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Research paper

The role of competences, engagement, and devices in configuring the impact of prices in energy demand response: Findings from three smart energy pilots with households

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Abstract

The paper discusses the dynamics behind price-based incentives in demand response programmes promoting time shifting of energy consumption in households. Through a comparative analysis of smart energy pilots in Norway, Austria, and Denmark, the study shows that economic incentives under certain conditions influence energy-consuming practices of households but not in ways anticipated by widespread rational conceptualisations within economic, engineering, and policy-making approaches. The paper elaborates the practice-theoretical understanding of financial structures in smart energy interventions and identifies the socio-material configurations causing price to play a role. This informs policymakers and developers of future smart energy interventions. The overall policy recommendation of the paper is that smart energy designers, planners, and policymakers need to consider the complexity of interrelated elements that co-determine the effectiveness of price incentives. Thus, a successful coupling between price incentives and demand response actions can best be realised via a productive mixture of mutually supporting elements (engagements, devices, and competences). In addition, the paper provides specific recommendations related to the design of effective and workable price schemes that fit into the everyday lives of households.

Keywords

Demand response; smart energy; households; economic incentives; practice theory; calculative agency

1. Introduction

For more than 30 years, social scientists studying energy consumption have criticised economic models of human rationality and decision-making (e.g. Aune, 2007; Lutzenhiser, 1993; Shove, 2010) by emphasising the cultural embeddedness of energy consumption (e.g. Stephenson et al., 2010) and the social practices of which energy consumption is a part (Shove et al., 2012; Strengers, 2013). Nevertheless, financial incentives continue to be a key mechanism deployed to change energy consumption in smart energy pilots, often with the intention of making energy demand more flexible in terms of time (i.e. demand response [DR]). From a social practice perspective, this paper empirically explores the role of financial incentives in shaping the everyday practices of households by discussing under which conditions electricity prices influence domestic consumption patterns. Thus, we explore the interaction between price and practice as a situated phenomenon with economically rational, calculative agency as *one* possible outcome (Callon and Muniesa, 2005).

Planners, policymakers, and designers promoting 'smart energy' tend to frame DR as a key asset of future energy systems to balance consumption with intermittent renewable energy sources (Ballo, 2015; Skjølsvold, 2014). Scholars working within Science and Technology Studies have noted how political work to activate end users entails efforts to produce new forms of calculation (Karlstrøm, 2012). We build on such insight by demonstrating how price-sensitive actions and performances of calculation are conditioned and become part of the everyday practices related to energy consumption. Thus, we align with social practice theories highlighting that increasing flexibility in energy demand is a matter of changing established everyday practices (e.g. Friis and Christensen, 2016; Powells et al., 2014; Shove and Walker, 2014; Strengers, 2013). This implies that time shifting electricity demand is a comprehensive task because practices comprise heterogeneous elements, such as meaning, competences, and materials. Interventions should seek to reconfigure or destabilise existing practice configurations.

Many smart energy initiatives have attempted to change energy demand by targeting consumers through price signals and improved (smarter) technology (Shove et al., 2015; Spurling and McMeekin, 2015; Strengers, 2013). Users are typically considered rational and utility-maximising agents who change consumption in response to better information, visibility, and financial incentives. This depiction of the user as a rational, informed and pertinaciously resource-optimising agent has been coined the ‘resource man’ by Strengers (2013), indicating that this representation is also highly gendered. Although a marginal group of people might act in similar ways to this depiction, most people do not measure up to the level of rational and utility-maximising behaviour that is expected by the designers of smart energy solutions. In fact, such strategies often fail or even increase energy demand, which further intensifies the need for recognising the complexities of social dynamics in resource-intensive demand practices (Shove, 2010; Shove and Walker, 2014; Strengers, 2013).

In this paper, we sympathise with the practice-theoretical critique of the conventional understanding of energy demand as a result of individual choice. However, our empirical data indicate that financial incentives and economic calculations play *some role* in shaping household energy-consumption practices. Hence, instead of ignoring this, we aim to demonstrate how prices and economic savings work as one component in household social practices. Thus, the paper makes two main contributions. First, it challenges the underlying assumption in most DR programmes that dynamic pricing is the lever of DR action in households. This is achieved by advocating a shift in focus from economic-rational behaviour to social practices. Second, the paper elaborates the social practice theories by showing how price-sensitive actions can be created through a variety of interrelated practice elements.

Our analysis builds on three case studies of household-targeted smart grid interventions in Austria, Norway, and Denmark, representing different socio-technical pilot configurations. Whereas they all seek to change the timing and composition of energy consumption, the individual pilots are characterised by a local heterogeneity of elements influencing the intervention outcomes. Thus, price is conceptualised, governed, and practised differently in the three pilots. Through an examination of the specific socio-technical configurations, the analysis explores how price influences flexible demand. Comparing different financial incentives (hourly net metering, power tariffs, and dynamic time-of-use prices [ToU]), we explore the interplay between performances of everyday practices and economic rationalities. This informs the designers of smart energy interventions and attempts to expand the social practice-theoretical understanding of the role of prices.

In Section 2, we elaborate on the theoretical basis for this study. This is followed by a brief introduction to the methods in our case studies (Section 3) and a presentation of the cases (Section 4). Section 5 presents the empirical case-study findings, and Section 6 provides the comparative analysis. Section 7 summarises the key analytical observations and policy implications.

2. Literature Review

2.1 Existing DR studies and the critique of economic-rational agency

Diverse DR solutions exist that target households, and key terms are often defined differently from study to study. Following Kessels et al. (2016), we define DR programmes as a 'subset of demand-side management (DSM) programs that rely on price signals as main incentives for altering patterns of electricity usage, which may involve time shifting and/or load reduction' (ibid., 2). A variety of designs exist within price-driven (Darby and McKenna, 2012; Yan et al., 2018) or tariff-based (Bradley et al., 2016) DR approaches, but three types have often been applied in previous DR trials: 1) ToU pricing where prices vary according to a fixed scheme, 2) real-time pricing where prices vary dynamically from hour to hour, often with a relatively short-term announcement of prices (e.g. a day ahead), and 3) critical peak pricing (CPP) that typically charges a high rate for electricity consumption at a limited number of short peak events, e.g. during heat waves in countries with widespread use of air conditioners (Kessels et al., 2016; Strengers, 2019). In addition, Kessels et al. (2016) note that an emerging DR scheme is residential demand charges that include a fee based on the highest measured power demand (in kW) of the household over a certain period. Mixed results have been found regarding the size of load shifting and peak reduction of DR pilots, but reviews by Faruqui and Sergici (2010) and Stromback et al. (2011) indicate that CPP schemes reach peak reductions at about 15% on average, whereas real-time pricing and ToU schemes reach lower reductions of about 5% to 10%. These peak reductions relate to programmes without automated or remote load control.

As Kessels et al. (2016) note, the effectiveness of the DR programme depends on numerous factors related to the climate, built environment, appliance ownership, socio-economic variables, and other characteristics. The response to DR varies considerably between individual households (Räsänen et al., 1995). Thus far, no consensus has been reached on how these factors influence DR effectiveness. Kessels et al. (2016) observe how meta-analyses of DR pilots tend to result in common-sense conclusions, such as that households with higher electricity consumption tend to achieve greater electricity demand reductions. The lack of consensus is likely related to the fact that the efficiency of the individual programmes depends on numerous factors. Another reason seems to be that most DR designs are based on the often-implicit assumption that householders are informed and rational agents who react to price signals by balancing economic benefits with trade-off costs related to factors such as the lack of inconvenience of time shifting consumption. This understanding builds on the classical economic thinking of *homo economicus* but has been criticised for being simplistic and even misleading (e.g. Hargreaves, 2011; Keller et al., 2016; Shove, 2010; Strengers, 2013).

In a DR review adopting the assumption of human behaviour as being guided by economic rationality, Good et al. (2017) review and classify a broad range of barriers and enablers of DR. Although they also find noneconomic barriers, it is characteristic that behavioural barriers are defined as 'those factors which explain why the behaviour of any individual *deviates* from that of the *ideal*, *fully rational* (in the classical economic sense) agent' (Good et al., 2017, 60; italics added). The authors specified that, in the case of individuals, rational means 'utility-maximising'. Thus, behaviour *not conforming* with economic-rational agency is explicitly defined as a deviation from the ideal. A similar example is found in the work by Bradley et al. (2016), which also discusses a range of 'consumer barriers' to DR. Six types of economic, psychological, and sociological barriers are identified, and two of these directly build on the idea of economic-rational agency. The first is uncertainty regarding the scale of financial benefit, which can be categorised as a lack of information/knowledge. The second explains nonrational actions through other economic theories, such as bounded rationality, which is defined as situations when:

> Time-poor consumers may make 'sufficing' decisions (…) based on a combination of inertia, incomplete or inaccurate knowledge about their electricity usage and the tariffs available (…) as well as their cognitive capabilities. In such situations 'rules of thumb' and other heuristics can replace rational choice. (Bradley et al., 2016, 109)

Again, economic-rational behaviour is portrayed as being the ‘natural’ form of behaviour, whereas deviations are explained as a result of *individual* time and cognitive limitations or *limited access* to accurate knowledge and not as contestations of the *a priori* assumption of economic-rational behaviour. Or as Strengers states:

> These psychological and behavioural explanations seek to rectify or ‘correct’ deviation from the expected demand response, thereby allowing price instruments and economic theories to retain their dominant status in planning and policy. (2019, 185)

An illustrative ‘deviation’ is an Australian household trial that compared the effect of information-only peak alerts (with no price incentives) with the effect of dynamic peak pricing and ToU pricing (Strengers, 2010). The study found that even the information-only group reduced their peak consumption by 11% on average. Even if this was considerably lower than for the dynamic peak pricing groups (about 25%), it is still much higher than for most ToU schemes (Strengers, 2013). Findings like these show that price does matter, but that there is much more to it than what is captured by economic theory and the widespread notion of the economic-rational agent. Strengers (2013, 2019) concludes that price incentives primarily work as a carrier of meaning about the status of the energy system, which people react to more in terms of their interest in contributing to the common good (e.g. a community effort to help avoid blackouts in case of CPP) than as utility-maximising individuals. Next, we present an alternative theoretical perspective on DR and price-sensitive agency, which we believe provides a more productive understanding of how DR schemes affect households, which will inform our empirical analysis.

2.2 Practice theories and social studies of markets

The energy consumption of households is intimately tied to the daily social practices people perform. To change current resource-intensive consumption patterns (e.g. by flexible demand among consumers), practice theorists argue that it is necessary to consider the elements constituting each practice and how practices are interrelated (Shove et al., 2012; Strengers, 2013). Thus, practice theories emphasise the limits of the focus of conventional smart energy interventions on visibility, information, and financial savings to increase flexibility (Hansen and Hauge, 2017; Hargreaves et al., 2010; Nyborg and Røpke, 2011; Strengers, 2013). Shove and Pantzar (2005) identify three types of elements that configure practices such as cooking, laundering, dishwashing, and so on: meaning (engagement), materials, and competences. As an example, doing laundry involves meaning elements, such as cleanliness and hygiene; material elements, such as washing machines and detergent; and competence elements, such as being able to operate washing machines and sort clothes according to temperature and colour. Together, these elements form the practice of laundering, and if one element is changed, this often has an influence on overall performance.

Practice theories shift focus from individuals and their decision-making processes and instead place social practices and their elements at the centre of analysis (Hargreaves, 2011; Shove, 2010; Strengers, 2013). As a result, practice-theoretical studies identify other types of dynamics and relations as important to the success of DR programmes. In addition to questioning the idea of economic-rational agency, practice-theoretical studies have shown how the success of DR depends on how easy it is to time shift daily practices and how time shifting affects the temporality of existing routines and habits in households and families (Friis; 2016; Friis and Christensen, 2016; Nicholls and Strengers , 2015; Ozaki et al., 2018; Powells et al., 2014). In addition, studies show that introducing new material elements can change the context of social practices in ways that might support active DR. For instance, producing one's own energy (microgeneration) increases household awareness of aspects like weather conditions, climate and environment, electricity-consuming devices, and saving money, prompting them to reschedule daily practices like laundering and dishwashing (Christensen et al., 2017; Strengers, 2013). However, the goal of this paper is not to provide a full review of all practice-theoretical studies of DR. While our analysis builds on the analytical perspective of practice theories, we specifically explore and elaborate on the role of price in configuring practices and their performance. Few practice-theoretical studies of DR have addressed the role of price specifically, and further elaboration is needed. Strengers (2013, 2019) is among the few who have addressed price in DR, and as mentioned, her key finding is that price in DR works as a signal that encourages households to practise time shifting. Specifically, Strengers suggests (2019, 186) that 'prices can convey meanings of scarcity and abundance, which in turn reposition some practices as wasteful or normal during different pricing scenarios'. In this way, price is mainly attributed to the meaning of practices.

However, our empirical study indicates that the effect of prices also relates to other practice elements, which is why we also draw on insight from a broader and emerging approach that emphasises the importance of actor relationships (Chilvers and Longhurst, 2016) and explores how actors in pilots work to produce specific forms of participation, such as citizenship (Ryghaug et al., 2018) or calculative agency (Pallesen and Jenle, 2018). In this vein, Pallesen and Jenle (2018) point out that price sensitivity and calculative agencies are produced and cultivated. Calculative agency does not reflect the inherent quality of the consumers (i.e. pre-defined preferences), as implied in many DR studies emphasising economic-rational agency, but is a configured performative agency that is highly influenced by the settings of the individual dynamic pricing scheme.

This analytical approach is embedded within what Silvast (2017) terms the *social studies of markets* tradition, which builds on works by Callon (1998) and MacKenzie (2007). A key concept is to understand economic institutions like 'the market' and the agency of 'market actors' as *performative* and situated (Silvast, 2017). In this way, social studies of markets deviate from classical economic understanding of markets and calculative agency as fixed institutions and inherent (cognitive) qualities of the individual. Social studies of markets also emphasise that calculative agencies are *distributed*. 'These agencies are equipped with instruments; calculation does not take place only in human minds, but is distributed among humans and non-humans' (Callon and Muniesa, 2005, 1236). The implication of this is that calculative agencies (e.g. price-sensitive electricity consumption) depend on material devices and their inscriptions, (e.g. smart meters and energy-consumption feedback apps) and on individual or shared knowledge and (cognitive) competences. As an example, Pallesen and Jenle (2018) show how smart energy pilot participants are purposefully framed, formatted (e.g. trained), and equipped to perform calculative agencies across their practices. Creating price-responsive electricity users is a practical task realised through instructions, automation, training, prices, and installation of technical equipment.

Based on the practice-configuring elements of meaning (sometimes termed 'engagement'), materials, and competences, with adaptions inspired by Pallesen and Jenle (2018), we use the following categorisation of elements to structure the presentation of the three case studies and the subsequent comparative analysis:

- **Engagement:** The focus is on strategies that make it attractive or meaningful for households to participate in DR programmes. Meaning can be inscribed in the smart energy design (e.g. through invitation letters or websites) or articulated by individual pilot participants or other key actors involved in the trial.
- **Devices:** These include physical and non-physical elements, such as price schemes, technical equipment installed in homes, infrastructure, phone apps, etc. Automation can be part of this (e.g. using timers on dishwashers to postpone dishwashing).
- **Competences:** These are bodily and cognitive skills and knowledge that are required for performing DR and calculative agency within everyday life settings. These can be routinised habits or rules that pilot participants learn and incorporate into their daily activities. In some pilots, these competences are communicated ("formatted") through meetings or home visits by installers introducing new equipment.

It is important to emphasise that the above analytical distinction of categories is applied to support and structure the empirical analysis of this paper, although the elements discovered in empirical studies might sometimes be hybrid. In the analysis, we will specifically study how price-sensitive habits and calculative agencies are constructed within each individual pilot case and how calculation is performed (or not) by the participants. The distinction between the calculative agency scripts of the pilots and actual performance by households is not necessarily an outcome. As Pallesen and Jenle (2018) note, participants might develop competing calculative agencies or even counter-agencies in response to those of pilot designers.

3. Methodology

The analysis of this paper is based on detailed studies of three smart energy pilots involving different types of financial incentives for DR in Denmark, Norway, and Austria. The cases were studied as part of an international research project focusing on the role of households in the future smart energy system. The case studies are based on recorded, transcribed, and coded semi-structured qualitative interviews (Kvale, 1996) with households and selected involved key actors (organisers and project owners). Nine interviews were conducted in Denmark, five in Austria, and 15 in Norway. The interviews were conducted during 2016–2017 and were based on the same overall interview guide themes (tailored to the local context) focusing on the participants' experiences with the pilots and how these affected their daily practices and energy consumption.

For all three pilots, we used diversity regarding socio-economic parameters, such as age and family type, as recruitment criteria for the interviews. Still, it is our assessment that the samples might have a slight bias towards an active segment of households, in a few cases similar to what von Hippel (1986) termed 'lead users'. This was most evident in Denmark and Norway.

As in other qualitative case studies, the interview samples are not statistically representative of the countries' populations. Instead, the pilots and interview samples were strategically selected (Flyvbjerg, 2006). Thus, the three pilots significantly differ on contextual factors, such as geography, energy production, supply and policy regulation, infrastructures, building types, social contexts, and commitment. This was done to ensure diversity to make it possible to illuminate how the role of price depends on local socio-technical configurations through a comparative analysis of the pilots. Table 1 provides an overview of the three pilots.

Table 1: Overview of the three pilots.

	GreenCom (Denmark)	**Smart Energy Hvaler (Norway)**	**Rosa Zukunft (Austria)**
Price scheme	Microgeneration combined with hourly net metering	Capacity-based tariffs and microgeneration	Variable tariffs (time of use) and 'traffic lights'
Location and trial period	The island of Fur, Denmark, 2011–2015	The islands of Hvaler, Norway, 2010–2017	The city of Salzburg, Austria, 2012–2013
Number of participating households and type of housing or ownership	20 households living in privately owned detached houses	About 100 households living in privately owned detached houses	33 households living in a social housing building complex

4. Presentation of Pilots

4.1 Microgeneration combined with hourly net metering (GreenCom)

The EU-funded GreenCom trial on the island of Fur in Denmark was conducted from 2011 to 2015 with strong involvement by the local electricity utility Eniig. The aim of the trial was to increase regulation and reserve power within the low-voltage grid and to test a variety of smart grid technologies in households. This included photovoltaics (PVs), heat pumps, home batteries, and a home energy monitoring and management system. Households with PVs in combination with either heat pumps or batteries were selected for this interview study. All selected households were on the so-called hourly net metering scheme, which can effectively be compared to what Darby and McKenna (2012) term real-time pricing in the sense that the *effective electricity price* is very low during hours with PV power production. Hourly net metering means that the amount of consumed electricity is deducted from the amount of electricity produced within the household on an hourly basis. If consumption exceeds production, the household pays the full customer price of electricity related to the net consumption (about .30 €/kWh). If production exceeds consumption, the household will earn only about .08 €/kWh of surplus electricity sold to the grid. In summary, this price scheme makes it profitable for households to consume electricity during hours with microgeneration. As part of the pilot, the GreenCom participants participated in several common meetings held by the project managers, who also visited the participants several times to install the energy technologies. Estimates of the households' actual time shifting of electricity is not available due to the lack of hourly consumption data from before the trial.

4.2 Capacity-based tariffs and microgeneration (Smart Energy Hvaler)

Smart Energy Hvaler is a collaborative project between the local energy utility Fredrikstad Energi AS, local municipality, and nearby Østfold University College. As a part of moving the region towards smarter energy grids, the project developed a pilot site within the island community of Hvaler. Some of the main components of the pilot were smart metering, energy monitoring, and fitting homes with rooftop PVs. In addition, a capacity-based grid tariff was introduced in 2015. According to the local grid company, the goal was to reduce grid investments and achieve a lower overall grid tariff by evening out consumption. The capacity part in the grid tariff for the individual household was based on the average of the three largest consumption peaks (each within a 24-h period) of each month multiplied by 65 NOK (about 7 €). Several houses were also fitted with an in-home display, called the eWave, displaying power consumption and production in real time and providing access to these data via an internet portal. In addition, smart plugs measured the power outtake from appliances, such as heat pumps, ovens, and boilers. Pilot participants were primarily recruited through email invitations from the energy company. Hourly electricity metering data and cost accounts were analysed for each participant and compared with hourly records for the winter of 2013 and a control group. The median for the test pilots shows 12% to 15% savings in the power consumption (kWh per h) and about 85% of the participants could document a net reduction in consumption. With economic savings averaging 62.5 € per participant, the conclusion was that the network tariff incentivises DR (Sæle et al., 2015).

4.3 Variable tariffs and 'traffic lights' (Rosa Zukunft)

The Rosa Zukunft project in the Austrian city of Salzburg aimed to test building capacities as active parts of a future electricity grid. It included eight newly built residential apartment complexes. One specific aim of the Rosa Zukunft project was to incorporate DR technologies in homes to test the potential for achieving load shifting and lower energy consumption. Out of the 129 apartments, 33 homes were equipped with advanced monitoring technology (a computer tablet) to provide feedback and partly control the use of energy, heating and water, humidity, and carbon dioxide levels in the rooms. Each apartment had a smart meter and an 'ECO-button' that could switch off all appliances except the refrigerator. It was also possible to control the heating system via the internet or a smartphone. The in-home monitoring test lasted one year, after which the devices were dismantled and removed. Critically, many of the participants appeared to have agreed to test the smart technology because they saw this as a criterion for being considered for an apartment in the housing complex.

Information about profitable consumption time was communicated through a 'traffic-light model' ('*Ampelmodell*') in which red indicated a critically high network load, yellow a medium load, and green a low load and, hence, a good time to consume electricity. Further, a variable tariff was communicated to the users via the in-home displays. A daily price curve was calculated that differentiated between the six cheapest hours (green) and the six most expensive hours (red). The price curve was submitted a day ahead. In the case of cost savings due to changed load profiles, customers would receive a voucher (Stutz et al., 2015). In the case of additional consumption, costumers were informed but did not actually have to pay. The red price was 0.22 €/kWh. The yellow price was 0.17 €/kWh, and the green price was 0.11 €/kWh. Thus, the red price was slightly higher than the regular average electricity price of 0.2 €/kWh for Austria. Compared with the control group, the monitoring households reduced their total electricity consumption by about 15% (Stutz et al., 2015), but the time of consumption (the load curve) was similar to the control group. This indicates that that the monitoring households had a general increased awareness of electricity consumption but that the tariffs of the traffic lights had no effect on the temporal pattern of consumption.

4.4 Supply and regulatory context of the pilots

Due to its high share of intermittent renewables (wind and solar) in the national electricity mix, Denmark faces the hardest challenge in relation to balancing electricity generation and consumption. In 2015, the combined share of wind and solar power amounted to 44% of the Danish electricity production, whereas the same share was 9% in Austria and only 2% in Norway (Ornetzeder et al., 2018). This makes DR strategies particular relevant in Denmark. In comparison, hydropower and other controllable sources, such as natural gas, represent a larger share in Austria and Norway. This is especially true in Norway, where hydropower provided 96% of the total electricity generation by 2016 (International Energy Agency, 2019).

In all three countries, only few households are on dynamic electricity pricing schemes. However, dynamic pricing is slowly on its way, such as in the case of the Danish distribution system operator *Radius*. By 2018, Radius had replaced flat-grid tariffs with a ToU scheme for its estimated 150,000 customers with smart meters (higher tariffs between 5 and 8 pm during winter months). Though, most household customers in all three countries still pay fixed electricity prices (Ornetzeder et al., 2018).

The market structure shows strong differences between household electricity prices (including taxes) in the three countries. Thus, the 2017 average electricity prices for households were 0.195 €/kWh in Austria, 0.305

€/kWh in Denmark, and 0.164 €/kWh in Norway (Ornetzeder et al., 2018). The much higher price for Danish households in comparison with those in the other countries is noteworthy.

5. Empirical Findings: Creating Price-sensitive Practices

In this section, we present the empirical findings for each pilot regarding the households' performance of time shifting daily practices. The elements of engagement, devices, and competences are presented for each case to provide the basis for the analytical comparison across pilots.

5.1 Microgeneration combined with hourly net metering (GreenCom)

Of the nine interviewed households on Fur, the majority (seven) reported that they time-shifted their electricity consumption to use more of their own PV power production. However, it was done to various degrees. Interestingly, only dishwashing and laundering were largely time-shifted, and only a few households reported time shifting other activities (e.g. ironing clothes or cooking).

Only one interviewee explained how he regularly checked the smartphone app to follow the PV power production and status of the battery charge to plan dishwashing and laundering to optimise the usage of PV power. Though none of the other interviewees followed the metered PV power production regularly (if at all), many explained that they judged when to start the dishwasher or washing machine on the basis of daily weather conditions, either by simply observing the weather in the morning or on the basis of the weather forecast. In general, households explained that it became a daily routine to do the dishwashing and laundering during daylight hours (irrespective of the actual weather conditions).

5.1.1 Engagement

When asked why they shifted electricity consumption, the interviewees most often referred to saving money:

> *Well, the more power we can use, then it is our own [PV] installation that produces the power, the better it is because we get 60 øre [~.08 €] per kilowatt, we are putting on the grid, but we pay almost 2 kroner [~.30 €] for what we pull back home. So, it is an*

extremely bad business for us, when we are not at home and are just letting it all run into the grid and then have to pull it back again later.

However, a few also found it appealing to consume 'their own' electricity. Another interviewee expressed the following:

It is this mixture. It is about economy but also this satisfaction with saying 'what we are doing now, it's something we have produced our own power for'. And what's weighting most, I don't really know.

Then, detailing their reasons for time shifting consumption, several interviewees referred to what they learned at the introductory meetings and workshops in the GreenCom project, as one interviewee said:

We have also been to some information meetings in the beginning, of course, where they explained a bit about what you can do in order to save money.

Despite the highlighting of saving money as the main reason for time shifting, none of the interviewees could give exact figures on how much they were saving. Thus, the idea of saving money acts as a general statement and not as something that the participants tried to calculate. It is apparent that the routine of time shifting is something they have either learned from the introduction meetings or deducted from the combination of hourly net metering and their own microgeneration. It makes sense to them to adopt the habit of time shifting because it saves them money (for some, also because of the ideal of consuming their own power). Some individuals time-shifted energy use as a new habit, whereas a few even planned their time shifting on a day-to-day basis from weather observations or monitoring PV power production.

5.1.2 Devices

The rooftop PV is a key device acting as a material reminder of consuming the participants' own power during the daytime. As one interviewee argued:

The thing that we got the solar cells put up that definitely made our eyes open to – okay, it is not nine in the evening that we are starting our dishwasher.

Another device is the national hourly net metering scheme, which makes self-consumption attractive. Most interviewees explicitly referred to this scheme as a reason for time shifting consumption. Three of the interviewed households also had a home battery installed with an automated energy management system controlling the discharging and recharging of the battery to optimise the self-consumption of PV power. Interestingly, to some extent, this lessened the motivation for active time shifting of electricity consumption. As one interviewee explained:

> *It has probably made it easier with the battery, because (...) when the sun is shining the entire day, then you know that your battery is charged 100%. And then, you can actually just start it [the dishwasher] in the evening.*

In other words, the activity of optimising the synchronicity of generation and consumption was delegated to the battery. Finally, an important device to some households was the timer on dishwashers and washing machines because it was used to start the machines during the daytime when they were away from home.

5.1.3 Competences

Time shifting partly involves new skills, such as handling timers, interpreting the signs of the weather in the morning, communicating among spouses on planning time shifting for dishwashing and laundering, etc. In addition, this typically involved *rules of thumb*, such as avoiding certain energy consumption during evening and night hours. As already mentioned, most households appeared to have learned these rules of thumb and other skills through the introductory meetings in the project, which played a key role for the pilot participants in forming (‘formatting’) their practices.

5.2 Microgeneration combined with capacity-based tariffs (Smart Energy Hvaler)

The introduction of capacity-based tariffs increased the participants’ awareness of consumption patterns, and the interviewed households frequently reported avoiding running several appliances at once. In general, households shifted the load for the use of several appliances, including space heating, boilers, washing machines, dryers, and electric vehicles (EVs), and plug-in hybrid electric vehicles. They often performed this manually by planning their use or with the aid of automation. Because selling electricity produced by the PV was about the same as buying it from the grid, the effect of microgeneration on time shifting was less prominent. However, the participants were quite proficient in their understanding of how their power demand correlated to the cost of electricity consumption.

5.2.1 Engagement

Information about the capacity-based tariff was disseminated by the energy company through information letters and in the local media. Another important contributor to households being interested in the new tariffs and their monitoring technology was community meetings. The rationale for the new tariff was primarily related to saving grid capacity, but some interviewees connected it to a larger environmental narrative:

> *It started with this meeting at Hvaler, where they were raising awareness on energy consumption. And we were using in this house about 27,000 kWh per year. And we were made conscious, we got this eWave, and were conscious about reducing peaks. So, you can save money on reducing peaks, but in the greater picture, it's important for society, the local community.*

Although the participants were well acquainted with their consumption and the grid capacity needs and thus found the introduction of the new tariff structure comprehensible, the majority stated that they learned something new when the tariffs were introduced that helped them incorporate changes into everyday routines.

> *What got our attention was that we could not do that many things at the same time. We see that immediately on those peaks in that hour.*

Whereas many were positive towards load shifting in general, they did not consider the efforts of peak shaving to be oppressive. Rather, the participants articulated a somewhat relaxed attitude focused on 'giving it a try' and thus refused to let the capacity tariff run the home:

> *Then, if I know that I'm about to make dinner, for instance, and I know I'm going to roast something in the oven for two hours, then, I might just consider that I should probably turn off the car charger (…) but it's not certain that I do [it].*

This indicates that households experience some capacity to incorporate flexibility into their energy use if this does not challenge their idea of free agency and convenience. However, several of the pilot participants did not care to time shift at all, which was ascribed to the rather low electricity prices in Norway.

5.2.2 Devices

Several devices played an important role in helping the users manage their consumption and load shifting. Most important was the monitoring equipment, but some respondents also had installed smart home equipment for automated or remote control and load shifting:

> *I run water heaters at different times (...). So, I make sure the heaters switch on, one of them between two and three [o'clock]. The other between three and four. And the same with the EV, I make it charge during given periods.*

The information about high demand and peaks was crucial to increase household awareness of consumption, and feedback on appliance demands led to instances of manual time shifting:

> *I think first and foremost it's the awareness, that we have this eWave standing there. And yes, it's centrally placed. When I switch stuff on, I go over to it and take a look at it (...). And then it's about, OK, what can we do. What can we turn off, now that's heating up, and then the oven goes off. Or we turn off the water heater.*

However, there is also evidence that the capacity-based tariff could be a cause of disengagement because of the way it was designed. If the household had incurred three rather large peaks within a current billing month, the incentive was lost:

> *Then, you can just use as much as you want, because if you fall into the trap within a month then there isn't anything more to think about.*

5.2.3 Competences

Many of the respondents demonstrated a rather acute sense of how load shift influences capacity terms and monetary savings (or cost). Thus, many have put a considerable amount of thought into how to gauge sensible ways to load shift and how much effort to put into it, resulting in statements like this:

> *If I come home and it's dinner (...), then I don't charge the hybrid [vehicle] (...). But it is a matter of judgement because the consumption of the heat pump is often higher at night when it's colder.*

Several interviewees expressed such an acute sense of connection between specific activities and the kilowatts and costs derived from the information provided by the feedback monitors. This once again indicates the importance of monitoring competences in relation to capacity tariffs.

5.3 Variable tariffs and traffic lights (Rosa Zukunft)

The experimental setting in the trial apartments generated limited time shifting. Many participants experienced dissatisfaction with the outcome of the experiment. Hoping for larger economic benefits as compensation for their efforts, they quickly became disillusioned with the whole idea of actively shifting energy consumption as a response to price signals (the realised savings were estimated at about 15 € per year). As a result, the participants showed opposition towards the utility and the idea of time shifting in general.

5.3.1 Engagement

The participants reported trying to adjust their cooking, dishwashing, and laundering based on the obtained information but were generally disappointed with the overall result. Cooking was perceived as impossible to time shift, and laundering was difficult to postpone to the low peak hours after 10 pm because Austrian residents in apartments are obligated by law to make as little noise as possible. Indeed, some neighbours complained to the residents in the pilot households who consequently stopped laundering at night.

Furthermore, at the end of the one-year period, the amount that residents had saved was much lower than they had expected and not worth the effort in their view. Some users also expressed a general mistrust in the involved companies. They felt exploited by the utility solely for its financial benefit:

For me [it] was the realisation (...) [that] what the energy provider wants, a rethinking in society, only to use the cheap electricity and sell it to us [as] equally expensive, so they have a larger profit.

Although the installed and clearly visible PVs on the residence were owned and operated by the utility, two households expressed a sense of ownership and felt entitled to profit from the 'home-grown' energy. As one interviewee expressed:

But that we do not use the whole electricity of our photovoltaic module, but give it away, sell it, I don't think is right. Because I think that should be used by us.

5.3.2 Devices

The price signal was accessible through two different devices. First, through the tablet's depiction of the traffic light and second through a more extensive online portal providing further information on signals from different monitors installed in the apartments. In general, the households did not feel sufficiently informed through the traffic light, which was calculated on the basis of the weather forecast, current consumption patterns, and other market information. Changes of colour felt erratic and unpredictable, which made it impossible for the participants to plan their energy consumption. It is important to note that this sentiment of unpredictability was reported after the participants realised that they did not save much money. Although the installed monitoring equipment was free, the majority (31 out of 33) of the participants decided not to keep it. The main reason was the high costs related to maintaining and repairing the equipment.

The monitoring displays were not clearly understandable to all users, and not all were satisfied with the reaction of the technologies to changes in settings. One of them reported finding workarounds to make the devices useable:

We draw lines. I mean, in the bedroom, we are not heating [it] up to 25 degrees, right? But in other rooms, we did draw a little line and a black dot, so that we know, when winter is coming, that we set it on that, so that we do not have to re-try every room.

Overall, several devices acted as constant reminders of the presence of the energy provider and the expected energy savings. In particular, all interviewees mentioned the clearly visible blinking monitor lights as intrusive to their lives and daily routines.

5.3.3 Competences

Overall, the participants showed a variety of skills in relation to economic thinking. Initially, they showed calculative agency and interest in complying with the trial setup. However, it is fair to argue that the necessary competences for managing the installed technologies were not successfully introduced to the participants or were too complex to acquire. The introduction to the traffic light, the online portal, the monitoring equipment, etc., was via voluntary meetings. However, one interviewee who did not participate in those meetings due to having belatedly joined the project expressed discomfort about her capabilities to understand the installed equipment. Thus, acquiring the needed skills for DR required active and dedicated participation.

The participants who expressed a high degree of knowhow regarding the detailed energy information were male participants who performed the role of ‘resource men’ (Strengers, 2013) by following an economic rationality and comparing prices to achieve the possible economic outcome. As previously alluded, all the interviewees expressed concern about their financial benefits of the project and were generally sceptic of the motives of the utility. In addition, as the time shifting was primarily promoted in terms of money savings from the utility side, the participants mostly focused on the lack of economic benefits without considering other possible benefits to the environment and so on. Although the participants had difficulties following the price signals, they did learn about their own energy-consumption patterns. The general message was that it is cheaper to consume energy at night.

6. Discussion: The Role of Price in Changing Energy Demand Practices

The empirical findings demonstrate how practices of DR and calculative agency are differently performed in the three trials. Despite sharing the overall aim of increasing DR among end users, the three pilots employed different means of engagement, devices, and competences to recruit and commit participants to follow the scripts of the trials. Regarding the overall success criteria of DR, the Danish and Norwegian pilots appear most successful in actively engaging householders in daily time-shifting practices, which indicates that the related combinations of elements had some potential.

Most of the interviewed Fur participants integrated new habits related to washing clothes and dishes. The core reason for time shifting these semi-automated practices was related to the hourly net metering scheme, which benefitted participants who ran the washing machine and dishwasher during daylight hours with microgeneration. Money savings related to consuming their own PV power thus seemed to be a main driver for the relatively high satisfaction and commitment on Fur. In addition, the power tariff on Hvaler increased the participants' awareness of their power consumption, which led to new skills related to not be running too many energy-intensive appliances simultaneously. In this way, the Hvaler participants reacted in accordance with the pilot scripts by avoiding power peaks and the related higher costs.

Compared with the two island pilots, the Rosa Zukunft project had limited effect on the timing of demand of the participants. From the participants' point of view, they initially shifted many activities, but eventually it had a small economic effect. As a result, almost all participants stopped time shifting after the trial period was over. Thus, an important reason for the limited participation was that the financial benefits of time shifting were perceived as almost negligible. However, this is not the entire story, as other disengaging factors included distrust in the utility company, noise problems related to running machines during late evening and night, and unpredictable price signals. These complex factors demonstrated that the assumption of direct causality between the (type of) price scheme and (volume of) time shifting is too simplified.

Prices, or more precisely, people's expectations about possible price advantages of changing behaviour, played a role in promoting time shifting, but the realised extent of time shifting was determined by all complex elements related to everyday practices and smart energy interventions. In this way, the elements of engagement, devices, competences, and their interrelations, determined to what degree the householders performed what appears to be a calculative agency. In the following section, by exploring the differences and similarities in the elements involved in the three trials, we identify the sets of elements that are most successful in promoting DR and are critical in designing workable DR interventions (key elements are summarised in Table 2).

Table 2: Summary of the key elements related to household performance of DR across the three pilots.

DR Pilot	Engagement	Devices	Competences
Microgeneration combined with hourly net metering (GreenCom)	• Save money • Reduce environmental effects • Save grid capacity to avoid grid investment • Self-sufficiency and being prosumers • Ownership of devices • Introduction meetings • Persistent contact with the project owner	• Hourly net metering scheme • Installation of monitoring devices in the homes • Advanced home energy monitoring system • Rooftop photovoltaics • Batteries and/or heat pumps • Automation (energy management system for battery charging and timers on the washing machine and dishwasher)	• Interpret weather conditions and synchronise laundry and dishwashing duties with photovoltaic generation • Rules of thumb to judge profitable consumption hours • Reading the smart equipment • Awareness of energy use
Microgeneration combined with capacity-based power tariff (Smart Energy Hvaler)	• Save money • grid capacity to avoid grid investment • Reduce environmental effects • Information from project owner (via local media, town meetings, and digital portal) • Increase awareness of energy use	• Capacity-based grid tariff • In-home display/monitoring (management) equipment (eWave) • Feed-in tariff (photovoltaics) • Web portal • Rooftop photovoltaics • Heat pumps and electric vehicles • Automation and manual control	• Awareness of energy use • Priority between energy power-consuming devices (selective use of appliances) • Reading the smart equipment

Traffic-light information feedback and ToU pricing (Rosa Zukunft)	• Save money • Reduce energy consumption • Awareness of energy use • Voluntary meetings arranged by the trial • Participation in the trial as a precondition for getting an apartment	• Photovoltaics on the rooftop of the housing complex • Tablet visualising energy use and price by a traffic-light system • Online portal disseminating information on energy and water consumption • Equipment (signal lamps) to monitor temperature, humidity, water, energy use, and carbon dioxide levels • Regulations prohibiting noise during late evening/night in apartments	• Active participation requires (advanced) skills to read devices to follow price signals and information on own consumption • Reading the smart equipment • Awareness of consumption

Although saving money was expressed as a key priority by the participants in all three trials, engagement also includes a range of noneconomic elements. First, place and geography play a role in commitment because living on the islands of Fur and Hvaler has a risk of blackouts due to the power limits of the mainland connections. This contextual factor brings an element of 'doing something for the common good' to the performance of DR, which goes beyond the individualistic and economic-rational conceptualisation of the 'resource man' described in Section 2. A further example is those believing that taking part in the DR initiative and investing in microgeneration, such as using PVs, contributes to a better environment and energy sovereignty. These engagement elements echo Strengers's (2019) findings that interest in being part of a community effort is central in making DR meaningful to people. The community identity might be particularly strong on islands, where the residents often share the vulnerability of being dependent on capacity-limited mainland connections.

In addition, several of the participants on Hvaler and Fur found self-sufficiency appealing and were motivated to increase this through time shifting consumption, which corroborates previous research showing that microgeneration can motivate time shifting (Section 2). However, this was much less visible in the Rosa Zukunft project, which points to a material factor but has important implications for engagement. The homeowners on the islands were living in detached houses, which implies that microgeneration (if installed) happens on the premises of one household and on the customer's side of the electricity meter. This is different from the Rosa Zukunft pilot, where the PVs were owned by the utility and were not directly related to individual homes. Thus, detached dwellings and homeownership appear to be material arrangements that make it easier to stimulate engagement in self-sufficiency.

Further, the interaction between project owners and participants (e.g. in terms of written or oral user instructions) plays a significant role in creating participant commitment. Again, there is huge variation between the three trials, and especially (dis)trust influenced commitment, but the extent and shape of communication and interaction also proved important. On Fur, the project owner offered frequent and personal advice through information meetings with knowledge exchange between participants. The value of a trusting, personal relation with a permanent contact person seems crucial. In contrast, the information meetings in the Rosa Zukunft pilot were voluntary, and many participants signed up to the trial to obtain an apartment, which indicates a mix of motives for participation in the pilot.

Finally, engagement also depends on different socio-economic parameters, such as gender and employment status. Thus, the Fur interview sample includes several retired participants who were much more flexible to adjust consumption to the daytime hours than employed people.

Different devices appear to have important influence on the performance of time shifting. First, visibility of microgeneration had a positive influence, especially on Fur, as the installed rooftop PVs reminded the owners of the economic incentives of consuming their own electricity. Second, the presence of complementary smart energy devices, such as meters and feedback devices, in some cases promoted DR actions. This was the case for Hvaler, where several households employed monitoring and smart home equipment to decide when to turn appliances on and off. Contrary to this, the meters and in-home displays installed in the Rosa Zukunft pilot almost disengaged DR actions because the traffic-light messages were perceived to be of little use due to their unpredictability. This trial reveals how the extensive information on energy consumption, price signals, and monitoring of temperature, humidity, carbon dioxide, and water and energy use was experienced as too advanced and required too much technical knowledge to interpret. In addition, much of the information was simply experienced as irrelevant. Similarly, only one interviewed family on Fur still used the advanced home energy monitoring system, and many had not even started using it due to technical trouble (e.g. with signing on to the online feedback platform). These findings show that metering and feedback *can* act as an 'enabler' (Good et al., 2017) or supportive element of DR actions and price-sensitive agency, but this depends on *simplicity* and *relevance* in the design of the feedback solutions to prevent annoyance and discomfort.

Finally, as mentioned earlier, the *combination* of price incentives with microgeneration, such as rooftop PVs, played an important role on Fur. However, this was less evident on Hvaler due to the customer price parity between selling and buying electricity from the grid. Again, this demonstrates how elements very often are co-determined; the material element (device) of microgeneration primarily works as an engagement element promoting DR *if it is supported* by an economic scheme favouring time shifting (which depends on the PV ownership model, as demonstrated in the Rosa Zukunft pilot). Similarly, microgeneration coupled with heat pumps or batteries (Fur) and EVs (Hvaler) also caused interest in DR.

Developing the right competences is decisive to realise flexibility in household daily practices. Some aspects were distinctive across the three cases. First, the degree of successful DR depends on the ability to develop or adopt simple *rules of thumb*. On Fur, this was supported by the communication from the pilot owner and the predictability of solar-based microgeneration (the daily and annual sun cycle) and its close association with weather conditions. It was fairly easy for the participants to plan time shifting and develop new temporal routines (e.g. shifting dishwashing from evening to daylight hours). On Hvaler, the capacity-based power tariff was translated into the simple rule of minimising simultaneous use of (energy-intensive) appliances. In contrast, the unpredictable nature of the dynamic ToU pricing in the Rosa Zukunft pilot made it difficult for the participants to develop rules of thumb and new temporal routines within the household. This was a source of stress and confusion to many. Nonetheless, the Rosa Zukunft participants eventually learned that (economic) benefits were mainly related to shifting consumption to the nighttime (although not a practical option due to the noise problem). The use of rules of thumb resemble the bounded rationality that Bradley et al. (2016) describe as a heuristic replacing rational choice due to, in this case, limited cognitive capability. The adoption of rules of thumb might be related to limited time and cognitive capacities. However, instead of interpreting this as a departure from a human inclination towards rational decision-making, as in bounded rationality, it might be interpreted as a basic human tendency related to the reproduction of the habits and routines that comprise the everyday lives of most people (Southerton, 2012). Thus, instances of making (economic) rational choices might be a deviation from normal human praxis rather than the epitome of human agency.

Figure 1 summarises the key elements and shows the mutual interrelations between individual elements. The identified elements across all three pilots are included in the figure (organised by type of element), and whether each individual element was present in one, two, or all three cases is indicated. In addition, we show how the individual elements are mutually connected in relation to the Fur pilot. We have not visualised the interrelations for the other pilots because this would make the figure too complex. Furthermore, we indicated with capitalised letters those elements that are traditionally perceived as economic measures and that most smart energy pilots emphasise as the main incentives for promoting DR behaviour. From Figure 1, it is evident that these economic elements are just a few of many elements that determine the successful outcomes of such pilots. It is this complexity of interrelated elements that designers, planners, and policymakers must consider when changing and shaping the future energy system.

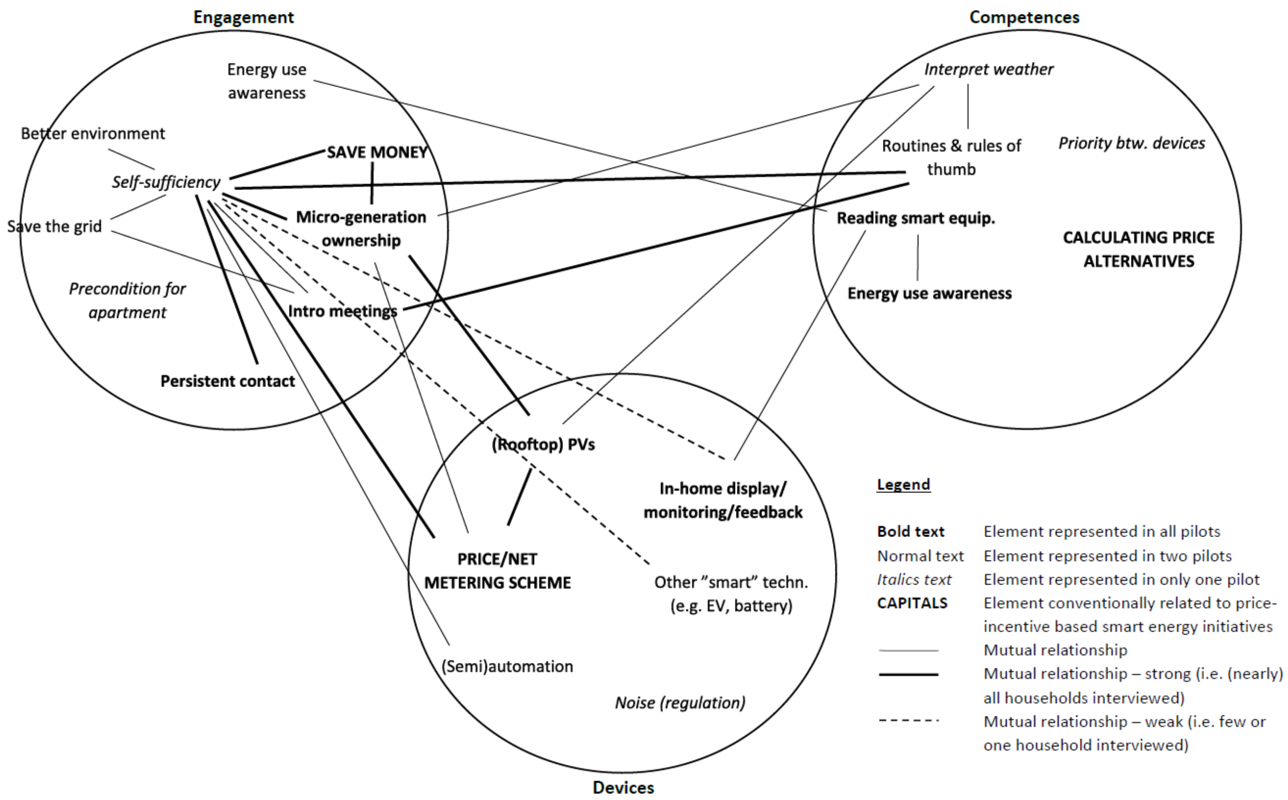

Figure 1: Mapping of the elements included in the three cases and their interconnections (only for the Fur pilot) in relation to configuring the changes in practices related to DR actions.

7. Conclusions and Policy Implications

Our study demonstrates how economic incentives, such as dynamic pricing, should not be an isolated measure in DR programmes because these incentives will always be closely interlinked with other elements of engagement, devices, and competences that are decisive for the actual effect of the pricing scheme. Previous studies have also shown that the effect of price is dependent on other nonfinancial factors (see review in Section 2.1), but this study presents a new framing of the elements based on a practice-theoretical framework. It also takes it a step further, as a key conclusion is that a successful coupling between price incentives and DR actions can only be realised via a *productive mixture* of *mutually supporting elements*.

Furthermore, in line with other studies reviewed in Section 2.1, the specific design of the dynamic pricing scheme itself is important. Our analysis demonstrates that schemes should be easy to understand and predictable; e.g. by associating the scheme with existing social or natural temporal rhythms already well-known to people, such as coupling the solar cycle and money saving via PV microgeneration and hourly net metering, as in the Fur case. Also, price schemes translated into simple rules of thumb have significant potential. This is not necessarily (or only) because these reduce complexity and save cognitive effort, as suggested by the bounded rationality argument often found in existing DR literature (e.g. in Bradley et al., 2016; Good et al., 2017), but more importantly because the association of these rules with existing temporal patterns of everyday practices or social and natural cycles makes them practicable to adopt in the everyday lives of households.

These observations illustrate how practice theories offer an alternative perspective to the dominating economic-rational agency approach within DR studies and pilots (Section 2.1). Shifting focus away from price incentives as the main lever for DR actions makes it possible to acknowledge the importance of the variety of other elements that are decisive for the success of DR schemes and the future design of smart energy interventions. The limitations of the economic-rational agency model are further demonstrated by the fact that most of the interviewees on Fur and Hvaler did perform DR actions, although only a few of them had a clear notion of how much they saved by doing this. Therefore, if economic reasoning plays a role, it seems primarily founded on general ideas about what is 'smart' to do in economic terms. The only pilot where the participants were informed about their actual money savings was Rosa Zukunft, and this paradoxically led most participants to abandon further efforts to time shift consumption because this was deemed not worth pursuing. In this way, information about money savings can have the exact opposite of the intended effect through what might be interpreted as one of the few examples of economic-rational agency found in our case studies (see also Pallesen and Jenle, 2018).

In summary, our conclusion is *not* that price incentives do not matter in shaping household practices. On the contrary, price schemes often play an important role in making it sensible for people to participate in DR (or not), as Strengers points out (2013, 2019). In addition, the size of the price incentives plays a role. The lack of a substantial price incentive explains why the households on Hvaler did not time shift to increase self-sufficiency from PV microgeneration, whereas the opposite was the case with the Fur households who were on an hourly net metering scheme incentivising self-consumption. After all, the cultural ideal of 'homo economicus' is widespread, and financial incentives play a role in making some practices more meaningful to adopt than others. However, this does not happen in the calculative and utility-maximising way implied by the economic-rational agency model but through general sense-making (Strengers, 2019). It is always, as demonstrated by our analysis, conditioned by other practice elements within context-specific configurations. This is an important contribution to the further elaboration of the practice-theoretical understanding of price. Further, the policy implication of this finding is that DR schemes should strategically establish productive configurations across elements of engagement, devices, and competences that support the role of price. For example, one strategy to promote active time shifting could be to design policies and solutions based on combining microgeneration with dynamic price schemes that are designed in ways that promote households to shift consumption to hours with microgeneration (e.g. the hourly net account settlement scheme in the Fur pilot).

In addition to recommending that designers, planners, and policymakers consider the complexity of interrelated elements that co-determine the effectiveness of price incentives, the specific recommendations from this study are the following. First, price schemes should be easy to understand, and variations in prices should be predictable. This also makes it easier to develop rules of thumb on how to adapt existing practices to the scheme. Second, and in relation to the first, too much information can have an adverse effect. Energy visualisation and feedback can support DR engagement (as seen in the Hvaler pilot), but too much information can disengage people (as seen in the Rosa Zukunft pilot). Third, price plays a role as an incentive, but it is important to combine with other aspects that make it meaningful to perform DR (e.g. environmental concerns). Fourth, the material context plays a decisive role for DR actions (generally more difficult in multi-storey blocks than in detached houses). Fifth, the type of ownership in relation to microgeneration is important for how households react in relation to pursuing self-sufficiency. Sixth, the socio-economic characteristics of participants (e.g. demographics and employment status) are a further critical dimension to include in the design.

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