Recommendations for researchers, designers and system planners

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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 programmes along the innovation chain provides a sustainable and service-oriented joint programming platform to finance projects in thematic areas such as smart power grids, regional and local energy systems, heating and cooling networks, digital energy and smart services, etc.

Co-creating with partners who 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.

In addition, ERA-Net SES provides a knowledge community, involving key demonstration projects and experts from all over Europe, to facilitate learning between projects and programmes from local level up to European level.

www.eranet-smartenergysystems.eu

The *Markets, actors, technologies: a comparative study of smart grid solutions* (MATCH) project ran from February 2016 to October 2018 and was 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 entails new ways of generating and consuming energy as well as new forms of relationships between energy producers and consumers. The MATCH project contributes to the shift towards a carbon-neutral energy system by focussing on the changing roles of small consumers in the future electricity system (the "smart grids").

The overall objective of MATCH was 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 demonstration projects in Austria, Denmark and Norway. Through comparative analysis across cases and countries, the study identified key factors related to technology, market and actor involvement in developing integrated solutions that "work in practice". Furthermore, the project applied energy system analysis and scenarios to discuss the wider energy system implications by upscaling the studied cases and solutions.

On this basis, the project developed recommendations for decision-makers, engineers and project developers. This final part of the MATCH project is included in this report.

1 Introduction

The overall objective of MATCH was to expand our understanding of how to design and implement comprehensive smart energy systems solutions that take into account the complexity of factors influencing the effectiveness and success of such initiatives targeted at small consumers.

Based on detailed case studies (three in each country), comparative analysis and an energy system modelling analysis, key factors related to technology, market and the involvement of actors (stakeholders) in developing integrated and workable smart energy solutions were identified. In addition, a number of energy system scenarios were developed in order to further explore the systemic implications of local solutions. The results from the project may inform designers, system planners and policy-makers about how to develop better smart energy solutions for small consumers such as households and small to medium-sized enterprises (SMEs).

As a result, MATCH aims to contribute to the ongoing energy transition in Europe. Main policy targets of this envisioned transition are 1) energy saving (reduction in absolute terms), 2) energy efficiency (reduction in relative terms), and 3) a higher share of renewable energy sources in all the systems (European Commission 2016). In addition to these energy objectives, the European Commission addresses industrial policy aims (global leadership in renewable energies) and societal goals (providing a fair deal for consumers) as equally important objectives. All these political positions are important points of reference when it comes to recommendations based on findings from the MATCH project.

Smart energy solutions – as studied in MATCH – usually involve a high degree of complexity: More (and new) actors and more (and new) technologies are involved in emerging configurations to create working and integrated solutions that fulfil several functions at the same time. A good example of this is the building-to-grid configuration in the *Rosa Zukunft* project. The configuration aims to support several goals of the politically encouraged clean energy transition at the same time: Energy saving, energy efficiency, a higher share of renewables (locally and trans-regional by providing balancing capacities for the electricity grid) and satisfied customers. The studied solution certainly worked in the specific local context. Moreover, to analyse whether these context-specific solutions can have positive system effects on a national level, when generalised and upscaled, a system analysis was carried out in MATCH.

Based on the nine case studies carried out in the project (WP2), we gained knowledge about the history of the studied projects, the actors involved, the (national, regional) framework conditions, the aims and objectives, outcomes and lessons learned. In WP3, we compared (and contrasted) findings from similar types of solutions obtained from different sites to identify key factors (e.g. similar patterns) related to technology, market and the involvement of actors (stakeholders) in developing integrated and workable smart energy solutions. WP4 relied on these findings, selected promising solutions and analysed their implications for the existing national energy systems in Austria, Denmark and Norway.

An earlier version of the following recommendations was presented to and discussed in detail with interested audiences in each of the three partner countries. The results of these three workshops have been incorporated in the formulation of the below recommendations.

2 Recommendations from the MATCH project

Each of the following sections starts with a presentation of the issue under discussion, followed by a brief analysis based on MATCH's results, and the resulting recommendation. Most recommendations deal with the overall question of how to develop and operate locally successful solutions. On the one hand, this was the main focus of the empirical research in the project. On the other hand, most of the solutions presented here are still at a relatively early innovation stage. It can therefore be assumed that further diversification (broadening) and improvement of existing solutions (deepening) will be seen over the coming years. However, given the socio-technical nature of the solutions studied, even a more or less straightforward replication of already tested solutions will heavily rely on tacit knowledge and experience from previous demonstration projects in order to adapt solutions as effectively as possible to existing local and regional conditions – in technical, economic, legal and social terms. This was one central argument for focussing the recommendations on the development of locally well-functioning solutions.

However, since we are aware that solutions functioning locally may lead to suboptimal results on a regional or national level, a final recommendation is presented with regard to the systematic effects of local solutions – based on the energy system analysis applied in WP4.

The recommendations presented below focus on the design of concrete solutions as socio-technical configurations, the question of their local anchoring, the role of tariff systems and price incentives, the question of how consumption and demand can be better aligned with each other, the role of users in the development and the operation of local solutions for small consumers, and finally the question of possible systemic effects of locally successful solutions.

2.1 How to design a "working" smart energy solution in general

Issue: The anticipated transformation of the energy system demands a wide range of different solutions that fit local and regional conditions and simultaneously fulfil various functions and requirements (e.g. better integration of renewable energy sources, higher levels of energy efficiency, grid parity, security of supply). Based on previous research, we might expect that a few one-fits-all solutions are not going to be the answer. Hence, socio-technical variation and testing of a large number of possible solutions is (and will be in the future) key for a successful transition of the energy system. Solutions studied in the MATCH project represent a good part of the current state-of-the-art, but certainly not the final stage of development in this area. Additional and better solutions must and will be developed and implemented over the coming years. Based on this assumption, we may ask which general recommendations can be derived from the MATCH analysis of already applied solutions for further development of new and enhanced solutions in the European context.

Analysis: The MATCH project showed that the studied projects successfully defined, set up, tested, and in most cases also ran a considerable number of new and quite different smart energy solutions. Main actors involved did provide sufficient information about the working of the implemented solutions and were able to name various qualities of "success". In WP2 and WP3 we aimed to improve our understanding of the different aspects of what was defined as success. One of our main research claims was that the working of the solutions could only be understood adequately if they were framed as socio-technical configurations. In doing so, technologies appear as one element amongst several others combined into a working structure. Consequently, this specific combination is the basis for their functioning. Technical elements such as photovoltaic (PV) panels, smart meters or battery systems are closely linked to social elements such as formal and informal agreements, tailor-made tariff schemes, specific ownership structures, user preferences and aspirations, or new maintenance routines. Designing such a “working” smart energy solution thus requires a broad focus, a variety of skills, different kinds of knowledge, and a sense of flexibility and adaptability with regard to pre-existing local conditions (culture, technology, infrastructure, social capital, etc.). In almost all of our cases, interdisciplinary teams were responsible for the development of the studied solutions. Moreover, designing is a process that does not end with the first implementation of a concept, but usually needs an introduction phase allowing for information, mutual exchange, social learning and adaptation. Such a design approach may in the end lead to working business models; however, what we did see in our cases usually went beyond a simple supplier-customer relationship.

Recommendation: Smart energy innovation could benefit from an approach that takes the comprehensive socio-technical configurations into account from the outset. Such a design approach would recognise heterogeneous elements as equally important for the working of solutions, focus on the combination and interaction of crucial elements, and consider and mobilise existing local conditions in a sensible way. The most important criterion for the development of such solutions is that the best possible outcome is achieved through joint alignment of social and technical elements. Critical for the implementation of such a strategy are interdisciplinary project teams and robust local networks.

2.2 How to ensure local anchoring, acceptance and support

Issue: A thorough transition and decarbonisation of the energy system ideally involves a wide range of actors and should be grounded upon widespread public acceptance. One promising road towards this appears to be the combination of comprehensive energy solutions that cover all sectors and the development of a wide range of integrated solutions (as already described in section 2.1) with local anchoring. In this section, we focus particularly on how to ensure the local anchoring of the energy transition. The assumption is that without this local anchoring, it will be difficult to realise the energy transition on a wider scale. Also, local anchoring can be part of activating local resources and actors in realising ambitious transition goals. On this basis, we may ask what general recommendations can be derived from the MATCH analysis of different cases for the development of locally-anchored solutions in the European context.

Analysis: The MATCH project shows that the success of community-oriented projects is dependent on three key characteristics. First, ambitious community-led *transition strategies* covering a specific locality or region played a strategic role in several cases. These strategies create a frame and narrative for local initiatives targeted at energy transition. It helps to coordinate and organise individual initiatives into a coherent move towards a decarbonised, local economy. By associating single initiatives with the overall strategy, the strategy itself becomes an organic and evolving vision that helps branding the local area. The strategies often also become recognised nationally or even internationally, which helps new initiatives secure funding by referring to the overall strategy and vision. In some of our cases, the energy transition strategies and visions were also connected with broader societal goals such as revitalising the local economy through attracting more business and citizens. This seems to provide the energy transition with further legitimacy within the local community. In this regard, we even found evidence of local citizens and business people being proud of the local achievements and their contributions to this. Second, a long history of transition initiatives played a key role in several of the studied cases. The history of energy conservation and installing local renewable energy capacity sometimes dated back several decades and represents a long list of initiatives that together form a successive progression towards decarbonisation and energy autonomy. New initiatives often build upon *previous experiences and local networks* of actors developed throughout the years. The long history of activities often also contributes to a local identity or narrative of being a national or international frontrunner in terms of the energy transition. Third, in the studied cases we identified one or more *“entities” that coordinate and align* the single, local initiatives. This entity can be the previously mentioned shared narrative (strategy) of local energy transition or the long history of initiatives that creates a local network of actors with mutual trust and interests. Another type of coordinating entity can be a local key actor (e.g. an energy provider/grid owner or a public-private partnership) that facilitates communication between other local actors, provides advice or technical expertise, coordinates proposals for funding, etc. In addition to these three key elements, *long-term funding opportunities* (e.g. local/regional funding programmes for energy transition) can play an important role. In most of the studied MATCH cases, several – or even all – of the above-mentioned three key characteristics could be identified.

Recommendation: Smart energy innovation needs to support processes of local anchoring in order to promote solutions with a high level of local legitimacy and to make local resources and actors become an active part in the transition. This can be done by promoting and nurturing the three key characteristics identified in the MATCH study: creating ambitious and community-led transition strategies covering local areas or regions; creating conditions that support a continued local engagement (e.g. through long-term funding programmes or by tapping into and build upon existing and previous energy transition initiatives); and supporting locally-anchored entities (key actors or shared narratives) that can help coordinate and align individual initiatives.

2.3 How to make price incentives work in practice

Issue: Throughout the years, much trust has been put in financial incentives as a main driver for behavioural change. In particular, time-of-use (ToU) pricing (or "dynamic pricing") has attracted attention as a way to promote demand response (DR) through making consumers time-shift their consumption from hours with high electricity prices to hours with low prices. This rests upon the idea of the price-sensitive energy consumer (customer), i.e. the idea of the individual customer as a "rational agent" who responds to price-signals. However, experience from pilots and demonstrations shows a more mixed picture as households did not respond to economic incentives in the expected way. Therefore, there is a need to revise the naive conceptualisation of the price-sensitive and economic-rational customer and develop a more nuanced and productive understanding of what role price can play, and under which conditions?

Analysis: The studied cases in MATCH included a variety of ToU pricing schemes, e.g. combining micro-PV generation with hourly net metering (promoting self-consumption through synchronisation with PV power generation), dynamic prices reflecting spot market prices or tariffs based on the customer's peak power consumption. Several analytical observations can be made regarding the role of economic incentives (price) in promoting load shifting (demand response) in households. First, ToU pricing (including capacity-based tariffs) had a positive influence on households' active engagement in time-shifting consumption in several of the studied cases. Also, the size of the price spread between lowest and highest price appears to play a role for households' engagement (with lower spreads implying lower interest). However, the specific impact of price incentives on households' active demand response engagement depends on a wide range of other (non-economic) elements in the socio-technical configuration, which the price schemes are part of. In particular: a) micro-generation appears to help make the local power production more "visible" to households and thereby promote engagement in active load shifting; b) dynamic ToU pricing schemes with unpredictable prices are generally refused by households as they are seen as too difficult to adapt to and build new routines around; c) the framing of ToU schemes and households' trust in these are important (e.g. distrust in the energy company promoting a scheme can disengage participants, while local anchoring of ToU initiatives is often a productive framing for active engagement); d) physical and material conditions such as the proximity to neighbours are pivotal, e.g. households in apartment buildings find it difficult to time-shift consumption to night hours due to problems of noise; f) the socio-economic parameters of the households such as education and income level, job, age, size, etc., also seem to influence the flexibility of households to time-shift; g) the design of ToU trials in terms of the strategic participatory approach, value framing and process is significant for households' persistence and commitment to establish and perform new routines related to demand respond; h) finally, it is mainly energy-intensive and/or semi-automated energy consumption such as dishwashing, laundering and electric vehicle (EV) charging that households manage to time-shift. With regard to the latter, it seems that households generally prefer automation of load shifting (e.g. by use of home batteries to store PV surplus production for later self-consumption), although automation only works in cases where the automated time-shifting of consumption does not affect daily household routines too much.

Recommendation: The overall recommendation is to avoid overestimating the effectiveness of financial incentives and ToU pricing as the essential means to promote active load shifting amongst small consumers and households. Financial incentives (and their size) do play a role, but often more as a "marker" or "signifier" that can attract households' attention to demand response schemes and to anchor the idea of time-shifting consumption. The actual effectiveness of ToU pricing schemes is conditioned by the wider context of the schemes, i.e. the socio-technical elements that the pricing schemes are embedded in. From the analysis, the following specific recommendations can be made: 1) Combining ToU pricing with local renewable energy production (e.g. rooftop PV systems) can help motivate local consumers to time-shift their consumption because of the visibility and profitability of the intermittent energy production; 2) it is recommended to avoid too complex ToU pricing schemes, especially those based on dynamic and unpredictable ToU prices – overall, static ToU pricing schemes should be preferred as these make it possible for people to adopt new daily routines and temporal rhythms according to the price scheme; 3) if possible, it is recommended to ensure a long-lasting and local anchoring of the ToU demand response initiative – noteworthy in this context is awareness of the importance of establishing people's trust and confidence in the scheme, e.g. through communication and local meetings; 4) local material conditions, e.g. households living in apartment buildings often find it more challenging to time-shift consumption (especially to night hours because of noise), must be taken into consideration; 5) consideration should be given to whether a proposed ToU pricing scheme promotes time-shifting actions that are practical and can easily be adapted to the daily routines and temporal rhythms of the (socio-economic) individual characters of the households.

2.4 How to balance generation and demand

Issue: A main challenge concerning the influx of smart energy technologies in households, such as e.g. PV systems and storage, is how to effectively use these additions when it comes to grid balancing. The fundamental expectation of the smart grid is that it introduces ways of alleviating strain in the grid as well as on the climate by giving end users the tools to reduce and time-shift electricity use to better accommodate intermittent resources and reduce grid investment costs.

Analysis: The move towards a smarter grid is happening in a context of ever-increasing electricity use, as for instance e-mobility and heating are switched over to electricity as energy carrier. This challenge has a double solution. On the one hand, smarter appliances can be programmed to achieve concerted load profiles that take into account restrictions in the system on a large scale. In our analysis, this was found to be a successful strategy in the case of apartment complexes and in professional settings. Here, the benefit was centralised and professionalised control of medium and large-scale measures (a fleet of EVs, a large PV park, heat pump, large water storage, etc.), ensuring they were effective and continuously maintained, in combination with a robust and powerful control and monitoring unit. This type of solution leaves out the role of end user agency to a large extent, and requires a high level of competence on part of the building operators who have a long-term commitment to deal with the system.

Conversely, our findings included cases where new technology, tariff schemes, knowledge, and practices were introduced into households in order to have balancing measures maintained by end users themselves. This proved feasible in several cases, but requires resources spent on professional surveillance/control of robust automation are instead diverted to spending time and resources on social learning. Social learning is necessary when the aim is to enrol end users as prosumers or flexibility providers, in addition to merely introducing the technological tools required for empowering households to participate in balancing generation and demand. Technological tools are of course necessary, and in our cases included things that either contributed or consumed a lot of electricity, for instance PV systems, EVs, heat pumps, and water boilers. But in order to influence and change the practices related to the use of these material objects, and thereby bringing about the actual load shifting behaviour that allocates and allows making use of end use flexibility, monitoring technologies and price signals are important, too. A higher degree of success in engaging end users and making them partake in balancing of generation and demand is thus contingent on a *sufficient* process of social learning. By sufficient we mean that it provides impetus for action in the form of price signals and potential for economic remuneration, but that it also provides practical knowledge of methods and tools that may be effectively employed to achieve results, such as reaping benefits from price incentives (e.g. capacity-based tariff). In other words, users must be in a position to act in accordance with smart grid design.

Notably, when relying on end users for bringing about the flexibility the successful smart grid relies on, it is possible to also introduce measures alongside user-centred interventions that are more or less centrally controlled with professional surveillance/control. This was demonstrated for example in the case of Heat-as-a-Service (GreenCom) and a trial involving intelligent demand-side management (DSM) equipment for appliances (Smart Energi Hvaler).

Recommendation: Balancing generation and demand on the scale of the household or neighbourhood can successfully be accomplished in two ways, either by 1) implementing automation that is maintained by professional operators, or 2) have users manually implement balancing measures by installing and programming automation and/or changing behaviour and practices. Our findings suggest both are feasible, but relying on user agency is less predictable (more contingent) and necessitates that project owners focus time and resources on social learning. Social learning involves applying multiple tools and inroads to increase user knowledge and agency over balancing measures. In sum, social learning should rely on an introduction of price signals and visualisation tools as well as training in what constitutes effective practice change, and/or automation tools and how to ideally employ them.

2.5 How to involve technology users

Issue: A key debate in discussions about smart energy technologies and their deployment revolve around how to engage and motivate users. The same is true for the socio-technical configurations and solutions explored in the MATCH project. This is not unusual since the "success" of all smart energy technologies heavily depends on the way they are actually used: e.g. technologies that aim at producing end user flexibility require practice changes amongst users in order for them to "work"; a technology meant to enable shared electro mobility does not really work unless anyone uses it to share electro mobility services. In addition, however, users may already play a decisive role in earlier phases of development under certain conditions, which has an influence on the design of the respective configuration.

Analysis: The analysis in the MATCH project supports recent claims in the sustainability transition literature highlighting that the role of users in smart energy innovation is much more diverse than "end users" who either accept or reject pre-defined technology scripts (e.g. Schot *et* *al.* 2016; Ryghaug *et al.* 2018). Instead, many of the cases indicated that users can take on a range of different roles which allow them to engage with the solution in question in different ways.

First, users, in cases studied in the MATCH project, have taken the form of *ordinary consumers* in which their engagement with the solution is limited to being a customer of companies involved in developing a demonstration project. Second, in other instances, users have been engaged as *research partners or citizen scientists*. In these cases, recruited technology users try out new technology and agree to be studied, but they often also contribute actively in developing and disseminating new knowledge. Sometimes, this is done in explicit technology development collaboration, sometimes even initiated by prospective users themselves. Third, several of our cases involved users as *prosumers*, which entails producing and selling electricity to the grid operator. An important, not to be underestimated aspect in this case is the fact that these users take a certain amount of entrepreneurial risk. Fourth, we have identified users that act as *energy citizens.* These users act as politically engaged stakeholders in the transition of the energy system towards greater sustainability, thus taking on a sense of responsibility that transcends participation as buying or selling something. Fifth, *affiliated users* are usually employees of the project owner. They effectively take on the role as early end users and test the solutions under development in real-world contexts. Sixth, there are *user-innovators or user-producers.* These users are drivers of innovation who develop a smart energy solution according to their own needs, and that are mainly based on their own resources and capacities.

The study of users in MATCH indicates that technology development and use is a much more complex phenomenon than simple instances of human-technology encounters in which humans either accept or reject technologies. Rather, we have seen that users participate in transition activities in very different ways. Since different roles usually appear in combination with each other, we called the resulting principle “bundles of user roles”. These bundles inform the technical design, influence the way in which problems are solved, and support the social and political stabilisation of the solutions.

Recommendation: The success of most smart energy solutions depends on users and their adoption of technology as well as associated changes in behaviour. Yet, this is not a challenge of “acceptance” where the clue is to find a “trick” to bring all possible users (addressed as customers) on board. Instead, it is important to manage the necessary diversity of different user roles and their associated perspectives, interests and requirements that may have a positive impact on the development and operation of the solutions. Based on our analysis, it can also be concluded that a certain degree of diversity makes sense even in early development phases, and that it is therefore less a question of a chronological sequence than of the particular bundles of different user roles in parallel. Generally speaking, project developers have to think about users as a diverse resource, and also a potential source of innovation from which we can pool important insights.

2.6 How to integrate smart energy solutions into national energy systems

Issue: Even though the studied socio-technical configurations work well for small customers and can be replicated and rescaled to a certain extent, the dynamic relationships and integration into the system level can prove difficult. A number of smart energy system solutions were studied and presented in WP2, but the question remained on how small-scale solutions can fit into the national energy system in Austria, Norway and Denmark. What works well in one situation cannot always be expected to work in a similar way in even slightly different situations. Instead, some solutions might only work on a certain local or national level, but may not work in a different location or nation. The remaining issue is therefore to discuss options and limits when wanting to replicate small successes to a larger scale. In this context, the focus cannot stay on the electricity sector only, but should evaluate smart energy system solutions affecting the whole energy system(s).

Analysis: Whilst the various study cases were successful on a small scale, some of their aspects were addressed on the national scale to point out opportunities as well as weaknesses. For this, the approaches in the field of DSM or DR, micro generation and storage were included, while representing typical technical solutions for the studied countries. Instead of being seen as independent smart grid solutions, the MATCH demonstration projects were rather put into context, both in terms of size and sector integration. This was done to evaluate the expansion or upscaling of the solutions as well as evaluating changes in the electricity sector and their impact on other sectors, such as the heating or transport sector, with its effects on fuel consumption and emissions. This way, the smart energy solutions are seen as not just individual projects, but as part of something bigger, namely as an integrated part of an energy system. In doing so, the possible implications can be evaluated beyond the local level and under different circumstances. At the same time, local aspects such as behaviour and social conditions can be included and tested on a larger scale than individual projects would have done. In relation to 2.2 (Ensure local anchoring), local anchoring was also kept in mind for the analysis. The coordination and communication in the smaller local context creates the basis for the results in the larger context. However, WP4 is rather addressing the technical simulation of upscaling the demonstration projects that included social aspects to a large extend, but cannot keep up with all the details of the small-scale versions. Three final energy system analyses (ESAs) were made addressing: applied micro-production and storage; DSM and DR; and DSM through electric vehicles – thereby including markets, actors and technologies (see MATCH deliverable D4.1 for further details on the energy system analyses). Therefore, the energy system analyses present options and possibilities that require the reader to bridge the gap between real projects and system evaluation, looking at both the local and the national level at the same time.

Recommendation: Through the ESAs, a basic comprehension of the contextual consequences should be achieved to understand the full impact of smart energy projects and “solutions”. This entails further research and modelling of the MATCH study cases, for example their functionality in other geographical areas or on different scales. Furthermore, the varying results and impacts must be understood because a certain solution might not be replicable elsewhere under the same conditions, and therefore causing different results. Depending on the targeted outcome, a replication or up-scaling can be seen as positive for some but not for others. For example, a reduction in imported and exported electricity or fuels can have different effects and results in different countries. Depending on the existing renewable energy sources capacity, the impact can vary greatly, and our recommendation is therefore to have awareness of the necessity of locally establishing sufficient renewable electricity, heat and fuels. If demands increase without such accompanying development, existing capacity will be drained fast and power plants would have to supply them by using coal or gas. For this, a detailed analysis, taking into account short-term variations, seasonal changes and future possibilities, is recommended, too. Finally, these considerations can help choose and integrate the “right” smart energy solutions to design and balance future energy systems.

3 Concluding remarks

The main focus of the MATCH project was to improve our understanding of how "successful" local energy solutions are designed and implemented. Success, however, was defined in relative terms, elaborated through statements and ascriptions mainly by the actors directly involved in the various projects and solutions. By comparing projects and configurations across the three participating countries, it was possible to describe a number of critical aspects more precisely and conduct more thorough analyses.

- We have pointed out that successful implementation of the solutions depends to a large extent on a well-designed interplay of social and technical elements. We have furthermore argued that smart energy solutions should be considered as heterogeneous configurations from the very beginning.
- We have shown that such solutions must rely on local anchoring activities and, based on our case studies, have made suggestions as to how this can be achieved in practice.
- We have discussed the role of tariff systems and price incentives (ToU pricing) and have concluded that financial incentives often work as a "marker" or "signifier" that may attract consumers' attention, but the actual effectiveness of pricing schemes is determined by the wider context of the schemes, i.e. the overall socio-technical configuration the pricing scheme is embedded in.
- We have addressed the issue of balancing consumption and demand, and pointed out that the success of such approaches essentially depends on the extent to which social learning is implemented.
- We have studied the role of users in innovation processes and seen that successful solutions are simultaneously influenced by a variety of user roles already during early phases of development. Based on this knowledge, we recommend that it is important to ensure diversity of different user roles and their associated perspectives, interests and requirements from early on.
- Finally, on the basis of our energy system modelling, we have suggested that it is important to examine the various systemic effects of locally successful solutions for existing energy systems (regional, national) before replicating or upscaling them.

One topic repeatedly addressed over the course of the project and discussed more intensively in the three public MATCH workshops carried out in 2018 relates to the upscaling and increased dissemination of already available (and well-working) smart energy solutions. Given the ambitious energy policy goals within the European Union, this is a legitimate question. Although this highly relevant question was outside of the scope of MATCH, a few comments and observations from the project will be addressed in this final section in brief.

- Although we have been presenting configurations that are already successful, there is hardly any solution in our sample which could be distributed on a large scale in its present form. There are three main reasons for this: First, the success of these solutions depends to a large extent on a coordinated interplay of elements and well-functioning local anchoring activities. This means, on the other hand, that replication depends on appropriate adaptation services: in another local or regional context, different elements of a successful configuration would need to be arranged differently. Second, from the point of view of the system as a whole, the widespread dissemination of a solution often does not appear to make sense, but rather the combination of many different solutions (see Eikeland and Inderberg 2016). And third, an explicit recommendation for the accelerated dissemination of solutions would have to include an external assessment of the direct effects and possible unintended consequences, something which could not be achieved in the present project.

- However, we were also able to observe diffusion processes in the context of this research. Some operate mainly via traditional *market mechanisms*, others essentially via locally established *social networks*. An example of the first type of distribution is the building-to-grid solution in the city of Salzburg. Following the example of the *Rosa Zukunft* project, the local energy supplier has already implemented similar projects in cooperation with local housing developers. Another example is the electric vehicle fleet solution from the VLOTTE project: the experience gained over the years is already being offered as a consulting service. ProjectZero in the Danish region of Sønderborg represents an example in which solutions are predominantly disseminated via social networks. ProjectZero is a public-private partnership between several local (energy-related) companies and the municipality of Sønderborg. The project acts as an intermediary that promotes and coordinates all relevant actions that support the local energy transition. The dissemination of solutions is very effective with this model, but remains limited to the respective region.
- Another way in which the results of local demonstration projects can be disseminated is by *generalising* specifically selected experiences. We found such an example e.g. in the case of the low-voltage grid field test in the municipality of Köstendorf in the province of Salzburg. The conducted real-world experiments showed that – at least up to a certain extent of PV distribution – the existing grid is sufficiently protected against overloading by phase shifting (phase-shifted current is fed into the low-voltage grid). Consequently, high investment costs for controllable transformers can be avoided with this measure in the future. The grid operator translated this result into an obligatory requirement for all new PV systems in the area.

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