual operation (since 01/2012)
- The technical feasibility of objectives such as voltage band management, active/reactive power management, loss reduction, power demand management, etc., could be demonstrated
- To this end, a multi-level control concept was developed which takes into account all relevant working cases in the network (error cases such as faults and short circuits, switching, parallel operation of transformers, failures of control and supervisory control components, etc.).
- The economic efficiency of the solution was quantified using concrete examples.

Concrete conclusions for widespread implementation have been drawn (general applicability, conditions, security, etc.). Details are presented in the final report.

Final report available at [www.smartgridssalzburg.at](http://www.smartgridssalzburg.at).

#### **DG Demo Net Validation**

How can the active operation of the distribution network using innovative voltage control concepts in a medium-voltage network be validated?

Implementation of a coordinated regional voltage and reactive power control of transformers and small hydropower plants with the goal of significantly increasing the hosting capacity of the distribution network to handle energy flow from decentralised renewable generation.

Piloted in the same medium-voltage network as ZUQDE.

Evaluation and comparison using the ZUQDE approach.

- Project launch January 2010, duration until June 2013,
- See objectives and results of the ZUQDE project,
- DG Demo Net Validation tests the distributed and coordinated control developed in the BAVIS project (as an addition to the voltage controller in the primary substation). The demo operation in the 30 kV network has run since 04/2012 with the same facilities as in the ZUQDE project,
- The practicability could be demonstrated correspondingly.

An evaluation of the two approaches by ZUQDE and DG Demo Net Validation will be developed within the scope of this project.

Final report available from December 2013 at [www.smartgridssalzburg.at](http://www.smartgridssalzburg.at).

#### **HiT – Buildings as interactive smart grid participants**

How can various smart grid applications in the context of buildings be grouped together in an innovative housing community?

Optimised planning, construction and operation of the Rosa Zukunft (engl. “rosy future”) block of flats in Rosa-Hoffmann-Straße, Salzburg Taxham.

- Duration: 01/2011-05/2015,
- Construction of the building and the energy centre; completion of the energy centre in July 2013; occupation of flats from September 2013,
- Detecting the potential of a smart grid-friendly building, optimisation and expansion of interaction and building technologies for the residential complex,

- Description of interactions between humans and the building,
- Evaluation of the network-friendliness of the building,
- Creation of a guide for the implementation of a smart grid-friendly residential complex.

Final report available from the end of 2015.

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### Smart Web Grid

How can data exchange between the different smart-grid participants be designed so that it is universal, interoperable, and effective, creating a boon for users such as residential customers through services that link different data sets together?

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A smart web grid core was established which, like a platform, is responsible for managing and sharing data access permissions in the scope of a smart grid-ICT infrastructure. The core of the system is used to keep the triangle data source – owner of the data – access rights up to date.

On the basis of the smart web grid cores, the following case uses were designed and implemented in the form of an app:

- Energy feedback,
- Smart electric vehicle charging,
- Photovoltaics monitoring,
- Energy balance Köstendorf.

"Security & Privacy by Design" was used in the implementation. Final report available from November 2013.

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### DG Demo Net Smart Low voltage Grid

How can a high share of photovoltaic systems and electric vehicles be optimally integrated in low-voltage networks using intelligent planning, real-time monitoring and active network management?

Field testing in the Smart Grids Model Community Köstendorf.

- 
- Project launch: March 2011, duration until February 2014,
  - Intelligent planning approaches: new planning methods for higher hosting capacities for distributed generation based on renewable energy sources in low voltage networks Intelligent monitoring: new monitoring approaches for network planning and network operation,
  - Active management and control on the basis of a smart meter- or IP-based
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communication infrastructure and therefore new and economic control and operation solutions,

- Based on the findings of the projects DG Demo Net Validation, ZUQDE, ISOLVES while taking into account the requirements of the low voltage network
- E.g. smart voltage control in secondary substations with an local on-load tap changer transformer, active and reactive power control in the generation units,
- Demand response: controllable loads and charging of electric cars.

In Köstendorf the joint optimisation and control of PV systems, electric cars, and household consumption is first carried out individually and then in coordination with the network status in a real low voltage grid. The necessary control algorithms, equipment and communication facilities are being developed and built. From April 2013, they are tested and evaluated during actual operation.

Final report available from mid-2014.

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#### **iGREENGrid**

How can guidelines and recommendations for the intelligent integration of renewable energies in electric distribution networks be developed through the comparison and evaluation of international projects?

Funding through the EU's Framework Programme FP7.

Project to implement the European Electricity Grid Initiative (EEGI) roadmap in the framework of the Strategic Energy Technology (SET) Plan.

- 
- Project launch: January 2013, duration until December 2015,
  - 12 project partners from 6 EU member states (Germany, Spain, France, Greece, Italy, Austria),
  - Expected results:
    - Grid code guidelines for the integration of small and medium-sized distributed generation in distribution systems,
    - Simulation and evaluation methods and tools,
    - Calculation criteria,
    - Best practice solutions,
    - Barriers and recommendations

Final report available 2016.

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**INTEGRA**

How can low- and medium-voltage networks be operated in a stable and secure manner in the presence of numerous interrelated and interdependent smart-grid services within the European energy markets?

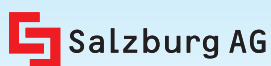
Start of the project in April 2013.

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# SMARTGRIDS

*Model Region Salzburg*



The Model Region is supported by

