Determining factors for integrated smart energy solutions

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About ERA-Net Smart Energy Systems and MATCH

ERA-Net Smart Energy Systems (ERA-Net SES) – formerly ERA-Net Smart Grids Plus – is a transnational joint programming platform of 30 national and regional funding partners for initiating co-creation and promoting energy system innovation. The network of owners and managers of national and regional public funding programs along the innovation chain provides a sustainable and service oriented joint programming platform to finance projects in thematic areas like Smart Power Grids, Regional and Local Energy Systems, Heating and Cooling Networks, Digital Energy and Smart Services, etc.

Co-creating with partners that help to understand the needs of relevant stakeholders, we team up with intermediaries to provide an innovation eco-system supporting consortia for research, innovation, technical development, piloting and demonstration activities. These co-operations pave the way towards implementation in real-life environments and market introduction.

Beyond that, ERA-Net SES provides a Knowledge Community, involving key demo projects and experts from all over Europe, to facilitate learning between projects and programs from the local level up to the European level.

www.eranet-smartenergysystems.eu

The *Markets, actors, technologies: a comparative study of smart grid solutions* (MATCH) project runs from February 2016 to October 2018 and is supported by ERA-Net SES.

https://www.match-project.eu

Improving energy efficiency and replacing fossil fuels with renewable energy are among the most important measures on the road to a sustainable energy system. This implies new ways of generating and consuming energy as well as new forms of relations between the energy producers and consumers. The MATCH project contributes to the shift to a carbon-neutral energy system by zooming in on the changing roles of small consumers in the future electricity system (the "smart grids").

The overall objective of MATCH is to expand our knowledge on 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. The study is cross-disciplinary and based on detailed studies of current smart grid demonstrations in Norway, Austria and Denmark. Through comparative analysis across cases and countries, the study identifies key factors related to technology, market and actor involvement in developing integrated solutions that "work in practice". This is addressed in this report.

1 Introduction

The aim of this WP is to identify and discuss critical factors related to market, technology and actor-involvement that are decisive for designing integrated smart grid solutions for small consumers that work under real-life settings. The comparative analysis is based on the findings of WP2 and involves additional data analysis where necessary.

Identifying critical factors in real-life constellations help to better define and understand the success of 'working solutions' across cases and national contexts. In the three country case studies, presented in WP2, we describe and explain various solutions for integrated smart energy systems in a comprehensive way. In each of the nine projects we were able to identify a number of different solutions and described them as socio-technical configurations. These configurations had been developed within different national, regional and project specific contexts. They 'work' – at least – within these specific local contexts and the applied case study research attempted to understand the working of the various solutions as integrated parts of these different framings and frameworks. In generic terms, these socio-technical solutions work successfully, because relevant actor groups – through interaction between actors in local-situated networks – to a certain degree have been able to define, set up and test these solutions in real-life settings.

Based on the detailed but hitherto separate isolated analysis we now aim to go beyond these findings and try to compare cases, projects and configurations across countries. Although the analysis aims to find general patterns, the results are sensitive to the local context of smart energy systems solutions.

Comparison in the social sciences is a highly contested approach, located between two radically different epistemological positions. On the one hand, we have methodological positivism, assuming that the comparative method will help us to uncover universal (social) laws. On the other hand, there is methodological relativism, stressing the importance of local contexts in understanding the meaning of particular human beliefs and activities (Deville et al. 2016).

However, as the new term 'comparative relativism' indicates, there indeed are efforts to deal with this seemingly paradox in a productively way (Jensen 2011). Picking up this discussion, Krause (2016) has argued that the social sciences should be more open to less restrictive forms of comparisons. Comparative approaches have more to offer when they aim for other than the traditional linear-causal forms of explanation as postulated by positivistic positions. Krause assumes that the rule to only compare 'like with like' does not longer hold "when all things can be described in terms of both similarities and differences" (Krause, 2016: 57). From this point of view description takes on a central role in any comparative study. With such a concept of social scientific comparison approach, we aim to contribute with comprehensive description, concept development, and critique, and thus attempt to provide comprehensions that distinguish from conventional explanations. As a consequence, research strategies may imply the use of different kinds of comparison, ranging from what Krause calls 'like with unlike comparisons', to 'asymmetrical comparisons', to 'hypothetical comparisons', or even to 'undigested comparisons'.

Informed by those description-oriented forms of comparison this report aims in the first place to provide a brief overview of the nine case studies and their respective national contexts. What problems are addressed by the studied projects? What kinds of solutions have been developed? What differences and similarities between countries, projects and solutions do we see? What kind of patterns can we observe? And finally: How was success framed and configured on the project level and what can we learn when we analyse and compare different constellations of context-depended cases? These and other questions will help us to identify clusters of solutions and critical factors that are relevant for further in-depth analysis. The following section will give an overview of the cases' national contexts: Austria, Denmark, and Norway and will discuss relevant national characteristics in direct comparison.

2 Three national contexts in comparison: Austria, Denmark and Norway

Austria, Denmark, and Norway are all three countries that are heavily influenced by regulation set in the European Union; either as members (Austria and Denmark) or as an associated country (Norway). Especially, common market and environmental protection regulation influence national laws and regulations with regard to smart grids. Nevertheless, the three countries differ on significant contextual determining factors such as e.g. geography and social conditions (Table 1). For instance, when it comes to area-size, Norway is by far the largest of the three countries. Both, Austria and Norway are very mountainous and can therefore profit from the use of hydropower. Further, in opposition to Austria, Denmark and Norway have long coastlines. Also, especially Norway has – due to its location in the northern hemisphere – longer days with a lot of daylight during summer and considerable shorter days in winter. In Austria, due to the more southern location, the variations are less intensive. Also differences according to dwellings are substantial. While Austria has a strong renting tradition, which makes only half of its population live in self-owned houses, more citizens in Denmark live in their own detached houses, and this is by far the dominant form of living in Norway.

Table 1. Country specific factors

	Austria	**Denmark**	**Norway**
Size	83,879 km^2	43,000 km^2	323,802 km^2
Population (Million)	8.77	5.73	5.26
Density (pop/km²⁾)	104.6	132.6	16.2
Geographic Profile	Mountainous/forests	Long coastline & many islands	Mountainous/long coastline
Daylight	8.5 h (winter) 16 h (summer)	7 h (winter) 17 ½ (summer)	In northern parts: neglectable in winter, plenty in summer. Southern parts: similar to Denmark
Housing Situation	55 % homeownership	62.7 % homeownership	82.8 % homeownership
Mean and median income by household in € 2016	23,694	28,659	39,569
Total Government debt/ GDP 2016	84 %	40 %	33 %
Industry share of GDP	26.87 % (2005) 27.74 % (2016)	30.54 % (2005) 23.48 % (2016)	44.48 % (2005) 31.96 % (2016)

Economically, Norwegian households have a considerable larger median income than both Danish and Austrian ones. Similarly, Norway has the smallest debt/GDP ratio, followed by Denmark and then (being double of the Danish one) Austria. In Norway, industry plays a large role for its economy, although it is declining. In Austria this importance is slightly less, but still considerable. In Denmark, industry has the smallest role amongst the three countries. Both Denmark and Norway experienced loss of importance of industry in the last 20 years, while industry-importance slightly increased in Austria.

Notably, the different geography of the three countries influences their choice of energy use substantially (Table 2). Noteworthy are here Norway's **fossil energy resources** that are one of the cornerstones for its wealth. In Denmark, fossil energy resources (oil and natural gas) are also playing an important role both for export and for domestic consumption, while in Austria fossil energy resources are neglectable. While Norway has vast amounts of fossil resources it does not consume them as energy, but exports them as a product. Conversely, Norway produces electricity through hydropower and exports some to neighbouring countries. While Denmark is more or less self-sufficient, Austria is a clear energy importer. In Austria, the expansion of wind power has already reached a relevant level. Both Austria and Norway profit from their mountainous landscape, which allows them to use pumped hydro storage. Hence, Denmark uses indirectly the Norwegian storage capacity.

Table 2. Energy regulation: sources, production and consumption etc.

	Austria	**Denmark**	**Norway**
Fossil energy resources	No	Yes, but decreasing	Yes
Energy Importer/ Exporter	Importer	Almost self-sufficient	Exporter
Total electricity production 2017	70.100 GWh	33.716 GWh	148.400 GWh
Solar in electricity production	1.5 % (2015)	2.1 % (2015)	0 % (2015)
Wind in electricity production	7.4 % (2015)	42.1 % (2015)	1.7 % (2015)
Storage	Pumped hydro	Miscellaneous	Pumped hydro
Household heating sources	30 % wood and pellets, 21.5 % gas, 20.7 % oil	64 % district, 25 % oil or natural gas	Electric, supplemented by biomass/stoves
CO_2 Emissions per capita	7.4 t/y	6.7 t/y	11.7 t/y
Share of passenger cars being electric vehicles	0.3 % (2017)	0.4 % (2017)	20.8 % (2017)

Electricity plays an important role in all three countries. However, in Norway electricity production is considerably larger than in Austria, which simultaneously is twice as large as in Denmark. The influence of renewables, however, varies significantly. Electricity based on wind is the dominant form in Denmark, followed by Austria and with almost negligible quantities in Norway – even though it is increasing. Wind-based electricity plays a substantial role for the Danish electricity production, accounting for 43 % of the total energy supply (in 2017).

Households in Austria and Denmark use mostly central **heating**, and with regard to source of heat, households in Denmark rely mostly on district heating. In Austria, the main source of heating is wood and pellets followed by gas and oil; district heating accounts only for 21 %. In Norway, electric heating plays a major role, which is also visible in Norway's electricity production. CO_2 emissions in Norway are also slightly larger than in both other countries. With regard to **electric vehicles**, Norway has by far the largest share of newly registered electric vehicles, followed with some distance by Austria and with a neglectable uptake in Denmark. In Norway, regulation and subsidies favours heavily the purchase of electric over conventional vehicles.

In Austria central **policy actors** are federal and regional agencies together with small and medium sized companies and transnational corporations (Table 3). In Denmark central policy actors are mainly on the national level. The Ministry of Energy, Utilities and Climate is the main policy actor, while funding in research and development is mainly provided by national funding programs (e.g. the Energy Technology Development and Demonstration Programme, EUDP, and the Innovation Fund) and supported by SMEs and transnational corporations.

In Austria, the research policy and related programs are the main drivers for Austrian smart grid initiatives (e.g. e!MISSION.at – Energy Mission Austria). Conversely in Denmark, the driving policy papers are Danish Smart Grid Strategy and, more broadly, the Energy Strategy 2050. Both strategies are addressing climate change and energy independence based primarily on domestic renewable energy. In Norway the driving policy for smart grids is both research and energy policy.

Climate policy has a central influence on Danish and Norwegian smart grid initiatives and is binding through agreement on European Economic area. In Austria however, although also bound to the same climate agreements, they do not have substantial practical influence over local political decision-making.

Local government and municipalities play a crucial role for the success of Austrian and Norwegian projects. In Denmark, the local governments are not in general playing a central role, except in relation to district heating, although some municipalities have developed specific strategies to achieve climate neutrality etc. within the coming 10-20 years – and in some of these municipalities, the activities also include smart grid related activities (in addition to traditional measures such as energy savings and/or installing new RE capacity).

For all the three countries, **research actors** are a combination of PPP, universities, research institutes, and industry companies, and public funding agencies.

The **smart metering** landscape differs between the three countries. While all three have specific targets for 2019 that include an almost fully complete cover of smart meters (in 2020 in Denmark), the actual roll out differs significantly. Denmark's rollout is well on the way, while Austria lags behind in reaching the set target. The progress reported by mid-2017 in Norway was 6 % slower than expected at the beginning of the year. The Norwegian plan is highly ambitious, as it demands for a complete smart metering rollout in households by 2019. Also, the Water and Resources and Energy Directorate has made smart meters obligatory.

Table 3. Overall policies and regulation and local initiatives supporting the national smart grid landscapes

	Austria	Denmark	Norway
Central Policy Actor for Smart Grid	Infrastructure Ministry and regions provide major funding together with SMEs and TNCs	Ministry of Energy, Utilities and Climate, national funding programs and SMEs and TNCs	The Norwegian Water Resources and Energy Directorate has made smart meters obligatory.
Driving National Smart Grid Policy	Research Policy	Climate and Energy Policy	Research and Energy policy
Binding Climate strategy	Binding through agreement on EU Area, no legal implementation at national level	Binding through agreement on EU Area (distribution by countries)	Binding through agreement on European Economic Area
Local Government	Municipalities and regions play central role	Municipalities and regions play a limited role	Municipalities and regions are central
Research Actors	Platform with industry and research institutes	Universities, institutes and industry in both classical energy and ICT central	Universities, institutes and industry in both classical energy and ICT central
Smart metering target	Infrastructure by 2019 of 95 %	Infrastructure by 2020 of 100 %	Infrastructure by 2019 of 100 %
Meters Installed 2016	8.5 %	More than 50 %	(Mid 2017) 31 %, 57 % before end of 2018 (exp.)

The market structure shows strong differences between household electricity prices (including taxes) in the three countries (Table 4). Noteworthy is hereby the much higher price for Danish households in comparison for those in the other countries. In contrast, electricity prices for non-households are similar in all three countries and notably lesser than prices for households.

All three countries show a high share of public ownership of the **power production** capacity and grid operation, which ensures a high level of control by public actors. However, in Denmark, the ownership of the power production capacity is divided between two major private companies (the Danish Ørsted and the Swedish Vattenfall) owning the large coal or gas-fired CHP plants and much of the wind power capacity, on the one side, and about 250 decentral CHP plants typically owned by local municipalities or as co-operatives owned by local customers (on the other side).

In all three countries **distribution system operators** are a mix of public-owned, co-ops and private companies, with a predominance of municipal actors in Denmark and Norway.

Austria's **energy market** is generally liberalized, but still dominated by incumbent, partially public, regional utilities, which still divide their commercial area amongst themselves. Similarly in Norway, while it was one of the first countries to fully liberalize electricity markets, it is still dominated by partially municipally owned utilities and long-standing relationships with local customers. In Denmark, the market has also been liberalized, but with a low entrance of new companies and the incumbent companies (partly municipal-owned, partly co-ops and private companies) still being the main actors and maintaining their local customer-base (established historically).

Table 4. Overview of the energy market structure

	Austria	**Denmark**	**Norway**
Electricity prices HH 2017s1 first of half year	0.195 €/kWh	0.305 €/kWh	0.164 €/kWh
Electricity prices non-HH 2017s1 first of half year	0.093 €/kWh	0.082 €/kWh	0.071 €/kWh
Public Ownership of power production capacity	high	Partly public (state and municipalities) or local co-ops.	high (around 90 %)
Distribution system Operators	Mix of state-, federal, municipal-owned and private companies	Mix of municipal-owned, co-ops and private companies	Mostly (partially) owned by municipalities, regulated by government regulator
Liberalization of energy market	Liberalized, but utilities are traditionally regional bound through partial regional government ownership and local customer base	Liberalized, traditionally regional bound through local customer base	One of the first countries to fully liberalize Electricity markets

In summary, this brief comparison shows that the three case study countries differ in many ways and in some respects quite considerably from each other. There are clear differences regarding demography, economic conditions, natural resources, geography and climate. Existing energy systems and the legal and political framework conditions for the development of smart energy systems are at least as diverse. As we will see in the following section, these clearly different contextual conditions also have a significant influence on the type and actual design of the solutions investigated in more detail in the MATCH project.

3 Projects and solutions in comparison

This chapter provides a brief overview of the nine projects and all studied ‘solutions’. The aim is to show differences and similarities in our total ‘sample’, and based on this overview, we hope to find a number of possible ‘clusters’ of solutions which are suitable for comparison. At least some of the characteristics of the selected solutions should be similar (e.g. similar target group, similar technology, similar project aim).

The cross-national sample of projects to some extent represent the great variety we actually see in field of smart energy systems innovation in Europe (Table 5). Our nine projects differ regarding the phase of the innovation process, which technologies are used predominantly and also which key actors are involved in the activities. However, projects usually focus on more than one topic as innovation activities in all our cases are inspired by the idea of combining technologies, services and sectors in new constellations.

Table 5. Overview of projects: Description, key actors and innovation phase

Country/ Project	Description	Key Actors	Phase of Innovation
Austria			
Köstendorf	Pilot and demonstration project with smart distribution grid field test	Regional DSO&ESCO, research institute, industrial group	R&D
Rosa Zukunft	Pilot and demonstration project with Building-to-grid solution and DSM field test	Regional DSO&ESCO, research institute, housing association	R&D
VLOTTE	E-mobility business implementation	Regional DSO&ESCO	R&D, Product development
Denmark			
Innovation Fur	Piloting and demonstration of balancing local energy exchange at the community micro grid level	DSO & Municipality	R&D
ProjectZero	Promote and facilitate energy efficient measures and local renewable energy to decarbonize consumption	DSO, regional Bank-Fund, Municipality	Local energy transition
Samso Energy Academy	Community participation project to increase energy autonomy of the island	Dedicated Organization for project implementation	Local energy transition
Norway			
PV demo Trondelag	Two related regional PV demonstration projects	Two regional DSOs	R&D
Smart Energy Hvaler	Testing the potential for balancing the local grid	Regional DSO, Municipality, University	R&D
ASKO midt-Norge	Business implementation using PV excess for decarbonisation of fleet and for on-site electricity use	Large grocery wholesaler	Technology/ product development

1.1 Phase and type of the innovation

The projects are situated in different innovation stages. Some are mainly organized around R&D activities, some apply a company specific innovation and development focus (closer to working business cases), and others, however, manly focus on the implementation and dissemination of already proven and available solutions. In our sample there are essentially three groups:

Projects with a main focus on R&D: Some projects focus mainly on R&D (Köstendorf, Rosa Zukunft, Innovation Fur, PV demo Trøndelag, Smart Energy Hvaler). They run test trials, set-up pilot projects, test new configurations, and aim at technology learning (new knowledge, practical know-how, e.g. to improve or complement their own product portfolio).

Projects with a main focus on technology and/or product development: Two projects belong to this category (VLOTTE and ASKO midt-Norge). Although these two projects differ regarding their history, today they focus mainly on the development of new solutions in the mobility sector (smart e-mobility infrastructure, hydrogen company fleet).

Projects with a main focus on a local energy transition: Two projects mainly aim at driving a local transition process towards a low carbon society (ProjectZero, Samso Energy Academy). In these examples a strong local actor develops a kind of holistic strategy to initiate change in a wide variety of sectors to achieve ambitious environmental and climate targets. Here the focus is on implementation and dissemination of effective solutions; why technology development, learning and knowledge production is less important.

1.2 Applied technologies

Except for one case all projects in our sample deal with PV systems. Some of them focus on the integration into the local grid (Köstendorf, Innovation Fur, PV demo Trøndelag, Smart Energy Hvaler). Some others try to learn more about the combination of PV systems, heat pumps and batteries on the household level (Köstendorf, VLOTTE, Innovation Fur). Another focus is on the combination of PV systems and e-vehicles (Köstendorf, VLOTTE). And a few projects use PV systems in an already tried and tested manner without a special research focus (Rosa Zukunft, VLOTTE, ProjectZero, ASKO midt-Norge).

Smart grid infrastructure technologies are involved and tested in several projects (e.g. Köstendorf, Rosa Zukunft, VLOTTE, Innovation Fur, PV demo Trøndelag). ICT systems, smart meters and similar information technologies are used to balance loads or to reduce the cost for infrastructure investments. Demand response and energy feedback on the household level, as an additional example of this area, was part of the test trial in the city of Salzburg (Rosa Zukunft), in Hvaler (Smart Energy Hvaler) and on Fur (Innovation Fur).

In several projects heat pump technology is used to consume surplus electricity from renewable sources (e.g. Rosa Zukunft, Innovation Fur) and store it in form of heat energy for later use.

E-vehicles are involved in three projects (Köstendorf, VLOTTE, Smart Energy Hvaler) and one project each deals with hydrogen technology for vehicles.

1.3 Key actors and main target groups

Main project owners in most cases are local or regional DSOs/ESCOs. Two projects are led by dedicated organisations created specifically for the implementation local energy transitions (ProjectZero, Samsø Energy Academy), and, in one particular case, the project is led by a company from outside the energy sector (ASKO midt-Norge). In addition to these main actors, several other partners and clients are involved in the implementation of the various solutions of the projects (e.g. research partner, local companies, municipalities).

In four out of nine cases, private households are the main target group of the activities. In these cases, householders are addressed in several roles, as consumers, end-users, prosumers, and field-test participants. Three projects deal with mixed target groups, usually addressing private households, local companies and public authorities as customers. In two cases the main target group are SMEs and their own staff (VLOTTE, ASKO).

For a detailed analysis of the success of the applied solutions, however, it is necessary to identify several 'clusters of solutions'. This is the aim of the following section.

Table 6. Overview of projects: Applied technology and main target groups

Country/ Project	**Applied Technologies**	**Main Target Group**
Austria		
Köstendorf	Local grid PV integration, combination of PV systems and batteries, PV systems and e-vehicles, testing smart grid Infrastructure	Households, SMEs, public authorities
Rosa Zukunft	PV systems without research focus, testing smart grid infrastructure, household level DR and energy feedback, heat-pumps, CHPs	Households
VLOTTE	Combination of PV systems and batteries, PV systems and e-vehicles, PV systems without research focus, testing smart grid infrastructure	SMEs & employees
Denmark		
Innovation Fur	Local grid PV integration, combination of PV systems with heat pumps or/and batteries, testing smart grid infrastructure	Households
ProjectZero	PV systems without research focus, EVs and heat pumps as well as "smart" building energy renovations to achieve higher energy efficiency	Households and SMEs
Samsø Energy Academy	Testing potentials for reduce energy demand by regulate temperature and install energy efficient equipment (energy efficiency measures)	Households and SMEs
Norway		
PV demo Trøndelag	Local grid PV integration, testing smart grid Infrastructure	Households
Smart Energy Hvaler	Local grid PV integration testing demand response and impact of smart technologies as PVs and e-vehicles	Households
ASKO midt-Norge	PV systems without research focus, hydrogen generation, hydrogen driven trucks	SMEs & employees

1.4 Clusters of solutions

A 'cluster of solution' consists of at least two working socio-technical configurations applied in two different projects (see tables 5, 6 & 7). At least some of the characteristics of the selected solutions should be similar (e.g. similar phase of innovation, similar target group, similar function, or similar project aim). These similarities should provide for a more stable basis for comparison and allow for the discussion of aspects and patterns that help to better understand the success across projects and solutions.

Table 7. Overview of studied socio-technical configurations (solutions)

Country/ Project	**Solution 1**	**Solution 2**	**Solution 3**
Austria			
Köstendorf	Smart distribution grid with vast PV generation	PV, EV & home battery	100 % renewable household
Rosa Zukunft	Building-to-grid	Energy feedback & DR	EV sharing
VLOTTE	PV & EV car park	Company e-fleet & fast charging point	PV, EV & home battery
Denmark			
Innovation Fur	PV & home battery	PV & heat pump	No other configuration
ProjectZero	Households (Zerobolig)	Sport centres (ZERO sport)	Shops (ZERObutik)
Samsø Energy Academy	Energy savings in local business	No other configuration	No other configuration
Norway			
PV demo Trøndelag	PV in private homes	No other configuration	No other configuration
Smart Energy Hvaler	SEH participant with solar PV (11/15)	SEH participant without solar PV (4/15)	No other configuration
ASKO midt-Norge	Large on-site PV sys-tem	PV, hydrogen production & hydrogen trucks	No other configuration

Combining main functions of the studied solutions and similarities regarding target groups and organizational set-ups, we were able to identify the following clusters, which will be analysed in more detail below (chapter 4):

- **Balancing generation and demand:** The main focus here is to better deal with variable renewable generation. The more renewable energies that are being developed, the greater demand for such solutions. The studied projects applied and tested several strategies for matching supply and demand, ranging from energy feedback & DSM (Rosa Zukunft) to smart charging (VLOTTE), the use of heat pumps and batteries at the household level (Innovation Fur) and the use for cooling or hydrogen production (ASKO).

- **Renewable powered company fleets:** In two of our cases the activities focus on the development of solutions that aim to convert vehicle fleets to renewable energy sources. In both cases these activities are in-house developments aiming first of all at the companies' own needs. In the VLOTTE project a regional DSO develops a smart e-car park; in the ASKO case a large grocery wholesaler establishes a hydrogen infrastructure for hydrogen-powered commercial vehicles.
- **Comprehensive energy concepts:** The aim of the approaches in this cluster is to provide complete solutions to achieve a maximum in terms of energy saving and use of renewables. The focus of our examples is on households (100% renewable household in Köstendorf), apartment buildings (Rosa Zukunft), supermarkets (Samsø, ZERObutik), and sports facilities (ZERO sport) – in some examples as part of a regional energy transition plan (Samsø and ProjectZero). In all these cases a number of technologies, rules and practices work together in a custom-made manner to achieve ambitious energy targets. In addition to various technologies, precise planning and consulting are of great importance in this cluster.

An additional topic for cross-country, cross-project and cross-solution comparison is user integration. We may assume that users are of great importance in all our cases. A cross-case analysis should therefore offer an additional perspective on the success of the solutions. This issue will be addressed in a separate analysis (chapter 4.4).

4 Successful solutions in comparison

In this chapter we aim to analyse a couple of selected solutions in comparison. The aim is to better understand the 'success' of solutions. This part of the report should provide a more detailed discussion what success means in the projects of a selected cluster, how it is defined and by whom. So far, success was defined as 'the working' of solutions in practical settings. A working solution provides a service making value for e.g. the grid, customers, and environment. In the following we attempt to broaden this definition a bit, as some of the solutions do work well as part of a research project, but did not end up as a (marketable) product or a working business case. Other solutions are better characterized as a successful experiment rather than a solution. In those cases 'success' means that actors were able to keep the development running (keep the building of the configuration running) and coming up with useful conclusions. Thus, while the socio-technical configuration of the solution might not be transferable, other elements of the innovation processes might be.

There are a several characteristics that seem necessary, but not sufficient to make the success of a solution. For example, the solutions in the project fulfil the aimed function for a project at its innovation stage. They are adapted to country conditions such as geography, market conditions, policies and regulatory frameworks. In addition, the specific solutions meet local conditions. Also, the involved actors such as project partners work well together and customers or other stakeholder are successfully addressed by the socio-technical configuration.

According to this, chapter 4 is a compilation of four cross-case comparisons. Each of these comparisons follows a similar structure, including (1) a short description of selected solutions (including arguments why a comparison make sense), (2) a discussion of how success is defined (by whom) in each of the selected solutions, and (3) a discussion of patterns (factors) that help to understand success across cases and solutions.

4.1 Balancing generation and demand using solar PV and storage

4.1.1 Introduction

The underlying assumption for solutions in this section is that installing production capacities at sites of consumption can contribute to reductions in peak demand, thus providing grid operators with leverage capabilities in balancing the grid. In some cases herein, distributed generation is a customer driven phenomenon and has driven grid operators to organize trials to gauge the effects of the introduction of local generation on the grid. Various solutions that have proven capable of balancing generation and demand will be presented. In short, they are characterized by utilizing residential rooftop solar PV panels and, in some cases, storage capacity in terms of a battery and/or the use of thermal capacity (heat pumps and boilers). As several of the studied solutions included economic incentives to support active demand response (i.e. time shifting loads), this will also be commented on in the following analysis.

The socio-technical constellations having to do with balancing generation and demand examined in the MATCH-project were comprised of four solutions with similar characteristics. The solutions are summarized as follows:

1. Households with solar PV (Trøndelag PV).
2. Households with solar PV & heat pumps (Smart Energi Hvaler, Innovation Fur/GreenCom).
3. Households with solar PV & battery (Innovation Fur/GreenCom, Köstendorf, VLOTTE).
4. Large scale solar PV & storage/heat pumps (Rosa Zukunft)

Solutions 1-3 are centred on private customers, or households, with small-scale (~3-5 kWp) solar PV panels, which can be utilized during peak production to charge in-house batteries, heat water, and run heat pumps. Load shifting these appliances can contribute to reducing capacity peak demand or local aggregated energy demand in general. The fourth solution described in this chapter is focused on the same goals but deployed on the scale of large housing complexes. All solutions introduced a form of visualized feedback mechanism, such as in-home displays or a web application, providing real time information on production and consumption, as well as cost variation. However, these were implemented and utilized to widely varying degrees across cases.

The first solution, involving households with rooftop solar PV, is covered in one of the Norwegian cases, Trøndelag PV. This is an example of a "bare minimum" case, in which simply installing and testing the PVs in the grid was the main goal. The motivation of the energy companies in charge was to drive business development processes regarding solar PV for the private market, and to gather experience in this area for all parts of the corporation (both were integrated energy companies). From the perspective of the grid operator, the aim was to meet changes in market demand constituted by increased shares of small-scale renewables and the necessary digitalized capabilities associated with handling such developments. From a market and business point of view, the company aimed to develop market models associated with micro-generation, which were thought to become more relevant in the future. In other words, this case was predominantly customer driven. The costumers' motivation for participating was most of all characterized by an environmental concern and self-identification as taking part in a technological vanguard for solving those concerns.

The second solution, including households with PV and heat pumps, was found in the case of the Smart Energi Hvaler (SEH) energy technology pilot in Norway and in the case of Innovation Fur (GreenCom) Denmark. Compared to solution 1, the cases employing solution 2 show an added level of sophistication in a variety of ways. More effort was devoted to adding visualized feedback mechanisms and some degree of automation capability, which contributed to making localized PV production more useful than in cases where there is no automation linking production with consumption. Automation can aid customers to practice load shifting by linking local production with consumption, making sure they happen at the most fortuitous times for grid balance purposes and for the customer, in relation to overall demand and market prices.

The third solution, featuring batteries in conjunction with PV production, was found in three cases, the GreenCom demo in Denmark, in the Austrian projects Model Village Köstendorf, and VLOTTE. In the case of GreenCom, batteries were operated in tandem with PV production aided by an intelligent storage system. Taking into consideration possible future low-voltage grid capacity problems, the aim of the project was to explore new methods of balancing exchange of energy at the local micro-grid level (e.g. by increasing self-sufficiency) in order to increase regulation capacity and reserve power. However, even though promising results in terms of load-shifting of some energy consuming practices in the households, the trial showed that the already existing grid capacity in the area is already more than ample to accommodate future increases in electricity demand and fluctuation from electric vehicles and more heat pumps. Secondly, The DG DemoNet Smart Low Voltage Grid project, situated in Köstendorf together with the LEAF project, implemented battery storage in a wide range of field tests involving already existing configurations of households with rooftop PVs. The aim of this project was to explore new tools for grid stabilization and learning about systemic implications of prosumer households for the grid. Finally, the VLOTTE project, though mainly focused on company fleet scale e-mobility, also feature a smart energy trial household consisting of a two-family home with rooftop PV panels and a battery (10 kWh). The battery installation has shown promise, as the families increased their PV self-consumption from 15 % to 40 % (and even up to 98 % in summer).

The fourth solution is technically similar to the three previous but differ in terms of scale, scope, and configuration. The HiT ("houses as interactive parts of the grid") Rosa Zukunft project features 8 apartment complexes with 129 units and an ambition to implement a scenario where entire buildings can be intelligent actors in the grid. It showcased a central Building Energy Agent (BEA) interoperating with the large-scale rooftop PV (72 kWp). This part of the project was highly automated in nature and relied to a large degree on end-users being entirely passive, while the building (and, not to forget, the building operators) intelligently maintained operational aspects of the system. In addition, 33 of the 129 apartments participated in a one-year demand response test trial. In this case a variable tariff was introduced under special approval by the regulator and the variability was communicated to the users via the in-home displays.

4.1.2 Outstanding qualities of the selected solutions

Solution 1 - Households with PV

As mentioned, solution 1 was found in two demonstration projects in Trøndelag, Norway, both of which were solar PV trials undertaken by the region's two leading energy company/DSOs, TrønderEnergi and Nord Trøndelag Energi (NTE). Due to the similar characteristics of these two projects, these two demo projects were merged into a single case within the MATCH study.

In both cases, a marketing campaign advertised for prospective solar PV end users, and in both cases, the response from interested households was massive. This resulted in a total of 30 households selected to trial based on how suitable their characteristics were for solar PV production. 11 of these were interviewed for this study, all of which had been provided smart meters, rooftop PVs, and access to data about production and consumption through a web and mobile application. The PVs were provided as a packaged deal, where the households purchased the installation – either outright or through regular down payments (with ensuing interest) over 15 years. Participants are contractually obligated to the energy company's energy provider for 15 years, during which time the company is responsible for service and maintenance. Moreover, for this period the participants signed a contract to become prosumers, or so-called "plus-customers", and any surplus energy generated by the PV panels would be sold back to the grid and the electricity provider at spot price.

In the spring of 2017, NTE introduced a small feed-in-tariff of a few NOK cents in addition to the spot price. However, this amount was a rather insignificant addition to the already insubstantial Norwegian spot price (The spot price hovered around €0.05.). Additional subsidies for the PV installation itself were available upon submitting an application after they have been purchased through the Norwegian energy agency, ENOVA. (The current support program is available for anyone with a new solar PV installation. The support provides a flat sum of about €1,000 and €125 per kW capacity installed.)

From the perspective of the grid operator, the project has thus far been quite successful. Finding participants and recruiting them was unproblematic, as there was ample interest among the general populace for joining such a project. For the purpose of testing for grid implications of micro-generation, that goal was met; although what exactly was learned by this demo was too early to say at the time of study. At any rate, it was established that the grid would accommodate micro-generation capacity and the operator had few large problems from this new and intermittent source of energy. From the view of the end users, participation in the project was experienced as mildly successful, but bore signs of constituting a surplus project for the ones involved. This means that participation is probably dependent on a relatively stable life and economy, being a home-owner at the very least, as the immediate financial gains of being a plus customer without a feed-in-tariff are not very large. However, end users achieved success in fulfilling personal ambitions related to environmental concerns and early technology adoption, concerns that seemed to have an important role alongside monetary remuneration upon making the investment decision.

In summary of Solution 1, from an economical perspective this scenario lacked a substantial feed-in tariff. Selling energy back to the grid would return earnings close to the spot price, whereas self-consumption would provide customers a saving per kWh of about 70%. In this case, a strong incentive to self-consume was prevalent, though this was to a large degree impractical in everyday life, even though respondents reported that they sometimes engaged in manual load shifting, and that they were "using when the sun was shining". In terms of having the appropriate overview and information about production and consumption, not all participants had successfully downloaded the app or familiarized themselves with the information web-portal. This indicated that information about electricity produced, sold, and consumed was of varying importance or interest to the participants.

In summary, from the standpoint of the grid operator, the somewhat modest ambitions to test equipment and learn about the impact on the grid was achieved, as they gained experience with PVs in the grid and learned that they would be able to manage it. From the point of view of the households, a full return on investment through self-consumption or sale of energy is not expected. This made the project mostly interesting for individuals who have motivations other than of the monetary kind (environmental, technical vanguard, etc.). Even so, the project managed to recruit a sufficient amount of people focusing on these motivations, and the demand for project participation was high.

Solution 2 – Household PV & Heat Pumps

Solution 2 was encountered in two of the MATCH cases. In the Smart Energi Hvaler (SEH) case, a collaboration involving the municipality, the local university college, and the energy company/DSO, had successfully deployed 3 kWp rooftop solar PV panels to about 100 households. 15 of them were interviewed for this study. A comprehensive marketing strategy involving strong elements of social interaction such as town hall meetings, information campaigns, and municipal as well as energy agency (ENOVA) funding led to a massive interest among the general population for acquiring solar PV, and subsequently aided recruitment strongly. Another factor was that the archipelago of Hvaler, where the demo was situated, had a rather weak connector to the mainland and a less than robust distribution grid, leading to a conceptual interest in self-reliance and localized production. This was effectively exploited in the recruitment effort. In addition, Hvaler is one of the first municipalities in Norway that have introduced capacity based tariffs (consumption is still based on monthly net energy metering), adding weight to the concept of keeping peak loads down by employing local micro-generation and self-consumption.

Households were provided access to a web application where production, consumption, sales of surplus, and peak loads could be monitored. Using smart plugs, consumption of individual appliances could be monitored in real-time. At the time of the study, intelligent demand-side management equipment was installed and had just started trial. This equipment added automated flexibility to boilers, heat pumps, and cooking stoves, to allow these appliances not to run concurrently on a neighbourhood scale (boilers), as well as within households (boilers, heat-pumps, and cooking stove). Unfortunately, the results of these efforts were not yet available at the time of this study, but initial findings suggested this would provide increased flexibility for the grid operator without having a large impact in the daily life of households. Even so, some end users reported they were already managing demand response manually, and some with systems integrated in their heat pumps or connected to panel ovens. This was due to the capacity-based grid tariff providing a strong incentive for avoiding large peak loads in the household. The data indicates rather strongly that most of the respondents have paid closer attention to their capacity outtake, and have engaged more strongly in time shifting practices. This is especially the case for laundry, cooking and – where applicable – car charging.

In addition to the support from ENOVA and the municipality (the latter on a limited, 30 person, first come, first serve basis), a feed-in tariff of about 80 øre (€0.08) made the deal for solar PV that was offered to households very lucrative. One kWh sold back to the grid was in rough market parity with a purchased kWh. A feed-in-tariff this strong is an expensive subsidy. As this study showed, the result gained with market parity of sold and purchased kWhs is that the market can function for the household as a form of storage; the funds received for selling a kWh can, with stable prices, be used to buy it back at a later time with no added cost. From the point of view of the customer, this is a great benefit. However, for the project owner it can be expensive to maintain. Furthermore, there is some indication that it dis-incentivises load-shifting. The tariff is guaranteed to be maintained throughout 2018, but are likely discontinued in the future. Consequences of such an action have not been examined in this project. Likely, it may make time shifting consumption practices more interesting and investing in solar panels slightly less interesting.

The Innovation Fur/GreenCom project also contained solutions configured by a combination of solar PV and heat pumps and, like SEH, the original Innovation Fur initiative gained much of its momentum from a strong and timely focus on face to face meetings with the public. This involved e.g. free energy consultation, involving local craft businesses, free courses on the pros and cons of different energy technologies and solutions, and several kinds of subsidies. In sum, the project was very much bottom up, rooted as it was in a local, citizen-led project called Branding Fur. GreenCom, part of Innovation Fur, is an EU-funded demonstration project using Fur as an international test area for smart grid development, aiming at balancing the local exchange of energy at the community micro grid level. The configurations relating to solution 2 in this project came from a pool of 33 households, 19 of which had home monitoring. 20 households had PVs installed and 11 of them were equipped with heat pumps, the sum total of households in this project with this specific solution (PV+heat pump). Heat pumps were equipped with HaaS-capability (Heat as a Service) and could be remotely controlled by the grid operator for gaining flexibility to the grid.

The home monitoring systems were largely ignored by households due to technical issues and ensuing disinterest. The HaaS capability had at the time of study only been taken for a calibration test run, which according to GreenCom successfully proved it could be used for load shaving to the amount of 1 kW of demand per household. However, due to the more than ample grid capacity already developed in the region, this load shaving was not implemented at the time of study. Measured in R&D goals from the point of view of the project owner (the local DSO), the solution combining solar PV and heat pumps was successful and more profitable than PV combined with batteries, due to their current cost. The households were happy with the solution, and reported they felt they had benefitted. Notably, many of the technologies they received were subsidized by the project. More general, the interviews with households with PVs on Fur (with/without heat pumps) showed that several households attempted to time shift some of their electricity consumption in order increase self-consumption (and save money); energy intensive appliances like dishwashers and washing machines were shifted to daylight hours, a shift which was connected to the hourly net metering scheme that households were subject to. Specifically, this was not related to the PV and heat pump combination, but to the PVs and the hourly net metering combination alone.

In summary of solution 2, evidence shows that applying automation for shifting demand of heavy use appliances so they avoid consuming at the same time seems providential, and this can also be used for having consumption concur with PV production. However, the incentive for time shifting and self-consumption can be lost if there is market parity of purchased and sold kWh. In a sense, this allows the market to function as “storage” capacity to the households, since revenue from sold surplus production could provide funds to purchase energy whenever it was in demand. However, the grid power tariffs and time-of-use pricing such as hourly net metering, incentivize load-shifting and makes households strive to keep peak loads lower than they otherwise would. The GreenCom case combined PVs with heat pumps as part of a Heat as a Service (HaaS) business model, remote controlling heat pumps to increase flexibility within present parameters. This solution was not ready at the time of study, but calibration data suggested this could prove quite successful seen from the perspective of the DSO.

Solution 3 – Household PV & Battery Storage

Solution 3 was encountered in Innovation Fur/GreenCom, Model Village Köstendorf, and the VLOTTE project. First of all, the GreenCom project had success with this solution, since the pilot showed that it was able to foster self-consumption greatly and reduce peak loads significantly (35-70%). However, because of batteries being expensive at this time, the solution was not profitable for either households or the DSO, nor for optimizing PV as a strategy for load management in general. Further, the interviews indicated that households with battery storage felt less engaged in time shifting their electricity consumption to optimize self-consumption; in this way, load shifting appears to be delegated to the battery storage.

Model Village Köstendorf was another venue in this study that included solution 3. Even though much of this project's success was associated with high levels of social interaction as well as strong public awareness efforts, the 43 buildings in this cluster provided with PVs notably also received subsidies from the federal state of Salzburg. Of these, 40 houses had PVs, a central Building Energy Agent, and smart meters installed. At a later stage, some of the houses were fitted with batteries. One house, the 100 % renewable case, had batteries and heat pumps in addition to PVs. One goal of the project was to manage the intermittent loads caused by such configurations, and to evaluate a newly installed controllable transformer. The hypothesis was that the old transformer could not handle the intermittency, and so, part of this project was to gauge if other areas in Salzburg with increased shares of local micro-generation needed to be upgraded with a phase controllable transformer as well. Rated as a success, the project revealed it was not necessary to have expensive, transformer-based phase shifting control as the localized inverters of every PV equipped household could take measures to make sure phase shifting at transformer level would not be necessary for stability in the grid. The success proved viable enough to work as regional grid standard for the entirety of Salzburg, proving it was ready for more PV in the future.

Success in terms of the householders were achieved partially due to strong social interactive elements as well as subsidies. Household time shifting appeared more as a side effect, with positive results for the grid. The project concluded, based on these findings, that it would be possible to double the local grid capacity at half the cost. In general, the project provided Köstendorf with much positive publicity, and the village could even reopen the local pub as there was a significant increase in energy-related visits to learn from the pilot. In Köstendorf, people appreciated that they were producing and using their own energy. Their reduced energy bill, due to self-consumption of the generated electricity, gave them a sense of self-reliance and autonomy, even if they were still dependent on a grid connection.

The VLOTTE project, while focused mainly on E-mobility, featured solution 3 in a two-family smart energy trial household. The test user in this case was an affiliated user, as the man in charge of this two-house smart energy trial was employed by the project owner at the time. The main goal was to gain practical experience with a PV system (5.1 kWp), a battery (10 kWh), and an EV in a realistic use environment. The results indicated a strong increase in own electricity consumption. Before batteries were installed, households consumed 15% of PV production. After installing batteries, this number was increased to 40%, while measurements in summer periods were as high as 98%. These numbers were achieved without any significant focus on practice change in terms of load shifting.

In summary, incorporating PV in the grid on a vast scale is achievable without the need for voltage control at transformer level, as this can be managed by solar PV inverters at the level of households. Furthermore, in the cases featuring PV and batteries, the results proved that batteries are extremely helpful for increasing capacity in the grid and helping households consume own production without adding a burden of manually shifting away loads from peak hours. However, as in the case of GreenCom, even though batteries are useful for increasing household flexibility, the cost of batteries at this time makes them an expensive way of achieving this goal.

Solution 4 – Large scale PV & Storage/Heat Pumps

Solution 4 was encountered in the Rosa Zukunft project. It is one of the more prominent projects of its kind in Austria and has a status as a pioneer in the building and scientific communities. In the context of this study, the findings reveal both successes and some failures with what was tested. The relevant configuration to this solution found in the project is the building-to-grid element, consisting of 8 buildings with a total of 129 apartment units, a rooftop PV system (72 kWp), a large water boiler (90 m^3), a heat pump, and a biogas-powered CHP unit. The system is managed by a central control system called the Building Energy Agent (BEA) which, aided by smart meter and data aggregation, undertakes demand side management and system optimization to reduce load peaks. This system was highly successful, but also very cost intensive, since it required a high level of electrical engineering and IT competencies.

Notably, the building operators necessary for the operation of this system is an example of the category of affiliated users. Conversely, the system has no conditions for involving any kind of active user apart from the affiliated ones, as all aspects are fully automated. With regard to the generation through PV, some users showed a sense of ownership to the "home-grown" energy produced on the projects premises. Although the PV installation and its production were solely owned by the ESCO, users felt betrayed that they did not share the earnings from "their" energy. In that sense, the users did not feel self-reliant with regard to their energy use, but were clearly aware that they were dependent upon the involved energy company. The integration of generation and storage was very successful from a technical point of view and provided the involved initiators of the trial with useful information for future development. Conversely, users felt disconnected from the installed capabilities that they perceived as only beneficial to the ESCO, due to a lack of ownership.

However, 33 of the 129 apartments were chosen to be included in a demand response program, and given special displays, gauges and switches. One way of conveying information about conditions in the grid to end users were by a so called "traffic light" system, which indicated at which times consumption would occur off peak. On top of this, a variable tariff was introduced, incentivizing load shifting. This part of the project would test a hypothesis that active participation from end users could be expected with favourable conditions (i.e. financial remunerations for time shifting). These expectations were not met as most people were unable to time shift any of their activities. This was made particularly difficult by the dynamic and unpredictable nature of this Time-of-Use pricing scheme. The ones that did time shift thought of the resulting savings at the end of the year as not sufficient enough to weight up for the added effort of time shifting. In the end, most of the end users wanted the project owner to remove the in-home display solutions altogether at the end of the project. The trials were instructive about the potential for time shifting in the case of apartment time shifting and the use of energy advice, which were also applied in this context and which did prove to be successful.

4.1.3 Discussion of critical factors and common patterns

Characteristic of all solutions described in this chapter has been the importance of anchoring of project in local context. Solutions 1 showcased a simple PV roll out, and its success was largely the result of a rather strong demand from local customers to make it possible for the grid operator to accommodate solar PV in the grid. The pilots of both companies were customer driven to begin with, and the projects were started in due to the necessity perceived by the energy companies/DSOs in question to gather knowledge about the impact of increased local micro-generation on the grid.

In the case of solution 2, featuring the Hvaler case and the GreenCom case, both projects had committed to a strong local anchoring of the project, involving a broad set of varied actors on the local level. Hvaler had an issue relating to its weak distribution grid, posing special challenges which was successfully leveraged in enrolling the public. In the case of GreenCom the grid was strong, but the project successfully borrowed driving force from the already ongoing Branding Fur project, which later turned into the Innovation Fur project. In both cases, local people, craftsmen, political leadership, key people in the municipality organization, and knowledge institutions were involved, in addition to the local energy industry actors.

Solution 3 featured VLOTTE and Köstendorf in addition to GreenCom. Similarly to GreenCom, Köstendorf had its renewable energy projects spring out of an effort to counter a trend of depopulation and economic stagnation. Rebranding and attracting renewable energy business was successful enough to among other things re-open the local pub and proves that local anchoring of a project does not necessarily need to connect directly to energy related issues. Even so, much of the success was due to energy consciousness of the local public, which lent itself to being translated into positive action, contributing enthusiasm and to the good will existing towards the project. The VLOTTE case was less dependent on local contextual support, since it was a company and could rely on line management to ensure participant engagement in the project. Even so, the efforts they made were met with enthusiasm by local clients and customers, as well as employees.

For solution 4, at Rosa Zukunft, the overall project was well connected to the already established programs within the region of Salzburg. Here, many policy makers and connected stakeholders showed long-term commitment to co-creating and designing new energy solutions. However, the community of residents in the housing complex did not grow organically over time, but came together through the creation of the project. Thus, ready-made solutions were inserted, which left users with limited agency over the scope of the project, leading to a perceived lack of ownership. Nonetheless, their participation in the trial was only temporarily required and yielded valuable information on smart grids for the involved stakeholder institutions.

Another critical factor seems to relate to subsidies and monetary remuneration, both of which undoubtedly govern the choices of pilot end use participation. In the case of solution 1 and the PV projects in Trøndelag, all households were given subsidies by the Norwegian Energy Authorities (ENOVA) for purchase of solar PV. Another example is the plus customer agreement, which the government has mandated grid operators to provide, making it possible to sell own production back to grid at spot prices. Furthermore, there was in the case of solution 2 and SEH the effects of feed-in-tariffs, which were effective but expensive.

In the case of GreenCom (solution 2 and 3), the participants acquired the tested technologies (PVs, heat pump and home battery) with a significant subsidy from the project, which was funded by EU (FP7) and a national energy R&D program. Also, the households got an indirect subsidy through the Danish hourly net metering schemes for prosumers, which means that electricity customers will not pay tax, VAT or net tariff of the electricity the household consumes within the hour of production. This represents about 24 eurocents/kWh of the total customer electricity price of about 28 eurocents/kWh. Finally, households get a fixed price (feed-in tariff) of 5 eurocent/kWh for surplus electricity supplied to the grid, which is about twice the market price of electricity.

In the case of the model Village Köstendorf and the Rosa Zukunft Project, both are part of the Smart Grid Energy Region Salzburg (SGMS) and received direct funding from several federal governmental (e.g. Neue Energien 2020 program of the Climate and Energy Fund) sources. They are co-created with several stakeholders from the sectors energy, housing, and industry, accompanied by consulting and research partners. In addition, the model village Köstendorf received direct funding from the state of Salzburg. The project Rosa Zukunft received indirect funding by the state through adjustment of public housing support schemes to fit the project.

Economic incentives through different types of Time-of-Use (ToU) pricing and capacity-based tariffs are present in many of the cases, except solution 1 where there was monthly net metering. In the case of Solution 2, Smart Energy Hvaler had ToU pricing and capacity-based grid tariffs, whereas GreenCom presented hourly net metering (making it economically attractive to increase self-consumption). Solutions 3 and 4, consisting of PV, storage and heat pumps, also had hourly net metering schemes. In all events, ToU-pricing proved somewhat effective for incentivizing time shifting of (in particular semi-automated) energy-intensive practices like laundering, dish washing, and car charging. In the case of Rosa Zukunft, however, ToU-incentives were experienced as inadequate to efforts made towards load shifting. This was indicated by the fact that even those most eagerly attempting to load shift were rewarded with very small savings. The reason for this might be the general fact that apartments often have few appliances installed and offer little leverage to load shift.

Based on the comparison of the ToU solutions, several analytical observations can be made regarding the role of economic incentives (price) in promoting load shifting in households. First, ToU pricing (including capacity-based tariffs) does have a positive influence on households' engagement in time shifting consumption, and the size of the price spread between lowest and highest price is important. However, the specific impact of price-incentives on households' active engagement in load shifting is dependent on a wide range of other (non-economic) elements in the socio-technical configuration, in particular: a) micro-generation appears to help make the local power production more "visible" to households and in this way promote engagement in load shifting; b) dynamic ToU pricing schemes with unpredictable prices are in general refused by households as too difficult to adapt to; c) trust in and the framing of the schemes are important (e.g. distrust in the energy company disengaged participants in Rosa Zukunft, while the local anchoring appeared as a productive framing in SEH and GreenCom; d) because of physical proximity to neighbours, households in apartment buildings have difficulties with time shifting consumption to night hours due to problems of noise.

4.1.4 Conclusion

In general, a high degree of social interaction, learning, and exploitation of issues in local context contributed to the viability of piloting the solutions described in the above. The projects that were most successful were the ones having made extensive and varied recruitment efforts consistent with aspects of social learning. Town hall meetings, involving different user groups (households, craftspeople, businesses, etc), education and information campaigns were all useful for both recruitment and teaching people about the benefits of time shifting (and how to avoid expensive peak loads!). Active participation and a positive judgment of the overall project could be seen in projects like model Village Köstendorf, GreenCom and SEH, where users felt a sense of ownership with the project. They identified with the project aim or the larger vision of energy transition behind it. Coming from a different angle, the results from Rosa Zukunft show that a sense of ownership was still felt even if the direct identification with the project was missing. In this case, users felt left out by the ESCO.

4.2 Renewable powered company fleet as a smart energy solution

4.2.1 Introduction

In this chapter, we compare two company driven projects with a focus on the development of solutions to convert vehicle fleets to renewable energy sources. In both cases the activities are in-house developments aiming first of all at the companies' own needs. However, at the same time both activities can be characterized as mission-oriented innovation, as they aim to contribute to a decarbonized transport sector in general. In the VLOTTE project a regional Austrian ESCO together with an associated DSO develops a smart e-car park as part of their own e-vehicle fleet; in the ASKO case a large grocery wholesaler from Norway establishes a hydrogen infrastructure for a hydrogen-powered fleet of heavy-duty delivery trucks and fork lifts. In addition to a similar thematic mission of the projects, there is another interesting common feature: In both cases, we are dealing with companies that have transformed their relation to and participation in the transport system as an outcome of the project.

In the case of ASKO, the current development is part of a broadly stated mission from the company and company owners to reduce the CO_2-imprint of the grocery sector at large. Additionally, being able to deliver groceries without emitting CO_2 is arguably a competitive advantage. The project we study started with a large rooftop PV-system that led to the idea for an economically and ecologically meaningful use of the excess energy from abundant sunlight during the summer season. The idea of using hydrogen came from a parallel small-scale project with positive experiences. Not only may the conversion of excess solar power into hydrogen fuel solve the problem of seasonal PV production fluctuations, but by producing their own emission free fuel ASKO are transforming their role in the transport system as well as the grocery sector. Similarly, in the VLOTTE project the concept for a smart e-car park is well embedded in the larger VLOTTE context of building a model region for e-mobility in the whole province. The main challenge in this case was the integration of a rooftop photovoltaic system and to develop the car park without additional investment in the expansion of the grid connection – a restriction set by the project owner to provide for realistic framework conditions form the outset.

In this cluster of solutions our main focus of analysis is on innovation processes, the various activities leading to working solutions. While the e-car park is already in use and vehicles are partly replaced by electric ones, the process to establish a company internal hydrogen infrastructure is still in a much earlier phase of development. Nevertheless, these two solutions are well-suited for a direct comparison as they deal with similar objectives and apply similar innovation strategies.

4.2.2 Outstanding qualities of the selected solutions

In this section we briefly recapitulate the specific features for the selected solutions. We address the question of why and by whom these solutions are described as a 'success', what the solution is contributing to and what actually works and for whom. In the first part, a short characterization of each solution is presented. In the second part, we directly compare both solutions and discuss critical factors, similarities and differences.

VLOTTE – e-car park

The smart e-car park started as a demo project and was already in regular operation at the time of our interviews. It is owned, operated and used by the company and continuously further developed. The technological elements are a multi-storey car park with rooftop PV, a converter, a stationary battery, smart wall boxes, a standard grid connection and an electronic reservation system. The project started in 2016 – at that time only the car park and the PV system existed. Since 2017 every employee can book a car online. Today, short distances are almost exclusively driven with e-vehicles. The mobility department of the company manages 600 car registration numbers. At two of their sites they have 60 vehicles at their disposal of which 18 vehicles are electric. By now, the amount of bookings of e-vehicles is similar to the bookings of standard vehicles. The range of the e-vehicles in use is roughly 250 km and this is sufficient for 80 % of the routes taken. When an e-vehicle is returned, it gets charged immediately. If several vehicles are charged simultaneously, the available power is distributed among them.

A well-working reservation system is key to the practicability of the solution. The now used booking system is the result of a longer development process. It is a significant improvement compared to the previous system as it makes the booking process transparent. Earlier, a standard software calendar with limited functionality was used. In this early phase, when a vehicle was not used it still was blocked if no one cancelled the reservation. The added transparency in the new system contributed to the reduction of range anxiety among the users as well. The latest solution is well accepted among the employees according to interviewees, though so far the cars in the system are mostly used for short distances. In the beginning, there were some minor software issues, which were solved within the first year of operation, but besides that no difficulties have been reported. The e-vehicles are sufficiently charged when needed, no vehicle shortages were reported, and no one has complained about range problems or the like. The overall goal was described by one of the interviewees as aiming at providing an easy-going solution for everyone. In their opinion, there is no need to be an electrician or to know how the systems actually work. E-mobility in the VLOTTE project means simply getting into the car and driving.

The solution is 'smart' which means it is energy efficient, infrastructure efficient and it uses renewable power from the rooftop PV. The rooftop PV was installed during an earlier VLOTTE project phase and is now embedded in the daily business, which means that the generated energy is used for the car park and excess energy is stored in the stationary battery or supplied to the grid. Also, the configuration is economically efficient as no additional grid investments were needed (providing for a stronger connection to the transformer). The internal load management using the smart wall boxes works well, ensuring the fair distribution of power among the e-vehicles while charged. This made the use of the existing infrastructure possible without the threat of short circuits, and the costs of the system operation can be maintained at a low level. In addition, it helps to charge a large number of EVs efficiently. 18 e-vehicles are charged in the car park and only if they are being charged simultaneously, the capacity of the supply cable would be exceeded. As the current car battery status is fed in the booking system, the load management can lower the power at which the e-vehicle is charged. In practice this means that the software is telling the e-vehicle that charging with 22kW is unnecessary and for instance 20kW or less should be enough. So, in this middle range car park a limited supply of power is fairly distributed, which is a remarkable achievement. For the future, the project managers plan to prioritize the loading processes in line with reservations already received. This should lead to an even better utilization of the existing infrastructure as certain vehicles can be addressed specifically.

The solution is comprehensive as it involves several technical and social elements that fit together well. In 2016, the head of the car park department decided to switch to an online booking system, which made the implementation of e-mobility easier. On the one hand, the booking of vehicles then became transparent while on the other hand the booking system could assign e-vehicles for short distances automatically. When an employee is booking a vehicle for a short distance, the system automatically assigns an e-vehicle. In the beginning, educational work had to be carried out as some employees did not feel comfortable using an e-vehicle. For the car park department leader it was a personal matter to convince the employees of the usability of e-mobility. Also, the positive reputation of the VLOTTE project in the federal state supported the action of the car park department as the positive responses from the public and the overall success of the pilot project convinced the employees of the applicability of e-mobility in daily life and business.

The solution is still in development but already used as a showcase and part of the consulting portfolio of the company. The head of the mobility department maintained that they were planning to increase the variety of e-vehicles. At the time of the interview in 2017, only Renault Zoes were part of the fleet. If other EV models will be integrated in the fleet, the load management is faced with new challenges as every vehicle model is charged differently. The person responsible for the IT solutions of the car park and load management said, that they are working on integrating different vehicle models in the charging system. Also, the booking system optimises the fleet with a CO_2-factor of the standard vehicles, so only the most efficient vehicles are in regular use. The vehicles with the highest CO_2-factor are exchanged for electric ones. The car park is used as a testing site, but is already in daily use. Besides that it also works as a showcase for potential customers. One interviewee said that there are more such sites in planning. The ESCO often develops unique solutions for customers (in other areas), so a potential customer can call the ESCO, tell them their demands and then a solution is developed. The solution developed for the company's own needs then serves as a reference model and know-how carrier.

ASKO – hydrogen-powered fleet

A 9000 m^2 rooftop PV system was installed and operates at a peak production of 1 MW. An electrolyser was acquired for the production of hydrogen fuel cells from solar power. The interest of the company in hydrogen production emerged from a pilot project where small fuel cells were tested to power distribution truck cooling systems and lifts, reducing the need for idling during urban grocery deliveries. The development of an on-site hydrogen production and distribution infrastructure was accomplished together with the research institute SINTEF, and a production and filling station was recently opened and works as planned. Ten hydrogen forklifts and one hydrogen truck will be delivered later this year (2018) and the plan is to have 30 hydrogen fuelled distribution trucks by 2023. The main technical elements are the large rooftop PV, the electrolyser (off-the shelf), two filling stations (350 + 700 bar), the hydrogen powered trucks, and hydrogen powered forklifts. The solution has the following main qualities:

The first quality of the solution is that it works in a real world context. The case is still unfolding and under development, but the aspects of the project that have materialised are working. While this is a pilot project – similar to the VLOTTE case – it is also part of the real ASKO corporate economy; and ASKO expects to invest at least €7 million in the project. The solar panels currently produce an equivalent of 20-25 % of the electricity used at ASKO Midt-Norge's storage facilities. The electrolyser and hydrogen filling station have been opened, but as we write this report, the first delivery truck has not yet been received from Scania. However, Scania is an actor from the traditional car-manufacturing regime, which has been described in the past as conservative and difficult to change (Geels et al. 2011). Their involvement here can be interpreted as an incremental innovation step, primarily driven by ASKOs work. Company employees seem to have accepted and embraced the solution, and they are proud of working for a company that acts with a technological impetus on environmental challenges. Since we conducted our fieldwork, it has also become clear that the solution has become part of the 'real world' as it was reported on extensively in local, national and, to a certain extent, international media. Through this, the pilot has become somewhat of a showcase and is part of producing new expectations for renewables and hydrogen, highlighted as important in sustainability transitions literature (e.g. Bakker, Maat and van Wee 2014).

The second quality of the solution is that it is both renewable and 'smart'. Renewable electricity is generated from solar panels. ASKO has a high demand for electricity because of their large cold storage facilities. The 'smartness' in this case, lies in combining solar power production with electrolysis to produce hydrogen, and fuel cells to cater for the company's main expenditure, its transportation demand. Thus, the solution brings a relatively new element to the notion of balancing supply and demand, as it does not only provide balance to the electricity grid but also leverages the demand for transportation services to balance the production of electricity. These dynamics of balancing across time and sectors is strengthened by the fact that solar production is high in Norway during summer months, and lower during the dark winter months.

This suggests that, as in the VLOTTE case, the solution is comprehensive. It involves implementing and shifting technologies across domains (trucks, forklifts, solar cells, electrolysis), which means that the solution 'produces' a series of new technology users (drivers, operators, maintenance personnel, the company itself), and re-configures work processes and modes of organization, in grocery wholesales, transportation, fuel supply and electricity generation. Beyond this, the solution feeds into an even more comprehensive strategy where ASKO works broadly to advance a sustainable agenda.

Table 8. Main characteristics of the two solutions

	VLOTTE	**ASKO**
Renewable	Uses renewable power from rooftop PV	Renewable electricity is generated from solar panels
Smart	Energy & infrastructure efficient	Combines solar power production with electrolysis to produce hydrogen
Comprehensive	Involves several technical & social elements that fit together well	Involves implementing & shifting technologies across domains & produces a series of new technology users
Development status	Still in development, but already used as a showcase	Works in real world context, but still unfolding & under development. Used as a showcase

4.2.3 Discussion of critical factors and common patterns

The ASKO and the VLOTTE solutions were arguably enabled by a set of critical factors. Some of these enabled the start-up of the project, while others have been more important for sustaining momentum within the project and to ensure that the solution continues to 'work' under real-life conditions. The discussion below does not entail a ranking of the factors in terms of importance and not all characteristics apply to every solution.

Supportive political context

The sustainability transition literature has long recognized the importance of political context for innovation endeavours (e.g. Smith, Stirling and Berkhout 2005), and for ensuring that solutions are accepted and promoted by political actors and market actors (e.g. Wüstenhagen et al. 2007). Both studies strengthen such assertions, highlighting the importance of a supportive political context. In the VLOTTE project, the idea to bring e-mobility to Vorarlberg was developed by a local consulting company, but illwerke vkw handed the project proposal in. The origin of the idea goes back to 2007 when the consulting company had the idea to bring 100 e-vehicles on the streets of Vorarlberg. In 2008 this was picked up again when the first call of the e-mobility model region program of the energy and climate fund provided the perfect opportunity for the project. The federal government and the ESCO commissioned the consulting company to write the proposal, but the responsibility was with the ESCO. This was due to the limited opportunities for action of the consulting company. The ESCO and DSO are to 95.5 % in public hand and as renewable energy was a major part of the call, it was decided that the ESCO handled the project. Vorarlberg pursues the strategy to become energy autonomous by 2050. For the relevant stakeholders in the federal state, renewable energy and e-mobility go hand in hand. Therefore e-mobility is an essential aspect of the state's energy strategy. As the experiences with the e-mobility model region and the VLOTTE project were positive, the government wants to build on that with further development of e-mobility. One of the respondents named the energy strategy also as an important aspect of the ESCO's engagement in the VLOTTE project.

In comparison, the ASKO solution also has been part of a supportive regime, in which both the political and organizational context has been vital for realizing the project. In terms of funding, the project received around €1.8 million from the Norwegian energy authorities, ENOVA, which is substantial in the context of a €7 million investment. Further, Norwegian regulations state that if an electricity production facility produces more than 100 kW at any time, it is legally defined as a power plant. This opens the door to a series of potential regulatory and bureaucratic issues dealing with fees and taxes on the power production, but due to special circumstances, ASKO was exempt from this rule, allowing them to exceed the production limit and still be considered and treated as a plus-customer in the grid. Just as important as these considerations is the sort of protection that this and similar projects receive within the corporate structure of ASKO itself, by benefitting of its ownership and the comprehensive strategy of promoting sustainability as discussed earlier in this report. The board of managers has explicitly stated they expect a significantly lower and slower return on investments in the case of environmentally or climate oriented projects, indicating a long-term position on this project. Thus, the development of solar panels, electrolysis and the hydrogen trucks and lorries have been subject to economic care and nurture both from external and internal sources.

In sum, this discussion points to the importance of a supportive socio-political context. On the one hand, this is related to the shielding or nurturing provided by formal political bodies external to the companies, which allows the project operators to take on risks that they might otherwise not have done. On the other hand, the discussion highlights the need to consider politics and policies as broader phenomena than those provided by such external bodies, also keeping an eye on the political work of the involved entrepreneurs and organizations.

Pre-existing resources/competence building in the region

There have been calls in the sustainability transitions literature for a better understanding of the role of space in transitions oriented innovation (STRN 2017). Our two cases analysed here, provide insights about the importance of pre-existing, locally embedded competence. After the VLOTTE project phase ended in 2011 the ESCO participated in several research projects as well as EU projects. In one of these projects the *"Mobilitätszentrale"* (mobility centre) was developed. The *Mobilitätszentrale* was funded in the 2012 e-mobility model region call of the Climate and Energy Fund of Austria. It is part of VLOTTE and an e-mobility information hub which serves as a service provider for potential customers interested in e-mobility. Before the *Mobilitätszentrale* was established, there were still reservations towards e-mobility and the *Mobilitätszentrale* is seen as a tool to reduce those reservations. Due to the success of this centre, illwerke vkw was invited to participate in two EU research projects. The establishment of the *Mobilitätszentrale* can be seen as the implementation of services that vkw had been offering before, but are now being offered centrally. This means, people interested in e-mobility only need to contact the *Mobilitätszentrale* and get services from different actors such as car dealers, electricians and others that are needed when switching to e-mobility. It functions as a central network node, maintaining contact with other actors is crucial. Therefore car dealers, electricians and other important people are contacted regularly. With the *Mobilitätszentrale* the complexity of the topic e-mobility is bundled in one place. By 2017, VLOTTE cooperates with research centres such as the Technical University of Vienna or the FH Vorarlberg. At the FH Vorarlberg an endowed chair is sponsored by illwerke vkw. Students from colleges and universities get the chance to round out their theoretical knowledge with work experience through summer or part time jobs. There is also the opportunity to write a bachelor or master thesis at the ESCO.

Similarly to VLOTTE, the geographical and organizational position of the company ASKO in knowledge and technology intensive networks of innovation and manufacturing is important. ASKO Midt-Norge is located in the same town as the key Norwegian research and innovation community that has been researching and promoting the hydrogen economy for a long time, arguably through what Callon (1986) has called translation (see Arnøy 2012 for an extensive analysis). These researchers convinced ASKO to become part of a small-scale project where hydrogen was tested to operate lifts and cooling systems on trucks, and thus replace the need to idle diesel engines in urban areas during deliveries. These small-scale hydrogen tests were essential in convincing ASKO that hydrogen could provide a potentially viable innovation pathway in a broader way. Once ASKO had been convinced of this, other elements of their pre-existing network enabled the project to unfold. At first, it was quite difficult for ASKO to convince any of the traditional car manufacturing companies that hydrogen powered trucks were viable in the short term. In the end, this was enabled by a long-term and trusting customer relationship with Scania, with whom they had previously worked on customization of other low-emission vehicles for close to a decade. Thus, networks of competence and trust, which on the one hand worked to pull ASKO in one direction, and on the other hand, ASKO could push in one direction, were critical factors enabling and sustaining the project. The case also illustrates the importance of geographical location to innovation and transition dynamics, for which the literature has called for more focus (STRN 2017).

Seen together, our two cases illustrate that knowledge intensive innovation benefits from being closely located in space and time to related initiatives, projects and communities. At the same time, they illustrate that closeness in itself is not sufficient to advance innovation, but that the success of the projects depend on their ability to become part of it.

Corporate culture as innovation driver

Tellis et al. (2009) have identified corporate culture as a significant driver of innovation within firms. In the innovation department attitudes and practices are different to other departments. In both cases analysed here, this appears as a central enabler of transformative action. We see VLOTTE and the *Mobilitätszentrale*, which is the locality of VLOTTE, as the innovation department of the ESCO. In corporate culture three mindsets are crucial for innovation: the willingness to sacrifice profit, foresight, and toleration of ventures (ibid.). These three mindsets can be found in the e-mobility department of the ESCO. The ESCO is taking the risk of venturing into an unknown business field such as e-mobility. The ESCO started investing in e-mobility when it was in an experimental phase and no production vehicles were available. The ESCO is acting long term as e-mobility is seen as the future and decentralised energy generation will become more important. The setup of new small hydroelectric power plants was an essential part of the first call of the e-mobility model region. What is also contributing to the success is the size of the team, which is small and tight knit. The e-mobility department has five employees and several interns. Before the VLOTTE and the EU project no one really knew how e-mobility worked and what kind of implications it will have regarding the electricity grid or how potential customers will react towards e-mobility, if they would accept or reject the new technology. Even though the employees of the e-mobility department were optimistic, the project results exceeded their expectations. On one hand, more people were interested in switching to e-mobility than was expected and on the other the development of the technology accelerated. One interviewee said that in 2008, when the proposal was written, there were only converted e-vehicles. These vehicles were Fiat 500 and Think C!ty models, that used to be combustion vehicles but were transformed to e-vehicles with ZEBRA batteries. By 2017, different production vehicles and e-mobility was about to become mainstream. In general, every member of the team is dedicated to e-mobility, uses it privately and knows what kind of issues are being faced by customers on a day to day basis. Flat hierarchies are an important part of the success and the creativity that is used when developing new products. Also, in the VLOTTE team staff from both the DSO and the ESCO works together in this informal cooperation.

In extension of the first point made, is the importance of the culture within ASKO and Norgesgruppen (the owner of ASKO) when it comes to promoting environmental solutions more broadly. Their role can be understood as that of an intermediary, or 'middle actor' (e.g. Janda 2014), that actively works not only to adopt and implement new technologies, but also to promote changes in the framework conditions for these socio-technical solutions. Both ASKO and Norgesgruppen do this by promoting environmentally oriented lifestyle choices amongst employees, and among other things lobbying the government for stricter procurement rules and for beneficial conditions promoting a hydrogen fuelled transport sector. Hence, one might also argue that they are part of co-producing (Jasanoff 2005) both projects and favourable conditions for these projects in Norway. A different way of looking at this factor could be to highlight that what we observed here is actually an instance of the kind of 'social acceptance' that some scholars have called (e.g. Wüstenhagen et al. 2007; Wolsink 2012; Devine-Wright et al. 2017) market acceptance. This concept suggests that 'social acceptance' (of solutions to the climate challenge) is not something that should be limited to the study of 'end users', but that the acceptance of political actors and market actors is an equally important factor explaining the proliferation of working solutions. These points can also be found in the VLOTTE solution as several interviewees stressed the importance of becoming a "green company". The educational programmes carried out by the transport department also includes telling new employees about alternative transport modes for daily commute such as cycling.

Both companies are innovation-friendly and actively support environmentally oriented lifestyle choices among their employees but foremost see it as a leading culture of the firm. Social acceptance is key and with ensuring that employees accept the changes the companies are fostering their credibility to the outside.

External know-how and expertise to solve certain bottlenecks

For overcoming certain bottlenecks external know-how was employed. Illwerke vkw does not develop hardware or software, but buys necessary tools from external service contractors. The software solution for the wallboxes and the load management is external. Also, the wallboxes are bought from certain product developers. There are different kinds of wallboxes on the market and the ESCO buys the model that is best for their needs. One of the interviewees said that biddings are announced on a regular basis for different kinds of needs and products. Furthermore, the existing cooperation with universities and colleges is used to experiment and to solve specific problems. One such case was the experiment with old ZEBRA batteries that are now in use as a stationary battery in the car park. At the time of the interview in 2017 the battery did not have a significant impact, but the experiment is a first stage of further development.

The company as user-innovator

Recent developments in the sustainability transition literature have argued strongly that one should consider the role of technology users in new ways. Users, however, do not only passively 'accept' solutions produced by others; they sometimes innovate on their own by producing solutions that they will use themselves (Schot et al 2016; Chilvers, Pallett and Hargreaves 2018). This is the situation in both our cases, where industrial users act as both a developer of the solution and user of the solution (although there is a division of labour within the company). In the VLOTTE case, the demand for the development of the concept of the car park was ordered by the fleet management department of the company and therefore was an internal order. Here, the company functions as a 'user-innovator' and benefits directly by using their own product. In the case of illwerke vkw it is the need of lowering the CO_2-emissions of the fleet and also the need of charging the electric fleet without having to expand the supply cable. The ESCO innovates a smart car park that makes the efficient charging of the e-fleet possible, involves the rooftop PV, which is also a prototype for a product.

In the ASKO-case, the user innovation mainly consisted of assembling ready-made technologies in a new way on their own property. Solar PV, the electrolyser and the filling station are all existing technologies; the novelty lies in assembling them around and within ASKO as a user of the newly assembled solution.

Real use-case with real end-users

A key debate in the transitions literature deals with how one can move solutions out of demonstration and pilot settings, how to scale up to broader societal settings (e.g. Naber, Raven and Kouw 2017). Our cases are already active, beyond pure pilot, embedded in broader societal processes. The staff of the e-mobility department of the ESCO uses e-mobility in daily business and some of them, such as the product manager, also in their private life. Therefore immediate feedback is available. Furthermore, when an employee returns the e-vehicle to the car park, difficulties have to be communicated immediately, and users do so via the booking system. This makes dealing with problems easier as there is no need to manually handle these problems as they are centrally processed via the booking system. That the staff of the e-mobility department are users also helps with the development of products and new product developments are discussed in the team. Sometimes aspects such as the price or certain conditions that present themselves are a matter of discussion as the developers are also private users and not just employees that use e-mobility in a business context. Also, this private use makes it possible to realise needs or difficulties. This means that team members get the opportunity to voice their needs or difficulties, and solutions are found with the help of the team. These solutions can later present themselves as beneficial for customers. This innovative process only works because employees are given liberties by the company to be creative in their job.

In a similar way, the ASKO solution works, in part because ASKO is a real-world technology user, who, as noted, works as a user-innovator' (Schot et al. 2016). ASKO does not produce any new technologies, their innovation mainly lies in assembling existing and ready-made technologies which have traditionally catered for different domains (electricity production and transport), and to put them together in a new context. ASKO is a company for which the demand for transportation services is high, since transportation is in effect what they do. Thus, they assemble technologies in a new way, with the intention of using these technologies themselves.

Table 9. Critical factors and common patterns

	VLOTTE	ASKO
Supportive political context	ESCO & DSO are to 95.5% in public hand. Public funding by federal government	ENOVA funded the project ASKO is treated as a plus-customer in the grid
Pre-existing resources and competence building in the region	Establishment & further development of the *Mobilitätszentrale*	Close connection to Norwegian research & innovation community
Corporate culture as innovation driver	Foresight, willing to sacrifice profit & toleration of venture	Promote environmentally oriented lifestyle choices Promote changes in the framework conditions
External know-how & expertise to solve certain bottlenecks	Necessary tools are bought from external service contractors	Cooperation with Scania
The company as user-innovator	Industrial user acts as developer & user of innovation	Industrial user acts as developer & user of innovation
Real use-case with real end-users	Part of daily business & also used as showcase	Assemble technology in a new way with intention of using themselves

4.2.4 Conclusion

This analysis had the main purpose of working out certain factors and patterns of the solutions that enabled their success. Here, the similarities of the solutions shall be summarised to stress the important factors of this cluster. The supportive political context was crucial for both solutions and the company's politics are also numbered among this point. Pre-existing resources and competence building in the region likewise contributed in both cases. For VLOTTE it was on one side the early success of the project, but also the network of research and university institutes. For ASKO it was the intensive networks of innovation and manufacturing that helped. Another point that was already touched on lightly in the first paragraph was the corporate culture that functioned as an innovation driver. The ESCO of VLOTTE did not shy away from venturing in an unknown business field as well as ASKO sees the promotion of an environmental solution and wants to promote changes in the framework conditions for such socio-technical solutions. Furthermore, both are real cases with real end-users, which is a key factor. In VLOTTE real life conditions helped to validate first ideas and to check if employees personally would be willing to accept prices and/or conditions. Also, this point works together with the companies both being user-innovators who benefit of their own inventions.

4.3 Comprehensive energy concepts

4.3.1 Introduction

This cluster includes solutions that are part of comprehensive and often community-based energy concepts with the overall attempt of achieving energy savings and/or increase the use of local renewable energy production through integrating several and diverse energy solutions (renewable energy, energy savings, demand-side management etc.). Although the individual characteristics of the studied solutions (cases) are strongly dependent on the local contexts, the analysis aims at identifying key similarities and differences between the individual cases and solutions. Even though to various degrees, all solutions in this cluster share the characteristic that they are elements in ambitious community-led transition strategies covering a specific locality (e.g. an island, a village or a region). In addition, the transition strategies typically involve a wide range of different initiatives as well as multiple actors and technologies that interconnect within the different contextual settings.

The selected cases and socio-technical configurations are: Model Village Köstendorf (focusing on homeowners in small residential buildings, including single-family homes), Rosa Zukunft (solutions targeted apartment buildings), Renewable Energy Island Samsø (in this study with a specific focus on initiatives targeted local businesses, including supermarkets), and Project Zero (in this study focusing on initiatives targeted homes, sport centres and supermarkets). In other words, the selected cases and socio-technical configurations all focus on creating a comprehensive energy transition within a specific geographical locality or region, but differ with regard to the type of users in focus (homeowners, residents in apartment buildings, local business/shops and sports centres) as well as to the specific mix of energy solutions applied.

Both the Model Village Köstendorf and Rosa Zukunft are situated within the Austrian Bundesland Salzburg, and both cases were originally part of the Smart Grids Model Region Salzburg (SGMS) initiative. The SGMS initiative – and thereby the specific cases of Köstendorf and Rosa Zukunft – reflects the ambitious climate policy targets of the federate state of Salzburg, which according to the Salzburg's Agenda 2050 aims for 30 % emissions reduction and 50 % renewable by 2020 and climate neutrality and energy autonomy by 2050 within the region of Salzburg. In this way, Model Village Köstendorf and Rosa Zukunft are inscribed within the region-wide climate change and energy transition policy. However, compared to Rosa Zukunft, the village of Köstendorf stands out by being, first, a small village community (compared to the city of Salzburg), and by having, second, an affinity towards energy conservation and local energy production that dates long back in time.

The studied solutions in the Model Village Köstendorf include three socio-technical configurations: (1) A field test focusing on the integration of a large number of small PV systems and electric vehicles to the local grid (testing the capacity of the local distribution network); (2) the single field-test households and their "internal" configurations within the home (typically combining rooftop PV, stationary battery and EVs); and, finally, (3) a single household experimenting with covering the energy need (almost) entirely by renewable energy produced on the premise. The two former configurations are part of the project called DG DemoNet Smart Low Voltage Grid, while the third is an independent initiative that originally goes back to the 1990s and is run by the male owner of the "100% renewable household" home. Even though the third solution was initiated by a single homeowner, the specific context of Köstendorf with regard to the area's long history of local energy production and conservation is obviously a significant key driver when it comes to such private initiatives.

Rosa Zukunft focuses on the testing and implementation of residential energy and mobility solutions; specifically, the incorporation of smart grid technologies (demand response) in new-built residential buildings (eight apartment buildings, including 129 dwelling units). Although being part of a “smart energy” agenda, an accompanying goal for the Rosa Zukunft development was social; the idea was to support local community building across different generations and income groups through offering organised social activities to the residents and other community building offers. Three configurations were studied in relation to Rosa Zukunft: (1) A building-to-grid configuration aimed at reducing load peaks through combining micro-CHP with a heat pump and a large energy storage tank to store surplus energy, all controlled with a Building Energy Agent; (2) energy feedback to residents via tablets and smart phone apps in order to motivate residents to shift energy consumption away from load-peak hours (partly through information about current grid load, partly through a variable tariff); and, finally, (3) EV sharing of a number of EVs with controlled recharging.

Project Zero is the name of a strategy of making the Danish city and municipality of Sønderborg climate neutral by 2029 as well as the name of a public-private partnership founded in 2007 with the aim of promoting and facilitating the energy and climate transition in Sønderborg. The Project Zero Secretariat facilitates this transition through a wide range of initiatives and in close collaboration with the municipality and other local actors. This project has studied the following three configurations: (1) ZEROhome (focusing on promoting energy efficiency and renewable energy in homes, e.g. by offering independent enegy-consultancy), (2) ZEROsport (focusing on promoting more energy efficient sports centres); and (3) ZEROshop (focusing on energy savings in local shops, such as supermarkets).

The Renewable Energy Island Samsø has a long history dating back to the late 1990s. The island (having 3,700 inhabitants) originally aimed at becoming self-sufficient with renewable energy, which was realized by 2008 (if measured by the annual net energy consumption and renewable energy production). Now, the goal is to get entirely rid of using fossil fuels by 2030; in particular by replacing fossil fuels for transport with renewable alternatives. Along with this, the Samsø Energy Academy continues activities focused on achieving energy reductions and higher energy efficiency. The MATCH-project has studied the activities of this key local actor targeted increasing energy efficiency in local businesses (including supermarkets, a hotel and restaurant and the local community center). The energy reductions have been facilitated by the Energy Academy through regular visits to and in close collaboration with the owners and staff of local businesses on the island. Activities include monitoring existing consumption and promoting conventional energy saving solutions such as replacing halogen spots with LED lights, etc.

The following analysis focuses on identifying the context-related conditions and features related to the specific design of the local initiatives that help to explain the relative successfulness of the individual cases/solutions.

4.3.2 Outstanding qualities of the selected solutions

Model Village Köstendorf

Overall, the three solutions tested are considered as successful in several respects and from different stakeholder perspectives (R&D objectives, planning objectives of the utilities provider Salzburg AG, the local community has profited from both direct subsidies and the technological momentum, etc.). The studied activities can be seen in continuation of previous energy and sustainability-aligned (e.g. Local Agenda 21) initiatives in Köstendorf. The configurations are still in place (upon end of trial period) and further initiatives are expected in the future. Thus, the studied solutions represent a significant element in a longer list of initiatives that together form a successive progression towards future climate neutrality and energy autonomy, which corresponds with the aim of the regional climate neutrality plan. A process in which technical manifestations form the basis for social alignments and new decisions for further technical implementations usually referred to as socio-technical production or co-evolution.

The following highlights the main qualities of the solutions implemented in the comprehensive energy concept of Model Village Köstendorf.

Firstly, the different solutions work well in real-world contexts of “real” users, and are therefore in general characterised as socially accepted and technically feasible solutions. The local energy provider Salzburg AG plays a central role in the two solutions that both are parts of the DG DemoNet Smart Low Voltage Grid trial. Here, Salzburg AG acts as a locally-anchored “key actor” within an otherwise diverse network of actors involved in these configurations. Thus, the provider is an important mediator between local actors (including residents/users) and national/international actors (e.g. Siemens). Further, the key role of Salzburg AG was facilitated by one particular community member employed by the company, even though this person was not professionally involved in the project. The community member was selected as the local mayor, after the solutions were initiated.

Secondly, these solutions gained strong local support and anchoring because the participants strongly identify with the objectives of the trial and hence were proud of playing an active part in the energy transitions. Also, the solutions were strongly supported by other related actors in the community, which helped with disseminating knowledge about the successes and challenges connected to the projects. In addition to early involvement of key actors, users, and local stakeholders, attractive subsidies, owing to the funded projects, seem to play a significant role for the great satisfaction about participation among the variety of actors.

Thirdly, the general success, positive reception and local support of the solutions are a result of the long history of energy transition initiatives in Köstendorf. The energy transition initiatives are partly institutionalised in the local energy group called “e5”. The solutions have achieved much (international) attention from smart energy researchers and developers. The activities have also helped attract further energy projects and R&D funding. In this way, the initiatives served to enforce local economic investment and development in the area. In terms of that, national funding and the variety of projects and programmes worked as making a valuable energy “test bed” for both research and industry, and consequently contributed to a long-term development in the region.

Finally, the 100 % household is comprehensive in terms of installing the patchwork of several advanced technical technologies by integrating them into the everyday life. By testing new technologies, the household control the usability of the solution by fitting the overall vision of 100 % self-sufficiency, and become a driving force for progressing development of prosumers interplay with the energy system. This actor exemplifies how an active energy citizen becomes a “role model” for a sustainable energy transition in the area.

Rosa Zukunft

This section highlights the main qualities and lessons-learned from Rosa Zukunft. Rosa Zukunft are comprehensive because of the involvement of several technological and social elements, which are mutually coordinated and jointly contribute to the functioning of the solutions.

Of the three studied solutions, the building-to-grid configuration turned out as particular successful. This configuration did not contradict (or even interact) with the daily routines of the residents and was regarded as financially viable (even without external funding). Also, this solution has been replicated in similar residential projects in Salzburg (although in a less sophisticated and hence economically more feasible version). While the building-to-grid configuration was highly automatized and did not involve active participation of the residents, the other two configurations were based on a much more direct user engagement. The engagement consisted either in adapting daily energy-consuming practices to variable prices and information about the current grid load or by taking part in the EV sharing scheme.

The other two configurations were never really adopted by the users. They could not profit economically from taking part in the time shifting, even if they tried hard. This lead to a feeling of deception and a decreased sense of ownership and identification with the project. The combination of several goals in one project to some extent explains the lack of active participation by the residents in the two configurations that called for active engagement. On the other hand, the latter two configurations were successful in the sense of providing knowledge about important factors for the success of demand response and EV sharing solutions.

Both Salzburg Wohnbau and Diakoniewerk Salzburg were important actors due to their roles as main contact for the participants (with Salzburg Wohnbau being the key actor as coordinator of the trial), and thus responsible for the primary communication with the residents about the smart energy initiative. These actors appear to focus mainly on the social dimension of the Rosa Zukunft development. Salzburg Wohnbau participated due to the initiative of other successful regional companies such as Salzburg AG and Diakoniewerk Salzburg. They trusted those, due to longstanding connections.

Project Zero

The three solutions are comprehensive, since they involve several technological and social elements that fit well together. Overall, the three configurations have been successful in the view of both Project Zero and the targeted users (households, shops and sports centres). Substantial energy reductions have been realized in local supermarkets and sport centres (resulting in financial savings), and the households in general find it meaningful to be actively engaged in the energy transition initiatives. Also, the individual configurations contribute to the overall aim of making the Sønderborg area CO_2 neutral by 2029. Finally, Project Zero has succeeded in making the vision of CO_2-neutrality by 2029 an active and visible element in the local community and is thus successful in aligning local activities and actors in relation to fulfilling this vision. Following findings are the main qualities to be highlighted with regard to the efforts initiated by Project Zero.

All three constellations of solutions work well in real-world contexts (real users, socially acceptable, feasible). According to the annual monitoring accomplished by the Project Zero secretary, the area's CO_2 emissions were 25 % lower in 2015 than in 2007. This reduction has been achieved through significantly more efficient energy consumption and increasing energy supply from the area's own renewable energy sources. Correspondingly, substantial energy savings are gained through the energy efficiency strategies in focus in the configurations of ZEROhome and ZEROshop.

Characteristically for the configurations is that they are facilitated by community-led initiatives as part of a greater, local-based transition initiative (developed and maintained by Project Zero). More generally, Project Zero is a key actor in promoting the local CO_2-neutrality vision and in aligning activities and creating networks of actors (including transferring knowledge and ideas among local actors). Regarding this, the configurations contribute to maintain and develop the local energy transition vision. Also, the solutions contribute to a national and international "branding" of Sønderborg, which helps – among other things – attract investments and public funding in further energy transition initiatives (including EU Horizon 2020 projects).

Common for the solutions promoting energy saving are the involvement of many actors/local stakeholders. Local companies are among the involved actors, sometimes in the role as providing and testing new technical solutions, as it was the case with the waste heat recovering system in the studied Supermarket. In this way, Project Zero activities contributes to substitute existing equipment with more efficient technologies in local companies as well.

External funding plays an important role in some of the cases in the ZEROsport configuration (particularly in the case of Diamanten), but appears to have a limited influence in the other two configurations which indicates that the solutions chosen are economically competitive even under today's conditions. Significantly, national (tax) regulation plays a pivotal role in making investment in renewable energy generation feasible (or not) for many households taking part in ZEROhome (especially with regard to installing PV panels). This also relates to the purchase of EVs.

Renewable Energy Island Samsø

The initiatives targeted energy savings in local shops appear successful as the shops have realized substantial energy savings through rather conventional measures such as adjusting room temperatures or replacing inefficient light bulbs with efficient alternatives. In this way, the innovative element of this configuration (solution) is mainly related to the approach and methods applied by the Energy Academy and thus less to new technical equipment as such. The energy savings are realized on basis of close monitoring of energy consumption and frequent visits to the shops carried out by the same staff members from the Academy. This includes continued dialogue with the shop owners or shop staff members about their daily routines (in order to find solutions that fit well with these) as well as in order to identify possible energy saving options. Compared to all other solutions in our sample, this configuration works most strongly through social elements. The following summarises the main qualities to be highlighted with regard to Renewable Energy Island Samsø.

The solution works well in a real-world context among real users due to high social acceptance and not least due to the substantial energy savings achieved. That said, the activities carried out by the Energy Academy depend very much on external funding, which makes it difficult to evaluate the economic feasibility of the solution.

The Energy Academy's approach gained strong local support and anchoring, and all the involved shops express great satisfaction about participation. The approach is characterised by close and continued involvement of users (shops) established through persistently follow-up visits accomplished by the same (one or two) staff members from the Energy Academy. In terms of that, the Academy is the key actor in the solution studied (as well as the broader energy transition of the island).

Overall, energy transition initiatives has a long history on the island of Samsø, which may partly explain the positive reception and local support by the shops. The Energy Academy is well known on the island and has an established reputation as the local authority on energy-related themes and energy saving initiatives. This, combined with the informal relations between the Academy and local citizens, implies that the Academy generally is met with trust engendered by the Academy's well-established and extensive network of relations.

The energy transition vision of Samsø combines the idea of decarbonizing the local energy consumption with the vision of revitalising the local community with regard to settlement and economic development. In this way, the transition initiatives are inscribed in a broader vision (narrative) for the future economic and social development of the island. The solution is part of promoting the local community and the Renewable Energy vision, which has achieved much (international) attention from smart energy researchers and developers. The activities have also helped attract further energy projects and R&D funding.

4.3.3 Discussion of critical factors and common patterns

Across the studied cases, the existence of local visions or strategies for a comprehensive energy transition appear to play a key role in aligning activities and actors within the specific configurations and solutions. This was in particular evident in Project Zero, Renewable Energy Island Samsø and Köstendorf, but less in the case of Rosa Zukunft. Summarising the success of the variety of the community-driven solutions critically depends on the productive role of local/regional energy transition visions.

With regard to this, the reason why Rosa Zukunft seems to differ from the other cases might be related to the critical importance of the long history embedded in locally anchored energy transition activities. In Köstendorf, Sønderborg and on Samsø, the studied configurations (solutions) are only single elements in an otherwise wide spectrum of energy transition initiatives. Thus, the studied configurations can be interpreted as continuations of previous initiatives and their material and semiotic manifestations. Significantly, the degree of the solutions' success often build on pre-existing networks of actors. The only exception from this anchoring of solutions in pre-existing energy transition activities and networks seems to be the case of Rosa Zukunft.

Framing the energy transition within a broader vision of local (community) development is essential. In several cases, the local/regional energy transition visions were framed within a broader vision of supporting general economic and social development (e.g. promoting settlement and economic development on the island of Samsø). This goes for Project Zero and Renewable Energy Island Samsø, and also Köstendorf. This framing appears to be particularly productive, if a local key actor (like Samsø Energy Academy) is taking on the responsibility of facilitating dialogues and processes through what has been termed (in the case of Samsø Energy Academy) "hope management", which "focuses … on the careful building of a process taking individual or group stakeholders' interests and worries as a starting point of situated negotiations" (Papazu 2015: 157).

Furthermore, the fact that one primary key actor with relations (often informal) to a wide range of local actors can be identified seems to play an important role. Across most of the cases, one actor can be identified as the key actor that takes on the leading role of communicating (mediating) between the network of actors related to the individual configurations. This is the Energy Academy on Samsø, Project Zero in Sønderborg and Salzburg AG in Köstendorf. In the case of Rosa Zukunft, Salzburg Wohnbau and Diakoniewerk Salzburg appear as accompanying actors. In addition to facilitating and supporting the communication within the network of actors, these key actors also play a key role of more direct involvement in developing the specific design of the solutions (as in the case of Salzburg AG in Köstendorf and Samsø Energy Academy on Samsø). Especially Samsø Energy Academy exemplifies an actor with a highly continued and frequent interaction with the actors involved in the studied configuration in particular at the sites (e.g. the supermarket). In comparison, the role of other key actors, such as Project Zero, appears to be primarily focused on network building and supporting the alignment of local actors and activities in relation to the energy transition vision through communication (and less direct involvement in the realisation of initiatives).

Moreover, competitions and rewards in several ways played a key role in two of the configurations related to Project Zero (ZEROshop and ZEROsport), which indicate that competitions, recognition and general publicity can motivate organisations like shops and sport centres to take part in energy saving initiatives. Such initiatives require a degree of rules setting and developing certification schemes, which also crucially depend on broader management of such programmes facilitated by one primary key actor.

4.3.4 Conclusion

The solutions outlined in this cluster analysis are all, though to a different level, part of comprehensive and often community-based energy transition strategies and visions attempting to reduce carbon emission through energy savings and increased local renewable energy production in the area. Despite the solutions are strongly dependent on specific localities and vary in terms of technologies, actors and networks, all the individual solutions are enrolled and embedded within ambitious community-led transition strategies that involve a wide range of different interconnecting initiatives, technologies and multiple actors. Commonly across these socio-technological configurations, the productive role of comprehensive community-driven local strategies and visions, typically established through a long history of anchored energy transition initiatives, appear essential for establishing and anchoring solutions. Successful solutions are part of longer history with previous experiments, implementations and initiatives. Hence, these solutions represent single elements in a much wider spectrum of energy transition initiatives. With exception of Rosa Zukunft, these solutions often build on pre-existing networks of actors, though one local key actor seem of particular importance in order to be the 'leading' responsible for designing the solutions as well as driving and facilitating the processes and initiatives of cooperation, network-building and communication. Furthermore, central key actors' performance of persistent continued and frequent interaction with the users appear as a valuable approach in order to create support and joint-responsibility, which are crucial for anchoring the workable solutions in real-life on a longer term.

4.4 The role of users in emerging socio-technical configurations

4.4.1 Introduction

A central idea of the MATCH project is to identify and describe smart energy solutions as socio-technical configurations. The studied solutions work, is one of our main arguments, because social and technical, semiotic and material elements are interlinked and enacted in a meaningful way. However, in this chapter we will focus on one specific aspect of energy solutions as socio-technical configurations: the various roles users play across the studied configurations. The aim is to better understand how users are configured, involved and actively engaged in these solutions and how users contribute to the development of solutions through social learning and the creation and stabilisation of new symbolic meanings and use patterns.

It is obvious that users matter in all of our cases. They play an integral part in the various field-tests and pilot-projects and are even, in some cases, almost completely responsible for the working of the solutions in place. However, as most of our solutions still are in an early phase of development – clearly before a significant market uptake – we have to direct our attention to the role of users in early phases of energy innovation processes, in particular.

Once a technical artefact (or a set of technical elements) leaves the limited context of research, engineering and design, contexts and ways of using the technology are normally far from clear. The range and character of possible roles of users can vary widely. From being restricted to what Williams and Edge (1996) have called 'veto power', meaning that consumers have no opportunity to engage with the design of technology other than deciding whether to adopt it or not, to being deeply involved in the design process or even becoming the main source of 'user innovation' (von Hippel 1986). This makes the role of users somewhat ambivalent: they can be considered as both active and able to shape the design and meanings of an artefact, or passive and reconfigured and shaped by technology. Put differently, users can be conceptually located within a field of tension, and thus being both passively configured by other actors or technologies and actively appropriating technologies at the same time (Shove 2001).

In our context, the focus is on the ability of users to actively shape the meaning and design of technology and through this, contribute to the successful working of the studied solutions. Early users always play an active part in meanings and practices related to an artefact (Mackay and Gillespie 1992), as artefacts only acquire social meaning in use contexts. The process behind this is what is sometimes called 'appropriation' or 'domestication' of a technological object, which refer to how technology is 'incorporated into the routines and rituals of everyday life, the way it is used, and the ways it becomes functional' (Vestby 1996: 68). In their role as users, consumers can be active, creative and expressive (Mackay and Gillespie 1992).

In the case of early and active first-users, the appropriation of technology becomes a broad and transcending activity, obviously 'blurring the boundaries between production and consumption' (Oudshoorn and Pinch 2008: 554). Users may become 'prosumers', as Toffler has called them already many years ago (Toffler 1980), which means that they are producers of technology, but nevertheless well grounded in the knowledge and the day-to-day experiences of ordinary users.

To what extent users are able to become active designers of technology is indeed dependent on a variety of different factors (we will discuss some of them below), covering socio-economic and demographic characteristics, personal skills, structural and cultural conditions, as well as properties of the technology itself. Therefore, it is important to bear in mind that there are different groups of users, which vary in their power to choose the technology, to acquire skills and authority to use it in different ways, to adapt or modify it, to fix problems, override functions or bypass its outputs, or perhaps to subvert or reject it (Russell and Williams 2002). In a similar way, Klein and Kleinman (2002) have stressed the power or capacity of users and other social actors in this context. They argue that the ability of users to shape technology depends largely on structural characteristics, such as economic, political, and cultural resources and assume that among different groups we may find systematic asymmetries of power, and that these differences are rooted in structural conditions of social life. It is very likely that such structural conditions also play an important role in our examples, as most solutions are still embedded in well-protected innovation niches.

Within innovation studies there is quite a long tradition of analysing users as an important source of innovation-related knowledge (see e.g. Rosenberg 1982, von Hippel 1986). Drawing on a number of empirical cases from different industrial sectors, von Hippel (1986) has shown that up to 90 percent of all innovations in a field were developed by product users. Of course, in these cases most users had not been individual end-users but firms or organisations. Nonetheless, the point is that these industrial users did act in their 'functional role' as users, rather than as manufacturers or suppliers of products. They provided solutions for their own needs, which eventually became successful innovations. In the contexts of the MATCH project the earlier studied cases of ASKO and VLOTTE are excellent examples for this kind of corporate users taking on the challenge to develop new solutions by themselves.

Von Hippel (1998) has shown that users have specific local knowledge that could be highly relevant for defining and solving problems (with their own interests as priority) and eventually lead to technological innovations and new market opportunities. Collins and Evans (2002) point out that so-called 'specialist uncertified expertise' know-how from users is integral to the development of the technology, especially in cases of public-use technologies such as cars, bicycles, and personal computers. But users could also contribute as 'narrow specialists', broadening the knowledge base, as users or active non-users. This second form of expertise based on experiences from users or non-users of technology is acknowledged as an integral part in establishing meaning and success for new technical artefacts.

So, there are different users, with different abilities, ambitions, skills, stocks of knowledge, etc. as well as different structural conditions and local settings. In the context of smart grid developments Goulden et al. (2014) compare two contrasting models of energy consumers with energy citizens (Devine-Wright 2007). These two user types deploy different personas and play different roles in energy innovation and it can be expected that they perform differently. While in the context of smart grids, energy consumers appear to perform 'managed demand side', energy citizens are likely to become managers in the process of consumption and (micro-)generation. With a focus on the relation between providers and consumers, van Vliet (2012) suggests to consider three different types of technology users: consumers, citizen-consumers, and co-providers.

From a sustainability transition perspective, Schot et al. (2016) have recently argued that consumers should be reconceptualised as users in the innovation process shaping new routines and enacting system change. Based on the existing scholarly work on the role of technology users in innovation processes the authors develop a new typology of users trying to link these user roles conceptually to the timely dynamic of transition processes. In the start-up phase of a transition process, they argue, user-producers and user-legitimators – users who are also committed to the political legitimation of alternative technical visions – help to create technological and symbolic variety. In the acceleration phase, user-intermediaries (e.g. user organisations) align various actors, user-consumers creatively embed new technologies in their everyday practices while user-citizens mobilize against the existing regime. In the last phase, called stabilization phase, a larger number of user-consumers switch over to the emerging regime with its re-defined practices. As most solutions studied in the MATCH project represent early manifestations of possible socio-technical pathways our focus in particular should be on the role of user as producers, legitimators, intermediaries, and consumers.

Based on this short literature review we may conclude that different types of users engage with socio-technical innovation on three interrelated levels: (1) the functionality/performance of the solution; (2) the development of the solution; and (3) the socio-political context of the solution. Users play a crucial role in any emerging socio-technical configuration. Users link elements together in meaningful ways, they perform practices integrating these new configurations and are involved in ensuring that certain outcomes are achieved. However, the importance of users goes far beyond the practical functioning of the studied configurations. Users are involved in shaping the symbolic meaning of novel solutions, provide practical knowledge, articulate individual preferences or directly fix technical problems. In sum, users are active drivers of innovation and can help to build up and stabilize social networks, improve the political meaning and legitimization of smart energy solutions.

4.4.2 Different user roles in comparison

A general overview shows that the collection of solutions studied in the MATCH project involves a number of different types of users. Users appear as:

Research partners and citizen scientists: An example of this type of users are the residents of the so-called monitoring households in the DSM-trial in the Rosa Zukunft residential building in the city of Salzburg (33 units with DSM equipment, 33 without equipment). Information and advice has been available to users in these households and they were provided with special equipment to test for one year. The users' experiences were documented and scientifically analysed. The households in Köstendorf also took part in (two different) research projects. In the second case, however, users were more deeply involved through own financial investments made in the process, and the involvement went beyond the research project period. However, the main contribution of users as field-test participants is the production of knowledge. To a certain extent, users in this case are 'research objects' who participate in the project through a mutual agreement and supported by benefits for a certain period of time. In the case of the Norwegian project in Hvaler and the Danish case of Innovation Fur, however, users play a more active role as citizen scientists; some of them are quite offensively involved in the production of new knowledge.

Traditional or ordinary users: The Rosa Zukunft residential building is also a case that involves ordinary consumers. All residents without monitoring equipment (around 100 units) belong to this type of users. Here, consumers obligatory have to be customers of Salzburg AG, as heat and hot water are exclusively produced by the implemented building-to-grid solution. Consumers share two interfaces with the utility, technically (through a small transfer station in each apartment) and legally (through supply contract, billing and customer service). In the first months of operation, the technical performance was improved on the basis of consumer feedback. In their role as consumers some of our interview partners complained about the quasi-monopoly status of the utility, but are generally satisfied with the heat-supply. Overall, the consumers in this case were able to stick with their existing habits and respond to the solution based on these preferences.

Prosumers: In Köstendorf, Trøndelag and Hvaler, private households act as users and producers of electricity. In all three cases, the associated financial risks for private investors were reduced through subsidies, but this does not change the fact that these users sell electricity to the grid operator and, in doing so, that they take a certain amount of entrepreneurial risk. In these households, energy becomes visible through technical equipment and smart meters that show the daily production and allow for different forms of data processing and energy visualisations. Even more, this is the case in prosumer-households equipped with stationary batteries and/or EVs (like in Innovation Fur and ZEROhome). However, in the Hvaler case the technological configuration along with the tariffs structures are set up in such a way that it demand little activity on behalf of the prosumers. For instance, whether the prosumers consume their own energy when production from PV is high, or sell it back to the grid have no consequences for them. Some of the users in the Trøndelag case also represent a weak form of prosumer; here, households technically and contractually sell electricity to the grid, but the energy provider owns and takes care of the equipment.

Energy citizens: The term energy citizenship assumes that the general public is a politically engaged stakeholder in the transition of the energy system towards greater sustainability (Devine-Wright 2007, Ryghaug et al. 2018). We find those politically active users in our cases in all three countries. In Austria, the person who created the (now) 100% renewable household over the last 25 years is a typical example. The decision to switch completely to renewable energy sources in this case is closely linked to a political agenda (ecological movement, climate change mitigation) and the actions taken in the home are part of the mission to show the public that it is possible to rely almost exclusively on renewable sources. The energy agenda clearly became an integral part of his personal identity. The same type of energy citizen can be found in Norway, in particular among the participants of the smart energy project on the island of Hvaler; people whose commitment to energy issues goes far beyond their participation in the on-going field trials, as evidenced, for example, by the fact that they give public lectures on their activities or generously guide groups of visitors through their home and share their experiences with the tested smart energy solutions. To some of these users their engagement is rooted in feelings of taking social responsibility for the developments of society.

'Affiliated users': In some configurations employees of the project owner take on the role as early end-users and test the solutions under development in real-world contexts. We may call this type of users 'affiliated users' as they are in an employment relationship with the project owner. This makes it relatively easy to actively enrol them as part of the applied configurations, enables direct and immediate feedback, allows for mutual learning processes and guarantees unrestricted access to data. At the same time this arrangement limits possible risks because the solution is tested within the own company only. Examples are the end-users in the VLOTTE project. In this project, in all three analysed configurations affiliated users do play an important role; they use e-vehicles and the electronic reservation system of the smart e-car park, and serve as a private test-household with PV panels and stationary batteries to learn more about economic and technical aspects of higher levels of self-consumption. Similar cases also exist in the Trøndelag case, where employees of the project owner act as test households.

User innovators or user-producers: The last type of user we could identify in our sample is the user as driver of innovation. Here, mainly a user develops a smart energy solution, according to own needs and mainly based on own resources and capacities. In this constellation the user acts as a producer, as a technology developer. This is the case with the VLOTTE project, where a regional energy service provider is developing a smart e-car park solution, as well as in the ASKO case, where a large Norwegian grocery wholesaler is developing a hydrogen infrastructure for hydrogen-powered fleet of heavy-duty delivery trucks. The innovation activities in both cases first of all aim to serve needs and goals that these companies have set for them, and, as there was no suitable offer available on the market, they decided to tackle the task by oneself. User innovators may not be experts in the new field they entered, but they have a lot of local knowledge and are very much aware of how the new solutions should work. User producers also could be found in the Danish ZEROhome, in particular in one household in which the male find it highly interesting and meaningful to 'tinker' with the technical energy systems on a continuous basis and who built his own advanced energy provision system combining and optimizing the dynamic interplay between solar panels, solar PV and a biomass oven.

In all our case study configurations, users take on (or are enrolled to take on) several roles. In the private test-household in the VLOTTE project, for example, the responsible person acts as prosumer and at the same time he is an affiliated user. In a similar way in the distribution grid research project in Köstendorf as well as in the smart energy project in Hvaler, participants take on several user roles at the time; they serve as research partners, prosumers, and some of them act as energy citizens. In the e-car park in Austria, user innovators and affiliated users complement each other. In the following we will discuss the different user roles in some selected configurations and their respective effects in more detail.

Example 1: 100 % renewable energy household

This configuration is located in a detached building on the outskirts of the small village of Köstendorf (Austria). The only two residents are an adult couple. The man is the driving force behind the project that he has been pushing for many years. While not having any related professional background, he managed – mostly with the help of professionals – to install and combine a variety of energy technologies. Examples for those are thermal solar panels, a storage tank, a heat pump, rooftop PV, and a stationary battery. Over the years, considerable sums of money have been spent on the equipment. Only recently, he even managed to get included into the subsidised EV and stationary battery scheme of the nearby smart-grid research project. His stated goal was and is to show that a green local energy transition is possible. The energy supply of the home is based exclusively on renewable resources. However, the household is not completely autonomous from the grid, but shows a very high degree of locally produced energy.

Although there are only two people in this household, we could identify four different user roles in this case: (1) energy citizen, (2) user-producer, (3) prosumer, and (4) ordinary user. The owner of the house definitely acts as an energy citizen; he is an active member of a local energy activism group that promotes the use of renewables, e.g. in the context of his professional activity. In addition, he holds lectures and teaches sustainability related topics at a university. He follows a clear vision and aims to build a sustainable future through the use of renewable energy. Many years ago, he was one of the first members of the then very active DIY solar energy groups in this region. Since then he has pursued the goal of completely converting his own house to renewable energies. He sees himself as an activist, attempting to influence the energy transition from bottom-up. The many years of commitment made it possible to develop this quite unique configuration, as the person is dedicated to improve the installed system through trial and error approaches, while accepting the considerable economic costs of these activities. Thus the homeowner is also a user producer. He planned and partly installed the elements for the configuration over several years, with a clear long-term vision in mind. The resulting concept is largely based on DIY activities and, according to the owner, it is certainly not perfect from today's perspective, but the entire installation became a part of the identity of its builder. He still is very enthusiastic about it, although he would revise many of the past decisions. As a result, the configuration is comprehensive, but remains a patchwork of several technical systems. Together the couple takes on the roles of a prosumer, being still dependent on consumption through the grid-connection, but also producing and selling PV electricity to the grid. Again, the monitoring of the technology and the energy produced (e.g. via web portal) is also carried out exclusively by the male household member. The fourth kind of user-type that can be seen in this configuration is the ordinary user. This role is occupied by the female member of the household, who slowly tries to adapt to the new routines revolving around the now more fluctuating energy supply. This person thus performs a kind of 'control function' which, for example, deals with questions of usability and thus clearly goes beyond the role of the energy citizen or the prosumer.

In this configuration we see a productive interplay between the energy citizen and the user consumer. On the one side the energy citizen is the driving force for the progressing development of the private energy system and the introduction of new technologies to fit the overall vision of a 100 % renewable energy household. On the other side, the user consumer serves as a practicability check for these technical attempts. Both roles are influencing the way in which the role of the user producer role can be exercised. Thus, the user producer's institutional frame is encouraged by the overall vision of an active energy citizen of being a role model for a sustainable energy transition and therefore dares developing and installing advanced technologies. Hereby, the interaction with other likeminded peers gives new ideas and input to the improvement of the configuration. In turn, new plans are checked by the practicability concerns of the ordinary user.

Example 2: ZEROhome (and Innovation Fur)

The ZEROhome programme launched by ProjectZero in 2010 focuses on engaging house-owners in energy retrofitting their private-owned homes. ZEROhome is thus one of a variety of ProjectZero's initiatives that overall aim to facilitate a transition of the municipality of Sønderborg to a CO2-neutral community by 2029. Embedded in the overall community-led transition strategy, ZEROhome aims to qualify ways to improve the individual houses' current energy standards by promoting energy efficiency by offering independent energy advise. Moreover, smart grid solutions to increase renewables in private homes, such as installing PVs, are significant strategic efforts within the programme. In the following, it is outlined how private home-owners are a diverse group of humans who perform/interact in various ways with the smart technologies and are motivated to install and invest in PVs in combination with electric vehicles (EVs) and heat pumps by different reasons. Thus, the specific socio-technical configuration consists of the technologies: PV panels, electric vehicles and heat pumps entangled within the everyday life of households, e.g. including social elements such as specific kinds of relations between actors, network of knowledge sharing, support and inspiration, drivers of motivation, stage of life phases, etc.

The users or owners of respectively PVs, EVs and heat pumps install the technologies for several reasons. This socio-technical configuration shows how participants combine different roles such as prosumers, energy citizens, user innovators and ordinary users.

Obviously, all households were prosumers (having PVs and connected to the grid), and thus were motivated by consuming their own production of renewable energy. The prosumer role was a key driver for purchasing the technologies for most of the households studied. The 'synergies' of combining PVs with an EV or/and heat pump was a significant driver for acquiring more than one technology. Thus, the purchase of different technologies typically reflects a certain sequence of investments; PVs seem to be the first object of investment, whereas heat pumps and EVs came after in order to optimize the utilisation of their own power production.

Often, the original idea of becoming a 'prosumer' was a consequence of other plans about comprehensive home renovation, e.g. replacing the roof or the old energy heating system (e.g. replacing an oil burner). This opened new dimensions of thinking in energy-related terms. Here, several users express a great interest in investing in the newest possible product on the market. In continuation of these considerations, some users were motivated by making eco-friendly choices. This indicates that users are driven by innovation and pursuing to test 'new technology' and in some cases simultaneously value sustainable energy performances. The acquisition of EVs was an example of this.

Although none of the users explicitly mentioned political activities, the users seem to be very aware of their role as ‘sustainable citizens’ or/and, in some cases, self-sufficient energy-independent consumers that are resilient to external threats. That said, the users did not manage to time shift the electricity consumption for the EVs according to their own “surplus” production of PV power. All users plugged in their EVs when they came home in afternoon. In addition, the only households who time shifted and changed routines on dish-washing, clothes-washing and baking were on the newest scheme of account settlement (hourly net metering), which increased the incentive to use the consumption while producing the energy.

The ZEROhome households were not ‘producers of knowledge’ as in the ‘research partner’ user role. ProjectZero attempts to maintain a good contact and relation with the households in order to have some good showcases to be used in their running campaigning for an energy transition in the Sønderborg area. Even though none of the participants were directly engaged in the initiatives facilitated by ProjectZero, the users positively declared the value of being a part of the ZEROhome network, which demonstrates how ProjectZero succeeded in creating and anchoring the vision within the local community as a shared vision. Thus, many of the ZEROhome members acted as “best practice” cases through hosting visits for guests at ProjectZero and/or being interviewed for news pieces on the ProjectZero website etc. In this way, they to an extent were ‘casted’ in the role of being local promoters of the energy transition – a role resembling the energy citizen role.

Finally, a few households were engaged in experimenting with combining different energy solutions and optimising energy efficiency and self-sufficiency within the home (cf. the example mentioned in the previous section). This shows that a smaller group of the ZEROhomes were dedicated user-producers (user-innovators), somewhat similar to the 100 % renewable energy household of Köstendorf.

Example 3: The multi-level user innovator

This example is located at the regional branch of a large Norwegian grocery wholesaler with the core activity related to selling and distributing groceries to stores, retailers and the catering industry across the country. The company has a 27 000 m^2 storage facility and distribute goods to more than 1700 stores and restaurants. Much of the storage space is energy intensive, as is used for cooling and freezing food by means of hydroelectricity. To distribute the goods, they have around 50 distribution trucks. The activities of the company are both fuel and electricity intensive.

The company is owned by a large national actor that possesses a broad portfolio of corporations such as grocery store and fast food chains. The last 7-8 years, a key group of owners have become environmental protagonists arguing for the importance of broader societal and environmental engagement in order for both the company and the planet to survive. In line with this, they have been able to reconfigure the overarching goal of the company. Thus, the ASKO case clearly highlights the energy citizen perspective of its owners. Environmental concern, climate mitigation and responsibility for future generations have been one of the driving factors behind the development of this development. The goal is to become climate neutral in every aspect of its operations. This first became manifest through a decision by the board of directors five years ago, where it was stressed that the return on environmentally oriented investments could be much lower that than return on “ordinary” investments. Thus, they have worked intensively to change the rules of the game towards a less profit oriented and towards an environmentally benign direction, both internally and externally. The owners did not dictate how companies in the structure should work to become sustainable, only that they should. However, it was quickly translated into concrete goals for ASKO being 100 % self-supplied with new renewable energy by 2020, as well as switching to 100 % renewable fuels for transport. On a corporate level, the first decision was to invest roughly 20 million euros in a wind park with a 60 GHW annual capacity.

This would cover the equivalent of 75 % of all annual electricity consumption throughout the corporation. Several respondents from the regional branch highlighted how their own initiative was the result of a combination of external push and internal motivation: they decided to install PV on the rooftop of the storage facilities, in total 12,000 square meters of PV. This would cover 15-20 % of the consumption. Thus, ASKO was now a prosumer.

Internally, this new emphasis on environmental issues on the company level was also used to promote sustainable choices to employees. An annual environmental fund of roughly 1 million Euro was established, funding electric bikes, environmentally and energy efficient home renovations, or tickets for collective transport for employees, as well as on-site electric vehicle chargers, which employees could use for free. This turned out to give employees a sense of pride and motivated the employees to think about the environment and to change to more environment-friendly practices.

Apart from being interested in building a sustainable business, they have also been interested in being innovative or "ahead of the pack", which of course can be seen as a business strategy as much as a will to act as energy citizens, as well as interests to innovate and being a research partner. In light of this, and their long relationship with certain research institutes, ASKO agreed to participate in a project to replace some of the lift batteries used in trucks with hydrogen fuel cells, which turned out to give approximately 85 % reduction of CO_2 emissions on the trucks. This success was essential for ASKO in terms of energy efficiency. However, just as important was the fact that the ASKO management now became convinced of the potential practical qualities of hydrogen fuel cells. Hydrogen, they now believed, was an option to pursue in the strategy to decarbonize their fleet of heavy-duty transport trucks and forklifts. This was not only a result of being newly convinced of the qualities of hydrogen itself. The move was further motivated by the prospects of surplus electricity production from their PV installation. Thus, what was originally a move to engage in energy generating practices was suddenly an essential ingredient in a shift towards producing their own fuels, and decarbonizing their transport fleet through hydrogen. Together with a long-term research partner institute, ASKO thus approached several large actors in European car manufacturing, with the goal of acquiring trucks for a pilot project on hydrogen trucks. Through intense lobbying together with the research institute, targeting their existing car manufacturer, they were able to commission three 27-tonne trucks, to be experimentally developed by the supplier in tandem with a project group consisting of people from ASKO and the research institute. The hydrogen tucks, will of course need fuel, thus ASKO proceeded to investing around €2.3 million in an off-the-shelf hydrogen production facility which will be installed on-site.

Over a few years, ASKO have substantially re-configured their relationship to energy and have gone from being a large consumer of energy to producing large quantities of electricity, as well as substantial quantities of hydrogen fuel cells for their transportation needs, as well as being involved with developing new transport technologies. Thus we clearly see how ASKO act as a driver of innovation developing a smart energy solution, according to own needs and mainly based on own resources and capacities. In this constellation, we see how the user acts as a producer and as a technology developer, where the grocery wholesaler is developing a hydrogen infrastructure for hydrogen-powered fleet of heavy-duty delivery trucks.

Externally, they have worked to push authorities into tightening demands and supporting transitions to more sustainable transport. Thus, they have worked to achieve both market and policy acceptance, and have had agency and capacity to enact transition agency. Further, they have taken part in re-writing the semi-coherent grammar or rule-set (Geels 2011) that they are embedded in. ASKO is a large company, and as we have seen above we could identify four different user roles in this case: the (1) energy citizen, (2) user-producer, (3) prosumer, and (4) user-innovator and the user-scientist.

4.4.3 Conclusion

The main focus of this subchapter was on the role of users in the studied smart energy solutions. Our analysis has clearly shown that users actively contribute to the success of the solutions. Users contribute to the development and the running operation of the solutions, help to build up and stabilize supporting social networks, and shape the political meaning and legitimization of smart energy solutions. In most cases different users take on specific roles, in other cases even individual actors perform several user roles. Based on our case studies, we were able to identify six different user roles and their respective characteristics.

As research partners, users participate in temporary projects and provide valuable information for the further technical development. Traditional users, on the other hand, represent more or less the mainstream, which provides important information for the wider dissemination of the solutions. Prosumers actively participate in the generation of electricity and partly they act as commercially oriented producers – they take on risks and expect profits. Energy citizens, on the contrary, are users who play a politically active role in the transition of the energy system towards greater sustainability and often accept larger financial costs during the process. Affiliated users – a type of user that has not yet been discussed in the literature – usually are employees of the project owner which take on the role as early end-users and test the solutions under development in real-world contexts. Finally, user innovators are social players who themselves develop new solutions according to their ideas and needs to a wide extent. We have found a selection of all these user roles in our cases. Together they contribute to the success of the solutions. In other words, our analysis has shown that users of smart energy solutions are collectives consisting of different constellations of users who perform different roles.

Since the different roles always occur in combination with each other, we speak of 'bundles of user roles'. These 'bundles' reveal a wider variation of requirements and preferences and therefore make it possible to influence our constellations on three levels effectively; (1) they contribute to the solutions functioning, i.e. fulfilling their intended purposes, (2) they enable problems and shortcomings to be identified and the solutions to be further developed, and (3) they support the social and political stabilisation of the solutions. It is only through the combination and interaction of different user roles that new knowledge is generated, practical experience is gained and the solutions are given social meanings that possibly go beyond the concrete situation.

5 Conclusion

In WP3 we have tried to compare projects and configurations across countries and cases to find common patterns that improve our understanding of the success of the studied solutions. The results of this work package are summarised in this report.

Our research strategy was mainly inductive, i.e. we searched for meaningful topics and cases that could be compared based on the available empirical material. The aim was to identify differences and similarities in our total 'sample', and based on this overview, we selected a number of 'clusters of solutions' for in-depth analysis. Thus, the following four topics were selected: Balancing generation and demand using solar PV and storage, renewable powered company fleet as a smart energy solution, comprehensive energy concepts, and the role of users in emerging socio-technical configurations. The first three topics represent empirically developed bottom-up thematic clusters, whereas the fourth issue was more theoretically motivated – since the role of users in any form of innovation is a critical issue.

The research on the four comparisons followed a similar approach. First, the projects and solutions used were described in more detail. Then differences and similarities were elaborated. Thereby we again accessed the existing empirical material and evaluated it from new perspectives. The final aim was to discuss critical factors and common patterns across countries and projects.

The first comparison of solutions that aim to better balance supply and demand revealed that working configurations most notably depend on local anchoring activities, favourable economic conditions, and ample opportunities for social learning. Usually those solutions fit well with existing local or regional policies and strategies, the activities are part of already on-going developments, and there are responsible actors on the ground who actively drive the developments forward. The economic situation of these configurations has been strengthened both by direct financial support and by advantageous tariff systems. Whereas social learning has been enabled by a high degree of social interaction, town hall meetings, or education and information campaigns.

In the case of the two company vehicle fleets powered by renewable energies: a number of outstanding similarities were found – despite major differences regarding the initial situation. In both cases a highly supportive political context, already existing social resources and network-building skills, an encouraging corporate culture focusing on innovation, external know-how strategically involved to solve emerging problems, and two companies acting as user-innovators with a real use case and actual end-users as test persons. In one of the two cases, the development has meanwhile progressed so far that the company is already offering the resulting knowledge as a consulting service to potential emulators. This was possible because the necessary development 'environment' (development, testing and application) was available and/or made available in the company's own operations.

A further comparative analysis related to the development of comprehensive energy solutions. In this context, the term 'comprehensive' refers to solutions with which as many energy-relevant measures as possible can be addressed simultaneously. As the analysis has shown, such solutions are also characterised by effective local anchoring. Usually, those examples are enrolled and embedded within ambitious community-led transition strategies that involve a wide range of different interconnecting initiatives, technologies and multiple actors. It seems that successful comprehensive solutions in any case are part of longer (political) processes involving previous experiments, implementations and reiterated initiatives. Hence, the studied solutions represent just single elements in a much wider spectrum of energy transition initiatives. Thus, path dependencies of innovation related activities cast a long shadow for follow-up projects. Although those solutions usually build on pre-existing social networks, one local key player seems of particular importance as the ‘leading’ actor for designing the solutions as well as driving and facilitating the processes and initiatives of cooperation, network building and communication.

The final comparative analysis dealt with the role of users in the solutions studied. The most remarkable finding of this analysis was that, in most cases, a variety of different user types or roles contributed to the functioning of the solutions. We were able to identify six different user roles and their respective characteristics: Research partners, traditional or ordinary users, prosumers, energy citizens, affiliated users, and user-innovators. Since the different roles (not all roles in any case, but most of them) did always occur in combination with each other, we called the resulting principle ‘bundle of user roles’. These bundles were able to inform the technical functioning, to influence the way in which problems have been solved, and to support the social and political stabilisation of the solutions. In summary, it was the diversity of perspectives, interests and requirements that had a positive impact on the development and operation of the solutions and the socio-political context that made this diversity of user roles possible.

The analysis carried out in this report forms the basis for the development of recommendations from the MATCH project (see the deliverable D 5.1 of MATCH). The comparisons presented in detail in this report will only briefly be taken up in the context of the recommendations from the project. The two reports therefore complement each other in this context.

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