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Smart Energy for the End-User: A Feasibility Study from Samso, Denmark

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ABSTRACT

Our study concerns smart energy with respect to three target groups of end-users: farmers, shop owners, and households. We found cattle farmers that can shift their energy demand in time. Shops are willing to save energy during the night and on days when they are closed, and we found 11% savings on average with little or no investments at all. House owners can often save at least 5% with little or no investments at all. In addition to the technical analysis of the energy saving and load time shifting potential, the paper also explores the users' experiences with these solutions. This part is based on qualitative interviews with local businesses. By also discussing the user experiences and the anchoring of these initiatives within the local network of actors, the paper pursues a cross-disciplinary approach combining both technical and social perspectives.

KEYWORDS

Smart energy system, transitional challenges, flexible demand, end-user acceptance, field work, islands.

INTRODUCTION

The Danish island of Samso promises to become fossil fuel free by the year 2030, twenty years ahead of Denmark, as a pilot case for the rest of the country. We already say the island is a renewable energy island, but that is in the sense of the annual energy balance. In other words, consumed energy equals renewable energy produced, in a year. Sea cables connect Samso with the mainland, and electricity flows both ways, but mostly in the export direction. Smart energy is part of the 2030 plan as well as energy savings [1, 2]. Smart energy should minimise the electricity export by maximising the internal use of renewable energy. One challenge is whether the end-users can and will accept new technology that aims to shift loads or cut peaks.

The energy balance in Figure 1 shows the consumed energy together with the produced energy, over a period of eighteen years [3]. Cooperatives, farmers, and the municipality installed district heating plants fuelled by biomass, as well as wind turbines on land and in the sea [4]. Private house owners invested in hot water solar collectors and biomass heating units. The island started to produce electricity in the year 2001, and some years after the island produced two to three times more electric energy than it consumed. The electric export

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compensated for the fossil fuels used by tractors, busses, cars, and ferries. The renewable production matched the annual consumption 100% for at least four years. The coverage is somewhat lower today (88% in 2015).

The plans for the future include a biogas plant, which will convert biomass to gas, electricity, heat, and fertilizer. The island has already a ferry that uses liquid natural gas. The idea is to produce fuel for the ferry, and other means of transportation, on the island instead of buying it from elsewhere. The following list shows some of the political goals regarding *energy*, *economy*, and the *environment*.

- To become fossil fuel free by 2030. This is twenty years ahead of the rest of the country, and Samso thus acts as a pilot case for Denmark.
- To improve the economy by increasing the population and the number of jobs. The island has suffered from depopulation for many years. The population is now 3700, which is the lowest level at all times.
- To protect the environment; in particular, to limit the use of drinking water, the CO2 emissions, and to control the use of land in a sustainable manner. The CO2 emissions per capita are already very low.

The population has declined for many years. Figure 2 shows graphically the last ten years [5], which corresponds to about 1% decrease every year. For reference, the population peaked in 1925 with 7300 islanders. Many houses have since been demolished, but others have been refurbished, and people from other parts of Denmark are allowed to buy a house and use it as a holiday cottage. There are 100 dwellings for sale at the moment, compared to about 2000 inhabited dwellings [5]. There are 81 workplaces per 100 citizens, which is almost the same as for the region and the country as a whole [6]. The number is decreasing, though, and 5.3% of the workforce was unemployed in 2016. It is preferable, maybe even necessary, to be able to offer two jobs to a couple of settlers. One third of the jobs are in the public sector, which is also the case for the country as a whole [6]; therefore the municipality is a major stakeholder with regard to development and growth.

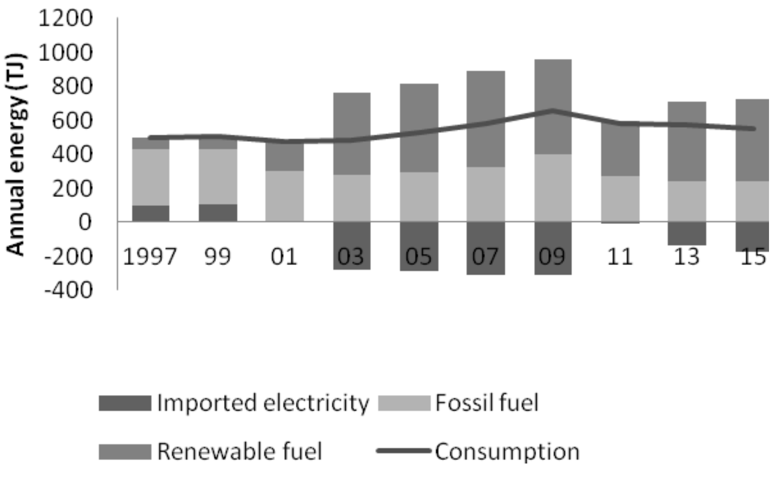

Figure 1. Energy balance. After 2001 the island exports electricity, which compensates for the fossil fuel consumption. By 2007 renewable energy production equals the energy consumption.

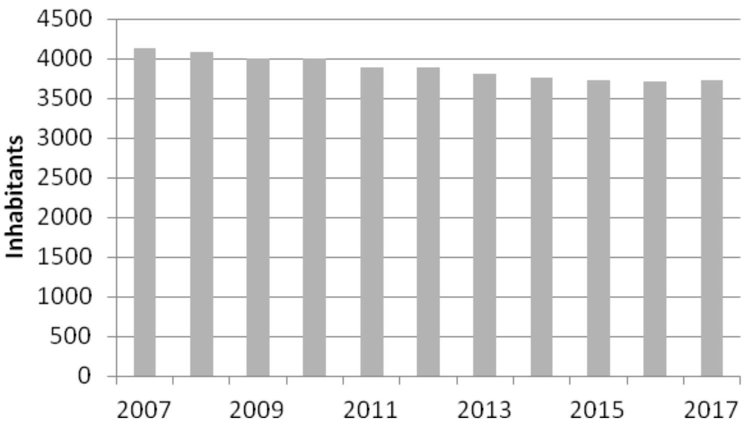

Figure 2. The population is declining, but there is a sign of stagnation during the recent years.

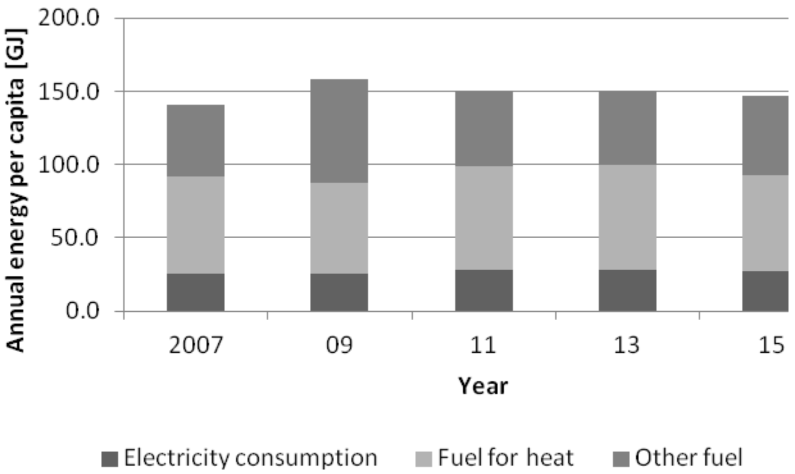

Figure 3. Energy consumption per capita. The energy is measured in terms of supplied energy, that is, before converting fuel to end-use energy. The average of the total energy consumption is 149 GJ/year per capita.

Despite the declining population, the energy consumption *per capita* is remarkably steady. Figure 3 shows the total energy consumption per capita, divided into electricity, fuel for heat, and other fuel (mainly transport) [3]. Some variation in the fuel for heat is to be expected, because colder heating seasons require more fuel for heat. Today, heat is mostly produced from biomass and oil, but the transition to the future energy system may rely more on electric heat pumps. The electricity share of the graph will thus increase, while the biomass fuel for heat will decrease. The excess biomass is to be used in a new biogas plant instead.

There are at least three arguments for working toward a smart energy system on the island.

- Renewable electricity is abundant on the island, but the amount of biomass is limited by the size of the island and the allocation of the land (zoning). If we can combine the two sources of energy, then we can consume more of the 'home-made' electricity rather than just exporting it [7].
- There is an electric bottleneck on the island (an aerial cable between two transformer stations). It may be necessary to temporarily disconnect the line, both day and night, if the wind turbine production increases in the future.
- It is cheaper to utilize the storage options in a combined energy system, rather than installing electric batteries and capacitors [7].

In the near future, end-users may choose to be billed for electricity on an hourly basis, and they may wish to act according to the market price and become flexible consumers. Electricity will likely be cheaper during the night, when other loads are low. However, there may be bottlenecks, due to excess wind, which cause prices to increase during the night anyway. In other words, we cannot always be sure that prices will be cheaper during the night.

We have a simulation study of the impacts on energy, economy, and environment resulting from various scenarios [7, 8]. That study concludes with a number of recommendations, as follows.

- Find heat savings as a first step.
- Interconnect existing district heating networks.
- Install large heat pumps for district heating, and small heat pumps for individual heating outside of the heating networks.
- Electrify the transport sector and the industry.
- Use the available biomass primarily in the transport sector. Boost the biomass with electricity through hydrogenation technologies.
- Use biogas technologies in order to use the wet fraction of the biomass potential.

It is clear that the island must exploit its electric resources better and prioritize the available biomass more carefully. We thus aim to combine the electricity sector with the heating sector and the transportation sector in one *smart energy system* [9]. Apart from the technical and economical aspects, which lend themselves to numerical processing, we are also concerned with urban planning, which requires both qualitative and quantitative evaluations. Vandevyvere and Stremke [10] suggest a three step approach: (1) Reduce energy demand, (2) optimize energy streams, and (3) provide renewable energy. They also remark that electricity is easy to transport and difficult to store, while the opposite applies to heat and cold. From the present outset, the urban planning aims to increase the available jobs and housing in order to attract settlers. However, planners should be aware that housing and business structures, including renewable energy businesses, will compete for the same land within the urban zones of the island [11]. On Samso, only four percent of the land is urban zone. The larger part is allocated to agriculture and protected nature.

Our immediate concern is whether the citizens will accept a transition to a smart energy system. Neighbours often oppose development plans, and often for a good reason: they fear the value of their property will decrease. Rule [12] analyses the problem from the viewpoint of legislation, and he proposes financial incentives, such as subsidy or tax relief, in order to improve the citizens' acceptance. On Samso, it is common to share investments between interested investors, for example: citizens, farmers, or the municipality. It is a common interest to keep financial profit within the island. Nevertheless, there is still opposition from neighbours, and the best we can do at this point is to inform citizens of the future plans and options. One means is to engage groups of citizens early in the planning.

We have thus conducted various *field studies* in order to test the willingness of various groups of citizens to make the transition to a smart energy system. It is necessary that the citizens support the transition, because they and the municipality are the major stakeholders. The target groups, so far, are the *farmers*, the *shop owners*, and the *private house owners*. Figure 4 shows the share of the electricity consumption of the three target groups. Households consume the most electricity, agriculture comes second, and finally the commerce sector, which amounts to only one fifth of the households. Regrettably, a simulation study on the national level showed that the value of flexible demand is limited, because more than a quarter of the classic electricity demand would need to be flexible within a month, which is highly unlikely [13]. In any case, our target groups received us with a positive attitude, and working with the target groups is an excellent way to campaign for a future smart energy system.

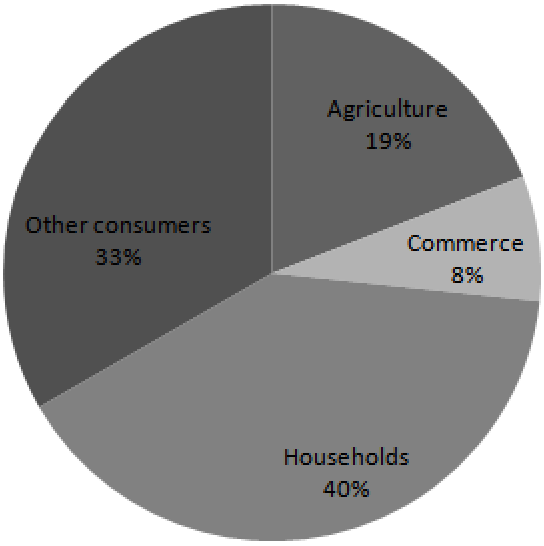

Figure 4. The relative *electric* energy consumption of the three target groups of interest: agriculture, commerce and households. The total corresponds to 100 TJ (2015).

CASE STUDIES

We installed various pieces of equipment, commercially available or developed with external partners, and we received feedback from the involved individuals. In several cases we have measurements to support our conclusions, for example from electricity meters, temperature sensors, calorimeters, and energy bills. With the farmers, we looked for ways to delay or shift electric loads [14]. They use an ice bank for cooling milk, and they are willing to produce more ice water than normal during the night and leave it off during the day, rather than running it all day. Even the distribution system operator can control the ice banks with our prototype of a remote switch. Photovoltaic panels motivated a farmer to consider delaying the milking of the cows enough to fit with the productive hours of the panels. With the shop owners, we looked for heat and electricity savings. Shops are willing to save energy during the night and on days when they are closed, and we found 11% savings on average with little or no investments at all [15]. With the house owners, we looked for heat and electricity savings by means of *home energy checks* [16]. It is almost always possible to find 5% savings in households, often more, with simple saving advices, such as switching to LED lighting or awareness measures [17, 18]. The validation is by means of interviews, questionnaires, and measurements.

Farmers

The most immediate loads to be shifted in time are the following: pumping for irrigation of fields, water heaters for cleaning and preheating, and coolers and freezers. Together, those loads consume one quarter of the electric energy consumption of farms in the whole country [14]. We studied milk cooling in particular.

Immediately after milking, the milk must be cooled from 38 °C to 4 °C. An ice bank is one way to cool the milk. An electric compressor drives the ice bank, and the ice storage can in principle be charged and recharged when there is a surplus of inexpensive electricity. The milking of the cows always takes place at the same times of the day, and it is therefore necessary to know the charging time of the ice bank.

Example 1 [14]. A herd of 165 cows are milked twice a day at 5 am and 5 pm. The cows produce together 1.8 tons of milk per milking session. The milk from one milking requires the following cooling energy, when the heat capacity of the milk is 4.2 kJ/kg·K,

Q = 1800 [kg] × 4.2 [kJ/kg·K] × (38 – 4) [K] = 257,000 kJ = 71 kWh

Since a milking takes about three hours, the required cooling capacity is 71 [kWh] / 3 [h]. A refrigeration plant's efficiency (coefficient of performance, COP) is typically 3.5, therefore the electrical compressor load is 71 [kWh] / (3 [h] × 3.5) or 6.8 kW, which could be shifted. Denmark produces about 4500 thousand litres of milk per year. If we scale the example to the whole country, the energy consumption can be calculated to about 43,785,000 kWh per year. ■

We analysed a dairy farm in detail in order to understand better what the possibilities for load shifting are in reality. The farm is small (8 cows) such that it was manageable to analyze in a relatively short time. The farm produces organic milk, butter and cheese. The diagram in Figure 5 gives an overview of the production, but it also identifies storages, which, by their nature, are possible candidates for controlling delays. The farmer agreed that it would be possible to use some of the storages in order to force a delay of some of the energy loads. Aided by the diagram we can identify several possible options for load shifting related to storages.

- Superheat hot water for pasteurisation, install a timer
- Preheat hot water for pasteurisation
- Superheat the building (winter), subcool the building (summer)
- Precool cooling water
- Subcool ice bank
- Keep cold milk in tank until electricity price is low
- Produce butter and cheese to storage when electricity price is low
- Defer washing and hosing, and thereby pumping to waste storage
- Compress air when price is low
- Produce fodder to storage when price is low
- Chop firewood to storage when price is low
- Consider using old car batteries for storage of electricity

The same farmer agreed that it would be possible to shift the milking time from early morning until later. He was interested in photovoltaic panels, and we showed him a graph of the potential production (12 kWp), which had a peak around 1 pm. He would be willing to delay the milking some hours, in order to fit better with the production from a photovoltaic plant on the roof.

Another possibility is to pump water when the electricity price is low. Fields are drained in order to remove excess water from the root zone. The drained water flows into a reservoir, in some cases, where it is pumped away. Today, the pumps are typically on/off, controlled by a level sensor, but they could be controlled smarter according to a price signal. We further developed a prototype of a remote switch [14]. The switch is supposed to be operated by the distribution system operator, within certain limits, depending on the prices on the electric power market.

On the other hand, we found that drying of for instance onions or grain is difficult to manipulate. An automatic control system controls the air flow and temperature over a fairly long period. The products are so delicate, that the farmers did not wish to interfere with the automatic controller. Vegetables are kept in a cold storage. The temperature should preferably be 1 °C always, controlled by a thermostat, and there is very little opportunity to shift the load.

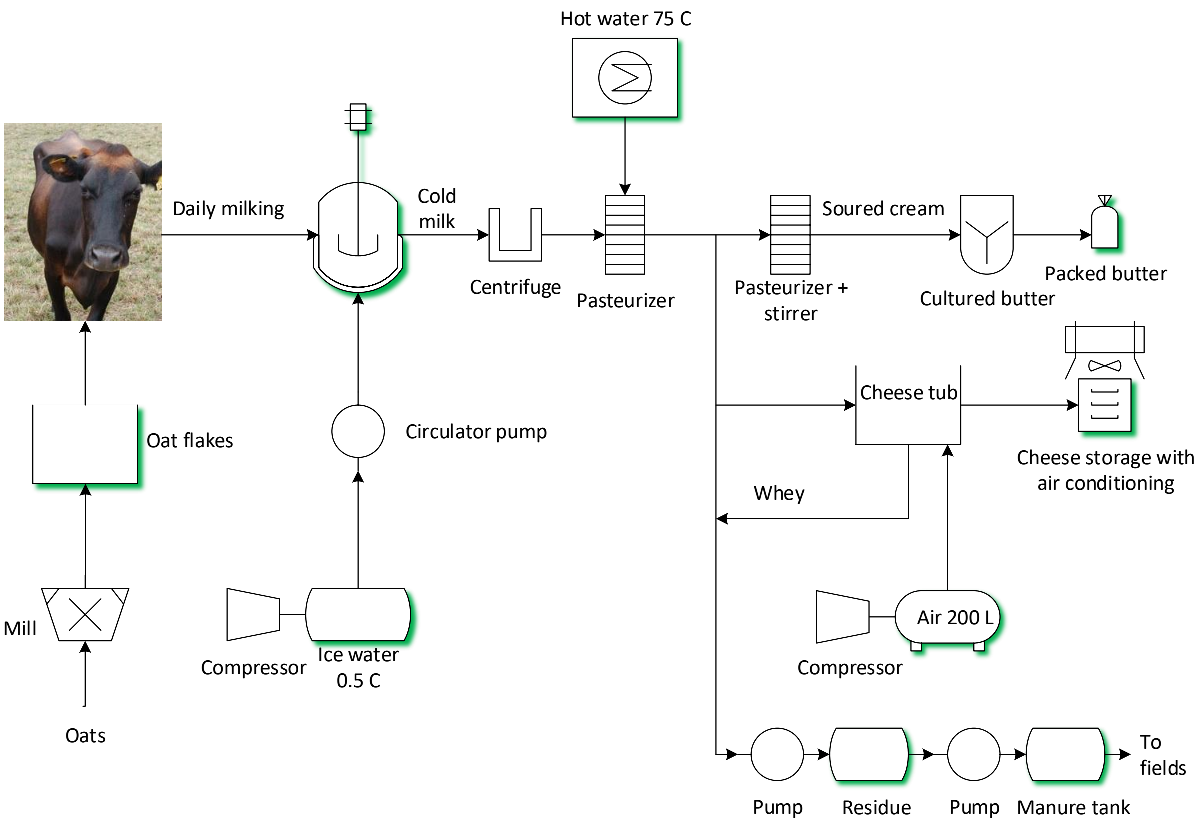

Figure 5. Process flow diagram of dairy. The shaded components are storages.

Shop owners

A night walk is an energy survey in a shop at a time when the shop is closed to the public. The idea is to discover unnecessary energy consumption, when all should be on standby. It was applied in 123 shops in eight European regions as part of an EU-funded project, and the average savings were 11% from measures that required very low investments [15]. The retail shops are highly exposed to the citizens, and there are plenty of opportunities to communicate energy efficiency to the customers.

For example, a supermarket on Samso (Superbrugsen) is open from 8 am to 8 pm, and thus closed half of the time. Our primary advice was to lower the nightly room temperature during the heating season. Savings are proportional to the reduction in average temperature [16].

Example 2. The average outdoor temperature on Samso during the heating season (October to April) is 8 °C. Assume the average indoor temperature is 20 °C. We propose to lower the temperature during the night, so the average becomes 19 °C. The saving factor is thus

$f = (20 - 19)\ [K] / (20 - 8)\ [K] = 1 / 12$

In other words, the shop will save 8.3% on the heating bill if it lowers the average temperature one degree. ■

If the shop lowers the average indoor temperature, even if it is only by night, the coolers and freezers save some additional work. For example, the temperature inside a food cooler might be 5 °C. If the room temperature is lowered, the temperature difference becomes smaller, and energy will be saved by the same type of calculation (7% for every degree, if the starting point is 20 °C). The savings are easily calculated, and it is possible to document the savings just by measuring temperatures before and after the action.

A bottle cooler can consume as much as a small average Danish single-family home with two residents (3000 kWh/year), and a timer switch saves energy. Figure 6 shows the temperature inside a bottle cooler, measured by a battery driven datalogger (Lascar Easylog USB-2+). The temperature is just below 7 °C, but around 6 pm a timer switches it off. The temperature rises during the night, and at 7 am the timer switches it back on. It takes about one hour to reach a steady temperature just below 7 °C. In this case, the timer saved 13% of the energy. All in all, the saving advices amounted to 7.5% of the annual energy budget of the supermarket, corresponding to 8400 EUR. Today, the management thinks they saved more.

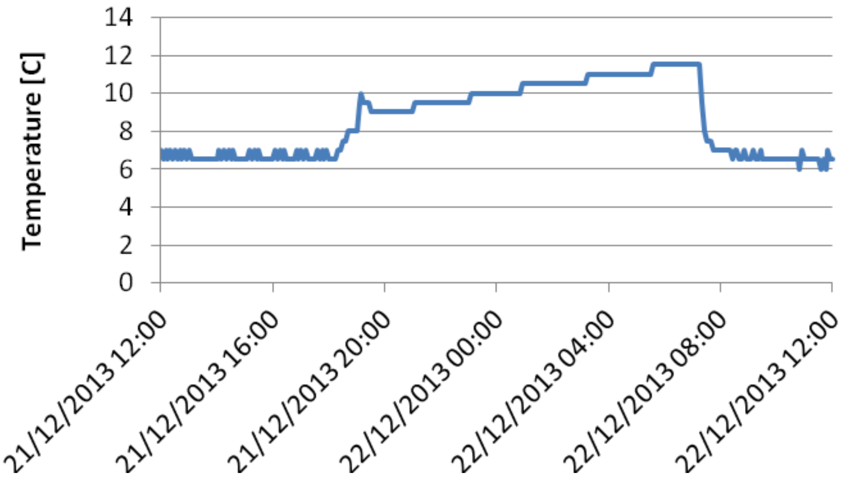

Figure 6. Temperature in a bottle cooler. A timer switches it off at 6 pm until 7 am next morning.

For future reference, we collected a small catalogue of the saving measures, as follows.

- Lower the room temperature
- Nightly room temperature setback
- Nightly temperature setback on bottle coolers
- Shut off unnecessary outdoor lights during the night
- Remove nightly standby consumption in a Solarium
- Correct the balance between heating and cooling
- Replace lamps by LED, especially spotlights
- Decrease ventilator speed
- Lower the hot water temperature
- Save a bottle cooler
- Replace a display cooler by a fridge
- Replace old circulator pumps
- Replace electric heating by district heating
- Replace old thermostat valves
- Replace gas cooker by an electric induction cooker
- Replace oil boiler by an air-to-water heatpump
- Install photovoltaic panels
- Correct the official area measure
- Tax exemption on process energy

Example 3. In the case of Superbrugsen we achieved 7.5% savings on the energy bill. Table 1 lists the individual advices together with their respective savings, in terms of energy and expenses. The table provides the magnitude of the individual saving measures, and it is clear that many small advices add up to a significant amount. To give an idea of the size of the site, the heated area is 1600 square metres, the recorded annual electricity consumption was 615,000 kWh (electric), and the recorded district heating consumption was 154,000 kWh (thermal).

To arrive at Table 1, it was necessary to perform some background calculations, first of all to estimate how the energy is distributed between various load classes. For example, if one advice concerns compressor cooling, we would like to know the share of energy for compressors relative to the whole electricity consumption, as in an energy balance. This may be done by means of measuring equipment with current clamps in the distribution board. If that is not possible, we estimate the consumption from the power rating and an estimated number of running hours.

We calculate a saving factor f, as described previously, and multiply it onto the estimate of the annual consumption. Finally, we have to multiply by the unit price. We use the *marginal* price, that is, the direct cost of the first saved kilowatt-hour (disregarding fixed costs). The total electricity cost amounts to 98,400 EUR/year, and the total heating cost amounts to 13,100 EUR/year using marginal prices. ■

Table 1. Savings advices for Superbrugsen.

Supply	Advice	Saved supply (kWh)	Saved money (EUR)	Saved money (% of cost)
Electricity	Nightly temperature setback in shop. Saves compressor work.	773	124	0.1
	Same advice, saves plug-in cooling.	123	20	0.0
	Same advice, saves electricity in the bottle coolers.	586	94	0.1
	Same advice, saves electricity in the milk room.	682	109	0.1
	Nightly temperature setback in butcher shop.	8648	1380	1.2
	Raise low temperature in bottle coolers from 6.5 to 10 deg.	5658	905	0.8
	Lower the average level of lighting from 650 to 550 lux.	16085	2570	2.3
	Stop ventilator after baking.	18450	2950	2.6
Heat	Nightly temperature setback in shop. Saves district heating.	2826	241	0.2
	Total		**8400**	**7.5**

Households

A *home energy check*, performed by an energy adviser, is a quick walk-through of the dwelling that results in a list of advices relevant to the particular household [16]. In one project, the participants performed 206 home energy checks in a target group of European islands [17]. The project found savings in the range 5% to 20% per household, where the first 5% can be implemented at a low cost for the household.

The home energy checks lasted typically one hour following a three step procedure: Find, ask, and calculate. The energy check provides the household with an estimate of the saved amount of money and energy. The estimate is calculated from measurements. The calculations allow for different climate zones [16], and it uses the actual energy consumption rather than a nominal, simulated demand of the building. Savings ranged from 1300 kWh annually (Tenerife) to 8200 kWh annually (Grimsey, Iceland) per household. Actual savings are difficult to measure, since it is not possible to know exactly what the household decides to do afterwards, or whether they were going to do it anyway. However, on Samso, a collaboration with a district heating company (Ballen-Brundby Fjernvarme) resulted in 13 homes making improvements, which they reported on a paper form signed by the house owner. Figure 7 shows that most houses in the district heating network consume 76-100 kilowatt-hours per heated square metre. The average is actually 96 kilowatt-hours per heated square metre. Some houses consume much more than the rest. This is either because those houses are large (such as a hotel), or, simply, because they have a large savings potential.

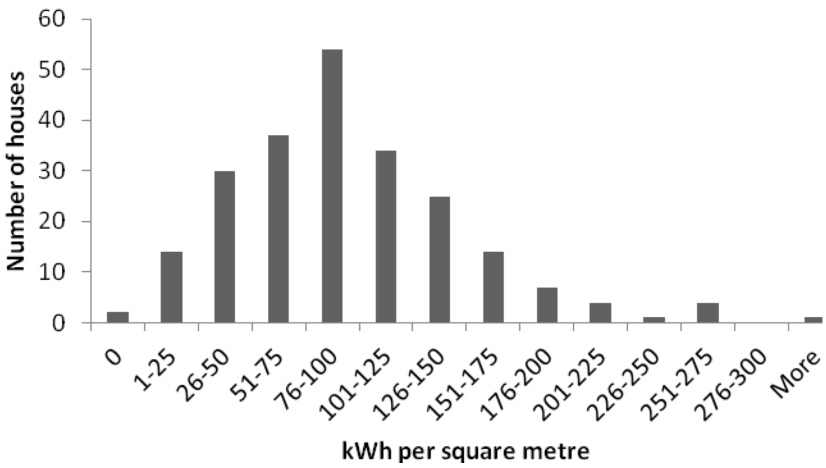

Figure 7. Most houses consume 76-100 kilowatt-hours per heated square metre (data from Ballen-Brundby district heating network 2009). The histogram comprises 253 consumers. The average consumption is 96 kWh per square metre.

THE COMPLEXITIES OF CARRYING OUT ENERGY SAVINGS

In this section, we will present a detailed discussion of the experiences with the involvement of the users – and the network of actors they are part of – in energy saving initiatives. We will specifically focus on the previously mentioned case involving a supermarket (Superbrugsen). The Samso Energy Academy (SE) carried out an energy audit of the supermarket and suggested several changes and improvements that would save energy, including nightly setback of indoor temperatures and replacing inefficient light bulbs with efficient LEDs etc. Subsequently, the employees at the shop also came up with a few of their own energy saving ideas.

In explaining the underlying approach behind the initiative, the SE several times emphasises that it was important for them to come up with ideas that would not compromise comfort, sales or the daily work routines at the supermarket. For the same reason, SE had a frequent dialogue with the manager and the staff during their planning and realisation of the energy saving measures. For instance, they had to plan the nightly setback of indoor temperatures according to the work schedules of different members of the staff (e.g. the staff in the butcher corner who start work early in the morning).

In the following, we will illustrate the complexity of actors and considerations involved in developing and carrying out energy saving measures. Also, the role of the SE in securing energy savings will be discussed.

The SE was the initiator of the process that led to the energy savings. What triggered SE to contact the supermarket for collaboration was the European project. As a site of intervention, the supermarket is surprisingly complex. Through their interaction with the manager and employees at the supermarket, the SE soon discovered that many kinds of actors were involved in decisions related to the energy management. Thus, instead of being a “simple technical” intervention, it turned out to be a complex social and organisational task, which also means that a successful intervention in general depends on many actors’ active involvement. The following are the most important actors involved in the energy saving initiative:

- *The supermarket*. Obviously, the supermarket (and its staff members) plays a crucial role in realizing the energy savings. The supermarket is the site of intervention, and the active and co-operative participation by the manager and the staff is decisive. The SE does not have any formal jurisdiction over the supermarket, and the only way of realizing energy saving measures is through dialogue and persuasion.
- *The supermarket chain*. However, the supermarket is also the local branch of a larger chain of supermarkets. The supermarket chain has a central unit that, among other things, organise renovations of the individual branches, sets up general rules and procedures for the interior design of the shops etc. The central unit have inhouse expertise on various technical fields, which is supervising the local branches.
- *Suppliers*. The supermarket (chain) owns the buildings, the HVAC installations and most of the cooling appliances etc. However, some of the refrigerators (e.g. the bottle coolers) are owned and maintained by the suppliers (e.g. the suppliers of beers and soda), even though the electricity costs are paid by the local shop. This complicates carrying out initiatives like installing controls like timers etc. on the refrigerators as this would manipulate with the private property of third parties (not owned by the local shop or the SE).
- *The Samso Energy Academy*. Obviously, the SE is also a central actor as it is the initiator of the energy saving process and plays a key role as local energy expert and facilitator.

In addition to these social actors or organisations, it is also important to mention the materiality of the supermarket. The energy consumption is, essentially, related to the operation of the appliances and HVAC systems at the site, and much of the energy saving was achieved through changing the controller settings.

An illustrative example of the complexity created by the interrelations between actors is the inefficient light bulbs placed above the refrigerated counters in the meat section (sliced meat, minced meet etc.). The SE noticed that these light bulbs were not only inefficient, but also (through heat radiation) added heat to the cold counters, resulting in an unnecessary waste of energy. Therefore, they suggested the local supermarket manager to replace them with efficient LEDs. However, it turned out, through the manager's communication with people at the central unit of the supermarket chain, that the choice of lighting above the cold counters with meat was restricted to a specific type of spot light, which emits a reddish light. Apparently, the reddish light should make the meat look more attractive and appealing to the customers, thus promoting higher sales. As a result, it was not possible to replace the existing lighting. As the manager explained in the interview made for this paper:

> *… there's some fixed agreements on what has to be on different places [in the shop], and it is one of these things… That belongs to the butcher corner, it is like that everywhere [in all shops] (...) there is someone [at the central office of the chain] who's developing all these concepts and how it should be.*

This exemplifies how an otherwise simple measure like replacing inefficient light bulbs can be complicated by actors external to the site of intervention, such as the central office of the supermarket chain. In this way, an energy saving intervention is no simple, one-directional activity, but is carried out within a complexity of distributed knowledge, responsibilities and competences.

Another example of the distributed knowledge and competences relates to the coolers provided by the suppliers of, e.g., beverages. An agreement is made between the supplier and the local shop, which gives the shop higher profits of, e.g., beverage sales in exchange for accepting the supplier to install their coolers (with their logos etc.) in the shop. The supplier has the responsibility for the maintenance of the cooler, while the energy consumption costs are paid by the local shop. This illustrates the so-called *principal-agent problem* (e.g. [19]), i.e. an uneven distribution of e.g. energy saving investment costs and energy saving benefits between agents. In this specific example, the beverage supplier does not have an incentive to provide the shops with more energy efficient (and more expensive) coolers as the energy costs are paid by the shops themselves. In addition, as also mentioned earlier, the coolers are third-party property, which complicates things further.

The role of SE was very much about providing an overall perspective and analysis showing the most obvious possibilities for savings. This was in part due to the organisational structure of the supermarket chain with specialisation of the expertise in different units. Here, the SE contributed with a more comprehensive and 'holistic' approach on how the different systems and sections of the shop work together and sometimes result in unintended extra energy consumption. As one of the SE staff members explained in the interview:

> *So, they [larger chains like the supermarket chain] have their own internal staff who's doing this [working with different aspects like cooling, heating, interior design etc.]… And one of the findings we made here (…) [was that] when it goes wrong, it is when they are not getting these areas coordinated. So, those who can manage the heat, they are not – for instance – thinking about ventilation or the settings of the cooling in the butcher's corner and things like that. So, … there is a potential for savings … when you get up in a helicopter and look at it as one big energy unit…*

In other words, SE provides the external and integrated view on the site (in this case a shop) that is otherwise managed by diversified sets of expertise (not always coordinating among themselves) and often with no local energy expertise among the managers or staff members.

One of the major savings in the shop was, indeed, an example of two systems working 'against each other'. From their initial observations, SE noticed that the meat in the butcher's corner was moved from the open counters (in the shop) to a cooler for the evening. For this reason, it did not make sense to cool down the butcher's corner during the night, as had been the case until then. Therefore, SE suggested to turn off the cooling for the night and let it start again a few hours before the staff arrived next morning. This not only saved electricity for cooling the butcher's corner, but as there where no physical separation (partition wall) between the butcher's corner and the rest of the shop (heated up to about 20 degrees C), the new solution also saved energy for heating (from heat flowing into the cooled butcher's corner). SE takes this as an example of how lack of coordination between various kinds of expertise (fields of responsibility), and not taking the daily working routines of the staff into consideration, can result in a waste of energy or that otherwise evident energy saving measures are not taken.

As an external, the SE can play the role of identifying examples of energy waste and evident energy saving measures. An important reason why the SE has managed to do this at this particular supermarket (and other places on the island of Samso, which have also been interviewed) seems to be that the SE enjoys a high level of trust among many actors on the island. This might relate to the year-long history of the SE and the energy initiatives on the island [21], but also because the SE staff seem to have a widespread local network of relations to local citizens. The local trust in the SE appears to be an important 'resource' at the SE.

Figure 8. Meat counters with the spot lights above.

CONCLUSION

We have combined quantitative and qualitative analyses in this study, in order to encompass both technological and social aspects in a transition toward a smart energy system. It is clearly feasible to achieve energy savings and flexibility of electrical loads among farmers, shop owners, and house owners. It remains to be seen whether the aggregated amounts of energy will be significant, seen from a system operator's viewpoint. Nevertheless, the mere engagement of the stakeholders, by means of field studies, is necessary in order to gain their acceptance. Their engagement seems to be not only necessary, but also sufficient to gain their acceptance.

The analysis of the complexities of carrying out energy initiatives demonstrates that many different actors and sets of expertise are involved in carrying out energy saving and smart energy measures. The role of the Samso Energy Academy (SE) appears to be central for the successful realization of these initiatives; the SE contributes with an external and integrated view, in the case of the supermarket, on the possibilities for energy savings that cuts across the established divisions of expertise and responsibilities within the organisation of the supermarket. Here, the successful realization depends very much on the communicative skills, the local anchoring and the facilitating role of the SE, which illustrates that realising the future smart energy vision includes a much broader set of competences and knowledge than technical expertise alone. An open question for further research is whether this kind of insight from Samso can be transferred to other places (regions), and whether the overall policy approach of the smart grid agenda, which has hitherto to a high extent been based on utility-driven and top-down design-and-adopt approaches [20], could learn from the methods and approaches applied on Samso.

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