EXPERIMENTS FOR IDENTIFYING NECESSARY AND MISSING COMPETENCES FOR A SMART AND SUSTAINABLE ENERGY SYSTEM

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1 Introduction

The notion that we can learn from experiments is topical in current discussions on societal transitions for combating climate change. Within a socio-technical transitions approach, strategic niche management (SNM) conceives of local experiments within protected spaces as important initiators of learning and empowerment of new technologies. Transition management –a governance approach– views "local experiments" as central in a societal learning process for sustainability. Several countries – among them Finland – aim to develop a culture of experimentation in order to meet the sustainability and climate challenges of the future.

This paper presents a new perspective on experiments and learning. Analytical studies on experiments, pilots, demonstrations and living labs show that experimental uses of new technologies can reveal *missing competences*. For example, demonstrations of building-applied solar energy technologies show how commissioning, maintenance, operation and use can be problematic due to missing services and missing competences in existing firms and among users (Janda and Parag 2013; Killip 2013; Janda et al. 2014; Heiskanen et al. 2015). Thus, demonstrations or experimental uses and combinations of new and innovative technologies can serve as a basis for anticipating what kinds of skills and competences will be needed in the future on a large scale. Very concretely, they could be used to anticipate professional and vocational training needs, needs for new forms of industrial organization, and needs for usability design of systems.

We demonstrate our approach with Finnish examples from pilots, demonstrations and experiments in embedding smart energy - solar power and other intermittent energy sources, energy management, smart metering and grids – into real-life environments. Our data consist of 8 case studies, and workshops with the users of research results (public authorities, educational bodies, interaction designers). We show how such experiments can be used to identify missing competences and anticipate future education and usability needs, i.e., how to co-adapt technologies and users to a climate-constrained future world.

Our particular focus is on experiments in *smart energy*, by which we refer to an energy system that is able to make use of distributed and intermittent, low-carbon energy sources. Since society needs to shift to an energy system that uses less energy and derives this energy from distributed and intermittent energy sources like wind and solar, this creates several significant changes in how the energy system works: (1) First, there is a need for increased energy storage (including conversion to other energy carriers) and better management of loads (demand response). (2) At the same time, changes in energy usage patterns (less energy use for buildings, buildings as energy producers and potential storage sites, new transport systems and sources) are increasing the integration of buildings and vehicles in the energy system. Thus, a much wider group of people in society are involved in energy production and management. (3) Digital technologies enable better energy management, but require the integration of new competences (e.g. ICT and energy) and the development of solutions that fit into the practices of several types of occupations and consumer contexts. Technologies for all these purposes exist, but there is still limited experience of their combination and use in real-life circumstances.

In the following, we first discuss previous literature on the role of field experiments in creating more sustainable energy systems, and present our new approach for analysing experiments in terms of required and missing competences. We then present a sample of eight experiments selected to illustrate and 'test' our approach. Our analysis focuses on identifying necessary and missing competences in different types of experiments. We draw on this analysis to present a first categorization of types of competences emerging from the case studies. Finally, we discuss some of the limitations of our analysis and the approach in general, and suggest ways forward.

2. Learning from field experiments for sustainable energy systems

In the following, we draw on previous research, in particular in strategic niche management, to illustrate how field experiments are conceptualized as important sites for learning for the proponents of new technologies, for prospective users, and for society. We then turn explicitly to existing literature on how field experiments may reveal necessary and missing competences in society.

2.1 The role of experiments in creating sustainable energy systems

How could society promote particular (more sustainable) directions for technological change? Well-known examples are R&D support and support for the deployment of technologies, such as the feed-in-tariff for solar power. However, the governance paradigm of *transition management* proposes a more active role for government in actively searching for more sustainable future technologies together with stakeholders. In this perspective, alongside visions, targeted experimentation plays an important role. Transition management as a model of governance relies on a learning cycle of problem structuring, visioning, experimentation, policy development, implementation and adaptation (Kemp et al. 2007, 12).

How could new technological combinations challenge established ones, given the path dependency of large technological systems? Research on *strategic niche management* has addressed this question in terms of protective spaces that technologies can seek and governments can create by nurturing, empowering and protecting emerging sustainable solutions. It has also been suggested that the most radically experimental niches can be understood as 'critical niches' which can serve to show shortcomings in society's ability to support sustainable energy systems (Smith et al. 2016).

Experiments in protected niches are important for learning (Schot and Geels 2008). Such protected niches can support learning by technology advocates in improving technical solutions and capabilities, developing new supply chains, and in adapting the new solutions to markets and user needs, as well as to regulations and infrastructures. Learning in niches can also pertain to the development of new cultural meanings surrounding the solutions (Raven et al. 2008), and niches are important places for learning about societal and environmental effects (Schot and Geels 2008). Moreover, learning can occur on several levels: it can be single-loop learning (acquisition of facts and skills), double-loop learning (changes in expectations and assumptions) or deutro-learning (learning to learn) (Schot and Geels 2008).

In SNM, learning is about *adapting new technologies to their contexts* on a small scale. Several authors have observed that this kind of learning entails *mutual adaptation*: it is not only the technology developers that learn about user and contextual requirements, but also the users and producers of the new technology that learn. However, this user-side learning has been elaborated less in previous research. *Moreover, we are not aware of research that has examined user learning in experiments in terms of its implications for societal learning: user learning in experiments might tell us about the kinds of capabilities that the wider group of similar users in society will need in the future.*

2.2 A new take on experiments: what do they reveal about missing competences in society around them?

While experiments, pilots and demonstrations are rapidly gaining an increasingly prominent role in climate governance, the discussion on how society systematically learns from such experiments is still rather fragmented. While this perspective is visible in scholarly discussions on *transition management*, even this literature is not very specific about how policy makers are to learn from experiments (Caniels and Romijn 2008; de Wildt-Liesveld et al. 2015; Boon and Bakker 2016).

In particular, there is little discussion on how policy makers should respond to difficulties and failures encountered in experiments: is it always the sustainable solutions that need to adapt, or can we also draw lessons concerning how society needs to adapt? Jagger et al. (2013) suggest that this is one of the shortcomings of the strategic niche management approach. While strategic technological niches can generate techniques and technologies, they might remain "ghettoes" due to their inability to generate the scale of workforce needed for the widespread adoption of those technologies.

Missing competences identified in innovative projects have been discussed in the field of low-carbon and low-energy buildings. Following Nösperger et al. (2011), we define competence as consisting of three elements: (1) technical know-how, (2) the skills and habits needed to take responsibility for one's actions and communicate effectively, and (3) the resources available. This is quite similar to how Levitt and March (1998) define organizational learning in terms of (1) experience, (2) development of organizational routines and finally (3) development of organizational structures (e.g. artefacts, functions, divisions of labour and authority) that can be termed the organization's collective memory.

In low-carbon buildings, a commonly identified problem is the lack of skills in the construction industry (WBCSD 2009), which is particularly prominent in the case of refurbishment of existing buildings. For example, Janda et al. (2014) investigated learning from innovative low-carbon refurbishment projects in France and the UK, and found "no evidence of systematic learning from monitoring and evaluation of the projects". Their analysis of the cases identified the importance of quality, not only of design but also of physical work and communications. They also stressed the importance of integration among the diverse professionals involved in low-carbon refurbishments, but also across projects. Moreover, they suggested that careful analysis of case studies could provide input into the needs for vocational education and training (see also Killip 2013).

The smart energy transition, however, is a more complex issue than constructing low-carbon buildings, which is a complex issue in itself, combining several technologies for building airtightness, HVAC, monitoring and control, and on-site renewable energy generation (Xing et al. 2011; De Boek et al. 2013). Additional elements relate to the distributed and intermittent nature of renewable energy sources, which leads to demands for widespread integration of both buildings and transport into the energy system, as well as the development of new solutions for energy storage and conversion (Mathiesen et al. 2015). Non-expert energy consumers are expected to play a much more active role than before, producing energy and balancing consumption with the availability of intermittent energy sources (Verbong et al. 2013).

Some elements of such complex local systems can be seen in local climate initiatives, which combine several technologies and diverse actors in local 'living labs' (Evans and Karvonen 2015; Voytenko et al. 2015). In these cases, the learning challenges are even greater. So might be the opportunities for learning by identifying missing competences, since several skills that are needed for deploying low-carbon technologies are highly localized (Fabrizio and Hawn 2013). In addition to the skills and competences of technology providers, installers and users, the skills and routines of local authorities may also be critical for the cost and time needed to deploy low-carbon technologies like solar PV (Dong and Wiser 2013).

3. Data and methods

Our data derive from Finland, which is a small and northern country that has quite a large share of renewable energy in its energy mix. However, since this has mainly consisted of hydropower and bioenergy, there are limits to further development. Wind power and solar are less developed in the country. Recently, however, the need to develop competences for a new, smarter energy system has been recognized, and several demonstration and pilot projects have been launched. Many are attempting to integrate solar power and load management into the built environment. Moreover, attempts to develop energy storage have recently emerged.

As data, we have examined eight innovative experiments that aim to introduce Finnish society to distributed and intermittent energy sources and 'test' various configurations for (partly) energy independent buildings (Table 1). For our analysis, we selected four cases that have attempted to experimentally develop distributed, renewable energy based systems on the scale of entire residential areas (cases 1,5,- 8) as well as three cases where experimental solutions have been tried out in individual buildings (cases 2-4). Most of the cases are urban and new-build areas, but we have tried to include cases involving rural communities (cases 7-8) as well as cases that are about retrofitting existing buildings (cases 4 and 8). Additional data were collected in a workshop for national-level officials and experts in charge of experimentation with new energy solutions in Finland.

The case studies draw on diverse data sources, including some published studies (Hakaste et al. 2004; Johansson 2009; Motiva 2010; Heiskanen et al. 2015a; Heiskanen et al. 2015b). We have complemented existing data with interviews, document analysis and media reports. The observations concerning necessary and missing competences are based on interviews, primarily with project coordinators, building owners and managers.

Table 1: Case studies of Finnish smart energy experiments (tark. vuodet, että olisi johdonmukaiset)

Case	Scope	Focus
1. Eko-Viikki (2000-2004)	new build suburban residential area	sustainable housing, including then largest solar installations in multifamily homes
2. Mestariasunnot (2011)	single residential building, elderly care facility	demonstration low-energy building, solar heat and power
3. Viikki Environment House (2011-)	single (office) building	demonstration low-energy office building, solar and wind power, energy storage
4. Hämeenpuisto 21 (2013-2014)	renovated single residential building, rental	low-energy renovation, smart controls, solar power
5. Skaftkärr,Povoo (2011-)	new build suburban residential area	energy spatial planning, incentives for developers, low-energy housing, smart metering
6. Smart Kalasatama (2013-)	new build urban (mainly) residential area	smart city, including smart controls, solar and storage
7. Kemple Eco-Village (2009-)	new build rural community (block of 10 buildings)	energy self-sufficiency, smart bioenergy, smart controls, load management
8. HINKU, Mynämäki (2008-)	existing rural community (residential + other)	carbon neutrality, diverse measures (renewable energy and energy efficiency, transport, food)

4. Competences in experiments for sustainable energy

The creation of new energy management systems is relatively simpler in new build areas than when retrofitting, and most of our cases are from new buildings or residential areas. In the following, we present eight cases of sustainable energy experimentation in Finland. Each case study first briefly presents the aims and content of the project, and then discusses the types of competences deployed and gaps or missing competences observed in the case. We first consider cases in urban areas, including both individual buildings and entire residential areas (4.1-4.6), roughly in chronological order. The order of the cases reflects learning processes (or lack of them) observed between projects. We then (sections 4.7-4.8) turn to cases of experimentation in rural areas, with section 4.7 presenting a case of a newbuild area and section 4.8 presenting a case of experimentation in an existing municipality with mixed uses (residential, business, farms and forestry).

4.1 Eko-Viikki, an early project constructing an entire ecological housing area

Eko-Viikki, a demonstration project integrating solar heat and power in apartment buildings was part of a broader plan for an entire ecological housing area built in 2000-2004. It aimed to integrate and mainstream several innovative solutions at the same time and deliver ecological housing at reasonable construction costs. An important driving force for solar energy uptake in the area was the sustainability scoring scheme developed for the project, which served as the basis for tendering sites for developers. These criteria included ambitious targets for reducing the external energy use of buildings.

Competences were developed, but also found lacking in the project (Heiskanen et al. 2015a). On the one hand, the integration of solar energy in mainstream building development offered an opportunity for proponents to explore synergies between solar energy and other elements of low-energy housing. On the other, several buildings failed in the end to meet the low energy demand targets, mainly due to problems in the commissioning, maintenance and operation of the building (Hakaste et al. 2004). Maintenance and operation problems were also identified in the use of the solar thermal systems (Johansson 2009). The overall lesson of the project was encapsulated in this comment by an architect involved throughout the project and its evaluation: *"The aim was for the entire chain to learn … and we did learn that each actor has its own role, and that the weakest link determines the performance of the whole. Everyone needs to participate, and in this case the last link, i.e. the commissioning and maintenance and users, was the weakest."* (Heiskanen et al. 2015).

A comprehensive evaluation was made of the Eko-Viiki project (Hakaste et al. 2004). This, and other published experiences led to learning in Finnish low-carbon building development (Heiskanen et al. 2015a), which is reflected in the following case.

4.2 Mestariasunnot: One of the first net-zero energy buildings for special accommodation

One of the projects that drew lessons from Eko-Viikki was a comprehensive rebuild demonstration of a near-zero-energy building for the elderly developed by a municipal housing provider, Mestariasunnot. Solar heat and power were deployed alongside design, orientation, high insulation, shading and ground source heat. The stimulus to construct the building as zero- energy arose at a seminar on new energy and climate requirements for buildings, where two municipal owners of special accommodation met and decided to start parallel projects in order to learn for the pending 2020 nZEB targets (Heiskanen et al. 2015a).

The project started with a careful planning process. Moreover, as there were two similar projects running simultaneously in different towns, there was much exchange of experience and lessons learned. Due to previous experience in low-energy building, the developers made sure that the contractors were committed to follow-up, monitoring and corrective action in the course of construction. Finally, time and resources were allocated to adjustment and fine-tuning of building systems. Furthermore, the maintenance staff from Eko-Viikki were invited over to train the staff of this building. The building was completed at a construction cost of 15% above normal and the next building is expected to only cost 10% more than standard solutions. In this project, the surplus power generated in the building could be sold over the grid, and excess heat was arranged to be sold to a neighboring building.

In this case, thus, everything went well. However, significant expert resources were devoted ensuring this was the case. First, the house was developed in parallel to another similar development in another town. This enabled some scale economies, which allowed the employment of expert support from a research institute, VTT, and from qualified suppliers, e.g., in building automation. Finally, the necessary research and development costs were covered by public funding bodies: Tekes, Sitra and ARA, the Finnish Housing Development Fund.

4.3 Viikki Environment House: Model nZEB public building

The Viikki Environment House is an office building built for the environmental administration of the City of Helsinki to showcase a nearly zero energy public building. The goals of this demonstration were to integrate all relevant planning aspects into the design of a low-energy building and sensibly combine existing cost-effective energy-saving solutions (including orientation, high inertia, shading, bedrock cooling, automation, solar PV and small horizontal wind turbines). Several parties were involved in the demonstration network both from within and outside of city administration: the Environment Centre, the Deputy Mayor and the Public Works Department of the city, a renowned architect's office, one of the country's largest construction companies and various contractors. Recently, the network has expanded to include new parties, the Finnish Funding Agency for Innovation (Tekes) and Siemens, with a new project to develop solutions for storage of the surplus solar power and use this for charging electric vehicles.

The building was completed at a construction cost on par to normal market prices and has exhibited good functionality so far, which is attributed to careful design, close inspections and training of the maintenance staff (Heiskanen et al. 2015a). PV panels supply about 20% of all energy. The Viikki Environment house was designed to integrate solar power into the existing energy system: panels were placed optimally for Northern conditions, where insolation is very high in summer and very low in winter when overall energy demand is high. Instead of striving for maximum solar power production, the building design maximizes the production of solar power in spring and fall, when demand for energy is greatest. The building carries the title of the most energy-efficient office building in Finland, and it is used as a showcase for successfully combining different solutions.

According to the building owners, everything went well during the entire process. However, this was due to the fact that a specialist architect was employed. Moreover, the future owners had an exceptional opportunity to monitor the construction work, since the laboratories of the administration had rented an adjacent building for the duration of the construction. They directed webcams toward the construction site for 24/7 monitoring, and when mishaps were noticed (such as insulation materials left out in the rain), it was not difficult for the environmental administration to alert another city body, the building inspection, to the site. The electricity storage project also revealed some competence gaps, which led to about a year of delays. Siemens was to install an X kW battery array and develop a smart control solution to optimize charging of the stationary batteries, the EV batteries and feed-in-to the grid. The first delay was due to the small size of the battery needed, which was not available off-the-shelf. The second delay related to fire safety inspection: there were no standards for locating batteries in office buildings, and it took some months for the relevant authorities to develop them.

4.4 Hämeenpuisto 21: Private investor retrofitting smart energy solutions using local contractors

The previous cases have been newbuild or comprehensive rebuilt, but these only represent a fraction of the building stock. These cases also include highly professional owners of large building volumes, and in most cases, diverse experts have been involved. The following case describes a project by a smaller commercial building owner retrofitting an individual building.

Hämeenpuisto 21, a multi-use apartment block, has sometimes been called the ugliest building in Tampere. In connection with a comprehensive renovation, the owners of the building, Lahtiset Yhtymä, decided to equip it with solar panels (15kW_p), solar collectors (80 kW_{th}), a monitoring and control system, as well as mechanical ventilation and cooling and some special safety features like sprinklers. This project is many ways unique in Finland, as it is driven by a private building investor, without the involvement of any universities or research institutes, and relying only on SMEs and local craftsmen. It was awarded by the regional authority as a pioneering project.

Most of the planning and installation has gone smoothly and the owners are very satisfied with the solar panels, which they are now installing in another building as well. However, the installation of the solar thermal system was complex due to communications between the system provider and the local HVAC installer, and due to the lack of exemplars in retrofitting solar thermal in existing buildings. In this local project, service providers were found mainly via the social networks of the CFO: "*I know this great guy, he is a real project management professional at N.N. (a large technology company), he always finds the best solutions for me.*" Having operated in the locality for 50 years, the company has established relations with local service providers. Because of this, they have a good ability to select the best: "*N.N. (the electrician used), is a really incredibly smart guy … lightyears ahead of the others in his class [at the polytechnic].*" This case study shows that entrepreneurial and enthusiastic building owners can be pioneers in the use of smart energy solutions, but that finding the right service providers in an emerging market relies on personal enthusiasm and the existence of appropriate service providers within existing social networks. The situation may be more confusing for property owners lacking such networks.

4.5 Skaftkärr: Integrating energy into spatial planning, building construction and use

The previous cases described examples of learning processes on the building construction level. However, when considering the built environment and its impacts on climate change, several important aspects are determined on a broader, residential area level. Spatial planning influences the types of energy supply systems that can be used, the types of infrastructures needed, as well as residents' transport and even consumption patterns.

Skaftkärr is a newbuild area in Porvoo, on the south coast of Finland. It represents an experiment in the integration of energy in spatial and urban planning (Motiva 2010). This local experiment has included several different activities: development and testing of a new form of spatial planning (including requirements and incentives for private developers), a new model for the building permit processes (anticipatory guidance), testing of real-time energy use metering and monitoring, as well as new methods for public engagement. Additionally, several innovative solutions, such as solar thermal district heating, were investigated during the course of the project.

The Skaftkärr project resulted in a model for creating an energy efficient town plan, which has been integrated into town planning in the City of Porvoo, while energy efficiency has been made part of the overall city strategy and its business development strategy. This model includes a calculation tool, which enables impact assessment of each stage of the plan, including all impacts of spatial planning from residential heating and household electricity to street lighting and commuting (Lylykangas et al. 2013). One of the most visible results of the plan is a quantification of the potential cost savings from infrastructure development, which is estimated as 5% (Sitra 2011). In a linked European project (IDEAS), ICT tools for smart metering, monitoring and data visualization using cloud computing were developed, resulting in a spinoff company. Several permanent structures were also retained: for example, a system of requirements and incentives for developers purchasing municipal land (including a 10% discount for developers committing to stringent energy targets) and a scheme for issuing permits to single-family home self-builders, where the builders are offered intensive training in energy efficiency, and land sales are scheduled so that several builders can be assembled in one course.

A diverse range of missing competences was identified in the project. For example, the IDEAS project revealed problems in monitoring and control of individual appliances using radio signals. However, the most important competence issues were identified in spatial planning.

The project identified several legal barriers in the spatial planning process that obstruct planners from making the best decisions from the perspective of the climate, for example for requiring certain heating systems or construction materials in the city plan (Lylykangas et al. 2013). However, there is still much scope for making improvements, since a simple Excel spreadsheet was successfully used to achieve significant reductions in carbon dioxide emissions. This was accomplished by bringing energy expertise into the planning process from the start. According to the experts involved in the project (Lylykangas et al. 2013), the nation-wide institutionalization of this kind of assessment and integration of carbon calculations in spatial planning routines would require national guidelines and revisions to national legislation, was well as improved national databases and harmonized calculation procedures.

4.6 Smart Kalasatama: influencing urban form and facilitating new services

While the previous case tested interventions in spatial planning, smart urban infrastructure can also include a broader range of new solutions to influence the built environment, transport and even consumption. The new Kalasatama area of Helsinki is an experimental innovation platform to co-create smart urban infrastructure and services in close co-operation with residents, city officials and other stakeholders such as industry, SMEs and researchers through piloting of novel low-carbon energy solutions. Smart Kalasatama has a wide scope and concept, covering a variety of different solutions ranging from smart grids to eHealth and smart retail. It is an urban living lab, forming an open innovation platform that offers a place to co-create new urban services in a real environment with the users and inhabitants. By the early 2030s, the Kalasatama district will offer a home for approximately 20,000 residents and jobs for 8,000 people. Currently, there are 2,000 people living in the area.

One of the smart energy projects tested in Smart Kalasatama is an online service called Hima for residents offered by the local energy company, the Helen Group in collaboration with ABB. It is built on a wired KNX home automation solution and a centralized server in the building, and enables users to monitor and turn off various appliances and groups of appliances in their apartment using their mobile phones. It has been developed in close co-operation with users. The users we interviewed have been satisfied with the service, though they have also offered feedback on ease of use, and on which appliances they want to control and how different appliances are grouped. One of the future challenges is how to expand the service to existing buildings, where rewiring would be too expensive. The development of new solutions, e.g., based on data transmission using radio signals, would require new business alliances. Hence, the Smart Kalasatama experience shows that alongside collaboration and co-creation with users, there is also a challenge of creating new business alliances and collaborations among established companies and startups.

The smart Hima service is only one of the solutions tested in Smart Kalasatama. It is a part of piloting a smart energy system that also includes other demand response systems, failure resistant circular electricity network and a smart remote controlled transformer station. Energy related innovations include also the installation of district cooling that turns the extra heat created by solar radiation in apartments into warm water, which on the other hand creates savings in the energy use of other kinds of cooling appliances and also brings savings in the heating of warm water that otherwise potentially would have been done with a fossil energy carrier. There will be an energy storage system operational in spring 2016 that will include 15000 Litium-ion batteries with a nominal efficiency of 1.2 MW and an energy capacity of 600 kWh. It is being installed in connection to a solar panel plant 'Suvilahti' that includes 1194 solar panels that can be individually rented by the inhabitants of the city of Helsinki.

There is strong support for testing use-driven innovations in the area, which is visible for example in the Smart Kalasatama's Programme for Agile Piloting buys small pilots that provide new innovative services for people living in the Kalasatama area and launch them quickly. The aim of the programme is to accelerate ideas to service innovations and reach users in a real life setting as well as spur experiments produced by several actors in a protected niche. The first four innovations are piloted in Kalasatama during spring 2016. One of them is the ‘Toop’-service that brings together different transportation services, such as parking, public transportation, taxis, rental vehicles and bike lending. This pilot aims at testing how to influence the choices the inhabitants make related to their mobility needs. The ‘Developers club’, on the other hand, aims at networking different actors (such as bigger and smaller firms, city officials and residents) active in Kalasatama in order to enable a better information flow about future events, changes and plans, which makes finding partners for cooperation and planning joint projects easier.

Therefore, the project involves a plethora of actors and solutions, some tested for a short period of time and some for longer. Identifying competence needs and missing competences in this kind of project can be quite complex, since several other factors interact with the experiment. Our case studies related to experiments in new build areas show that the competences needed include coordination and networking skills, especially if the experiment is as large in scale and scope as the Smart Kalasatama case. There is a need for an intermediary actor that has the possibility to take into account the multitude of activities, actors, interests and objectives in the experiment and that can build up competences needed.

4.7 Kempele Eco-Village: Product development project in a real residential area

The Kempele Eco-Village is a small residential area in Northern Finland, which was set up in 2009 to develop and demonstrate an innovative solution for micro combined heat and power (micro-CHP) from gasification of wood chips. This village of 10 houses was built by the entrepreneurs developing (and later marketing) the micro-CHP plant, as well as other builders purchasing the plots, all committed to creating a completely energy self-sufficient and off-grid community. Product development has been the main aim of the project, as the micro-CHP company CEO stated: “*In a lab, it is too easy to just turn out the lights and go home when things get difficult … We wanted a sufficiently important place to implement it, so that we were forced to solve problems and finalize the product*”. Several of the residents also joined in order to test their own ideas in energy efficient construction, such as airtightness and replacement air pre-heating with buried pipe systems (Motiva 2010).

The owners deem the experiment a success. The system operated off-grid with high reliability for five and a half years. In 2015, grid connections were established in order to shut down the plant in the summer and adjust the micro-CHP plant on the basis of ideas gained during the first years of operating. With the plant itself, the main problems have related to gaining sufficient quality of fuel and to wear of parts given the high temperature. The houses were designed to consume about 50% less energy than was required at the time of construction. Some good advice was gained from the building inspectors in a nearby city, Oulu, where guidance for energy efficient construction has been developed for several years. Energy efficiency was required in the plot allocation agreements, and particular attention has been devoted to peak power demand as well (energy efficient appliances, no electric sauna stoves) (Motiva 2010). The households building in the area were also required to commit to purchasing their heat and power from the local plant, hence negotiations and contracts were needed to fix appropriate prices. The micro CHP plant is not economically competitive in Finnish conditions, with relatively cheap electricity, but it is economically attractive in areas where electricity is more expensive and there is a demand for heat (e.g. Alaska), and more than 50 plants have been sold by 2016, to more than 10 countries, including both on-grid and off-grid solutions.

Since the plant is operated and maintained by the company that designed and built it, no major problems have been encountered in operation and use, according to the company CEO. However, when new plants are sold to customers, training is required for new users: the company trains sales agents, and all sold plants are remotely monitored. Moreover, no problems in use have been observed, though it is worth noting that 50% of all residents are engineers (Motiva 2010). Grid connections created some extra effort, since regulations made connecting a micro-grid to the distribution grid complicated, but these were resolved. A further analysis of necessary and missing competences would likely require interviews and studies with customers, who do not enjoy the close relationship to the technology that the developer-users have.

4.8 HINKU: Deployment of renewable and energy efficient solutions in a small rural municipality

While the Kempele ecovillage case represents a new-build area, experimentation also occurs in existing rural contexts. The following case, HINKU in Mynämäki, illustrates some of the complexities when applying and combining several technologies and organizational solutions in a rural context. We focus here on one category of solutions that has gained particular attention: the creation of small-scale renewable energy based district heating systems and in general the joint procurement of new technologies (Heiskanen et al. 2015b).

Mynämäki is a small municipality in Southwest Finland that joined a carbon neutral communities programme, HINKU, committing to reduce greenhouse gas emissions by 80% by 2030. The programme does not offer funding, but some technical support by the Finnish Environment Institue. Since joining in 2008, Mynämäki has made improvements in municipal buildings, such as changing heating systems from oil to woodchips or ground-source heat pumps, energy audits, heat recovery systems and LED lighting. Private households, farms and companies (e.g. greenhouses) have made investments in similar sustainable energy solutions through advice, encouragement and the example set by others. Our study (Heiskanen et al. 2015) shows that technical support offered by the Finnish Environment Institute has been crucial in identifying cost-effective solutions and making cost calculations, since municipal staff is overworked, and SMEs do not have energy experts either. Through this support, suitable solutions have been found and investor confidence has been built up in, e.g. LEDs and heat pumps, which were viewed as somewhat “experimental” at the start of the project. Moreover, a few local companies offering sustainable energy solutions (ground-source heat, solar water heaters) had gained a boost from the publicity of the programme and increased demand.

An innovative solution promoted by ‘outsiders’ has been small district heating systems. There have been several attempts to build up a small district heating system, first with heat pumps (Heiskanen et al. 2011) and then with a woodchip burner as a heating source. This has been difficult due to the lack of suitable organizational forms (residents or the municipality did not want to take responsibility for the system, and outside entrepreneurs were deemed unreliable). Our analysis also showed that it has also been difficult to get tenders from companies, which are not used to these kinds of projects (the quality of the offers was not good, very few were received, and local companies were not very active). One local village heating system was eventually completed in 2013, but it currently serves only one property, since the entrepreneur that built it was not able to make an attractive marketing offer to households nearby (total costs/kWh were not competitive with individual pellet boilers). Better progress has recently been made with joint purchasing of solar panels, which is less complex organizationally, and a more standardized project to purchase.

The case of Mynämäki shows that if we are to create a carbon neutral society (outside a few experimental projects) a great deal of new competence development is needed in Finnish society. It is not only needed in universities, expert bodies and consultancies, but explicitly in the field, among builders, electricians, heating system operators and ordinary users. Moreover, companies do not only need technological competences, but also marketing and service design competences. In the following, we will try to specify which competences in particular have been found missing or scarce.

5 Analysis of missing and scarce competences

The cases reveal a diverse picture of missing and scarce competences. Many of the examples considered here include projects that were part of a research or development project and involved experts with a close understanding of the technologies involved. They have been explicitly about testing new solutions and finding new ways to combine existing technologies in a smart way, in those cases, usually involving public funding. We take such cases as examples in which the services provided by research institutes can be considered as 'missing' outside such pilot contexts, since they would not be available for 'ordinary' users. In projects that did not involve expert research institutes, building owners have hunted for appropriate service providers through their social networks, and in some cases, it seems that the projects have been opportunity driven (solutions have been selected because appropriate services happened to be available).

Table 2 presents a summary of our analysis of necessary competences in the eight experimental contexts investigated in the case studies.

Table 2: Types of competences needed in the experiments

Category of competence	Who is involved/implicated	Why important	What type of competence
choice, purchasing and installation of products and services	consumers, installation companies, potential intermediaries	difficulties in matching technologies with user needs and contexts	tech competence skills and habits resources
use of solutions	consumers, other users (e.g. companies, municipalities)	difficulties in fitting technology into everyday activities	skills and habits resources
maintenance and operation	building users: usually maintenance staff (automated modern buildings), but sometimes also users (e.g. heat pumps in single-family homes)	important for reliability and meeting performance targets	tech competence skills and habits resources
new regulatory procedures and practices	spatial planners, permit authorities, safety inspectors	mandating or facilitation of new technologies, removal of barriers or delayers of adopting new technologies	legal frameworks, skills and habits, resources
grid connections	electric and district heat operators	financial performance of system	skills and habits
service design, delivery and marketing	all providers of technology and new solutions	reach customers, offer high-quality customer-oriented service	(tech competence) skills and habits resources
new supply chains, new business alliances, new organizational forms	system integrators, managers of joint purchases or systems, convenient and cost-effective ways of retrofitting appliance-level control systems in buildings	cost and speed of deploying new technologies	(tech competence) skills and habits resources

An additional category, which is not strictly speaking a competence, is trust and confidence. Problems of trust in new technology were found in many of the cases; many of our interviewees mentioned the creation of a trustful environment and the inspiration of confidence as an important factor in the field experiment. When trust in, for example automation or in a particular entrepreneur is missing, it is difficult to create working systems. Competence is a key element in trust, which consists of trust in competence and trust in intentions (e.g. Noteboom 2006). Our further analysis of competence needs in a smart energy system will require further reconceptualization to link the concept of trust to an overall analysis of competence needs.

5. Discussion and concluding remarks

This paper has attempted to test the notion that we could analyse field experiments, pilots and demonstration projects from the perspective of necessary and missing competences revealed in them. Our analysis suggests that a great deal of new competence development is needed in Finnish society. It is not only needed in universities, expert bodies and consultancies, but explicitly in the field, among builders, electricians, heating system operators and ordinary users. Moreover, companies do not only need technological competences, but also marketing and service design competences and the creation of new organizational and market structures.

We were able to identify several categories of necessary competences, including (a) choice, purchasing and installation of products and services, (b) use of solutions, (c) maintenance and operation, (d) new regulatory procedures and practices, (e) grid connections, and (f) new supply chains, new business alliances and new organizational forms. All parts of the value chain, as well as users and regulators need to develop new competences when smart energy solutions are deployed. The perspective taken serves to highlight the importance of 'skills and habits', since technical competence can be acquired, but skills and habits take time to develop.

Our analysis is very preliminary and requires more work in several respects. First, the conceptualization of competence requires more work, since we are investigating competence in an extremely broad sense. We are looking at the competence of several types of actor groups, from technology developers to ordinary consumers. We are also trying to capture several different categories of competence, which are not easy to capture under three simple headings: technical competence, skills and habits and resources. We will need a more elaborated and differentiated conceptualization of competence as we go ahead. Second, since we only investigated eight cases, it is difficult to generalize what are the most frequently missing competences. This is also difficult since many of the cases are special. Missing competences might be underestimated in this kind of data due to the involvement of various experts, and to the R&D character of many of the cases. They might also be overestimated, since many things were done for the first time in the cases (e.g. safety inspection for stationary battery systems within an office building). It is possible that necessary routines or guides can be developed and disseminated fairly easily, although one can also ask whether guides (and particularly routines) can be transferred easily from one location to another.

A further limitation of our preliminary study is that it is difficult to establish whether competence gaps are 'genuine' shortcomings of the context in which the new technologies are embedded, or fundamental problems in scaling and combining the solutions under field conditions (i.e., whether these experiments are worth scaling up). We have tried to focus on experiments that deal with established technologies, but it is still possible that some solutions or combinations of solutions "are just too difficult to work" in a certain context. Another methodological issue is that we have only investigated 'smart' and 'experimental' developments, and tried to identify necessary and missing competences there. However, we have no comparative analysis of 'conventional' developments. It is possible that similar problems arise in some of the conventional projects as well (Zaleska-Jonsson 2012).

The methods for identifying necessary and missing competences still need to be developed. However, this methodological tests suggests that local experiments with technologies in field conditions, and in particular when combining several new technologies in one site, can be a fruitful one for anticipating what kinds of competences society will need in the future. It could be complemented with other data, including more long-term studies of competence and labour market developement over time in countries that are advanced in the deployment of particular technologies (e.g. Dewald and Truffer 2012). We found it easier and simpler to identify necessary and missing competences in individual building-level demonstration projects, which have been analysed in previous literature with similar results (Killip 2013; Janda et al. 2014). In these cases, where the project has a limited time-span and it easier to see which competences are missing (or happen, through luck or special measures, to be available). Evaluation and analysis of local sustainability experiments applying and developing multiple solutions can be more complicated, and would require more detailed documentation, monitoring and analysis than has been the case until now.

Another question for further research is to investigate how new competences develop in real-life conditions. This could be interesting for the development of training and education, in particular for those whose main task does not relate to (renewable) energy. By investigating how new competences actually develop, we might find ways to attract electricians into extension training. By investigating how users develop an interest in control applications (for example, through fun and play rather than serious utilitarian use), we might find valuable insights for product and service design.

There is much to learn from learning from experimentation – indeed, until now, most of the learning has been fairly fragmented and rarely brought together in comprehensive evaluations or analyses (Heiskanen and Matschoss *forthcoming*). Analysis of a wider group of case studies and a deeper analysis of cases is likely to uncover new insights. Moreover, cross-country comparisons across Europe would offer further insights. Another line of research is who to address with the results and how. In the case of installation and maintenance, the results should be further discussed with organizers of vocational and extension education. However, in the case of missing competences among consumers and other heterogeneous users, providing detailed education might be unfeasible, and solutions should preferably be sought in usability design and service design to make solutions easy to use.

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