Smart Grids Austria Technology Roadmap

Implementation Steps for the Power System Transition up to 2020

Smart Grids Austria
Technology Roadmap

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Contents

1. Introduction to the Technology Roadmap Smart Grids Austria 16
1.1. Motivation 16
1.2. Objectives of the roadmap 18
1.3. Smart grids: drivers and basic concepts 19
1.4. Smart grid requirements 21
1.5. The technology roadmap development process 21
1.6. Structure and organisation of the Technology Roadmap Smart Grids Austria 22

2. The technology roadmap: pathway to implementation 23
2.1. Smart grids organised by development axes, use cases, and technologies 23
2.2. Development steps in the technology roadmap 25
2.3. The overall ICT architecture as the common basis of the development axes 25
2.3.1. Current state of the ICT architecture 26
2.3.2. Development of the overall ICT architecture 27
2.3.3. Need for action for an overall ICT architecture 30
2.4. Grid development axis: optimised distribution grid operation 31
2.4.1. Current state of the grid development axis 31
2.4.2. Use case: distribution grid monitoring 32
2.4.3. Use case: R&D infrastructure 34
2.4.4. Use case: operation of efficient distribution grids 35
2.4.5. Use case: planning efficient distribution grids 39
2.4.6. Need for action for the grid development axis 40
2.5. System development axis: utilising flexibility for the market and grid 42
2.5.1. Current state of the system development axis 43
2.5.2. Use case: coordinating the market and grid 43
2.5.3. Use case: utilising flexibility for the market 44
2.5.4. Need for action for the system development axis 46
2.6. End customer development axis: smart solutions for consumers' market entry 47
2.6.1. Current state of the end customer development axis 48
2.6.2. Use case: prosumers 50
2.6.3. Use case: non-energy services 50
2.6.4. Use case: integrating end consumers into market processes 50
2.6.5. Need for action for the end customer development axis 53

3. Austria's initiatives and players in smart grid development 55
3.1. bmvit as the driver of strategy and KLIEN as the funding body 55
3.1.1. Smart Grids 2.0 strategy process 55
3.1.2. Strategic Research Agenda 56
3.1.3. Smart Grids Security Round Table 56
3.2. Austrian model regions and demonstration projects 56
3.3. Technology Platform Smart Grids Austria 57
3.4. Austrian industrial companies 57
3.5. Austrian energy sector 57
3.6. Austria's research landscape 57
3.7. The place of Austrian initiatives in the international smart grid environment 58
3.8. Topic-related fields of innovation in Austria 59

4. Benefits of smart grids 60

4.1. Benefits of smart grids from a macroeconomic perspective 60
4.2. Benefits of smart grids from the perspective of Austria's energy industry 62
4.2.1. Benefits for grid operators 62
4.2.2. Benefits for electricity suppliers and energy traders 63
4.2.3. Benefits for distributed producers 64
4.3. Benefits of smart grids from the industry perspective 64
4.4. Benefits of smart grids from the household perspective 65
4.5. Benefits of smart grids from the research perspective 66
5.1. Determining education requirements 67
5.1.1. General requirements for smart grid technicians 67
5.1.2. Technical requirements for smart grid technicians 67

5. Education as the key to the future 67
5.2. Education and further training 68
5.2.1. Vocational training 68
5.2.2. Training at the secondary, HTL, level 68
5.2.3. Education at universities of applied sciences 68
5.2.4. Education at technical universities 68
5.2.5. Continuing professional training opportunities 68
5.2.6. Training for instructors 69
5.3. Recommended courses of action for future education 69
5.3.1. Pedagogical requirements 69
5.3.2. Opportunities for use within the education system 69
5.3.3. Company requirements 70
6.1. Need for action by all stakeholders in the development of smart grids 71
6.2. Need for action by public authorities 71
6.2.1. Need for action by government ministries 71

6. Need for action and results 71
6.2.2. Need for regulatory action 72
6.2.3. Need for action related to innovation structures and funding mechanisms 73
6.3. Need for action by grid operators 73
6.3.1. Need for action related to framework conditions 73
6.3.2. Need for technological and economic action 74
6.4. Need for action by electricity suppliers and energy traders 74
6.4.1. Need for action related to framework conditions 74
6.4.2. Need for technological and economic action 75
6.5. Need for action by technology providers 75
6.5.1. Need for action related to framework conditions 75
6.5.2. Need for technological and economic action 76
6.6. Need for action in research and education 76
6.6.1. Need for action related to framework conditions 77
6.6.2. Need for technological and economic action 77
6.7. Need for action by the Technology Platform Smart Grids Austria 77

7. Appendix 78
7.1. Connection to the Research Roadmap Smart Grids Austria 2010 78
7.2. ICT architecture for smart grids in the international context 79

7.3. The traffic light model in Austria and elsewhere ... 80
7.4. Austrian model regions and demonstration projects ... 82
7.4.1. Overview of model regions in Austria ... 82
7.5. Overview of international platforms ... 92
7.6. Standardisation in the smart grid ... 94
7.6.1. Overview of current international standardisation work ... 94
7.6.2. Overview of Austrian standardisation work ... 95
7.6.3. Opportunity to collaborate on standardisation and contact data ... 95

8. Works cited ... 96
8.1. Acronyms and abbreviations ... 101
8.2. Glossary ... 102
8.3. Acknowledgements ... 102

Preface

One of the most exciting innovation tasks

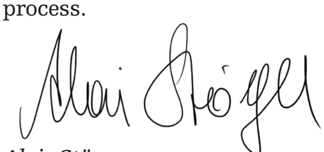
The reorganisation and modernisation of our electricity supply is one of the most important and exciting innovation tasks we face at the start of the 21st century. New technologies are increasingly enabling distributed generation of electric energy, primarily from renewable sources.

At the same time, thanks to information technology, systems can be connected to an ever greater degree, which enables better control of our energy systems. But as technological advances continue, the institutional and organisational framework also needs to be developed further so that co-operation among stakeholders is dynamic and flexible enough. As part of its efforts to work with other partners to secure Europe's energy supply over the long term, the European Commission has also repeatedly emphasised the important role of research and technology development and the major importance of efficient energy grids.

By actively contributing to this development, we can strengthen Austria as a business location in two ways. On one hand, we can do so by establishing an efficient, high-performance infrastructure that ensures an environmentally friendly energy supply and that optimises the use of resources over the long term. Moreover, this infrastructure will enable a number of specific services for citizens, from the ability to individually control their own energy supply to the use of electromobility. And on the other hand, we can increase opportunities for Austrian businesses by actively shaping this development. Competition in the market for energy technologies, planning and research services, and energy-related services is increasingly global. In light of this, Austria must hold its own.

Thanks to the establishment of pilot projects and model regions and its involvement in the European Strategic Energy Technology Plan (SET-Plan), which is based on these projects and regions, Austria has already succeeded in using its existing knowledge base and years of experience with renewable energy and in making a name for itself internationally as a knowledgeable partner. Despite all that has been achieved thus far, a comprehensive and broad-based strategy for Austria is essential to ensure planning certainty for decision makers.

The Smart Grids 2.0 strategy process of the Federal Ministry for Transport, Innovation and Technology (bmvit) provides a platform for creating foundations for decision-making and components of implementation on which a consensus can be reached – based on the findings of research, technology, and innovation (RTI) initiatives and with the involvement of stakeholders. This technology roadmap and the systematic ongoing dialogue conducted through the Technology Platform Smart Grids Austria are an important part of this process.



Alois Stöger
Federal Minister for
Transport, Innovation and Technology

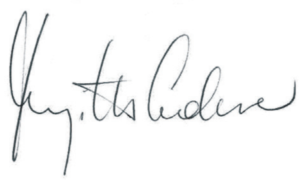
Renewable energy needs smart grids

In the coming decades, the electricity infrastructure will be transformed from one that is controlled centrally to one in which power is generated locally. This development is being driven by the greater integration of renewable energy sources. The rapid increase in the supply of renewable energy sources such as solar and wind power to the grid – sources that are generally supplied to the grid locally – means that active and dynamic management is needed, especially in the medium- and low-voltage range. The most technologically efficient solution for fundamentally restructuring the energy supply is the smart grid.

We in Austria are pioneers in the development of smart grid technologies. Current surveys by the European Commission and EURELECTRIC[1], the Union of the European Electricity Industry, confirm that Austria is leading other countries in terms of research, development, and demonstration projects. But there is still much to be done before smart grids become standard. The Technology Roadmap Smart Grids Austria has succeeded in setting the necessary milestones. Collaboration among smart grid experts in industry, the electricity sector, and the research community through the Technology Platform Smart Grids Austria in particular, which has already been in place for years, served as an excellent starting point for developing the technology roadmap.

Creating a smart energy infrastructure requires considerable investment, but brings with it considerable potential for the business location to grow. Investments must be arranged so that value creation grows at home, jobs are protected, and Austrian companies are stronger competitors internationally. Austria will only be able to position itself as a lead market if it succeeds in implementing end-to-end, integrated smart grid solutions. Austrian companies will be able to use this to gain international visibility for the system expertise they have acquired – expertise that could become a clear advantage over international competitors. In turn, Austrian grid operators will benefit from the smart technologies developed by companies in their environment that enable sustainable and efficient grid operation and that are less expensive to implement than conventional grid expansion.

Companies in the electrical and electronics industry are willing to put their innovations to use to further develop key technologies for a sustainable and modern energy infrastructure in Austria and the world. It would behove us to get started today so that we can make this a reality by 2020.



Mag. Brigitte Ederer
President of FEEI – Association
of the Austrian Electrical and Electronics Industries

1 https://portal.smartgridsprojects.eu/Pages/Map.aspx

From planning to implementation

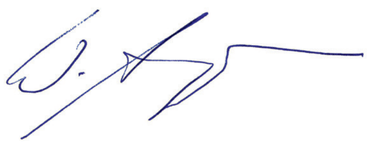
Basic technological innovations and infrastructures are some of the key factors that determine a country's prosperity and future viability. We expect smart grids not only to transform electricity supply systems; we also expect a fundamental technological revolution that will extend to major areas of modern life.

As an association of stakeholders in the field of electricity supply, the national Technology Platform Smart Grids Austria has set out to join forces for future smart grids and strengthen Austria's expertise in this important field of the future. Austria's smart grid industry has a high level of technical expertise, recognised products, and enormous innovative capacity. Several research and development institutions have been active in the field of smart grids for years and have carried out important development work. Grid operators and energy suppliers from Austria's e-economy have taken these innovations and, through a number of projects, have laid the foundation for nationwide use of smart grids in the coming years.

"Der Weg in die Zukunft der elektrischen Stromnetze" (the roadmap to the future of electric power grids) published by the national Technology Platform Smart Grids Austria illustrated a coordinated, structured, and continuously fine-tuned roadmap to smart grids – from describing the initial situation and necessary technological developments to achieving a sustainable and secure electrical power supply in Austria.

By publishing the present Technology Roadmap Smart Grids, we are setting out on the path of research and design, heading toward implementation. Technical approaches that have been tested in model regions serve as the basis for the Technology Roadmap Smart Grids you have in your hands. The roadmap not only illustrates the state of development; it also contains specific measures for introducing systems and further research measures. The roadmap also includes information about the importance of the project as a whole and the opportunities it will create for our country.

Everyone who has collaborated on this extensive and multifaceted project, which is nowhere near completion, deserves our gratitude and appreciation. For those who would like to join our project, this brochure provides information and inspiration for tackling this major future project along with us. Electricity is the energy of the future, and smart energy is the solution to many of the challenges we will need to overcome.



Wolfgang Anzengruber
President of Oesterreichs Energie

Management summary

Objectives of the Smart Grid Technology Roadmap

This technology roadmap is a key component of the Smart Grids 2.0 strategy process, which was initiated by the bmvit. It covers the short and medium-term stages of development for the implementation of smart grids including the development and implementation of marketable products and services, with a focus on the period from 2015 to 2020. Austria's industry, energy sector, and research community expect the implementation of this national technology roadmap to result in end-to-end smart grid solutions and tremendous opportunities for Austria to secure global technology leadership, while also strengthening Austria as a business location.

Challenges in the energy system

As the share of renewable energy sources in overall energy provision increases, the planning and operation of the power grid – and especially the necessary task of balancing generation and consumption – are becoming more and more difficult. In many cases, a conventional expansion of the existing grids is necessary. The smart grid approach is aimed at an increasingly decentralised, regional load balance. This is achieved by establishing communication networks between individual components such as distributed generation units, distributed storage systems, flexible consumers, and intelligent buildings.

Individual technologies for smart grid solutions are already available today. Now these technologies have to be more widely integrated into distribution grids, systematically linked together, and optimised.

Benefits of smart grid technologies and solutions

The roadmap examines the development towards smart grids from an economic perspective. By increasing the share of renewable energy in final energy consumption, smart grids help to increase the country's energy independence. The reduction of fossil fuel imports leads to a decline in carbon dioxide emissions. In addition, smart grids contribute to increasing the energy efficiency and security of supply of the power grid.

Development axes of the technology roadmap

The path towards the widespread implementation of smart grid solutions up to 2020 that is laid out in the technology roadmap focuses on the following steps: working on the framework conditions, the large-scale system validation of technologies that have already been developed, applied research and further development, and the implementation phase. With this in mind, the implementation and migration processes must be properly coordinated with one another from a strategic perspective. This coordination will occur along three development axes (grid, system, and end customers) and in an overall ICT architecture.

The **grid development axis** aims to achieve a cost-effective increase in the hosting capacity of distribution grids for distributed generation, flexible consumers, storage systems, and electromobility. The focus here is on solutions and technologies for distribution grid monitoring, R&D testing infrastructure, and the operation and planning of distribution grids.

The **system development axis** is aimed at the utilisation of flexibility for all market participants. Consideration must be given to the various needs relating to the smart grid and to ensuring the compatibility of the flexibility requirements on the market side and on the grid side.

The **end customer development axis** deals with the integration of the end customer – the prosumer (market participants who are both producers and consumers of electricity) – into the market and system operation.

The **overall ICT architecture** serves as the central technical foundation for the technologies and solutions in all three development axes. It describes the architecture of the central IT environment and the communication infrastructure based on the operational processes specific to the distribution grid operators.

Key steps for the implementation of smart grids

The following issues were identified as the most important results that must be achieved together by the stakeholders:

Clarification of the framework conditions, roles, and responsibilities

The first step involves clarifying requirements with regard to the technical and organisational framework conditions and the various possible roles and responsibilities within the smart grid (e.g. rights to access flexibility in the context of a free market and a regulated grid) based on previous experiences in individual projects and discussions at the international level.
A process for dialogue between the stakeholders must be initiated in order to facilitate this.

Development of an overall ICT architecture and smart grid migration path

Starting from the current state of the ICT infrastructure and the illustrated development of an overall ICT architecture that will be required in the future, the next necessary steps are as follows:

- Expansion/adaptation of the existing operating processes of the distribution grid operators in order to be able to meet the new market and system requirements
- Description of the system interfaces with other market participants and internal system interfaces with consideration of the existing infrastructure
- Definition of the requirements for an optimal overall ICT architecture including possible synergies with existing systems

On the basis of these steps, a migration path will be developed in order to initiate a gradual convergence of the various technology generations to the common target architecture. Consideration for international standardisation will play a key role in this process. The path towards a standardised, scalable, and efficient solution necessitates the clarification and optimisation of process questions through the large-scale system validation described above.

Demonstration of new business models and services

New business models in the smart grid determine the framework conditions for the processes involved with the technological solutions. Therefore, the development of new services must occur within the context of the technological requirements, and their real-world implementation must be demonstrated.

Large-scale validation projects in Austria

Extensive system tests are required in order to be able to test the smart grid solutions that have been developed thus far in a real-world environment, optimise them, and apply them more efficiently. For the validation and field testing of system approaches, entire distribution grid sections must be fully equipped with the appropriate technology in the course of large-scale implementation projects. Validation should be performed for at least one urban, one rural, and one hybrid grid and should include the areas of infrastructure for monitoring operating conditions, systems for active grid management, and an ICT migration path (including new functions for individual IT components). The interaction of the many new processes, components, and functions required for smart grids can only be tested under real conditions and their functionality and economic viability optimised in large-scale validation projects. The implementation of such validation projects should be supported through the Austrian subsidy landscape.

Development of a lead market for Austria

If Austria successfully implements end-to-end, integrated smart grid solutions, it can position itself as a lead market for smart grids. This will serve Austrian companies as a reference with international visibility

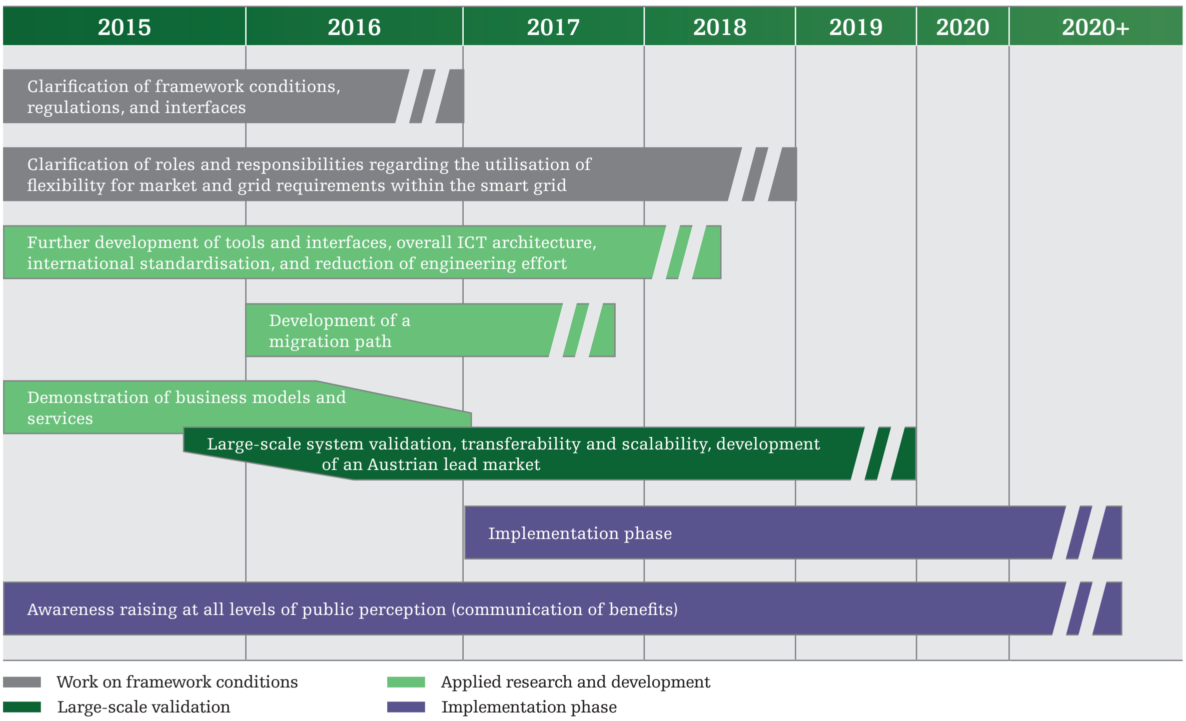


Figure 1

Key steps for the implementation of smart grids for the system expertise they have acquired. Application-oriented R&D funding is an important source of support for boosting the expertise of Austrian technology providers so that they can position themselves well in international competition.

Awareness raising

Awareness raising measures aimed at the general public will be necessary in parallel with the migration towards smart grids on the basis of the technical, economic, and legal framework conditions. For this, experts and decision makers must present a concerted view of the benefits of smart grids and discuss this in public. Active communication is urgently needed not only about risks and how to minimise them, but also about benefits and opportunities.

Identified need for action by the individual smart grid stakeholders

The roadmap describes the need for action by the key stakeholders such as public authorities, grid operators, technology providers, and research institutes in detail. In the interests of the successful joint implementation of smart grids, all stakeholders should be involved in support measures. A permanent process of dialogue between the involved stakeholders must be established in order to improve the associated tasks and fields of action and, in turn, to enhance the stakeholders' understanding of one another.

The most important areas in which there is a need for action are summarised for each individual stakeholder below:

Need for action by public authorities

In Austria, the responsibility for the topics associated with the field of smart grids, such as energy, research, safety and security, and economy, is distributed among several different ministries and authorities. The co-ordination between the affected authorities must be strengthened so that the necessary frame-work conditions for innovations in industry, the energy sector, and research can be created through a joint strategy.

Need for action in the regulatory environment

In many cases, smart grid solutions lead to a reduction or delay of investment costs, while also often resulting in increased personnel expenses for operations. The approval of these costs incurred by the grid operators must be ensured on a long-term basis, with consideration being given to the overall optimum. In order to ensure innovation over the long term, the approval of the costs for validation projects must be taken into consideration.

The utilisation of flexibility ranging all the way down to prosumers and consumers in the household segment offers many possibilities for marketing. The framework conditions with regard to the rights of access to flexibility must be clarified in order to regulate the divergent requirements of the involved stakeholders (e.g. using the traffic signal model).

The various use cases described in the roadmap give rise to numerous requirements with regard to market design. As a result, the questions of whether new roles are necessary and which existing and/or new stakeholders could fill these roles must be clarified.

It is also necessary to define balanced requirements for security and privacy in line with the relevant potential risks.

Need for action by technology providers

The need for action in terms of technology must be clarified by the technology providers in co-operation with the future users of the relevant technology – primarily grid operators and final energy customers. Points of emphasis include the technical and economic optimisation of the solutions for grid operators with due consideration being given to CAPEX and OPEX in light of the requirements for the overall energy system while simultaneously ensuring quality of supply. At the same time, all of the requirements with regard to security, privacy, and safety must be taken into account, and plug-and-automate solutions must be developed in order to reduce the engineering effort and costs associated with smart grid solutions.

Need for action by grid operators

Smart grid technologies offer grid operators new possibilities for the operation of the grid, innovative methods for grid planning, and additional functions in order to be able to meet the new market requirements that are arising. Well-established processes often have to be redefined and implemented within the companies.

As a result, each grid operator must have a needs-based migration scenario for these new technologies and processes, which must be developed on an individual basis. The experience gained in the large-scale validation projects is crucial in this context.

With regard to the operation of the grid, the requirements related to the following issues, among others, must be clarified and appropriate solutions developed:

- Definition of functional requirements for distribution grid monitoring
- Integration of existing installations into smart grid solutions
- Technical integration of end customers for line-commutated flexibility enquiries
- Validation of possibilities for distributed control technology

Need for action in research and education

Research and education institutions must ensure the availability of the necessary expertise and transfer of knowledge. In order to achieve this, they must continuously adapt to the current developments to ensure the high level of research quality in the field of smart grids and constantly advance the level of education.

In the interests of making the solutions developed in Austria transferable and scalable, collaborative European and international projects should be implemented.

Need for action by the Technology Platform Smart Grids Austria

The technology platform serves to network representatives of the energy sector, industry, and the research community within the platform and has been able to establish a good rapport with ministries, authorities, and international experts in recent years. Its task for the future is to establish and strengthen its contacts with stakeholders that are not yet involved in the current development of smart grids. In addition, it can facilitate the appropriate further development of funding priorities by continuously monitoring the topics that are emphasised.

Austrian model regions and pilot projects

Several model regions have been established in Austria in the course of the research activities being conducted here. The smart grid technologies that have been developed were field tested in these regions. Figure 27 (see page 56) shows the Austrian model regions and smart city projects. Descriptions of the projects can be found in the technology roadmap and on the web site of the Technology Platform Smart Grids Austria (www.smartgrids.at).

1. Introduction to the Technology Roadmap Smart Grids Austria

1.1. Motivation

The energy transition initiated by policy and the expansion of renewable energy sources it promotes, particularly hydroelectric power, wind power, and photovoltaics, mean that grid operators are facing the challenge of taking appropriate measures to ensure power can continue to be supplied in Austria with the same high quality. As a result of the energy transition over the coming decades, the power supply will evolve from one that is controlled centrally into an electricity infrastructure with additional distributed intelligence. One technological solution is for the power supply to develop into a smart grid. Austria's industry, research community, and energy sector expect the implementation of this national technology roadmap toward smart grid solutions to create tremendous opportunities for Austria to secure global technology leadership, while also strengthening Austria as a business location.

New requirements for the power grid

Operating a power grid with a high share of renewable energy sources requires much more information. This is because electricity transmission at the medium- and low-voltage level is also be coming bidirectional, and grid utilisation becomes much more dynamic. Consequently, grid utilisation must be monitored, and dynamic management is needed to be able to integrate a high share of renewable energy sources into the existing infrastructure. This requires information and communications technology (ICT) in the distribution grid to be expanded, which creates opportunities for real-time monitoring and control.

ICT components are already part of power grids, but they have generally been isolated and operated only at higher voltage levels (high-voltage and extra high-voltage grids, and in some cases the medium-voltage grid). The future smart grid will involve an energy system networked by IT on a broad scale since many medium-sized and small producers will be integrated at the distribution grid level. Development of the necessary components and ICT must account for special requirements for the power grid, particularly requirements for security of supply.

New demands on the overall system

As the share of renewable energy sources in overall energy provision increases, system operation, especially the necessary task of balancing generation and consumption, will become increasingly difficult. The smart grid approach is aimed at an increasingly distributed regional load balance (generation-oriented consumption) by establishing communication networks between individual components such as distributed generation units, distributed storage, and flexible consumers and includes innovative applications such as electromobility, load flexibility, smart building control, and home automation.

The new role of end consumers

As the energy system is transformed, the customer's role changes as well. Smaller photovoltaic (PV) systems, and more recently even battery storage systems, are being installed on the end-consumer side. As a result, customers are no longer just consumers, but are at times producers as well, or "prosumers". Prosumers can become part of the smart grid by making their flexibility as an energy consumer and producer available as a service to the local grid and for the overall system, for example in the form of storage or reactive power management.

Benefits of implementing smart grids

The fundamental changes described above are already happening and will continue to take place so that a sustainable electric energy system can be created. The implementation of smart grid solutions will ensure that increases in the cost of the energy system associated with the energy transition will be reduced and that the functions of the overall system will be able to be expanded for our society and all stakeholders.

- **Smart grids as enablers of the energy transition**
  The primary objective of smart grids is the policy commitment to the energy transition in Austria and Europe. Major efforts to promote the expansion of renewable energy sources have been made, and the decision to roll out smart meters has been taken as part of:
  - The definition of 20-20-20 targets,
  - The Energy Efficiency Directive, and
  - Climate protection.

- **Optimising the energy system as a whole**
  The central principle is ultimately to achieve a sustainable overall economic optimum in Austria's supply system. Using potential regional flexibility and economies of scale (including involving storage systems) on the demand and generation side can make grid operation more efficient by removing some of the burden on the grid and can reduce, or at least delay, expansion of the grid. This could prevent or minimise a considerable hike in grid costs. Security of supply and quality must be ensured and covered by regulations.

- **Establishing new markets and services**
  Integrating new stakeholders and technologies (generation, storage, system operation, consumption, new energy and information services, electromobility, etc.) as best as possible will enable new smart services thanks to secure ICT communication and the availability of additional data. This will also create an incentive for new markets, roles, and companies.

- **Strengthening Austria as a business location**
  From an economic policy standpoint, smart grid implementation must be used to improve Austria's ability to compete internationally. The primary advantage of a domestic market is that expertise that is gained can be consolidated and put to use at home as well as abroad. In other words, the development of smart grids can be a boon for Austrian companies. In addition to developing a domestic market for Austrian industrial companies, important arguments in favour of Austria as a business location include a sustainable renewable energy supply, efficient grids with a secure supply, and high quality for the entire country.

The vision for smart grid development in Austria

Over the course of the bmvit's Smart Grid 2.0 strategy process the various stakeholders defined a common smart grid vision for Austria, which is described as follows (see also Section 3.1.1.):

- By developing distributed and regional smart energy systems and highly networked infrastructures, Austria is setting an example in Europe of successful innovation policy and can draw on successful international partnerships (such as DACH) and broad experience in integrating renewable energy.
- Smart grids, as an enabler of Austrian technology and system solutions, attract attention to Austrian technology providers in European and global markets (Austria holds a pole position).
- Austria's scientific community is becoming a frontrunner in research (already among the top in European SET-Plan initiative grids) and training.
- The development of sustainable energy systems that are highly efficient, optimised for resources, renewable, distributed, synergistic, resilient, participatory, and market-based ensures a sustainable energy supply.

Smart grids as a challenge

There are still major technical, organisational, and, not least, legal challenges to solutions for migrating existing grids to smart grids. Individual technologies are already available today, including smart metering, communication solutions (fibre-optic networks, wireless communication, and power line communication), and active distribution grid management (automation and control technology) for the medium-voltage level.

These technologies now need to be used in distribution grids on a large scale, and similar solutions for low voltage need to be added. In order for smart grids to ultimately be run for profit, the challenges resulting from energy infrastructure expansion through the widespread use of ICT need to be understood and resolved. This also involves the issue of the extent to which smart grid solutions are needed, in what form, and in what places in the system.

One of the primary challenges for smart grids is interoperability. Since the future power supply grid will consist of a variety of technologies, it must be ensured that individual components from different areas and different manufacturers can communicate seamlessly and securely with each other. Existing standards must be harmonised and in some cases expanded to meet the growing need for interoperability. Work on standards must be prepared according to the outcomes of research, field tests, and demonstration projects and brought to European (ETSI, CENELEC, CEN) and international (IEC) bodies.

In light of this, the technology roadmap, which has been coordinated with stakeholders in the energy sector, industry, and research, is an important tool for the strategic development of smart grids in Austria.

1.2. Objectives of the roadmap

The primary aim of the technology roadmap is to define the short and medium-term development steps that must be completed by key stakeholders – the energy industry, technology providers, and the research community – so that smart grids can be implemented.

Implementation of electricity infrastructure visions by 2020

The Research Roadmap Smart Grids Austria [1], which was published by the Technology Platform Smart Grids Austria in 2010, addressed the development of a vision for the electricity infrastructure in 2050. Research questions were then developed based on this vision. Some have since been answered, while others remain open. Several R&D projects on the development of concepts, smart grid components, and demonstration of system approaches have since been conducted (see Section 7.1 for detailed explanations). The Technology Roadmap Smart Grids Austria analyses the situation as it exists today against this backdrop and elaborates the need for further action so that the key components of the established smart grid vision for 2020 can be implemented.

Pivotal component of the smart grid introduction strategy

This technology roadmap is a key component of the Smart Grids 2.0 strategy process, which was initiated by the bmvit. The bmvit's Smart Grids 2.0 strategy process is a platform for creating foundations for decision-making and implementation components on which a consensus can be reached – based on findings of research, technology, and innovation (RTI) initiatives and with the involvement of stakeholders. This technology roadmap covers the short and medium-term stages of development for the implementation of smart grids up to and including the development of marketable products and services. It focuses on implementation-oriented requirements in terms of technologies for the period from 2015 to 2020.

As illustrated above, important technologies that are part of smart grid solutions have been successfully implemented in research projects and tested in demonstration projects, and real-world experience has been gained in recent years. As a result, Austria has taken on a leading role in the international smart grid environment. The aim is now to expand this role to ensure that Austrian companies have competitive advantages and can secure technology leadership and to actively support implementation and further development of the RTI strategy.

Demonstrations and comparative validations constitute the next step toward nationwide implementation of smart grid technologies and solutions. During this step, smart grids and implementation of smart grid systems are being tested in entire regions, and operating processes are being optimised. This will make it possible to ascertain the operating requirements that smart grid components must meet, for example for smart metering and active distribution grid management (control technology), and to obtain information for bringing these components to market and optimising them.

1.3. Smart grids: drivers and basic concepts

The international discussion of smart grids has led to the identification of aspects generally accepted to be driving smart grid development:

- **Changing requirements in the grid**
  Throughout Europe implementation of smart grids is being promoted primarily through the energy transition. The integration of renewable energy sources means that existing distribution grids must meet new requirements, such as variable distributed generation. Moreover, distribution grids need to be successively prepared for additional applications, such as electromobility.

- **Energy market in transition**
  Energy markets have changed dramatically, and this change has also been driven by the energy transition. As distributed wind and solar power plants become increasingly widespread, the share of energy whose generation fluctuates and which is produced independently of market requirements has grown immensely. Since ICT has become much more pervasive, the loads and energy sources that are controlled and distributed in the smart grid can be offered to the market in aggregate form as flexibility. This creates new market opportunities that will help compensate for the difference between variable generation and current demand and will also help create new energy products and services.

- **Involving end customers**
  New requirements for grids and the energy trade have brought about changes in the environment for end customers, too. In future, end customers will be able to participate in the energy market and support system stability by offering up flexibility. Realistically, this can only be achieved if system services are provided and flexibility is offered automatically, without end customers having to intervene manually.

In this context, a few basic terms have become established in the international discussion. These terms are

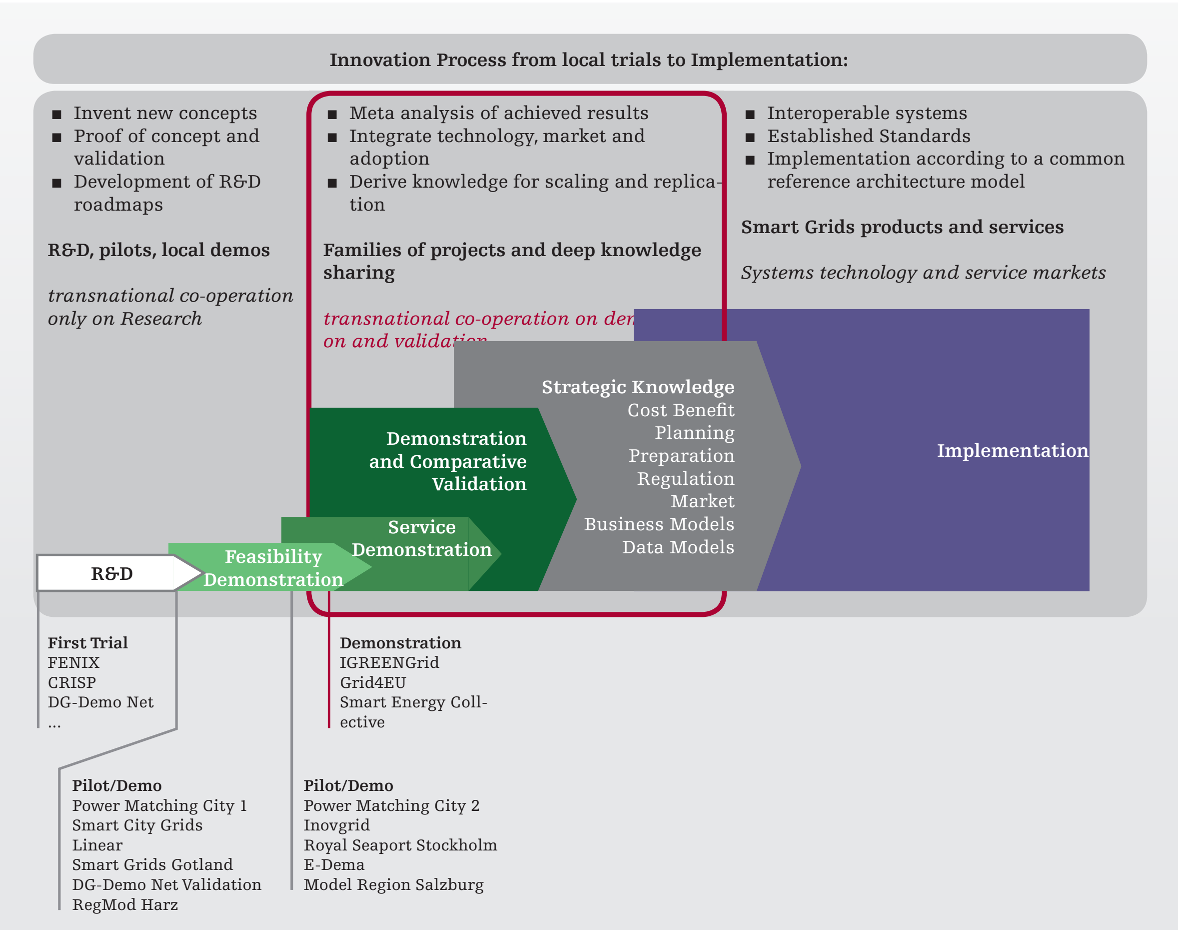


Figure 2

Smart grids innovation strategy

Source: ERA-Net Smart Grids Plus, adapted from ISGAN case book on Active Demand/ Netherlands Power Matching City explained in the following, as they are used throughout the remainder of the roadmap – above all, the definition of "smart grid".

Definition of smart grids in the context of the Technology Platform Smart Grids Austria

Smart grids are power grids that promote energy-efficient and cost-effective system operation for future requirements. Thanks to coordinated management, they use real-time two-way communication between

- grid components,
- producers,
- storage, and
- consumers.

(*www.smartgrids.at*)

Smart Grid Architecture Model (SGAM) as a reference model for smart grid ICT architecture

In addition to developing standards for interoperability among grid participants mentioned in the definition, Europe has defined a Smart Grid Architecture Model (SGAM) in recent years (see also the description in Section 7.2. and [87]). SGAM has since become a recognised reference for organising and discussing information systems in the smart grid. The model is also used in the work of the Technology Platform Smart Grids Austria and has proven to be a suitable tool for structuring work on the roadmap.

The traffic light model as guidelines for stakeholders

A traffic light model for evaluating grid status was developed in Germany as part of the E-Energy programme [58] (see also the description in Section 7.3.). The idea behind the traffic light model is to no longer expand the distribution grid infrastructure for 100% of the theoretically possible two-way full load scenario. This scenario occurs rarely and is very expensive. For this idea to be implemented in practice, the grid load must be monitored constantly, and when the grid reaches capacity, intervention in market-oriented processes becomes necessary to prevent damage. A traffic light is used to involve market processes in this system. The green phase means that all market-based energy processes can be implemented without restriction. Amber indicates a potential grid overload. This signal means that consumers should adapt their consumption to the needs of the grid. The red phase indicates that the grid's capacity has been reached, and the grid operator intervenes to take control of energy processes in order to prevent grid overload. A more detailed description of the traffic light model is provided in Section 7.3.

Flexibility

The management measures available in the power grid itself (primarily state of operation and transformer levels) when used alone are often not enough to enable targeted interventions in grid and system operation in a smart grid. This is where flexibility provided by grid

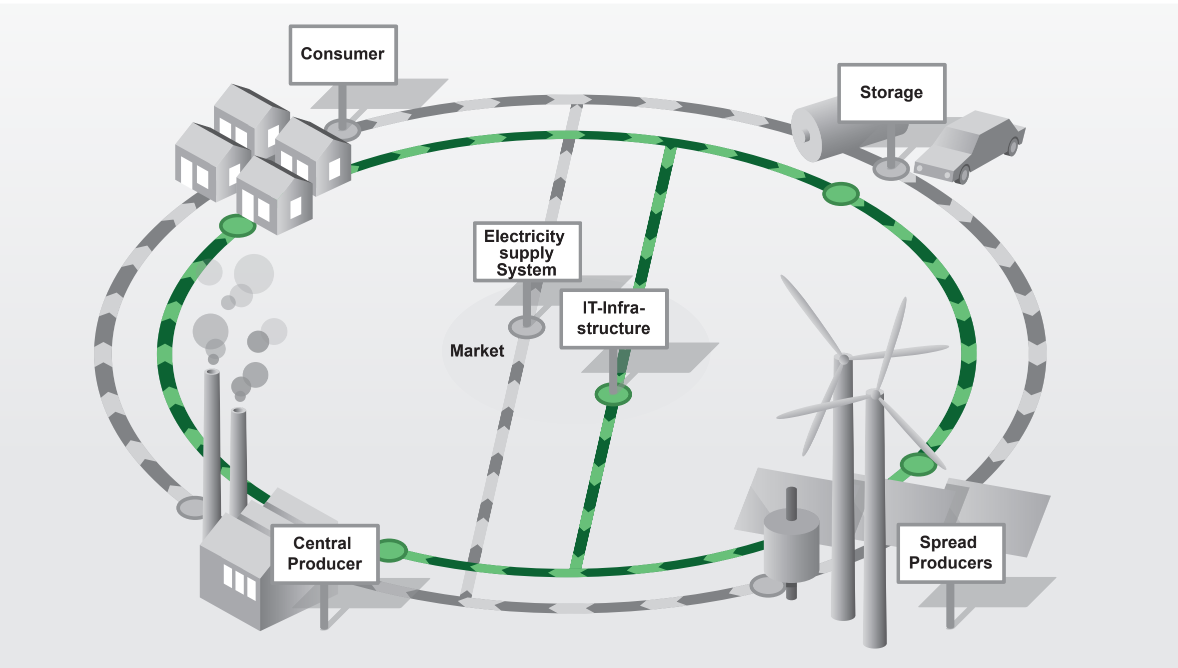


Figure 3

Smart grids definition illustration

Source: www.smartgrids.at

participants comes into play, which poses a challenge in terms of integrating it into system operation (see Section 2 of this roadmap). According to the definition in EU Mandate 490 [111], flexibility in general refers to the elasticity of resource deployment (demand, storage, generation), in particular to provide ancillary services for grid stability and/or market optimisation (change of power consumption, reduction of power supply to the grid, reactive power supply, etc.).

1.4. Smart grid requirements

In order for the strategic objectives outlined in the Motivation section to be fulfilled, smart grids must be designed in a way that allows essential basic requirements to be met.

1. Creation of a sustainable and eco-friendly power supply system must be ensured through the gradual integration of renewable energy sources.
2. Existing and new energy supply processes must be transparent, and applicable regulations and market requirements must be met.
3. Smart grid operating paradigms must enable cost-effective system and grid operation while ensuring quality of supply.
4. The system must be able to adapt easily and quickly to new market requirements in a volatile environment.
5. Demand-driven and gradual migration to new technologies and management concepts must be encouraged in the interest of making the best possible use of the existing grid infrastructure.

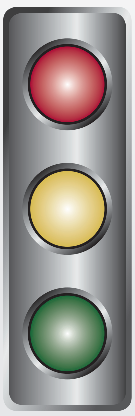
1.5. The technology roadmap development process

The Technology Roadmap Smart Grids was developed under the direction and by members of the Technology Platform Smart Grids Austria on behalf of the bmvit through workshops, expert surveys, and feedback loops. Members of the research community, industry, and the energy sector contributed their technical background, experience, and expertise in the field of smart grids.

The first phase involved conducting a survey of the literature and projects to ascertain the current state of smart grid technologies. Work continued in workshops and feedback sessions during the second phase of the development process. This was intended to ensure the broadest participation possible. During the third phase, content that was developed and evaluated in the earlier phases was coordinated among the stakeholders and compiled to create a roadmap.

Additional stakeholders were involved in the drafting process through a project advisory committee, which consisted of public bodies (ministries, public authorities, interest groups, and associations) and companies not yet directly active in the smart grid environment.

Figure 5 provides an overview of the stakeholders that were directly involved in the technology roadmap development processes or that were taken into account



The grid infrastructure has reached capacity. The grid operator must manage/control customer systems to prevent the grid's capacity from being exceeded, and thus to prevent damage.

Early warning stage – there is a risk that the grid infrastructure will reach capacity. Customer systems must meet grid-side requirements for management and control in order to prevent a red traffic light scenario.

The grid infrastructure can cover all of the market's and prosumers' requirements without restriction.

Figure 4

The traffic light model and meaning of the traffic light phases in the requirements for smart grids, for example for training.

1.6. Structure and organisation of the Technology Roadmap Smart Grids Austria

Based on the process and objectives outlined above, the technology roadmap is organised as follows: Section 2 analyses the current state of each of the technologies along three development axes and using various use cases. It identifies specific need for action and market development requirements for bringing technologies to market and implementing them on a broad scale. For the purpose of the roadmap, the necessary steps between now and 2020 are illustrated using a timeline. The requirements for the overall ICT architecture are described as a foundation shared by the three development axes. Austria's activities, initiatives, and stakeholders in the field of smart grids are presented and analysed in more detail in Section 3. Austria's position in the international environment is also analysed. Based on the analysis of Austria's pro- -ject environment, the need for action, and the literature review, Section 4 illustrates the benefits of smart grids from the economic perspective and for industry, the energy sector, and end customers in Austria. Section 5 outlines training requirements in different areas in order to establish the expertise needed to implement smart grids. Consequences and recommended courses of action for relevant players are discussed in Section 6. The appendix (Section 7) contains in-depth and additional background information on the roadmap.

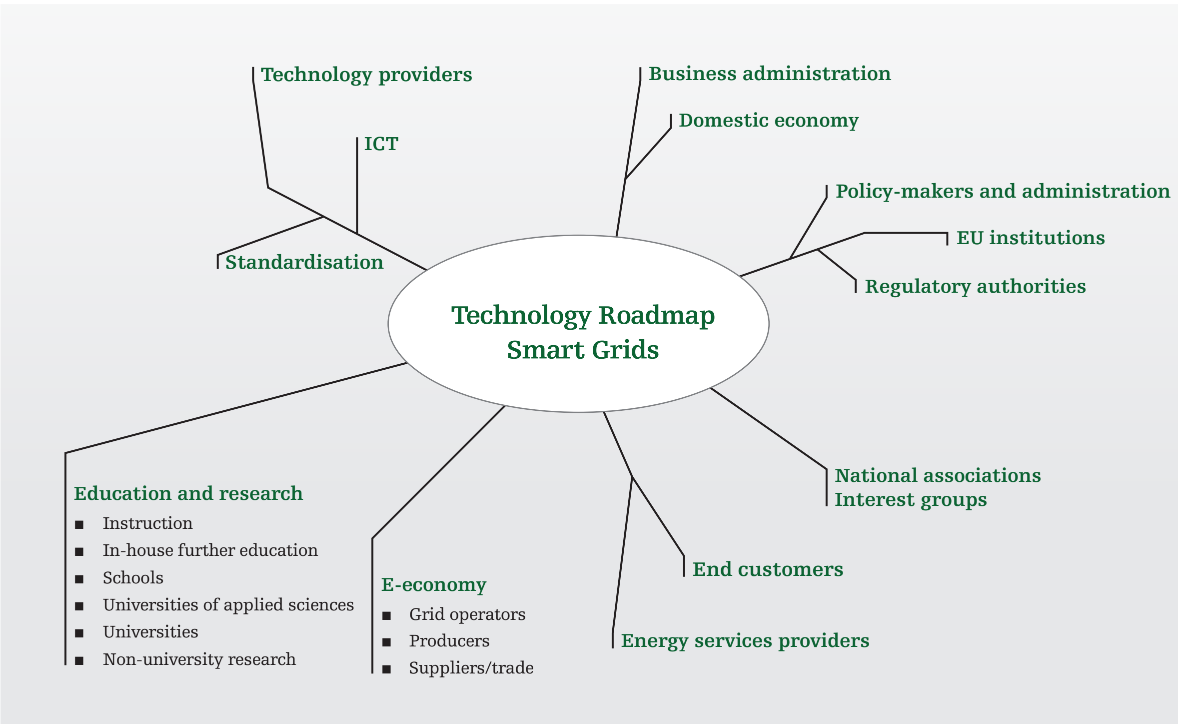


Figure 5

Overview of stakeholders that were involved or taken into account in the technology roadmap

2. The technology roadmap: pathway to implementation

This section of the roadmap, which is organised according to individual smart grid technologies, outlines the pathway from the prototypical smart grid solutions available today to market-ready products.

2.1. Smart grids organised by development axes, use cases, and technologies

In order to organise the results of smart grid R&D and demonstration projects conducted to date, an organisational structure was selected that groups the wide array of technological solutions along three main development axes, which share an overall ICT architecture. The development axes represent the pillars for the future design of the electricity system and the markets and services behind it.

We identified the following three main development axes based on experience from previous smart grid projects in Austria and/or the international context:

1. **Grid: optimised distribution grid operation** – solutions for technical system integration of a high share of distributed generation, flexible loads, storage, and electromobility into distribution grids while maintaining a high quality of supply

2. **System: utilisation of flexibility for the market and grid** – harnessing of flexibility for all market participants with different requirements in the smart grid and ensuring compatibility of the flexibility requirements on the market side and on the grid side

3. **End customers: smart solutions for consumers' market entry** – integration of the end customer – the prosumer (market participants who are both producers and consumers of electricity) – into the market and the operation of the system

During the development of this roadmap along these axes, it became apparent that it is important to have a common **overall ICT architecture** that serves as a central technical foundation for the technologies and solutions of all three development axes. The overall ICT architecture is the architecture of the central IT landscape and the communication infrastructure and is based on the operational processes specific to distribution grid operators. All three development axes share many of the requirements for an overall ICT architecture. It therefore makes sense to consider the architecture in the following both as an element that links the development axes and as their foundation.

Based on previous experience from field tests and research projects, a distinction is made within the development axes between specific use cases (indicated in the development axes), with some use cases being the logical prerequisite of others.

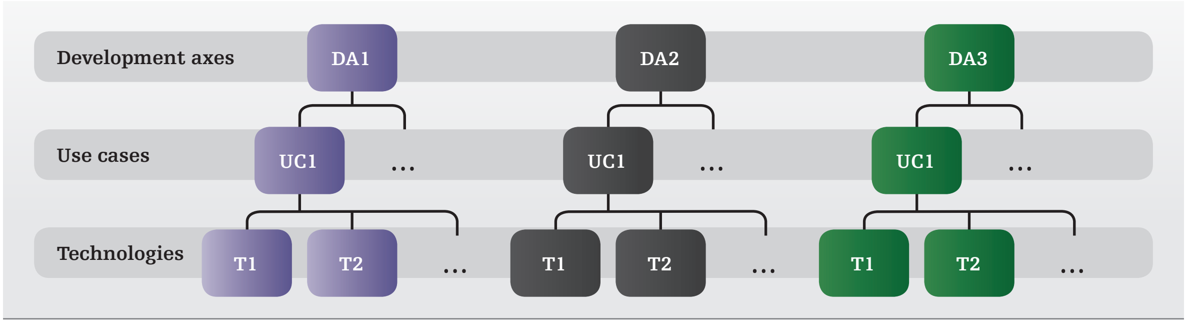


Figure 6
Levels under consideration in the

The use cases describe the specific technologies that enable implementation of the particular use case (for example, the technology "integrating coordinated control approaches into process control systems" for the "operating efficient grids" use case). What this roadmap contributes is an analysis of unanswered questions and barriers and the identification of need for action in order to bring the relevant technologies to market by 2020.

The specified development axes provide the content framework for considering the technological solutions in the roadmap. The hierarchy of development axes, use cases, and technologies is shown in Figure 6.

The three development axes and the role of the overall ICT architecture are shown in Figure 7. As a general rule, the development axes have been selected to minimise interdependencies and enable work to be carried out along all axes simultaneously.

Coordinating with the Smart Grids 2.0 strategy process initiated by the bmvit (see Section 3.1.1.) made it possible to achieve broad conformity with the drivers identified in the strategy process (grid, market, and end customer).

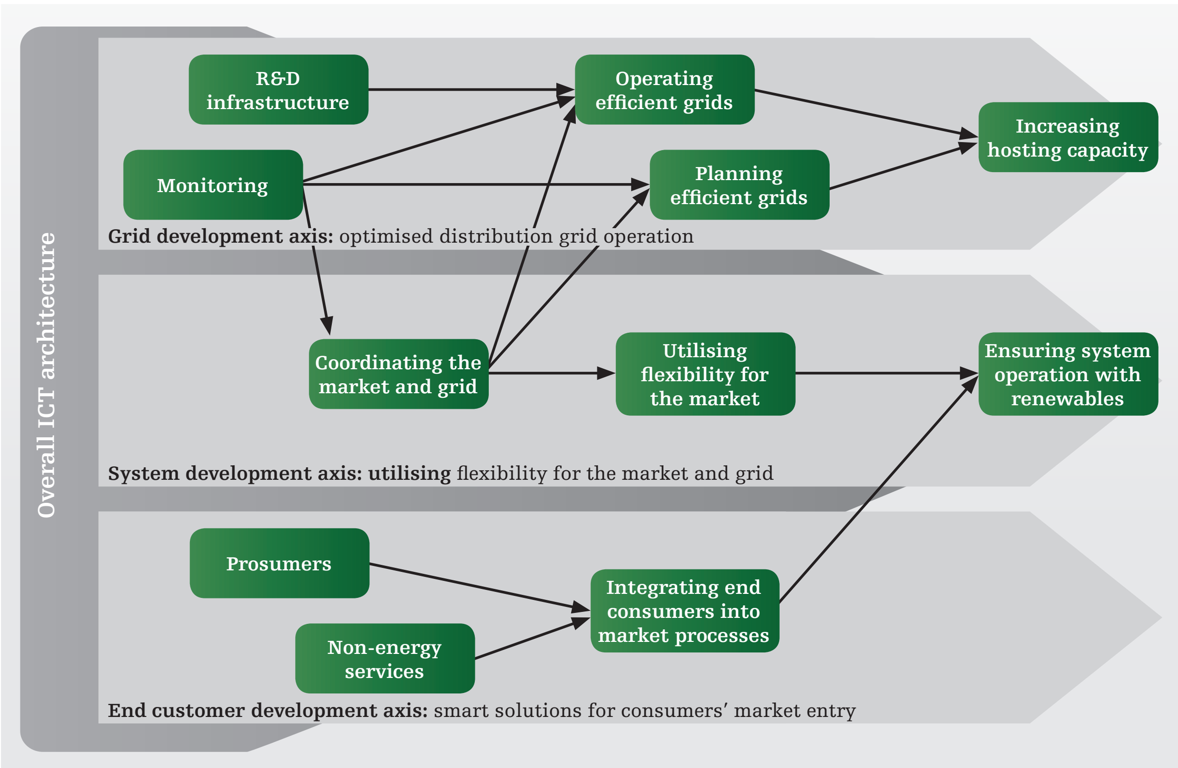


Figure 7
Overview of the overall ICT architecture and development axes, including use cases

2.2. Development steps in the technology roadmap

The steps outlined in the following are organised according to four colour-coded development phases. This makes it possible to systematically illustrate the further developments of individual technologies that are still needed in some cases, all the way up to the development axes in this roadmap. Since a group of individual technologies was used to develop an overall strategy in this roadmap, illustration using the established technology readiness levels [112] is only of limited value here. A separate classification method was therefore developed for this roadmap.

Work on framework conditions

This development step is intended to clarify or specify framework conditions (at the policy, legislative, public authority, or market model level) that are prerequisites for implementing the technology concerned.

Applied research and development

This development step involves answering research questions and developing new technologies or services, including the associated standardisation work and demonstration projects on a small scale (such as one section of a grid).

Large-scale system validation

Process issues (such as efficient operating processes) play a major role in the commercial implementation of smart grids. But these effects appear only once a system reaches a critical size. Large-scale system validation is therefore a necessary step in development before a technology can be implemented.

Implementation phase

In this step of development, a mature technology is installed in the field based on demand. Unless otherwise described, this phase follows every large-scale system validation.

2.3. The overall ICT architecture as the common basis of the development axes

One of the primary challenges of implementing smart grids is to develop the ICT used for operating the grid and systems. This enhanced infrastructure makes new technologies and solutions possible, but expanding and operating it is expensive.

Information and communication technologies are essential in order to be able to efficiently coordinate the energy supply and all associated processes. The overall ICT architecture for smart grids must meet the smart grid requirements outlined in Section 1.4., especially the possibility of a demand-driven gradual migration to new technologies and management concepts.

Growing number of stakeholders

One key aspect of the use cases in the roadmap is the growing number of stakeholders in the system. From the ICT perspective, this means a large number of new interfaces to different systems, which presents new challenges, especially for interoperability and security. Increasingly complex market mechanisms and operating processes for distribution grids mean more reporting and verification is required to document that the obligations of each of the market partners are met. Choosing an appropriate design for the overall ICT architecture could automate this task to the greatest possible extent. Connecting the new components via their interfaces would require a robust communication network, which would have to meet different requirements depending on the grid level. A well coordinated combination of distributed intelligence in smart grid components and an appropriate central IT landscape should be used for data acquisition and processing. Coordination among the relevant stakeholders is essential for working out the technical aspects of the overall ICT architecture.

Accounting for standardisation

Standards for interfaces, data models, and basic functions are needed throughout to minimise the cost of an overall smart grid solution. These standards must ensure interoperability among components from different manufacturers. Existing standards, particularly international and European standards, can be used as a basis. Development of the optimised process and infrastructure architecture must involve identifying existing gaps in standardisation and any need for harmonising existing standards, developing proposed solutions for these deficiencies, and submitting the solutions to the relevant standardisation organisations (ETSI, CENELEC, CEN, and IEC).

2.3.1. Current state of the ICT architecture

The ICT architecture's current state of development is illustrated in Figure 8.

All components at substations (high/medium voltage) and, in some cases, even components at secondary substations (medium/low voltage) are connected to a central IT system by a communication network that has grown over time and is based on a wide range of different technologies. The central IT system includes the grid control system, which monitors and manages the grid. The existing infrastructure has the following characteristics:

1. The communication network currently covers the high-voltage level and parts of the medium-voltage level. The bandwidth available for data transfer is designed for previous requirements and in many cases cannot be expanded due to technological limitations. Management is generally complex because there is no system for managing communication components across all technologies.

2. The central IT system generally consists of multiple subsystems (such as a grid control system, GIS, workforce management, billing, asset management, etc.), which are connected by multiple logical interfaces in an application-oriented way. In the most extreme cases, each subsystem is connected to each of the other subsystems by separate interfaces.

3. Moreover, each subsystem generally has its own database, which manages all of the data needed for each task that the subsystem performs. As a result, large volumes of data occasionally need to be managed by multiple systems at the same time, which,

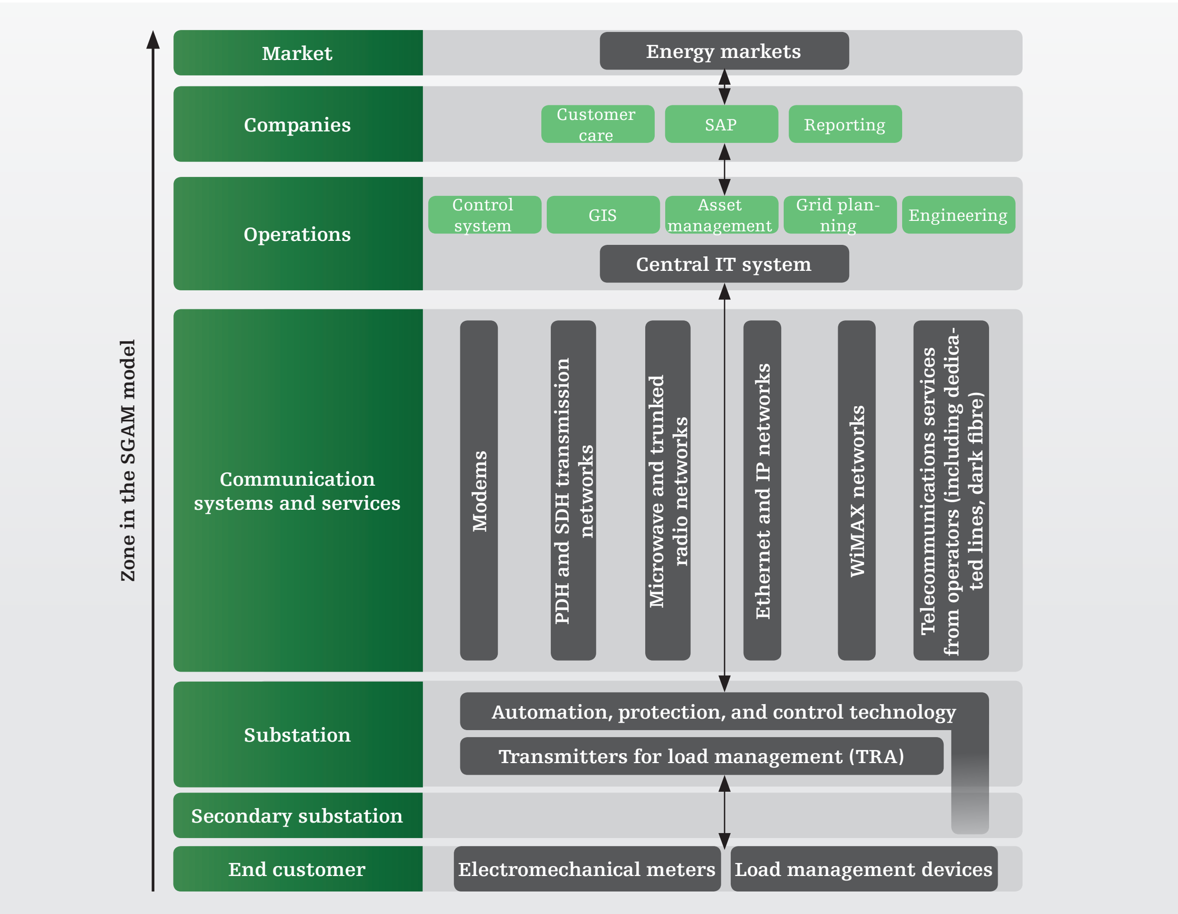


Figure 8

Current state of ICT architecture (example) at the very least, can cause temporary inconsistencies in the data.

Maintenance for solutions like these increases disproportionally as the number of connected subsystems increases. For example, each time a change is made to the software (such as updating to a new release), multiple interfaces may need to be updated. Moreover, these types of solutions are very inflexible when system requirements change quickly. If a new IT subsystem is needed for new market processes or new business models, for instance, the subsystem has to be connected to the existing systems using a number of interfaces.

Since existing systems were generally implemented for a specific grid, the introduction of new smart grid technologies must overcome an enormous hurdle.

2.3.2. Development of the overall ICT architecture

The strategic development of the overall ICT architecture should be coordinated with international developments in the four areas outlined in Table 1. Figure 9 (p. 30) provides an overview of the development timeline for individual steps in these areas.

Table 1

Areas identified in the development of the overall ICT architecture

Identifying a vision for processes and operating procedures		
Current state	**Steps needed to make the transition to market**	
Optimised processes and operating procedures have been defined and implemented for the existing infrastructure and task.	2015–2016	**Identifying gaps in the implementation of new solutions with a high level of technological maturity:** The additional functions that need to be added by the ICT infrastructure (central IT system and communication networks) for each of the use cases need to be determined. These include, but are not limited to: ■ Provision of topology information for use cases ■ Overarching coordination of distributed components to ensure optimised, secure, and safe grid operation ■ Compilation of data for internal and external reporting ■ Ensuring the necessary availability of data and communication links
	2015–2016	**Identifying necessary functions to add to use cases with a low level of technological maturity:** Estimate of functions that will need to be added to these use cases in future and accounting for related requirements in the overall ICT architecture and components affected
	2015–2016	**Defining a vision for operating procedures:** Starting with existing operating procedures, additions and/or modifications to these procedures that would be required in order to realise these use cases in the development axes need to be identified. In addition to normal system operation, operating procedures include component rollout, emergency management, and maintenance. The adapted operating procedures can then be used to determine staffing requirements, which companies staff will come from, where staff will need to be deployed (in the field, at operations buildings, at the central office, etc.), what information is needed, and how information must be disseminated.

Determining data management and communication network requirements	
Current state	**Steps needed to make the transition to market**
Necessary data is provided and processed according to the current task. Existing communications networks are designed in accordance with current requirements, but their bandwidths cannot be expanded in a few sub-areas due to technological reasons.	2015–2016 **Classifying necessary data and data streams:** What data and functions are needed to maintain supply, and what data and functions are used for planning, optimisation, and reporting? What availability is required for which data (and data streams), and what is the data volume in these two areas? The answers to these questions play a key role in determining the requirements of operational IT = grid control system + necessary assistance systems and backoffice IT. 2015–2017 **Determining communication network requirements:** Communication network requirements can be framed based on the classification of data and data streams. In addition to providing the necessary bandwidth with the necessary availability, requirements include defining internal and external interfaces, and these, together with the operating procedures (which staff need which data?), form the basis of security concepts. The communication network also needs to account for the following important items: ▪ Integration possibilities for existing systems ▪ Greatest possible support of existing communication media, while meeting e-control risk analysis requirements for energy sector information systems ▪ Scalability at all grid levels ▪ Support for the necessary availability (redundancy concepts) ▪ Support for security and data privacy concepts in conjunction with the central IT components and system components distributed throughout the grid ▪ End-to-end management

Draft of a target IT architecture for distribution grid operators	
Current state	**Steps needed to make the transition to market**
Central IT systems have grown over time, and different components are integrated to a greater or lesser extent. Components are generally connected using logical interfaces, which were designed to fulfil the particular operating requirements. There is no target architecture that would fulfil the new tasks stemming from the use cases of the individual technology axes	The use cases described in the development axes mean that a much greater volume of data can be expected near the grid control centre for coordinating distributed intelligence, fault management, optimisation, planning, and reporting. The goal should be to create an IT architecture that is as open and scalable as possible and that minimises operating effort. 2015–2016 **Gradual expansion and adaptation of the operational IT system** (grid control system and assistance systems) to meet the requirements determined in the “Classifying necessary data and data streams” step. 2016–2017 **Specifying a backoffice architecture:** For convenience purposes, this architecture can be based on a combination of a data warehouse (= database with an overlying layer that accommodates the different import-export interfaces) and business analytics applications (= software that generates analyses from the database). A comprehensive data model must be developed in order for the backoffice to be as open as possible.

	2016–2017	**Determining a service-oriented architecture** to connect IT systems. This, together with the data model mentioned above, would achieve the highest possible interoperability with the lowest amount of effort and cost for operation and maintenance.
ICT system migration path toward the target architecture		
Current state	**Steps needed to make the transition to market**	
There is no migration path	2016–2017	**Migration step 1:** ■ Scaled implementation of the concept for the communication network in accordance with the requirements described above ■ Functional expansion of the operational IT system in accordance with the requirements of the use cases with a high level of technical maturity ■ Development of a system to capture additional data from the lowest grid level ■ Development of the first business analytics applications in accordance with the requirements of each of the use cases in the technology axes
	2016–2017	**Clarifying and optimising process-related questions through large-scale system validation:** ■ Optimising the coordination of distributed smart components by evaluating collected operating data ■ Minimising effort and expense for data, communication, and central management, and control in the context of optimising grid operation ■ Validating and optimising operating processes and procedures ■ Identifying any additional requirements derived from operating processes and procedures for smart components in the field
	2018–2020	**Migration step 2:** Introduction of a service-oriented architecture to connect IT systems; the aim is to reduce the number of interfaces needed between each of the systems in the central IT system. Provision of the relevant data in the central database of the data warehouse so that grid operators can optimally perform their future task as the central hub in a complex energy system.

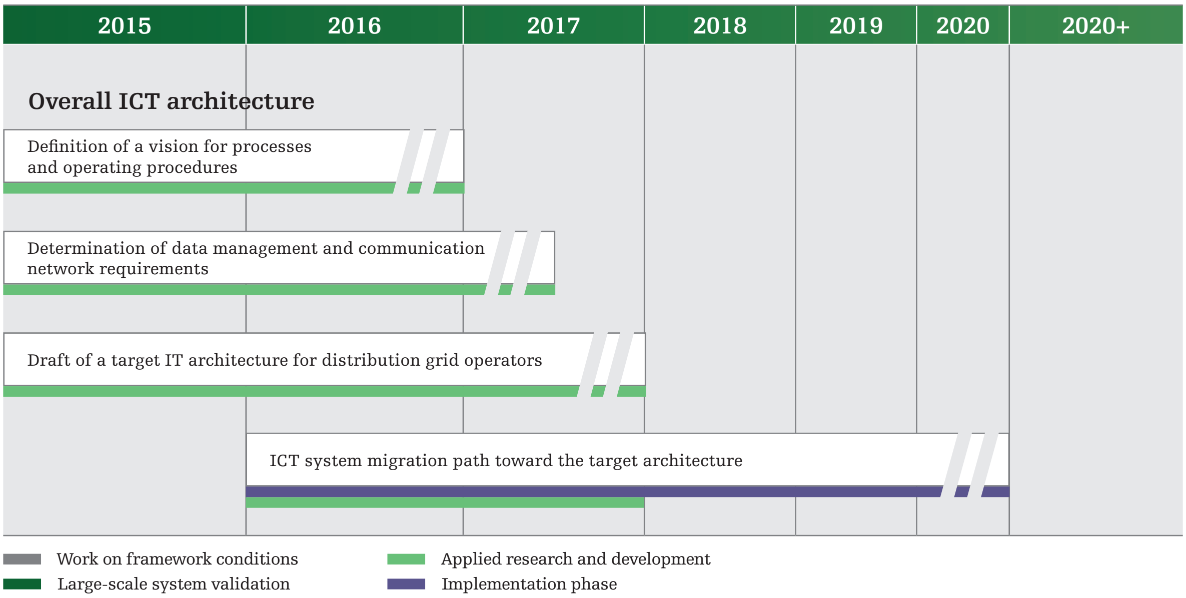


Figure 9

Overview of the steps in developing the overall ICT architecture

2.3.3. Need for action for an overall ICT architecture

In order to meet the requirements for a smart grid (see section 1.4.), a grid operator needs additional information from all levels of the grid, the ability to demand flexible consumption, and multiple "external" interfaces to exchange information with all market partners. Internal system interfaces are also needed, and the form they take plays a key role in achieving the highest possible component interoperability. A number of new players will need to exchange large amounts of information with existing market partners in order to perform their tasks. It is therefore essential to coordinate the strategic development of the ICT infrastructure with all relevant players. Starting from the current state and the development of the overall ICT architecture described above, the next steps are:

2015–2016 **A harmonised specification for ICT interfaces to customer systems** is a key component of the definition of the overall architecture, as these interfaces are a prerequisite for many use cases (see the description of the development axes in the following). A top priority is to harmonise interfaces to inverters, home energy storage systems, smart buildings, and the charging infrastructure for electromobility on a widely accepted basis.

2015–2016 **Definition of overall ICT architecture requirements, including security and synergies with smart metering:** The planned parallel rollout of smart metering interferes with the process for developing an overall ICT architecture. Smart metering concepts should therefore account for the requirements from each of the use cases of the technology axes and the requirements of the overall ICT architecture as far as possible. This step must also include the development of an overarching and scalable concept for security, safety, and privacy.

2015–2017 **Development of a migration path:** The basic procedure for creating a migration path described above must be adapted to the relevant existing systems and operating processes for each grid operator. The aim is for the different starting points on the migration path to eventually converge on a common target architecture.

2016–2018 **Large-scale system validation:** The priorities of large-scale system validation mentioned in the preceding section depend very much on the grid infrastructure and different resulting requirements. Validation should be performed for at least one urban, one rural, and one hybrid grid.

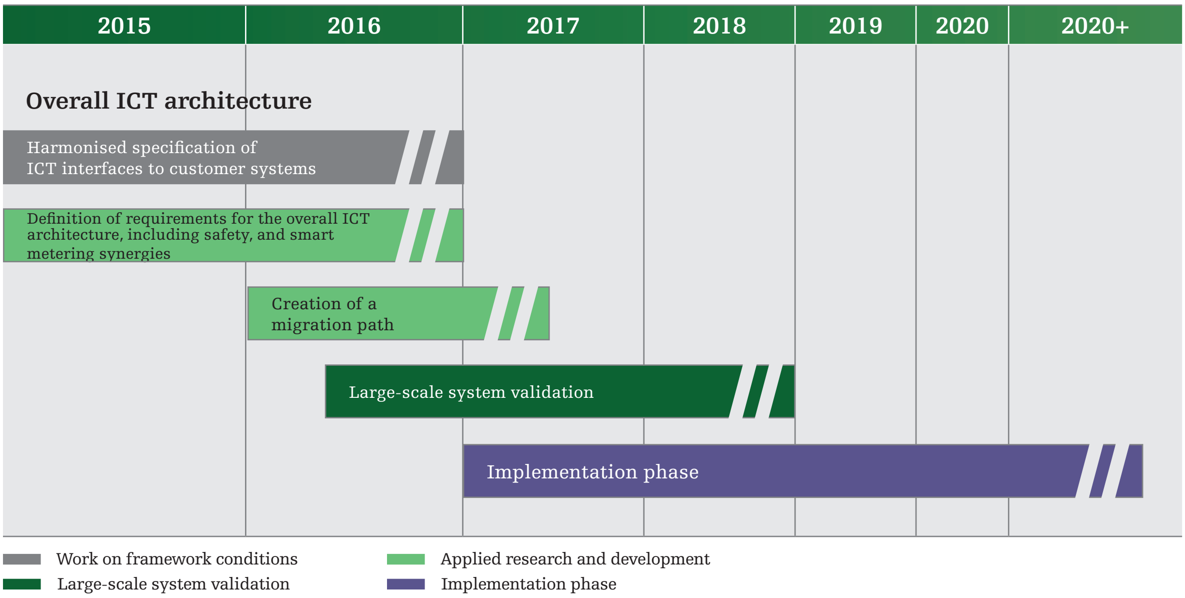


Figure 10
Summary of the need for action related to the overall ICT architecture

2.4. Grid development axis: optimised distribution grid operation

The "optimised distribution grid operation" development axis puts the emphasis on applications and technologies for operating and planning distribution grids with a growing number and density of distributed generation units, flexible consumers, storage, and electromobility. According to the definition of smart grids in Austria, this axis is concerned primarily with the management and interaction of grid components, producers, consumers, and storage (see [1]). The topic of optimised distribution grid operation has been divided into four use cases based on previous experience from Austrian research projects:

1. **Distribution grid monitoring** – ongoing monitoring of infrastructure utilisation parameters, monitoring of critical grid states, and analysis of effects on the grid are the basis for grid operation and planning.
2. **R&D test infrastructure** – for Austrian smart grid products with a short time to market
3. **Operating efficient grids** – demand-driven use of smart grid components, maintenance, operation of new control systems, and distributed smart components, as well as ongoing process optimisation
4. **Planning efficient grids** – better utilisation of the existing grid infrastructure, grid planning measures such as selective grid expansion in accordance with local requirements, accounting for flexibility, storage, reactive power management, etc. in planning

These use cases aim to **increase the hosting capacity** of existing grids for distributed generation and thus reduce the need for future grid expansion (see Figure 11).

2.4.1. Current state of the grid development axis

Relevant research and development projects were analysed in order to assess the current state of smart

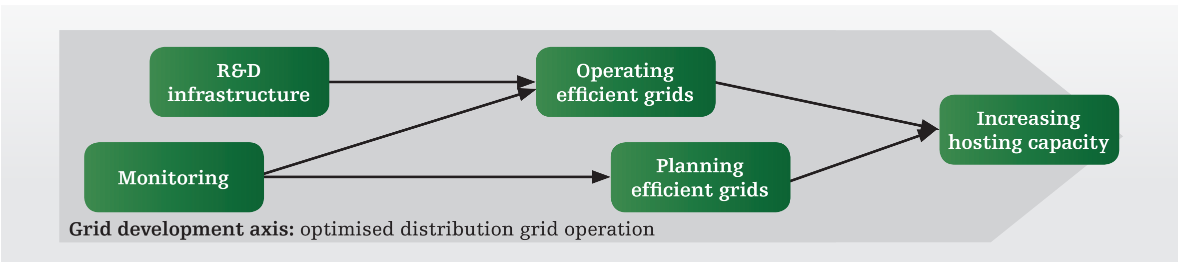


Figure 11
Grid development axis

grid development in Austria: DG DemoNet concept, BAVIS, DG DemoNet validation, CoOpt, ADRES concept, ISOLVES:PSSA-M, morePV2grid, DG DemoNet Smart LV Grid, EmporA, DG-EV-HIL, HIT, iGREENGrid, PlanGridEV, INTEGRA, Smart Grid Model Region Salzburg report on findings, and V2G Strategies.

Innovative technologies to increase the hosting capacity are on the verge of market readiness. Prototype solutions and the first products are already available for areas where an immediate benefit of quick implementation could be identified (for example, voltage band management in low-voltage grids with a high concentration of PV). A number of different technical approaches are currently being validated in the field, using similar basic principles. Details on the current state of each of the technologies are provided in the following sections.

2.4.2. Use case: distribution grid monitoring

Smart grid technologies and approaches can delay grid expansion made necessary by the integration of distributed energy resources, or in some circumstances, can even make it obsolete. Relevant grid parameters such as voltage and current need to be measured in real time to take advantage of expanded reserves. Because grids, especially low-voltage grids, were planned based on maximum load, this hasn't been necessary in the past or has only been necessary to a limited extent. Appropriate countermeasures need to be taken early enough before limits are exceeded to ensure quality of supply and grid availability. Grid monitoring also provides essential data for supporting optimised grid planning processes and input data for distributed smart components (such as voltage controllers in secondary substations).

Table 2 lists each of the technologies identified for distribution grid monitoring systems. A timeline of the development steps is provided in Figure 12.

Technologies for monitoring low-voltage grids

Current state	Steps needed to make the transition to market	
Projects in recent years (such as the ISOLVES: PSSA-M project [53]) have developed smart meters with an integrated grid sensor function for monitoring low-voltage grids. It has been shown that using smart meters with an integrated grid monitoring function greatly reduces expenses for additional sensors.	2015–2016	**Clarifying the framework for using data for grid monitoring**
	2015–2016	**Establishing a link between meter data and grid topology:** The exact grid topology at the time measurements are recorded must be known in order to evaluate values (for example, for grid planning and analysing faults). Simple solutions (from identifying the state of operation to archiving meter data) that can be integrated into existing systems need to be developed for this.
	2016–2018	**Clarifying and optimising process-related questions through large-scale system validation** (see also overall ICT architecture, Section 2.3.3.).
	2017–2019	**Implementation**

Table 2

Identified technologies and sources for the distribution grid monitoring use case

Statistical analysis of monitoring data		
Current state	**Steps needed to make the transition to market**	
Some grid operators have already successfully implemented statistical analysis of monitoring data (primarily voltage quality) for analysing changes over longer periods.	2015–2016	**Data recorded by a monitoring system must be identified** accurately, and data storage requirements must be determined in order to obtain congruent data records for analyses with comparable results.
	2015–2016	**Identifying appropriate algorithms** for statistical analysis of monitoring data and appropriate indicators
	2015–2018	**Making data with different temporal resolutions consistent:** specifying congruent data records for analyses in order to obtain comparable results
	2017–2019	**Implementation**

Control system-based monitoring with state estimation for medium voltage		
Current state	**Steps needed to make the transition to market**	
Approaches have been successfully tested (see ZUQDE project [49][50]). The process control system is being expanded to include the medium-voltage level, and function modules for state estimation and monitoring are being added. The basic technologies are available on the market but are rarely used for the medium-voltage level.	2015–2016	**Developing an overall monitoring concept:** State estimation and a load flow calculation using a process control system can help greatly reduce the sensor technology needed in the field and serve to verify measured values against topology information (see also overall ICT architecture, Section 2.3.3.).
	2016–2017	**Validating efficient processes:** The medium-voltage level must be integrated into a process control system in order to co-ordinate the use of smart grid applications (for example, for voltage stability) and for grid monitoring. The amount of work needed for processes related to updating grid, load, and generation modelling and for integration into management must be reduced.
	2017–2019	**Implementation**

Monitoring of the voltage range by measuring critical medium-voltage nodes		
Current state	**Steps needed to make the transition to market**	
The concept has been developed and successfully tested (see the ZUQDE [49][50] and DG DemoNet projects [51][52]). It is possible to gain an almost full picture of the voltage situation in the grid. The solution is available as a test platform.	2015–2016	**Developing efficient processes to record system states:** Historical and dynamic generation, load, and grid topology data that make it possible to identify critical nodes is needed for this technology to become widespread. This data has not yet been recorded.
	2016–2017	**Validation of processes and engineering tools**
	2017–2019	**Implementation**

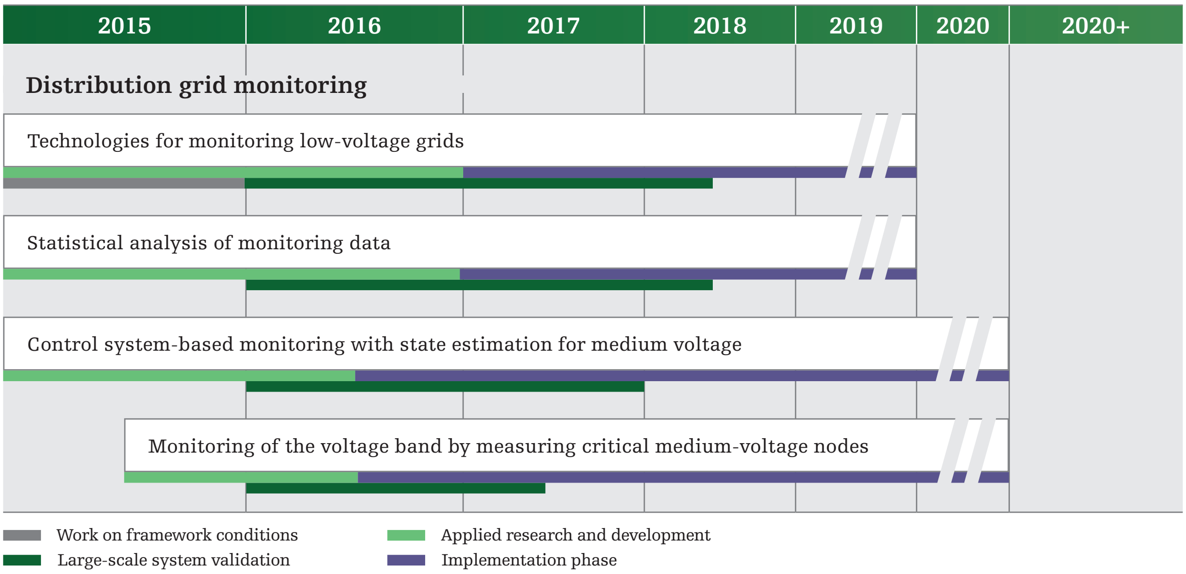


Figure 12

Overview of the steps in developing the distribution grid monitoring use case

Specific action is still required for a number of the technologies before widespread implementation is possible.

2.4.3. Use case: R&D infrastructure

Validation that interconnected smart grid systems function correctly is extremely important due to the increasing complexity and stringent requirements related to quality of supply. It is not always possible to conduct all tests relevant for development during operation. To minimise risk when new systems are used for the first time, it is important to have access to a realistic research and test infrastructure as early as the development phase.

Table 3 provides an overview of the current state and necessary measures for bringing smart grids to market.

Laboratory for studies of the interaction between grid components and controllers and the distribution grid		
Current state	**Steps needed to make the transition to market**	
A research infrastructure in the power range up to 1 MVA was built in Austria with support from the Climate and Energy Fund (KLIEN) [108]. Key criteria included the openness of systems, the greatest possible ability to reproduce test results, and the ability to study current and future systems.	2015–2016	**Creating the possibility to study system integration:** Suitable models of grids and components must be available in order to ensure real-world conditions in a laboratory infrastructure. Opportunities to study system stability must also be created. These include methods for co-simulating different system domains (for example, power grid and communication network).
	2015–2019	**Preparing methods in order to reduce development time of interconnected smart grid systems:** Short time-to-market is one of the keys to the success of Austrian smart grid products. A significant portion of development time is spent on testing and validation. The amount of manual work for planning, designing, and conducting experiments in the lab and in field tests must be reduced. This also includes co-simulating and co-emulating real and simulated systems (see DG-EV-HIL [56] and DG DemoNet Smart LV Grid [12][52])
	2016–2019	**Improving scalability:** The scalability of small-scale lab tests to real-world scenarios needs to be improved at the methodology level. One of the keys to this is the power-hardware-in-the-loop method.

Table 3

Identified technologies and sources for the R&D infrastructure use case

Manufacturer-independent test environment for smart metering components		
Current state	**Steps needed to make the transition to market**	
Testing and implementation laboratories for smart metering components are available over the course of the smart meter rollout. Tests have been conducted by grid operators and manufacturers.	2015–2019	**Creation of a manufacturer-independent test environment** is recommended. In the interest of integrating components from different manufacturers, it would be an advantage to have a testing and development infrastructure that is not specific to any one particular manufacturer. Manufacturer-independent system integration (with interoperability the ultimate goal) can then be tested using this infrastructure over the course of smart meter rollout. Requirements must be coordinated with the overall ICT architecture (see Section 2.3.).

A timeline of the development steps is provided in Figure 13.

In addition to the infrastructures presented above, there is also an ICT laboratory at Salzburg University of Applied Sciences – the Josef Ressel Centre for User-Centric Smart Grid Privacy, Security, and Control.

2.4.4. Use case: operation of efficient distribution grids

Solutions for managing grids with a high share of renewable energy have emerged as one of the top-priority development areas in Austria. It is important that these solutions integrate new active components into grid management (for example, on-load tap-changer transformers at secondary substation level, generation units, storage) and that larger parts of the medium-voltage grid are made available in control systems (see, for example, the ZUQDE project [50]) and, later, that appropriate solutions for low-voltage grids are also developed. Marketable extensions to process control systems (Volt/VAR control and state estimation) were developed for medium voltage as part of the ZUQDE project. Other projects have determined, however, that in addition to actively integrating distributed generation units, including new grid components (such as storage) in grid management is becoming increasingly important (see the EMPORA2 [106] and ProAktivNetz projects [107]).

Table 4 lists each of the technologies identified for operating efficient distribution grids. Specific action is still required for a number of the technologies before widespread implementation is possible. A timeline of the development steps is provided in Figure 14.

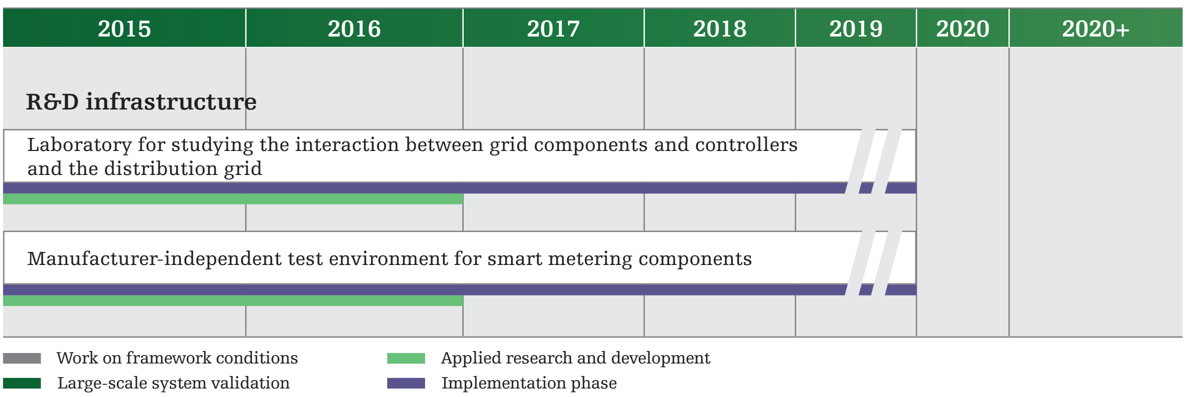


Figure 13
Overview of the steps in developing the R&D infrastructure use case

Table 4

Identified technologies and sources for the "operating efficient distribution grids" use case

Active and reactive power management in inverters (with or without a communication link)

Current state	Steps needed to make the transition to market	
Reactive power management of generation units (of PV inverters, for example) has already been successfully tested and is already required by standards (see technical organisational rules – TOR). Local management is already customary in some cases. The communication link from generation units to control systems and the management of the degree of freedom from grid management given to reactive power that the standard calls for have not yet been resolved, however. The effects of voltage control based on reactive power in the next higher grid levels must also be examined and evaluated in terms of the necessary provision of reactive power.	2015–2016	**Creating framework conditions for power management:** Integrating generation units into a voltage band management system can potentially cause (minor) drops in income for producers. A legal provision to cover this is needed.
	2015–2016	**Expanding communication protocols** for integrating active and reactive power management using telecontrol technology
	2016–2017	**Gaining practical experience** to help determine whether integrating small systems would be beneficial for grid management. The actual data needed and the resolution can be determined based on experience.
	2016–2019	**Implementation**

Active grid components: on-load tap-changer transformers at secondary substation level and line voltage regulators

Current state	Steps needed to make the transition to market	
On-load tap-changer transformers at secondary substation level and similar technologies have recently come onto the market. They are used primarily to increase the hosting capacity for generation units in low-voltage grids. The first solutions for compensating voltage imbalance are already available. Most of the solutions are line voltage regulators, which make it possible to control the three phases independently of each other.	2015–2016	**Improving ICT integration** in smart secondary substations, in other words with control systems and sensors out in the field, in coordination with the overall ICT architecture (see Section 2.3.)
	2015–2017	**Determining added value:** The added value of and any cost reduction resulting from using this technology must be demonstrated based on experience from field tests.
	2016–2019	**Implementation**

Use of distributed storage, load flexibility, and electromobility in grid management

Current state	Steps needed to make the transition to market	
Storage solutions, especially for use in low-voltage grids, are increasingly coming onto the market. However, no operating experience or experience integrating solutions into a distribution grid is available yet. The number of storage systems in the grid, particularly in conjunction with photovoltaics (home PV storage), is expected to increase considerably in the coming years.	2015	**Clarifying to what extent storage operation is possible for distribution grid operators**
	2015–2016	**Clarifying the mode of access to customer systems:** In the interest of legal certainty, whether and how storage systems at customer premises can be accessed and whether a storage system can be integrated into a balancing group must be determined.

It has been demonstrated that, from the grid perspective and with uncontrolled loads, in some cases more e-mobility can be integrated into the low-voltage grid than was previously thought (see Vehicle2Grid strategies [16]). If grids' hosting capacity is exceeded, the next step studied was grid driven charging of electric vehicles (e.g. Salzburg model region – Köstendorf [14][19]). For grid-wide use of load flexibility, see Section 2.5.2.	2015–2016	**Estimating the potential of electromobility:** The actual expected development of electromobility (expected penetration and expected requirements for grid infrastructure) must be determined, or at least realistically estimated, in order for technologies to be developed further.
	2015–2016	**Define grid interconnection requirements for controlled charging stations:** Rules for permitted and possible system perturbation, such as the requirements for behaviour caused by electromobility that contribute to grid stability (such as frequency-dependent behaviour), need to be defined.
	2015–2017	**Considering enhanced applications of storage systems:** Since it is difficult to imagine that storage-only solutions will be economical over the longer term, combined applications, for example with USV functionality, must also be weighed.
	2016–2019	**Integrating charging stations into the grid infrastructure:** Technical solutions for coordinating mobility needs, the integration of charging stations (home, campus, public areas, quick charging stations, etc.) into the grid infrastructure, and limitations stemming from the grid need to be validated on a large scale.
	2017–2020+	**Implementation**

Integrating coordinated control approaches into process control systems

Current state	Steps needed to make the transition to market	
Approaches for increasing the concentration of distributed generation units have already been successfully integrated into control systems (see the ZUQDE projects [49]). The medium-voltage level is not covered by control systems at all grid operators in Austria. In some cases, integrating existing plants into reactive power management systems has proven very difficult for technological reasons.	2015–2016	**Developing efficient solutions for integrating existing systems:** The primary need for action in order to implement this technology is to implement existing systems economically, something that is currently very expensive.
	2015–2016	**Conducting a feasibility and cost-benefit analysis:** Whether and how active power management for voltage stability in medium-voltage grids makes sense from a technical, and most importantly, a financial standpoint.
	2016–2017	**Coordinating the influence on higher grid levels:** In the system operation context, possible influence of all methods to increase hosting capacity on the medium- and high-voltage grid need to be analysed in practice and discussed.
	2017–2019	**Implementation**

Coordinated voltage control at station level		
Current state	**Steps needed to make the transition to market**	
Low voltage: Local solutions based on voltage control using PV inverters have been validated (see [55] and [52]). Solutions for the coordinated control of secondary substations, inverters, and e-mobility charging stations were in the test phase at the time this roadmap was drafted. The actual effectiveness of these solutions in practice has not yet been quantified. Regional differences between low-voltage grids are also significant ([54]). Medium voltage: The ability to coordinate a transformer and manage reactive power from generation units in order to control voltage has already been successfully demonstrated multiple times (see [12], [51], [52], [19], and [105]). The solution is not yet available as a product, however. The engineering for implementing voltage band management solutions is currently still overly complicated.	2015–2016	**Adapting grid use fees:** The current method for calculating fees is based on the amount of energy transported. Grids have to be sized and funded based on peak power, however. The number of prosumers that produce a high percentage of the energy they need is on the rise, and because their financial contribution is ever decreasing, the grid fee model urgently needs to be adjusted. The resulting additional costs also have to be borne by other grid users.
	2015–2016	**Determining whether coordinated control of small systems makes sense:** This approach will not be able to be applied in the same way in all cases given the diversity among individual grids.
	2015–2017	**Coordinating the influence on higher grid levels:** In the context of system operation, possible repercussions for the medium-voltage grid and high-voltage grid need to be analysed and discussed.
	2015–2017	**Reducing engineering effort by using appropriate planning and support tools:** As smart grids are being introduced, existing secondary technology will need to be expanded to include additional components, primarily at secondary substations and in the low-voltage grid. These components must have plug-and-play functionality whenever possible to minimise the amount of work involved in implementing, operating, and maintaining them.
	2016–2018	**Gathering practical experience** needed to make general recommendations and develop standardised approaches to increase hosting capacity. This experience is necessary to ensure a sound basis for analysing the cost and benefit of coordinated approaches for voltage stability.
	2017–2020+	**Implementation**

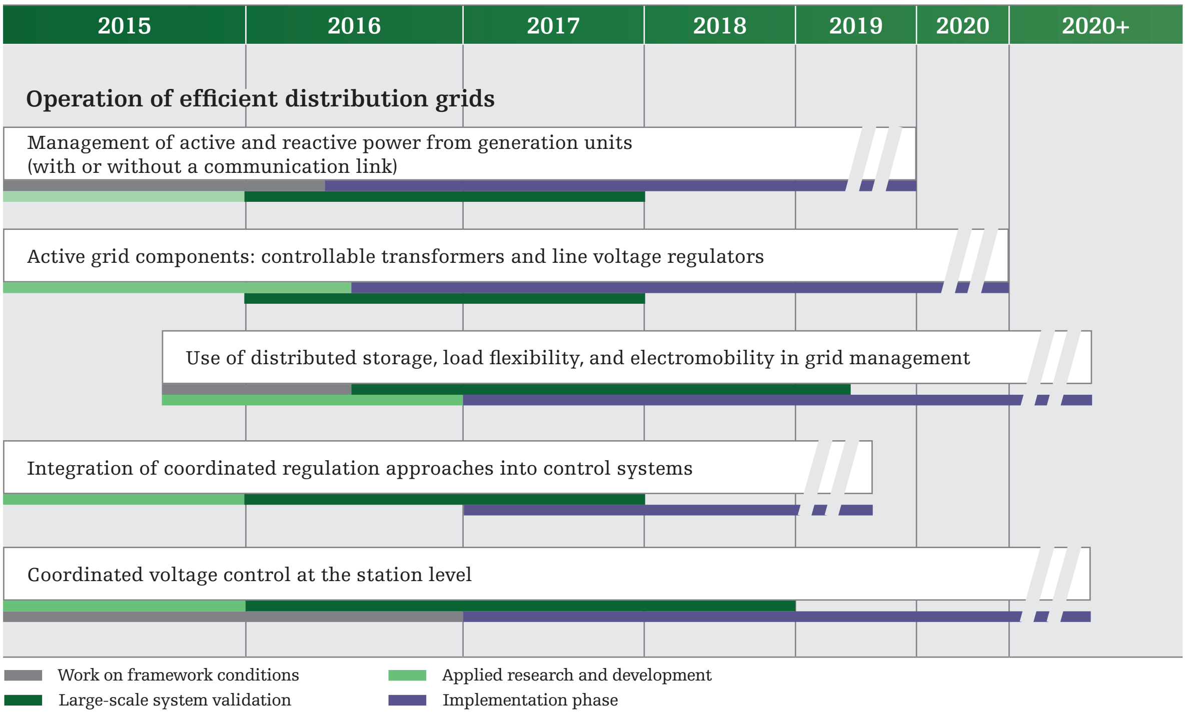


Figure 14
Overview of the steps in developing the "planning efficient distribution grids" use case

2.4.5. Use case: planning efficient distribution grids

Research and technology development projects in Austria in recent years have generally focused on integrating renewable energy sources into distribution grids (see [1] and the KLIEN and bmvit strategy). This is also the case in the Austrian project landscape, which has also produced internationally recognised field test and demonstration projects (see [11], [18], and [48] to [51]). The goal was, and remains, to use new solutions to integrate the highest possible share of distributed generation into existing distribution grids. This is referred to as increasing grids' hosting capacity.

Table 5 lists each of the technologies identified for planning efficient distribution grids. A timeline of the development steps is provided in Figure 15.

Feeding comprehensive operating data back into grid planning		
Current state	**Steps needed to make the transition to market**	
Feeding data from grid operations back into grid planning is currently only possible in isolated instances because little monitoring data is available. There is considerable cost-saving potential in designing grids efficiently based on detailed empirical data.	2015–2016	**Developing methods for accounting for operating data from the grid and market:** Section 2.3. covers the creation of the data acquisition infrastructure. New planning approaches can be validated only by using scenario calculations or years of experience.
	2016–2019	**Implementation**

Table 5
Identified technologies and sources for the "planning efficient distribution grids" use case

SMARTGRIDS AUSTRIA

Consideration of smart grid control approaches in grid planning		
Current state	**Steps needed to make the transition to market**	
Today's distribution grids are designed without accounting for smart grid control approaches. The allocation of voltage band has changed as the amount of generation has increased. Strategies for considering smart grid solutions are in the research stage (e.g. [109]).	2016–2017	**Developing grid planning tools:** Active components need to be taken into account during grid planning in order to be used effectively.
	2017–2020+	**Implementation**

Consideration of load flexibility in grid planning		
Current state	**Steps needed to make the transition to market**	
Theoretical studies and concepts for load flexibility are available, but Austria does not yet have any results from larger field tests. Results from the Salzburg model region (see the HiT project [40]) and from the first commercially available solutions from Austrian manufacturers are expected in 2014.	2016–2019	**Evaluating field tests:** Experiences from the development axes system and end costumer (sections 2.4 and 2.6) must be gained and evaluated in order to efficiently consider load flexibility in grid planning.
	2016–2020+	**Implementation**

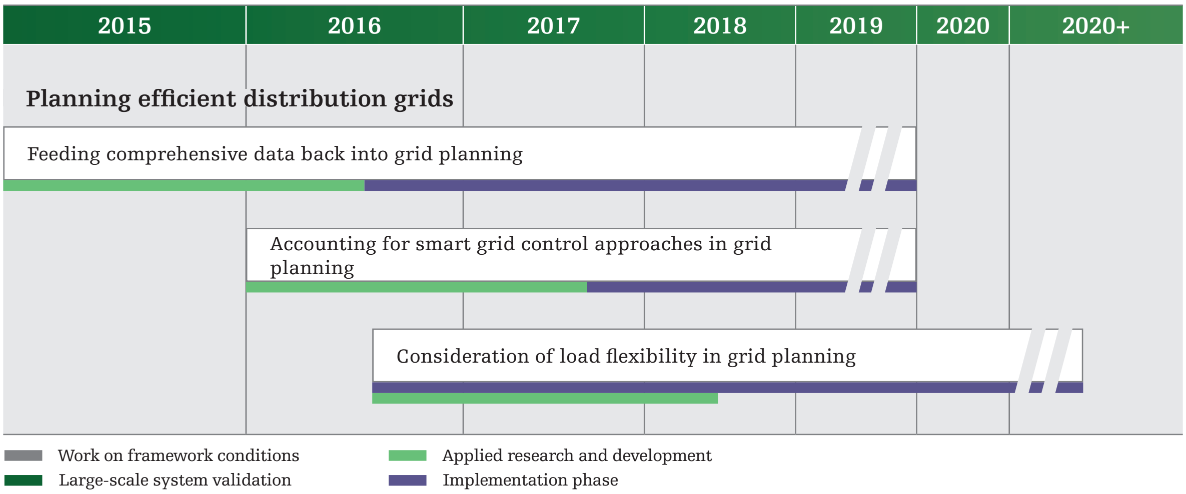


Figure 15
Overview of the steps in developing the "planning efficient distribution grids" use case

2.4.6. Need for action for the grid development axis

In places where it is economically viable, distribution grid operation will evolve into active grid management at medium-voltage level, and later at low-voltage level, as a result of new digitalisation and data availability opportunities and requirements caused by the increase in distributed generation and electromobility. The technologies needed for this will be described in each of the use cases of this development axis. A summary of the identified need for action, which addresses multiple use cases, is provided here. Figure 16 provides a timeline.

2015–2016 **Developing harmonised requirements for monitoring systems:** In order to implement and begin distribution grid monitoring, we need to determine what data is needed to record critical grid states in the lowest voltage levels and how this data is to be illustrated and processed further in an expanded grid control system. In addition, the data needed for offline processes, such as those that support grid planning and support/optimise operating procedures (technical, logistical, and business) also need to be determined. Any gaps between the minimum requirements of the IMA regulation [86], smart meters used today, and future requirements of smart grid applications then need to be analysed. The next step would then be to specify and develop the applications that would be needed for implementing each of the tasks.

2015–2016 **Developing the framework conditions of cost approval for monitoring:** In order to implement and operate monitoring systems, recommendations for cost approval, including additional staffing needs, must be developed. Innovative approaches should be less expensive than traditional grid expansion with a similar increase in hosting capacity. Operating costs and the sustainability of solutions need to be considered.

2015–2017 **Clarifying options for providing system services and remuneration for services:** We need to clarify which functions and services distribution grid operators can provide to other market partners and how to appropriately remunerate operators. Which functions and services supporting system operation can be required from customers and remunerated also needs to be determined. These include the framework conditions for energy not supplied to the grid as a result of a necessary active power curtailment of distributed generation (for voltage range management, for example).

2015–2016 **Adapting the framework conditions for grid operator interventions in customer systems:** The legalities of how grid operators can control generation units, storage (e.g. e-mobility), and loads (e.g. DSM) under normal operating conditions need to be clarified. In the interest of legal certainty, it must be determined how generation units, storage systems, and flexible loads at customer premises can or are will be permitted to be accessed and how storage can be integrated into a balancing group.

2015–2017 **Further developing local solutions for prosumers** that do not require communication. One example of developments that are needed is the identification of consistent configuration values for inverter controllers (reactive power, active power if necessary).

2015–2018 **Reducing engineering when smart grid technologies are introduced:** Since equipping the lowest voltage levels with the necessary smart grid infrastructure always means that a relatively high number of components needs to be rolled out, the amount of engineering and maintenance, in addition to the cost of components, plays a key role in economic viability. Existing plug-and-automate concepts need to be developed further and optimised in large-scale validations. In addition, the existing automation infrastructure needs to be integrated into a seamless overall solution.

2015-2019 **Reducing the development time for smart grid systems using an R&D test infrastructure:** The growing complexity of systems caused by interconnected smart grid systems has made it necessary to test newly developed solutions. Enhanced methods and tools for testing and validating interconnected smart grid systems are needed. The recommendation at the component level is to create a manufacturer-independent test environment for smart meters to ensure interoperability among grid and system components and third party providers (the user domain).

2016–2018 **Validating replicability and scalability:** The replicability and scalability of tested and developed solutions must be quantified. A concept for integrating existing systems into smart grid solutions also needs to be developed and must be proved and tested in this framework.

2017–2020+ **Implementation phase**

2.5. System development axis: utilising flexibility for the market and grid

This development axis covers the shifting of large loads, such as commercial, industrial, and building complexes. The need for flexibility in the electricity market (e.g. spot, intraday, and balancing markets) is rising, due primarily to the steadily growing percentage of volatile generation in the system. Grid operators, producers, suppliers, consumers, and virtual power plants need to be able to respond to changing market situations with increasing flexibility.

New players are entering the field, new roles for existing players are being debated (such as the flexibility operator role), and new responsibilities in the market need to be allocated. Changing market requirements mean that the need for new services is growing. The tools that existing and new players need, and how they will be able to and permitted to use them, must be arranged in detail and reflected in the legal framework. This will then enable new market rules to be defined and/or existing ones to be adapted.

Based on the key issues of the ongoing activities studied (review of the literature), we have divided this topic into the following use cases for the discussion of the development axes:

1. **Coordinating the market and grid** – technologies for providing market and grid-side flexibility

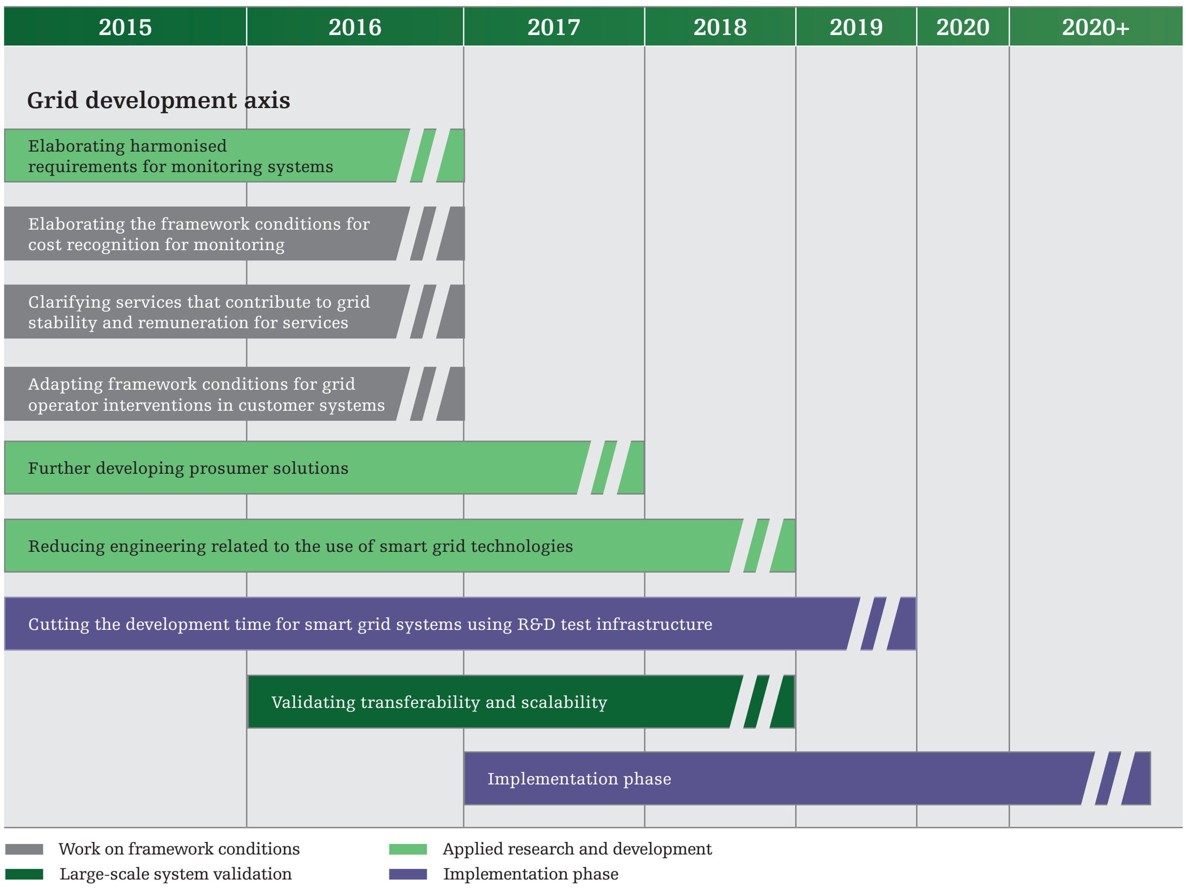


Figure 16

Summary of the need for action in the grid development axis

2. **Utilising flexibility for the market** – technologies for cost-effective balancing of generation and consumption

Both use cases are a prerequisite for ensuring system operation with a high share of renewable generation (see Figure 17).

As used in this context, the term "market" refers primarily to electricity markets (see [25]). Markets can be spot, intraday, or balancing markets depending on the use case and technology.

2.5.1. Current state of the system development axis

Relevant research and development projects were analysed to determine the current state of the system development axis:

Technology development projects: E-Energy, Flexpower, FENIX, DK storage study, B2G, SGMS findings, Smart Heat Net, HIT, V2G strategies, EMPORA, EDISON, BHKW Netz co-generation station grid project, MBS, NightWind, Oreanis, GROW-DERS, Wind und Last, Virtuelles Ökostromkraftwerk (virtual green power plant), SOL-ION, KONDEA, INTECOOP, IncentiveNet, Smaragd, INTEGRA, and IN2VPP

Analyses of the benefits of smart grids: DENA Grid Study II, Demand Side Integration VDE, FENIX, SG Backup, and ECONGRID

There are already a number of individual technical solutions for both use cases in this development axis, some of which are already available as products or are already being used (such as taking advantage of load flexibility in the commercial and industrial domain).

Some solutions need to be developed further, primarily in the event of consistent and market-side optimisation of the use of flexibility. Automation of the components needed for responding to flexible prices and rates must also be developed further.

2.5.2. Use case: coordinating the market and grid

This use case concerns the clarification of coordinating responsibilities related to coverage of market and grid-side flexibility requirements. Responsibilities are intended to determine whether and when grid-side interventions in free-market processes should or can be enabled.

Table 6 illustrates the main technology identified during the roadmap process – the flexibility operator – for ensuring that market and grid-side flexibility requirements are covered and provides the corresponding project and literature sources. A timeline of the development steps is provided in Figure 18.

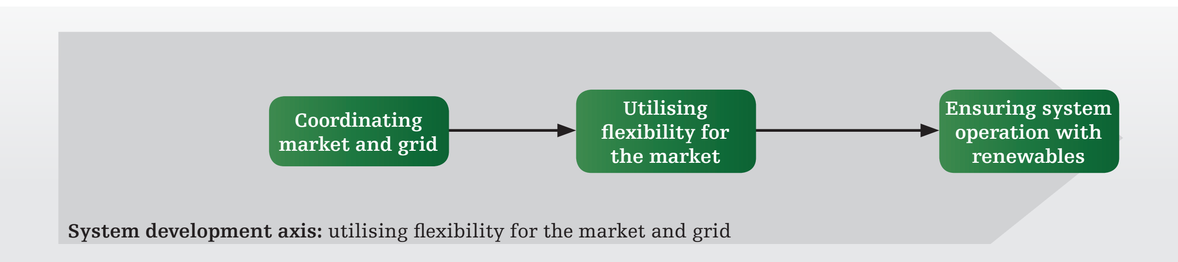


Figure 17
System development axis

Table 6

Identified technologies and sources for the "coordinating the market and grid" use case

Flexibility operator		
Current state	**Steps needed to make the transition to market**	
Different R&D projects (such as the Integra project [25], [99], and [101]) are currently studying and developing role definitions and the technical implementation of a flexibility operator. The necessary requirements and components of a smart grid reference architecture are also the subject of studies and are in the development or design phase.	2015–2016	**Determining roles and logical interfaces in the context of a flexibility operator** at the intersection of grid operators, virtual power plants, and flexible load
	2015–2018	**Defining business models and market rules of the flexibility operator for the amber phase**
	2015–2016	**Identifying the overall optimum for the energy system:** For a flexibility operator to be used, there must be a financial advantage over a conventional solution. This advantage must be demonstrated before a flexibility operator is implemented.
	2015–2016	**Simplifying technical components:** The solution for the amber phase must not be more complicated as to reinforce the grid in order to deal with the amber phase.
	2016–2018	**System validation of flexibility operators** including rules for the amber phase and less technical complexity
	2018–2020+	**Implementation**

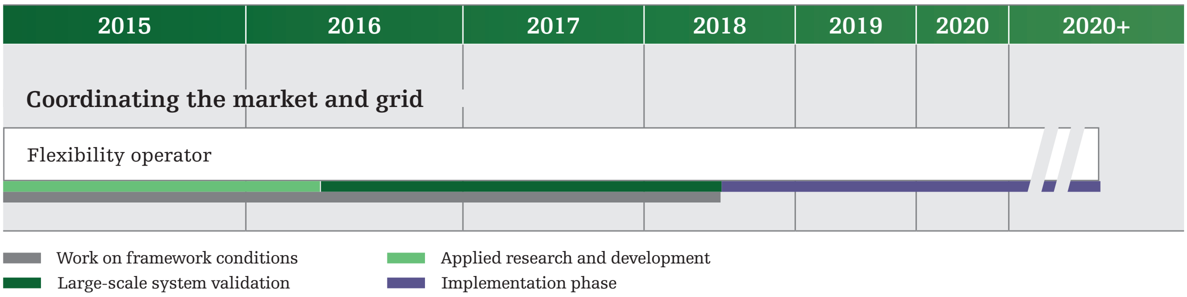


Figure 18

Overview of the steps in developing the "coordinating the market and grid" use case

2.5.3. Use case: utilising flexibility for the market

If the share of renewables in the system as a whole continues to rise, new approaches will be needed to be able to offer more, and if necessary more efficient, mechanisms to balance generation and consumption in the associated markets. This use case covers those technologies that will be needed over the long term in order to respond better to unexpected or unpredicted fluctuations in generation or consumption to minimise the use of control energy.

As in all use cases, the right ICT solution is needed to be able to implement each of the functionalities. Important technology fields are automation and resource scheduling (loads, generation, hybrid grid solutions, storage including e-mobility, buildings including building energy agents, and forecasting); data acquisition and transmission, primarily of consumption data (smart metering); and flexibility activation, for example using interruptible tariffs.

For most technologies, products on the market can be used or are available, but some technologies are still in need of development. Reliable and secure ICT solutions for acquiring and transmitting data (such as consumption data and load management) are theoretically available on the market. However, action still needs to be taken regarding the specification of interfaces and the strategic expansion of the relevant infrastructure (see Section 2.3.).

Table 7 lists the technologies identified for utilising flexibility for the market and the corresponding project and literature sources (see Figure 19).

Table 7

Identified technologies and sources for the "utilising flexibility for the market" use case

Flexibility, virtual power plants, and pooling		
Current state	**Steps needed to make the transition to market**	
The ability to take advantage of flexibility for commercial and industrial customers is already state of the art. Software solutions are available to optimise the use of virtual power plants and consumer pools. The willingness to participate is often limited by production processes or because potential income is too low. Load-shifting processes seem best suited, as was demonstrated by the Smart Grid Backup study [60]. See also [11] to [22] and [29] to [48].	2016–2017	**Defining the technical rules for using load flexibility** (market-driven approaches vs. local restrictions or grid-side requirements)
	2016–2017	**Clarifying the framework conditions for players:** Absent conditions for market development must be resolved, and solutions need to be sought with the involvement of relevant players.
	2015–2016	**Defining industry solutions and interfaces:** The complexity of connecting flexible loads must be reduced using standardised industry solutions and interfaces (see overall ICT architecture, Section 2.3.).
	2015–2017	**System validation of large-scale flexibility** to prepare for system operation with a significantly high share of renewables
	2018–2020+	**Implementation**

Hybrid grid solutions: Power2Gas, Power2Heat		
Current state	**Steps needed to make the transition to market**	
Some of the components for linking energy infrastructures are available as test equipment, but not standardised market-side operation optimisation. See also [23].	2015–2020+	**Determining suitability for grid operation support**
	2015–2020+	**Technology development and market analyses**
	2017–2020+	**Cost-benefit analyses**

Variable tariffs and prices		
Current state	**Steps needed to make the transition to market**	
Currently only minimal monetary savings are possible. Grid services are provided by flexible end customers through interruptible tariffs (load management). See also [40], [35], [34], [33], and [25].	2015–2019	**Creating the framework conditions to coordinate the different requirements of market and grid operation** (e.g. the traffic light model)
	2015–2019	**Developing flexible tariff and price models:** There is a need for clarification regarding the introduction of variable tariffs and prices due to smart meters, primarily related to the necessary legal, regulatory, and organisational specifications.
	2015–2019	**Defining infrastructure requirements** (for metering, billing, etc.) Existing systems that are as simple as possible should be used at the beginning (such as load management, connecting boilers, etc).
	2016–2019	**Implementation**

Interfaces to energy management systems		
Current state	**Steps needed to make the transition to market**	
Energy management systems on the customer side have developed over time and do not have standardised data or process interfaces for managing flexibility. See also [14], [25], [12], [14], [29], [30], [34], [43], and [48].	2015–2016	**Clarifying definitions of market processes**
	2015–2016	**Standardisation of interfaces and protocols** (see overall ICT architecture)
	2016–2018	**Validation and automation of processes** e.g. cost reduction due to automated provisioning
	2017–2019	**Implementation**

2.5.4. Need for action for the system development axis

The most important areas where action is needed in order to successfully activate flexibility in the market environment were identified in the context of the two use cases of this development axis. These areas are summarised for each of the development steps in the following. Figure 20 provides an overview of the need for action.

2015–2016 **Identifying potential advantages for the economy:** The most important area where action is needed in the system development axis is the identification of potential economic advantages (such as minimum pool size and requirements for participating in markets) of activating flexibility in electricity markets or in the energy system. Identifying these advantages is imperative, primarily for creating security of investment for industry.

2015–2016 **Proposals for market designs:** In terms of proposals for specific new market designs, the following aspects and issues in particular need to be clarified:

- Do new markets, such as cross-regional/local flexibility markets, need to be created, or can existing markets be added to?
- Market processes for new markets need to be determined.
- How can the price/value of flexibility be determined for market players, and is this supported by the existing market system?

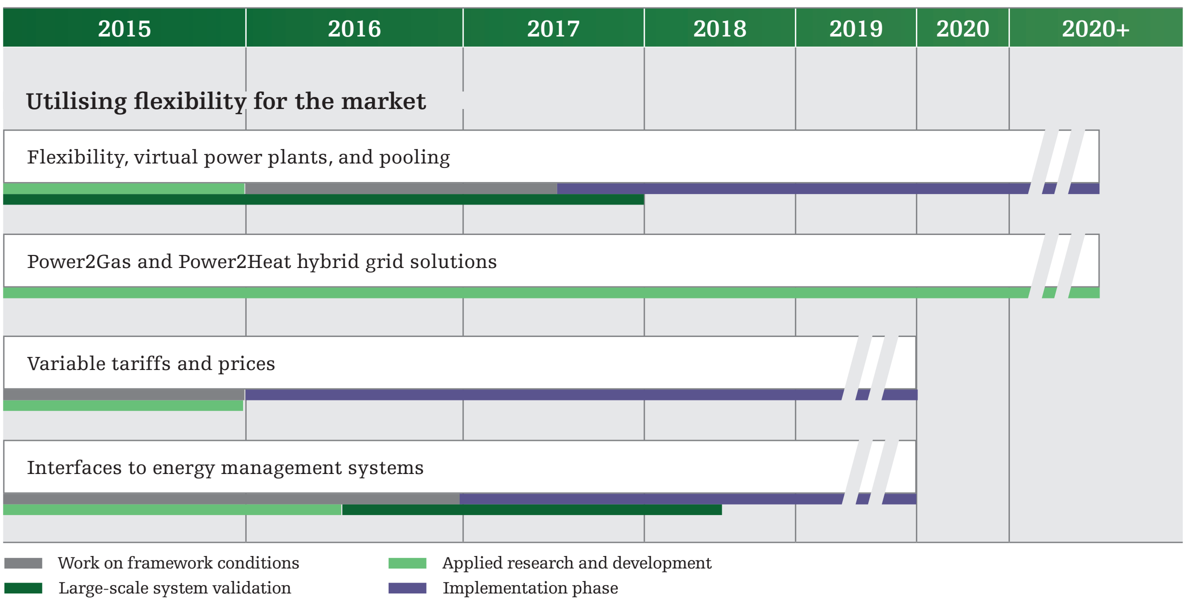


Figure 19

Overview of the steps for developing the “utilising flexibility for the market” use case

In addition, customers and customer segments and their potential for savings and added value need to be identified in the new markets.

2015–2016 **Specifying standard interfaces, roles, and responsibilities:** If relevant advantages can be achieved by using flexibility, standard interfaces, roles (such as a flexibility operator and market facilitator), and responsibilities in particular need to be specified. This would permit implementation of new market designs based on adapted market rules and framework conditions.

2015–2018 **Defining the traffic light model:** This also includes creating or developing a detailed definition of the necessary rules for the amber and red phases in the traffic light model (restrictions due to anticipated or existing local grid congestion).

2015–2018 **Gradually developing and validating industry solutions:** Reproducible solutions for individual industries that build on simple and existing technical solutions and that meet the requirements of players and electricity markets should be gradually developed and validated on a large scale.

2016–2020+ **Implementation phase**

Section 2.3. addresses the need for action related to an overall ICT architecture, which plays a major role in transitioning technological solutions to the market.

2.6. End customer development axis: smart solutions for consumers' market entry

This development axis examines the shifting of small loads and local supply. The use of large flexibility potential was covered in the system development axis (see Section 2.5.).

It only makes sense to activate end consumers in the market when there is significant flexibility potential. The specific investment costs for utilising flexibility are the lowest in these situations. In addition to being used in electricity markets, the typical connected power and energy consumption of small end consumers can be used to overcome local grid congestion.

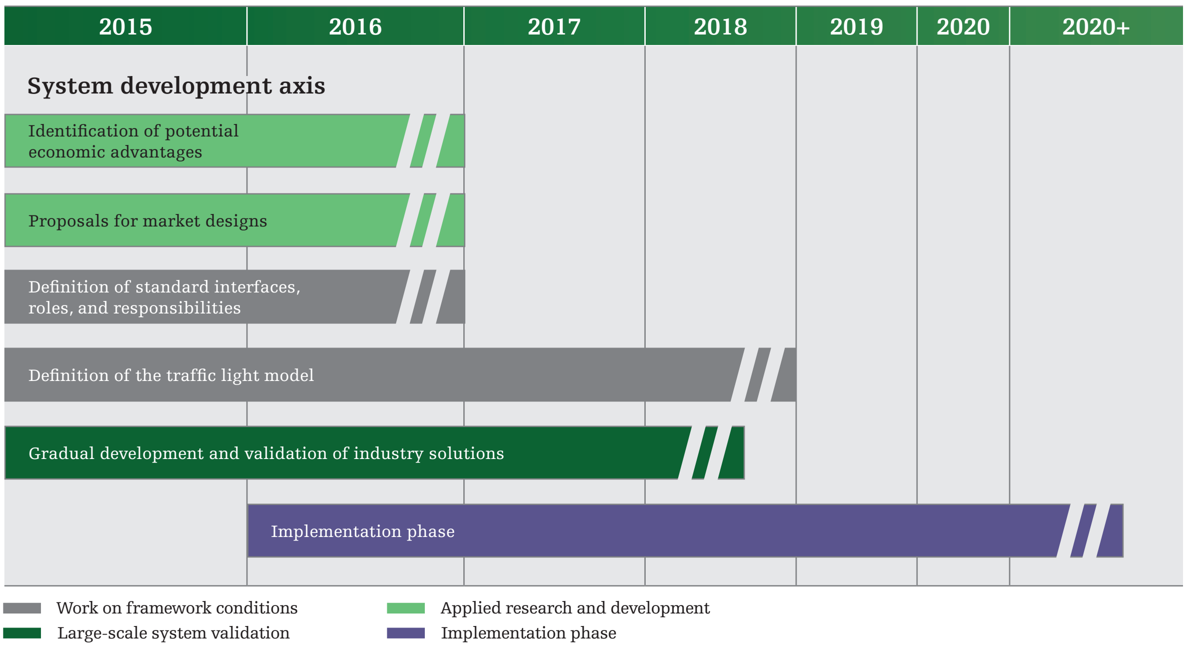


Figure 20

Summary of the need for action in the system development axis

Significant barriers must be overcome, however, before the potential flexibility of small end customers (private households, small commercial customers, and prosumers) can be utilised. From a technical standpoint, solutions are already available, as illustrated in the following sections. However, in many cases, small end customers are not willing to participate since there are scarcely any incentives, security concerns are prevalent in isolated cases, the products offered on the market are primarily in the high-end segment, it is simply too expensive and complicated for end consumers to use technologies, and/or the benefits are not directly clear.

In order to develop solutions to overcome these obstacles and enable small end customers to successfully enter the market, the project content studied (review of the literature) during the roadmap development process for this development axis was divided into the following topic-based use cases:

1. **Prosumers** – technologies for activating prosumers' flexibility for the market

2. **Non-energy services** – additional solutions for the end customer sector, which combine energy services and non-energy services

3. **Integrating end customers into market processes** – technologies for integrating small end consumers into market processes

An overview of the end customer development phase is provided in Figure 21.

2.6.1. Current state of the end customer development axis

Relevant research and development projects were analysed to determine the current state of the end customer development axis:

Technology projects: Allplan DSM project, VDE DSI study, DENA II, DISS Klobasa; FFE studies, DSM study at supermarkets, NightWind, GAVE, €CO_2-Management, Smart Response, Power Saver, SM Pilot EVN, Inspired Regions, Smart Web Grid, Metering and Privacy, Beware, DEHEMS, V2G Interfaces, PEEM, ZENVIS, IRON, E-DEMA, EU-DEEP, OPEN Meter, INTEGRIS, INTEGRA, ENCOURAGE, IN2VPP, INRAPLAN, EIGENLAST Cluster, GEBEN, MBS, IMPROSUME, and SmartHeatNet

Study on the benefits of end customer load shifting: DENA Grid Study II, Demand Side Integration VDE, ECONGRID

Relevant technologies were identified in the following fields of technology during the roadmap development process: data acquisition, smart applications at end-consumer premises, energy management systems, interfaces, controls, and monitoring.

Products and applications are available on the market. However, many technologies are only implemented in isolated cases because of current market conditions or a lack of interoperability (which leads to fragmentation of the technologies and markets) in Austria or because end customers consider the purchase price too high for the benefits they provide. Most are technological or system-specific standalone solutions that are not compatible with each other.

The lack of interoperability between different technical domains means that potential synergy effects and added value for end customers lie dormant. There is also room for improvement in making system installation, configuration, and operation more user friendly. From the grid operator perspective, there are no regulatory incentives to be more willing to invest.

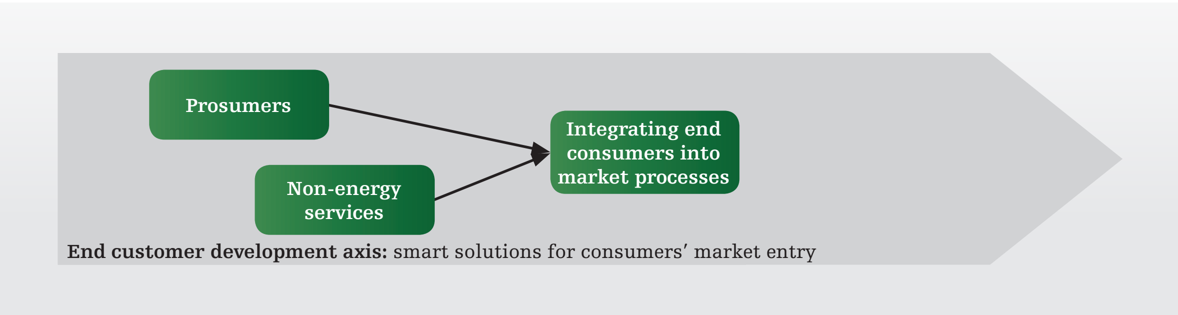


Figure 21

End customer development axis

Table 8

Identified technologies and sources for the prosumer use case

Optimising self-consumption of energy by controlling consumption		
Current state	**Steps needed to make the transition to market**	
Standalone systems for optimising own energy consumption in buildings are available (electric heating, heat pumps with backup storage, heater batteries, and air-conditioning units). There is potential for improvement primarily in anticipatory optimisation. Energy management systems connected to the market and grid (see the role of the flexibility operator in Section 2.5.2.) do not yet exist. See also [25], [16], [23], [33], [40], [42], and [34].	2015–2016	**Illustrating added value:** The services that can be offered to customers need to be specified in more detail.
	2015–2016	**Developing a vision for the impact on the system as a whole:** Long-term impact of optimising prosumers' self-consumption on the market, grid, and other players; interaction with smart metering
	2015–2016	**Clarifying the roles of the market participants involved:** The marketing of flexibility needs to be considered when legal and organisational regulations are created: who is permitted to sell harnessed flexibility to whom and when.
	2015–2016	Determining whether **self-consumption can be improved across building boundaries**, both technically and legally, by creating building clusters and whether improvement of self-consumption would provide a framework for new electricity marketing opportunities for prosumers (for example, by simplifying the local energy trade).
	2016–2018	**Efficiently implementing energy management systems for prosumers:** Integrating energy management functionality with efficient processes into energy management gateways or home management systems
	2017–2020+	**Implementation**

Storage systems for household applications		
Current state	**Steps needed to make the transition to market**	
Storage systems for household applications are available on the market. The use of small alternative electricity storage systems has been tested, but no experience has been gathered so far on the impacts of a large number of distributed storage systems in a distribution network. See also [18] and [46].	2015	**Defining grid interconnection requirements**, accounting for intentional and unintentional repercussions on the grid and, if applicable, building restrictions (application of the directive regarding the parallel operation of battery systems [110])
	2015–2016	**Specifying regulations and interfaces for market-oriented management of the method of operating storage systems**
	2017–2018	**Encouraging economies of scale and volume effects** to reduce the cost of storage systems
	2016–2020+	**Implementation**

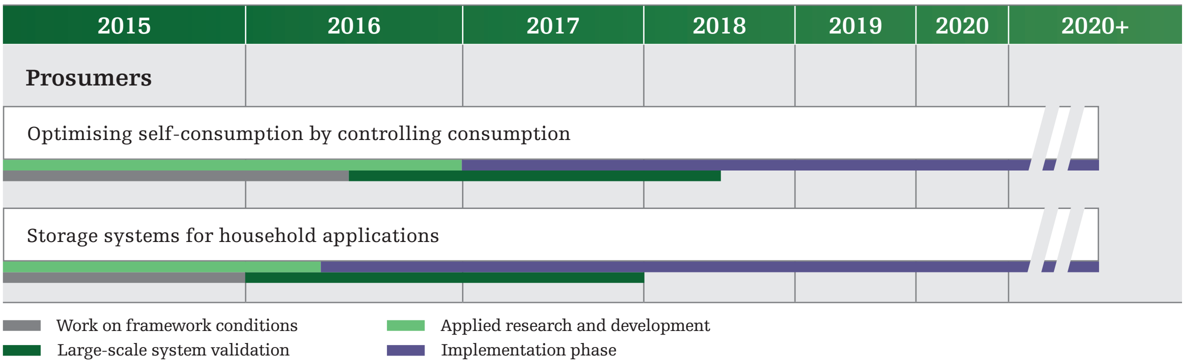


Figure 22

Overview of the steps in developing the prosumer use case

2.6.2. Use case: prosumers

This use case identifies technologies that need to be considered in the development of smart grids in light of the prosumer role. There is potential for load shifting when prosumers participate in the market (power supplied to the grid vs. own power consumed), which needs to be tapped. In addition to an appropriate ICT architecture, the projects studied mention solutions to optimise self-consumption of energy (controllers and software) and power storage technology as integrated components of smart grid development for prosumers.

Table 8 lists each of the technologies identified for the prosumer use case. A timeline of the development steps is provided in Figure 22.

2.6.3. Use case: non-energy services

Non-energy services are intended to make it possible to offer alternative services using the smart grid architecture. Non-energy services have a purpose that is not related to energy, but can be easily combined with energy, boosting the chance of success. Examples include services that aim to control general building functions or provide support for the elderly.

It still needs to be determined who will be allowed to offer these services using the smart grid infrastructure (see need for action and development path below). Add-on solutions for feedback, home automation, and smart homes in particular are considered attractive.

Table 9 lists the technologies identified for developing non-energy services and the corresponding project and literature sources (see Figure 19). A timeline of the development steps is provided in Figure 23.

2.6.4. Use case: integrating end consumers into market processes

This use case covers options that would make it possible to integrate end consumers into market processes to a greater extent. The technologies needed include,

Interfaces to non-energy services		
Current state	**Steps needed to make the transition to market**	
Some of the technologies and applications identified are already available as products, but there is still a need for further development, particularly in terms of simplifying use for end consumers. Home automation solutions are now relatively inexpensive, but market volume is low because the benefit to customers is limited. Creating interoperability and simplifying startup and configuration could enable greater market penetration. See also [29], [30], [35], [37], [38], [41], [42], [43], [44], [45], [47], and [48].	2015–2016	**Further developing interfaces** to improve the interoperability of devices (such as smart home gateways, actuators, and sensors): It needs to be determined which approaches are suitable for enabling interoperability.
	2016–2017	**Increasing market penetration of smart home solutions:** Clarifying interfaces to third-party providers, developing home automation gateways with smart grid functionality as add-ons to other products and services, and creating incentives to connect non-energy services to smart grid solutions
	2015–2018	**Implementation**

Table 9

Identified technologies and sources for the non-energy services use case

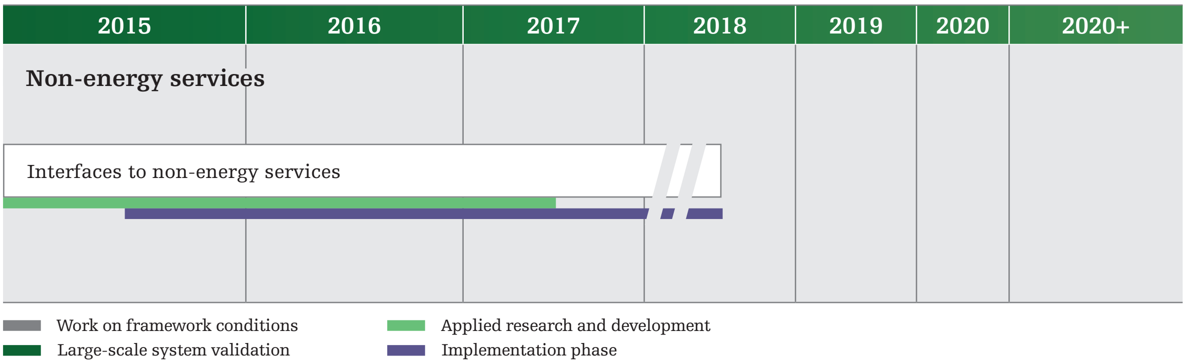


Figure 23

Overview of the steps in developing the "non-energy services" use case

once again, ICT solutions as well as automation solutions (home and building automation, customer energy management, building services, and white goods) along with the corresponding interfaces or gateways. Meter data and access rights management systems and directives are also needed in order to ensure sufficient data handling, data privacy, and data security.

Table 10

Identified technologies and sources for the "integrating end customers into market processes" use case

Smart meter and meter data management		
Current state	**Steps needed to make the transition to market**	
Meter data management systems to activate customers, or shift loads, are available. The smart meter infrastructure is being rolled out in accordance with the rollout guidelines in force. Products with different functions and data interfaces (for example, for visualising meter data) are available on the market. Customers alone decide who can use their data. The provision of data (for example, for billing third parties) is clearly set out in legislation and the IMA regulation [97]. See also [19], [24], [35], [40], [41], [42], [43], [44], [45], [47], and [48].	2015–2016	**Harmonising interfaces for providing meter data to third parties:** Standardisation promotes economies of scale.
	2016–2018	The **development of business models** (tariff and price) is considered helpful for this. Experience must be acquired from existing flexibility markets (such as the control energy market) and translated into an end-to-end technical solution (connecting market partners, the right components for prosumers and the grid) to be able to react to the increasing volatility of the power supply system.
	2017–2019	**Implementation**
Energy management systems for buildings and household applications, including interfaces		
Current state	**Steps needed to make the transition to market**	
Customer energy management systems – for integrating smart buildings into smart grid solutions – are already available in some cases as products, but there is still a need for further development, particularly in terms of simplifying use for end consumers. Creating interoperability and simplifying startup and configuration could enable further development and greater market penetration. See also [29], [30], [35], [37], [38], [41], [42], [43], [44], [45], [47], and [48].	2015–2016	**Further developing interfaces** to improve the interoperability of devices.
	2015–2016	**Identifying new fee models** based on players' requirements and interests, such as using buildings or home automation to optimise energy for pooling or grid support

	2015–2017	**Further developing customer energy management systems:** Building management systems should be developed further as the communication interface between consumers/prosumers and grid operators or energy suppliers to optimise energy. In Germany, building interfaces are also being developed for the purposes of access to generation units. Parallel infrastructures must be prevented.
	2016–2017	**Increasing market penetration of smart home solutions:** Clarifying interfaces to third-party providers, developing customer energy management solutions with smart grid functionality as add-ons to other products and services, and creating incentives to connect non-energy services to smart grid solutions
	2016–2018	**Establishing a standard for future home automation gateways** (see IEC/TR 62746 and PC118): Current home area network technologies are not standardised, resulting in heterogeneity. In future, sensors and actuators from different manufacturers should be able to be embedded in a smart grid. The necessary requirements for interfaces (which may or may not yet exist) and standards must be defined to counteract fragmentation of technologies and markets.
	2018–2020+	**Implementation**
Automating white goods		
Current state	**Steps needed to make the transition to market**	
The first products have been on the market for some time but have not become widespread because they offer little potential for benefits. The challenge is to tie into a concept and gain customer acceptance through cost savings over the medium and long term. See also [43], [29], and [30].	2015	**Clarifying potential benefits:** Additional benefits for customers and grid operators and the associated positive impact on energy efficiency need to be clarified. Financial incentives may need to be created to enable widespread acceptance and implementation. The cost-benefit ratio for integrating small devices into smart grids must be positive, however.
	2016–2018	**Harmonising interfaces and protocols,** in particular for communications in buildings (for example, between the gateway and controlling or controllable devices) and between local/distributed and external/central systems (such as energy management systems)
	2018–2020+	**Implementation**

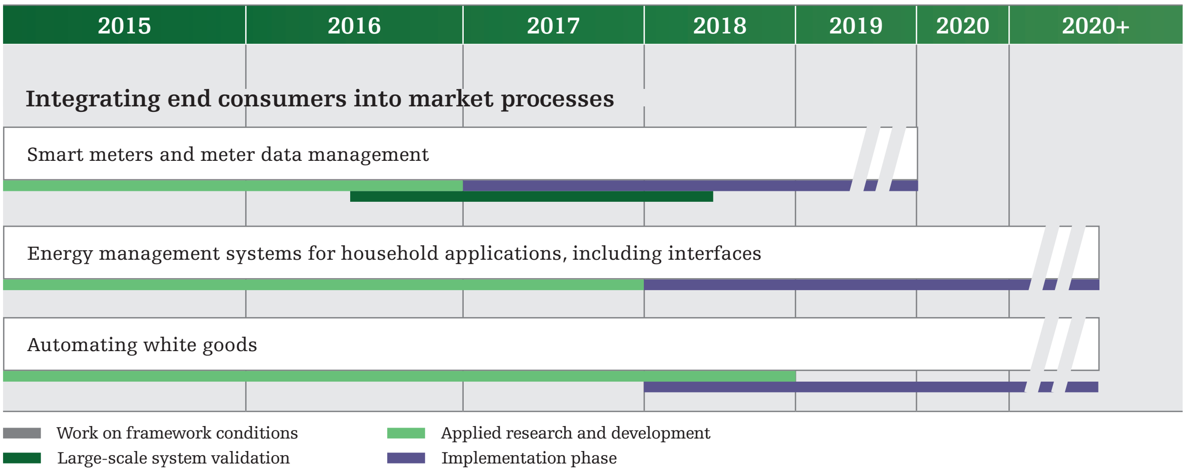


Figure 24
Overview of the steps in developing the "integrating end customers into market processes" use case

Table 10 lists the technologies identified for integrating end customers into market processes as well as the corresponding project and literature sources (see Figure 19). A timeline of the development steps is provided in Figure 24.

2.6.5. Need for action for the end customer development axis

Areas in this development axis where action is needed include generation of a sufficient (additional) benefit and the development of new usage opportunities for end consumers to achieve greater acceptance of the technologies and smart applications described in the roadmap. A timeline of the development steps is provided in Figure 25.

2015–2016 **Identifying benefits and exact requirements for using flexibility:** The identification of and proposals for dealing with potentially contradicting requirements of the players involved (such as the market and grid operators) are a basic prerequisite for the implementation of this development axis.

2015–2016 **Reducing complexity for users:** Technologies need to be easier to install, configure, and operate in order for end customer-side measures to be accepted.

2015–2016 **Adapting regulations:** Existing regulations need to be adapted, and new regulations may need to be created to cover the use of technologies and applications on the market for grid operation (at the legal and organisational level) during the second step.

2015–2017 **Developing widely accepted data privacy solutions:** A precise definition of the justifiable level of security is needed. Once a definition is available, the basis would exist for alleviating concerns about data privacy, and this would promote the development of solutions with appropriate security and privacy standards.

2015–2017 **Establishing widely accepted standards for interfaces** is needed in all use cases to create economies of scale to help reduce costs, something that is urgently needed.

2015–2020+ **Raising awareness:** Raising people's awareness of additional opportunities and the financial benefit of new technologies in the form of accompanying measures is a key factor that will help determine whether this development axis can be implemented successfully.

2017–2020+ **Implementation phase**

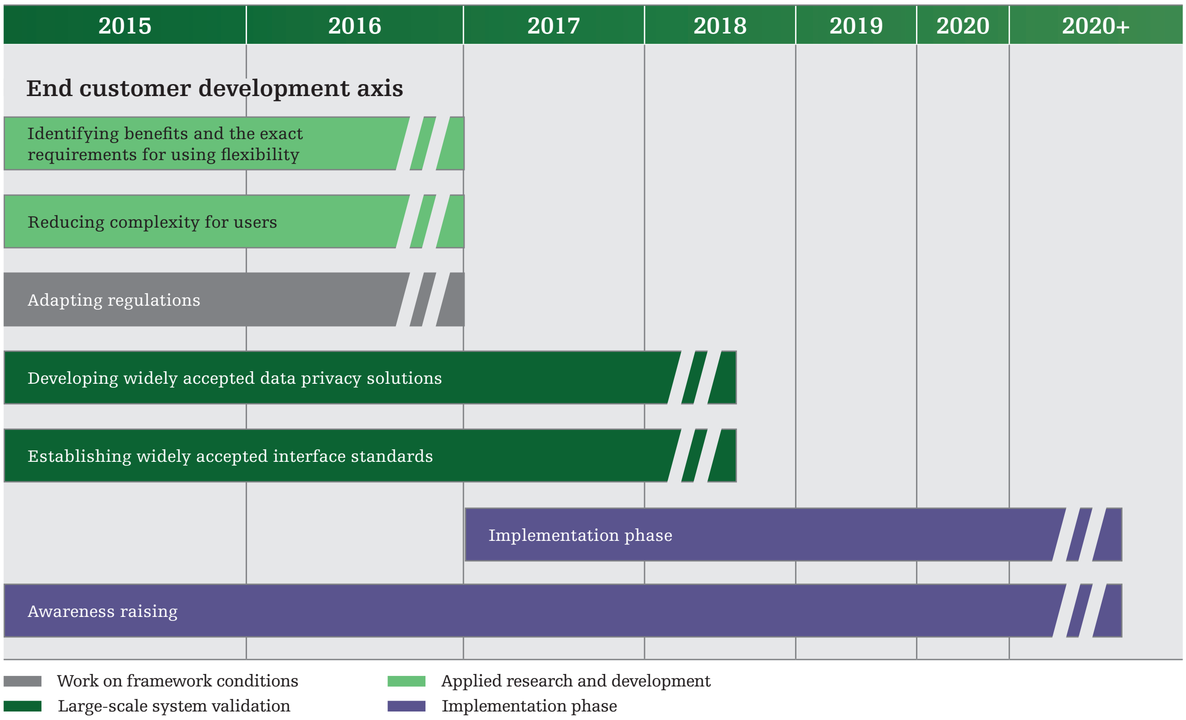


Figure 25

Summary of the need for action in the end customer axis

3. Austria's initiatives and players in smart grid development

This section presents the stakeholder landscape and main initiatives in Austria's smart grid environment. Austria has invested considerable resources in smart grid research and development in recent years through a large number of projects with the participation of industry, the energy sector, and researchers and with the support of KLIEN and the bmvit. This has spawned a number of activities, which have attracted attention internationally. The following section presents the essential activities, the players, and the position in the international environment.

3.1. bmvit as the driver of strategy and KLIEN as the funding body

The ongoing strategic activities of the bmvit and the technology programmes of the bmvit (Energy Systems of the Future, City of the Future, ICT of the Future, and Security Research) and the Climate and Energy Fund (Neue Energien 2020, e!MISSION, Smart Cities Demo) have helped promote the development of smart grids in Austria. The results of the projects were a key part of the technology roadmap development process. Project references are provided with explanations of the state of the technological solutions.

3.1.1. Smart Grids 2.0 strategy process

The bmvit's Smart Grids 2.0 strategy process is a platform for creating foundations for decision-making and implementation components on which a consensus can be reached – based on findings of research, technology, and innovation (RTI) initiatives and with the broad-based involvement of stakeholders. Three initiatives were launched as the pillars of the strategy, which are supported by additional national working groups and international research programmes.

The outcomes will be incorporated into the federal government's RTI strategy.

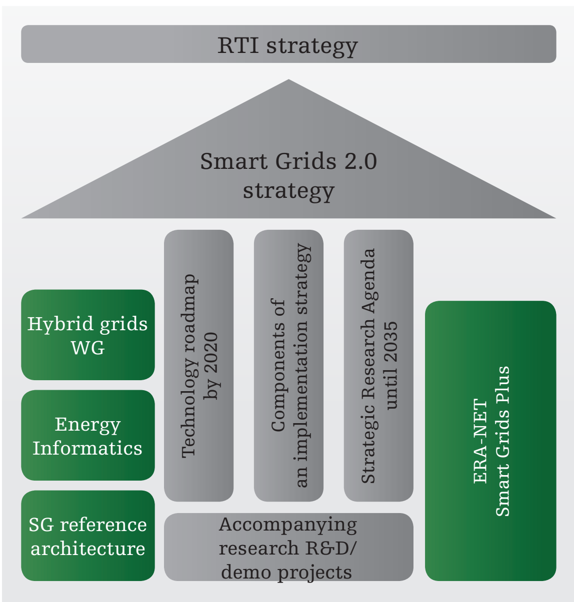


Figure 26
Smart Grids 2.0 strategy process

Source: bmvit

3.1.2. Strategic Research Agenda

The Strategic Research Agenda determines the need for research in smart grid technologies with the goal of optimising the entire energy infrastructure between now and 2035. It aims to consider all relevant topics across sectors and to identify synergies in light of the transition to integrated energy and ICT infrastructures. It consolidates individual topic areas into one single research agenda.

The primary participants are researchers in Austria: universities, universities of applied sciences, and non-university research institutions. These participants consolidate elaborated content together with stakeholders from industry, the energy sector, interest groups, government ministries, and public authorities.

3.1.3. Smart Grids Security Round Table

The bmvit and the Technology Platform Smart Grids Austria laid the foundation for a top-level discussion of the development of future energy grids by establishing the Smart Grids Security Round Table. This discussion among stakeholders, including government ministries and decision makers in the economy, is being conducted within an appropriate framework to ensure that future technologies are not developed in isolation, without society's involvement. The goal is to begin a dialogue with all relevant stakeholders at an early stage to define the framework conditions at the legal, regulatory, social, and economic level and to set priorities accordingly.

3.2. Austrian model regions and demonstration projects

Several model regions have been established in Austria in the course of the research projects being conducted here. The smart grid technologies that have been developed were field tested in these regions. Descriptions of the regions are provided in the appendix (Section 7.4.). Current model regions and demonstration projects in Austria are:

Model regions:

Smart Grids Pioneers

- Smart Grids Model Region Salzburg (EEGI Core Project)
- Smart Grids Pioneer Region Upper Austria
- Smart Grids Pioneer Region Vorarlberg
- Smart Services for the Greater Linz Area
- Smart Grids Pioneer Region Styria

Smart cities/smart (urban) regions:

- Smart City Salzburg – Smart District Gnigl
- Smart City Regau
- Smart City Demo Vienna Aspern
- Smart City Rheintal
- Smart City Villach

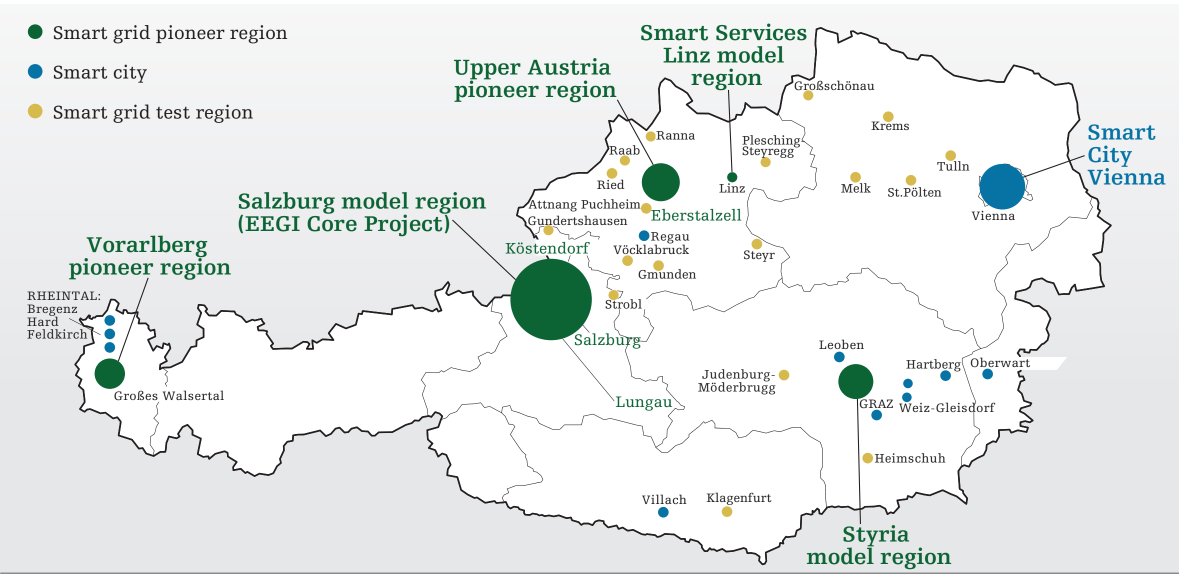


Figure 27

Smart grid pioneer and test regions in Austria
As of 2014

Source: Climate and Energy Fund, bmvit

- Smart City Smart Future Graz
- Smart Urban Region Weiz-Gleisdorf
- Smart City Hartberg
- Smart City Leoben
- Smart City Oberwart
- Smart Community Großschönau

3.3. Technology Platform Smart Grids Austria

The Technology Platform Smart Grids Austria[1] is an established platform in Austria whose members consist of the relevant stakeholders for the development of smart grids. Representatives from the energy sector, industry, and research are active within the platform. The platform also considers it essential for stakeholders not involved in the platform, such as ministries, authorities, and international experts, to participate in helping shape topics for the platform's work. The platform has also attracted international attention at conferences as well as through the activities of its members.

In its role as a network, the technology platform aims to position Austria as a leading smart grid market. Its focus in the medium term is to develop and implement a coordinated and target-oriented research and development strategy.

3.4. Austrian industrial companies

The innovative expertise of Austrian companies with global potential can be found in ICT, e-mobility, and the energy and transport infrastructure. Austria, as a technology location, has been able to claim top spots internationally in a number of technological fields, demonstrating that Austrian industry is in a strong position, particularly for the development of smart grids. Austrian technology providers have acquired extensive knowledge of planning, setting up, and managing energy grids and have developed outstanding technological equipment (switched-mode transformers, protection technology, grid automation and control technology, IT solutions, inverters, etc.). Participation in research projects in particular helps promote the long-term protection of Austrian jobs in innovation in the area of building system expertise.

3.5. Austrian energy sector

The Austrian energy sector is one of the most innovative translators of the smart grids vision worldwide. A number of projects all the way up to entire model regions are researching and testing all aspects of the energy future in live operations from a technical and operational perspective. The primary goal is to maintain a high degree of security of supply. Modern technologies will help equip the grid infrastructure for future challenges and plan urgently needed grid expansion with the greatest accuracy. This will make it possible to affordably realise the vision of a sustainable energy supply.

3.6. Austria's research landscape

Austria's research landscape in the field of smart grids is characterised by seamless co-operation between university and non-university researchers on one hand and in-depth co-operation among researchers, industry, and infrastructure operators on the other hand. Players in Austria's smart grid research community are well connected to international partners. Austrian research institutions are among the pioneers in the field and, together with professionals, have successfully developed smart grids from the very beginning. All partners of

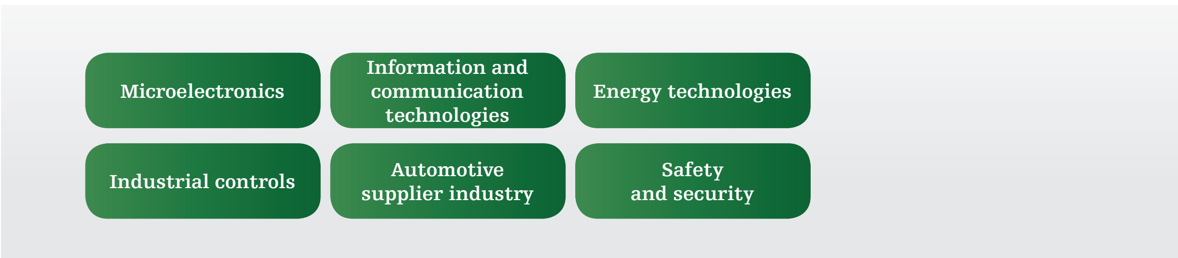


Figure 28

Technological strengths of Austria's electrical and electronics industry

Source: FEEI

1 *www.smartgrids.at*

the technology platform share a commitment to maintaining this practical relevance in terms of the development of smart grids.

3.7. The place of Austrian initiatives in the international smart grid environment

Developments based on joint national as well as international research projects constitute one of the points of departure for the technology roadmap. With the support of the bmvit and KLIEN, individual Austrian projects have been strategically pooled in recent years to generate a critical mass. This has increased European and international visibility of projects and strengthened Austria’s position in the implementation of the European Commission’s Strategic Energy Technology Plan (SET-Plan). The focus is unmistakably on an integrated approach to planning and operating distribution grids, which can be divided into two sub-aspects:

- Distribution grid planning, design, and operation to optimise integration of distributed electricity generation
- Integration of customers into a smart grid

At the level of DACH co-operation, individual Austrian players have participated in different working groups by involving their projects in the collaboration with relevant ministries in Germany, Austria, and Switzerland. Content-related co-operation among the three countries comprises developing and testing strategies for introducing smart grids.

The European Electricity Grid Initiative (EEGI), which was launched as an initiative of the European electricity industry as part of the SET-Plan, is one of the key pillars for implementing European smart grid aims. The EEGI published a research and innovation roadmap for the period to 2022 and a smart grid implementation plan for the period to 2016. The goal of the EEGI and the European Commission was, and remains, to bring together national projects relevant for Europe as a whole and evaluate whether the individual solutions are transferable and scalable. The EEGI selects national and international projects that are relevant to Europe and important for the implementation of the EEGI Roadmap. The 26 projects currently labelled[2] (as of May 2014) include three national projects from Austria and six European projects in which Austria is involved.

The excellent position held by Austrian research projects is evident in a variety of international projects:

On the initiative of the bmvit, Austria has already positioned itself as a leading and successful partner in the Electricity Networks Analysis, Research and Development (ENARD) Implementing Agreement by heading Annex 2[3]. Austrian projects were also named and became established as best practices in IEA’s subsequent initiative, the International Smart Grid Action Network (ISGAN), whose aims include an exchange of technological expertise among international experts and the identification of best-practice examples and recommendations for policy-makers.

International smart grid platforms

A detailed overview of international platforms and a description of international activities is provided in Section 7.5.

Standardisation related to smart grids

Activities related to standardisation from the international perspective and relevant Austrian bodies are summarised in Section 7.6.

National standardisation strategy and roadmap

The government programme has specified the “creation of an Austrian standardisation strategy (by the Federal Ministry of Science, Research and Economy (bmwfw))”. The bmwfw created a working group in Autumn 2014 to draft this national standardisation strategy.

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2 *http://www.gridplus.eu/eegi/eegi-project-labelling-started*

3 The topic was the integration of distributed energy generation into the distribution grid.

3.8. Topic-related fields of innovation in Austria

Energy Informatics Working Group

The Energy Informatics Working Group of the Austrian Computer Society (OCG) has set out to identify areas of research that are relevant to the implementation of smart grids and also to demonstrate potential for innovation in the field of computer science. The goal is not simply to apply known methods in the field of energy. Instead, the working group is concerned with smart grids as a driver of innovation and their impact on computer science.

Technology Platform Smart Cities Austria

The Smart Cities Initiative is a stakeholder platform that aims to account for the larger range of groups to involve through its membership. The ministry tasked the Energy Institute for Business in March 2011 with preparing and seeing through the process for establishing the national Technology Platform Smart Cities. This platform aims to raise awareness in Austria's business community and enable structured involvement in future activities both at the EU level and in the resulting demonstration projects. Information about the Smart Cities Austria Technology Platform is available at *www.tp-smartcities.at*.

The web site *www.smartcities.at* is a resource of the Climate and Energy Fund dedicated specifically to funding smart cities.

4. Benefits of smart grids

This section aims to illustrate the benefits of implementing smart grids in Austria. The transition occurring in international and national energy systems is motivated by the European Union's energy and environmental policy objectives. Smart grids are one of the keys to achieving these objectives.[4]

Austria's industry, research community, and energy sector expect the implementation of the technology roadmap, and ultimately smart grid solutions, to create tremendous opportunities for Austria to secure global technology leadership, while also strengthening Austria as a business location.

To date, the economic benefits of investing in smart grids have not been evaluated on a broad, systematic scale, either at the European or national level.[5] However, existing analyses, assessments, and results leave little doubt that the development of smart grids is a key factor in ensuring over the long term that increases in the cost of the energy system stemming from the energy transition will be reduced and that the functions of the overall system will be able to be expanded for our society and all stakeholders, creating a forward-looking energy market with a small carbon footprint. In this context, Section 4.1 examines the development toward smart grids from an economic perspective as it fits in with Austria's economic and energy policy aims. Sections 4.2. to 4.5. use a meta-analysis of existing research outcomes for Austria to illustrate the benefits of smart grids for Austria's energy sector, companies, households, and research community.

4.1. Benefits of smart grids from a macroeconomic perspective

The preceding sections of the technology roadmap described the opportunities made possible by individual smart grid technologies and solutions. They serve as the point of departure for this section, which describes the benefits and macroeconomic potential of using the technologies and solutions and puts the benefits in the context of overarching national energy policy aims (as far as possible, given the findings currently available).

Reducing Austria's energy dependence and fossil fuel imports

Smart grids contribute to energy independence and the significant drain of added value out of Austria to other countries by enabling distributed generation units to become more widespread [12], [85], which reduces the need to expand the grid further. Existing studies clearly demonstrate the extent of additional integration made possible by smart grid technologies. The DG DemoNet project [12] calculates, for example, that smart control concepts could cut the cost of integrating distributed electricity generation technologies into the grid by up to 80%, with conventional grid reinforcement measures. SG Essences [81] came to the conclusion that reactive and active power control concepts (without distribution transformers) could be

4 Timetable for transitioning to a competitive low-carbon economy by 2050

5 An exception is the Econgrid project [71], which analysed investment costs of individual technologies and assessed employment and value creation effects.

used to integrate an average of 40% to 52% more electric energy from photovoltaic plants than the reference scenario (grid section with maximum PV). The increase in electromobility and decrease in petroleum imports that this would make possible would also contribute to reducing Austria's energy dependence overall [84].

Boosting energy efficiency

European energy efficiency targets were specified in the Energy Efficiency Directive (2012/27/EU), as well as other documents, which all member states were to implement in national law by June 2014. In Austria, the directive was implemented through the Energy Efficiency Act, which set a cumulative energy efficiency target of 310 PJ by 2020 for the entire country. A number of aspects required by the Energy Efficiency Directive underlying the Austrian Energy Efficiency Act can only be achieved with the use of smart technologies. The directive requires access to real-time and historical energy consumption data to be provided to consumers. Smart grids can contribute to more efficient use of energy from multiple perspectives. Using smart control concepts can make the use of primary energy sources and capacity utilisation of the existing grid more efficient [12]. Taking advantage of load flexibility can also boost energy efficiency (and help save energy) [64].

Maintaining a high security of supply

Austria has a high level of security of supply.[6] E-Control reported only 33.36 minutes of unplanned interruptions in supply in 2013. BlackÖ.I [65] identified integration of wind energy and PV into the grid, European transits, load growth, and spatial distribution of large storage potential as key factors that affect the likelihood of interruptions in supply. The cost of power outages varies greatly depending on where the outages occur, how long they last, and what form they take. According to calculations from the BlackÖ.I project [65], the cost ranges from €90 million to €140 million per hour.[7]

Increasing the share of renewable energy in final energy consumption creates jobs

Renewable energy currently (as of 2012) accounts for 65.3% of the final energy consumption of electricity generation and 32.2% of the total mix.[8] According to Directive 2009/28/EC for renewable energy, Austria is required to increase this share to 34% by 2020. Smart control concepts make it possible to increase the percentage of distributed generation using renewables (see [12], [64], [81], and [49]). At the same time, replacing conventional fuels can help to reach the goal of increasing the share of renewable energy [84]. The EconRES project [72] used a macroeconomic simulation analysis to calculate that Austria succeeded in boosting its gross domestic product by €1.647 billion in 2011 compared to a scenario in which renewable energy sources had not been expanded since 2000. Moreover, promoting renewable energy sources would create an additional 3,300 jobs on average. Over 42,000 people in all were already working in "renewable forms of energy" in 2012; turnover for companies in this sector totalled some €14 billion.[9]

Reducing carbon emissions

Austria currently emits 80.2 million t CO_{2eq}, putting it well above the 68.8 million t CO_{2eq} target set in the Kyoto Protocol.[10] Smart power grids can help reduce CO_2 emissions by potentially increasing the concentration of distributed generation (see [12], [64], [81], and [49]).

The target improvements in energy efficiency would also help to reach this goal [84]. E-Motivation [37] showed that households can generate significant energy savings, leading to up to 150,000 t CO_2 per year, when they receive more information about their electricity consumption. The ability to use smart technologies to shift loads can also play a role in reducing emissions since load shifting makes it possible to step up use of renewable energy sources. Two international studies found that smart grid technologies and solutions can cut CO_2 emissions by up to 15%.[11]

6 See the 5th CEER Benchmarking Report on the Quality of Electricity Supply 2011. *http://www.energy-community.org/pls/portal/docs/1522177.PDF* accessed 28 June 2014.

7 Values refer to business hours during business days.

8 Source: Statistics Austria, overall energy balance Austria.

9 See Austrian Federal Council inquiry: "Bundesrats-Enquete: Erneuerbare Energien und lokale Wertschöpfung". Parlamentskorrespondenz No. 548 of 11 June 2014.

10 Source: Environment Agency Austria: greenhouse gas inventory 2012 at *http://tinyurl.com/lflqezv* accessed 28 June 2014.

11 GeSI: SMART 2020, *http://gesi.org/portfolio/project/5* und EPRI2008: The green grid: Energy savings and carbon emissions reductions enabled by a smart grid, Palo Alto, California, USA *http://www.smartgridnews.com/artman/uploads/1/SGNR_2009_EPRI_Green_Grid_June_2008.pdf*

The following sections describe the above-mentioned benefits from the perspective of each of the players in the smart grid – the energy sector, companies, households, and researchers.

4.2. Benefits of smart grids from the perspective of Austria's energy industry

From the perspective of the energy sector, there are a variety of benefits for grid operators, power suppliers, traders, and producers.

4.2.1. Benefits for grid operators

Grid operators operate in the regulated field of energy supply. Grid operators are required to keep the cost of the grid infrastructure as low as possible while maintaining a high level of security and quality of supply. If the use of new technologies increases the cost of operating the grid slightly, then these increases can be passed on to the consumer. The benefits of smart grid technologies for grid operators should, therefore, not be illustrated as direct monetary benefits. Target gains in efficiency are an economic benefit in the form of a cost-optimised energy grid. This means that the grid operator is also responsible for implementing regulatory requirements at the national and international level (such as the European Framework Directive).

In many cases, a conventional expansion of existing grids is necessary due to higher requirements regarding grid efficiency. Smart grid technologies make additional functions available to grid operators, however. These functions provide system operations support, which makes it possible to respond to new grid operation requirements, thereby also generating benefits for grid operators.

Monitoring in the distribution grid increases infrastructure use

Greater use of sensors and monitoring systems enables a detailed overview of operating parameters in the distribution grid and effective utilisation of reserves. An accurate analysis of the current situation is needed in order to determine whether the hosting capacity of existing grid structures is exhausted and grid-side measures are needed. In the future power distribution structure, ICT can be used as a metering system on a large scale, along with grid control and management [71]. Special metering methods can deepen our understanding of the medium- and low-voltage grid, making it possible to greatly improve grid planning and operation. We still need exact and generally applicable findings on the amount of monitoring that would be needed to obtain all relevant information about grid state with sufficient temporal resolution.

Increasing the hosting capacity for renewable generation

As results of Austrian projects have shown, the use of smart grid solutions not only makes it possible to reduce the need to expand the grid in some cases; it also makes it possible to integrate equal, or in some cases, higher amounts of renewable energy into existing grids at a minimal additional cost.

Different smart grid technologies, such as information and communication technologies (see [53], [65], [66], [71], and [83]), smart control concepts (see [12], [49], and [81]), and on-load tap-change transformer at secondary substation level (see [71] and [81]) are available for locally increasing the hosting capacity of volatile generation units based on the current grid state.

In addition to ensuring stable grid operation, the primary benefit of smart control concepts is that they increase the concentration of distributed electricity provision technologies and enable the grid to be expanded at the medium- and low-voltage level at minimal additional cost (see [12], [53], and [81]).

As the technology roadmap was being developed, grid operators identified the ability of smart grid technologies to increase hosting capacity (see Section 2.4.) in particular.

Cost-effective grid expansion measures

Without smart grids, the requirements associated with increasing supply from distributed generation units (see [12], [64], and [49]) can, for the most part, be met only through conventional expansion of transmission and distribution grids. Studies (see [12] and [81]) that compare grid expansion measures with smart grid applications show that smart grid technologies can reduce the added cost of upgrading the grid infrastructure.

From an economic perspective, this is an added benefit of smart grids.

Flexibility made accessible for grid operation

Based on information about grid states, grid operators can use the communication and information infrastructure to carry out measures to manage the load flow [66]. Distributed generation and many small distributed consumers can be coordinated efficiently and relieve grid operation through need-based use.

If the grid does not need to be expanded to cover 100% of the full load and full generation, additional costs for grid expansion can be reduced. In this case, there is an added benefit to harnessing flexibility: Remote management, for example of suitable loads, or the ability of the grid operator to control energy demand on short notice, is a suitable means of ensuring power quality (see [12] and [64]). According to Econgrid [71], greater use of storage technologies among end customers should enable higher capacity factors for renewable electricity technologies and help prevent peak loads.

From the grid operator's perspective, the new technologies that support grid operation described in Section 2.4.4. have considerable potential benefit. Smart grid technologies not only make it possible to harness flexibility for grid operation; they also make it easier to coordinate the flexibility requirements of the energy market with those of grid operation (see Section 2.5.2.). This is expected to be greatly beneficial.

4.2.2. Benefits for electricity suppliers and energy traders

Smart grids benefit electricity suppliers and energy traders primarily because of the increased availability of consumption data and the ICT link to end customers. This enables new or improved business models and services.

Smart grids make it possible to involve the demand side in the energy market

Private and commercial/industrial power customers primarily have to pay electricity prices and grid fees regardless of time or volume. Demand is only slightly responsive to the generation situation. High demand for electricity is often up against expensive power plant capacity, which is inefficient from an economic standpoint.

Integrating the demand side would make electricity consumption more economically efficient, which would result in financial savings for end consumers and positive effects on economic prosperity (see [71] and [80]). Electricity from volatile sources like wind and solar in particular requires the demand side to be networked and involved to a greater extent in grid management activities.

Because they are networked using ICT, smart grids make it possible to involve the demand side in the energy market. For the energy market, this plays a role primarily in the transmission of signals to customers (such as price information, control signals, etc.). Added to that are ICT-based applications such as high-frequency measurement and automation.

New business models and services emerging for customer retention

Flexible energy prices

If smart meters are installed nationwide, there will be more opportunities to offer flexible energy prices. If detailed data is provided, customers could be offered energy prices that vary depending on the time of day or load.

This would make it possible to provide consumption data to customers more frequently, which is also in the interest of efficient energy use. End customers could then obtain more information about their electricity consumption, for example from an online portal.

Smart buildings and households

Once a nationwide smart meter infrastructure is established, buildings and households could then be equipped with smart technology, which falls under the topic of energy efficiency. The first step would involve preparing consumption data to give customers real-time feedback about their behaviour. The second step would involve optimising energy costs for consumers. Building and home automation systems (customer energy management systems) would automatically take price signals into account when controlling equipment and systems in households. This would further increase the flexibility that will be needed in future to compensate for volatility by integrating fluctuating renewable energy into the energy system.

Utilising load flexibility

The main system used in Austria is the interruptible supply system (for example, off-peak electricity). In future, pooling loads at small customers' premises (such as heat pumps) could make it possible to provide more complex grid services as well. In general, the decision on whether to arrange load shifting with the grid operator will remain up to the customer [74].

Different field tests have shown end customer-side signalling to be effective. Traffic lights for prices were able to permanently shift 12% from peak load to off-peak times and 4% from high load to off-peak times (see [68] and [78]). Event tariffs, which signal times in which grid capacity is critical or electricity is available at a less expensive price, for example, have been proven to boost consumption by 30% or reduce it by 20% in event times depending on the tariff (see [68] and [30]). Traditional peak and off-peak tariffs also achieved a combination of load shifting and savings ranging from 5% to 8% (see [68], [70], and [79]).[12]

Balancing groups can be optimised

Smart grid technologies make it possible to obtain more precise information about consumption and generation. Knowledge of demand at a particular point in time and the use of better forecasting for renewable generation can improve schedules for balancing groups. The ability to use load flexibility means additional optimisation potential when generation in balancing groups fluctuates.

4.2.3. Benefits for distributed producers

Renewable generation technologies such as photovoltaics and wind power are considered drivers behind the implementation of smart grid solutions (see [12], [64], and [49]) for distribution grids. One of the key benefits of smart grids is the ability to integrate more distributed generation into existing grids more efficiently and more quickly than conventional expansion of grids would allow. This gives distributed producers the benefit of being connected to the grid under optimal conditions.

DG DemoNet [12] is studying existing and additional distributed supply from hydropower, wind power, photovoltaics, and biomass/biogas for multiple demo grids, while SG Essences [81] is analysing different measures (smart control concepts) for maximum PV integration into rural low-voltage grids. Other studies are looking at distributed generation as a driver to deal with U and Q control [49]. Studies are looking at the potential for distributed generation for the relevant grid section, and there are also studies of the potential of each generation technology, such as photovoltaics and wind power.

CO_2 emissions have been shown to be lower than in the reference scenario, and moderate impacts on the low-voltage grid have been demonstrated. The results also show that combined heat and power (CHP), for example, is not economically efficient under current framework conditions.

4.3. Benefits of smart grids from the industry perspective

By making more data available from the grid, providing real-time consumption data from end consumers, and making it possible to utilise flexibility, smart grids enable new market opportunities for innovative products, technologies, and services. What is more, it is already becoming apparent that new players will become established in the market.

Protecting jobs and creating new ones

Implementation of smart grid technologies will require considerable investment in the coming years. Efforts by Austria's innovative industry and policy-makers must be aimed at using this investment to increase added value in Austria, protect jobs, and strengthen Austrian companies in the international competition.

The European Commission estimates that 1.4 million jobs have already been created in the low-carbon energy sector and expects a significant number of additional jobs to be created if and when smart grids are implemented in Europe (in particular given the situation in the United States, where investment in smart grids has directly created some 280,000 new jobs).[13]

12 German studies [MeRegio, moma, etelligence, and ECOFYS].

13 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions of 24 April 2011 - Smart Grids: from innovation to deployment, /cOM(2011) 202 final

Austrian companies have comparatively few employees who work solely in the smart grid sector, apart from those working for manufacturers of smart grid-only components and systems, such as inverters, and control, automation, and communication technology. The number of employees is expected to rise at all of these companies. As a result, smart grids will become a job engine in Austria.

Opening new export markets

New jobs will be created especially if Austria can position itself as a leading smart grid market, which could also increase export opportunities for Austrian companies. The companies in the use cases described in the technology roadmap already generate a relatively high percentage of their turnover from exports. Austrian companies expect to further increase their export rate by 2020.

Current surveys by the European Commission and EURELECTRIC[14] clearly show that Austria is leading other countries in smart grid research, development and demonstration, something it can translate into a considerable advantage over international competitors.

Export opportunities for innovative Austrian companies in the field of smart grids have not yet been assessed, however. The twelve most important countries for Austrian exports include the three most active countries, in absolute figures, in smart grid research and demonstration: France, Great Britain, and Germany. Austria also has important trade relationships with countries such as Poland, Hungary, and Slovakia, which are currently less active in the field of smart grids. Austrian manufacturers of technologies and components related to smart grids see these countries as potential export markets with which Austria already has long-standing, stable relationships, not as new markets that need to be tapped. At the same time, these markets are at different phases of development, which means they need a wide range of products and services.

Establishing innovative services

The fact that the market for new services is only just emerging is also reflected in Austria's company landscape. Today, there are already some solutions that concentrate on end customers (see also the description of the end customer development axis). A growing market for services in all areas of the smart grid use cases is expected by 2020. The market for services, particularly for ICT services, is highly dynamic. Recent surveys by Statistics Austria[15] show that over 20% of fast growing companies in Austria have activities in these two areas.

Since services in the energy sector, such as generation and consumption pooling and self-consumption optimisation, generally require local solutions, the companies that offer these services will presumably tend to be be SMEs. This is a good thing for Austria's company landscape since SMEs in Austria account for a high percentage of overall economic performance. But large companies that have so far worked in manufacturing also see the potential to develop new lines of business in the service sector between now and 2020. This often happens in co-operation with smaller service companies.

Boosting co-operation between industry and SMEs

Experience has shown that co-operation between established companies and innovative SMEs can spark the development of efficient solution strategies. The example of collaboration between Verbund and entelios shows that an SME's operational expertise (pooling and energy trade) can indeed be of interest to an energy company looking to develop new business models. The Cybergrid example is proof that new companies can apparently gain advantages from relationships with large corporations after developing a promising business idea.

4.4. Benefits of smart grids from the household perspective

The number of Austrian households able to produce distributed energy, for example by using PV plants, has risen continuously. Prior research has clearly shown that smart grid technologies have the benefit of reducing the cost of integrating distributed generation units and controllable loads and make it possible to do so to a greater extent.

Smart grids mean real benefits even for households that only consume energy.

14 *https://portal.smartgridsprojects.eu/Pages/Map.aspx*

15 2013 export share from Statistics Austria, foreign trade

New tariff and price models

New tariff and price models have advantages for customers. In general, studies of load shifting, which can be initiated by innovative tariff models, have also identified high potential. Preventing loads at peak times, or peak clipping, in particular has high potential, and part of the target effect is not used up later, which translates into savings. Customers with higher consumption can generate greater benefits, in relative and absolute terms, from load shifting [73]. In general, it makes sense to focus on certain groups, as is the case with results on load shifting. Different field tests have shown end customer-side signalling to be effective. Traffic lights for prices were able to steadily shift 12% from peak to off-peak times and 4% from high load to off-peak times (see [68] and [78]).

More detailed consumption information

From the perspective of households, there are also benefits to the high-resolution consumption information that smart grids enable (see [71], [80], [67], and [74]). This information makes it possible to draw conclusions about households' self-consumption behaviour and can highlight relationships between use and consumption.

Austrian field tests of the effect of more consumption information determined that household consumption of electricity could be cut by an average of 3% to 5% (see [37], [63], [73], and [69]). These Austrian values are being confirmed by field tests conducted as part of Germany's E-Energy programme. In addition to the positive effects of immediate consumption information, offering dynamic and/or time of day-based fees can also lead customers to become more conscious of their consumption, which in turn leads to similar savings [68].

This would make it possible to provide customers with consumption data more frequently, which also encourages efficient energy use. End customers could then obtain more information about their electricity consumption, for example from an online portal.

Other indirect advantages for households

There are also advantages that benefit customers indirectly (such as advantages from new products). Advantages include the ability to ascertain distribution grid state; products that are currently less tangible, such as those used by a flexibility operator or other energy services providers and technology providers (see [65], [74], [77], [37]); and not least the transition of the energy system and relatively less inexpensive operation.

4.5. Benefits of smart grids from the research perspective

Researchers have so far made an important contribution to the development of smart grid technologies and have carried out important groundwork. Non-university research institutes as well as universities and universities of applied sciences have identified the following benefits:

New fields of research and expertise

New fields of research and expertise related to smart grids have been, and continue to be, established. This is reflected in the co-operation and integrative examination of previously separate disciplines, such as energy engineering and communications engineering. New jobs in research and development are being created as a result of the new research fields, and new knowledge is being acquired, leading to new expertise.

Continuity in the R&D environment

The development of smart grids is a long-term project that is not susceptible to any short-term currents, and the R&D environment has the continuity needed to establish expertise over the long term. In addition to the new fields of research and Austrian projects behind them, this makes it possible to establish sustainable research excellence, which has already given Austrian research companies a leading position in smart grids in Europe and internationally. Research and development projects have resulted in a number of excellent scientific publications, which ultimately makes Austria even more appealing as a research location.

Partnerships between industry and the energy sector

Partnerships between research institutions, industry, and the energy sector make it possible to offer research services, which can in some cases lead to spin-offs, bolstering the economy.

5. Education as the key to the future

Whether smart grids are able to be successfully developed, implemented, and integrated into the existing structures of electric energy systems and supply depends not least on the availability of qualified employees. Human resource planning and staff development, in particular education and continuing training, are closely linked to broad-scale implementation of smart grids.

5.1. Determining education requirements

Interviews were conducted with delegates from representative companies (technology providers, grid operators, and research and educational institutions) to determine the need for qualified employees in the various technological fields related to smart grids. This information was then used to evaluate education requirements.

5.1.1. General requirements for smart grid technicians

Activities related to smart grids require trained technicians who can work on developments in different areas, such as smart metering, grid operation components, soft-ware development, and ICT links. Technicians must have:

- A solid knowledge base in electrical engineering
- Solid knowledge of traditional energy engineering (including grid operation)
- The specialised expertise needed for their particular task
- Fundamental scientific knowledge (including energy management).

Future technicians will also need to apply a great deal of interdisciplinary expertise in order to be able to create solutions and verify whether these solutions are technically and economically feasible. Moreover, the international focus of companies means that foreign language skills, particularly English, will continue to be essential.

5.1.2. Technical requirements for smart grid technicians

In the understanding of smart grids, it is clear that smart grid technologies themselves are mostly secondary and tertiary technologies, not primary technologies. It is therefore no surprise that all surveys indicated that technical requirements were essential, beginning with:

- Practical knowledge of and expertise in the fundamentals of electrical engineering
- Practical knowledge and understanding of the structure and functionality of electricity supply, in particular energy distribution systems.

These requirements were followed by those in supplemental smart grid fields that are required depending on the particular discipline, such as practical knowledge of and expertise in:

- Power electronics, automation technology, and measurement and control technology
- Energy and grid management
- Software development, software engineering, and energy informatics
- Telecommunications in conjunction with energy engineering
- Innovation management technologies.

Austrian companies identified the greatest need for graduates of universities and universities of applied sciences in the following fields:

- Grid control and power electronics
- IT and energy informatics
- Telecommunications in conjunction with energy engineering
- Software development and software engineering
- Grid technology
- Energy and grid management
- Innovation management
- Information technology and electrical engineering

They also identified a need at the secondary level (graduates of technical secondary schools (HTLs) and apprentices) in the following fields:

- Telecommunications in conjunction with energy engineering
- Energy/automation and IT combination
- Software development and software engineering
- Information technology and electrical engineering

5.2. Education and further training

Representatives from technical universities (TUs), universities of applied sciences (FHs), and technical secondary schools (HTLs) in electrical energy engineering and information technology were interviewed, and their responses along with the curricula of relevant educational institutions (vocational training institutions and HTLs) and branches of study at FHs and TUs were used to identify education opportunities. The ibw's report to the Public Employment Service Austria (AMS) Standing Committee on New Skills for the electrical engineering, electronics and telecommunications cluster was also used.

5.2.1. Vocational training

Utilities and grid operators continuously add the latest education requirements and competencies to their apprenticeship programmes. Emphasis is placed on knowledge of new components and how to use them correctly. Apprenticeships in energy management make up the backbone of apprentice training in energy engineering. The special training programme established for apprentices in renewable energy is a supplemental training track.

5.2.2. Training at the secondary, HTL, level

The upper divisions for electrical engineering at HTLs either offer training for generalists in electrical engineering with a concentration in smart grids (such as HTL Mödling) or training with a school-specific concentration in renewable energy (such as TGM Vienna). Given the wide range of education and instruction content that has to be covered and the number of hours both curricula options allocate to energy systems and/or renewable energy, including in-depth study in year five, there are limits to how much can be taught about smart grids, even if instructors have relevant experience. The thesis required in year five is a chance for students to examine a topic related to smart grids more closely, ideally in co-operation with industry partners or partners in the energy sector.

5.2.3. Education at universities of applied sciences

Campus Wien does not offer a specific programme with a specialisation in smart grids, but it is developing projects related to smart grids in co-operation with industry partners on such topics as distributed voltage stabilisation and energy storage in smart grids. UAS Technikum Wien, FH Salzburg's Ressel Centre, and FH Kufstein offer special courses on smart grids.

Course content is extremely extensive in all curricula. It is therefore possible that only superficial coverage is given to smart grids and their context. Mandatory practical semesters for bachelor's and master's programmes and the thesis required for these degrees, which is written in collaboration with technology providers and operators of medium- and low-voltage grids, are an opportunity for students to examine smart grids in more detail.

5.2.4. Education at technical universities

Vienna and Graz universities of technology offer special smart grid courses. Bachelor's and master's students at technical universities also have the opportunity to focus on smart grids for their thesis projects.

5.2.5. Continuing professional training opportunities

Continuing professional training courses offered by WIFI, BFI, ÖVE, etc. and technical courses in the AMS New Skills programme cover different segments of smart grid technologies to teach the necessary skills and abilities to working professionals.

5.2.6. Training for instructors

In order to teach the complex requirements of smart grids, instructors need profound knowledge and a great deal of experience with electrical energy systems and need to be open to ICT technology. The question is how instructors can continue to stay abreast of the latest scientific knowledge, regardless of training level. Organised support is needed. Teacher training colleges do not offer any relevant programmes.

As part of new instructor training and further training, HTL instructors who specialise in electrical engineering or electronics attend multi-day workshops with representatives from the energy sector and the Austrian Electrotechnical Association (ÖVE) at the Lower Austrian teacher training college. The workshops describe energy systems of the future, with a focus on alternative energy generation systems and transmission grids.

5.3. Recommended courses of action for future education

As a general rule, raising awareness of the energy transition, efficiency, and technology among the population as a whole is a desirable goal. An education initiative that is an integral component of the energy transition in Austria could encourage and accelerate the transfer of knowledge related to energy. Children should be introduced to this topic from elementary school all the way up to general educational branches of secondary school.

5.3.1. Pedagogical requirements

On one hand, the surveys of companies identified the need for better teaching of technology basics to future technicians. In recent years, specialisation in new technologies in particular has come at the cost of learning the basics. On the other hand, future training needs to be practical, and in some cases, offered in new combinations.

Based on this information, future education and further training programmes should meet the following requirements:

- Solid instruction in:
  - Fundamentals:
    - Electrical engineering: energy engineering
    - Electrical engineering and general ICT
    - ICT: transmission technologies, security aspects
  - Current topics, technology trends
  - Technical and scientific methods

- Training documents need to be updated based on the latest state of innovations

- Phase of in-depth study of the interdisciplinary connection between electrical engineering and ICT:
  - In-depth examination using selected typical real-world examples
  - Learning by doing, an experienced mix of theory and practise

- Practical training component through partnerships with companies:
  - Bringing practical experience from companies to HTLs
  - Industry Goes Students
  - Practical semester/students work at companies to encourage interest and motivation
  - Recruiting through company internships, thesis projects, etc.

- Soft skills: presentation, communication, teamwork, and languages

- Specialisation through short courses or in-depth learning and specialisation once employed, on-the-job training, interdisciplinary thinking (grid operators, industry, and research)

5.3.2. Opportunities for use within the education system

Instruction, even at lower education levels, should draw on the diverse range of information about energy that is available.

A training initiative for technology expertise could achieve the goal of improving the quality of education and further training in selected areas of technology with a practical focus at an early stage of training. Interdisciplinary consortia consisting of research and educational institutions that would help encourage innovation, creativity, and greater openness to technology-related topics at all training levels would be productive.

Another option would be student laboratories, which would allow students to grapple with modern science.

Labs with modern equipment would need to be made available so that young people could experiment on their own. This would serve to spark young people's interest at a very early stage in working in a scientific and technical profession later on.

Germany currently has 189 student laboratories in the narrower sense, which cover all STEM[16] disciplines, age ranges, and types of schools through a broad range of offerings.

5.3.3. Company requirements

Some of the responsibility for education and further training also lies with grid operators and technology operators themselves since they are the most familiar with their specific needs:

- Grid operators are invited to inform their employees, or provide relevant training as needed.

- Technology providers and grid operators should use the WIFI and BFI branches to offer knowledge transfer to commercial businesses.

- The ÖVE should further expand courses in electrical engineering and electronics for HTL instructors.

- The industry and grid operators should push for appropriate training content at FHs and TUs and provide enough places for practical semesters and topics for thesis projects.

- Companies must campaign for high-quality training and further education for people. They can actively support these efforts by:
  - Offering school field trips to companies
  - Offering internships to students required to complete an internship
  - Supervising projects (for example, for school-leaving examinations)

16 The acronym "STEM" stands for science, technology, engineering, and mathematics.

6. Need for action and results

Section 2 described the technological solutions and specific need for action in order to implement smart grids in Austria arranged according to development axes. This section covers the need for action on the part of key stakeholders that play an essential role in implementing smart grids.

The key stakeholders are:
- Public bodies (government ministries, regulators, and the like)
- The energy sector (grid operators, electricity suppliers)
- Technology providers
- Research institutions

6.1. Need for action by all stakeholders in the development of smart grids

In the interest of the successful joint implementation of smart grids, all stakeholders should be involved in support measures. As an internal measure, a permanent process of dialogue **between players involved in the development of smart grids** must be established in order to improve the associated tasks and spheres of activity and to enhance the players' understanding of one another. And as a joint measure, it is relevant to **communicate the subject matter and benefits of smart grids**.

The increase in distributed generation has made it possible for end customers to better understand the importance of energy generation. Smart grids will play an ever greater role in public debate. This opportunity must be seized so that experts and decision makers can present a concerted view of the advantages and opportunities made possible by smart grids. In particular, we must resolve and clearly communicate the issue of protecting personal data in a way that does not diminish its great benefit and the possibility to use necessary measured data to make the energy system secure and efficient. Active communication about risks and how to solve them, but also about benefits and opportunities, is urgently needed. Smart grids have a positive impact on the economy (see Section 4.1.). This benefit can be publicised in a positive way by communicating the added value of technologies.

6.2. Need for action by public authorities

Policy-makers need to be unequivocally committed to the energy transition and a secure energy supply in order for optimal economic results to be achieved in the long term.

6.2.1. Need for action by government ministries

- **Strengthening coordination among responsible bodies:** In Austria, the responsibility for issues associated with smart grids, such as energy, research, safety, security, and business, is shared among several different ministries and authorities. This makes development of a consistent strategy difficult. A coordinated approach is absolutely essential, particularly for critical infrastructure and security.

The federal government's RTI strategy [89] contains the following specific points:

- "We *intend to clearly coordinate the competencies of the responsible ministries. To achieve this, the responsible departments must establish efficient coordination mechanisms.*
- *Task allocation among departments and funding agencies should be optimised by increasing agencies' operational independence, while strengthening strategic control by the departments."*

The goal is now for this coordination among the relevant bodies to take place in order to create a common strategy so that the framework conditions for industry and the energy sector can be established.

- **Establishing clear framework conditions for innovations:** An unequivocal commitment to the energy transition and to the cost of the energy transition on the part of policy-makers would create security for investment in technologies that improve efficiency, which would allow the energy sector to continue to operate and implement smart grids. Implementation that has a positive impact on the economy can take place only with a clear political mandate and objectives that involve customers and create incentives for customers to actively participate.

  Grid operators could, and should, take on the role of drivers of innovation in co-operation with industry and the research community. A climate that encourages innovation and the regulatory framework that would create this climate need to be ensured.

6.2.2. Need for regulatory action

- **Continued approval of appropriate operating costs:** The evolution of the energy system offers a number of advantages over traditional supply, in part because synergy effects and economies of scale can be used. These benefits come at a cost, however. In many cases, smart grid solutions reduce or delay investment costs, but also often result in increased personnel expenses for operations, for example for system maintenance or data management. The approval of these costs incurred by the grid operators must be ensured on a long-term basis, with consideration being given **to the overall optimum.**

- **Approval of validation projects:** A regulatory framework must be created that would make it possible to implement validation regions and conduct additional research projects. In order to ensure innovation over the long term, approval of the costs of appropriate validation projects must be taken into consideration.

- **Clarifying requirements for market design:** Roles and responsibilities that allow new market opportunities need to be defined. Developments at the European level must be taken into account. The various use cases described in the roadmap give rise to numerous requirements with regard to market design, as described in Section 2. As a result, the questions of whether new roles are necessary and which existing and/or new stakeholders could perform these roles must be answered. To clarify these ideas, transparent and understandable conditions need to be established, and customers (households, industry), ministries, grid operators, and representatives of the energy market need to be involved.

- **Using storage and harnessing flexibility to support grid operation:** It may be advantageous for grid operators to operate storage systems to prevent or delay grid expansion measures, integrate renewables, or improve grid security. A coordinated framework for the management of storage by grid operators must be created. Moreover, rules are needed to define how grid operators, along with market players, can access customer systems and smart buildings. This can happen through appropriate grid interconnection requirements and/or free market mechanisms. The issue of whether a storage system can and should be integrated into a balancing group also needs to be clarified. Clarification will require discussions among all stakeholders, in other words, public authorities, grid operators, participants in the energy market, and technology providers.

- **Identifying opportunities for utilising flexibility:** Stakeholders' requirements, which are sometimes at odds with each other, need to be sorted out. Clarification will require in-depth discussions among all stakeholders, in other words, public authorities, grid operators, and participants in the energy market.

- **Determining minimum requirements for security and privacy:** Minimum requirements must be set out in order to create security of investment, whereby higher levels of protection can be encouraged in the interest of security of supply and reliability. The cost and technical work needed for security and privacy measures must be in proportion to potential risk. A coordination process among regulators, research institutions, technology providers, and grid operators is needed to strike a balance between investment and potential risk. The process begun by the technology platform to develop a smart grid reference architecture in the RASSA initiative would be a suitable way to accomplish this.

6.2.3. Need for action related to innovation structures and funding mechanisms

Austrian stakeholders produce world-class research results, but Austria has been much less successful at translating the results of research and development into innovation and added value. Better opportunities for testing and implementing innovations urgently need to be created:

- **Arranging funding programmes for next steps in development:**
  Factors that drive topics related to innovation include ongoing strategic activities, such as energy research programmes in Austria's funding landscape. Action is needed in the form of ongoing monitoring of main topics and further development of funding priorities. The following should be made priorities for smart grids:
  - Large-scale validation projects in Austria: Larger distribution grid areas need to be equipped with the right technology throughout to make it possible to implement known and developed technical solutions in a way that is economically viable. These validation areas should make it possible to specify and optimise all processes associated with rollout and operations. Processes include infrastructure interfaces for active grid management, new functionalities for ICT components, and the migration path for ICT systems, including incident diagnostics, troubleshooting, grid planning, and customer care. The regulatory framework must allow demonstration regions.
  - The new EU guidelines on state aid for environmental protection and energy 2014–2020 allow funding for smart grid investments in "regional assisted areas" [104] under certain circumstances. The extent to which potential demonstration regions are allowed in these assisted areas needs to be clarified in order to be able to take advantage of EU support. Agreement needs to be reached between funding bodies and stakeholders in the energy sector and technology providers.
  - Funding programmes for long-term developments: Long-term developments, such as the development of a smart grid architecture, need a research framework that separates development of the framework from approval of subprojects.

  The right cross-programme funding strategies and funding programmes of the bmvit, FFG, and KLIEN need to be coordinated with representatives from the research community, the energy sector, and technology providers.

6.3. Need for action by grid operators

Smart grids give grid operators the opportunity to ensure safe, secure, and efficient grid operation at an optimal cost. There is still need for action in the following areas:

6.3.1. Need for action related to framework conditions

- **Defining criteria for cost recognition:** To minimise risk related to the recognition of costs for implementing and operating smart grid solutions, recommendations for cost recognition need to be developed together with the regulator. This area for action is considered a top priority and should be clarified before the next regulatory period (beginning in 2019).

- **Large-scale validation projects:** The scope of and requirements for validation regions need to be defined for public bodies to provide appropriate funding instruments and framework conditions. The transferability and scalability of developed solutions must be able to be tested and ensured. There is urgent need for large-scale validation projects for the development of a system solution for Austria. Clarification therefore needs to happen by the end of 2015 to create the appropriate framework and aid conditions for validation.

- **Specifying security requirements for the ICT infrastructure:** A number of specialists at Oesterreichs Energie are already dealing with this issue in close co-operation with experts in the security sector. Issues related to ICT system security are a high priority for grid operators and producers. They will be able to be resolved during the development of a reference architecture. This is an ongoing process, which began with the RASSA Initiative [103] of the Technology Platform Smart Grids Austria. Grid operators play a key role in the development of a reference architecture.

- **Determining ways to use flexibility:** Rules need to be developed to specify how grid operators can access the control opportunities and flexibility made available by customer systems and smart buildings. This can happen through regulatory requirements, appropriate grid interconnection requirements, and/or free market mechanisms. Once the use of flexibility has been clarified, framework conditions on how to manage this flexibility need to be coordinated with the energy market.

- **Clarifying market design requirements:** Smart grids create new market opportunities for new and existing players. This also creates new tasks and responsibilities for grid operators, which need to be clarified.
  - Enough options must be available for grid operators to be able to maintain grid security.
  - New players entering the market create new interfaces between existing and new market partners, and the framework conditions (reference model, protocols, logical communication pathways, and data models) need to be defined.

6.3.2. Need for technological and economic action

- **Developing and validating new planning approaches:** Innovative approaches to planning grids (such as probabilistic principles of evaluating generation units) can delay the need for expansion if there is a high share of distributed generation. Such approaches should be used in future.

- **Developing and validating operating processes:** Smart grid technologies provide grid operators with new functionalities for grid operation and also transform existing processes. The availability of more data from grid operations will trigger changes to grid operators' daily operating processes. Well-established procedures often have to be redefined and implemented within companies. Action will need to be taken as soon as smart meters are implemented. Clarification needs to happen together with technology providers.

- **Specifying functional requirements for distribution grid monitoring:** Detailed functional requirements for implementing distribution grid monitoring (see Section 2.4.2.) need to be clarified with technology providers. Any gaps between the minimum requirements of the IMA regulation [86] and future requirements of smart grid applications need to be analysed.

- **Integrating existing installations:** Concepts for integrating existing systems into smart grid solutions need to be developed together with technology providers.

- **Technical integration of customers:** The technical availability of end customers for line-commutated access to flexibility must be clarified.

- **Local solutions:** Recommendations for generally applicable or standard (local) solutions to be used need to be drafted based on controller functions that can be used locally and settings for certain grid types.

6.4. Need for action by electricity suppliers and energy traders

Smart grids offer new market opportunities for electricity suppliers and energy traders, but action is still needed in the following areas.

6.4.1. Need for action related to framework conditions

- **Specifying market design requirements:** Smart grids create new market opportunities for suppliers and traders, and these still need to be clarified.
  - The role of the flexibility operator is the main topic of discussion. Coordination and interfaces between the market and grid in particular need to be resolved. The balancing group system must be studied, and any need for changes must be

identified to clarify how suitable the existing market model is.
- Classification of customer segments: Customer segments and their potential for savings and added value must be identified. If there are sufficient advantages to using flexibility, business models can be developed.
- Determining market design requirements is a high priority for energy suppliers and dealers since these requirements form the basis of new business models.

- **Determining opportunities to use flexibility:** The utilisation of flexibility ranging all the way down to prosumers and consumers in the household segment provides many opportunities for marketing. Framework conditions, such as access rights to flexibility in the event that the requirements of the players involved differ, need to be established (creation of regulations, for example for implementing the traffic light model). This is a high priority for energy suppliers and dealers since these conditions form the basis of new business models.

6.4.2. Need for technological and economic action

- **Enabling new business models:** Smart grid technologies that have been developed and the availability of more precise consumption data make new business models and services possible. New market opportunities give companies the chance to try out new distribution channels and enter into strategic partnerships. In terms of load flexibility, experience with the potential of customer flexibility needs to be gained from initial field tests. Rising demand means that early adopters (businesses and end customers) can take advantage of economies of scale in terms of product prices. Customer segmentation would be helpful for successfully initiating this effect. Customers' real needs must be identified and addressed.

- **Developing and validating new business processes:** The availability of more data means that the everyday business of traders and suppliers is changing. Well-established processes often have to be redefined and implemented within companies. Clarification needs to happen together with technology providers.

6.5. Need for action by technology providers

The need for action by technology providers naturally consists primarily of further developing their smart grid solutions. However, thanks to their expertise, they can also play a major role in the development of framework conditions for making Austria, as a technology location, a leading market for smart grid solutions.

6.5.1. Need for action related to framework conditions

- **Cooperation and transfer of technology across sectors:** "Due to the increasing integration of energy and information technologies and the effects that different smart grid solutions have on each other in the power system, industrial companies, power utilities, and research institutions must exchange know-how and collaborate, as is provided for in Austria's national technology platform.

  The challenge is the industry's willingness to co-operate in the pre-competition phase in order to secure positions internationally as a technology pioneer.

- **Large-scale validation projects:** Larger validation areas (comprising, for example, some 50,000 to 100,000 smart meters) for system tests are required. This would enable the system technology of known technical solutions and solutions that have been developed thus far to be tested in a real-world environment and to be used more efficiently. These system tests will make it possible to gain additional process experience with multiple smart-grid technologies operating in parallel as well as with business models and to optimise products and solutions. Findings gleaned from optimisation will lead to specific supplemental product requirements, which can then be implemented by industry. Large-scale validation projects are expected to cost €100 to €150 million, and industry will need to help cover its share of the costs.

- **Ensuring national smart grid research:** In addition to a stable funding environment (bmvit, KLIEN, etc.), industry needs a funding concept that involves industry in co-operation with the energy sector in order to be able to leverage additional opportunities from the national development of technology in Austria. This concept needs to be developed and implemented. Industrial companies need to be able to protect and expand competence centres for technology development in Austria.

6.5.2. Need for technological and economic action

The need for action in terms of technology must be clarified by technology providers in co-operation with the future users of the technology – primarily energy end customers and grid operators. This section describes the need for action that is largely technology and provider-independent. The technology-specific requirements of each of the use cases are described in detail in Section 2.

- **Reducing engineering effort for provisioning smart grid solutions (e.g. automation components, inverters, customer energy management systems, etc.):** The number of smart grid field components is skyrocketing (> 100,000 units). This calls for the development and advancement of tools and plug-and-automate solutions to greatly reduce engineering and configuration work, which would reduce costs and complexity.

- **Standardisation, interfaces, and interoperability:** From a technological standpoint, there are already a number of standards for smart grids in grid automation, smart metering, IT architecture, communication, and internet technologies that can be used. As smart grid solutions are being developed further, any need for harmonisation between standards and gaps in standardisation based on EU Mandate M490 need to be identified, and solutions need to be developed and submitted to the relevant standardisation bodies. The aim of this is to ensure the highest possible interoperability at the functional and communication levels.

- **Further developing efficient security, safety, and privacy solutions:** Requirements for security, safety, and privacy are especially important. Risk analyses and existing safety and security standards need to be used so that the necessary measures and functions can be taken into account as early as product design and development. A risk analysis also needs to be conducted when facilities and systems are designed. This would then be used as the basis for developing and implementing an appropriate security and safety policy.
  - Products from technology companies permit protection measures to be adapted quickly based on changing technological, legal, and economic framework conditions.
  - The cost and technical work needed for security and privacy must be in proportion to the potential risk.

- **Adopting protection technologies for distributed power grids:** The ongoing decentralisation of grids is bringing about new requirements for protection technologies. There are a number of consequences of distributed (renewable) sources, such as two-way power flow, more constant voltage values due to more supply points, and smaller differences between load current and fault current. Protection concepts and technologies available today cannot handle these types of situations, or cannot address them sufficiently. New developments are needed.

- **Additional technological solutions for integrating existing medium-sized generation units (0.1 to 10 MW) into smart grid solutions (such as voltage control at the medium-voltage level):** Existing, often older, generation units (such as hydropower plants and biomass plants, which supply medium voltage) need technical solutions that would cost-effectively integrate them into communication and management systems.

- **Further developing local solutions:** Grid equipment and generation units that can be operated in the distribution grid without communicating and that are beneficial to grid stability are becoming increasingly widespread, such as Q(U) at PV inverters. These types of autonomous solutions should be developed further in co-operation with users (grid planning, grid operation) so that they can be made more user friendly. Identifying control parameters that are as generally applicable as possible reduces configuration work at distributed generation units. Moreover, local solutions for integrating local (battery) storage (for example in inverter systems) need to be developed further.

6.6. Need for action in research and education

Research institutions, and educational institutions in particular, must ensure knowledge transfer.

To do this, they need to constantly adapt to the latest developments.

6.6.1. Need for action related to framework conditions

- **Sharing knowledge and skills:**
  Research and education ensure that human resources with the necessary knowledge and skills are available, and staff can also move from research to industry and the energy sector at several levels:
  - Research institutions make suitable, in-demand services available for industry and the energy sector, and these include education and training.
  - A cooperative support network for master's and doctoral students needs to be developed together with industry and the energy sector.
  - Education must be adapted and refined based on smart grid requirements. This includes training skilled workers and providing education at HTLs, master's programmes, and doctoral programmes.
  - Suitable initiatives for raising awareness of mart grids among students need to be started and established using methods such as student laboratories.

- **Cooperative European and international projects:** Cooperative European and international projects should be conducted to ensure that solutions developed in Austria are transferable and scalable.

6.6.2. Need for technological and economic action

- **Methods and tools for implementing smart grid systems:** The development of methods and tools for planning and supervising the implementation of smart grid technologies and systems in the grid includes:
  - Development environments for technologies
  - Environments for system analyses, including evaluation of whether tested and developed solutions are scalable and can be transferred elsewhere
  - Methods for validating and analysing solutions that have already been rolled out and applying findings to the development of new product generations

These types of tools need to be developed in collaboration with technology providers and grid operators based on the necessary available data.

- **Research and test infrastructure:** Research institutions should provide and further develop a research and test infrastructure for supporting developments and quality assurance (certification and accredited testing) of smart grid technologies.

6.7. Need for action by the Technology Platform Smart Grids Austria

Energy supply systems and legal frameworks are country-specific. The top priorities of the technical challenges that need to be solved immediately therefore need to be examined solely from an Austrian perspective. The Technology Platform Smart Grids was developed for this reason. It serves to network representatives from the energy sector, industry, and the research community within the platform and has been able to establish a good rapport with ministries, authorities, and international experts in recent years.

- **The platform should carry out the following tasks in future:**
  - Establishing contact with stakeholders not yet involved in smart grid development, and maintaining and intensifying existing contacts
  - Continuously monitoring high-priority topics and supporting the necessary further development of funding priorities
  - Communicating and disseminating current results and happenings related to smart grids among experts and to the public

7. Appendix

The appendix contains detailed information about topics covered in this roadmap.

7.1. Connection to the Research Roadmap Smart Grids Austria 2010

The Research Roadmap Smart Grids Austria [1], which was published by the Technology Platform Smart Grids Austria in 2010, addressed the development of a vision for the electricity infrastructure in 2050. Research questions were then developed based on this vision.

We have divided the need for research into four topic areas:

- Customer and market/regulation
- System operation and management
- Communication and information infrastructure
- Smart components

The R&D implementation strategy that was presented highlighted how the smart grid vision can be implemented in Austria up to 2020 and beyond through detailed R&D and demonstration projects. Several R&D projects on the development of concepts, smart grid components, and demonstration of system approaches have since been conducted.

Results for customers and the market

Many questions related to the smart grid market design still need to be answered. The role of a flexibility operator has been discussed, but it is still unclear who should assume this responsibility. Moreover, project findings have shown that customers will not take on active roles in smart grids and are not especially willing to pay for new services. Automated solutions are needed to activate end customers. The business models developed still generally fail because they are not economically efficient enough: ICT components are often more expensive than potential income generated on the market. Automation for systems with low power consumption is still not worth the cost, given the limited benefit.

Most R&D projects involved representatives from the (energy) market only to a limited extent. They will need to participate more in future activities.

Results for system operation and management

The new smart grid requirements need to be taken into account in coordinated system operation of distribution grids. To this end, data that is collected must meet the necessary quality level, and data transmission must be secure so that smart system operation and data management can be integrated efficiently into widely distributed systems (such as smart distribution substations) and into grid control technologies. Data privacy has developed its own dynamic, which has become evident in the privacy and security debates related to the introduction of smart meters.

Findings from research projects have identified an urgent need for planning and simulation tools to provide support for investment decisions and resource planning and optimisation.

Results for communication and information infrastructure

Important activities in this area include further developing, harmonising, and supplementing standards and solutions that enable safe, secure, simple, and cost-effective information exchange (plug-and-automate solutions) among the system components involved. Standards are largely available, but in some cases there are multiple standards for solutions. It is not yet known which will become the standard in future and how interoperability among standards can be promoted.

SCADA systems require data from smart meters and electromobility to be integrated, and control systems need to be expanded to lower voltage levels. Proof of concept has been established at the medium-voltage level for active distribution grids. Progress needs to continue with the rollout of technology, and synergies with other applications need to be taken into account. In the area of smart homes and smart buildings, issues related to cybersecurity and privacy in particular still need to be resolved in conjunction with connections using ICT gateways.

Results for smart components

Many solutions have been developed in recent years, particularly in the field of smart components. The impact of components and their contribution to voltage quality have been determined. Further studies of the effectiveness of concepts are needed.

In the area of primary technology, for the most part, new requirements have involved system components and their integration into smart system operations.

Adapting existing systems has proven difficult and very expensive. Major progress has been made in recent years with reactive power control for PV inverters. The high cost of developing and analysing solutions for storage management (such as small pumped-storage power plants and hybrid PV systems) has proven to be the main hurdle. More research is needed.

7.2. ICT architecture for smart grids in the international context

In addition to developing standards for individual technical areas, such as communication protocols, Europe has developed a Smart Grid Architecture Model (SGAM) in recent years.[17] This development was initiated by the European Union's Mandate 490 and carried out[18] by the CEN, CENELC, and ETSI standardisation organisations as part of the Smart Grid Coordination Group (SG-CG) (see Figure 28). The Smart Grid Interoperability Model

17 *http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/xpert_group1_reference_architecture.pdf*

18 *http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/2011_03_01_mandate_m490_en.pdf*

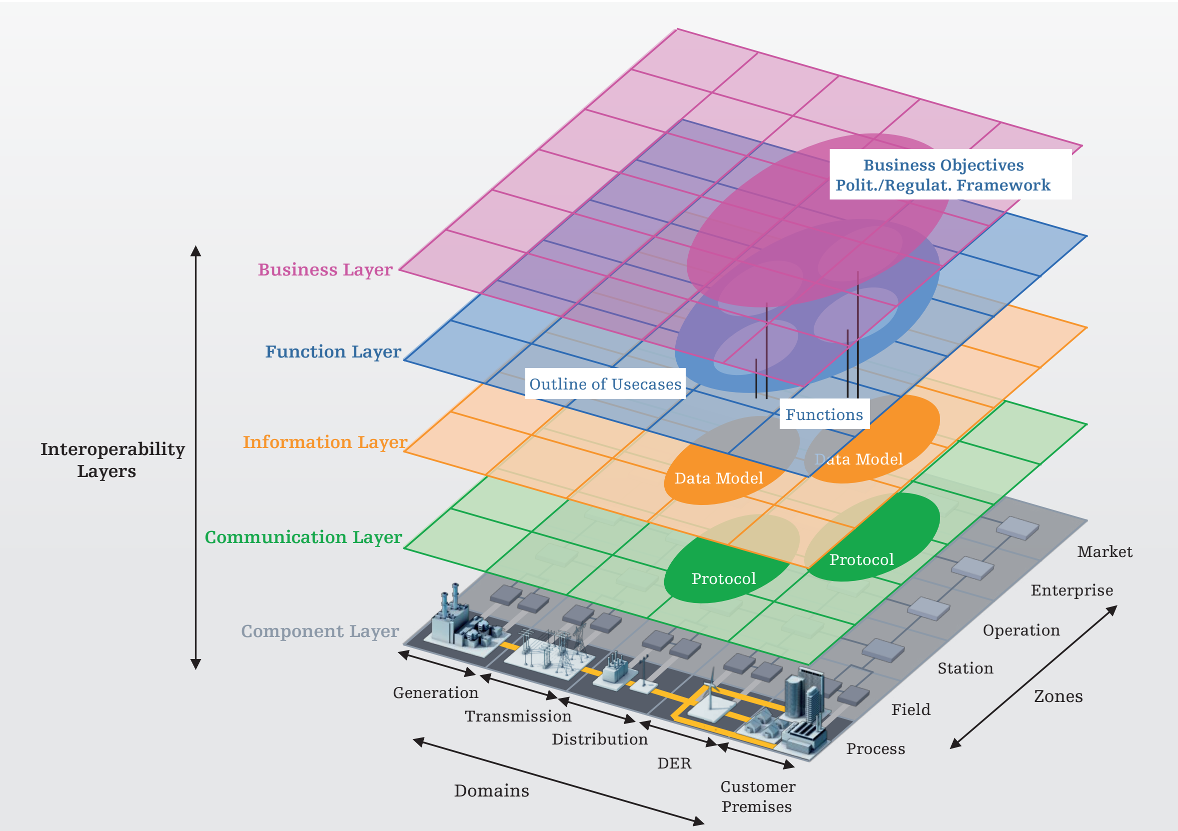

Abbildung 29

SGAM-Referenzmodell (aus CEN-CENELEC-ETSI „Smart Grid Reference Architecture") developed by the NIST[19] is the conceptual basis, and it is currently being reworked.

The SGAM illustrates the different aspects of smart grid development using a one-dimensional model [87]. The model is based on five interoperability layers on which the exchange of information in smart grids needs to be organised. The other two axes represent the domains, from generation to consumption, and the zones, from the process level of control technology to the market mechanisms. The SGAM has since become a recognised reference for classifying and discussing information systems in the smart grid and should therefore also serve as a basis for more in-depth architecture developments.

Support tool for developing an architecture

Developing architecture solutions for smart energy systems involves bringing a number of different stakeholders with different perspectives on board. It has become clear over the course of the pilot projects conducted so far that co-operation among participants from different disciplines and domains is a challenge due to the participants' different approaches and different terminology.

A common basis or common language for architecture development needs to be created in order to appropriately account for all stakeholders and their requirements. In addition to clearly separating functional aspects (requirements) and architecture aspects (solutions), an integrated picture must be created along with the option to look into specific areas in more detail. Ideas for possible solutions could be found in other domains that face similar challenges. For example, the development of distributed control units in the automotive industry also involves safety-critical aspects and different stakeholders from different disciplines.

One established approach for dealing with technical complexity is model-driven engineering (MDE), which implements the paradigms of "separation of concerns" and "divide and conquer". MDE concepts combined with a domain-specific language (DSL) could deliver a common basis for developing architecture in the smart grid.

19 *http://www.nist.gov/manuscript-publication-search.cfm?pub_id=910824*

The European Smart Grid Architecture Model could serve as the basis for developing an appropriate DSL, as has already been demonstrated in the SGAM Toolbox, which is publicly available.

7.3. The traffic light model in Austria and elsewhere

A traffic light model for ascertaining grid status was developed in Germany as part of the E-Energy programme [58]. The model was developed further as part of the DACH co-operation together with Austria. At the time of writing, however, there is no conclusive definition of the criteria for each of the traffic light phases.

Market and grid integration is moving in the direction of being considered an integrated system. This has emerged as a key element, which illustrates the great number of approaches linked to the term "smart grid" [90] and is something that the common objective of laying out, and subsequently using, an energy supply infrastructure that is optimised in economic terms should be geared toward. Distribution grid operators are concerned with optimising investments and ensuring that security of supply is in no way put at risk. The growing number of small and micro participants requires efficient processes that ensure the necessary coordination between the interests of the market and the interests of the grid. Traffic light models were developed in Germany and Austria to make it easier to understand this interaction so that the necessary future market rules can be established.

Figure 30 shows the traffic light model that was developed by the Technology Platform Smart Grids Austria (SGA TP) and coordinated with other organisations, including the German Association of Energy and Water Industries (BDEW). Widespread agreement has been reached on what the red and green phases mean. The common understanding is that red indicates a risk to the grid that is great enough to allow the distribution grid operator to intervene without having to account for market mechanisms. Green indicates that sufficient grid capacity is available to enable all prosumers to participate in energy markets without restriction.

The crux of studies is now to determine how to design or implement the amber phase. A first step is described in [91], which involves specific recommendations for designing the amber phase – taking into account applicable regulatory framework conditions as far as possible – and an outlook of what will be needed in future is also provided. A number of research projects studying the different interpretations of the amber phase is currently being tendered and launched in Germany. At the scientific level, the integration of grid and market-driven operation has been examined primarily from a theoretical perspective.

There are different approaches to interpreting the amber phase, such as those of Biegel et al. [93] and Sundstrom and Binding [94].

The first projects are already under way in Austria, and they include INTEGRA [25], which is studying the scientific basis along with the technical prerequisites of the flexibility operator. From a technology standpoint, there is still some uncertainty about the full requirements related to the functionality of the flexibility operator. Although a national and international discussion process has been happening for some time, there are still many unknowns in this area. In addition to the distinct complexity of the function as an ICT hub (brokering grid and market data), there are still major challenges in particular with the wide range of additional contractual and regulatory conditions that affect optimisation of system requirements.

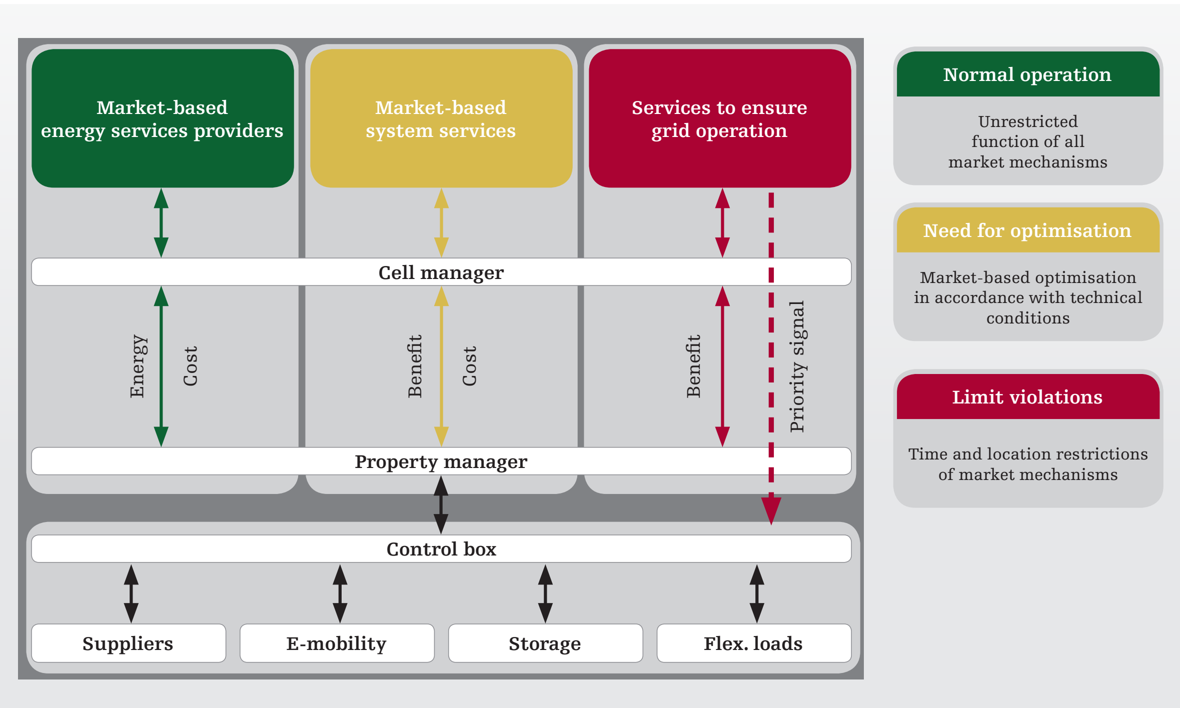

Figure 30
The traffic light model in Austria

Source: www.en-trust.at/SGAM-Toolbox

7.4. Austrian model regions and demonstration projects

This section is a compilation of short descriptions and references to Austrian model regions and demonstration projects.

7.4.1. Overview of model regions in Austria

Smart Grids Model Region Salzburg – Demo Region Lungau	
Project:	ZUQDE – Smart Grids Model Region Salzburg – central voltage and reactive power control of distributed power plants (FFG No. 825468)
Model region:	Lungau (S)
Lead partner in the research consortium:	Salzburg Netz GmbH
Project partner:	Siemens AG Österreich
Duration:	July 2010 – April 2012
Final report:	*http://www.smartgridssalzburg.at/fileadmin/user_upload/downloads/Endbericht_ZUQDE_publizierbar_final.pdf*

Summary: Plans call for additional small hydropower plants to be connected to the 30 kV medium-voltage grid in Lungau in addition to the existing small hydropower, photovoltaic, and biomass plants. The grid could be reinforced in a conventional manner, but it makes more sense and is less expensive to use coordinated and largely automated voltage control to considerably increase the grid's hosting capacity for distributed renewable generation without reinforcing lines, which, at the same time, improves the quality of supply. A central voltage and reactive power controller uses a central computer in the control room to manage reactive power and ensures that voltage does not fall below the minimum value or exceed the maximum value. This is also intended to minimise energy loss in the grid.

An automatic centrally controlled voltage and reactive power controller for transformers, producers, and loads was developed for the Lungau demo grid. It was tested during trial operations and compared to the DG DemoNet approach.

Smart Grids Model Region Salzburg – Model Community Köstendorf	
Project:	DG DemoNet – Smart LV Grid – Control concepts for active low-voltage network operation with a high share of distributed energy resources (FFG No. 829867)
Model region:	Köstendorf (S)
Lead partner in the research consortium:	AIT Austrian Institute of Technology
Project partners:	Bewag Netz GmbH, Energie AG OÖ Netz GmbH, Fronius International GmbH, Linz Strom Netz GmbH, Salzburg Netz GmbH, Siemens AG Österreich, Vienna University of Technology – Institute of Energy Systems and Electric Drives, Vienna University of Technology – Institute of Computer Technology
Duration:	March 2011 – September 2014

Summary: Combined optimisation and management of PV systems, electric cars, and household consumption was carried out separately and then in coordination with the grid state in the Köstendorf smart grids model community in Salzburg-Flachgau. One in two homes in the model region has a photovoltaic plant (43 plants with 192 kWp total) and one in two garages houses an electric car [36].

A building energy agent (BEA) ensures that energy produced by the PV plant is consumed in the building if at all possible. To this end, the weather forecast for the current day is included in optimisation, and different loads, such as electric heating systems and electric car charging stations, are connected when the PV system is producing electricity. When problems occur in the power grid, the BEA in the building receives signals from the controllable five-stage secondary substation transformer, which allows it to support safe and efficient grid operation. This transformer station, the first prototype in the world, went into operation in October 2012. Together with the ICT infrastructure, controllable inverters and charging stations, smart meters, and so on, supply and demand are balanced to ensure that the low-voltage grid can be operated without a loss of convenience for customers.

Developed and established control algorithms, devices, and communication equipment have been tested and evaluated in operating systems since April 2013.

Smart Grids Model Region Salzburg – Rosa Zukunft	
Project:	SGMS – HiT Planung+Bau – Smart Grids Model Region Salzburg – buildings as interactive participants in a smart grid – planning and construction (FFG No. 829996)
Model region:	Rosa Zukunft residential building on Rosa-Hofmann-Straße, Salzburg Taxham (S)
Lead partner in the research consortium:	Salzburg AG
Project partners:	Salzburg Wohnbau AG, Siemens AG Österreich, AIT Austrian Institute of Technology, Vienna University of Technology, CURE, Fichtner IT Consulting
Duration:	January 2011 – May 2015

Summary: Austria's first residential complex optimised for smart grid applications is located on Rosa-Hofmann-Straße in Salzburg. All of the smart grid components relevant for the low-voltage level are combined into an integrated building concept. The project includes the planning, construction, operation, and monitoring of a residential complex with 130 apartments and condominiums for different user groups (young people; senior citizens: residents needing assisted, age-appropriate living with technical support). The project examines the main issues related to energy generation from renewable sources, building technologies, storage, and electromobility during live operation. The complex has a smart energy management system, which manages energy generation and consumption (using, for example, automated load shifting) and can use available storage (such as the batteries of electric vehicles). The overall concept includes environmentally friendly energy generation using photovoltaics and co-generation plants as well as sustainable mobility concepts for residents. Some of the apartments have been designated as monitoring apartments and are equipped with additional smart features, such as a display indicating the current electricity, heat, and water consumption; an eco-button, which residents can use to switch off certain devices when they leave the apartment; a smart control unit for the heating system, which allows certain preset functions on the internet or a smartphone; and full monitoring of the temperature, humidity, and CO_2 content of the air, which can be used to improve ventilation behaviour. Energy generation and consumption are displayed in the common area, where visitors and residents can learn about the smart grid complex.

Smart Grid Test Region Upper Austria	
Project:	AMIS – developing an automatic metering and information system in the energy grid (FFG No. 818895)
Model region:	Steyr, Attnang Puchheim, Gmunden, Vöcklabruck, Ried-Raab-Ranna, Gundertshausen, and Strobl (OÖ)
Lead partner in the research consortium:	Energie AG Oberösterreich Data GmbH
Project partners:	N/A
Duration:	June 2008 – December 2009
Final report:	*https://www.klimafonds.gv.at/assets/Uploads/Blue-Globe-Reports/Smart-Energies/2009-2012/BGR12009KB08NE0F40494SE-AMIS.pdf*

Summary: Information and metering systems – interfaces between customers and providers – are one of the core components of smart energy systems. Siemens Energy and Energie AG developed the Automatic Metering and Information System (AMIS) and tested it live in the Upper Austria smart grid test region with 10,000 customer systems.

The main component of the system is a new family of meters that can be rolled out, setting new Europe-wide standards in Upper Austria. These electricity meters are software-controlled, which means they are open for future developments and use cases, such as home automation. AMIS creates the basis for brand new business models and a new customer relationship quality.

Since the successful test run, over 90,000 smart meters have already been installed for customers of Energie AG in Upper Austria.

Smart services for the greater Linz area	
Project:	Energy park – new European energy efficiency with active climate protection (FFG No. 818938)
Model region:	Plesching-Steyregg (OÖ)
Lead partner in the research consortium:	LINZ STROM GmbH für Energieerzeugung, -handel, -dienstleistungen und Telekommunikation
Project partners:	N/A
Duration:	June 2008 – January 2010

Summary: Options for using smart metering across energy sectors were tested at Plesching Energy Park. An overall system for remote querying, control, and evaluation of electricity, heating, natural gas, and water consumption data as well as billing was installed in 121 residential units. The data is combined and transmitted using state-of-the-art broadband power-line technology.

The IEM energy management solution from ubitronix is the basis for metering and management processes. Residential customers can use a home automation display or the online Unified IEM portal to track their consumption values or regulate their heating, lighting, and watering over the internet. Adapted tariffs and online monitoring help reduce overall energy consumption by up to 7%.

Unified IEM also offers special control options for public street and path lighting. Light sensors, dimmers, electrical ballasts, and additional meters can be used in combination to control entire blocks or individual lights.

Smart grid pioneer region	
Project:	DG DemoNet – Smart LV Grid – Control concepts for active low-voltage network operation with a high share of distributed energy resources (FFG No. 829867)
Model region:	Eberstallzell (OÖ)
Lead partner in the research consortium:	AIT Austrian Institute of Technology
Project partners:	Bewag Netz GmbH, Energie AG OÖ Netz GmbH, Fronius International GmbH, Linz Strom Netz GmbH, Salzburg Netz GmbH, Siemens AG Österreich, Vienna University of Technology – Institute of Energy Systems and Electric Drives, Vienna University of Technology – Institute of Computer Technology
Duration:	March 2011 – September 2014

Summary: The rise in the use of renewable electricity from photovoltaic plants in the active low-voltage grid is being studied in the Upper Austrian community of Eberstalzell, which has a population of 2,300. The two-year research operation phase will run until the end of 2015. Some 70 photovoltaic plants in two local grids, a housing development area with businesses in the centre, and an agricultural area were integrated into the grid. Smart meters record load and voltage states and transmit this data to a control unit in the first on-load tap change transformer at secondary substation level in Austria. As of May 2012, the new transformer has to balance the energy supplied by the 70 distributed photovoltaic plants and the current supplied to consumers. At the same time, it also has to ensure top voltage quality for all customer systems.

The Fronius IG Plus V inverter is another component being used. The inverter can control reactive power, which keeps grid voltage within the required limits. Direct communication with the smart grid makes it possible for technically sophisticated control algorithms in the Fronius inverter to be managed by remote control. The smart grid controller uses data from the smart meters on controllable transformers as well as inverters to control voltage. The result is active distribution grid operation, which can send control commands and parameters to all components.

Smart Grids Model Region Vorarlberg – Demo Region Großes Walsertal Biosphere Park	
Project:	DG DemoNet validation – active operation of electric distribution grids with a high share of distributed renewable energy generation (FFG No. 825514)
Model region:	Großes Walsertal (V)
Lead partner in the research consortium:	AIT Austrian Institute of Technology
Project partners:	Energie AG OÖ Netz GmbH, Salzburg Netz GmbH, Siemens AG Österreich, Vienna University of Technology – Institute of Energy Systems and Electric Drives, Vorarlberger Energienetze GmbH
Duration:	March 2010 – June 2013

Summary: The Großes Walsertal biosphere park is a typical alpine region. Energy consumption is high in winter as a result of tourism, and surplus energy is produced in summer. Distributed generation units cause problems with grid voltage stability in summer. No new power plants were able to be integrated into the grid, despite expansion potential for small hydropower stations with approximately 10 MW.

This field trial centred on the economical integration of small distributed hydropower plants in the 30 kV medium-voltage grid. The voltage control concepts developed in the DG DemoNet and BAVIS projects were implemented in real applications in the form of test platforms and validated in a field test.

Sixteen meter points were installed at critical nodes distributed throughout the grid. These meter points continuously transmit their data to a control centre. At the Nenzing substation, an optimised target voltage value is used to respond to discrepancies at the meter points (remote control). In addition, generators are actively involved in operating the distribution grid by adjusting reactive power to manage voltage, which is referred to as coordinated voltage management. The economic conditions of all stakeholders are taken into account.

Smart Grid Model Region Carinthia	
Project:	ProAktivNetz – predictive and automated active distribution network management integration with distributed generators (FFG No. 838639)
Model region:	Carinthia
Lead partner in the research consortium:	KELAG-Kärnten Netz GmbH
Project partners:	AIT Austrian Institute of Technology, Siemens AG Österreich, UBIMET GmbH, Vienna University of Technology
Duration:	January 2013 – December 2014

Summary: ProAktivNetz studied how the integration of renewable energy sources can be optimised under all conditions that arise in real grid operation (such as maintenance work or any incidents that occur).

The power supplied by renewable distributed generation depends directly on local weather conditions (wind, sunlight, and amount of water available). The distribution grid operator must know the expected power to be supplied and connect the grid at the right time to deliver a guaranteed voltage quality to grid customers at all times and to be able to operate the distribution grid within its limits at all times. The project is also developing and testing an algorithm that is optimised for active distribution grid management and accounts for current and forecast behaviour of distributed generation units based primarily on renewable energy.This is the first time that the connections and interactions between individual influencing factors are being analysed in detail and approaches to solutions are being developed to enable automated planning for up to 48 hours in advance. The optimal operating procedures are calculated using timetables of distributed generation units, connections due to maintenance work, and any incidents in the distribution grid.

ProAktivNetz lays the foundation for operating future active distribution grids with an optimal timetable that reconfigures the connection status of the grid, taking the expected load and generation situation into account.

Smart Grids Model Region Styria	
Project:	hybrid-VPP4DSO – active management of consumers and renewable generation in the distribution grid (FFG No. 843923)
Model region:	South Styria and Bela Krajina (Slovenia)
Lead partner in the research consortium:	AIT Austrian Institute of Technology GmbH
Project partners:	cyberGRID GmbH, Vienna University of Technology – Institute of Energy Systems and Electric Drives, Energetic Solutions, Grazer Energieagentur GmbH, Elektro Ljubljana, Stromnetz Steiermark, Steweag Steg GmbH, Elektro energija d.o.o.
Duration:	April 2014 – September 2016

Summary: A cross-border virtual power plant (VPP) that combines grid-driven and market-driven approaches is currently being established in Styria and Slovenia. The aim is to ensure safe and secure operation of the distribution grid with intensive demand-response activities and to make technical demand-response solutions for distribution grid operation more economically efficient.

The project covers the simulation-based validation of grid impact, technical and economic simulation of demand-response aggregation, and simulation of appropriate business models during the operation of a virtual power plant.

Each grid section is categorised in real time from non-critical to highly critical, and the grid operator can request hybrid VPPs to switch loads on or off. Hybrid VPPs can then use this information to calculate possible connection options based on short-notice grid operation and electricity trade requirements and calculate the least expensive option.

Once technical proof of concept has been established in the laboratory, the goal is to test the concept in real grid sections in Slovenia and Styria.

Smart District Gnigl Salzburg	
Project:	Smart District Gnigl – from the vision Smart City Salzburg to a showcase (FFG No. 836092)
Model region:	Gnigl, City of Salzburg (S)
Lead partner in the research consortium:	City of Salzburg 6/01 Structural Engineering – Energy Management
Project partners:	Salzburg AG, Salzburg Institute of Regional Planning and Housing (SIR), AIT Austrian Institute of Technology, Schleicher Architekten, Komobile Gmunden GmbH, pro 21 GmbH
Duration:	June 2012 – December 2014

Summary: The Smart District Gnigl project, which focuses on energy, architecture, and mobility, was launched based on the Smart City Master Plan of the City of Salzburg. The new education campus, which includes a preschool, an elementary school, a clubhouse, and an urban residential building, makes up the core of the smart district. Some 100 preschoolers and 450 elementary school students will attend facilities there.

A new carbon-neutral building was built in the centre of the Gnigl education campus. Renovation plans are being developed for the surrounding existing buildings. The project aims to define target building standards and develop a smart energy supply concept that uses potential from waste heat. Findings from practical experience gained during the Smart District Gnigl project will then be used in the development of other CO_2-neutral districts.

Smart Village Regau	
Project:	Smart Village Regau (FFG No. 846138)
Model region:	Regau, Vöcklabruck district (OÖ)
Lead partner in the research consortium:	Riedenhof GmbH
Project partners:	Energie AG Oberösterreich, Energy Institute at Johannes Kepler University Linz, Doma Elektro Engineering GmbH, s_arquitex Schreder & Partner ZT GmbH, Loxone Electronics GmbH, Planungsbüro Heinz Koberger.
Duration:	August 2014 – July 2017

Summary: Smart Village Regau is a smart village structure in which energy produced on site can be stored and used for a planned multi-storey residential building and town houses. The project is a representative example of new residential settlements in suburban residential and metropolitan areas.

The project features an expandable living lab in a housing development, which is home to some 170 residents. The lab is used for live testing of innovative energy supply systems and home automation services and for testing and adapting their technological, energy, and socio-technical aspects.

The demonstration project focuses on real-world testing and demonstration of different energy supply units, such as fuel cells and Stirling engines. The objective is to compare innovative solutions to conventional supply solutions, such as photovoltaics, solar thermal, heat pumps, and condensing gas boilers with optional use of biogas within the test bed. The living lab includes a visual component: visible and accessible energy technology centres. A home automation concept that is tailored to user needs is being installed and evaluted in apartments in order to improve user friendliness. Main aims of the project also include developments such as an energy cloud and smart meter interface.

The demo project also involves testing smart tariff systems for electricity purchase.

Smart Cities Demo Aspern	
Project:	Smart Cities Demo Aspern – ICT integration for smart buildings and smart grids involving social and municipality aspects in Aspern (FFG No. 846141)
Model region:	Aspern (W)
Lead partner in the research consortium:	Forschungsgesellschaft Aspern Smart City Research GmbH & Co KG (ASCR)
Project partners:	Siemens AG Österreich, Wien Energie GmbH, Wiener Netze GmbH, Chief Executive Office/ Director General of Urban Planning, Development and Construction, AIT Austrian Institute of Technology, Moosmoar Energies OG, Technisches Büro Käferhaus GmbH, SERA energy & resources e.U.
Duration:	April 2014 – March 2017

Summary: Seestadt Aspern – Vienna's Urban Lakeside – is one of Europe's largest urban development projects and is home to one of Austria's largest smart city projects: Smart City Demo Aspern.
A test area for energy-efficient urban living is being built on three construction sites. Participating buildings include the education campus of the real estate company Bundesimmobiliengesellschaft (BIG), the student residence of the Union of Private Employees (GPA), and a residential complex owned by the public property developer EBG.
The project aims to demonstrate how buildings can produce the electricity they need, make it available to the low-voltage grid for stabilisation, or sell it on the electricity market for a profit (buildings as providers of flexibility).
A building energy management system (BEMS) serves as the interface between the buildings and the electricity market. The BEMS creates timetables at regular intervals, which forecast a building's electricity consumption and calculates potential flexibility that can be offered on the electricity market. An energy pool manager queries the available electricity and sells it on the electricity market, for example.
Smart meters are used to record electricity consumption. Sensors record additional data such as room temperature and indoor air quality. This information is

used to identify different lifestyle types related to energy use (energy types). The goal is for customised information and incentive systems to improve consumption over the long term. Dynamic tariff models are one example of a tool that could be used to accomplish this.

Smart City Rheintal	
Project:	Smart City Rheintal (FFG No. 836088)
Model region:	Rheintal (V)
Lead partner in the research consortium:	Vorarlberger Kraftwerke AG
Project partners:	AIT Austrian Institute of Technology, Bosch Software Innovations, IBM Austria GmbH, City of Feldkirch, Seequartiererrichtungs GmbH, Prisma Zentrum für Standort und Regionalentwicklung, I-R Schertler Alge GmbH, Betrieb Kultur Kongress Freizeit GmbH,
Duration:	July 2012 – June 2015

Summary: Smart City Rheintal aims to create four zero-emission districts along the Rhine Valley rail corridor for Bregenz, Hard, and Feldkirch.

A new district with multilayer functionalities is being built near Bregenz main station. The highlight is a new multi-storey passive timber-construction building, the Life Cycle Tower, which uses special heat pumps and water from Lake Constance to supply heating and cooling energy. The goal is to generate at least 2 MW.

In Hard, the project is revitalising a former industrial zone, and in Feldkirch, a high-efficiency zero-emissions conference centre is being built according to a green meeting concept.

Project partner Bosch Software Innovations is leading the development of a virtual power plant for monitoring and managing distributed energy generation and demand. The primary tasks of the virtual power plant are to monitor electricity generated by PV plants, manage load for the electric vehicle charging infrastructure, and manage in-home consumers in the four zero-emissions areas of the Smart City Rheintal regions.

Smart City Villach	
Project:	Realising Villach's Smart City Vision – Step I (FFG No. 836083)
Model region:	Villach (K): Villach technology park and district of Auen
Lead partner in the research consortium:	Town of Villach
Project partners:	AIT Austrian Institute of Technology, ALPINE-ENERGIE Österreich GmbH, CTR Carinthian Tech Research AG, FH Kärnten, Ressourcen Management Agentur, Infineon Technologies Austria AG, KELAG Netz GmbH, PwC Corporate Finance Beratung GmbH, Siemens AG Österreich, Symvaro GmbH
Duration:	September 2012 – August 2015

Summary: Smart City Villach serves as a testbed for innovative and renewable technologies developed at the technology location of Villach.

Coordinated measures are being implemented at two sites. Innovative energy storage concepts are being developed and tested at the experimental testbed at Villach technology park. The power grid in Villach's Auen district, which comprises some 1,300 households and makes up the DEMO site testbed, is being equipped as a smart grid.

Smart meters and smart transformers are being installed in the low-voltage network, which will serve as the basis for increasing self-sufficiency with distributed renewable energy and for reducing the grid load. An online "energy genie" platform provides residents of the DEMO site easy-to-understand customised information and energy-saving tips on the internet and via smartphone. Households in the SMART Mieter Villach living lab can also evaluate their own energy consumption behaviour with the help of experts.

Innovative business models give residents the option of participating in renewable energy projects in the city and helping implement the smart city vision.

Smart City Future Graz	
Project:	Smart City Project Graz Mitte (FFG No. 836094)
Model region:	Waagner Biro grounds between Waagner-Biro-Straße and Peter-Tunner-Straße, Graz (ST)
Lead partner in the research consortium:	Executive Board for Urban Planning, Development, and Construction of the City of Graz
Project partners:	Energie Steiermark AG, Holding Graz – Kommunale Dienstleistungen GmbH, DI Markus Pernthaler Architekt ZT GmbH, Forschungszentrum für integrales Bauwesen AG (FIBAG), SFL technologies, AVL List GmbH, Alfen Consult GmbH, Energie Graz, SOT Süd-Ost-Teurhand GmbH, The City of Zagreb, Wissenschaftsstadt Darmstadt, Labor Stadt Graz, Graz University of Technology
Duration:	July 2012 – June 2016

Summary: A former industrial site on Waagner-Biro-Straße west of Graz main station is undergoing smart redevelopment. The Smart City Project – Graz in Styria's capital city bundles together four main priorities: an innovative photovoltaic technology (dye-sensitised solar cells), a smart local energy grid for heating and cooling energy, a mobility concept for reducing private motor transport, and the involvement and informing of residents. Implementation is covered by PPP agreements between the City of Graz and owners and investors.

The technological and research core of the project is the Science Tower, which is being built by FIBAG and SFL Technologies. The 60 metre tower is being built north of Helmut-List-Halle and will not only house research projects; the tower itself will also serve as a research subject for new smart building technology. Once successfully tested in the tower, building technology will then be used in other buildings in the district. Plans call for the energy generation for heating and cooling the building to be 100% carbon-neutral.

Project:	ECR Energy City Graz Reininghaus (FFG No. 832742)
Model region:	Reininghaus grounds on Peter-Rossegger-Straße
Lead partner in the research consortium:	Graz University of Technology, Institute of Urbanism
Project partners:	Executive Board for Urban Planning, Development, and Construction of the City of Graz, Province of Styria, Graz University of Technology (Institute of Thermal Engineering, Institute of Electrical Power Systems, Institute of Technology and Testing of Building Materials), Aktiv Klimahaus GmbH, WEGRAZ GmbH, AEE Intec, Nussmüller Architekten ZT GmbH
Duration:	October 2009 – December 2014
Final report:	*http://www.hausderzukunft.at/results.html/id5854*

Summary: The main focus of this project is connecting energy-plus buildings, which generate more energy than they consume and which supply their surplus energy to the community grid. The Energy City Graz-Reinighaus framework plan studied energy consumption, supply, and distribution; building services engineering; and urban planning aspects (such as geothermal, optimal structural orientation, solar activation of roofs and façades, process heat use, co-generation plants, etc.).

Twelve individual residential buildings with 143 units in all and a net floor space of 9,955 m^2 were combined into a multi-purpose building association. The energy-plus approach is based on different measures. Energy use was optimised at each of the buildings individually (using geothermal energy piles and photovoltaics), and synergies were created between the residential buildings and the office complex. The energy control centres of each of the residential buildings were connected, and an energy association was created for the office and commercial buildings in order to offset generation and consumption peaks.

Smart Urban Region Weiz-Gleisdorf	
Project:	iENERGY Weiz-Gleisdorf 2.0 (FFG No. 836099)
Model region:	Weiz, Gleisdorf (ST)
Lead partner in the research consortium:	Energie Steiermark AG
Project partners:	EU LEADER Energieregion Weiz-Gleisdorf GmbH, Graz University of Technology, Weizer Energie Innovations Zentrum GmbH, Joanneum Research Forschungs-gesellschaft mbH, BM Leitner, Planung & Bauaufsicht GmbH, LIM Projektentwicklungs GmbH
Duration:	June 2012 – May 2015

Summary: The Weiz-Gleisdorf region, which includes the cities of Weiz and Gleisdorf, is located 20 km to the east of Graz and struggles with the typical challenges of growing suburban regions: rising energy consumption, urban sprawl, high cost of infrastructure and public services, and a high percentage of commuters.

Using the Weiz-Gleisdorf 2050 energy vision as a basis, smart user-centric overall solutions are being develop-ed for four different target groups (business and services, industry, private users, and public orga-nisations) along with the relevant stakeholders. If met with the necessary acceptance, these solutions will then be implemented.

At the project level, this integrative planning ap-proach is being implemented through four demo projects, each with the goal of generating 100% of its energy from renewables: Innovationszentrum W.E.I.Z. IV, ELIN Motoren, smart-x development, and renovation of the Gleisdorf retirement home.

In addition, regional subprojects are also being designed (public vision monitors, a regional energy fund, applications for visualising the energy future), and connected electromobility activities are being carried out.

Smart City Hartberg	
Project:	Città Slow Hartberg demonstrates Smart City (FFG No. 836093)
Model region:	Hartberg (ST)
Lead partner in the research consortium:	City of Hartberg
Project partners:	4ward Energy Research GmbH, Interuniversity Research Centre for Tehcnology, Labour and Cul-ture (IFZ), Stadtwerke Hartberg Verwaltungs GmbH, Ökopark Errichtungsgesellschaft mbH, KELAM Wärme GmbH, HSI Hartberg Standortentwicklung und Immobilien GmbH, B.I.M – Beratung und Informationsver-arbeitung im Mobilitätsbereich, DICUBE Media GmbH, Projekt Alleegasse GmbH & Co KG, Eaton Industries (Austria) GmbH
Duration:	September 2012 – August 2015

Summary: With approximately 11,000 residents, a compact space, a historic city centre, and commercial real estate at the edge of the city, Hartberg, which is located in Styria, is typical of many small Austrian towns. The main objective is to demonstrate a smart district in Hartberg's city centre, in the historic core zone.

A PPP model was developed to revitalise a model building complex. The municipality makes electric carsharing and real-time traffic information available to residents. A new business model was developed to expand a smart biomass-based district heating system. The Hartberg city utility is building a carport solution with an integrated photovoltaic station for charging electric vehicles.

Project:	Hybrid Grids Demo Hartberg – demonstration of a smart connection between urban electricity, natural gas, and district heating grids and functional electricity storage (FFG No. 846142)
Lead partner in the research consortium:	Forschung Burgenland GmbH
Project partners:	Stadtwerke Hartberg VerwaltungsgesmbH, General Electric Austria GmbH, Technisches Büro Ing. Bernhard Hammer GmbH, 4ward Energy Research GmbH.
Duration:	December 2014 – November 2017

Summary: The town's energy system is being transformed into a working energy storage system. The top-priority goals are to develop an innovative, area-wide, and integrated energy sponge system for electricity, heating, and cooling and their grids and to test system operation. The aim is to optimise energy flows in real time across grids and energy sources.

The project centres around a new technical approach, in which a central optimiser is being implemented in the existing control infrastructure and which makes recommendations to distributed stakeholders (producers and consumers) and obtains information from this infrastructure. The result is passive instead of active intervention in sensitive grid control. The distributed stakeholders also receive a financial incentive signal and can decide manually or automatically whether or not to to follow the recommendation or take the incentive.

Smart City Leoben	
Project:	STELA: Smart Tower Enhancement Leoben Austria (FFG No. 841239)
Model region:	Leoben-Judendorf (ST)
Lead partner in the research consortium:	City of Leoben
Project partners:	Energie Steiermark, Gangoly & Kristiner Architekten ZT-GmbH, IBO Austrian Institute for Healthy and Ecological Building, Graz University of Technology (Institute for Building Theory, Institute for Structural Design), Montanuniversität Leoben, neukühn OG, Norbert Rabl ZT-GmbH, Sammer & Partner ZT-GmbH, VATTER & Partner ZT-GmbH, Energie Steiermark Mobilitäts GmbH
Duration:	March 2014 – March 2017

Summary: The Sonneninsel Leoben project shows how municipality-owned multi-storey residential buildings dating from the 1980s in the Leoben-Judendorf district can undergo a comprehensive thermal renovation and improve quality of life. The decision to renovate is by choice. Residents of Salzlände and Pebalstraße will decide for themselves whether and which building will be updated. They will be involved in the planned renovation process from the beginning.

The building will be given a thermal buffer zone, which will also serve as an extended living area. The new façade will include hybrid modules that generate electricity using photovoltaics. Integrated solar thermal components will cool the photovoltaics as needed to increase their efficiency, which will also keep the buffer area from overheating. Excess heat will be diverted using geothermal probes. Geothermal energy helps will temper the new building shell in the winter.

The mobility concept involves converting the ground floor area into an E-LOBBY carsharing mobility centre, and public and/or commercial use will also be made possible. A coordinated energy supply concept is being created in conjunction with the façade components and the electric vehicles parked in the building, which provide a way to store energy.

Smart Community Großschönau	
Project:	GAVE – Großschönau as virtual energy storage (FFG No. 825396)
Model region:	Großschönau (NÖ)
Lead partner in the research consortium:	Sonnenplatz Großschönau GmbH
Project partners:	AIT Austrian Institute of Technology, Vienna University of Technology
Duration:	June 2010 – May 2012

Summary: This project in Großschönau studied whether and how a municipality can combine commercial, private, and public consumers with smart load management to create a flexible consumer, thereby helping reduce peak electricity demand.

During a field trial, real load shifting potential was determined by an automated load management system, and experience was gained with user convenience and acceptance. Fifteen relevant properties with consumer-side load-shifting potential were identified. Heat pumps were used as household loads that could be shifted. In the public sphere, pumps used for local heating, drinking water pumps, and air-conditioning and ventilation systems in public buildings were identified.

Load-shifting potential was also identified at the local wastewater treatment plant, which contains a sewage sludge pump, blower system, and sewage sludge drying system, as well as in select energy consumption processes of industrial plants located in Großschönau.

7.5. Overview of international platforms

EU Strategic Energy Technology Plan (SET-Plan):
http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm
The SET-Plan is Europe's energy technology policy. The strategic plan aims to speed up the development and introduction of cost-effective technologies with low CO_2 emissions. It calls for measures in planning, execution, resources, and international collaboration in the field of energy technologies.

ERA NET Smart Grids plus:
www.eranet-smartgridsplus.eu
ERA-Net Smart Grids Plus is an initiative of 21 countries in Europe. It aims to promote technologies, market designs, and customer acceptance to help design a power grid with a high security of supply and low greenhouse gas emissions.

- Support transnational co-operation projects with partner countries in the EU
- Develop an international knowledge community consisting of projects and external stakeholders
- Integral component of the SET-Plan initiative

European Electricity Grid Initiative – EEGI Label:
www.gridplus.eu/eegi/eegi-project-labelling-started
The industry initiative published a research and innovation roadmap for the period to 2022 and a smart grid implementation plan for the period to 2016. The goal of the EEGI and the European Commission was, and remains, to bring together national projects relevant for Europe as a whole and evaluate whether the individual solutions are transferable and scalable.

- Twenty-six projects have been given the EEGI label (as of the end of 2013)
- The Salzburg smart grid model region earned the core label
- DG DemoNet Smart LV Grid and DG DemoNet validation earned the support level
- Other recognised projects in which Austria is involved: EcoGrid4EU, iGREENGrid, PlanGridEV, and Cotevos

IEA Technology Roadmaps:
www.iea.org/roadmaps/

IEA International Smart Grid Action Network (ISGAN)
www.iea-isgan.org/
The network's aims include an exchange of technological expertise among international experts and the identification of best-practice examples and recommendations for policy-makers. For example, a discussion paper on transmission and distribution interaction was published as part of Annex 6 (Power Transmission and Distribution) in Autumn 2014.

7. EU research framework programme:
http://cordis.europa.eu/fp7/

Horizon 2020:
http://ec.europa.eu/programmes/horizon2020/en

- Smart grids have moved from DG Research to DG Energy (in Horizon 2020)
- Tenders in 2014 focused on the distribution grid, and tenders in 2015 focus on the transmission grid.

EU Smart Grids Task Force:
http://ec.europa.eu/energy/gas_electricity/smartgrids/taskforce_en.htm
The European Commission introduced the Smart Grids Task Force in late 2009. The task force has developed political and regulatory guidelines for the introduction of smart grids over the past two years. It also made recommendations on standardisation and on consumer data privacy and security.

Based on this, the Commission adopted a communication on smart grids in 2011, which tasks European standardisation organisations with developing standards for smart grids and creates a directory of relevant projects and findings obtained in the EU. The Commission also adopted a communication on the introduction of smart meters and published guidelines for conducting cost-benefit analyses for smart grid projects in 2012.

Expert Groups:

- EG1: Reference Group for Smart Grid Standards
- EG2. Expert Group for Regulatory Recommendations for Privacy, Data Protection and Cyber-security in the Smart Grid Environment
- EG3. Expert Group for Regulatory Recommendations for Smart Grids Deployment
- EG4. Expert Group for Smart Grid Infrastructure Deployment

European Energy Research Alliance:
www.eera-set.eu/

ETP Smart Grids:
www.smartgrids.eu/

ENTSO-E Research & Development Roadmap 2013–2022
The R&D Roadmap includes the active distribution grid, as joint TSO/DSO activities, as one of its first milestones, on which other milestones build. In light of this, there seem to be conflicting ideas about a realistic timeline for the milestones. For this reason, clarification with the Smart Grid 2.0 process is needed.

CEER
http://www.ceer.eu/
The Council of European Energy Regulators (CEER) is the voice of European national regulators of electricity and natural gas. One of the organisation's key objectives is to facilitate the creation of a single, competitive, efficient, and sustainable EU internal energy market that works in the public interest.

EURELECTRIC
www.eurelectric.org/
The Union of the Electricity Industry (EURELECTRIC) is the sector association which represents the common interests of the electricity industry at the pan-European level. EURELECTRIC currently has 30 full members representing 32 European countries.
Its three main objectives are:

- Delivering carbon-neural electricity in Europe by 2050
- Ensuring a cost-efficient, reliable supply through an integrated market
- Developing energy efficiency to mitigate climate change

E-Energy funding programme of the German Federal Ministry for Economic Affairs and Energy (BMWi):
www.e-energy.de/
"E-Energy: ICT-based energy system of the future" is a new funding priority of the Federal Ministry for Economic Affairs and Energy (BMWi) initiated as part of the German federal government's technology policy. Six model projects were chosen in an E-Energy technology competition. All of the projects take an integrated system approach that includes all economic activities related to energy at the market level and at the technical operational level. The selected model regions were to develop their promising proposals to make them market-ready and test their marketability in everyday applications by 2012.

7.6. Standardisation in the smart grid

7.6.1. Overview of current international standardisation work

7.6.1.1. Interactive IEC Smart Grid Standards Mapping Tool

Current standards need to be defined and implemented for different complex components and functionalities to interact within smart grids.

The International Electrotechnical Commission (IEC, *www.iec.ch*) created a graphical, interactive overview organised by subject area and published it on its interactive web site. Information can now be obtained about specific individual standards that need to be followed and about the development status of these standards.

The different subject areas include:

- Energy generation
- Voltage and frequency control
- Energy distribution and energy consumption
- Metering and communication technology
- Building automation
- Interdisciplinary areas (telecommunications, security, EMC, and power quality)

7.6.1.2. Smart Grid Standardisation Documentation Map

The extensive STARGRID Smart Grid Standardisation Documentation Map delivers detailed documentation for international standardisation work relevant to smart grids.

It contains information on the individual activities of all of the important European, American, and international standardisation organisations. The document was first published on 28 June 2013 and is updated as needed. The latest version is published on the STARGRID web site (see Standards Hub for Smart Grids Industries *http://stargrid.eu/*).

STARGRID had announced that a standardisation document analysis would be published in Spring 2014, but the publication is not yet available at the time of writing (see *http://stargrid.eu/* > Publications).

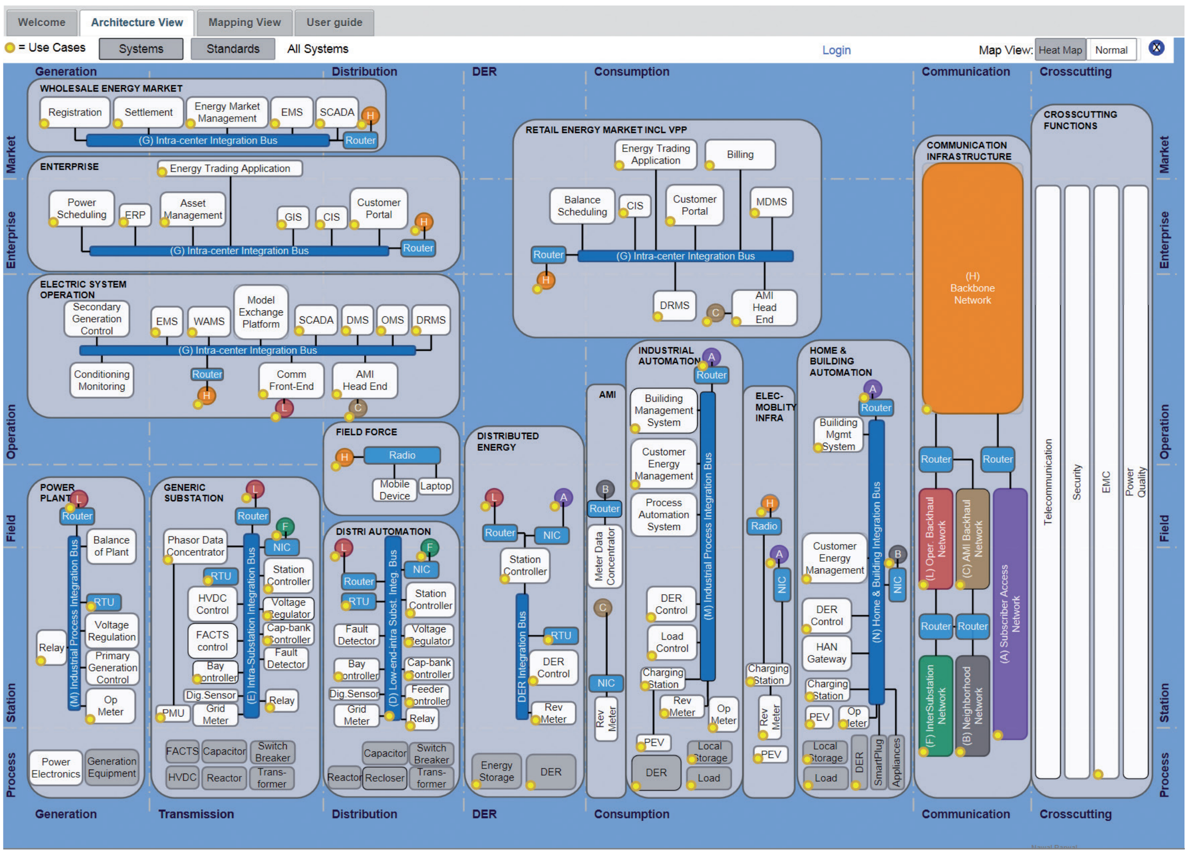

Figure 31

IEC Smart Grid Standards Mapping Tool, Architecture View

(interactive version at *http://smartgrid-standardsmap.com/* > Architecture View)

7.6.2. Overview of Austrian standardisation work

The results of our research are listed in Table 11, which indicates Austrian organisations and the relevant international organisation.

7.6.3. Opportunity to collaborate on standardisation and contact data

Active collaboration on standardisation processes in electrical engineering, information technology, and communications technology for smart grids is organised by the bodies of the Austrian Electrotechnical Committee (OEK) of the Austrian Electrotechnical Association (OVE).

The following technical committees (TCs) and associated subcommittees are involved:

E – Electrical low-voltage systems

- EMV – Electromagnetic compatibility
- IS – Wiring and switching devices
- IT-EG – Information technology, telecommunications and electronics
- MR – Metering and control technology
- TM – Traction and motor functions

Concerned or interested standardisation experts can participate in committee work (no membership or meeting fees) after attending a one-day workshop (fee required).

Contact information for the Austrian Electrotechnical Association and Austrian Electrotechnical Committee is available at:
www.ove.at

Contact information for Austrian Standards Institute (ASI) is available at:
www.austrian-standards.at

Body	Name	Austrian counterpart
IEC SMB/SG3	Standardization Management Board/Sector Group 3 – Smart Grid	OEK-AK AG Smart Grid
IEC TC 8	Systems aspects for electrical energy supply	TSK EMV01
CLC TC 8X/WG 5	Systems aspects for electrical energy supply/Smart grid requirements	TSK EMV01
IEC/CLC TC 13	Electrical energy measurement, tariff- and load control	TSK MR13
IEC/CLC TC 57	Power systems management and associated information exchange	TSK MR57
IEC PC 118	Smart grid user interface	TK MR
ISO / IEC JTC 1	Information Technology	ASI K-001
CLC TC 205	Home and Building Electronic Systems (HBES)	TSK IT-EG 2x5
CLC SC 205A	Mains communicating systems	TSK EMV01
CLC TC 210	Electromagnetic Compatibility (EMC)	TK EMV
CISPR S	International special committee on radio interference/Steering Committee	
ITU-T	ITU Telecommunication Standardization Sector	
IEEE	Institute of Electrical and Electronics Engineers	IEEE EMC Austria Chapter
ETSI	European Telecommunications Standards Institute	TSK IT-EG ETS
CEN-CENELEC-ETSI SGCG	Smart Grid Coordination Group	OEK-AK AG Smart Grid

Table 11
Standardisation bodies and their counterparts in Austria

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8.1. Acronyms and abbreviations

AIT	Austrian Institute of Technology
BFI	Berufsförderungsinstitut vocational training institute
bmvit	Federal Ministry for Transport, Innovation and Technology
CEM	Customer Energy Management
DER	Distributed energy resource
DR	Demand response
DSM	Demand side management
DW, DWH	Data warehouse
GDP	Gross domestic product
GIS	Geographic information system
HR	Human resources
ICT	Information and communication technologies
IP/MPLS	Internet Protocol Multiprotocol Label Switching
KLIEN	Climate and Energy Fund
LV	Low voltage
MV	Medium voltage
MVA	Mega-volt ampere, apparent power
ÖVE	Austrian Electrotechnical Association
P2G	Power to gas
P2H	Power to heat
P-HIL	Power hardware in the loop
PLC	Power line communication
PQ monitoring	Power quality monitoring (voltage quality)
PROSUMER	Consumer that also produces electricity itself (-> producer)
PV	Photovoltaics
RE	Renewable energy
SG	Smart grids
SGAM	Smart Grids Architecture Model
SM	Smart meter
TSO	Transmission system operator
VPP	Virtual power plant
WIFI	Institutes for Economic Promotion

SMARTGRIDS AUSTRIA

8.2. Glossary

Data warehouse	Database in which data from different sources is displayed in a single format
IP/MPLS	Connection-oriented transmission of data packets in a connectionless network along a path signalled in advance
Power hardware in the loop	Method for testing complex, embedded real-time systems
Prosumer	A consumer that also produces electricity
State estimation	Estimate of the real, current grid state
Volt/Var-Control	Voltage control using reactive power management

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