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Development and implementation of Aggregator products to household

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Introduction

Today´s energy market is facing several challenges. The growing numbers of electric vehicles and households with electric heating is putting a strain on the electricity grid. Secondly, the ambition to harvest an ever-increasing amount of energy from fluctuating renewable sources is forcing a greater flexibility in terms of production and consumption. Traditionally this flexibility was obtained exclusively by controlling the energy production. EcoGrid 2.0 and several other projects before it, are exploring the possibility to provide flexibility at the consumers side. This is also known as Demand-Response. Much of the energy used by consumers is spend on lighting, cooking and generally by appliances of any sort. This energy usage is difficult to control with any amount of flexibility, but energy spend on heating does present an opportunity to control. The shear mass in a building and the insulation allows to turn the heating of in shorter periods of time without affecting the comfort of the people in the building. The purpose of EcoGrid 2.0 is to explorer the flexibility of a large number of households on the island of Bornholm. The households are either heated by electric heating panels, heat pumps or a mix of the two. These heat sources can be remote controlled. Some of the houses are fitted with indoor temperature meters, the rest are controlled based solely on outdoor temperatures and weather forecasts. It is important to realize that controlling energy consumption to gain flexibility does not imply any energy saving. It is expected that the same amount of energy is used, only at a later time to re-heat the building.

The aggregator role

The ability to accumulate a significant amount of flexibility in the energy consumption by regular household heating, requires a large number of households. It is not possible for one household to sell its flexibility to the market alone. There is a need for a new player in the electricity system that can pool the flexible consumption from the households and sell it on the electricity market. That could be the electricity dealer, balance responsible parties or other players. In EcoGrid 2.0 we call this new player an aggregator.
In our setup there are two aggregators operating in parallel, competing at the market for flexibility on behalf of the households. Each with its own portfolio of households.

The households do most likely not use the same type of equipment for heating. This could be heat pumps or heat panels from different manufactures. In EcoGrid 2.0 this has led to the development of an abstraction layer between the aggregators and the households. This allows the aggregators to control all the resources in a uniform manner as well as allowing households to switch to another aggregator. In a real-world setup, this abstraction layer would probably be part of each aggregator or in the future be a part of the equipment.

The aggregator calculates a reference energy consumption forecast based on historical electricity meter data and weather data. This is known as a baseline and it shows the expected energy usage if no external control is applied. Based on the baseline and empirical data from experiments, the aggregator defines a model for how much flexibility that can be achieved under different circumstances. This model tells the aggregator how many houses needs to be activated to achieve a certain amount of flexibility. Then the baseline is used as reference to verify the amount of flexibility by comparing to the actual meter data during the activation. This verified flexibility is what the aggregator can sell at the electricity market.

The challenge with products to the household

It is the electricity system that needs the flexibility not the households. As stated earlier, controlling the energy consumption of a household for flexibility does not imply any energy saving.
This means that the aggregator needs to provide a different means of motivating people to participate in the project. This is done in the form of aggregator products, that offer some sort of value to the households. In a real-world commercial scenario, the aggregator products add an additional dimension to the business case besides selling flexibility, by directly offering the suppliers of flexibility a concrete value in return. That could be yearly service of the heat pump, lower electricity bill or control of the heat to minimize CO_2 emission.

In EcoGrid 2.0, being a research and development project, it is not possible to offer the participating households any monetary compensation for their participation and flexibility. Instead we have tried to test what could interest the customers besides money – what products or services do the household request/need besides money? An offer could be access to data from the electricity meters, temperature measurements, etc. but the customers have for the most part, participated in the earlier EcoGrid EU project where they had their houses fitted with electricity meters and given access to the usage data. So, unless the household residents have a particular interest in the EcoGrid 2.0 project, it is very limited what can be offered.

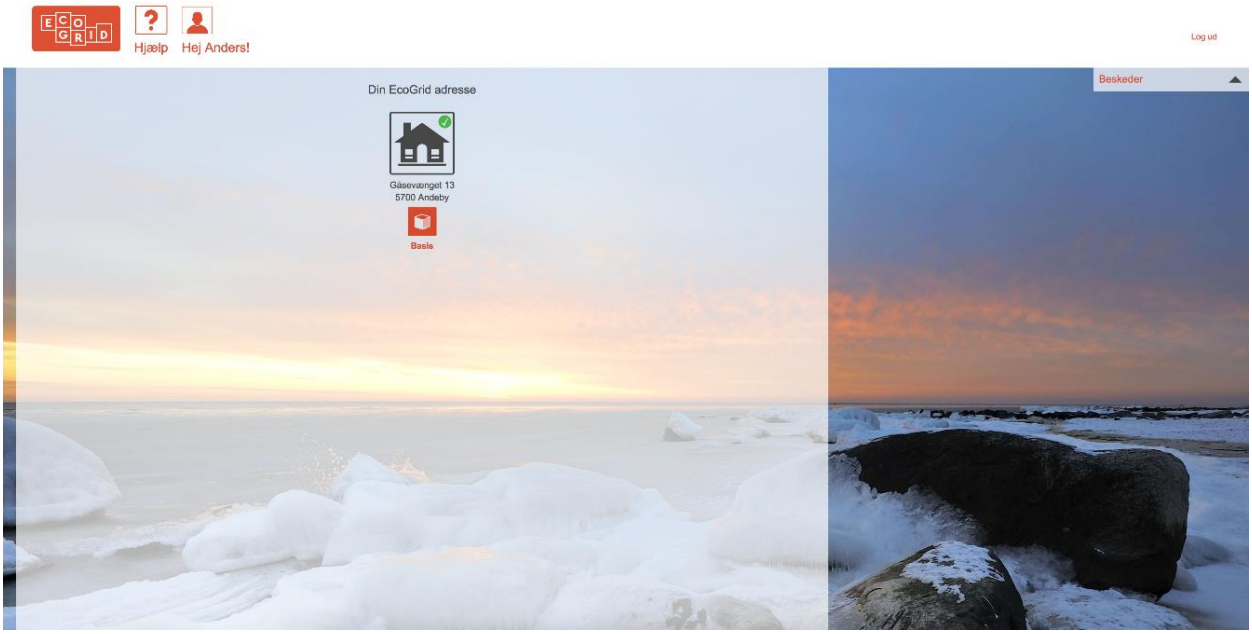
Several product configurations have been tested throughout the project, but for the final heating season, two distinct products and a basic product have been chosen.
Firstly, a product where the aggregator controls the household heating based on electricity prices.
Secondly, a product where the aggregator controls based on CO2 emission. The products are described in more detail in the next chapter.
For those customers who have not chosen one of the two themed products, we offer a basic product with basic features, but no optimizations.

The products to household

The aggregators offer three different products to the household customers. The households are encouraged by a letter and emails to enter the EcoGrid customer web-page and select a product. If no product is selected, the household is automatically given the Basis product.

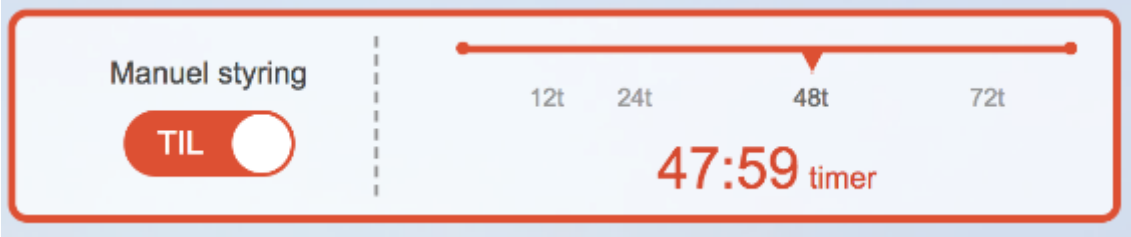
Basis Product

The basis product is suited for households that have no special requirements outside of participating in the project. It is also offered as the default choice for households that have not actively selected a product. The basis product offers a personal web-page where the customer can monitor the energy usage of the household.



Landing page

The customer can actively choose to opt-out for a period of time, in which the aggregators will not control the heating. This can be used to prevent any potential drop in indoor temperature over a specified timespan should the household customers choose so. The next figure shows the opt-out option. The user activates “Manuel styring” (manual control) and selects how long time to opt-out.



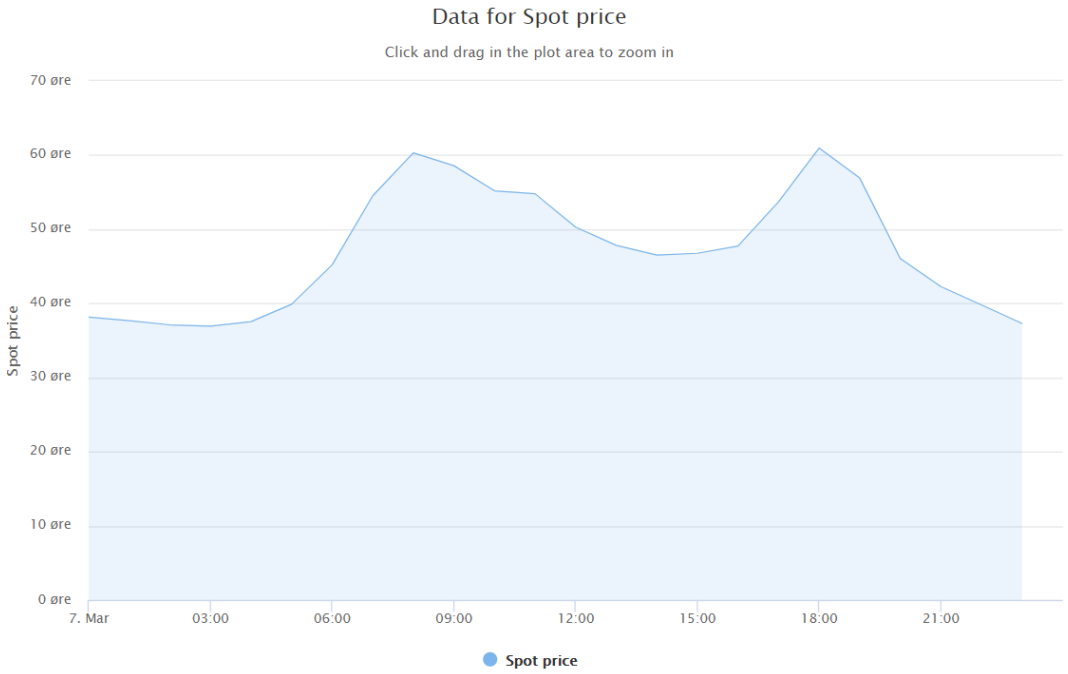
Opt-out feature

Also, in case the control starts to affect the comfort in the house, the customer can indicate too hot or too cold temperature in the house through the web-page. See the next figure.

Too hot/too cold

Economy Product

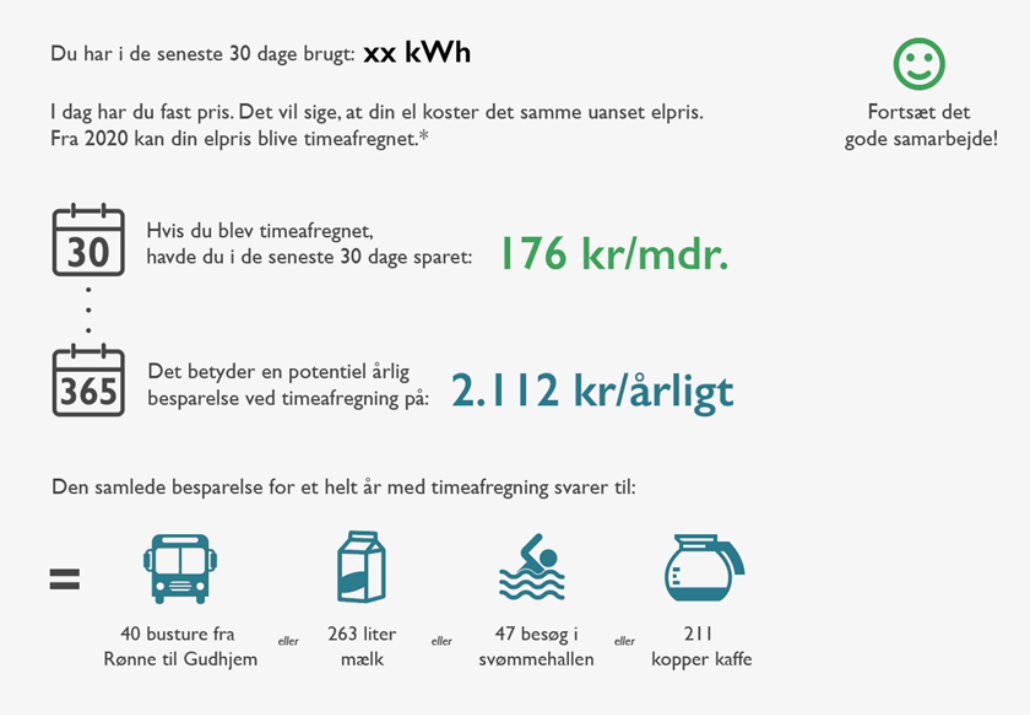
The economy product adds to the basis product an optimization of the energy used for heating based on electricity prices.
In today´s electricity market, the household´s electricity prices are based on tariffs (fixed per kWh) and an electricity price (fixed per kWh or variable). Market prices however, are dynamic and may change significantly on an hourly basis, based on demand and production. The graph below shows the price fluctuations during a day.



Spot prices during a day

The legislation states that from year 2020 all households must have the opportunity to have their consumption billing based on the hourly electricity prices on the electricity market.
With an intelligent control of energy usage and opportunity to get the billing based on the hourly electricity prices, it is possible to save money on a household's electricity bill. This is basically achieved by turning off the heating while the prices are high and turning back on when the price has dropped. The aggregator activates once pr. day when the price peaks. In theory it is possible to activate several times each day, but in practice the aggregator will most likely have committed itself to activations through the market and the house needs time in between to fully recover the temperature. As the market will most likely request flexibility at times where the grid load is highest and probably also high prices, these activations will have a positive effect on the economy optimization.

Household customers who have chosen the economy product will have their electricity billed based on spot prices and as the product implies, the aggregator will optimize the usage based on these prices.
Economy product customers will in addition the electricity usage, also be able to see the how much money it is possible to save on their personalized web-page.

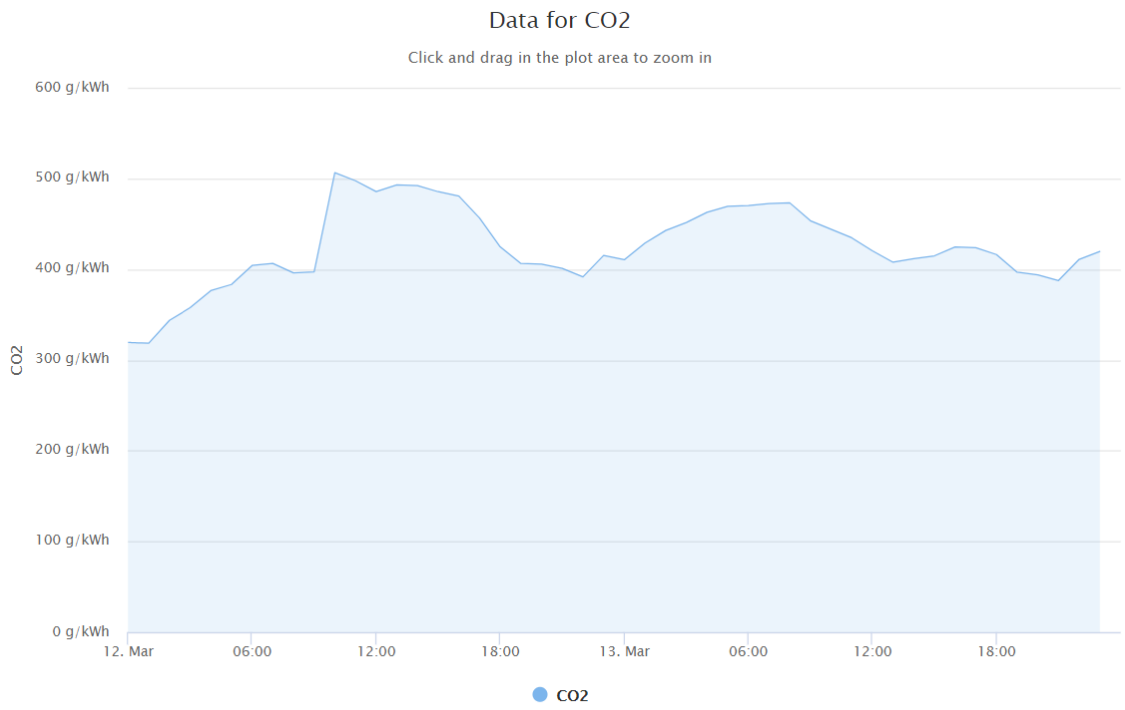


Savings from Economy product

The savings are calculated as the difference between tariffs and the spot price for the optimized consumption. This calculation is performed for the last 30 days. Based on the current consumption pattern, a potential saving for the whole year is calculated and presented both in Danish kroner and in corresponding amounts of daily expenses.

CO_2 Product

The environmentally friendly CO_2 product is targeted household customers with a high priority on the environment. This product contains the basic features as well as an optimizing of the energy consumption based on CO_2 emissions. The level of energy production that comes from renewable energy depends on the weather conditions such as wind and sunshine. At times with a low energy production from renewable sources, a larger percentage of the energy is produced by traditional powerplants leading to a higher CO_2 emission. This level fluctuates during a day as seen in the following table.



CO2 emission from electricity production during a day

For household customer that choose the CO_2 product, the aggregator will attempt to optimize the energy consumption by controlling the heat sources in a fashion where they use less power at times with a high CO_2 emission from production and more power at times with low CO_2 emission. The environmental impact from each household may not be huge, but by aggregating the potential from many households, it can have a significant contribution.

The CO_2 product activates only a few times day along with the market requested activations. This is done to allow the houses to fully recover the temperature.

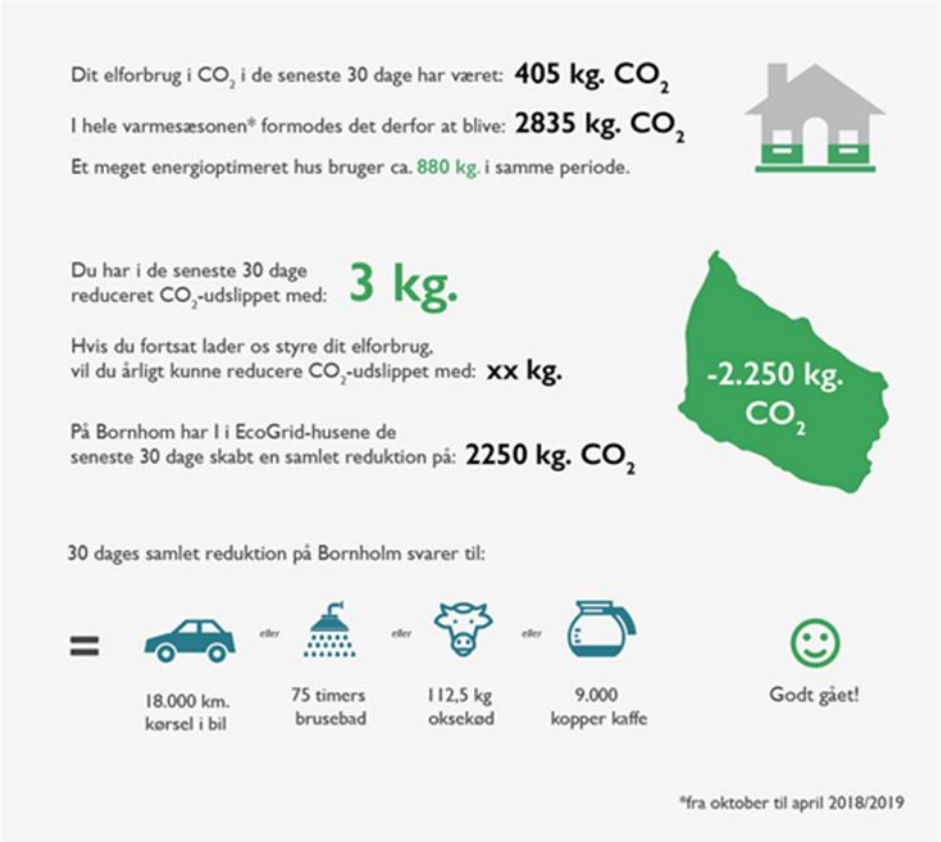
All energy produced on Bornholm comes from renewable sources or from biomass. This means that the energy production on Bornholm is CO_2 neutral. To determine the CO_2 emission, it requires determining the percentage of imported energy to Bornholm. Tomorrow, the company behind the web-site www.electricitymap.org, publishes numbers for amount of emitted CO_2 per kWh consumed. These numbers are calculated on an hourly basis and will fluctuate as seen in the graph on the previous page. The CO_2 emission for a household is calculated by multiplying the CO_2 emitted per kWh with the consumed electricity for each hour.
Household customers who have chosen the CO_2 product will in addition to the electricity usage also be able to see the how much CO_2 has been emitted due to heating on their personalized web-page. The amount of CO_2 for the household is compared to climate goals and to a reference house.

The household´s CO2 consumption in relation to the climate goals

To keep global warming below 2 degrees, we must each keep our emissions below 2,000 kg per year over our total activities. Since electricity and heating for households are responsible for 11% of our CO_2 emissions, the emission from these must not exceed 0.11 * 2.000 = 220 kg CO_2 per person per year. One household with 4 persons must thus emit a maximum of 220 * 4 = 880 kg CO_2 per year in its electricity and heat consumption.
The House-icon on the Environment page compares the expected annual consumption with this indicative consumption. If the household is expected to spend less than 880 kg of CO_2 during the heating season, the house will be full green - if the household is expected to use 1,760 kg CO_2 or more, it will be completely gray. If the household is in between these extremes, the house will be partially green.

How much CO_2 the household has saved over the last 30 days

To calculate the savings, we first calculate the consumption from a fictitious comparable household.
Data for the fictitious household is based on the average CO_2 consumption for all households who participates in EcoGrid 2.0 without having chosen the Environmental Package. Since the electricity consumption of these households is not optimized after minimizing CO_2 emissions, we assume that they are a comparable basis.
To ensure that CO_2 consumption can be compared across households with varying electricity consumption, we scale the fictitious household's CO_2 consumption in relation to the electricity consumption in the last year, so the size of the electricity consumption does not affect the comparison.
The savings on your CO_2 consumption are thus obtained by subtracting the household's CO_2 consumption from the fictitious household´s CO_2 consumption over the last 30 days.
The potential saving for a whole year is calculated using a linear projection of the last 30 days´ savings.
To put the savings in a perspective, all the households that has chosen the CO_2 product will be compared to all the other households in EcoGrid 2.0 to estimate the total CO_2 savings for all of Bornholm. This amount is then compared to a list of everyday references.



CO2 savings web-page

Evaluation

The expectations for heating season 3

During the third and final heating season, the EcoGrid 2.0 project aims to demonstrate two different achievements related to products to customers. Firstly, to demonstrate the operation of the products themselves and the resulting effects on the CO_2 reduction and savings on economy. Secondly, to demonstrate the ability to freely choose a product and the effects of nudging customers to actively choose a specific product.

Results of products

Customers choosing a product and the nudging process

Prior to heating season 3 a newly designed web page was launched, which allowed customers to view their currently selected product and to choose a different product. This was introduced to the end user via newsletters sent by BEOF. Changing products across aggregators is a seamless transition for the customers, so they do not need to concern themselves with the details of their product selection. For further reading and results from customer choosing products, please refer to EcoGrid 2.0: "D4.5.2 Tool for flexibility interface"

In order to nudge customers to actively choose a product, an initiative with encouraging e-mails were developed. To encourage customers to change from a basic product to either the environmental or economical product, we simplified the information about the products, framed the wording beneficial and added a CTA to make it easy for the receiver to act upon the message directly. This e-mail was sent to all customers having a basis product. A month later this was followed by another e-mail to remind the remaining customers who had not changed products yet. Here, the headers of the e-mails were changed to nudge further, e.g. by communicating a matter of urgency in the wording.

The goal was to move

- 5-10% (13-27 houses) of customers from Insero Basis -> IBM Environment
- 5-10% (14-29 houses) of customer from IBM Basis -> Insero Economy

The achieved results of the nudging are:

- Insero Basis -> IBM Environment: 27
- IBM Basis -> Insero Economy: 50

We have succeeded in moving the desired number of customers. Thus, the customer interactions and product selections are not due to the nudging initiatives isolated.
For more information on the nudging strategy and the results, please refer to Appendix A

Economy product

The economy product was activated in week 2, 2019 and has been performing daily activations in the weekdays during January, February and March. As mentioned earlier, the product is only activated once every day due to the amount of other market operated activations and to avoid causing discomfort to the customers. The economy product is evaluated on two parameters. The combined savings that the customers would have made, had the economy product been real, as well as the savings achieved solely by optimizing the electrical usage. The total electricity price based on spot is simply calculated by summing the electrical usage times spot price for each hour. The reference is the total consumption times the estimated tariff price. It is more difficult to calculate the savings contribution from the optimizations alone. As is the case with demand response activations, these are generally evaluated against a baseline. In this case a baseline usage has been calculated for each activation period by averaging the usage for similar times of day with similar outdoor temperatures. Based on this reference, each response and rebound is calculated, and from this the savings contribution for each activation is calculated using the relevant spot prices for the hours of response and rebound. These calculations can only be performed on the whole portfolio because it would be almost impossible to calculate usable baselines for each house. Therefore, the results are evaluated as average values for all the ~180 houses that has chosen the economy product. The results can be seen in the table below, all prices are in DKR.

Period	Tariff price	Optimized spot price	Savings	Savings from optimizing	Savings from billing method
Jan 19	2216,02	2238,47	-22,45	0,23	-22,22
Feb 19	1722,09	1677,97	44,12	4,78	39,34
Mar 19	1574,85	1484,52	90,33	2,43	87,90
Total	5512,96	5400,96	112,00	7,44	104,56

The table shows that the average customer would have saved 112DKR on their electricity bill from choosing the economy product during January to March, but also that only 7,44DKR comes from the actual optimization of the usage. This calculation only considers activations that are done as part of product activations. Activations done as part of market operations will also have an impact, but since these are not focused on saving money, they are not considered.

During January the combined savings where negative, due to higher spot prices and a low contribution from the optimization. The numbers indicate that the potential for optimizing electricity usage under these

conditions is limited and fluctuations in the spot prices might have a bigger impact on the actual electricity bill.

Environmental product

The environmentally friendly product focused on CO_2 reduction was activated in week 3, 2019 by the IBM aggregator. Overall 41 households were registered for the CO_2 product until the end of the demonstration period at the beginning of April. 28 of these households were resident and 13 were holiday or summer households. Particularly the holiday households offer very little flexibility as the heating of these households is often limited. Many of the households which selected the CO_2 reduction product are equipped with energy generating equipment which makes an accurate estimation of their flexibility by the aggregator more challenging.

The product was activated on 40 working days during the demonstration period of HS3. Overall 112 product activations were performed in weekdays during January, February and March; on average about 11 CO_2 product activations were performed in one week during the demonstrations period. The CO_2-Intensity forecast data for Bornholm was used to plan the activations. Every day the CO_2-Intensity forecast for the coming day was obtained from EcoGrid 2.0 data warehouse by the aggregator. The resolution of the available CO_2-Intensity data is one hour. The activation of the product was planned for a period of one hour reflecting the resolution of the forecast data. The aggregator scheduled the product activation for an hour of high CO_2 intensity ideally followed by an hour of low CO_2-Intensity to accommodate for rebound following the response of an activation. The minimum period between subsequent product activations for a household was set to five hours to ensure the comfort of the participants is maintained. The scheduled CO_2 product activations were also accounted and used to additionally accommodate TSO market requests; this combination was helpful for the aggregator to offer higher volumes in its bids for TSO markets. The overall response volume of all CO_2 product activations during the demonstration period was around 980 kWh; this aggregated power consumption of households was shifted from hours with higher CO_2-Intensity to hours with lower CO_2 Intensity.

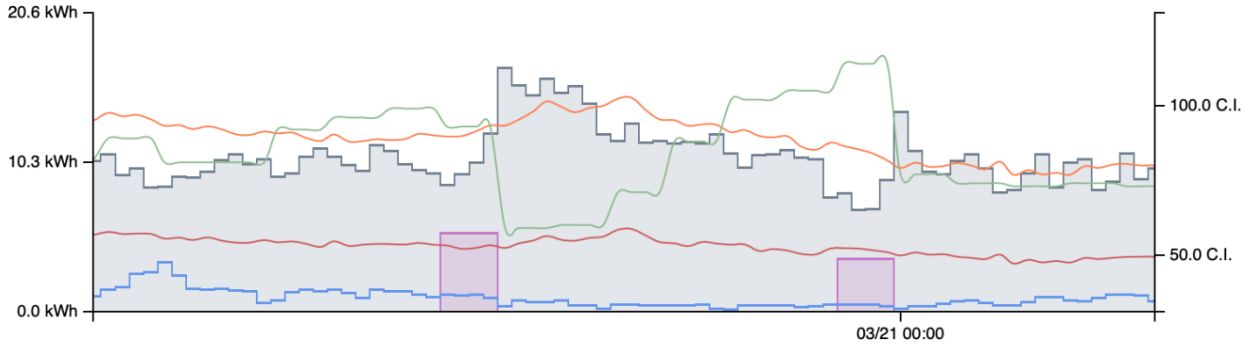


Figure showing two CO_2 product activations.

The figure above shows two CO_2 product activations on 28 resident household. The filled gray area shows the overall measured power consumption of these households in kWh with 15 min resolution and the blue line shows the measured output power generated by the households. The orange line shows the forecast of the power consumption for these households in kWh computed by the aggregator at the time of

planning based on historical data; the red line shows the estimated flexibility of these households at a point of time. The forecast of CO_2-Intensity (C.I.) is shown by the green line and the volume of a planned activation by the pink filled area. As demonstrated by the figure, the CO_2 product activations reduce the power consumption during hours with high CO_2-Intensity while the rebound following the activations lies the time of lower CO_2-Intensity. In this example the period between the two activations is exactly five hours.

Based on CO_2 intensity definition, moving power consumption of 1 kWh into a period with CO_2 intensity lower by 1 C.I. saves 3.6 g of CO_2. The first activation shown in the figure moves approximately 8 kWh from an hour with CO_2 intensity of 93 C.I. to an hour with 59 C.I. which saves 979 grams of CO_2 emission. The second activation in the figure moves approximately 7 kWh from an hour with 114 C.I. to an hour with 77 C.I. which saves 932 grams of CO_2 emission. Overall, the 112 activations of the CO_2 reduction product on 28 resident households during the 40 days in the HS3 demonstration period resulted in savings of approximately 62 kilograms of CO_2 emission.

Overall conclusion

The experience from offering aggregator products throughout heating season 3 may be divided into two areas. Firstly, the technical conclusions. Both products have been executing activations daily through 3 months. Technically both products have been operating without any major issues. The scheduling of product activations along with market driven and manual activations has been largely unproblematic. The tools to allow customers to change products during the heating season through the web page have also worked as expected. From a technical perspective, the EcoGrid 2.0 setup has demonstrated that it is technically possible to offer aggregator products as described.

The second but equally important aspect of the evaluation of the aggregator products is the results that has been achieved by the products in the sense of money saved or CO_2 emitted, but also the value perceived by the customers who chose the products. During the 3 months of execution, both products have produced savings. Though especially the economy product has not performed as well as hoped, with most of the savings coming from a decrease in spot prices.

The interviews performed with household customers, show that the aggregator products are understandable and meaningful but not a key condition for participation in the project. The customers would definitely like to save money or CO_2, but the products where not the driver. For additional information on customer interviews please refer to EcoGrid 2.0: "D8.4 Evaluation of customer acceptance and aggregator products". Looking from a commercial perspective, the services provided through the aggregator products might not generate enough value on their own, in the current setup, to qualify as distinct products. But there is a potential to serve as part of the incentive for households to offer flexibility to the market. The services in combination could perhaps be offered as part of an incentive package along with other services for households as compensation for their flexibility. Other services could include e.g. free service on heat pumps. This would also serve the purpose of relieving customers of actively selecting products, which they for the most part do not concern themselves with.

The aggregator product demonstrations have proven technical feasibility and a potential for adding value to the customers. In a future commercial setup, these findings may be used to tailor a complete customer offer in return for their flexibility.

Appendix A

Abilities and willingness and technical/support work

Each user is a complex mix of abilities (education, skills to operate a pc etc.), the characteristics of their homes (type of heating appliances, insulation, number of rooms etc.), their motivation (how willing are they to change behavior), the kind of life lived (life with kids, working at night etc.) to be taken into account to make them behave as flexible users. In other words, for households to become a resource in the aggregator's portfolio, technicians continuously have to 'push' the user to the personal website and assist them in multiple ways.

The ability of the participants is to some extent compromised by the communication; most prominently, when the guidance offered in the letters regarding insulation and energy labelling is read by participants as minimum requirements, they are likely to be unable to make choices based alone on their preferences. Furthermore, the use of notions such as 'standard' or 'basis' was often understood as relating to size of the house or the consumption of the household.

Willingness

As indicated several times, it is rather difficult to make conclusions regarding the willingness of participants. Their willingness to comply to the script may primarily be an effect of a local 'community' feeling, i.e. to support the island and help reproduce a strong identity for Bornholm. Without this local setting, it is quite likely that consumers' willingness would be different. The participants know that the setting is a demonstration project. This is an inherent challenge to the demonstration; on one hand, the project needs a setting in which the households may be convinced to take part. On the other hand, this challenges the transferability and scalability of the results. However, towards the end of our interviews we asked the EcoGrid participants if they would consider engaging with an aggregator after the demonstration, and most of the participants answered that they most likely would do so if they got a good/valuable offer.

Many of the interviewees have not entered the webpage (apart from choosing a product), and they did not consider doing so. Some told us that they had more interests in engaging when EcoGrid EU started, but their motivation to do so has declined over time. The few participants, who claimed to make use of the web portal, actually used it to access their Greenwave webpage. What ties together the technical system, and the user is often an outcome of technicians' work of maintaining the social contract. In the demonstration project an important part of the successful alignment is to be found in the mundane and everyday interactions between the support team and the users. The users' willingness to participate in EcoGrid 2.0 is related to the trust in the increasingly personal relationship build between them and technicians. Users know they can call staff from the local energy supplier if, or when, they have a problem with the equipment. And the service is free of charge. Also, many potentially critical questions never get raised, because of this social contract: "we trust them", is a common answer to questions regarding users concerns of delegating control over their heating to external parties. With "them", users refer to technicians and their colleagues at the local utility. This trust implies accepting that participation in the experiment may

involve increased energy consumption, as illustrated in the following example: A user called Lars, one of the technicians, because he could detect an increase in the consumption in his currently empty summer house. He asked Lars to figure out if there was a problem. Lars could inform the user that the house was currently used for testing, and the test was the reason for the increase in consumption. The user simply accepted the explanation, as he had willingly signed up for the demonstration.

What we have tried to demonstrate here is that the multiple sites of a large-scale experiment such as EcoGrid 2.0 requires an organizing work, which is not undertaken by the scientists and experts themselves, but in the case studied here, by technicians. This work includes alignment, coordination and translation of the interrelation between the different sites of the experiment. The implications of this fragmented work is only fully grasped when it is situated in the larger demonstration work in EcoGrid 2.0—and its effects on the possible evaluation of the demonstration. Whereas the technical experts and scientists usually highlight Bornholm as being 'representative' of other parts of Denmark, and thus the possibility of achieving similar results in terms of consumer flexibility, our study rather points to dedicated technicians and participants bound by a highly local social contract mediated by the technicians. And technicians, on their side, seem committed to engage with problems and situations in a way that seems rather exceptional. To the extent that the scientists who evaluate the results lose sight of technicians' work, they also miss out on the complex and intensive work of making flexible consumption possible — let alone the work involved in operating the system.

Nudging to increase willingness amongst EcoGrid 2.0- participants

To increase willingness amongst participants in In EcoGrid 2.0, we designed and tested generic products and two nudge interventions.

Generic products

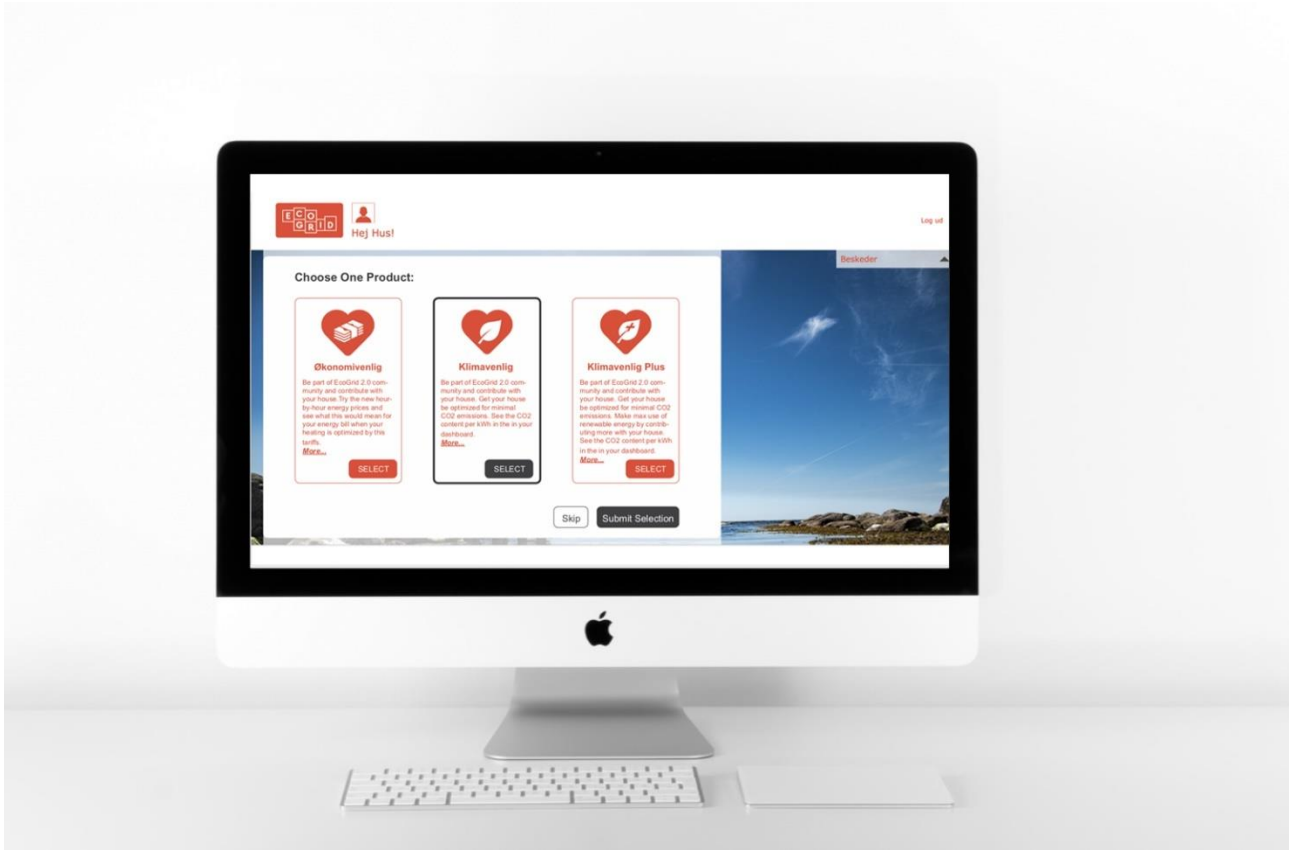
To ensure the abilities and willingness amongst customer to give up the control of their households easy, we introduced generic customer products to make it easy for users to know and understand the benefits of the products. To make the products attractive, we based them on previous EcoGrid research showing that customer decisions is based mainly on motivations within two areas:

1. Supporting the green transition: The users were motivated to be part of a green transition and help improve the environment by changing to renewable energy sources
2. Optimizing household cost: The users saw the project as an opportunity to optimize cost related to their household and doing so by better matching usage with cost-efficient products.

This led us to introduced products within two categories: The environmentally friendly and the cost-efficient products. Within each category there was a range of sub-products allowing the users to choose to what extent they wanted to give up control and stretch their level of comfort.

Product integration in web portal

To make it easy to understand the benefits of the products, we integrated product descriptions on the EcoGrid website and hereby making it part of the existing user journey and touch points. We used visualizations, infographics and images on the website and in newsletters to communicate the benefits of each product and differentiate them from each other.



When entering the website during HS2, the users were introduced to two overall products: The environmentally friendly and the cost-efficient ones.

Visualization of benefits related to the cost-efficient products

Visualization of benefits related to the environmentally friendly products

The two nudge interventions in HS3.

During HS2, 75% of the participants did not actively choose one of the generic products (environment or economic). This meant that 75% was, by default given a Basic product. The challenge in HS3 was to demonstrate how we could engage the 75% to actively choose either the environmental or the economic product. To activate the consumers in HS3 we designed two type of nudge-emails that, based nudge theory and cognitive psychology, made it attractive to take action. Through simple and visual information, we introduced consumers to the benefits of choosing the two products. The benefits were put in relation to how their choice would benefit either the community, the environment and their financial situation. The overall results were good. During HS3 27% of the participants who, in HS2 was given the Basic default product, actively choose a new product. This small email-intervention lead to an overall increase in the number of economic products being chosen by 33, 1% and for the environmental products the increase was by 70%. Furthermore, and based on that demonstration in HS3, we could see that the opening rate on emails framed around the environmental benefits was 15,5% higher than the opening rate of emails introducing the financial benefits.

Nudge-emails using positive framing and visualizations to increase willingness and product selection amongst customers, easy.

Read more at www.ecogrid.dk