Case study report Austria

Findings from case studies of Model Village Köstendorf, HiT Housing Project and VLOTTE

Version 1.0

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CONTENTS

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About ERA-Net Smart Grids Plus

ERA-Net Smart Grids Plus is an initiative of 21 European countries and regions. The vision for Smart Grids in Europe is to create an electric power system that integrates renewable energies and enables flexible consumer and production technologies. This can help to shape an electricity grid with a high security of supply, coupled with low greenhouse gas emissions, at an affordable price. Our aim is to support the development of the technologies, market designs and customer adoptions that are necessary to reach this goal. The initiative is providing a hub for the collaboration of European member-states. It supports the coordination of funding partners, enabling joint funding of RDD projects. Beyond that ERA-Net SG+ builds up a knowledge community, involving key demo projects and experts from all over Europe, to organise the learning between projects and programs from the local level up to the European level.

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Preface

This report is the outcome of work package 2 *Detailed case studies* of the ERA-Net Smart Grids Plus project *Markets, Actors and Technologies: A comparative study of smart grid solutions* (MATCH), which involves partners from Austria, Norway and Denmark.

The aim of MATCH is to explore how to design and implement comprehensive smart grid solutions that take into account the complexity of factors influencing the effectiveness and success of smart grid initiatives targeted at small consumers. This is studied on basis of detailed national case studies carried out in each of the three participating countries. This report (MATCH deliverable D2.1) presents the main findings from the Austrian case studies.

The national case studies establish the empirical foundation for the comparative analysis across cases and countries in work package 3 *Identifying determining factors for integrated and successful smart grid solutions* and for the later work package 5 *Recommendations for designers, planners and policy-makers*. The deliverables from these work packages will be published on the website of MATCH (http://www.match-project.eu/), which also includes further information about the project and its other publications. The latter includes coming scientific papers that are going to explore differences and similarities between cases in further detail in relation to specific research questions.

The empirical work in relation to the national case studies was guided by an analytical framework developed in the MATCH work package 1 *Design of overall analytical framework for case studies*. This deliverable (D1) can be downloaded from the MATCH website. The framework combined different theoretical perspectives in order to establish a shared understanding of how we should approach the cases and what kind of data to collect. This ensured a certain degree of empirical homogeneity between the national case studies.

In order to support the comparative analysis, the national case study reports (D2.1-D2.3) follow the same outline. Thus, in the following, we will first present the national context of the Austrian case studies (Chapter 1). This includes a brief introduction to the national profile of Austria in addition to a presentation of the Austrian energy system, policies & regulation, market structure & energy consumption and, finally, the smart grid landscape. Then follows the main part of the report (Chapter 2), which presents the outcome of the Austrian case studies. A brief description of the empirical work carried out introduces this chapter, and is followed by three sub-sections presenting the findings from the three national cases: Model Village Köstendorf (section 2.1), HiT Housing Project (section 2.2) and VLOTTE (section 2.3). Each of these case presentations is organised in three sub-sections: Background and project characteristics; Socio-technical configurations; Discussion of successes and outcomes.

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Vienna, 17th of November 2017

1 National Case Study Context: Austria

1.1 Country Profile of Austria

The Republic of Austria has a population of 8.77 million and an area of 83.879 km^2. It borders on Germany and the Czech Republic to the north, Switzerland and Liechtenstein to the west, Italy and Slovenia to the south, and Hungary and Slovakia to the east. Almost two-thirds of Austria's territory is mountainous with the Alps reaching its highest point with 3.798 m over sea level. The east of the country has lower lying plains of the Danube valley. 45 % of Austria is covered by forests (IEA 2014). Moreover, arable land amounts to around 16.1 % of the Austrian territory (Statistik Austria 2017).

Two climate regions are found in Austria. The eastern part shows hereby a Pannonian climate that is typical for Central Europe and consists of warm summers and cold winters. The west in the central Alpine region shows a typical alpine weather with more precipitation in summer and heavy snowfall during long winters (Ministry of Foreign Affairs 2017). Due to the topography, the temperature range is immense: highest measured temperature for 2016 are with 36.0 °C in Krems in July and lowest measured temperature was obtained with -28.2 °C in Tyrol in 3.437 m altitude and with -23.4 °C (1.442 m) in an inhabited area in Vorarlberg. Daylight ranges from 8.5 hours in winter up to 16 hours during summer (ZAMG 2017).

Austria's population is rising in the last decades up to 8.77 million inhabitants in January 2017. Of these inhabitants were 1.3 million without Austrian citizenship. While the strong population growth amid the 20th century resulted from baby boom, the latest increase in population is mainly due to immigration since the fall of the Iron Curtain around 1990. However, the birth surplus over deaths remains slightly positive. While all federal *Länder* experience population increase, those with larger cities (Vienna, Graz, Linz, Salzburg, and Bregenz) experienced a steeper increase than the others, again, due to net migration (Statistik Austria 2017).

In 2016, the average Austrian household consists of 2.22 persons and witnesses a trend to smaller households with single households having a share of 16.6 % of the population, while the majority (61 %) still resides in family households. In rented dwellings live 42 % of households. Ownership of these rented out dwellings was 18 % communal flats, 39 % were let by co-operatives and non-profit organizations, and the rest by private owners. Less than half of all Austrian households own the dwelling they live in (Statistik Austria 2017).

According to Esping-Andersen (1990), the Austrian welfare system can be classified as following the conservative-corporatist model. The system of social security in the Austrian welfare state consists of central elements such as the social insurance benefit issued by the federal government, while regional entities such as the Länder, and local municipalities organize healthcare, housing and most of the social services such as childcare (Social Affairs Ministry 2016).

In the Federal Republic of Austria, the nine *Bundesländer* (provinces) play an important role in designing and implementing energy policy. Their governments have responsibility for policy making, setting subsidy levels and implementing regulatory control of energy companies. Central to the Austrian opinion-forming and law-making processes are the "social partners" from labor and employer side. The labor stakeholders are the Austrian Chamber of Labour and the Austrian Trade Union Federation, while the employer stakeholders are represented through the Economic Chamber, the Chamber of Agriculture, and the Austrian Federation of Industry (IEA 2014, Social Affairs Ministry 2016). As in any EU member state, Austria's energy policy is heavily influenced by EU regulations. Crucial and important EU legislation on energy issues are the Energy and Climate package, with its 20-20-20 goals, and the Third Package for the Internal Energy market. Further central EU-directives are on energy services and end-use efficiency, on the energy performance of buildings, on the ecodesign of energy-related products, and on the regulation on security of natural gas supply. These directives found their way into Austrian law as, the Climate Protection Law (2011), the Buildings Initiative (2010), the Electricity Act (2010), and the Gas Act (2011) (IEA 2014, Austrian Environmental Agency 2016).

Austria has an open and relatively robust economy. Its gross domestic product (GDP) grew by 1.6 % in 2015 and by 2.3 % in 2016 in nominal terms, reaching EUR 350 billion in 2016. GDP per person is relatively high, at EUR 39.970 in 2016. The unemployment rate according to the ILO concept at 6 % in 2016, has been the highest for Austria since 1995. As in all developed economies, services are the largest sector, accounting for 70.4 % of GDP in 2016. Industry accounted for 28.3 % and the primary sector (agriculture, forestry and mining) for 1.3 %. In industry, the largest subsectors by turnover are machinery, basic metals, foodstuffs and chemicals (IEA 2014, Statistik Austria 2017).

1.2 The Austrian Energy System

The Austrian power transmission network (Figure 1) has a grid-length over 6.970 km and is composed of the three different voltage levels 110 kV, 220 kV, and 380 kV. Hereby, the extra high voltage level (380 kV) is used as a standard for transporting high transmission load over long distances. Transformation of high to lower voltage levels to supply households happens in over 58 switching stations with close proximity to residential and industrial areas. The high-power grid covers all of Austria and is divided into two operating regions North & West and South & East (APG 2017).

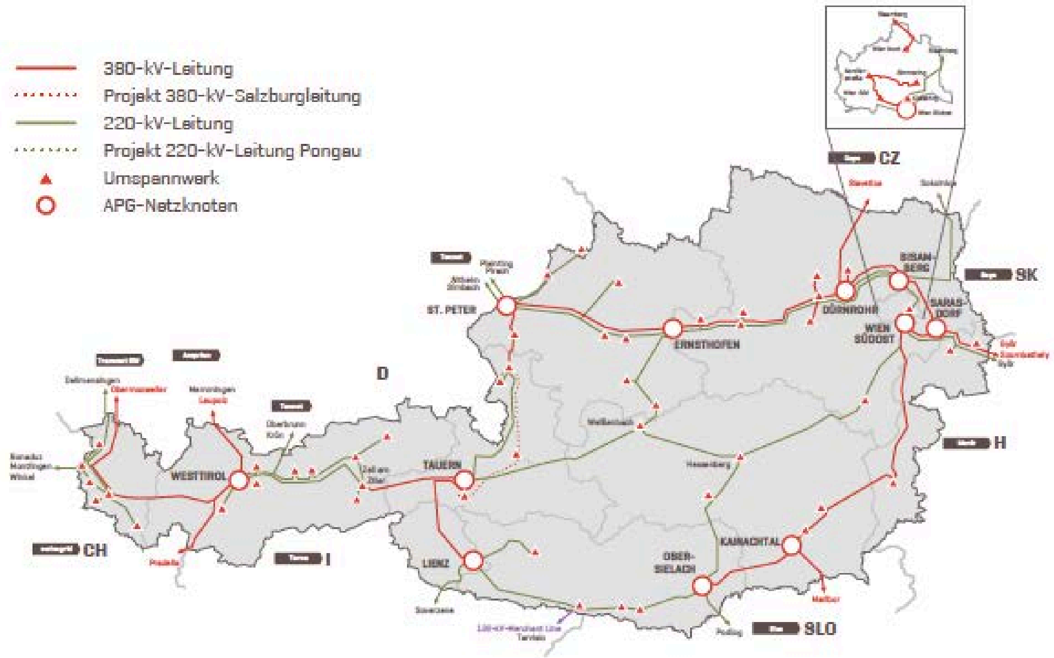

Figure 1: Austrian electricity grid of 380kV (red) and 220kV (green) (E-Control retrieved 22 June 2017)

Austria, through its central continental position, is deeply integrated in the emerging European electricity grids with AC interconnection to the Czech Republic, Hungary, Italy, Slovenia, and Switzerland. Congestion management is necessary between all these countries. This is organized through implicit auctions according to the European day ahead market couplings in the Austria-Italy border and through explicit auctions for the other border grids. Slovakia is the only neighboring country without any direct grid connection to Austria. Now, Germany and Austria form one price zone and both enjoy grid connections that do not require congestion management as capacity is sufficient (E-Control 2016b). However, congestion management of 4.900 MWh will be re-introduced that will likely lead to a small increase in Austrian electricity prices, but will be gradually increased to 7.000 MWh. Further, Austrian thermal power plants will provide from autumn 2017 onwards 1 GW of production capacity to German TSOs (E-Control 2017, Bundesnetzagentur 2017, WKO 2017). Thus, while the re-introduction of congestion management is a step back for market integration, the announced measurements between Germany and Austria can be judged as small dents in the process to full integration.

Austria is part of the Central Eastern Europe (CEE) region with Czech Republic, Germany, Hungary, Slovakia and Slovenia where Austria's energy regulator (E-Control) assumes the role of lead regulator. Further, Austria participates as an observer country in the Central Southern Europe (CSE) region with France, Germany, Italy Greece, and Slovenia where day-ahead market coupling was introduced at almost all Italian borders in 2015. Through its current strong interconnection with the German market through the single price zone Austria is also linked through the Central Western Europe (CWE) region of Belgium, France, Luxembourg, and the Netherlands (E-Control 2017).

According to the World Economic Forum, Austria has a very high energy security and is accredited with having a quite reliable electric system (WEF 2014) (WEF retrieved 2017-june-22). Outages and disturbances in the Austrian grid remain minimal. In 2015, the Austrian grid had an average outage for every customer served (SAIDI) of 42.31 minutes, which shows high reliability (E-Control 2016a).

By 2014, renewable energy (wind power, biomass and renewable waste, solar power, and hydro power) had a share of 82 % of the Austrian electricity while other waste incineration made 1 % and fossil fuels 17 %. Figure 2 shows how the distribution of the electricity production by energy sources developed from 1994 to 2014. This development shows the historic importance of hydro power for the Austrian electricity production and the slight increase of biomass use and wind power while decreasing use of solid fuels such as coal and of gas.

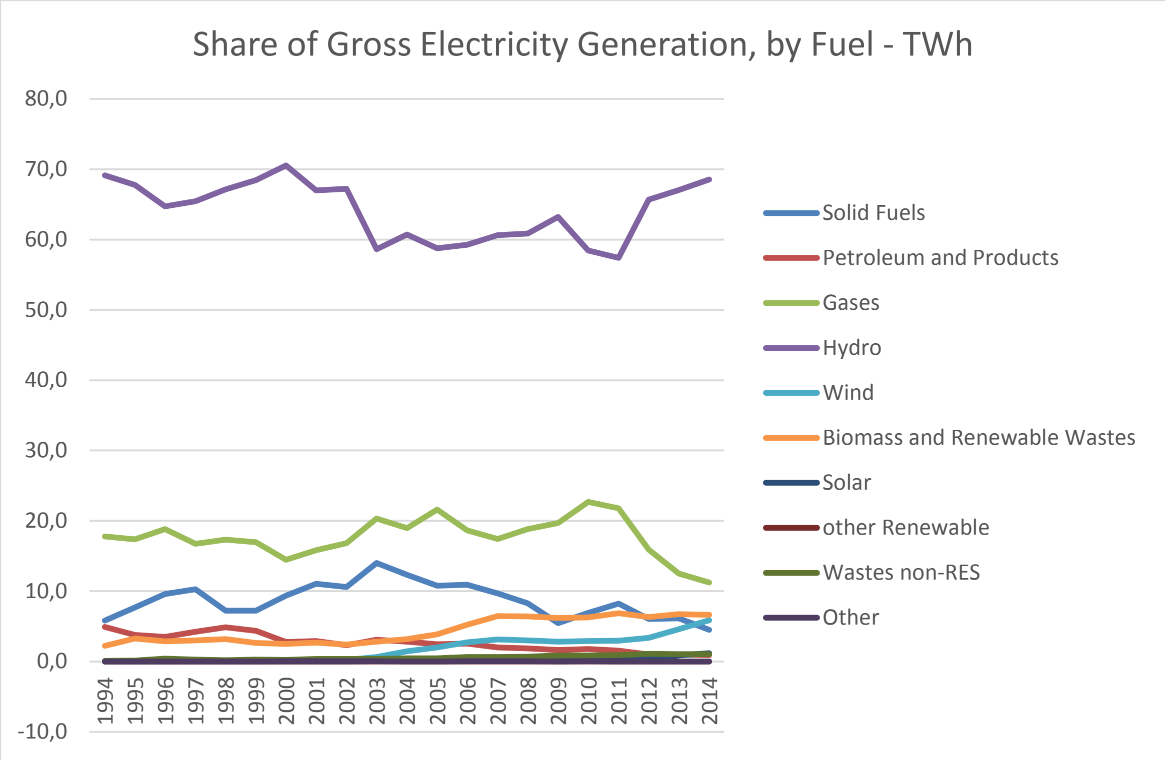

Figure 2: Share of gross electricity generation in Austria (Source: EU Commission, DG ENERGY, Unit A4)

The strong share of hydro power for Austrian electricity generation must be taken with care since hydro power in pumped hydro energy storage (PHES) facilities includes partially hidden non-renewable sources in energy accounting. Electricity imports from nuclear and fossil fuels heavy energy mixes (e.g. Germany) will end up being transformed into renewable hydro power. However, since 2015 according to the Austrian regulatory agency, energy of unknown origin (grey energy) is impossible to deliver anymore and subsequently no nuclear energy was permissioned to enter the system (E-Control 2017).

In 2016, around 62 % of households have central and floor heating. The second largest share with around 28 % received district heating as main form of heating. Other forms of heating such as electric heating (4 %) play a minor role for Austrian households. Regarding the source of heat generation, the largest share in 2014 has with 36 PJ renewable energies, which entail almost exclusively the use of biomass. While firewood consumption has remained relatively constant since the 1980s modern biofuels (wood chips, sawmill by-products, pellets, etc.) experienced a steep increase especially in the last ten years. The second largest source of heat generation are gases with 31 PJ in 2014 (Figure 3). The most important driver of the increase in natural gas consumption is the industrial sector. On average, industrial energy consumption rose by 2 % per year between 1995 and 2014 (BMWFW 2016b).

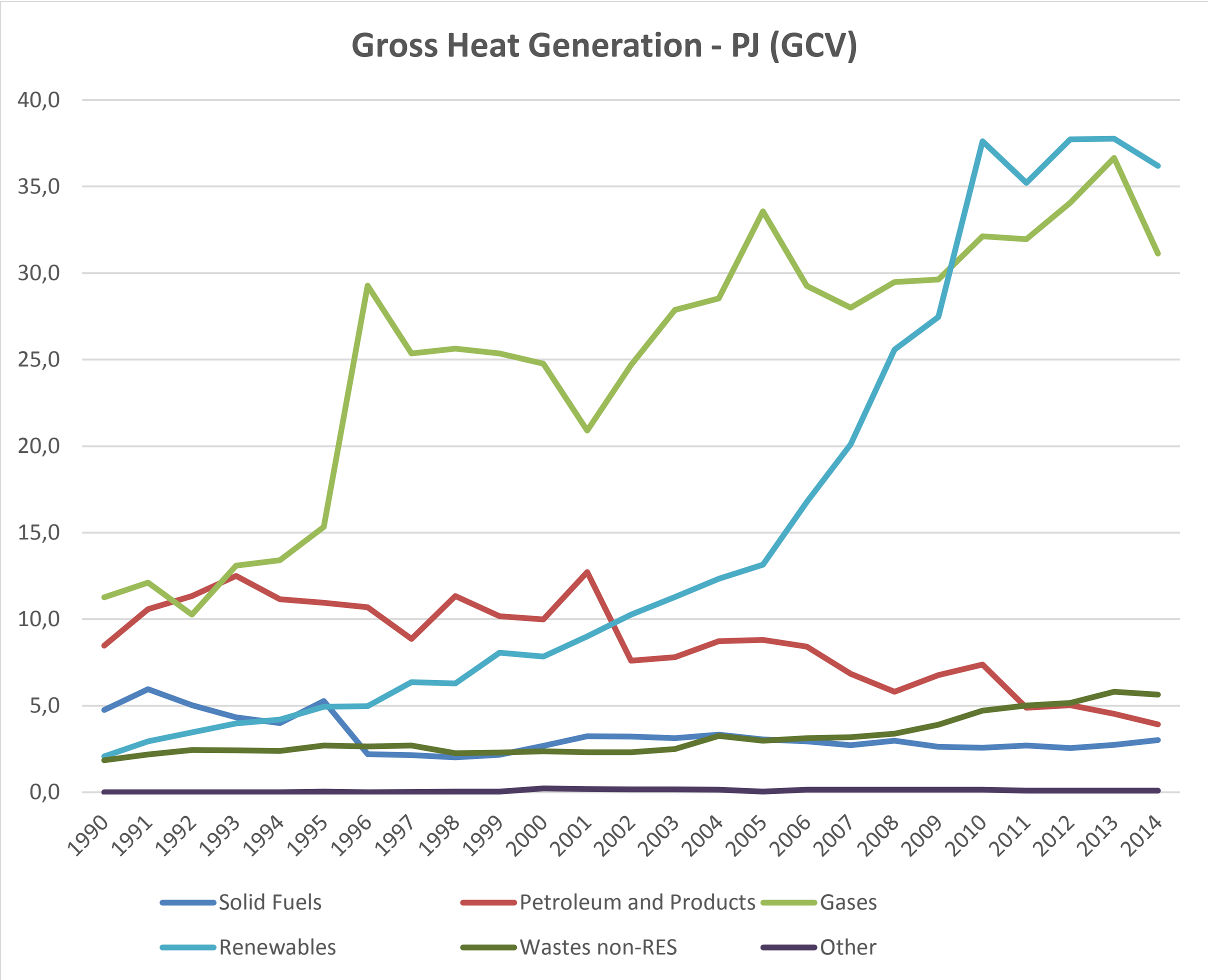

Figure 3: Gross heat generation in Austria (Source: EU Commission, DG ENERGY, Unit A4)

In 2016, with newly registered 3.826 battery electric vehicles (BEV) and 1.237 plug-in hybrid vehicles (PHEV) Austria saw a stark increase in the use of personal electric vehicles and had the highest share of newly registered vehicles in the European Union (VCO 2017). The overall market penetration in 2016 had a share of 1.54 % (EAFO 2017). Within Austria, the *Bundesland* of Vorarlberg, which is in the west next to neighboring Liechtenstein, Switzerland, and Germany, showed the highest share of newly registered electric vehicles. This was also achieved through incentives to municipalities to procure electric vehicles (VCO 2017).

Austria's overall gross energy consumption is significantly higher than its production as Figure 4 illustrates. Thus, Austria is highly import dependent. The largest share of import stems from different forms of fossil fuels such as coal, gas, and petroleum products (Figure 5). These products are alien to Austria (Figures 5 and 6), but nonetheless essential for its current functioning as an import dependency of around 100 % for hard coal, 92 % for petroleum, and 97 % for gases shows (DG Energy 2017). However, the last coal fire plant is announced to be shut down in 2025 (Environment Agency Austria 2016).

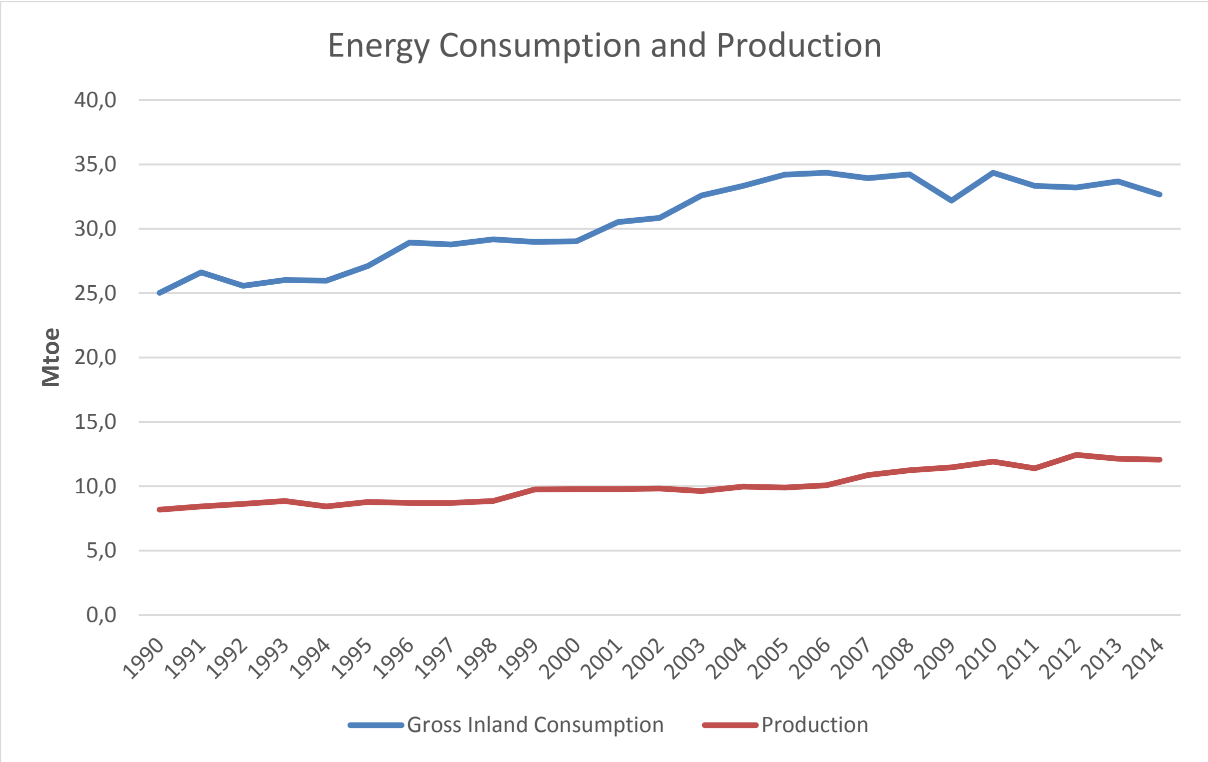

Figure 4: Energy consumption and production in Austria (Source: EU Commission, DG ENERGY, Unit A4)

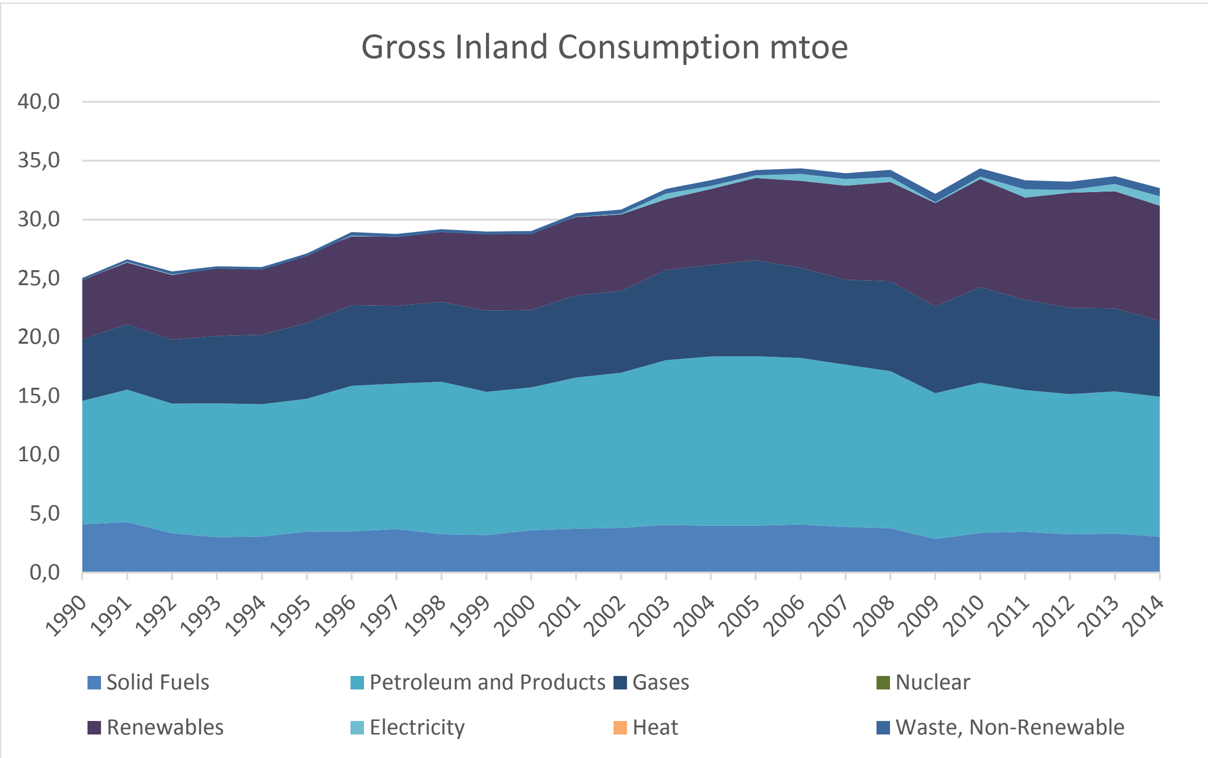

Figure 5: Gross inland consumption in Austria (Source: EU Commission, DG ENERGY, Unit A4

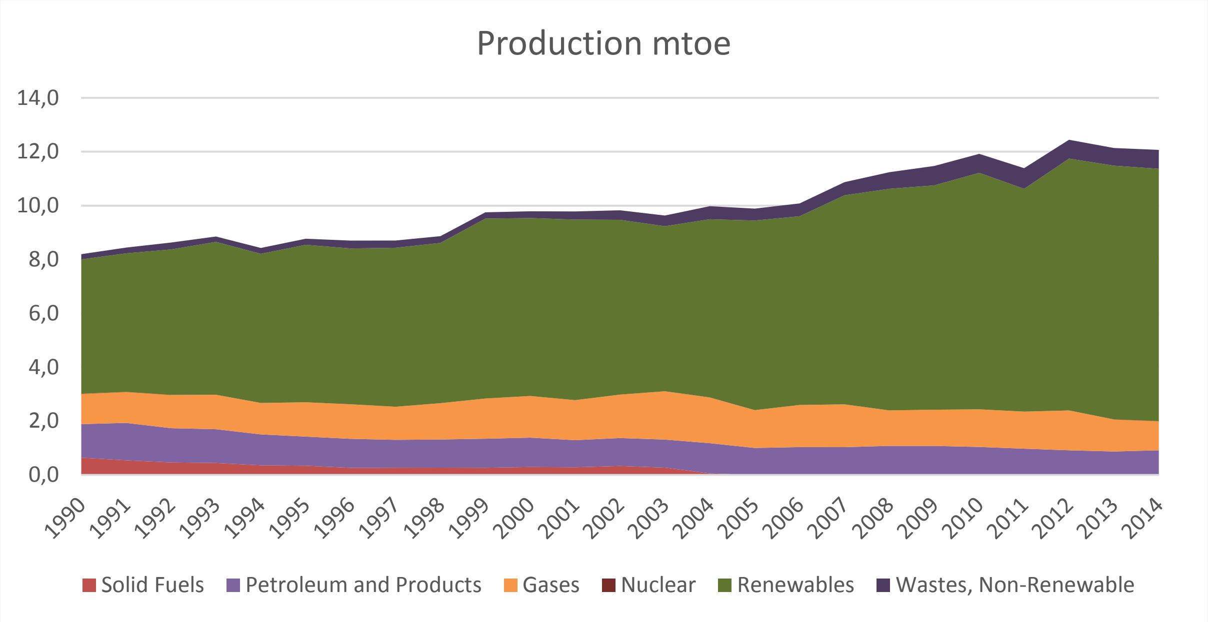

Figure 6: Inland production in Austria (Source: EU Commission, DG ENERGY, Unit A4)

The production and consumption of the renewable energy hydro power and biomass and renewable waste has always been considerable large, and saw a slight increase over the years (Figure 7). Renewables such as solar and wind power saw a dramatic increase particularly in the last 15 years, while their overall importance to the energy systems remains currently low.

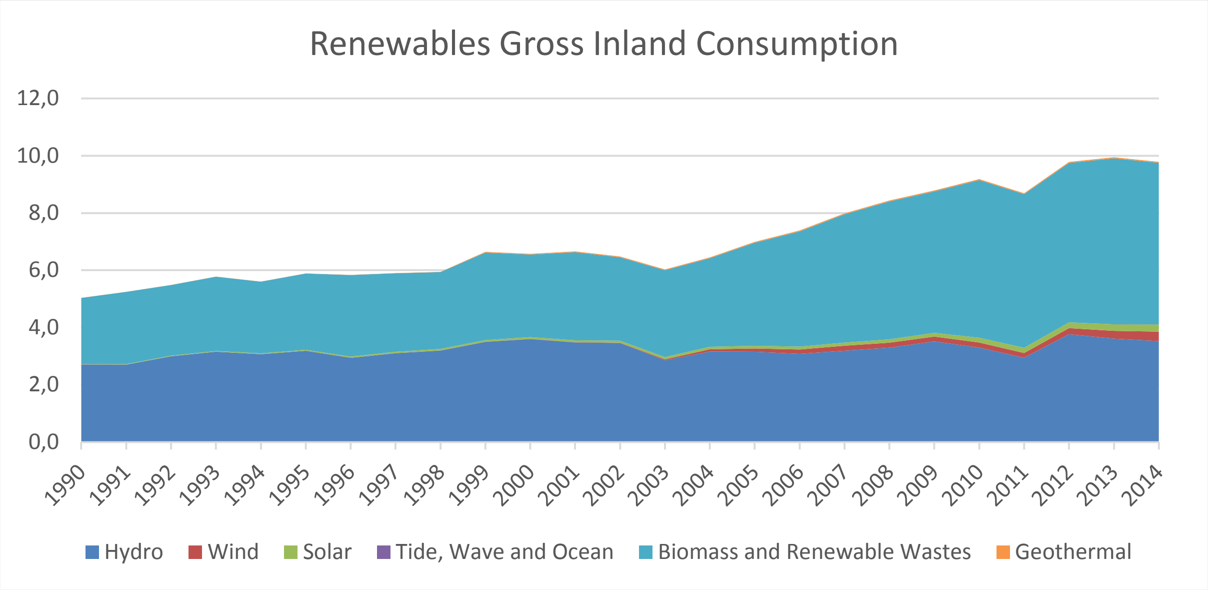

Figure 7: Renewables gross inland consumption in Austria (Source: EU Commission, DG ENERGY, Unit A4

In 2013, the Austrian production based CO_2 emissions per capita were 7.4 tons/year and range in the middle of Norway (11.7 tons/year) and Denmark (6.7 tons/year). Biggest contributors are the sectors energy, industry, transportation, agriculture, and buildings (BMWFW 2016).

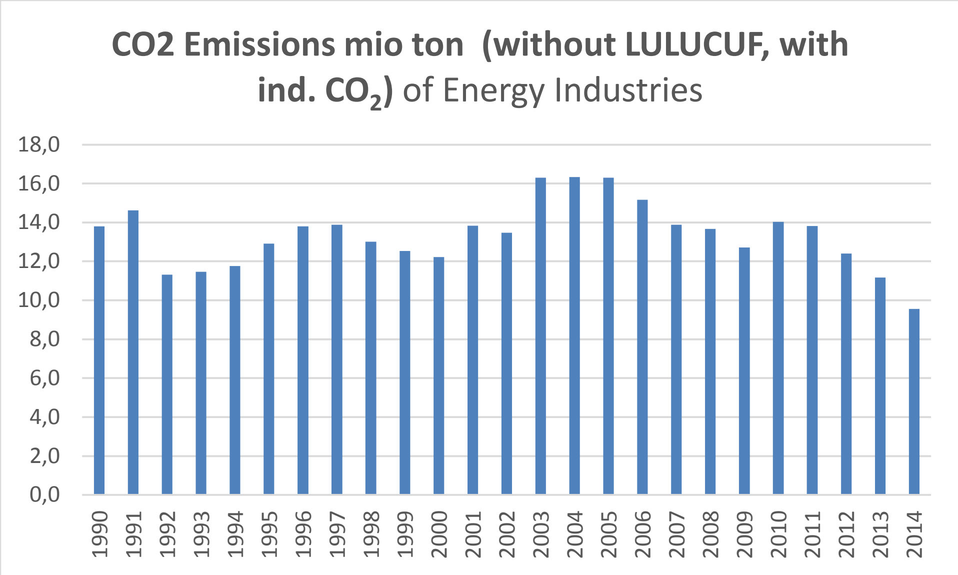

Figure 8: CO2 emissions of energy industries in Austria (Source: EU Commission, DG ENERGY, Unit A4

CO_2 emissions of the Austrian energy industry saw a slow but steady decline since 2005 from 16.3 million tons to 9.6 million tons in 2014 with a clear dent in the trend during the financial crisis (Figure 8). This trend can be explained with the continuous substitution of coal with natural gas and fossil fuels with renewable forms of energy (BMWFW 2016).

According to the *Climate Change Performance Index 2017*, prepared by the German NGO *Germanwatch* and the European *Climate Action Network Europe*, which is an index that evaluates and compares the climate protection performance of countries, Austria ranks as number 41, in comparison to Denmark 13 and Norway 38 (Germanwatch 2016).

1.3 Policy and Regulation of the Energy Market

Austria's long term energy policy goal is to solely rely on renewable energies by 2050. The Austrian energy strategy that was established in 2009 based on EU's 2020 process and submitted to the Commission in 2010 rests on three substantial pillars: security of supply, energy efficiency and renewable energy resources (IEA 2014, BMWFW 2010). Energy efficiency includes a fixed target of 1.100 PJ of final energy consumption in 2020 – this target corresponds approximately to the value of the base year 2005 (BMWFW 2010) with a cumulative energy efficiency goal of 200 PJ since 2005. From 2014 to 2020 energy producers must show energy efficiency measurements of 0.6 % per year of their production. In addition, according to the latest buildings directive[1], all new public owned or used buildings from 2018 and all newly constructed buildings from 2020 must be built as low-energy houses. Renewable energy resources include the increase of water power, wind power, biomass and -gas, and photovoltaic (Environment Agency Austria 2016).[2]

Based on the EU goal to substantially decarbonize the energy system by 2050 several steps are established to reach this goal through EU (targets for Austria: 36 % emissions reduction until 2030 to the base 2005[3]) and Austrian regulation.[4]

[1] Buildings Directive (RL 2010/31/EG).

[2] Green Electricity Acts 2012 (BGBl. I Nr. 75/2011).

[3] RL 2009/28/EG

The EU's Energy and Climate Package translates the European to Austrian targets with: a 34 % renewable energy target, an overall indicative 20 % energy efficiency, and a 20 % reduction of GHG emissions. According to the IEA, Austria is on track regarding the renewable energy target and shows significant progress regarding energy efficiency (IEA 2014). In its National Energy Efficiency Action Plan (NEEAP) Austria established even more ambitious renewable energy targets of 50 % renewable energy in 2020 (BMWFW 2017). Currently, quantitative (Table 1) and qualitative targets can be distinguished.

Table 1: Quantitative political goals for the transition of the Austrian energy system

100 % renewable energy in 2050	20 % reduction of GHG emissions (2020)
179.9 PJ electricity from renewables	396.5 PJ or 35.48% energy from renewable energy (2020)
143.4 PJ heating from renewables in 2020	district heating from renewables 38.2 PJ in 2020

Sources: (BMWFW 2010, Environment Agency Austria 2016)

Table 2: Qualitative political goals for the transition of the Austrian energy system

Goal	**Description**
Energy efficiency	This includes all stages of provision and use of energy such as building, mobility, implementation of energy management systems, and spatial planning.
Renewable energy	Hereby, the focus is on hydro power, wind power, biomass, and photovoltaic.
Security of supply	The security is aimed at the highest possible degree of cost effectiveness through district heating and cooling, new transmission networks, diversification of sources and routes, gas storage, smart grids, and smart metering.
Stabilizing the final energy consumption	The stabilizing will be achieved through the above mentioned fix target of 1.100 PJ final energy consumption in 2020.

Source: (BMWFW 2010)

In the current (July 2017) program of the Federal Government, four initiatives are explicitly mentioned that will change the energy sector:

[4] Austrian Climate Protection Law KSG BGBl. I. Nr. 106/2011

- The first small eco-electricity amendment (*kleine Ökostromnovelle*) simplifies the installation and using of PV-panels on multiple family dwellings and provides more governmental funding for small scale hydro plants.
- The larger eco-electricity amendment (*große Ökostromnovelle*) aims at extending the use of renewable energy sources through re-organization of the eco-electricity subsidies to achieve EU-climate and energy goals and establish 100% net-balance coverage of Austrian electricity in 2030. The planned measures follow a market liberalization logic and focus cost-efficient, competition based founding system such as transparent tender and auctioning of investment subsidies and premiums. To achieve affordable electricity, there will be a cost cap on eco-electricity subsidies.
- To avoid higher electricity prices through the separation of the Austrian-German price zone, Austria will actively advocate for continuing the current trade.
- The White Paper on energy and climate strategy aims to build the cornerstone for the new energy strategy and has economic growth and new employment opportunities as central goals. Hereby, it focuses on renewable energy, energy efficiency, infrastructure, as well as innovation and research of environmental and energy technologies. Building on intensive consultation processes that include the previous energy strategy that was also build on simulation runs, public consultations, and EU and national targets, the White Paper will establish the definitive climate and energy strategy of the Federal Government until 2030. (Federal Government of Austria 2016, 2017)

1.4 Market Structure and Energy Consumption

Prices at the Austrian spot market fluctuate. In rare cases of electricity excess they reach even negative prices. End user electricity prices for households are considerably larger than for companies with 0.2 €/kWh instead of 0.07 €/kWh in 2016 (Figure 9).

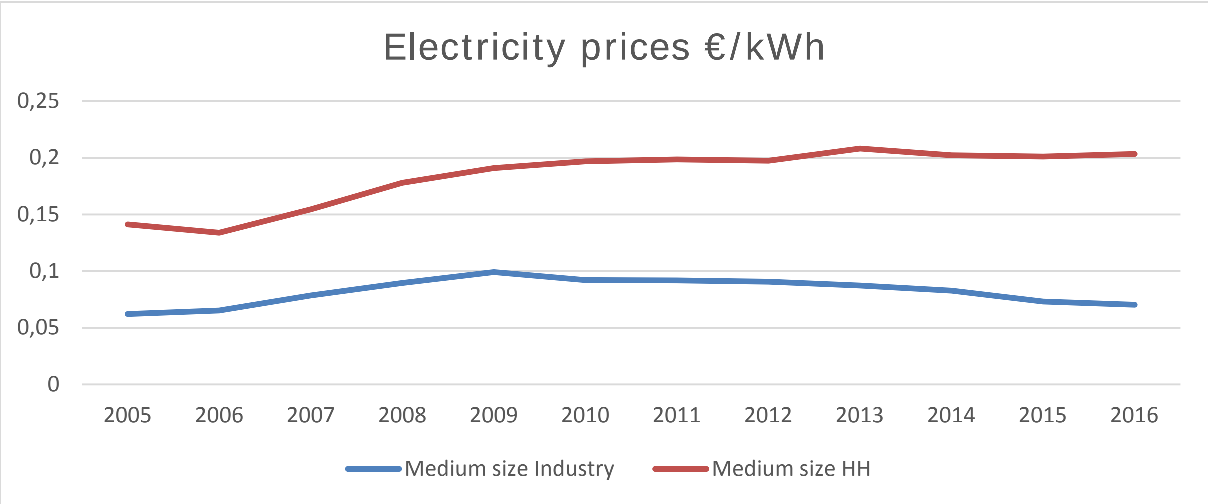

Figure 9: Electricity prices in Austria (Eurostat 2017)

The energy prices for medium size households[5] consists to 32.3 % of the actual energy prices, 40.1 % taxes and charges, and 27.7 % grid charges (Figure 10).

[5] 3500 kWh electricity/ year

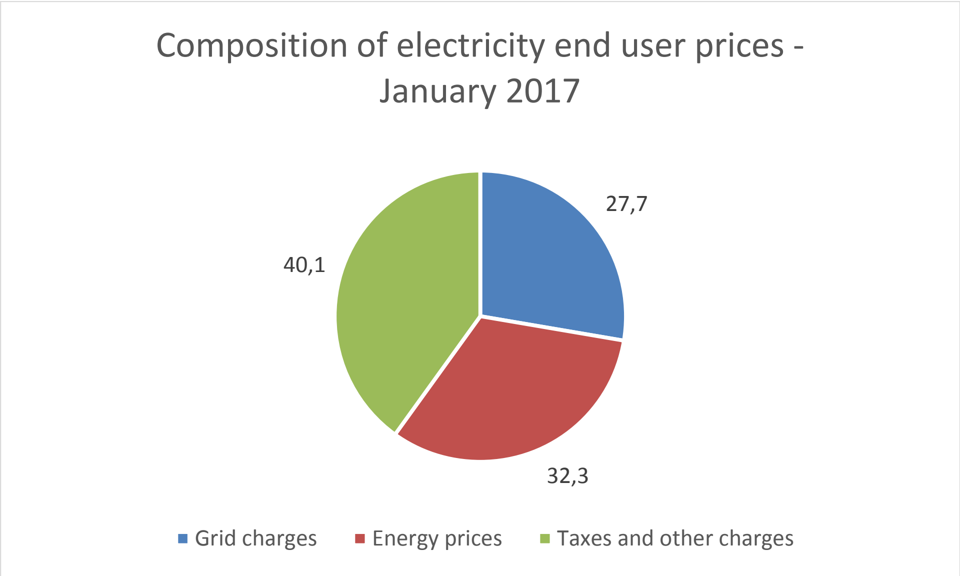

Figure 10: Composition of electricity end user prices in Austria (Source: E-control retrieved 2017-june-30)

Austria has implemented the Third Package for the Internal Energy Market to follow the EU-way to more market liberalization with specific legislation in 2010, which includes the creation of an independent energy regulator (E-Control). As mentioned above, the directives on electricity and gas markets have been implemented through the Elektrizitätswirtschafts- und Organisations-Gesetz 2010 (Electricity Act) and the Gaswirtschafts-Gesetz 2011 (Gas Act) (IEA 2014, Austrian Environmental Agency 2016).

In Austria, the one nation-wide *transmission system operator* (TSO) is the Austrian Power Grid (APG), which is an independent enterprise that belongs to VERBUND AG and was separated from it due to market liberalization of the third EU energy packet. VERBUND AG, in turn, is majorly owned by the Republic of Austria. APG regulates all of Austria except a small corridor in Vorarlberg, which is part of the German regulatory block (APG 2017).

In Austria, a variety of primary power producing companies is active. There are over 140 electricity producing companies in Austria, as well as over 30 gas providing companies: all with varying prices between companies and differing regional reach. Some provide power only in few municipalities or *Länder*, while others provide power across *Länder*-borders (E-Control 2017). The biggest 10 electricity producing companies, however, supply 70 % of all industrial customers and 80 % of all households (PWC 2016). The biggest electricity producer VERBUND AG provides 40 % of all Austrian electricity and is majorly owned by the Republic of Austria. The second biggest provider, Energie Allianz Austria GmbH, is an alliance of several other *Länder*-provider such as Wien Energie, EVN, and Burgenland AG (E-Control 2017).

The distribution system operators (DSOs) task of transporting electricity between producers and withdrawers, while maintaining network stability is currently undertaken by several different DSOs in Austria. In June 2017, 21 DSOs where registered in Austria that differ in size and shape. Many of these DSOs are owned by municipalities or as joint companies by a combination of Austrian *Bundesländer*, other Austrian energy providers and publicly owned bank and insurance groups. Further, they must meter consumption and attribute it to the balance groups and transmit consumption data to the clearing and settlement agent (a public company owned by the Austrian energy industry: APCS Power Clearing and Settlement AG) (E-Control 2017; APCS 2017).

Especially for new customers, those that switch suppliers, prices are considerably lower than for long-term customers. In 2016, the lowest price was 3 cent/kWh without any deductibles. In contrast, new customers had prices of 1.06 cent/kWh in their first year. This is clearly below the market price of 3.27 cent/kWh.[6]

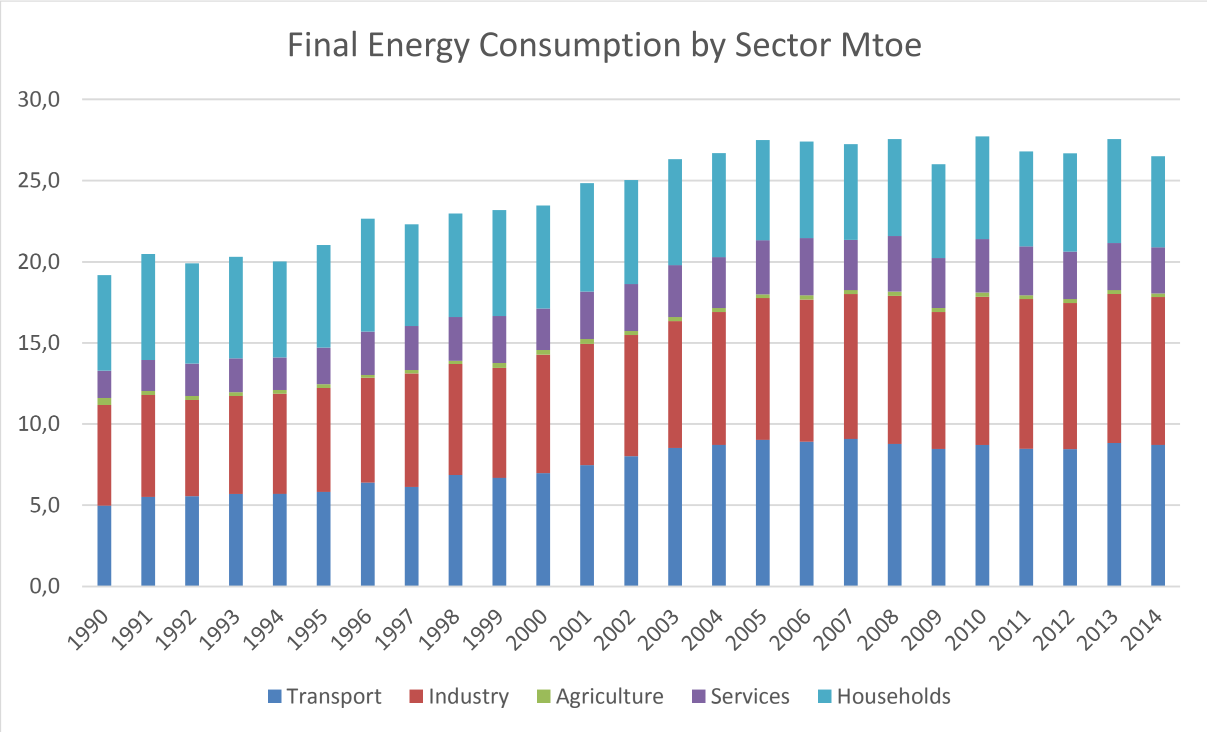

Figure 11: Final energy consumption by sector in Austria (Source: EU Commission, DG ENERGY, Unit A4)

Figure 11 shows the development in the Austrian final energy consumption from 1990-2014 (distributed by sectors). Overall, the energy consumption of the transport sectors has been steadily increasing, as well as for the industrial sector and services. Energy consumption by households, however, remains fairly constant over the time from 5.9 mtoe in 1990 to 5.6 mtoe in 2014.

1.5 The Smart Grid Landscape in Austria

There are a lot of smart grid activities in Austria, from governmental initiatives, subsidies and consultations, and conversely a strong push by ICT industry. Normalized per capita, Austria invests heavily in smart grids and is close to the investment per capita of Norway (Figure 12).

[6] December 2016 (EEX/EPEX spot market Year-ahead 80% Base/20% Peak, monthly average)

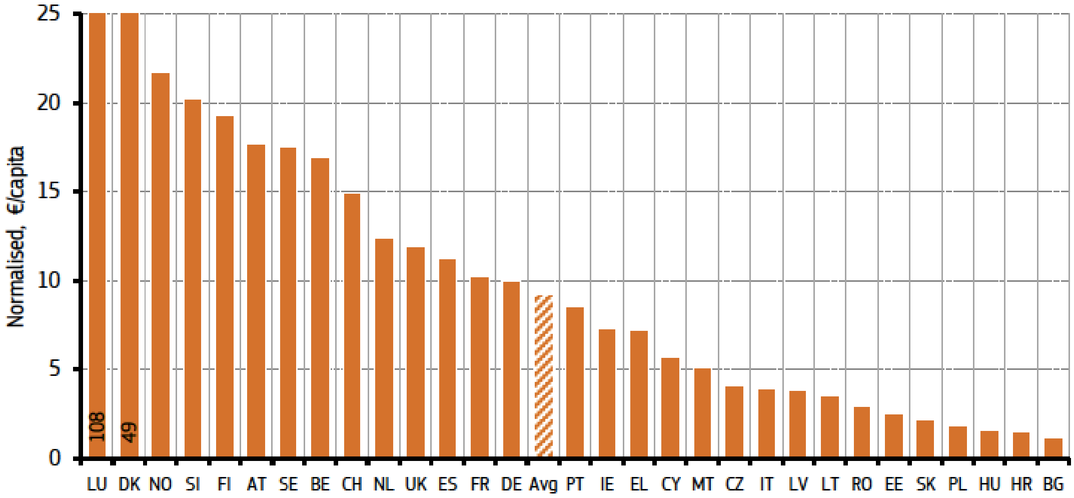

Figure 12 Total Investment in Smart Grids normalized per capita (Source: JRC 2017)

While Austria's capacity of large-scale storage through pumped hydro is considerably large due to mountainous areas of the alps, the maximum amount of storable electricity is 450 GWh (Environment Agency Austria 2016). Thus, large hydro pumped storage provides substantial storage capacity, but can and need to be expanded for about five times, if the entire electricity supply is to be provided from renewable sources (Maier 2013). Incentives to invest in these technologies, however, remain quite low, due to low electricity prices (Environment Agency Austria 2016).

Austria's governmental smart grid strategy, subsumed under "Strategy Process Smart Grids 2.0", currently attempts to establish a multi-facetted process that involves technology companies, utilities, and regulatory agencies (BMVIT 2016). Further, the process is accompanied by several scientific programs to assess and assist the development of R&D projects and accompanying regulation. Central elements are the following:

- Decentralizing and participation through an interactive energy system that allows for citizen engagement.
- Achieve equal distribution of cost and benefits of smart energy solutions.
- Create economic opportunities from existing flexibility options for dynamic energy systems.
- Enable the use of data created through smart services by use of data processing.
- Security of supply, resilience, and data privacy protection have highest priority and must be central for designing smart grids.
- Strengthening Austrian engineering capacities.

Two recent strategies where hereby created, a long-term "strategic research agenda" to support the transition of the Austrian energy sector until 2050, and a second short-term strategy to accompany this process until 2020. The latter, first published in 2013 by Austria's Ministry for Transport, Innovation and Technology published a substantial technology roadmap on smart grids (BMVIT 2015), as part of this strategic process, in cooperation with the actors of Austrian ICT companies, energy agencies, universities, and industry organizations (BMVIT 2015). The key objectives of this strategy include: in addition to conventional grid extension, smart-grid solutions to enable decentral and regional matching of supply and demand. This is achieved through communicative connection between single components such as production facilitates, decentral energy storage, flexible consumers, and intelligent buildings. The plan is hereby to build an environment that allows Austria's ICT companies to increase competitive advantage and to establish their regulatory and technological standards. The technology roadmap has three short range targets until 2020:

- Finding scalable ICT solutions, based on the current system's ICT architecture.
- Validate projects that assess practicality of systemic grid solutions, which are applied to larger scale real-world cases.
- Developing a working market as a show-case for the leadership of Austrian technology companies.

(BMVIT 2017)

Austria's long term strategy consists of four central themes that will be initiated with different stakeholders of research institutes, companies and through participatory processes that involve a larger public (BMVIT 2017):

- Infrastructure development across different kind of energy sources and geographies.
- Governance of energy transition.
- Electricity system, heat- and cold supply, as well as ICT and storage technologies.
- Issues of energy efficiency that show relevancy for the grid and for developing new business models.

A third strategy is a large and substantial consultation process with different stakeholders in the Austrian public (BMVIT 2016).

Austria's industry is heavily pushing for initiating smart grid projects, lobbying for government support, and actively connecting companies from the ICT and traditional energy sectors. One incubator for these activities provides the smart grid platform. This platform aims at coordinating within industry and with national and supranational agencies to initiate pilot projects and to establish new industry standards. In Austria, the platform is also engaged in the pilot projects of model regions which include rural and urban projects (Figure 13).

The hereby created roadmap tries to connect these activities within a coherent process until 2020. In addition to the mentioned cornerstones of shared projects, model regions, etc., another focus is on cyber security of smart grids and their surrounding architecture (Smartgrid Austria 2017).

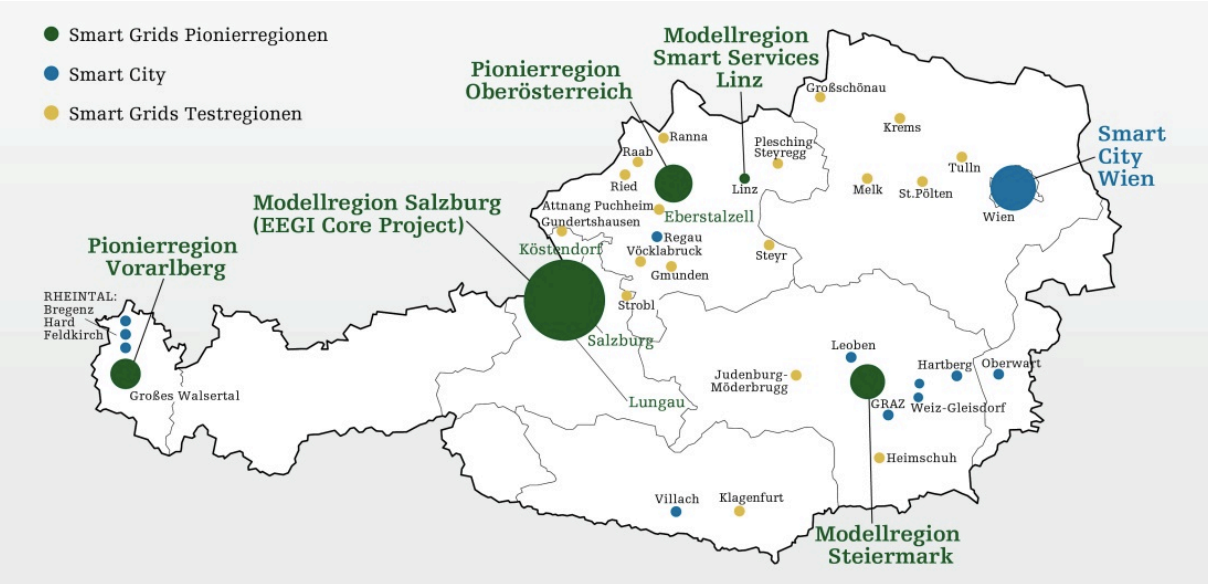

Figure 13: *Model Regions in Austria* (Smartgrid Austria 2017)

The Austrian demo-projects work next to the integration of smart grid systems in households on behavior and user acceptance of its inhabitants. This is attempted through interactive use-displays, and mobile devices that allow for more monitoring (even remotely) over energy consumption, humidity, and air quality in these homes (BMVIT 2015). Other pilot projects focus on identifying different user profiles regarding their energy consumption using smart meters and further sensors. With these information, tailored incentive systems to reduce energy use, while achieving satisfied users, are developed. This variety of approaches of the Austrian projects, which focus on both technical and non-technical aspects is further exemplified in the two case studies *Köstendorf* and *Rosa Zukunft*, which are located in the model region of Salzburg.

2 Austrian Case Studies

The selected Austrian cases represent three different aspects of a future smart energy system. The main focus of the first case – the model village Köstendorf – is to experiment with smart distribution networks involving private households with PV, EVs and stationary battery systems. The second case – called Rosa Zukunft – is located in an urban setting and it represents a comprehensive building-to-grid solution. The third case – called VLOTTE – focuses on e-mobility, distributed generation and load-management. The first two cases (Köstendorf and Rosa Zukunft), are located in the region of Salzburg and the third case (VLOTTE) is located in Vorarlberg, the most western region of Austria. In addition to their main thematic foci (see Table 3 below) all cases involve a number of additional aspects of smart energy solutions. They target small to medium consumers, run for several years and show a variety of 'working' solutions. Moreover, in all three cases local actors agreed to support the MATCH project. In the case model village Köstendorf the project MATCH cooperates with the on-going ERA-NET project ReFlex[7].

Table 3. Austrian cases in comparison

	Case 1	Case 2	Case 3
Name	Model village Köstendorf	Rosa Zukunft	VLOTTE
Main focus	Smart distribution grid field test	Building-to-grid solution DSM field test	E-mobility model region
Type of consumers	Households, SMEs, public buildings	Private households (apartments)	Own use (employees), private customers, SMEs
DSM	Demand response	Energy efficiency Demand response Dynamic demand	Demand response (load management)
Micro generation	Rooftop PV systems	Rooftop PV systems CHP unit (biogas)	Rooftop PV systems
Storage	Car batteries Stationary batteries	Large heat storage	Car batteries Stationary battery

Austria has a strong environmental technology sector and the selected cases must be viewed against this background. In the last 20 years innovation-specific funding for small and medium sized companies have played an important role in this field. In 2003, the Austrian government started to fund research in smart grid technologies with the program "Energy Systems of Tomorrow" that applied a broad approach with a focus on basic studies and concepts. The total funding sum was EUR 16 Mio. over a time of four

[7] In order to coordinate this cooperation occasional meetings were agreed. A first meeting took place in June 2016, a second meeting took place in October 2016.

years and different demonstration and pilot regions could be established (BMVIT 2017). In 2008, stakeholders from industry, research and public bodies founded a national technology platform for smart grids to represent interests and coordinate the activities in this field.

The first region in Austria that has been the focus of large-scale funding for smart grids research was the federal state of Salzburg. The Smart Grids Model Region Salzburg (SGMS) was an initiative launched by the Ministry for Transport, Innovation and Technology and is led by different stakeholders of the energy sector (Salzburg AG, Salzburg Netz GmbH), the housing industry (Salzburg Wohnbau), the industry (Siemens), consulting (Fichtner) and partners from research institutions (Austrian Institute of Technology, TU Wien, CURE).[8] Different funding programs helped to develop the region. Starting in 2008 with the program New Energies 2020 (Neue Energien 2020) of the Climate and Energy Fund. This program was followed by the program e!MISSION.at - Energy Mission Austria, which is still active today. The SGMS received about EUR 3.1 million in 2009 for pilot and demonstration projects in the area of smart grid research and development.[9] Between 2009 and 2013 the municipality of Köstendorf was selected as a site for a smart grid demo project as part of the model region programme, and has since been further developing and investing in smart grid solutions with the support of the local grid operator (Salzburg Netz GmbH). The second case study project, Rosa Zukunft, was also implemented as part of the smart grid model region Salzburg.

The third case study project, VLOTTE, started in 2008. It was the first e-mobility field test in Austria. Similarly to the other two cases, national funding played an important role to stimulate regional activities. However, as we will show later, the project also profited from a number of supportive local conditions. Today, Vorarlberg is one of the leading e-mobility regions in Europe.

For the selection of the Austrian case study projects we applied a multi-step process. First, based on desk research and informal expert interviews a long-list of possible case study sites was prepared. This list included 15 possible cases. Based on this long-list the project team selected a smaller number of case study candidates for further investigation. Important criteria for the final selection of cases were of theoretical (variety of thematic focus, technological options, implementation of solutions) as well as of practical nature (accessibility, willingness of main local actors to cooperate with the project team).

Based on the MATCH research framework, an interview guideline for stakeholders, experts and end-users was drawn up. The questions cover the history of the case, its context, the role of main stakeholders and/or users, elements of the socio-technical configurations applied, experiences made in the project, success criteria, and a short outlook section.

In November 2016 the project team made a first round of field trips to the three case study sites. On November 22 we visited the project VLOTTE in Bregenz. On November 28 we were in Salzburg to visit both projects. During the site visits seven interviews were carried out. Several additional interviews with experts in Vienna followed. The second round of field trips took part in May 2017. Overall, 31 interviews have been conducted. Interviews lasted between one and two hours. All interviews were transcribed and coded using the programme MAXQDA and prepared for analysis. In addition, existing studies and other written documents were also used for the case studies.

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[8] http://www.smartgridssalzburg.at/content/dam/websites/smartgrids/Downloads/SGMS-Ergebnisse-2013.pdf, last accessed 18 October 2017.

[9] http://www.smartgridssalzburg.at/content/website_smartgrids/de_at/modellregion-salzburg/foerderungen.html, last accessed 18 October 2017.

2.1 Case 1: Modell Village Köstendorf

2.1.1 Background and Project Characteristics

Köstendorf is a small village in the Austrian Bundesland Salzburg. As of 1 January 2016 it had 2.555 inhabitants[10]. In 2011 Köstendorf was selected as the location for the testing of smart grid energy technology solutions as part of the research project DG[11] DemoNet Smart Low Voltage Grid (Kupzog et al., 2013)[12]. The project ran between 2011 and 2013. DG DemoNet is part of the federal government's strategic research and testing initiative Smart Grid Model Region Salzburg (SGMS). About 23 projects were funded under this programme, the funds for which were provided by the Austrian Climate and Energy Fund (KLIEN)[13], and the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT). The relatively large research programmes Energy for the Future, New Energies 2020 and e!mission are precursors of the SMGS initiative. All programmes broadly focus on the testing of smart grid technologies in practice at the level of buildings, communities and regions, with the aim of solving technological problems of energy technologies and their integration with existing energy systems, and other sectors such as transportation and increasing tourism by attracting people to the region for reasons such as energy innovation.

The federate state of Salzburg has adopted specific policy targets pertaining to the reduction of CO^2 emissions and increase in the use of renewable energy, as set out in Agenda 2020[14], Agenda 2050[15] and policies at the EU level (the binding targets are those defined at the EU level). Formulated in 2013, Salzburg's Agenda 2050 aims for state-wide climate neutrality and autonomy in its energy production. These goals refer to all primary energy systems such as heating, transportation and electricity.

The SGMS funded research projects, such as DG DemoNet Smart Low Voltage Grid and its predecessor DG DemoNet, aim at testing and technological problem-solving in the integration of renewables and ICTs in existing energy technology systems in real-world settings in the state of Salzburg. DG DemoNet and its follow-on project DG DemoNet Smart Low Voltage Grid focused on understanding the planning investments required to solve the problems of fluctuating energy demand on the one hand (high in the early morning and evenings) and changes in the supply of solar energy on the other (high at daytime and during the summer, low at other times). The goal is to gain knowledge on how to balance out these changes with limited investments in infrastructure, devices and systems, and minimising discomfort to consumers.

The main actors in the DG DemoNet Smart Low Voltage Grid project implemented in Köstendorf are the Austrian government, the regional energy sector, industry, and universities and research institutes. The initial team behind the project was composed of the local government of Salzburg, the regional energy provider Salzburg AG, the regional grid operator Salzburg Netze GmbH, the firm Siemens, the Vienna University of Technology (TU Wien), the Austrian Institute of Technology (AIT), and the grid provider Netz Oberösterreich GmbH. These actors had collaborated in projects in the past, although not necessarily all in exactly the same consortia. The call for projects on the topic of smart grids was launched by the Austrian Climate and Energy Fund (KLIEN) in 2010 and at this time the project idea was made concrete.

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[10] http://www.koestendorf.at/.

[11] DG is short for distribution grid.

[12] https://www.ait.ac.at/en/research-fields/smart-grids/projects/dg-demonet-smart-lv-grid/.

[13] https://www.klimafonds.gv.at.

[14] https://www.salzburg.gv.at/umweltnaturwasser_/Seiten/salzburg2050.aspx.

[15] https://www.ait.ac.at/en/research-fields/smart-grids/projects/dg-demonet-smart-lv-grid/.

As previously stated, the project DG DemoNet, which was the predecessor to the project DG DemoNet Smart Low Voltage Grid which was implemented in Köstendorf, focused on medium voltage and had been carried out in Vorarlberg. After this first project, the research focus shifted to low voltage. Low-voltage was then addressed in the follow-on project, and this time in a different region of Austria. The consortium of both projects was quite similar, except that in the second project the partners from Vorarlberg no longer participated, and the state of Upper Austria was added to the regions in which products and systems were tested. The field-test was carried out in the municipality Eberstallzell in Upper Austria. The goal of the follow-on project was to explore low voltage smart grid technologies. The criteria were to test out the possibilities of having a penetration share of about 50% PV energy production and 30% electric vehicles (EVs) share of total vehicles in a local community, and the interactions this would have with the existing grid. In this first stage of the project formulation, it was still unclear which local community would be the testbed.

The criteria for site selection were to find a low voltage grid that resembles what a smart grid might look like in the next 20 to 30 years, which specific cabling features, demographic characteristics, sufficient length of the existing low-voltage cable, and suitability of the building hosting the existing transformer station and whether it needs to be rebuilt to host a second (smart) transformer. Ten local communities in Salzburg including Köstendorf had these desired features. Köstendorf was the first locality approached to take part in the project and they quickly accepted. Some of the reasons for the quick acceptance are some pre-existing local affinity towards energy conservation and own production (for example, installation of PVs at own cost), as well as the close personal ties between one community member (who later on in the project became the local mayor) and the local energy provider Salzburg AG. The local affinity towards renewable form of energy and environmental conservation in general has a long history in Austria. Indeed, together with Germany, Austria has been a pioneer in promoting public awareness of environmental concerns and what people can do about it. Furthermore, these projects are always accompanied by subsidies and investments either directly from the government or indirectly through research funds. Pilot and demonstration projects are known to be accompanied with this and local communities are often keen on both the money that comes to the community through these projects, as well as the technological upgrading that is a result of R&D performed locally (e.g. knowledge spillovers). It is impossible to separate the direct effects of each of these factors but they are often stated as supporting factors in the literature on strategic niche management (for example, Schot and Geels, 2008) on the development of niches.

From the beginning of the project, many households and small companies supported the project. At the village level, investments had already been made in the past, for example through the installation of biomass heating plants. Overall, the local community had an affinity towards sustainable energy production and consumption, which was an important factor for choosing it as the research site. Following site selection at the beginning of the project in 2011, different funds were raised to install the necessary equipment such as solar panels and the controllable transformer. The federate state of Salzburg provided the subsidies to supply the participating households with PV solar panels. In total 43 buildings (private houses, the municipal office, the school, and some small companies) were chosen to participate in the research. The households agreed to have the following devices and systems installed: PV panels, building energy agent (BEA) and smart meter. Some households also received electric vehicles and wall boxes installed on site (for free during the project, later at a price of 29 Euros per month per e-vehicle). At a later stage, as part of the next pilot and demonstration project on the site (the LEAFS[16] project), the

[16] https://www.ait.ac.at/en/research-fields/smart-grids/projects/leafs-lv-loads-and-storage-integration/

households got batteries installed. The households bought the following themselves (at heavily subsidised prices): PV panels and smart inverter. All other components, specifically the Building Energy Agent (BEA), the smart meter, and all technologies supporting the smart meter were bought and remain in ownership of Salzburg AG. The local community of Köstendorf also received funding from the Bundesland Salzburg designed for small projects in small communities. Because of financial restrictions not all interested households could have been selected to take part in the project, there were some negative sentiments raised in the non-participating households, some of which had only previously bought solar panels and electric vehicles using much smaller subsidies than were offered as part of the project. These households had not purchased this equipment because they would be more eligible to participate (they did not know about it when they bought the equipment), but rather because they had a keen personal interest in self-generation and energy autonomy. As these households are located in other parts of the village, they were not considered as participants of the filed test in principle.

One of the background goals of the pilot projects was to manage the intermittent supply of renewable solar energy with changes in demand. The testing phase of the technical elements involved finding out how well the controllable transformer[17] can be controlled in the context of decentralised electricity production in private households through PVs, the charging of electric vehicles in the households, and the controllable transformer. The controllable transformer costs about twice as much as a regular transformer, and even though it would work, its high price is a barrier to widespread implementation. The field-test also should explore whether such a transformer is actually necessary under the given circumstances or not. A further aim was to test whether the low voltage grid is sufficient if there is an expansion of PVs, or whether it is necessary to extend the grid. The project had the following research question: How can a high share of photovoltaic systems and electric vehicles be optimally integrated in low voltage networks using intelligent planning, real-time monitoring and active network management?[18]

Today, the installed devices and systems are still being used, and the subsidy for the electric vehicles has been changed to a monthly fee of 29 Euros per vehicle per month (the vehicles are the Nissan Leaf or the Renault ZOE). Both the expansion of the test region is planned for the future, as well as the kinds of technologies that are to be tested. For example, a follow-on project in which Power2Heat technologies are tested is already being planned. The Power2Heat devices are already available on site (biomass), and the installation is dependent upon funding, which if it comes before December 2017 will be put in use in 2018, and is aimed at substituting the amount of heating oil used with the use of a heat pump (the oil burner will be replaced by a heat pump). Planning of a further project is underway, focusing on the development of a building project featuring open internal exchange of electricity from on-site PV systems. The realization of the project is however highly dependent upon the new Austrian economic and organisational regulation for the electricity industry (Elektrizitaetswirtschafts- und -organisationsgesetz (EIWOG))[19].

2.1.2 Socio-Technical Configurations

In the model village Köstendorf we can identify three different socio-technical configurations that are of interest from a smart energy perspective (see Table 4): There is a smart distribution grid with an extraordinary high share of PV generation, there are single households with PV systems, EVs and stationary batteries, and there is a 100% renewable energy household.

[17] For an explanation of how a transformer works, please see: https://en.wikipedia.org/wiki/Transformer

[18] Kupzog et al., (2013, p.17).

[19] https://www.e-control.at/recht/bundesrecht/strom/gesetze.

Smart distribution grid with vast PV generation

The first configuration covers the part of the field-test that focuses on the integration of a large number of small PV-systems and electric vehicles (EVs) to the local grid (within one single string of the local distribution grid). In this case, the main interest of the field-test was to learn more about effects that appear when local electricity generation is based on solar energy to a large extent and at the same time the local grid has to deal with significant higher levels of electricity consumption due to a local concentration of EVs. The main technical elements of this configuration consist of a controllable low voltage transformer, an ICT-infrastructure and a control unit. Data on the voltage level in the local grid from the smart meters is used to stabilize the load situation in the local distribution grid. In addition, single households are equipped with smart inverters that allow for phase shifting which alternatively can be used to balance the distribution grid. The high density of PV systems and EVs was essential to create real-world conditions for testing the behaviour of the local distribution grid over a longer period of time. The willingness of local homeowners to participate in the field-test was backed by attractive subsidies, awareness for energy issues stimulated by previous activities in the village and a strong personal and political commitment of the municipality. In addition to 40 private households and some small companies, three larger PV systems are run by the municipality as part of the field-test. Technically, the field-test revealed that the grid can be stabilized using phase shifting only. The controllable transformer did work properly but was not necessary to stabilize the local grid. As a result, the responsible grid operator decided to use smart PV inverters at the household level (which allow for phase shifting) as the standard solution in the future. The participants identify strongly with the objectives of the project. They are proud to play an active part in the energy transitions. Some participants reported that they tried to shift electricity consumption patterns and others showed some interest to increase their self-consumption. The main focus of the researchers in this project was not to find out the implications of time shifting, but to identify the technical impacts of an increase in the share of PVs and EVs on the local grid. It was about investigating options for grid management in the context of proliferation of these two solutions. Time shifting was a very minor side-effect which had a small influence on the households themselves, but not on the grid, which was the real focus. However, the most important experience of the households as part of the field-test related to electric mobility. In most cases the electric vehicles from the field-test are still in use and became an integral part of the household's mobility practices. All households interviewed reported to using the EVs more than their regular ICE cars although the EVs did not replace the original car.

Figure 13: PVs on house rooftops in Koestendorf

Figure 14: Smart grid monitoring equipment in Koestendorf households

Table 4: Socio-technical configurations in the model village Köstendorf (Smart energy system field-test)

	Smart distribution grid with vast PV generation	Generation & storage household (field-test)	100% renewable household
Technical elements	Low voltage grid (covering 90 buildings) Controllable transformer 43 distributed PV units (192 kWp), smart meters, IT control units, smart inverters, stationary batteries (in some households) 36 E-vehicles, wall boxes ICT-infrastructure	Rooftop PV (3,5 kWp) Smart inverter (phase shifting), web interface Grid connection Smart meters, IT control units Stationary battery (in some households) Wall box E-vehicle	Thermal solar system, large storage tank Wood stove Heat pump Rooftop and free-standing PV systems (6,3 kWp) Inverter, web interface Grid connection Stationary battery Wall box E-vehicle
Social elements	40 households participate in the field test 3 PV units are run by the municipality Households/municipality own and operate the equipment in the homes Field-test households belong to the same neighbourhood ("Vogltenn") No economic connection between participants, households 'sell' surplus electricity to the grid Mayor of Köstendorf works at Salzburg AG Active energy group at the municipal level (e5) High subsidies for private households (PV, batteries) and EVs for free On-going demo project and showcase	Household owns the equipment and 'sells' surplus electricity to the grid EVs are owned by Salzburg AG and rented by household High subsidies for private household On-going demo project (optimisation of self-consumption) Agreement between household and Salzburg AG Household in close contact with field-test project manager who cares for the technology	Homeowner is investor and system operator Highly motivated 'resource man' and active member of local energy group (e5) Household buys green electricity but is otherwise a normal customer of Salzburg AG Household is not part of the field-test

Generation and storage household

The second interesting configuration is represented by the single field-test households, usually equipped with rooftop PV, stationary battery and EV (the same households as in the smart grid field-test but with a different research focus). Here, the main focus is on user acceptance and experiences with the provided technology. In households with stationary battery systems on-going research is about the optimization of self-consumption, which referred to for example using electric appliances when either solar energy was available directly or with the battery, as well as moving towards energy autonomy. A locally installed IT control unit make sure that self-produced electricity is first of all used in the household (for direct consumption or to charge the battery) only then electricity is fed into the grid. Although the households own most of the technical equipment (only the EV is rented from the Salzburg AG in the same 29 Euro per month deal) responsible staff from the Salzburg AG play an important role regarding the operation and optimization of the technology. The cooperation between the project leader (Salzburg AG) and the households is regulated by an agreement that guarantees unrestricted access to data and to the technical equipment in the homes. Homeowners and project staff jointly take care of the technology. Over the years close personal relationships have been developed. Although the local grid operator (Salzburg AG) is the main actor in this configuration, participants with battery systems stated that the technology will help them to become more independent from the local utility and be self-sufficient in the future. The grid operator, however, again is interested to use local batteries as elements to stabilize the local grid and learn more about the systemic implications of prosumer-households.

Figure 15: EVs and charging stations in a household in Koestendorf

100% renewable household

The third configuration is realized in only one household and developed much earlier independently of the field-test. However, there are plans that also this household will become part of the household battery research project. This configuration can be characterized as a full renewable household. In this case, almost the entire energy needs of the two-person household is covered by renewable energy sources. The detached building is heated with wood, solar thermal, and geothermal energy. Electricity is produced by three PV systems and, apart from normal electricity needs, the own generation is used to run a heat pump and to charge two EVs. The system is connected to the grid but the household consumes a large share of the own self-generated electricity by itself. Additional electricity needs in the winter season are covered by the grid using green electricity. Mastermind and operator of the quite complex technical system is the male householder. Already in the early 1990s he joined one of the at that time very popular thermal solar panel DIY groups. Since then the whole technical system of the private home has gradually been developed towards renewable energies. The male household member perfectly fits the ‘resource man’ typology. He not only designed the whole system by himself and actively cares for the technology, he also has a lot of knowledge, and regularly checks the measured data. Over the years the household has invested a lot of money in this system, even the owner itself sees these high financial investments as problematic.

2.1.3 Discussion: Success and Outcomes

The solutions tested in the project can be considered as successful in several respects from different stakeholder perspectives. In particular, the project has succeeded in its R&D objectives, the planning objectives of the utilities provider Salzburg AG, the local community has profited both from direct subsidies and the technological momentum that has been created from the implementation, testing and management of the solutions. In terms of R&D, the project set out to address the specific problem of integration of PVs and electric vehicles without disruption to the existing energy system and at a feasible cost. A successful planning aspect was arriving at the finding that with local regulation and an integrated approach it is possible to achieve 100% increase in local grid capacity and reduce the additional costs by 50% (interview MR Salzburg AG p. 14). Furthermore, one of the technical solutions (phase shifting) that was tested in Köstendorf and which proved to be suitable will be rolled out to the Salzburg region.

A further success feature is that the community interactions led by the utilities provider Salzburg AG and the local mayor, and the project’s publicity brought benefits to Köstendorf that were not directly intended. For example, the only local pub was reopened because of the large numbers of visitors coming to the village to learn about the local energy project. The satisfied customers in Köstendorf have told others about their experiences and supported the diffusion of the technologies amongst the village and to other villages as well. It was reported that over 70 different country delegations came to visit the village, creating a type of “energy tourism” which had not existed there before. Through the active engagement from the utilities provider, who are also the equipment owners, the customers gained more awareness of the challenges facing sustainable energy supply, the role they can play in energy production. A positive image was created of the utilities providers, which had not been as positive prior to the project. The project participants who were fortunate enough to receive one or two free electric vehicles for the duration of the project (and heavily subsidised thereafter) got much more confident in driving electric vehicles, and some households even started to plan their holidays around where they will be able to charge their car throughout the journey.

The main preliminary findings with regards to the MATCH framework dimensions of markets, actors and technologies, are:

Markets

- In the first two configurations, the subsidies dimension (both the quantity of resources and who administers them) are very important. Households that have received them are shielded from real-world economic conditions. Most of these solutions are not economically viable, at least in the short to medium term. The households that are not put off by economic inefficiency of the solutions are few and far between (in our survey we found only one such household, described in the third configuration, who maintains the investments with no significant near-term pay-off andbut out of conviction and as a role model as a kind of hobby).
- The interest in either keeping up existing subsidies (through Salzburg AG) remains, with new demonstration projects currently taking place and others planned for the near-term future. The region is a protected niche and test bed for both research and industry. These and other features of the project (for example,

the research and industry driver) means that market formation in this regional context is highly mediated and controlled. The main player, Salzburg AG, has a clear interest in maintaining its gatekeeper position in the overall market and is exploring options to do so, in this case in a rural setting.

- The project boosted the regular sale of PV systems in Köstendorf and made it one of the leading villages in this respect in all of Austria. These conditions have created a fruitful ground for spin-off projects as well as further developments of the energy technology field in Köstendorf.
- The households favour the solutions also because they would like to move towards self-sufficiency and autonomy in energy production and consumption. This is despite the involvement of the big player Salzburg AG, and the associated subsidies. This creates an interesting contradicting dynamic in the process for the longer term, but makes sense at present because both parties perceive a benefit in the current set-up.
- An important insight gained for the EVs market is the good experience that households had with them after they had the opportunity to test them out at almost no cost. This is in line with the current literature on EVs, which states that consumers tend to be quite sceptical at first, but given the opportunity to own and charge the vehicles they are lose their scepticism and become regular users (add source).

Actors

- The project consortium was highly competent in engineering, and management know-how, as well as well-networked with the local and regional government which was important for obtaining resources and lowering transaction costs. All parties learned in the process.
- Users were involved from the very beginning, and treated as 'partners on a level playing field'. There was and remains good communication between the project leader and the local citizens. The involvement of local installers for the equipment worked well by helping to improve their installation skills for PVs as well as improving local support for the field-test.
- Users enjoyed using the electric vehicles and highly appreciate being able to have an active part in the 'Energiewende' in Austria. They are proud to produce green electricity, and endeavour to further improve their energy autonomy and optimize the consumption of their self-generated electricity (with or without a battery).
- The 100% RE household is run by a typical 'resource man' who is driven by a desire "to show the world that it is possible to rely almost exclusively on renewable sources" (direct quote). For this household, the last 25 years have been a period of repeated experimentation and learning with the installing and re-installing of different bits of equipment, and although he was unable to participate in the project because his house did not meet the infrastructural requirements (which he, together with exchanges with Salzburg AG, is trying to improve, so that he increases his chances in taking part in initiatives in the future), he has benefited in other ways from it by being able to discuss and learn from the project consortium.
- The project could be viewed as a strategy to create local market niches because individual decisions have sustained the momentum but rather there has been a very successful group dynamic (similar to the famous DIY thermal solar panel groups in Austria) created by the field-test. This was based, however, on pre-existing social resources such as the "e5 Group", which meets on a regular basis in self-organised events to develop plans for the expansion of renewable energy production and consumption in the village. The group is made up of private households (mostly male retirees) and the local mayor. In contrast, the single

100% renewable energy household is an example that shows that it is even possible to achieve this with much fewer subsidies under existing market conditions.

- As previously stated, the solutions are a success from the perspective of the local community. The solutions have full local support, evident from the included and not included local households, their support of the continued involvement of Salzburg AG, the formation of an interest group to gather and exchange information and push change along in terms of energy self-sufficiency in the village, the re-opening of the local pub, and other spillovers such as more awareness of the existence of these products and systems which speeds up diffusion both locally and in the neighbouring villages.
- The project and the solutions improved the local economy by attracting energy tourists and other visitors to the village.
- The participating households are very satisfied with their involvement in the project. They are happy with the solutions that have been implemented in their households (smart PVs and EVs and charging stations, batteries). For the households, the most important part of the field-test were the EVs. As stated previously, during the field-test the free provision of the EVs allowed the households to experience them at virtually no economic risk, and they had all changed their opinions about EVs as a result, becoming passionate users of them although the provided vehicles were very early models.

Technologies

- In terms of technology research outcomes technical change, it can be saidsaid it was found out that even a high share of PV generation can function in the existing grid without a controllable transformer (a smart inverters with phase shifting will do the job). EVs and PVs partly work together, but even when the EVs are charged in the evenings and at night no problems are caused for the grid. These results indicate that, given the same configuration, the solution is most likely transferable to other adopting contexts.
- Research on batteries is ongoing, for example optimization and the consumption of electricity generated from one’s own PV system could be beneficial for the grid, but the extent and degree of this is unclear. In comparison, the motivation for consuming the energy generated by own PVs and stored in own battery systems in Denmark was motivated by regulation.
- The 100% renewable household case shows that the solutions are also useful for upgrading existing systems that were implemented before the start of the project.
- An understanding of the regional requirements and differences in regional conditions was built during the research. For example, the solutions work in Salzburg and in Upper Austria, but not in Lower Austria because in the latter the reactive power in the households does not exist, so they do not have the capacity to do the stress optimization (Spannungsbandoptimierung, MR page 24 bottom). Salzburg has a high degree of cabling which means that the grid has a high capacity so the inductive idle power/reactive power is very useful.

2.2 Case 2: HiT Housing Project

2.2.1 Background and Project Characteristics

The city of Salzburg is the fourth largest city of Austria. The city has a surface area of 65.68 km^2 and a population of 150,887[20]. It is located about 300 km to the west of

[20]As of January 2016, see https://en.wikipedia.org/wiki/Salzburg.

Vienna and about 140 km to the east of Munich. The city is divided by the Salzach river, with medieval and baroque buildings of the *Altstadt* (old town) on the left bank, and the 19th century *Neustadt* (new city) on the right. The city is internationally famous for being the birthplace of the composer Wolfgang Amadeus Mozart. The *Altstadt* of the city is very well preserved, and has been listed as a UNESCO World Heritage Site since 1997. The city is a tourist favourite, with the number of tourists outnumbering locals by a large share in peak season. Salzburg is part of the temperate zone, also classified as either oceanic climate or humid continental, with four distinct seasons. The temperature averages 0 degrees Celsius in the winter months (December to March) and 20 degrees Celsius in the summer months (June to September). Due to its location at the northern boundary of the Alps, the amount of rain is relatively high, especially in the summer months. Salzburg is a centre of education and hosts three universities, as well as several polytechnics (*Fachhochschulen*) and high schools (*Gymnasien*). The city is served by comprehensive rail and air transport connections. There are frequent trains to Vienna, Munich, Innsbruck and Zurich. The city acts as a hub for southbound trains to Italy. Salzburg Airport is the second busiest airport in Austria, after Vienna Airport. Due to its relatively small size, it is fairly common that people working in the larger public and private organisations know each other and are used to networking with each other. Such conditions make it feasible to get projects off the ground, especially those that correspond to the state's strategic policy goals of climate neutrality, resource efficiency and innovation.

The Salzburg region has been hosting pilot and demonstration projects in the field of smart grid technologies since the early 2000s. Between 2003 and 2013 the region was a focus of 23 projects funded under the remit of the large scale research programme (relative to other topics in Austria these programmes secure quite a large amount of funds for smart grids research) known as the Smart Grids Model Region Salzburg (SGMS)[21]. The primary actors driving the programme are private actors, as in the previous case (Köstendorf), namely the regional distribution system operator (DSO) Salzburg AG, the regional building developer Salzburg Wohnbau and Siemens Austria. Project funding comes from the Austrian Climate and Energy Fund (KLIEN) specially created for innovation towards a decarbonized economy. At the core of the SGMS programme lies the specialised testing and development of technologies for a better integration of renewables, upgrading of electricity distribution networks, diffusion of electric mobility, integration of residential and commercial buildings in the smart grid, and advancements in load management (AIT et al., 2013). Depending on the project, the private actors are supported in their research by public research institutions in Austria such as the Austrian Institute of Technology (AIT) and the Vienna Technical University (TU Wien).

The "HiT – houses as interactive participant in the smart grid" project

The HiT Rosa Zukunft[22] project, the focus of our case study, is one of 23 projects under the remit of the SGMS programme and focused on the testing and implementation of residential energy and mobility solutions. The research part of the project ran between 2011 and 2013. It was a partnership between the private firms Salzburg Wohnbau,

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[21] http://www.smartgridssalzburg.at/content/website_smartgrids/de_at.html. Smart energy technologies have been a strategic R&D and innovation focus of the Austrian government, scientific and research organisations, and firms for at least two decades (Kletzan-Slamanig and Koeppl, 2009). Some larger research funding programmes which are predecessors to SGMS are Energy for the Future, New Energies 2020 and e!mission.

[22] The HiT Rosa Zukunft development project is named after its location on the Rosa Hoffmann Street in Salzburg Maxglan, where Rosa Hoffman, an Austrian resistance fighter, grew up. On 9 March 1943 she was murdered by the Nazis in Berlin.

Salzburg AG, and Siemens Austria, with support from an interdisciplinary research team from the public research institutes AIT, CURE and Fichtner, and the Vienna Technical University (TU Wien). The development and construction of the eight residential buildings (129 dwelling units) in the HiT project was carried out by the housing corporation "die salzburg", Salzburger Siedlungswerk/Salzburg Wohnbau, the evangelical charity Diakoniewerk Salzburg (organising the social and community events such as information evenings and support groups, for example), the building firm Baumeister Steiner, and the SGMS organisation. The start of construction was 2012 and the first residents moved in in late 2013. The city of Salzburg, although not a direct partner in the energy aspects of the project, played a significant role in paving the way for the project through the creation of favourable framework conditions. Salzburg state directly supported the project by adjusting housing support to include partial public funding for the installation of photovoltaic (PV) panels. Furthermore, disability access and the building of living spaces to meet special social and healthcare needs of residents were ensured through cooperation between the developer and the builders.

The aim of the HiT project was to test the incorporation of smart grid technologies (demand response) in residential buildings, and lead the way for change in these areas for future housing developments in Salzburg (AIT et al., 2013:11). At the basis of the project were two innovative energy concepts, one mobility concept, and a broad overarching social concept. The energy and mobility concepts were developed by the core team of the firms Salzburg AG, Siemens and the research institutions AIT and TU Wien, who mainly focused on the highly technical and modelling aspects of the project. Several supporting individuals from Salzburg Wohnbau and the Diakoniewerk Salzburg managed the active involvement of the users, by providing information evenings, and acting as a one-stop-shop for any questions, concerns and complaints the residents had about energy use in the buildings. These information evenings were well attended at first, but over time the residents lost interest in taking part. It was said that only a few "usual suspects" were regularly present at all the meetings, for whom it was important to be there and get informed. Briefly here, the first energy concept focused on decentralised energy generation (CHP unit with biogas fuel and PVs), and automated load transfer (controlled thermal heat pump, controlled EV charging and home automation). The second energy concept focused on energy feedback with user interaction (using smartphone and tablet) as well as special monitoring apartments that were equipped with technology to monitor the use of energy, heating and water, as well as room temperature, humidity and CO_2 levels in the rooms. The goal of this concept was both load shifting and the corresponding reduction of energy costs. The mobility concept involved a shared fleet of EVs and an EV charging station. The idea was that residents could freely use the EVs for a small monthly fee, but car-sharing concepts never really took off. The energy and mobility concepts are explained in more detail in the section on socio-technical configurations.

The social concept was the main focus of Salzburg Wohnbau and the Diakoniewerk Salzburg. The underlying idea behind this part of the project was to have a housing complex in which different generations and income groups live together. The aim was that a local community develops and that there is social cohesion between the residents. The role of the Diakoniewerk Salzburg was to participate in the selection of residents (young persons, seniors, singles and families, persons needing assistance), to coordinate the living arrangements, and to manage the common room (or recreation room) as a central meeting point for all the residents (SMGS et al., 2013). There is support for the creation of neighbourhood support networks and a continuous chaperonage and living coordination (ibid.). The living coordinator Diakoniewerk is present on site 30 hours per week and financed through a monthly fee from each resident. It organises social events and activities of a secular nature in which residents can participate in, managing the different interests of the residents, and organises assistance to elderly residents. It also manages the use of the Diakonie app which also aims to support community building processes in the housing complex.

Throughout the duration of the research project, all concepts were very closely monitored by the actors responsible for them, specifically Salzburg AG, the research consortium, Salzburg Wohnbau for the energy concepts, and Diakonie and die Salzburg for the social and daily living aspects. A lot of effort was put in making them work. Over time however, it became clear that the first energy concept (building-to-grid - decentralised energy generation & automated load transfer) worked best of all because it was automatic and involved very little effort and no changes in user behaviour. This is also the part of the project that later became internationally famous and currently has a kind of pioneering reputation in the scientific and building communities. The in-home monitoring displays, the demand side management (DSM) concept, was much less successful, as users reported that the time-shifting changes that they had to implement did not pay off. Similarly, there was very little user interest in the shared EVs, because of reasons such as wanting to have an own car at disposal at all times, and not trusting that the battery would last for the trips that the residents wanted to make. The social housing concept continues to work well (social housing has a very long history in Austria and this concept builds on this long and successful tradition) and residents report being generally satisfied with the living arrangements.

In the case study, we focused on collecting expert views and user experiences on the two energy concepts and the mobility concept. We carried out expert interviews with engineers, managers and scientists from Salzburg AG, Salzburg Netze and AIT. Our user interviews were carried out with residents living in the regular as well as the special home monitoring apartments. The following section describes the three socio-technical configurations studied.

2.2.2 Socio-technical Configurations

The three configurations we analysed in this case study are building-to-grid, in-home monitoring, and EV sharing. The first configuration focused on energy management of the entire housing complex with micro generation (PVs and CHP), energy storage (heat, 90 m^3 water tank), and smart metering. The second configuration closely connected to the first, involved in-home smart monitoring with feedback communication between the consumers, the main heating system, and Salzburg AG. EV sharing is our third configuration, involving a planned car sharing system with two EVs per four to six apartments, an on-site charging station, a booking system, and electric bicycles. As previously stated the first configuration remains fully operational and in use today, whereas the second and the third configurations dissolved when the project ended, as it became clear that users were not interested in continuing the use of these technologies (except for one exception). The main socio-technical dimensions in each configuration are presented in Table 5 below.

Table 5: Socio-technical configurations in the HiT Rosa Zukunft (building-to-grid) project

	Building-to-grid	Energy feedback & DR	EV sharing
Technical elements	8 buildings with a total of 129 apartment units Combined heat and power (CHP) unit (biogas) Heat pump Energy storage tank (hot water, 90 m3) Rooftop PV (72 kWp) Central heating system in the settlement, District heating as backup IT control unit, smart meters	33 monitoring apartment units In-home display (tablet) Bus system, eco-button and smart meter in the apartment Sensors to measure humidity, CO2-level, temperature in the apartment Central hard and software and web portal IT control unit	On-site charging station EV
Social elements	Local (energy) utility owns technical equipment and provides heat and electricity Contract between utility and the housing company Variable tariff (calculated on a daily basis) Surplus electricity is fed into the power grid (domestic production) Occupants are passive consumers (but obliged to buy heat from Salzburg AG) Biogas virtual (offset)	Demand response field test (one year) Consumption measuring at 15 minutes intervals Agreement to take part at the field test Variable tariff (calculated on a 12 hours basis, special approval by regulator) Traffic light system Technical equipment sponsored by Siemens and research funds	Closed e-car sharing system (4 households share 1 EV) Provided by the housing company

Figure 16: Residential building complex HiT Rosa Zukunft

Building-to-grid configuration

At the heart of this configuration are questions on how load peaks in the grid can be reduced through the connection of intelligent residential buildings into the smart grid (AIT et al., 2013). In this configuration, the technical elements include the equipping of the eight residential buildings (129 apartment units) with a centralised heating system consisting of a micro cogeneration unit (which runs on biogas), a heat pump, and a large energy storage tank to store surplus energy. When the energy production in the building complex that was generated through the on-site heating system (micro cogeneration and heat pump) does not meet the housing energy demand, then district central heating is used as a backup.

The central communications system is located in one of the apartment blocks (known as the “HiT Energiezentrale” or “HiT energy centre”, see figure XXX). The main communications device of this technical set-up is a development of the company Siemens called Building Energy Agent (BEA). The BEA communicates between the smart meter, user interface, the weather predictions, the building automation system, the electric vehicle charging station and the electricity grid. The planning and building of this configuration was highly computer and electrical engineering intensive, mainly because of the nature of the equipment and the sophisticated modelling and programming that is involved in making such a system work well. For example, one of our expert interviewees from AIT stated that it takes much effort to calculate how much energy such a complex needs, at what times, and to design the corresponding size of the energy production and storage units. It was even said that the slow diffusion of these specific building-to-grid technologies, is in part due to the highly advanced modelling skills that are required to build them, which are currently in very short supply both in Austria and globally.

A key social aspect of this configuration is that all of the technical equipment is owned and operated by the local energy utility firm Salzburg AG. This includes the generated data. Salzburg AG shares the data with the AIT, who use it for their research and optimisation of the individual products, several of which have already been patented as a result of the research carried out in this project. The housing company Salzburg Wohnbau has a contract with Salzburg AG for this equipment. The user residents cannot tell whether they are consuming electricity from solar or any other source, and the PV surplus is fed back into the power grid. Indeed, in this configuration, there are no conditions created for an active role for users in which they are involved in the design, rule-setting, functionality, or in defining the boundaries of the configuration. Rather the advantages and disadvantages are experienced at the level of the local energy utility provider and spread out over the energy system.

Figure 17: Central energy station of the residential building complex

Energy feedback and DR

In contrast to the first configuration where users had a passive role, in the second configuration they are given a very active (albeit scripted) role. The main interest of this configuration is to find out if users can be integrated in the smart grid if they are provided with information on network load and their own individual electricity consumption. Out of the total 129 apartments, 33 were chosen as monitoring apartments in which special displays, gauges and switches were installed. And there was similar large control group… Upon registering for the apartments the residents could specify whether they wanted to be part of the field-test or not. A criterion for narrowing the sample even further, was to include different households with different compositions (singles, couples, families, and the elderly). These apartments were provided with a tablet PC that showed their use of energy, heat and water. Each apartment had a smart meter, and an “ECO-button” which, if pressed, switches off all appliances except the refrigerator with just one switch. It was also possible to control the heating system via the internet or smartphone, as well as to monitor room temperature, humidity and CO_2 levels.

A function that was introduced to complement the information provided by BEA and to transfer it to the users is a “traffic light model” (“*Ampelmodell*”) which is based on the principle of the traffic lights, red indicates the network load is critically high, yellow indicates a medium level, and green shows that the load is low and thus a “good” time to consume electricity. Users could observe the colour on the traffic light model to organise their use of household appliances, and thereby directly adjust their behaviour to what is going on in the grid.

The in-home monitoring field-test lasted one year, after which the devices (which had been funded by Siemens) were dismantled and removed. The households were required to indicate their acceptance to take part in the field test as soon as they registered their interest for an apartment in the housing complex. According to one of our interviewees who participated, they had agreed to take part in the field test because they feared that otherwise they would not be considered for an apartment. It was said that three times as many people expressed interest for the apartments than were available, so the competition for them was high.

During the field-test (2012-2013), the consumption of electricity, heat and water was measured at 15 minute intervals. A variable tariff was introduced under special approval by the regulator. The variability in pricing was communicated to the users via the in-home displays. The residents reported to have tried to adjust their cooking, dish-washing and laundering based on the information obtained, but were generally disappointed with the overall result. Cooking at different times proved to be impossible because people were used to eating at other times than when the electricity price and the network load were low. Laundering was difficult to do at the cheaper times because that was usually after 10 pm in the evening, after which time people in Austria are legally required to make as little noise as possible (the police can be called and will normally come to your house if a neighbour reports that your washing machine is working loudly in the night). Indeed, some neighbours did complain to the residents in the monitoring households and they therefore stopped laundering at night. Furthermore, at the end of the one-year period when the residents of the monitoring apartments made their calculations, the amount that they had saved was much lower than they had expected and in their view not worth the effort[23]. Energy monitoring is still in use in a couple of apartments. However, the vast majority of the participants decided against taking over the monitoring equipment although this would have been free of charge. Only one out of 33 households decided to keep all of the monitoring equipment, and a second household decided to keep a part of it, namely the CO_2 monitoring display. The male in the first household continues to read all the available information from the equipment. The male in the second household, who kept the CO_2 monitor, also continues to use it and has learned how and when the windows and balcony door need to be opened to let enough fresh air in to balance out CO_2 level in the flat. It has to be said here that keeping the monitoring equipment is motivated more by a passion and keen interest in energy saving than economic reasoning. The bus system based equipment is very expensive to maintain and repair: each of the monitors/sensors can cost up to 200 Euros, and then if they break it can cost between 100 and 400 Euros to repair them. This is of course much more than the 15 Euros per year that could be saved if DSM routines are followed in the household.

[23] From a systems perspective even a small degree of savings (such as 15 Euros per year as the households reported) is a relatively large amount scaled up to the entire population, even if it would only occur perhaps once at the end of one specific year.

Figure 18: Model of the monitoring equipment switches installed in the monitoring apartments during the field-test

EV sharing configuration

The third configuration involved the provision (by Salzburg AG) of EVs, an on-site charging station, as well as an electric bike and a charging station for the electric bicycles. The idea behind this configuration was to understand the barriers and supports to the promotion of green mobility, to see how this approach can help contribute to load balancing, and to test a sharing approach to electrical mobility in a residential setting (AIT et al., 2013). The funding for this was provided by the housing firm Salzburg Wohnbau. The plan for this configuration was as follows: The EVs could be rented for a highly favourable rate of 90 Euros per month, which included unlimited charging, insurance, repairs, and any other aspects of regular car use costs. The EVs could be charged and shared by the residents using an online booking system. Two EVs were to be made available for sharing between four and six apartments. A further two EVs were to be shared between the housing coordinator and the facility manager. There was reserved underground parking for all EVs, which is also where the charging station was located. However, this plan was never realised because none of the residents wanted to take part in the sharing scheme (they were unwilling to share the car between two or more people). It was said in the interviews that they were apprehensive about using the EVs because they did not have confidence in how long the battery would last, where they would be able to charge the car, and how they would be able to integrate that with the trips they needed to make during the day. Furthermore, it was said that for people who needed their cars to go to and from work on a daily basis, the sharing option was not reliable enough as they could not risk that a car was not available exactly when they needed it.

2.2.3 Discussion: Success and Outcomes

Overall, the project is viewed as a success from a research perspective. The most successful configuration in the project is the building-to-grid solution, which is still operative today, and is financially viable. In fact, it was said that even if the solution had to be built without external funding it would still be feasible to do so (with some modification such as having a smaller storage tank which is currently oversized for the building complex). Another important research success is the finding is that even though district heating is being used as a back-up in this configuration, it could still function without it (the CHP and the heat pump are sufficient). Currently, a second project is underway in Austria that follows on from these findings, and it is the same configuration without the use of district heating as back-up.

The stakeholders and experts interviewed are very pleased with the research outcomes, and that the solution works so well in practice, and have reported that it has been an internationally significant success that has kept the attention of Siemens, and led to patents and a potential license. From the point of view of the users, the building-to-grid configuration is considered as a success only after the initial problems in the first few months (lack of hot water in some apartments, problems with heating) had been solved. After these early problems were solved, the residents were not really able to see or feel a real difference neither in the comfort in their home (which was already quite high in international comparison – Austria has the highest standards in subsidised housing in the world) nor in the energy bills they pay from the regular buildings they lived in previously.

The monitoring configuration has been relatively less successful from the perspective of the researchers and stakeholders, and almost completely unsuccessful from the perspective of the users. Nevertheless, a lot was learned from both parties. The researchers learned that many aspects of daily routines that were the focus of the 'traffic light model' feedback system, such as washing, laundry and cooking, are highly sticky, especially if children live in the household as well as if the financial incentive is so extremely low (about 15 Euros per year). Furthermore, the times at which the indicator was red (high load and price), yellow or green was not predictable during the day, so it was difficult to plan the chores. Users reported to be quite annoyed by this, and one user said that she was disturbed by the sensor lights in the rooms and she taped over them so she could no longer see them, and was happy when it was all removed. A further unpredictability was the energy bill at the end of the month. Users said that the bills did not always correspond to their expectations, some larger households had lower bills than smaller ones, despite some changes in energy saving behaviour. Users who later reported on what changes they had made in their behaviour were under the impression that they were changing a lot (35% said that they changed the time at which they did the laundry, and 22% reported to changing the time at which they put on the dishwasher) (source: interview with research from the AIT). However, when the calculations were made by the researchers, the share of energy usage during the "green" times were almost the same in the monitoring households as they were in the control group. The researchers were surprised by this, and the users grew frustrated because the researchers could not explain to them why their efforts did not show up as lower energy bills. The researchers had suggested big impacts of the technologies which were later not realized. Thus, overall, the expectations of the users were quite high, but ended in disappointment. One interviewee said that if he had to do the same again, he would appreciate being told a more accurate story of what he could expect.

Stickiness of daily routines was known from previous projects and this project further confirmed this finding. Throughout the duration of the field-test, only about half of the monitoring households had a look at the information on their energy consumption provided in the tablet, and this also varied a lot during the project (higher at the beginning and at the end). One criticism from the users was that it was not possible to see on the tablet what kind of energy source was currently being used to produce the energy. So they could not adjust their consumption to solar energy or other clean energy for example, but only to the price and the load information provided, which was not as satisfactory. The majority of users put more effort in complying with the project demands when they knew that a meeting with the project leaders was coming up and they would be asked questions. Only one household was passionate about the monitoring equipment and decided to keep it, even though it currently does not pay off.

A lot was also learned in the closed EV sharing configuration, especially about the differences in perception between researchers and users. From a research point of view this part of the project failed in getting people to use the shared EVs. It also showed what was wrong with the concept and what needed to be changed. The residents were very positive about the concept when they first heard about the plan, but reluctant to use it when it was made available to them. Some users thought that a move towards emissions free vehicles are generally a good idea, but they are not confident enough to rely on them for their daily needs. It might be too early a stage to expect this shift in this context, and trust still needs to be built over time. In addition to the insecurities involved in how long the car battery will last, and where they will be able to charge it, users placed a lot of importance on always having a car available, which was not believed to be possible in this haring configuration which was 'closed' or limited to a small number of cars for a small pre-defined group of people. Rather, it was learned that an open car sharing service may have been more successful, also because there is a comparable open car sharing project in Salzburg (called EMIL) which currently does work very well. The use of the electric bicycle was also not as frequent as expected, mainly because the elderly residents who live in the housing complex found it too difficult to cycle with. There were also problems with the charging point for the bicycle (it was too sensitive and stopped charging when the bicycle was accidentally moved only by a little bit) and it was sent back to the producing firm to be improved further.

The main preliminary findings with regards to the MATCH framework dimensions of markets, actors and technologies, are:

Markets:

- The configuration that worked best of all was one in which people did not have to change their day to day behaviour for it to work, but rather it worked 'in the background'.
- No loss of comfort to the user was very important for the solution to be considered 'workable'. If different energy sources are being used in the background this is not considered a loss of comfort, although users would like to be informed about the source. A loss of comfort is caused by having to perform daily chores at different times every day. The enthusiasm of making daily modifications to behaviour can be quite high at the beginning when everything is new, but peters off after some time and people tend to lose interest if they are not pressed to do so and no (or minimal) short to medium term benefit is experienced.
- The building-to-grid solution works but it creates a "natural" monopoly, restricting users' freedom of choice. The solution only works because all customers receive the heat (warm water and heating) from one supplier (Salzburg AG).
- The building-to-grid solution works on the flexibility market. It is able to generate power (CHP) when there is a demand from the grid and is able consume electricity (heat pump) at times when there is a surplus supply (renewable production) in the grid.
- EVs are, in this market context studied (apartment buildings, high proportion of elderly residents) still a product that is met with a lot of scepticism. People do not trust that the car batteries will last and that they will be able to charge the cars easily and conveniently.
- The closed sharing concept for cars does not work in this context. People do not trust that a car will be available as and when they need it.
- Even though people were sometimes unhappy with what the solutions may have required of them, they were happy that their apartment buildings got so media and public attention and that they were part of that.

Actors:

- The actors consider the project to be a success for both research purposes and for gaining an understanding of how solutions work in practice. Foremost the DSO

Salzburg AG and the research institute AIT find that their objectives were met in the building-to-grid configuration.

- The involvement in such projects increases user awareness of energy generation and usage (due to direct energy advice), and how they themselves can play a role in this system by changing their household usage. This awareness alone can be very powerful in leading users to try to buy energy efficient devices and save electricity, even if the overall economic outcome for them is quite minimal.
- The project partners maintained a good working relationship during the project and continue to work together on the sharing of data and licensing of patents.
- The households are happy with their apartments, but they were not generally positive about having participated in the energy feedback and DR configuration. They had invested in energy saving equipment when they moved in (state-of-the-art ovens, dishwashers and washing machines) which made energy saving through time-shifting even more difficult. They had expected a greater economic return on their time-shifting efforts, and wished that they had been properly informed about what kinds of savings they could reasonably expect at the start of the project.
- The DSO (Salzburg AG) on the other hand learned from the users about what kinds of energy efficient household devices are on the market today.

Technologies:

- Technically all configurations and solutions can function in practice, but only the building-to-grid configuration can be said to match the current market and actor conditions in this context.
- The building-to-grid solution can even function without district heating as a back-up and it is also economically viable. It of course helps to have a national government subsidy for solar panels, but it is likely that the DSO would build it even without the subsidy.
- The functioning of these technologies in practice is heavily dependent upon diverse actors (for example, DSO, building authority, users) working together. For the technical and business aspects to better fit the market, greater alignment is needed between what users need and want in their day to day lives and what solutions the project actors want to experiment with.

2.3 Case 3: VLOTTE

2.3.1 Background and Project Characteristics

The federal state of Vorarlberg is the most western state of Austria and borders the countries Germany, Switzerland and Liechtenstein. It covers 2.601 km^2 from the river Rhine to Lake Constance to the Arlberg and the Silvretta Alps. Only 69 km of the 321 km long border connect Vorarlberg with the rest of Austria. Two thirds of the state is at an altitude higher than 1.000 m above sea level, 35.9 % is covered by forest and the Alps make 23.3 %. Compared with the rest of Austria, it is situated in the drainage area of the Rhine and not the Danube. From its area and population, it is the second smallest state in Austria and has a population of 383.094 (2015). In the last thirty years, it had the highest demographic growth in Austria with 22 %. It is also the state with the highest share of young persons (16 % are less than 15 years old).[24] Vorarlberg has a GDP per capita of 41.500 € and an unemployment rate of 3.4 % (2014) which is low compared to the Austrian average of 5.6 %.[25]

Vorarlberg's industry underwent a substantial transformation in the past 40 years. It changed from textile production as the main driver to the production of machines and metal making, which now make up around 50 % of the industry. Vorarlberg exports 60 % of its goods to foreign countries. In comparison, foreign exports for the rest of Austria are 40 %. The energy sector is growing due to the expansion of hydropower and favourable natural conditions. Renewable energy roughly covers the energy demand in the state and surplus is exported to neighbouring countries such as Germany. Further, the tourism industry is an important part of Vorarlberg's economy and it is an attractive tourist destination throughout the entire year. The majority of people are employed in the services followed by industry and trade (cf. Landespressestelle 2015).

What makes Vorarlberg unique in Austria is not only its geographic position, but also the dialect. It is the only state with Alemannic dialects[26], which are spoken equally in private as well as in public. Dialect is an essential part of the people's identity in Vorarlberg. In the rest of Austria Bavarian dialects are prevalent.

Vorarlberg is constituted of the four districts Bregenz, Dornbirn, Feldkirch and Bludenz and has 96 municipalities, 5 cities and 11 market towns. Since the beginning of the Second Republic (1945) Vorarlberg has been dominated by the conservative party (*ÖVP*) and since the last election 16 of 36 seats are held by them. Federalism is traditionally emphasised in Vorarlberg and there is also a tradition of being fundamentally oppositional to the Federal Government in Vienna in some cases.

In 2009, all parties agreed on the strategic goal of Vorarlberg becoming energy autonomous by 2050.[27] The energy autonomy goal is understood as a process for development and design of a sustainable energy supply. Therefore, it aims at producing as much energy from renewable resources as is demanded. The strategy is based on four pillars: saving energy, energy efficiency, renewable energy as well as research, development and education. To reach this goal, the federal government initiated several steps that have already been taken and further steps that are currently in the process of development. Some of the preferential measures are a program for mobility planning for

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[24] https://www.vorarlberg.at/pdf/vorarlbergkompaktb11153_1.pdf, accessed 29 August 2017.

[25] https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/Vorarlberg, accessed 29 August 2017.

[26] There are also small regions in Tyrol where Alemannic dialects are spoken, but not as extensively as in Vorarlberg (https://de.wikipedia.org/wiki/Alemannische_Dialekte, accessed 20 August 2017).

[27] https://www.energieautonomie-vorarlberg.at/de/, accessed 27 August 2017.

municipalities, expansion of the cycle path network, energy monitoring of public buildings and expansion of hydropower. A visionary process was the basis for reaching the climate goals and therefore working groups for the topics renewable energy, buildings, trade and industry as well as mobility and spatial planning have been built. These working groups wrote frameworks where the steps for each topic are formulated. Currently, it has been agreed on steps to be taken until 2020, which is seen as the first stage of the plan to reach energy autonomy by 2050. This stage is based on the European Union's 2020 goals. The 1990 level is taken as the initial point and for Vorarlberg this means that the energy consumption has to be reduced by 15 % in comparison to 2005, CO_2 emissions by 18 % and the share of renewable energy has to be expanded by 13 % in comparison to 2009. More precisely, 101 measures need to be adopted. They are called the *101 enkeltaugliche Maßnahmen* (measures fit for grandchildren) (Energieautonomie Vorarlberg 2011). As the name already suggests, the measures are meant to preserve the world as a liveable place for the grandchildren who are yet to come.

illwerke vkw is a group of companies composed of Vorarlberger Illwerke AG (peak and control energy and tourism), Vorarlberger Kraftwerke AG (energy supply, energy services and energy trading) and Vorarlberger Energienetze GmbH (electricity and gas network). The group is 95.5 % state-owned (Vorarlberg) and the remaining 5 % are owned by an asset company in property of the state Vorarlberg as well as in diversified holdings (Vorarlberger Illwerke AG 2016). As a state-owned company, illwerke vkw supports Vorarlberg in reaching its aim to become energy autonomous by 2050. Different measures are necessary to achieve this goal, one of which is the diffusion of electric mobility. Vorarlberg is the electric mobility pioneer region in Austria and the leading state in new registrations of e-vehicles. There are several reasons behind the region's successful implementation of e-mobility. In general, different tax benefits, low maintenance costs and an increasing driving range bring more and more private persons as well as businesses to buying an e-vehicle. Short distances, a pro-active federal government, a general eco-friendly mentality of the people and illwerke vkw's dedication to e-mobility are supporting factors. Furthermore, illwerke vkw has established a mobility centre (*Mobilitätszentrale*) where counsel is offered free of charge and different kinds of e-vehicles can be tested. However, the origin of the success of e-mobility in Vorarlberg lies in the project VLOTTE.

VLOTTE started as a project initiated by the e-mobility model region funding program (*Modellregionen der Elektromobilität*) of the Climate and Energy Fund (*Klima- und Energiefonds – KLIEN*) and the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (*BMLFUW*) in late 2008. E-mobility model regions were not common in Austria at that time and the Climate and Energy Fund was one of the groundbreakers for the establishment of electric mobility. Today, there are 7 model regions in the whole of Austria: Vorarlberg (*VLOTTE*, call 2008 and 2009), Salzburg (*ElectroDrive Salzburg*, call 2009), Vienna (*e-mobility on demand*, call 2010), Graz (*e-mobility Graz*, call 2010), Lower Austria (*e-pendler in niederösterreich* (e-commuters in Lower Austria) call 2011), Carinthia (*E-LOG Klagenfurt*, call 2011) and Vienna (*E-Mobility Post*, call 2011). Except the *E-Mobility Post* project which runs in all of Austria, all the other projects are limited to a geographic region. The general idea behind the e-mobility model region programme was to test different e-mobility systems and to pave the way for e-mobility technology for everyday life. The different actions in the projects on vehicles, infrastructure, business and distribution models made it possible to bring around 2000 e-vehicles on the streets and to install about 3000 charging points between 2009 and 2011. The funding programme included three stages: 1. test of electric mobility in different regions und building up of different systems; 2. funding of networking and consolidating projects in cooperation with the different model regions; 3. spreading of experiences and gained knowledge in whole Austria (Klima- und Energiefonds 2017). The last call of the funding program was in 2014.

The project VLOTTE (2009-2011) was initiated by the independent non-profit organisation Kairos in Bregenz. illwerke vkw then submitted the proposal to the first e-mobility model region call in late 2008 also due to support from the federal government. It was the only accepted project during that time. According to the person responsible at KLIEN only one project was funded because of the limited financial resources. One condition of the call was that an operating company was handing in an application, so the risk would not be on the side of the customers. At that time, the development of e-vehicles was in an early phase and there was only a very limited amount of charging points available. Also, the proposition had to lay out a plan for an overall mobility concept for a larger region. The idea of VLOTTE was to establish an e-mobility model region and therefore prove the suitability for daily use of e-vehicles. In the early days, VLOTTE did not have a specific focus, but a broader approach: new plants for renewable energy were built, charging infrastructure was established and early e-vehicles were brought to Vorarlberg. Then, e-vehicles were not common and electric mass-production vehicles did not exist. Therefore, experimental e-vehicles and conversion vehicles had to be sought, the early cars were four Th!nk City of the Norwegian company Think Global. Potential customers had to accept these cars and pay a comparably high price to be able to drive an electric car. The first batteries in use were ZEBRA-batteries, which today cost around 12.000 € for 2 kWh.[28] These early batteries were not only very expensive, but also highly inconvenient. When not in use, they had to be kept at a temperature of 260 °C to stay operative (VLOTTE 2016). Therefore, energy was not only used during operating times, but it was also wasted when the vehicle was not in use. The target group was composed of 40 % public administration, 40 % businesses and 20 % private customers. Especially public administration institutions and businesses were of interest due to the risks and the high costs in the beginning. They were seen as forerunners in the e-mobility innovation process. After the launch of serial models like Mitsubishi i-MiEV more private persons were targeted. ZEBRA-batteries were in use until late 2010. In 2011, 631 e-vehicles were newly registered in Austria. 279 e-vehicles within the project VLOTTE, which amounts to 44 % of new registrations. Then, 272 of the 279 e-vehicles were equipped with lithium-ion batteries (ibid.).

After the publicly funded project phase, illwerke vkw turned VLOTTE into a business model, which is still operative today. The early business model of VLOTTE was built around a mobility card (*Mobilitätskarte*), which cost around 500 €/month. It covered the lease of an e-vehicle, maintenance costs, a ticket for public transport in Vorarlberg, unlimited access to charging stations and membership in the Austrian automobile club with roadside assistance (*ÖAMTC*). After four years of use, the customers could buy the e-vehicle for 25 % of the original price. From 2011, it was possible for business and public administration customers to return the car to the Raiffeisen Leasing GmbH (financing institution of the e-vehicles) after five years of use.

Throughout the project duration, 113 public charging points were established. In spring 2012, 29 further charging stations and three fast charging stations were built. The stations are situated at well accessible and convenient places like supermarkets car parks.

In 2010, the second phase of VLOTTE started, called *VLOTTE II*. It aimed at making electric mobility more accessible. Therefore, so called *e-stationen* (e-stations) were implemented, where e-vehicles, e-scooters and e-bicycles could be rented. The idea was to make e-mobility accessible for every third person in Vorarlberg. After two years this stage of the project showed that the offer was not accepted by the public.

VLOTTE III or *VLOTTE EMOTIONS* (start 2012) was the stage of VLOTTE where the *E-Mobilitätszentrale* (e-mobility centre) was established, positive awareness in the public was actively spread and impact studies were conducted to substantiate efforts at persuasion in politics and in business. The *E-Mobilitätszentrale* is a measure to develop a comprehensive range of consulting and technical services for e-mobility. It is also a

[28] https://sedl.at/Elektroauto/Akkus, last accessed 6 September 2017.

platform for automakers to present their models and their companies. Potential customers can consult the *E-Mobilitätszentrale* online, via phone as well as physically at the location of the illwerke vkw in Bregenz. As of 2014 the service is free of charge after the purchase of the *VLOTTE Mobilitätskarte*[29] (VLOTTE mobility card, 5€). There is no bias to a specific brand of car and it is possible to go on test rides. This project ended in late 2015, but is still operative.

Even though VLOTTE evolved from a demo project to a business, most of the technology is still in an experimental phase. Therefore, small demo projects are also carried out on the site of illwerke vkw. A business-oriented demo project is the EV car park at the head office in Bregenz, internally called *Hochgarage* (multi-storey car park), which started in 2015. A smaller scale and private-oriented demo project is the smart energy trial household, which started in 2011. Both projects are still running and the *Hochgarage* is today well-implemented in the day to day business. These projects are not only carried out due to testing purposes, but they also substantiate the credibility of illwerke vkw internally as well as externally in the public.

In *VLOTTE IV* or *VLOTTE MEET&CHARGE* e-mobility was further spread in Vorarlberg. In addition to the already established public charging points, e-parking at restaurants was built (*e-Gastro*). This phase of the project builds on experiences made in the former phases. Smart wall boxes with at least 11 kWh delivery rate fuel by green electricity were installed. It is financed by *Ökostrom für E-Mobile* (green electricity for e-vehicles) and a structure fee of the restaurant. The restaurant in return can charge their customers for the use of the e-charging stations. The first site was opened in September 2014. One year later already 13 sites have been opened. Further sites are already being planned (November 2016). Hotels and restaurants are generally of interest as e-mobility is gaining more and more significance in tourism. However, potential business partners are still not convinced and are under the impression of not being well informed enough of conditions and possibilities. Therefore, VLOTTE cooperated with the *Wirtschaftskammer Vorarlberg* (Economic Chamber Vorarlberg) and contacted 800 hotels as well as restaurants. Of the 800 potential customers, 38 decided to test one of the three packages illwerke vkw has on offer. For illwerke vkw hotels and restaurants are a future market opportunity. In October 2017, it was announced that VLOTTE is expanding to Salzburg. Here, charging infrastructure for hotels and restaurants is offered. The key products are customised solutions so hotels and restaurants can meet the e-mobility needs of customers and employees (Vorarlberger Kraftwerke AG 2015).

VLOTTE 2.00 is the most recent initiative. In this initiative commuters are the target audience. 125 e-vehicles for commuters were subsidised with EUR 4000 each. EUR 500.000 was the whole funding sum and it is a product of illwerke vkw. Until November 2016, 113 subsidies were handed out and 85 commuters have already received the funding. To simplify the communication between car dealers and illwerke vkw a new platform was programmed, where all relevant data is gathered.

The current and last phase VLOTTE is in shifted from a project-oriented to product-oriented program. When the first phase was primarily about testing the technology and finding interested customers, and the second phase was about the distribution and dissemination of e-mobility itself, the third phase is more business- and user-oriented. This means that illwerke vkw reacts to customers' needs and develops products induced by customers' demands. One example is the configuration company e-fleet. In this configuration, a business owner approached illwerke vkw with the demand to build public charging infrastructure on the company's car park, which is also the car park of a shopping centre. Hence, the installed fast charger belongs to illwerke vkw, can be used by customers that own a *vkw Mobilitätskarte*, but it is also in front of the company's office and therefore easily accessible by the employees.

[29] Not to be mistaken with the first *Mobilitätskarte*, that offered a whole e-mobility package. The second *Mobilitätskarte* only covers the information service as well as test drives.

2.3.2 Socio-technical Configurations

In our case study, we analysed the three configurations EV car-park, company e-fleet and smart energy trial household, which were all realised within the frame of the project VLOTTE.

The first configuration is a car park of illwerke vkw, where the company's e-fleet is charged. The second configuration is the e-fleet of an external company with a contracting fast charging point from illwerke vkw. The third configuration is a demo project and operates on the household level. All three configurations are still operational today and in the process of being further developed. The main socio-technical dimensions in each configuration are presented in Table 6 below.

Table 6. Socio-technical configurations in the VLOTTE (E-Mobility) project

	EV car park	Company e-fleet	Smart energy trial household
Technical elements	Car park with rooftop PV (60 kW peak) Converter Stationary battery (reused care batteries) Smart (interconnected) wall boxes Standard grid connection Company e-fleet with approximately 40 EVs Online reservation system	Company e-fleet with 15 EVs Fast charging point Strong grid connection Two wall boxes	Rooftop PV (5,2 kW peak) Converter and control unit Stationary battery (10 kWh) 2 Conventional chargers E-vehicle (16 kWh battery) Monitoring equipment and online tools (for the battery and the converter)
Social elements	Owned, operated, and used by the energy service company (ESCO) No contracts with external partners Demo project (now in regular use)	Contracting model (between the ESCO and the fleet owner) The fast charging station is open for the public Smaller wall boxes for internal use only Commercial solution	Private household (3 adults) Technical equipment owned by the ESCO (except PV) Subsidised feed-in tariff (till 2016) Contact person is employed by regional ESCO Company-internal research Informal agreement

EV car park

The first configuration is an internal project of illwerke vkw. The Hochgarage (high-storey car park) started as a demo project and is now in regular use. It is owned, operated and used by the company and continuously further developed. The technological elements are a car park with rooftop PV, a converter, a stationary battery (reused car ZEBRA-batteries), smart wall boxes and a standard grid connection. It all started in the year 2015 when illwerke vkw did a review of the efficiency of the company's own fleet of vehicles (how often cars are actually used, how many kilometres they are driven etc.). Today, every employee can book a car online, they have to type in where they are going and then the system assigns them a vehicle (both types of vehicles). Today, short distances are usually driven with e-vehicles. In the beginning, the fleet department had to monitor when which car was booked and for what distance. If a combustion car was booked for a short distance, the employee was contacted by the fleet department with the offer to change the selection from combustion to e-vehicle. This way, educational work was carried out as the employees were a little hesitant to choose an e-vehicle over a combustion car in the beginning. The introduction of e-vehicles and the smart booking system happened simultaneously but are not connected. However, the booking system eases the management of the e-vehicles for the fleet department. At the moment, the automakers have not shared the interface of the state of charge of the battery yet, so the battery cannot communicate with the system. Therefore, the user has to tell the system the battery status when returning the e-vehicle and the system automatically blocks the car for roughly one hour to ensure that the next user will find a fully loaded battery. The whole fleet at the car park site has roughly 60 cars, about 18 of them are e-vehicles (Renault ZOE). There are many more e-vehicles throughout the entire fleet, but these are assigned to specific employees. In total illwerke vkw has 35-40 e-vehicles available at different sites. Load management is the other challenge that needs to be tackled. The supply cable of the Hochgarage is quite generous, but not sufficient for the need of all 20 e-vehicles. As an expansion of the grid connection would require high investments, a smart load management strategy is implemented. The rooftop PV with 60 kW peak is also contributing to the power that is needed, but is not a key element of the configuration. The PV energy is stored in a stationary battery, which consists of two Zebra batteries of discarded Th!nk City e-vehicles. The vision is that the battery will be contributing to the load management, but it is still in an experimental phase of the project and not fully applied. The controller of the load management communicates with the wall boxes. There are two master wall boxes that communicate with the client wall boxes. A crucial aspect of the configuration is the smart, fair und grid-friendly distribution of power as the whole facility has a limited grid connection (it was decided at the beginning to avoid costly investments for a stronger grid connection in order to “simulate” real-world conditions). If several e-vehicles are charging at the same time, they are also all being charged at the same speed. Prioritising one vehicle over another is not implemented yet, but it is one of the next goals. Prioritising in this case would mean charging vehicles according to the immediate requirements (reservation ranking and planned routes). The automatic blocking of returned e-vehicles is just a temporary solution. However, the system tells the e-vehicle that it does not necessarily need to load with 22 kW when the battery is still half full and 11 kW would be sufficient. Generally speaking, the configuration works very well and the *Hochgarage* is also an ideal test site and will be continuously used as such.

Figure 19: Renault Zoes charging at the EV car park of illwerke vkw.

Company e-fleet

The company e-fleet is the most recent configuration, started in May 2016 and can be counted as one of VLOTTE's products. The company, which is a customer of illwerke vkw, has two sites in smaller municipalities in Vorarlberg and the fleet is based in the primary location of the business. The business owner decided that he wanted to transform the company's combustion fleet to an electric one. Several reasons supported this decision, such as his desire to boist the overall image of the company, tax reasons for both the employer as well as the employees, funding by the government and also environmental factors as the company has been active in several eco-projects in the past. The entry point into e-mobility and renewable energy was the installation of a rooftop PV two years before the transformation of the fleet. This rooftop PV has an output of around 1 MWh per year and started a transformation process towards green energy. The technical elements of the configuration are 15 EVs, a fast charging point and a strong grid connection. The EVs are leased from a car dealer the business has a partnership with and the fast charging point is part of the contracting model with illwerke vkw. There are also two wall boxes in the underground parking facility of the company. The reason why the e-cars are leased is that the technology is quickly evolving and buying such a technology is not of interest to them. In 2011, illwerke vkw contacted the company in the early days of the VLOTTE project and provided a Mitsubishi i-MIEV for a monthly lease, so this was not the first time the company had an e-vehicle in their fleet. The e-car was only used randomly as the employees were not happy with the model itself. During that time a charging point was also installed close by at the car park. Today, the e-fleet consists of ten VW e-Golfs and five Renault ZOEs. Both vehicles usually take between six and eight hours to load using the standard wall box. As it is a building company and therefore frequent travel is happening during the day, six to eight hours are not practicable in any case. Therefore, the business owner contacted illwerke vkw and asked them to build a fast charging point with 50-60 kW. The cost for a fast charging point is approximately around 30.000 €, which the business owner did not want to invest. Based on these aspects the contracting model evolved: illwerke vkw planned and built the fast charging point, the company provided the building ground and pays a monthly fee (between 600-700 €/month) that covers unlimited charging. The fast charging point is also open to public use. Overall, the business owner as well as the employees are satisfied with the transformation and did not make any negative experiences. Especially the employees who use the EVs on a daily basis are content and were surprised how well everything works. Key is a Good communication, coordination, and mutual help between the employees are key, as well as knowledge about when their colleagues need to use the fast charging point. A major concern they had in the beginning was about the range of the e-vehicles, but as the construction sites are mostly close by, and a construction manager roughly commutes around 160 km/day, the range of the current models is sufficient. However, they would not mind if they had to charge the vehicle less frequently.

Figure 20: Public charging station at the car park of the company e-fleet.

Smart energy trial household

The third configuration is a technical trial arrangement located in a private two family house in Vorarlberg. The trial was initiated and implemented by the regional ESCO (illwerke) as a spin-off activity of the VLOTTE project. The main focus of this trial was to gain practical experience with PV system, stationary battery systems and electric vehicles in a realistic use environment. The trial household has been selected from among the employees. The selected test site has been already equipped with a PV rooftop system (5,2 kW peak) at that time and the employee (contact person) was highly motivated to run the trial. The trial started in 2011 with the e-vehicle (Citroen C-Zero), and in 2014 the battery system was added. The local contact person still uses and monitors the technical equipment, main findings, however, have already been collected in the first two years. The technical elements of this configuration involve the rooftop PV system, a converter and a control unit, a large stationary battery system (10 kWh), monitoring and metering technology, a conventional charging device, and the e-vehicle. All equipment except the PV system is (still) owned by the regional ESCO. The homeowner did not have to pay any costs except for a very cheap rental of the e-vehicle. The trial household can use the devices without restriction and benefit financially from it. In return, the homeowner provides all data, actively participates in the project and guarantees the project owner unrestricted access to the facilities. These rules only are set out in an informal agreement. First and foremost, this arrangement led to a significant increase in the share of own electricity consumption. Before the battery had been installed, the household was able to consume 15% of the electricity from the own PV system on an annual basis. With the battery system this number rose to 40% (in the summer half-year, the household is almost self-sufficient at 98%). Within the trial period the household could not profit from this higher share of self-consumption due to an existing subsidized feed-in tariff. However, this situation has changed in the meantime, now only the first 3000 kWh per year are being purchased by the energy supplier at a high tariff (15 Cents per kWh) but it is too early to assess the economic impact of this change in the tariff system. The PV system, the stationary battery and the e-vehicle the technology work reliably with one exception – in the beginning of the trial an installation error caused an overvoltage that destroyed the inverter and the charger. The users did not have to adapt their daily routines to the technology at all as load shifting never was part of the trial. The e-vehicle worked well, but due to the very small capacity of battery and charger and because it was only used as a second car it had no considerable impact on the energy consumption pattern of the household. The project owner learnt a lot about the proper dimensioning of this technology and the knowledge which was gained has been incorporated into the consulting activities of the ESCO.

2.3.3 Discussion: Success and Outcomes

Seen from the perspective of the stakeholders the project is very successful. Starting with the organisation Kairos, which wanted to promote e-mobility in Vorarlberg to the federal government with their climate goals to illwerke vkw, who want to support the federal government in their sustainable development goals but also expanded their product line. The Climate and Energy Fund as a federal project funder wanted to pave the way for alternative modes of driving with the funding program e-mobility model region (*Modellregionen der Elektromobilität*) and has expanded their e-mobility region funding program. In terms of technology the project was very experimental in the beginning and therefore risky for both stakeholders as well as users. However, taking the risk has paid off and VLOTTE made the transition from an experimental project to a business model. At the moment, the range of e-vehicles is still controversially discussed and might be one of the reasons why some potential customers are still not convinced enough to purchase them. The company with an e-fleet solved this problem by leasing e-vehicles, which was also part of the early VLOTTE concept. Important aspects are the strong ties between the company and the regional government and the dedication of illwerke vkw to the topics renewable energy and e-mobility. New technologies are not only tested, but there is awareness within the company that trials should be run in the first place with participation of the employees instead of regular users. Therefore, the company can build up credibility and it is more likely to get support from the public. This is the case with the smart energy trial household. Here, not only the technology, but also different tariff models could be tested. These findings helped with the setup of new projects and business ideas. A concrete example in the trial household case is the development of the product “virtual storage”. In order to meet the customer's desire for more autonomy and at the same time to take into account the currently still very high costs of battery systems, customers can store their surplus solar power in a pumped storage power plant and purchase it later at no additional cost. Also, the company e-fleet is a successful business case. It was a direct spin-off of the VLOTTE project and the contracting has now been in use in other businesses as well. The business partner was an early adopter, but is still satisfied with the solution and is currently cooperating with illwerke vkw at one of the company's other locations. Furthermore, the internal project *Hochgarage* can be seen as being on the threshold from an experimental to a potential product. Subsidies were always beneficial as these motivated the customers to take part in the project. Financial incentives have been mentioned throughout the case as key factors.

The VLOTTE project and its implementation have shown that communication and interaction are crucial in this still experimental field. Businesses like car dealers are still very sceptical of EVs, but are important partners and need to be motivated. Furthermore, customers and potential users need to be approached. illwerke vkw did so by hosting events and offering communication platforms like the *Mobilitätszentrale*, where interested parties had the opportunity to discuss their concerns. The involvement of people is of general importance as they are usually more cooperative and supportive if they feel heard. These events also strengthened the social cohesion of EV drivers to organise their own events, drive in convoys to events and are generally very positive in their attitude towards e-mobility. This is not necessarily the case when the EV is a company car.

The regional aspect of the success of the project should not be underestimated. Even though the goal to become energy autonomous by 2050 is based on the EU's 2020 goals and Austria in general pursues similar goals, the federal government of Vorarlberg has been very supportive of experimental demo projects. Another aspect are the short driving distances in Vorarlberg on account of its spatial small size, that probably reduced some of the prejudices towards the range of e-vehicles and the progressive attitude of illwerke vkw as a state-owned company. It is questionable that a similar project in Lower Austria would be as successful as in Vorarlberg.

Overall, the success of VLOTTE can be summarised as follows:

Markets

- EVs have transformed from converting vehicles to serial models, which of course is not directly related to the project.
- However, in parallel to these developments, VLOTTE prepared a favourable and well-working environment for e-mobility including charging infrastructure expansion (e.g. region with the highest number of charging points per capita in Austria), a broad range of consulting services (e.g. tailor-made energy solutions), new business models (e.g. public-private charging station) and products (e.g. virtual electricity storage).
- The expansion of VLOTTE to Salzburg is also due to the successful implementation of e-mobility in Vorarlberg.

Actors

- A significant part of the success lies in the strong connection between illwerke vkw and the federal government. As a consequence, political visions directly influence the strategic orientation of the company (and vice versa).
- Furthermore, the ESCO usually runs trials internally before reaching out to the public, which fosters the credibility; this was the case with the trial household as well as the *Hochgarage*.
- Moreover, the cooperation with customers and the meeting of customers' demands also works very well; as seen in the tailor-made company e-fleet solution. The project owner is still enthusiastic about the topic and is constantly working on new related projects and products. They are working together with other

actors like funders and potential customers to adapt their products to the existing needs and demands.

Technology

- The technology has proven that it works.
- In case of the EVs the range is still a limiting factor, but the technological progress in this area is rapidly advancing.
- Load management in the *Hochgarage* works well and helps to charge a larger number EVs in an efficient way. E-vehicles are charged when needed and at the same time additional financial investments in network infrastructure could be avoided.
- Based on the practical experience, a series of new ideas for further improvements of the tested solutions have been developed, some of which have already been taken up, such as the prioritised charging in the car park or the integration of the second life battery.
- The main focus in this case is on the integration of existing technological options to well-working solutions.

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