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EVIDENCE FROM AUSTRIA, DENMARK AND NORWAY

ITA – INSTITUTE OF TECHNOLOGY ASSESSMENT

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ABSTRACT

It is widely recognised that users strongly influence how new technologies get developed. In practice, however, it is often difficult to reconcile the expectations of technology developers and potential users in the early stages of innovation. This is one of the reasons why pilot and demonstration (P&D) projects do not reach their full potential. This paper is based on the findings of a European comparative study, which looked at different smart energy P&D projects from three different countries (Austria, Denmark, Norway). Three projects were selected and analysed for this paper, focusing on the role of users in their success. A series of qualitative interviews were conducted and written documents were reviewed. The analysis shows how a variety of different user roles contributed to the functioning of the P&D projects. Across all the cases studied, we were able to identify six different user roles and their respective characteristics: Research partners, traditional or ordinary users, prosumers, user citizens, affiliated users and user innovators. As the different roles occurred in combination with each other, we called the resulting principle sets of user roles. These sets of user roles were able to inform technical functions, influence the way problems were solved, and support social and political (de-)stabilisation of the applied technologies.

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INTRODUCTION

The ongoing transformation of energy systems across Europe calls for a variety of different solutions that fit local and regional conditions, while at the same time fulfilling functions and requirements such as better social and technical integration of renewable energy sources, adaptation to more volatile energy production patterns, higher levels of energy efficiency, user-friendliness and security of supply. Previous research suggests that one-size-fits-all solutions are unlikely to be the answer (Eikeland & Inderberg, 2016) and highlights the diversity of possible socio-technical arrangements (Parag & Sovacool, 2016; Wolsink, 2012). Therefore, innovators are currently focusing on piloting and testing a wide range of socio-technical solutions to achieve a successful energy system transition (McLean, Bulkeley, & Crang, 2016; Skjølsvold, Throndsen, Ryghaug, Fjellså, & Koksvik, 2018; Smale, van Vliet, & Spaargaren, 2017), and pilot and demonstration (P&D) projects have become a key tool in advancing transition agendas.

P&D projects may not only serve as an extension of prototype development, improving technical functionalities and bringing new technologies closer to the market. Rather, the existing literature offers different views on the tasks and objectives of P&D projects. However, there is general agreement that they should facilitate social learning and thus reduce existing uncertainties through the creation of new social roles and experimentation (Frishammar, Söderholm, Bäckström, Hellsmark, & Ylinenpää, 2015; Huguenin & Jeannerat, 2017; Pallesen & Jenle, 2018). A literature review on energy demonstration projects identified four key types of learning opportunities that should be provided: To technically develop sustainable prototypes, to inform upscaling activities, to contribute to rethinking public policies and to develop effective market introduction strategies (Bossink, 2017). In the context of the sustainability transition literature, learning in local experiments or technological niches is considered to play an even more fundamental role. From this perspective, P&D projects should actively support reflexive forms of learning, i.e., the underlying assumptions of the experiments themselves should also be questioned, leading to what is often called second-order learning (Brown & Vergragt, 2008; Hoogma, Kemp, Schot, Truffer, & Banister, 2002; Sengers, Wieczorek, & Raven, 2019). Among other factors, user involvement is considered to be extremely important in order to take full advantage of all these learning opportunities (Macey & Brown, 1990). Against this background, it is surprising that there is so little research on user involvement in P&D projects.

In this paper, we will focus on a specific aspect of the development of smart energy solutions in the context of P&D environments: the different roles that users play in the cases studied. The aim is to better understand how users are configured, involved and actively engaged in these projects. This allows us to examine how users contribute to the development of emerging socio-technical configurations through social learning and reflection, as well as the creation and stabilisation of new symbolic meanings and patterns of use. We will show that the dynamics and learning progress in development niches are strongly related to the existence of diverse user articulations.

In the next section, we provide a general overview of the literature on the role of users in the development of new technologies. We then briefly discuss the empirical methods and case studies used for this paper. We then present typical user roles that were relevant in our case studies and demonstrate the interaction of these roles using three specific examples. Finally, we discuss the implications of these findings for the success of P&D projects.

1 THE ROLE OF USERS IN TECHNOLOGY DEVELOPMENT

Users always play a role in technological innovation, at least passively through the ability of technology developers to imagine future users and potential applications (Stewart & Hyysalo, 2008; Woolgar, 1990). However, the range and nature of possible user roles can vary widely. From being limited to what Williams and Edge (1996) have termed "veto power", where consumers have no opportunity to engage with the design of technology other than to decide whether or not to adopt it, to being actively involved in the design process or even becoming the main source of innovation (Von Hippel, 1986). This makes the role of users somewhat ambivalent: they can be conceptually located in a field of tension, being both passively configured by other actors or technologies, and at the same time actively appropriating technologies (Shove, 2001).

In our context, the focus is on the ability of users to actively shape the meaning and design of technology and thus contribute to the successful functioning of the P&D projects studied. Early adopters often play an active role in the meanings and practices associated with an artefact (Mackay & Gillespie, 1992, p. 68), as artefacts only acquire social meaning in the context of their use. The related process is sometimes referred to as the appropriation or domestication of a technological object (Ryghaug & Toftaker, 2014), which refers to how technology is "incorporated into the routines and rituals of everyday life, the way it is used and the way it becomes functional" (Vestby, 1996: 68). In their role as users, consumers can be active, creative and expressive (Mackay and Gillespie 1992). In the case of active early adopters, the appropriation of technology becomes a broad and transcending activity, apparently "blurring the boundaries between production and consumption" (Oudshoorn & Pinch, 2008: 554). Users may also become "prosumers", (Toffler, 1980), i.e. they are producers of technology, but nevertheless grounded in the knowledge and everyday experiences of ordinary users.

Indeed, the extent to which users are able to become active creators of technology depends on a variety of different factors, including socio-economic and demographic characteristics, personal capabilities, structural and cultural conditions, as well as characteristics of the technology itself. It is therefore important to bear in mind that there are different groups of users and different roles that users can take on, which vary in their power to choose the technology, to acquire skills and authority to use it in different ways, to adapt or modify the technology, to override functions or bypass outputs, or perhaps to subvert or reject it (Russell & Williams, 2002). In a similar way, Klein and Kleinman (2002) have stressed the capacity of users and that we may find systematic asymmetries of power and differences rooted in structural conditions of social life.

There is a long tradition in innovation studies of analysing users as an important source of innovation-related knowledge (see e.g. Lundvall, 1988; Rosenberg, 1982). Drawing on a number of empirical cases from different industrial sectors, von Hippel (1986) has shown that the vast majority of innovations in a field were initially developed by product users. Of course, in these cases most of the users were not individual end-users but firms or organisations. Nevertheless, the point is that these industrial users acted in their "functional role" as (future) users of the intended technologies, rather than as producers or suppliers of products. They articulated solutions for their own needs, which eventually became successful innovations.

Von Hippel (1998) has shown that users have specific local knowledge that can be highly relevant for defining and solving problems and ultimately lead to technological innovation and new market opportunities. In some cases, end-users have indeed played a crucial role in the early stages of technological development. Technologies such as the personal computer (Schmidt, 1997), open source software (Tuomi, 2002) and sports-related consumer products (Franke & Shah, 2003) have been actively shaped or even entirely developed by active users. Other examples include the development of wind turbines in Denmark (Jorgensen & Karnøe, 1995; Karnøe, 1996), which was strongly influenced by local cooperatives, and the development and distribution of solar heating systems in Austria (Ornetzeder & Rohracher, 2006). Solar heating was strongly pushed by "self-building groups", i.e., prospective users who collectively assembled and improved the technology. These user-innovators led to a series of improvements that resulted in specific design features that proved extremely useful for further dissemination of the technology.

Overall, case studies have shown that users take on different roles, with different capabilities, ambitions, skills, knowledge stocks, etc. under different structural conditions and local settings. This is also evident in the context of smart grid developments, where Goulden, Bedwell, Rennick-Egglestone, Rodden, and Spence (2014) compare energy consumers with energy citizens (Devine-Wright, 2007) as two contrasting models. These two types of users deploy different personas, play different roles in energy innovation and are likely to behave differently. While in the context of smart grids, energy consumers appear to be the "managed demand side", energy citizens are likely to become managers in the process of consumption and (micro)-production. In P&D projects, it has also been shown how such user roles are emergent and depend on the broader socio-technical arrangements of the projects, which can lead to the configuration of users as resources of innovation or as passive agents who can accept or reject new solutions (Skjølsvold & Lindkvist, 2015). Focusing on the relationship between providers and consumers, Van Vliet (2012) suggests considering three different types of technology users: consumers, citizen-consumers and co-providers. Thus, also with regard to the development of smart grid technologies, it can be assumed that structural conditions influence the ability of users to influence developments.

Applying a longer-term transition perspective, Schot, Kanger, and Verbong (2016) have explored more systematically the important role of users in transition and innovation processes and how they are able to shape routines and implement system change through these roles (see also Kanger & Schot, 2016). The authors develop a typology that attempts to conceptually link different user roles to the temporal dynamics of transition processes. In the start-up phase of a transition process, they argue, user-producers and user-legitimators (users who are also involved in the political legitimation of alternative technical visions) help to create technological and symbolic diversity. Later, in the acceleration phase, user-intermediaries (e.g. user organisations) align different actors, user-consumers creatively embed new technologies in their everyday practices, while user-citizens mobilise against the existing regime. In the final, so-called stabilisation phase, a larger number of user-consumers switch to the emerging regime with its redefined practices. Thus, Schot et al. (2016) illustrate how users engage in a wide range of activities, from lobbying and political work to promote the success of specific niches to the adoption of innovations.

In this paper, where most of the technologies studied represent the start-up phase with early manifestations of possible socio-technical pathways, we should therefore particularly expect to find user-producers and user-legitimators helping to create both technological and symbolic diversity, and as the technologies develop and are expected to be scaled up, we would expect users in our study to take on roles as user-producers, legitimators, intermediaries and consumers.

Based on this literature review, we can conclude that users can play a crucial role in any emerging socio-technical configuration. Users can help to link elements together in meaningful ways; they perform practices that integrate these new configurations; and they are involved in ensuring that certain outcomes are achieved. However, as previous research on the role of users has shown, the importance of users goes beyond the practical functioning of the configurations studied. For example, users may be involved in shaping the symbolic meaning of novel solutions, providing practical knowledge, articulating individual preferences or directly solving technical problems, and even criticising and rejecting proposed solutions.

With this in mind, the main questions to ask about the role of users in P&D projects are: what types of users will be involved and are there typical roles that these users will play? How do different types of user groups contribute to the development of P&D projects and how are these contributions made available?

2 METHODS

The data was collected in a three-year research project analysing smart energy P&D projects in Austria, Denmark and Norway[1]. The selected cases were successful examples of P&D projects, where success in the context of the research was defined as the potential to stimulate further activities and learning beyond the specific P&D project, measured by the number of popular and academic publications and the perception as a significant project in the local or national context. The research project used a mixed methods approach to study three cases in each country from different perspectives and to ensure a qualified and in-depth analysis of how specific smart energy innovations depend on different factors related to technology, market design and stakeholder involvement. Thus, the project used qualitative methods such as interviews with project owners, users and other relevant stakeholders, existing secondary data (such as evaluation studies or technical reports) and quantitative methods related to energy system analysis (not covered here). The following findings are largely based on the 80 semi-structured qualitative interviews conducted, transcribed and analysed for this project.

[1] The project MATCH was funded by the *ERA-Net Smart Grids Plus* programme, involved partners from Austria, Denmark and Norway and ran from February 2016 to October 2018.

3 CASE STUDIES IN THE MATCH PROJECT

Before discussing the role of users in more detail, we will briefly describe the cases studied in the MATCH project. The cross-national sample of projects is to some extent representative of the great diversity we actually see in the field of smart energy systems innovation in Europe (Table 1). Our nine projects differ in terms of the technologies used and the key actors involved in the activities. However, the projects tend to focus on more than one theme as an innovation activity, and all our cases are inspired by the idea of combining technologies, services and sectors in new constellations to solve energy and mobility challenges. The projects represent different stages of innovation. Some are mainly organised around R&D activities, others have a company-specific innovation and development focus, and still others focus mainly on the implementation and dissemination of existing and available technologies and configurations.

All but one of the projects in our sample implement some form of PV system. Some projects focus on the integration of PV into the local grid (1, 4, 7, 8). Other projects try to learn more about the combination of PV systems, heat pumps and batteries at the household level (1, 3, 4) or focus on the combination of PV systems and EVs (1, 3). A few projects use PV systems in a tried and tested way without a specific research focus (2, 3, 5, 9). Smart Grid infrastructure technologies are included and tested in several projects (e.g. 1, 2, 3, 4, 7). ICT systems, smart meters and similar information technologies are used to balance loads or reduce the cost of infrastructure investments. Demand response and energy feedback at household level is another example in this area and is part of the pilot in the city of Salzburg (2), on the islands of Hvaler (8) and Fur (4). Several projects use heat pump technology to consume excess electricity from renewable sources (e.g. 2, 4) and store it as thermal energy for later use. Three projects deal with electric vehicles (1, 3, 8) and one project deals with hydrogen technology for heavy duty trucks (9).

Table 1: Overview of cases: Description, applied technologies, key actors and main target group

Country/ Case	Description	Applied Technologies	Key Actors	Target Groups
		AUSTRIA		
(1) Köstendorf	Pilot and demonstration project with smart distribution grid field test	Local grid PV integration, combination of PV systems and batteries, PV systems and e-vehicles, testing smart grid infrastructure	Regional DSO & ESCO, research institute, industrial group	Households, SMEs, public authorities
(2) Rosa Zukunft	Pilot and demonstration project with Building-to-grid solution and DSM field test	PV systems without research focus, testing smart grid infrastructure, household level DR and energy feedback, heat-pumps, CHPs	Regional DSO & ESCO, research institute, housing association	Households
(3) VLOTTE	E-mobility business implementation	Combination of PV systems and batteries, PV systems and e-vehicles, PV systems without research focus, testing smart grid infrastructure	Regional DSO & ESCO	SMEs & employees

Country/ Case	Description	Applied Technologies	Key Actors	Target Groups
		DENMARK		
(4) Innovation Fur	Piloting and demonstration of balancing local energy exchange at the community micro grid level	Local grid PV integration, combination of PV systems with heat pumps or/and batteries, testing smart grid infrastructure	DSO & Municipality	Households
(5) ProjectZero	Promote and facilitate energy efficient measures and local renewable energy to decarbonize consumption	PV systems without research focus, EVs and heat pumps as well as "smart" building energy renovations to achieve higher energy efficiency	DSO, regional Bank-Fund, Municipality	Households and SMEs
(6) Samso Energy Academy	Community participation project to increase energy autonomy of the island	Testing potentials for reduce energy demand by regulate temperature and install energy efficient equipment (energy efficiency measures)	Dedicated Organization for project implementation	Households and SMEs
		NORWAY		
(7) PV demo Trondelag	Two related regional PV demonstration projects	Local grid PV integration, testing smart grid infrastructure	Two regional DSOs	Households
(8) Smart Energy Hvaler	Testing the potential for balancing the local grid	Local grid PV integration testing demand response and impact of smart technologies, PV and e-vehicles	Regional DSO, Municipality, University	Households
(9) ASKO midt-Norge	Large PV for decarbonisation of vehicle fleet and for on-site electricity use	PV systems without research focus, hydrogen production, hydrogen driven trucks	Large grocery wholesaler	SMEs & employees

The main project owners are in most cases local or regional DSOs/ESCOs. Two projects are led by dedicated organisations created specifically to promote local energy projects (5, 6), and in one special case the project is led by a company from outside the energy sector (9). In addition to these main actors, several other partners and customers are involved in the implementation of the different solutions of the projects (e.g. research partners, local companies, municipalities). In four out of nine cases, households are the main target group. In these cases, households are addressed in several roles, as consumers, end-users, prosumers and field test participants. Three projects have mixed target groups, usually targeting households, local businesses and public authorities as customers. In two cases, the main target group is SMEs and their own employees (3, 9).

It is clear that users play an important role in the various activities and in some cases are almost entirely responsible for the functioning of the solutions in place. However, as most of the technologies studied are still at an early stage of development, we need to pay particular attention to the role of users in the early stages of energy innovation.

4 DIFFERENT TYPES OF USERS IN SMART ENERGY P&D PROJECTS

The following overview shows that the collection of socio-technical configurations studied in the MATCH project involves a number of different types of users. Users appear as research partners, as traditional or ordinary users, as prosumers, energy citizens, affiliated users, and user innovators (see Table 2 for an overview). In the following, these six typical user roles and their importance for the respective P&D projects are presented in more detail.

As several of the projects studied are research-based, the user as research partner is an important user role. Examples of this type of user are, for example, the residents of the monitoring households in the DSM trial in the Rosa Zukunft residential building in the city of Salzburg (33 units with DSM equipment, 33 without equipment). Users in these households were provided with information and advice and were given special equipment to test for one year. The users' experiences were documented and scientifically analysed. The Köstendorf households also took part in two consecutive research projects. In this case, however, the users were more involved through their own financial investment in the process, and their involvement extended beyond the research project period. However, the main role of users as participants in field trials is to support the production of scientific knowledge. In a sense, users in these cases are 'research objects', participating in the project by mutual agreement and supported by benefits for a certain period of time. In the case of the Norwegian Hvaler project and the Danish Innovation Fur case, however, users played a more active role as citizen scientists, as some of them were very involved in the production of new knowledge.

In addition to these particularly committed users, there are also ordinary users. Again, the Rosa Future apartment building is an example of such a case. All residents without monitoring devices (about 100 units) belong to this type of user. Here the consumers are obliged to be customers of Salzburg AG, as heat and hot water are produced exclusively by the implemented building-to-grid solution. The consumers had two interfaces with the utility, one technical (a small transfer station in each apartment) and one legal (supply contract, billing and customer service). In the first months of operation, the technical performance was improved based on feedback from these ordinary users. In their role as consumers, some of our interviewees complained about the quasi-monopoly status of the utility, but were generally satisfied with the heat supply. Overall, consumers in this case were able to maintain their existing habits and respond to the solution based on these preferences.

Another important group can best be described as prosumers. In Köstendorf, Trøndelag and Hvaler, households are both users and producers of electricity. In all three cases, the financial risks for private investors have been reduced through subsidies, but this does not change the fact that these users sell electricity to the grid operator and thus take a certain entrepreneurial risk. In these households, energy is made visible through technical equipment and smart meters that show daily production and allow various forms of data processing and energy visualisation. This is even more the case in prosumer households equipped with stationary batteries and/or electric vehicles (as in Innovation Fur and ZEROhome). In the Hvaler case, however, the technological configuration and tariff structures are set up in such a way as to require little activity on the part of the prosumers. For example, it is of no consequence to the prosumers whether they consume their own energy or sell it back to the grid when PV production is high. Some of the users in the Trøndelag case also represented a light version of the prosumer, where households technically and contractually sell electricity to the grid, but the utility owns and maintains the equipment.

In all three countries we also find politically engaged user citizens. In Austria, the 100% renewable household in the Köstendorf pilot project is a typical example. In this case, the decision to go completely renewable is closely linked to a political agenda (ecological movement, climate change mitigation) and the actions taken in the household are part of the mission to show the public that it is possible to rely almost exclusively on renewable energy sources. The energy agenda has clearly become an integral part of the male homeowner's personal identity. The same type of user citizen could be found in Norway, particularly among the participants in the smart energy project on the island of Hvaler; people whose commitment to energy issues goes far beyond their participation in the ongoing field trials, as evidenced, for example, by the fact that they give public lectures on their activities or generously show groups of visitors around their home, sharing their experiences with the smart energy solutions they have tested. For some of these users, their involvement is rooted in a sense of social responsibility for the development of society.

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

The last type of user we could identify in our sample is the user innovator (sometimes also called user producer). In this case, the user develops an intelligent energy solution according to his own needs and mainly based on his own resources and capacities. In this constellation, the user acts as a technology developer and producer. This is again the case in the VLOTTE project, where a regional energy service provider is developing an intelligent e-car park solution, as well as in the ASKO case, where a large Norwegian food wholesaler is developing a hydrogen infrastructure for a hydrogen-powered fleet of heavy delivery trucks. In both cases, the innovation activities are primarily aimed at meeting needs and goals that these companies have set for themselves, and as there was no suitable offer on the market, they decided to tackle the task themselves. User innovators may not be experts in the new field they have entered, but they have a lot of local knowledge and are very aware of how the new solutions should work. User-innovators were also found in the Danish ZEROhome, in particular in one household where the male occupant found it highly interesting and meaningful to "tinker" with the technical energy systems on an ongoing basis and built his own advanced energy supply system, combining and optimising the dynamic interplay between solar panels, solar PV and a biomass boiler.

Table 2: Overview of typical user roles

Name	Description	Typical Activities	Examples
Research partner	End users who are involved in a research project by contract for a certain period of time	• Provide structured feedback • Enable on-site measurements • Articulate preferences	• DSM-trial (Rosa Zukunft) • Test-households in Köstendorf, Hvaler and Fur
Ordinary user	Average energy consumers without any particular function or interest in the technologies tested	• Provide unstructured feedback • Serve as a control group • Demonstrate unaffected consumption patterns	• DSM-trial (control group), Rosa Zukunft • 100 % renewable energy household in Köstendorf • People living in test households without any interest in the P&D project
Prosumer	Households or organisations which at times produce surplus energy and feed it into the grid	• Make financial investments • Are active participants in the smart grid • Aim for higher self-consumption	• Test-households in Köstendorf, Hvaler, Trøndelag and Fur • 100 % renewable energy household in Köstendorf • Company internal household trial (VLOTTE)

Name	Description	Typical Activities	Examples
User citizen	Users who play a politically active role in the transition of the energy system towards greater sustainability	• Are politically committed to the energy system transformation • Accept higher costs • Try to convince peers	• 100 % renewable energy household in Köstendorf • Showcase household in Hvaler
Affiliated user	Employees of the project owner which take on the role as early end-users	• Test solutions under development in real-world contexts • Provide structured feedback • Articulate preferences	• Employees of illwerke AG (VLOTTE) • Employees of ASKO midt-Norge • Employees of TrønderEnergi and Nord Trøndelag Energi
User innovator	Social players who themselves develop new solutions according to their ideas and needs	• Specify concrete tasks and objectives • Develop technical solutions • Make financial investments • Commission specialized companies	• 100 % renewable energy household in Köstendorf • VLOTTE • ASKO

In all our case study configurations, users take on (or are enrolled to take on) several roles (Table 2). For example, in the private test household in the VLOTTE project, the person in charge is both a prosumer and an affiliated user. Similarly, in the distribution grid research project in Köstendorf and the smart energy project in Hvaler, participants take on several user roles at the same time; they are research partners, prosumers and some act as energy citizens. In the e-car park in Austria, user innovators and connected users complement each other. In the following, the different user roles in some selected contexts and their respective impacts are discussed in more detail.

5 USER ROLES IN CONTEXT

In the following section we have selected three examples from Austria, Denmark and Norway. The first example is the 100% renewable energy household mentioned above, which is part of the Köstendorf pilot project in Austria. The second example comes from Denmark, where ProjectZERO is running a project to improve private households. The third example is the Norwegian company ASKO, which is working with research partners to set up its own hydrogen infrastructure pilot project.

EXAMPLE 1: 100 % RENEWABLE ENERGY HOUSEHOLD IN KÖSTENDORF

This case is located in a detached house on the outskirts of the small village of Köstendorf (Austria). The only two residents are a married couple. The male resident is the driving force behind the project, which he has been promoting for many years. Although he has no professional background in the field, he has managed – mostly with the help of professionals – to install and combine a variety of energy technologies in his house. These include thermal solar panels, a storage tank, a heat pump, rooftop PV and a stationary battery. Over the years, considerable sums of money have been spent on the equipment. More recently, he has been accepted into the subsidised EV and stationary battery scheme of the nearby smart grid research project. His stated aim was, and still is, to show that a green local energy transition is possible. The home's energy supply is based entirely on renewable resources. However, the household is not completely autonomous from the grid, but has a very high level of locally produced energy.

Although there are only two people in this household, we could identify four different user roles in this case: user-citizen, user-producer, prosumer and ordinary user. The owner of the house definitely acts as a user-citizen; he is an active member of a local energy activism group that promotes the use of renewable energy, e.g. in the context of his professional activity. He also lectures and teaches sustainability issues at a university. He has a clear vision of building a sustainable future through the use of renewable energy. Many years ago, he was one of the first members of the then very active DIY solar energy groups in this region (Ornetzeder, 2001; Ornetzeder & Rohracher, 2013). Since then, his goal has been to completely convert his own home to renewable energy. He sees himself as an activist, trying to influence the energy transition from the bottom up. Years of commitment have led to this unique configuration, in which the individual is committed to improving the installed system through trial and error, while accepting the considerable economic costs of these activities. The homeowner is also a user-innovator. He has planned and partly installed the various elements of the configuration over several years, with a clear long-term vision in mind. The resulting concept is largely based on do-it-yourself activities and, according to the owner, is certainly not perfect from today's perspective, but the entire installation has become part of the owner's identity. He is still very enthusiastic about it, although he would revise many of the decisions he made in the past. As a result, the configuration is comprehensive, but remains a patchwork of different technical systems. Together, the couple take on the role of a prosumer household, still dependent on consumption through the grid connection, but also producing and selling PV electricity to the grid. Again, the monitoring of the technology and the energy produced (e.g. via a web portal) is carried out exclusively by the male member of the household. The fourth type of user that can be seen in this configuration is the ordinary user. This role is played by the female member of the household, who slowly tries to adapt to the new routines around the now more fluctuating energy supply. This person thus performs a kind of "control function", which, for example, deals with questions of usability and thus clearly goes beyond the role of the user citizen or the prosumer.

In this unique configuration, we see a productive interplay between the user citizen and the ordinary user. On the one hand, the user citizen is the driving force behind the progressive development of the private energy system and the introduction of new technologies in line with the overall vision of a 100 % renewable energy household. On the other hand, the ordinary user serves as a feasibility check for these technical endeavours. Both roles influence the way in which the user producer role can be exercised. Thus, the institutional framework of the user producer is encouraged by the overall vision of an active energy citizen to be a role model for a sustainable energy transition and therefore dares to develop and install advanced technologies. Interaction with other like-minded people provides new ideas and input for improving the configuration. In turn, new plans are tested against the practical concerns of ordinary users.

EXAMPLE 2: ZEROHOME

The ZEROhome programme, launched by ProjectZero in 2010, focuses on engaging homeowners in the energy retrofitting of their private homes. ZEROhome is one of a number of ProjectZero initiatives that together aim to facilitate the transition of the municipality of Sønderborg (Denmark) to a CO_2-neutral community by 2029. As part of the overall community-led transition strategy, ZEROhome aims to qualify ways to improve the current energy standards of individual homes by promoting energy efficiency through independent energy advice. In addition, smart grid solutions to increase renewable energy in homes, such as the installation of PV, are an important strategic effort within the programme. The following outlines how private homeowners are a diverse group of users who perform and interact with the smart technologies in different ways, and are motivated by different reasons to install and invest in PV in combination with electric vehicles (EVs) and heat pumps.

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

Obviously, all households were prosumers (having PV and being connected to the grid) and therefore motivated to consume their own renewable energy production. The prosumer role was a key driver for the purchase of the technologies for most of the households surveyed. The synergies of combining PVs with an electric vehicle and/or a heat pump was an important driver for the purchase of more than one technology. Thus, the purchase of different technologies typically reflects a certain sequence of investments; PVs seem to be the first object of investment, while heat pumps and EVs come after to optimise the use of their own electricity production. Often the initial idea of becoming a prosumer was a consequence of other plans for major home improvements, such as replacing the roof or the old energy heating system (e.g. replacing an oil burner). This opened up a new dimension of thinking about energy. Several users expressed a strong interest in investing in the latest product on the market. Following on from this, some users were motivated to make environmentally friendly choices. This suggests that users are driven by innovation and the desire to test "new technologies", and in some cases also value sustainable energy performance. The purchase of electric vehicles was an example of this.

Although none of the users explicitly mentioned political activities, the users seem to be very aware of their role as sustainable citizens or/and in some cases as self-sufficient, energy-independent consumers, resilient to external threats. However, the users did not manage to time the consumption of electricity for the EVs according to their own "surplus" production of PV electricity. All users plugged in their EVs when they came home in the afternoon. The only households that time-shifted and changed their dishwashing, washing and baking routines were those on the latest hourly net metering scheme, which increased the incentive to consume while producing.

The ZEROhome households were not knowledge producers as in the research partner's role as user. ProjectZero tries to maintain a good contact and relationship with the households in order to have some good showcases to use in their ongoing campaigning for an energy transition in the Sønderborg area. Even though none of the participants were directly involved in the initiatives facilitated by ProjectZero, the users positively declared the value of being part of the ZEROhome network, which shows how ProjectZero has succeeded in creating and anchoring the vision as a shared vision within the local community. For example, many of the ZEROhome members acted as "best practice" cases by hosting visits to ProjectZero and/or being interviewed for news articles on the ProjectZero website, etc. In this way, they were to some extent 'cast' in the role of local promoters of the energy transition – a role similar to that of the user-citizen.

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

EXAMPLE 3: THE MULTI-LEVEL USER INNOVATOR (ASKO)

This example is located in the regional branch of a large Norwegian food wholesaler whose core business is the sale and distribution of food products to stores, retailers and the food service industry throughout the country. The company has a 27,000 m^2 warehouse and distributes goods to more than 1,700 stores and restaurants. Much of the warehouse space is energy-intensive, as it uses hydroelectric power to cool and freeze food. To distribute the goods, they have around 50 distribution trucks. The company's operations are both fuel and electricity intensive.

The company is owned by a large national player with a broad portfolio of businesses including grocery and fast-food chains. In recent years, a key group of owners have become environmental protagonists, arguing for the importance of broader social and environmental engagement for the survival of both the company and the planet. As a result, they have been able to reconfigure the company's overarching purpose. The case of ASKO clearly illustrates the user-citizen perspective of its owners. Environmental concerns, climate protection and responsibility for future generations were among the driving factors behind this development. The aim is to become carbon neutral in every aspect of the company's operations. The first manifestation of this was a decision taken by the Board of Directors five years ago, in which it was emphasised that the return on environmentally oriented investments could be much lower than the return on "normal" investments. They have therefore worked hard to change the rules of the game, both internally and externally, in a less profit-driven and more environmentally friendly direction. The owners did not dictate how the companies in the structure should work to become sustainable, only that they should. However, this was quickly translated into concrete targets for ASKO to be 100 % self-sufficient in new renewable energy by 2020 and to switch to 100 % renewable fuels for transport. At company level, the first decision was to invest around 20 million euros in a wind farm with an annual capacity of 60 GHW. This would cover the equivalent of 75 % of the company's total annual electricity consumption. Several respondents from the regional office highlighted how their own initiative was the result of a combination of external pressure and internal motivation: they decided to install PV on the roofs of the storage facilities, a total of 12,000 square metres of PV. This would cover 15-20 % of consumption. ASKO was now also a prosumer.

As well as being interested in building a sustainable business, they were also interested in being innovative or "ahead of the pack", which can of course be seen as both a business strategy and a will to act as a user-citizen, as well as being interested in innovation and being a research partner. For this reason, and because of its long-standing relationship with certain research institutes, ASKO agreed to participate in a project to replace some of the lift batteries used in trucks with hydrogen fuel cells, which resulted in a reduction in CO_2 emissions from the trucks of around 85 %. This success was crucial for ASKO in terms of energy efficiency. But just as importantly, it convinced ASKO's management of the potential qualities of hydrogen fuel cells. Hydrogen, they now believed, was an option to be pursued in the strategy to decarbonise their fleet of heavy-duty trucks and forklifts. This was not just a result of a new belief in the qualities of hydrogen itself. It was also motivated by the prospect of surplus electricity production from their PV installation.

What had originally been a move towards energy production suddenly became an essential part of a move towards producing one's own fuels and decarbonising one's transport fleet with hydrogen. Together with a long-term research partner institute, ASKO approached several major players in the European automotive industry with the aim of acquiring trucks for a hydrogen truck pilot project. Through intensive lobbying together with the research institute, targeting their existing car manufacturer, they were able to commission three 27-tonne trucks to be developed on an experimental basis by the supplier together with a project group consisting of people from ASKO and the research institute. As the hydrogen trucks need fuel, ASKO invested around €2.3 million in a standard hydrogen production plant to be installed on site.

In just a few years, ASKO has significantly changed its relationship with energy, moving from being a large consumer of energy to producing large amounts of electricity and significant amounts of hydrogen fuel cells for its transport needs, as well as being involved in the development of new transport technologies. In this way, we can clearly see ASKO acting as a driver of innovation, developing a sustainable energy solution according to its own needs and mainly based on its own resources and capacities. In this constellation we see the user acting as a producer and technology developer, as the food wholesaler develops a hydrogen infrastructure for a fleet of hydrogen-powered heavy goods vehicles.

Externally, they have worked to persuade public authorities to tighten requirements and support transitions to more sustainable transport. In this way, they have worked to achieve both market and political acceptance, and they have had the agency and capacity to implement the transition. Furthermore, they have been involved in rewriting the semi-coherent grammar or set of rules (Geels, 2011) in which they are embedded. ASKO is a large company and, as we have seen above, we could identify three different user roles in this case: the user citizen, prosumer, and user innovator.

6 DISCUSSION

Our analysis shows that different types of users actively contribute to the success of the P&D projects studied. Based on nine case studies, we were able to identify six clearly distinguishable user roles and some of their respective characteristics. As (1) research partners, users participate in temporary projects and provide feedback for technical development. (2) Ordinary users, on the other hand, more or less represent the mainstream and thus provide important information for the wider dissemination of the tested technologies. (3) Prosumers actively participate in the generation of electricity and partly also act as commercially oriented producers – they take risks and expect profits. (4) User citizens, on the other hand, are users who play a politically active role in the transition of the energy system towards greater sustainability. They often accept higher financial costs in the process and actively help to convince other users that the chosen options are beneficial for the environment. (5) Affiliated users – a type of user not yet discussed in the literature – are usually employees of the project owner who take on the role of early end-users and test the solutions being developed in real-world contexts. Finally, (6) user innovators are social actors who develop new solutions according to their own ideas and needs. We have found a selection of most of these user roles in all our cases. Together they contribute to different learning processes in the studied P&D projects. The analysis shows that users in smart energy experiments are collectives consisting of different constellations of users playing different roles.

Since different roles always occur in combination in the cases studied, we can speak of sets of user roles that had a positive impact on the development and outcomes of the P&D projects studied. These sets of user roles reveal a wide variety of requirements and preferences, and thus make it possible to effectively influence the socio-technical constellations in the cases on three levels; (1) they contribute to the functioning of the technologies, i.e. to the fulfilment of their intended or newly discovered purposes, (2) they enable the identification of problems and shortcomings and the further development of the technologies, and (3) they support the social and political stabilisation and/or enable a more fundamental reflection of the tested technologies. It seems that it is only through the combination and interaction of different user roles that new knowledge is generated at these three levels, practical experience is gained and the technologies demonstrated are given social meanings that are relevant beyond the particular situation of the P&D project. In this way, they enabled comprehensive learning processes, as is particularly required from an innovation system perspective (Sengers et al., 2019).

In our cases users, and their roles are initially created or configured, as Woolgar (1990) put it, by the technologies in place. However, as this is a relatively early stage of development and the project teams were interested in learning more about the possibilities demonstrated, a reverse process also took place. The different articulations of the users involved influenced the design of the technologies and the socio-technical configurations associated with them. Users were able to appropriate and domesticate (Vestby 1996) the tested technologies to a certain extent. In two of our cases, user innovators (von Hippel 1986) became the main drivers of technology development. In most cases we saw a co-production (Polk, 2015) of social and technical elements, where the development of the technology responded to user feedback. In a few cases, this has even led to certain technical options no longer being offered or used.

In some cases these different roles were defined from the outset, in others these types of user roles emerged more arbitrarily in the course of project implementation. An example of the planned assignment of defined roles with specific expectations and responsibilities can be found in the DSM field test in the city of Salzburg. At the beginning of the test phase, a subgroup of residents was divided into two groups: Research partners in one group and ordinary users without DSM equipment in the other. The hydrogen pilot project at ASKO, on the other hand, is an example where different roles emerged only in the course of the project due to growing demands and tasks. The common feature of the examples examined, however, is that in all cases the project leaders valued the diversity of roles, actively sought to incorporate the different and sometimes contradictory articulations, and were able to draw productive insights from this diversity.

In any case, we can conclude that user roles are not simply found, but rather constructed, just as technologies are constructed before they are implemented. A higher degree of diversity in P&D projects, it seems, can be planned and influenced in the same way as the technologies involved.

However, the diversity mentioned above manifests itself in two ways: In the form of differences between individuals within a particular relatively homogeneous user group, and in the form of differences that are more closely related to the roles identified and the role expectations associated with them. For example, the participants in the PV demonstration site in Trøndelag are a relatively homogeneous group of householders who, as prosumers, have typical expectations of the project due to this particular role (e.g. return on investment). However, the individual households also differ from each other. On the one hand because of different socio-economic characteristics (age, income, household size, occupation, milieu) and on the other hand because one and the same person can take on different roles (e.g. the group of energy prosumers could also include citizens). This means that user diversity played a role on two levels in the cases studied. On the one hand as differences between typical roles, with typical expectations, requirements and competences, and on the other hand at the more individual level, where individual differences come into play. Gender differences were articulated on this second level, for example in the form of different demands of the vehicle users in the case of VLOTTE, or different views of the research partners in the case of the Rosa Zukunft test households. In any case, dealing with diversity in P&D projects means enabling the articulation of expectations and experiences from both levels and incorporating them into ongoing and follow-up developments.

Our examples also show that the involvement of different user categories does not follow a chronological order. On the contrary, in most of the P&D projects examined in this study, very different user groups are represented in this particular phase of the innovation process. Different from what Schot & Karger (2016) assumed, we found highly motivated user-citizens, who are strongly committed to the political legitimation of the tested technological visions, next to average users without any political or entrepreneurial intentions. On the one hand, this is certainly related to the specific character of P&D projects, which aim to implement, test and further develop new socio-technical configurations under real-life conditions (Macey & Brown 1990). On the other hand, as mentioned above, the observed diversity of user roles can also be explained by the deliberate intentions of project sponsors as well as by more serendipitous developments. On this basis, it can be argued that the projects in our sample are characterised by the participation of a wide range of user types, which usually only comes into play when technologies are widely disseminated in society.

The projects studied can be seen as protected spaces (Smith & Raven, 2012) in which users' practices, preferences and beliefs were represented in a way that was already close to society at large. Of course, such situations are not without problems, as requirements and opinions about the technologies used, tested and developed may contradict each other, and project leaders need to be able to draw meaningful conclusions. In several of our cases, the initial assumptions of the project owners were not met, technologies were used differently than intended, and ordinary users did not accept some options at all. In most cases, however, these experiences became input for further development and new research projects.

7 CONCLUSION

The main focus of this paper was on the role of users in smart energy P&D projects in three European countries. The empirical basis for this analysis consisted of nine qualitative case studies in Austria, Denmark and Norway. Our analysis clearly showed that users actively contributed to the success of the projects – in terms of lessons learned and follow-up activities. In most cases, different groups of users took on specific roles, in other cases even individual actors played different roles. We were able to identify six different user roles and their respective characteristics: Research partners, traditional or ordinary users, prosumers, user citizens, affiliated users and user innovators. To some extent, this result contradicts clams that assume that certain types of users appear much later in time (like e.g. Schot & Karger 2016).

Most of these user roles have already been described in various ways in other studies focusing on the relationship between users and the development of new technologies (see Chapter 2). In the context of user-driven P&D projects, however, we were able to identify a type of user that had not been considered before. This is the so-called affiliated user, who has a contractual relationship with the project owner, but who is not part of the project team, but is primarily involved in the developments as a normal user. In two of the projects studied, these affiliated users were crucial to the development of new solutions.

In addition to these typical roles, which are sometimes associated with very different articulations, the examples examined also showed that individual feedback from users in one of these typical groups also made an important contribution to the reported learning processes. Successful projects are thus able to process user input on two different levels – individual users and user roles.

The findings showed that diversity emerged both planned and unplanned. However, an important feature of all cases was that the articulations associated with the different user roles were actively encouraged and used by the project operators. In most cases, this resulted in a co-production process in which technical development took the form of a dialogue with the user side.

Another finding of this analysis was that in most cases a variety of articulations of different user roles contributed to the success of the P&D projects. As the different roles always occurred in combination with each other, we called the resulting principle sets of user roles. These sets were able to inform the technical functioning, influence the way problems were solved, and shape the political meaning and (de)legitimisation of the solutions applied. It was clearly the diversity of perspectives, interests and requirements that had a positive impact on the development, operation and outcome of the P&D projects studied.

We have been able to show that involving different types of users can be of great value to P&D projects. However, we still know very little about how this diversity can be created, stabilised and exploited. In particular, it is not clear how ordinary users, who are usually not involved in innovation processes, can be attracted to participate in P&D projects. Future research should therefore focus on how different user roles can be empowered and consciously shaped in P&D projects, and which methods can productively use different perspectives and requirements for the development of sustainable technologies. A second point relates to how project sponsors and/or the core project team deal with these very different articulations. In other words, how these different perspectives are actually processed in a productive way. Future research could therefore focus more on the question of which methods, competences and normative visions contribute to such a process in the context of P&D projects.

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