

Assessing the Potential of Home Automation in Norway

A report commissioned by NVE

VaasaETT

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Summary: This report explores the potential of home automation technology to reduce electricity consumption and manage peak demand in Norway, both at household level and aggregated at national level. In order to reap the full benefits of home automation, VaasaETTs findings indicate that home automation offerings should go hand in hand with dynamic tariffs, consumption feedback and consumer education.

Keywords: Consumption feedback, demand response, dynamic pricing, energy efficiency, home automation, smart meters.

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Preface

This report is commissioned by NVE as part of the R&D-project "Smart meters, smarter consumers". The project aims to generate knowledge about measures in the retail electricity market that can help consumers utilize the opportunities following the roll-out of smart meters in Norway. Every Norwegian household will have a smart meter installed by January 1 2019.

The report explores the potential of home automation technology to reduce electricity consumption and manage peak consumption in Norway, both at household level and aggregated at national level. In order to reap the full benefits of home automation, VaasaETTs findings indicate that home automation offerings should go hand in hand with dynamic tariffs, consumption feedback and consumer education.

In order to know the actual effects of home automation in Norway, different home automation solutions needs to be tested in a large scale amongst Norwegian household costumers. This report can hopefully help in preparations for future large-scale pilot projects.

The content and recommendations contained within this report are those of the consultant, and have neither been accepted nor rejected by NVE.

Oslo, April 2017

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A report commissioned by the Norwegian Water Resources and Energy Directorate (NVE)



Assessing the Potential of Home Automation in Norway

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List of Acronyms

CAPEX: Capital Expenditure **CPP: Critical Peak Pricing** CPR: Critical Peak Rebate **DR: Demand Response** DSM: Demand Side Management DSO: Distribution System Operator **EE: Energy Efficiency** EU: European Union **EV: Electric Vehicle** HAN: Home Area Network IHD: In-House Display **OPEX: Operating Expense PV: Photovoltaic RTP: Real Time Pricing** TOU: Time of Use tariff **TSO: Transmission System Operator**

Executive Summary

This report explores the potential of home automation technology to reduce electricity consumption and manage peak consumption in Norway under different scenarios for market adoption both at household level and aggregated at national level. It also highlights critical success factors of home automation projects that, when combined, ensure better consumer engagement and ultimately greater impacts of the technology and, finally, presents several examples of what the future of home automation might look like.

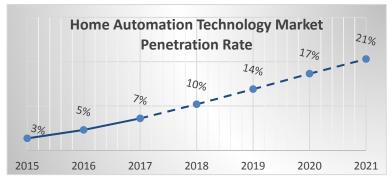
The ability to both increase and reduce energy demand is often seen as an important and relatively inexpensive element in providing grid flexibility whilst integrating a greater proportion of intermittent energy and preparing the grid for the increasing penetration of new electricity intensive appliances such as electric cars and heat pumps (both expanding rapidly in Norway). There are however limits to the speed with which consumers can manually react – when they can react at all - to price or volume signals. By automating the usage of certain appliances, household electricity consumption can instantly drop whenever prices are high or networks congested benefiting consumers, network operators and the broader community.

However, the size of loads being switched is usually limited and the cost of the technology required is often seen as a deterrent. Consequently, the scale of rewards compared to the effort and cost of installing a home automation system may be seen as inadequate.

This is to ignore that residential demand is often a significant portion of total national consumption and an even higher portion of national peak consumption. In addition, residential peak profile is different to that of industry and therefore the two provide complementary flexibility resources. Multiple trials have demonstrated that home automation delivers not only substantial consumption reductions and cost-savings to energy consumers, they can also bring high levels of satisfaction and loyalty, an improved perception of the industry and allow for other services that provide added value and convenience to the consumer as well as new business models for the energy industry.

Intuitively, Norway represents one of the most suitable markets in the world for home automation and the services that follow on from them: high residential consumption and energy bills (despite some of the lowest electricity prices in Europe), a high proportion of electric heating (controllable load), an increasing penetration of electric cars and heat pumps (also controllable loads), technologically savvy population, significant levels of retail market competition, ongoing smart meter deployment and high income levels (consumers with higher incomes are better able to invest in Energy Efficiency (EE) solutions).

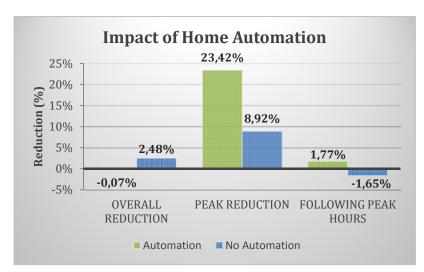
Though slow to develop until recently, home energy management systems are being increasingly commercialised. Revenues in the home automation segment are expected



to grow at an annual rate of 20.6% between now and 2021; resulting in a market volume of US\$78m or US\$161 per active Norwegian household. By 2021, 21% of Norwegian households are expected to have

Market penetration of home automation technology in Norway 2015 – 2021 (Figure 9)

home energy management systems up from 5% today. By extrapolating these figures, market penetration rates of 48% and 78% are expected in 2030 and 2040.



Added value of home automation

Appliance automation proves very effective shifting at consumption away from peak hours ¹. Pilots with home automation managed to reduce peak consumption by 23% Vs. 9% for pilots

Impact of home automation on electricity consumption (Figure 10)

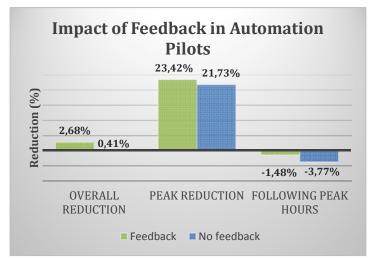
¹ Peak consumption refers to high consumption hours at national level. Reduction in peak hour consumption refers to the reduction in consumption over the duration of the peak.

without automation (manual response to dynamic pricing and/or consumption feedback). There are several reasons for it. Even though consumers should always be allowed to overrun the program, automation enables fast reactions as well as controllable levels of reduction and has the advantage of being available during unplanned system emergencies for instance. In addition, critical situations do not always occur when residential consumers are able to take action (when they are away or asleep for instance). Another important consideration for grid operators is that without automation they risk seeing millions of appliances come back on line at the same time right after high-price-hours end. Automation can help mitigate this risk by switching appliances back on in cycles.

However, home automation alone often leads to increased levels of electricity consumption. Pilots with home automation led to a slight increase in overall consumption (-0.07%) whilst pilots without home automation technology led to sizeable reductions in overall energy consumption (2.48%). While some argue that there is no point trying to engage and educate customers who have automated appliances, pilot results (and behavioural science) show that when efficiency improvements come solely from the technological side, people remain passive actors, leading to low levels of awareness, continued inefficient habits and behaviours and well documented rebound effects. In summary, while pilot results indicate that automation drives peak consumption reductions, it is essential to introduce other mechanism to develop sustainable energy saving habits.

Automation, consumption feedback and consumer education

This point is supported by our findings. Pilots combining home automation with consumption feedback and consumer education (in other words make use of the data



generated by the home automation system to help consumers reduce overall energy consumption) are more effective at reducing both peak (23% vs 22%) and overall consumption (2.7% vs. 0.41%). In real-life however, home automation

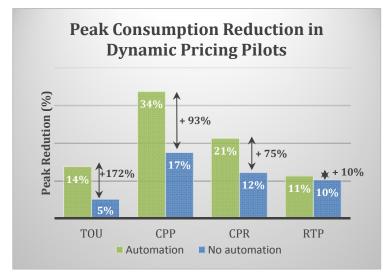
Impact of feedback on automation pilots (Figure 20)

has often been introduced following an inverted evolution whereby technology has been at the fore-front, with consumer education and feedback being introduced as a next-step or a reaction to negative publicity. Consumer education and consumption feedback is not about giving access to graphs, it is about establishing a continuous and dynamic dialogue with the customer, based on collecting data and adapted to behaviour or consumption patterns on a regular basis and through multiple platforms. Last but not least, a positive business case and an appealing payback time are other fundamental reasons why education and feedback should be part of any home automation package. A 2017 report by VaasaETT and Joule Assets looking at the business case for residential demand side flexibility in 4 EU countries found that between 77% and 87% of endconsumers' financial benefits come from overall consumption reductions (the rest from peak consumption reduction). This can be easily understood if one considers the fact that critical peaks take place for only about 30 hours a year whilst benefits from lowering overall electricity consumption take place continuously.

Automation and dynamic tariffs

Dynamic pricing involves substantially increased retail electricity prices during times of either heightened consumption (for example on abnormally cold winter days in Norway) or when the stability of the system is threatened and black-outs may occur. In this respect, the different tariffs in the report are not specified as either a regulated network tariff or a competitive retail price. The tariffs could in theory be managed by a third entity "the Demand Side Management (DSM) authority" bridging the economics of the wholesale market and the balancing activities of the grid companies. The dynamic tariffs are thus making up for the fact that consumers' decisions do not account for the cost of producing and transporting electricity in the different time periods – which from an economist's point of view has been one of electricity market's major failures. The duration and frequency of the high priced hours differ depending on the pricing scheme as explained in Chapter 2.3 and detailed in Figure 25. It is important to note that whether the dynamic part of the tariff is linked to the regulated network tariff or the competitive retail price - or both - does not influence the consumer's (or the technology's) response. As far as the consumer (or the technology) is concerned, he/she/it is receiving price signals to shift consumption to cheaper hours.

Pilot results show that home automation enhances the impact of dynamic tariffs by 75-172% (ignoring RTP). Though all the tested tariffs schemes have pros and cons, dynamic pricing coupled with home automation have proven one of the most effective ways to



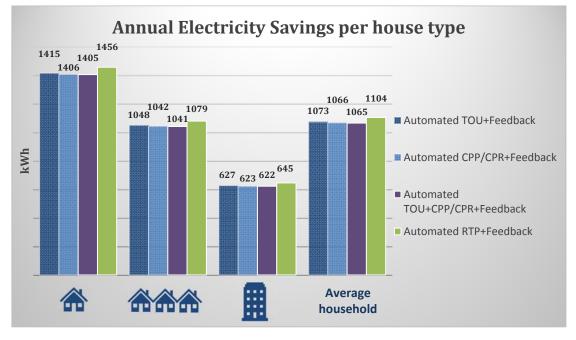
Consumption reduction at peak times (Figure 11)

secure demand flexibility in the residential sector. It is important to keep in mind that though TOU and RTP peak consumption reductions are the lowest, they occur daily, whilst CPP and CPR produce the highest reductions but only for critical peak periods, typically about 30 hours a year. Pilot results would

indicate that rewards for peak clipping (CPR) are much less effective than penalties (CPP). It is important to keep in mind that CPR might constitute a more acceptable form of dynamic pricing, thus achieving greater market penetration and a greater aggregated impact on national consumption. CPP alone may also be perceived negatively by consumers and thus hinder the introduction of other products and services related to home automation which require satisfaction and trust in energy supplier.

In order to reap the full benefits of home automation (i.e. peak clipping, managing surrounding peak time consumption and energy efficiency), our findings indicate that home automation offerings should go hand in hand with dynamic tariffs, consumption feedback and consumer education. Various modelling exercises were conducted based on this finding.

How would home automation impact Norwegian households' power consumption?



Impact on annual consumption

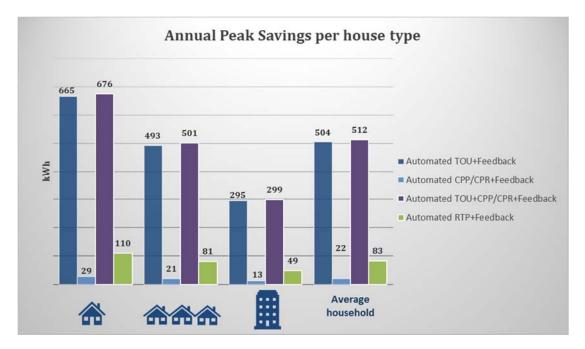
Impact of feedback and automated DR on annual electricity consumption (Figure 26)

Norwegian households could decrease electricity consumption by an amount equivalent to about 7% of their annual usage thanks to home automation, dynamic pricing, consumption feedback and consumer education. This amounts to 1,065 – 1,104 kWh per year for an average household depending on the dynamic tariff scheme. A similar impact on annual consumption is observed across pricing schemes. This can be explained by the fact that overall consumption is mostly influenced by feedback and consumer education rather than by dynamic pricing (which targets peak consumption).

- Impact on annual peak consumption

When investigating the effects of home automation, dynamic pricing, consumption feedback and consumer education on annual peak consumption, the effectiveness of TOU stands out. An average Norwegian household with automated TOU could reduce consumption by an amount equivalent to about 14% of its annual peak consumption. This is due to the fact that TOU impacts consumption daily whereas CPP and CPR impact consumption on critical peak days only (typically 12 – 15 times a year). It is important to keep in mind that TOU, due to its rigid structure, lacks the flexibility to deal with extreme prices on the wholesale market outside of "usual" peak hours or unexpected network constraints. TOU and CPP (or CPR) can however be combined to retain the

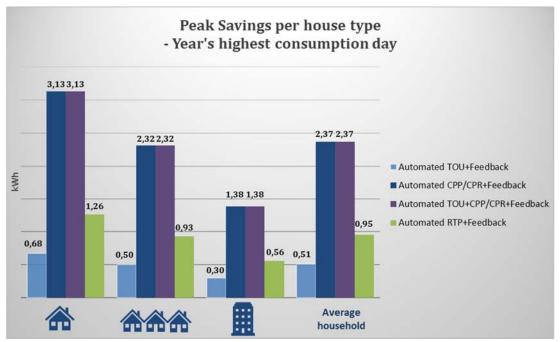
possibility to deal with unexpected events (CPP / CPR prices are triggered on critical days) whilst having a daily impact on peak usage (as TOU are in force every other day). In fact, our results indicate that a combination of TOU and CPP/CPR works best at reducing annual peak consumption (512 kWh per year for an average household).



Impact of feedback and automated DR on annual peak electricity consumption (Figure 27)

- Impacts on the peak consumption of the year's highest consumption day

Although, the impact of CPP/CPR on annual consumption is limited, they prove very powerful at lowering critical peak consumption when combined with home automation. An average Norwegian household on CPP/CPR pricing could lower peak consumption by 2.37 kWh (28%) on the highest consumption day of the year when CPP peak prices are in force.



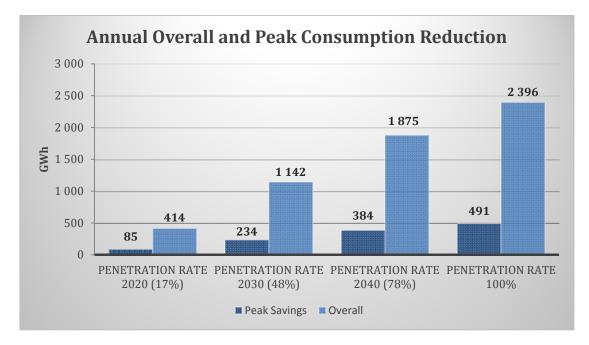
Impact of feedback and automated DR on highest consumption day peak electricity consumption (Figure 32)

How would home automation impact Norway's power consumption?

The results show that Norway could benefit enormously from a greater penetration of home automation technology, dynamic pricing, consumption feedback and consumer education.

- Impact on Norway's annual consumption

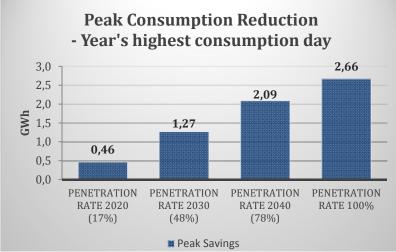
Norway's annual overall and peak electricity consumption could decrease by 414 GWh (1.17%) and 85 GWh (2.31%) respectively by 2020 when 17% of households have adopted a combination of home automation, dynamic pricing, consumption feedback and consumer education. By 2030, with a market penetration of 48%, these figures could reach 1,142 GWh (3.22%) and 234 GWh (6.37%).



Impact on Norway's overall and peak electricity consumption (Figure 28)

- Impact on Norway's peak consumption

Using January 2nd 2015 (year's highest consumption day) as a baseline – when CPP/CPR prices are in force and consumers with RTP have been notified of high wholesale prices – our modelling shows that home automation technology, dynamic tariffs and feedback could lower Norway's electricity peak consumption by 0.46 GWh (2.81%) by 2020. By 2030, this figure could reach 1.27 GWh (7.75%).



Norway is one of the few countries where electricity is household's main heating source. Our findings reveal that on Norway's highest consumption day, electric heating alone could provide 43% of

Impact on highest consumption day of 2015 (Figure 33)

the country's potential for residential peak consumption reduction. Our analysis also shows that electric water boilers and white goods represent a significant portion of electricity consumption in Norwegian homes and could provide sizeable demand flexibility and energy efficiency gains.

Technologies – for now...

Even though there is no clear winner around home automation technologies, it does seem to be coming together. The report discusses four scenarios which all are probable outcomes of the political decisions and business investments in the next two to three years. The dependencies are still related to finding common communication standards of Home Area Network (HAN), and the investments being made in this area lately shows, that the industry is now making their final decisions on whom they think will be the winners.

...and the future

Finally, the report introduces some of the most innovative automation-focused services and technologies currently being tested or commercialised around the world. Interestingly, home automation technology is not only rapidly becoming far more developed, but it is increasingly focused on more than just one or just a few appliances. The trend is to create comprehensive and inclusive solutions through the integration of multiple services, technologies and consumers. This evolution is built on the internet of things, communities and facilitating platforms, creating synergies of ever increasing benefits for the consumer. Put simply, the more elements that are integrated, the greater the returns for customers, the more attractive the business case, the more sustainable the business model.

Smart meters, home energy management systems, smart homes, distributed generation, storage, electric vehicles and more are all being brought together into harmonised ecosystems. Automation ensures that the integration takes place discretely in the background in the way that we would want it to happen, with minimal need for customer effort. What's more, the greater the number and variety of elements that are integrated, the more important the role of automation becomes.

Introduction

The ability to both increase and reduce energy demand is often seen as an important and relatively inexpensive element in providing grid flexibility whilst integrating a greater proportion of intermittent energy and preparing the grid for the increasing penetration of new electricity intensive appliances such as electric cars and heat pumps (both expanding rapidly in Norway). There are however limits to the speed with which consumers can manually react – when they can react at all - to price or volume signals. This means that without automation a utility can only ask residential consumers to shift load if they know this will be necessary well in advance (typically a day). This is not always the case as unforeseen emergency situations can occur which decreases the value of the Demand Response (DR) program. By automating the usage of certain appliances, household electricity consumption can instantly drop when prices are high, network are congested or increase when green energy is available benefiting consumers, network operators and the broader community.

However, in the residential sector, the size of loads being switched is usually limited and the cost of the technology required is often seen as a deterrent. Consequently, the scale of rewards compared to the effort and cost of installing a home automation system may be seen as inadequate.

This is to ignore that residential demand is often a significant portion of total national demand and an even higher portion of national peak demand. In 2015 in the UK the residential sector made up 30% of the total electricity power demanded (35% in Norway) and 60% of peak consumption. In addition, residential peak profile is different to that of industry and therefore the two provide complementary flexibility resources. The challenge is thus to find ways of enabling it to be accessed. Multiple trials have been conducted to explore the potential of home automation. While these trials generally have demonstrated that when used effectively, home automation delivers not only substantial consumption reductions and cost-savings to energy consumers, they can also bring high levels of satisfaction and loyalty, an improved perception of the industry and allow for other services that provide added value and convenience to the consumer as well as new business models for the energy industry. Though slow to develop until recently, business applications of these trials are now being increasingly commercialised.

It is expected that Norway represents one of the most suitable markets in the world for home automation and the services that follow on from them: high residential consumption and energy bills (despite some of the lowest electricity prices in Europe), a high proportion of electric heating (controllable load), an increasing penetration of electric cars and heat pumps (also controllable load), technologically savvy population, significant levels of retail market competition, ongoing smart meter deployment and high income levels (consumers with higher incomes are better able to invest in EE solutions). This research thus explores the potential of home automation technologies in Norway and identifies:

- The critical success factors of home automation projects: Main learnings from projects on how to facilitate the adoption by customers of smart home technologies and maximise their impacts;
- 2. **The potential of home automation for EE and flexibility in Norway**: Assess the impact of home automation technology and services in the Norwegian context based on results of several hundred pilots;
- 3. The potential impact of home automation on Norway's residential and national power consumption: Output from the previous research questions will constitute the building block of further analyses for Norwegian households and for Norway;
- 4. **State-of-the-art home automation technologies and projects:** Review of the latest trends and most promising home automation technologies and projects.

A definition of home automation

In assessing the potential of home automation one may rapidly run into the question; "What is home automation?" A simple search of the term on Google returns no less than 21 million hits and the related "Smart Home" more than twice this number. According to Collins English Dictionary home automation is: "the control of domestic appliances by electronically controlled systems". However, this definition is not taking into consideration the possible feedback and educative aspects also enabled by the technology. Hence for this report we will broaden the term and describe home automation as: "Building automation in households, which involves elements of control, monitoring, feedback and automation of energy consuming appliances such as: lighting, heating, ventilation, air conditioning, as well as white goods such as washing machines/dryers, ovens or refrigerators/freezers with the aim of decreasing overall and peak energy consumption." Home automation is often extended to also include comfort and security related measures such as air quality and surveillance/alarms. These features are not included in this report even though they might be of importance for developing a comprehensive value proposition to consumers and related business models.

1 Success factors in home automation projects

Going into detail about all the barriers to home automation and how to overcome them would require a separate study and should also include a thorough investigation of the specific Norwegian conditions to be addressed. This chapter seeks instead to highlight critical success factors from a high-level perspective to be considered before undertaking home automation projects.

1.1 Communication technologies



One of the main barriers which has prevented many people from buying existing home automation systems is the lack of communication standards – and in this respect the lack of confidence that the product will be able to uphold maintenance supply

and compatibility with new products. This is one of the main critical factors in relation to home automation becoming a success.

The two leading technologies have so far been ZigBee and Z-wave – two radio technologies with different pros and cons – and different supporter groups in many countries. Neither of these technologies however, has gained a significant advantage over the other – especially because the two technologies are good for different purposes. ZigBee is cheaper and easier to incorporate into new solutions, as it is open source. Z-wave tries to avoid interference problems by operating in a different frequency than most other radio transmitters. It also tries to become the customer's choice by keeping a strict policy for development and use of the protocol.

"Many experts seem to believe that the end for Z-wave and ZigBee is soon to come." Many experts seem to believe that the end for Zwave and ZigBee is soon to come partly because none of the big market players has adopted them, and more importantly because the Bluetooth technology, which is already present in many household devices, has recently announced a low

energy, MESH capable protocol called Bluetooth-Low-Energy or BLE; technology recently acquired by Qualcomm, one of the very big players in the field. This report is focused on the communication technologies to enable a smart home to function, i.e.: the communication technologies between smart appliances, which should be wireless to get customer acceptance. In a Norwegian context, it is however good to observe that some thought on standards has already been envisioned. A report by NEK (2015) concludes that smart meters in a Norwegian context cannot function as a hub and that smart appliances would need another central device to function, which could act as a middleware between the smart meter and the smart home.

The report touches upon the connection between the smart meter in itself and the HAN. It is concluded that the connection needs to be wired and be based on the M-Bus standard. This is the same standard which is promoted by the EU to read smart meters remotely - hence it does make sense to adopt these prescriptions also for residential users to have access to real time data. There are however a lot of considerations to take in order to make the technology accessible to the end-customer. First and foremost, the wiring process might complicate the customer acceptance of In-House Displays (IHDs) as most of these functions are only possible if the meter is read optically or from wire clamps. It is not 100% clear whether this is accepted in a Norwegian context, as there is no real connection involved - only an automated reading. Second, M-Bus is not a common standard in most home automation equipment, since it requires wiring and simply uses too much electricity to be performing well (home automation equipment often requires batteries to function). From this it should thus be noted, that home automation under the current Norwegian legislation will need a piece of middleware to ensure the connection between the smart meter and the home automation system, as it is unlikely that the whole system will work from the M-Bus standard alone.

1.2 **Choice of technology**

When it comes to home automation systems, strategies have been manifold. The first systems were proprietary, not any Home Automation system and connected and focused on only one or a very few appliances in the household, like a heat pump or the lights. There is still no satisfactory choice for a mass

"There is still no satisfactory choice for a mass market deployment of this can be seen as one of the main critical success factors in order to reach scale in the residential market."

market deployment of any home automation system and this can be seen as one of the main critical success factors in order to reach scale in the residential market.

There are different anticipations to the future of the connected home. In May 2016 PA consulting had a session with experts from all over the world to extract the main views into one consolidated model.

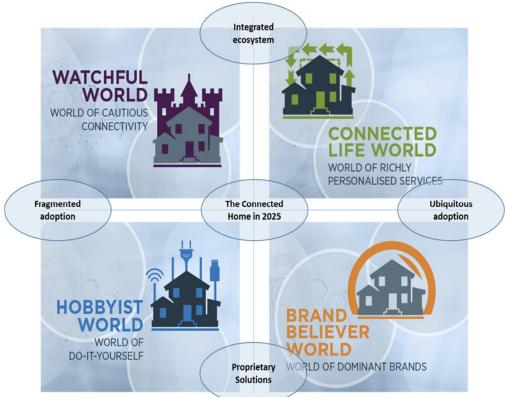


Figure 1: The Connected Home in 2025 (Source: PA Consulting 2016)

Basically, the model predicts four different scenarios, which could all be a reality in 2025 depending on decisions now and in the coming years. In the scenarios on the left-hand side, there is a risk, that solutions are only fragmentarily adopted, if either no communication standard emerges or if data security measures are so strict that data cannot be exchanged relatively easily between service providers and the customer. As discussed in Chapter 1.1 it seems that communications standards will finally emerge. For security, however it is still very much up to the national legislators to determine how data must be handled.



Figure 2: Amazon Echo - A main contender to become the heart of the connected home

For a home automation scenario to function, the two scenarios on the right-hand side are however the most suitable, since they are the only ones with mass adoption of technology. The difference between the two scenarios are also a clear indication of the battle which is being fought right now as Apple, Microsoft, Google and Amazon are all trying to secure their role as the main enablers of connected homes of the future.

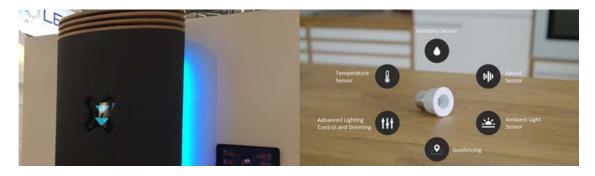


Figure 3: Anyware (right picture) and Green Energy Options (left picture) - Home Automation Solutions

It is by no means sure however, that the leading technology providers of today will also lead the future. One critical success factor has always been the ability to incorporate new ideas, something which proprietary solutions have always missed out on. In this respect the announcement of IBM to join the EnOcean Alliance was a clear indication that supporters of open standards had to stand up against the proprietary brands. EnOcean already counts such prominent members as Yamaha, Siemens and Schneider Electric but is based on a protocol developed by one of the leading providers of technology for the connected home which has been providing solutions for more than 15 years. It is also worth mentioning, that new 2nd generation technology is now being developed and brought to market by smaller companies. One such solution is the integrated storage battery by the well acclaimed British manufacturer of IHDs; Green Energy Options. Another is the Kickstarter founded geo-fence solution Anyware, which integrates with existing lamp sockets to provide additional services in combination with other wireless technology.

1.3 Tariffs as barrier and enabler

The fact that consumers' consumption decisions do not account for the cost of producing and transporting electricity in the different time periods is one of electricity market's major failures from an economist's point of view. Indeed, although the cost of supplying power to consumers can vary by an order of magnitude within the same day, the price paid by most end-users remains flat all year round in many countries leading to a number of inefficiencies and avoidable externalities². Mitigating the effect of this market failure by passing on some or most of the price volatility on to consumers is arguably dynamic pricing's major objective. Dynamic pricing involves substantially increased retail electricity prices during times of heightened wholesale prices caused by heightened consumption (for example on abnormally cold winter days in Norway) and or when the stability of the system is threatened and black-outs may occur³. In this respect, the different tariffs in the report are not specified as either a regulated network tariff or a competitive retail price. The tariffs could in theory be managed by a third entity "the DSM authority" bridging the economics of the wholesale market and the balancing activities of the grid companies. It is important to note that whether the dynamic part of the tariff is linked to the regulated network tariff or the competitive retail price - or both - does not influence the consumer's (or the technology's) response. As far as the consumer (or the technology) is concerned, he/she/it is receiving price signals to shift consumption to cheaper hours. High prices may occur daily as with TOU, or at critical times for the security of the electricity network as with CPP and CPR. There is no doubt that dynamic pricing has proven its value in securing consumption reductions at peak times. There are however important and critical factors which should always be taken into account when assessing whether or not to introduce dynamic tariffs.

² Need for building seldom used peak capacity, dirtier on-peak generation, and curtailment of green generation to cite only a few.

³ Dynamic pricing schemes are described in Chapter 2.3.

"Dynamic tariffs are effective at managing peak demand but can be regarded as just another way of increasing income and thus ruining a utility's opportunity to introduce other products and services which require customer satisfaction and engagement." First and foremost, it is very clear that dynamic tariffs work because people try to avoid paying high prices during peak hours. However, the impact of peak pricing is not similar across all segments of

consumers. The California State-wide Pricing Pilot, a large pilot assessing the impacts of dynamic pricing on peak consumption and energy bills which took place in 2003 and 2004, showed that high-use customers *respond* significantly more than do low-use customers, while low-use customers *save* significantly more on their annual bill than do high-use customers. This illustrates just one of many elements in the complexity of introducing a tariff like CPP. Whereas flexibility is secured by targeting only high-use customers, the benefit and economic value of participating is worth more for the low-use groups. Following the pilot results, CPP tariffs have been introduced as opt-out by many Californian utilities to avoid black-outs during the summer. In a context of very high needs – and where people can see the immediate benefit (for example as in the Californian case) introducing this kind of tariffs should be considered. However, the other side of the coin is that CPP tariffs alone can be regarded as just another way of increasing the energy bill and thus ruining a utility's opportunity to introduce other products and services (e.g. home automation) which require customer satisfaction and engagement.

It is important to consider carefully what the main goal of introducing dynamic tariffs is and what they can achieve. Dynamic tariffs work very well for peak clipping and to address exceptional stress on the grid. However, if the target is also to secure sustainable reductions in overall consumption, dynamic pricing alone is not the answer. Education and customer engagement must be part of the equation. The figure below illustrates this point. Dynamic pricing pilots in which participants were educated as to how to take advantage of the tariffs achieved much better results in every aspect.

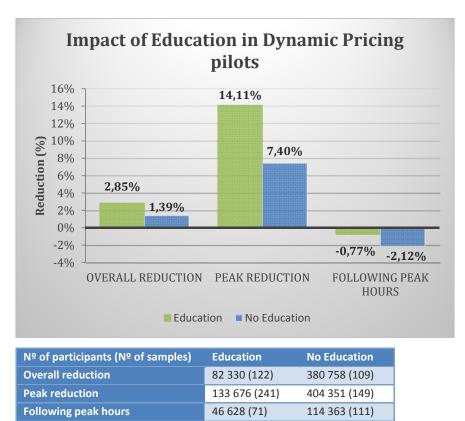


Figure 4: Dynamic Pricing Pilots and Education (Source: VaasaETT Database 2016)

1.4 Education and engagement

While some argue that there is no point trying to engage and educate consumers since home automation technology is ready, behavioural science and pilot results point to the

"Step-by-step discovery and consumer education are critical to create a mass market for home automation." contrary. Behavioural experts state that when efficiency improvements come solely from the technological side, people remain passive actors, leading to low levels of awareness, continued inefficient habits and behaviours and well documented

rebound effects. In effect home automation on its own will almost certainly lead to peak clipping but it will not lead to any significant long lasting reductions in overall consumption. We will discuss this in more details in Chapter 2.5.

There may be two additional reasons related to education and engagement that explain, why market adoption of home automation has been slow. First, home automation has often been introduced following an inverted evolution whereby technology has been at the fore-front, with consumer education and feedback being introduced as a next-step or reaction to negative publicity. Pilots and consumer research have shown that it can be useful and important for many consumers to understand, for instance through manual involvement at first, the relationship between their consumption behaviour and their bills and how they could benefit from home automation technology.

STEP-BY-STEP DISCOVERY: BE-AWARE PROJECT

Launched in 2010 in Italy, Finland and Sweden, the project introduced applications that enabled consumers to monitor their energy use and compete with other participants through quizzes and serious games. Consumers were able to check on the consumption of individual appliances presented as cards in a carousel by tapping on the card of their choice to reveal further details. Participants were only presented with the amount of information they required, when they requested it.



Figure 5: Be-Aware Project Discovery (2011)

Users reported increased awareness and knowledge about energy consumption and a high satisfaction with the tested solution.

"it is a critical success factor for automation programmes that all stakeholders see the benefits. Education and engagement are not limited to end-customers." Another reason may be that DR seems to conflict with traditional business models in the industry whereby retailers sell kWh and Distribution System Operators (DSO)/Transmission System Operators (TSO) are paid to build networks that meet peak demand. It is thus important to understand the drivers and barriers of the different parties in the value chain. Education and engagement are in this respect not limited to end-consumers. Benefits from DR programs are summarised in the following graph and analysed afterwards focusing separately on the perspectives of the different stakeholders: DSOs, TSOs and intermediaries (i.e. suppliers, aggregators).

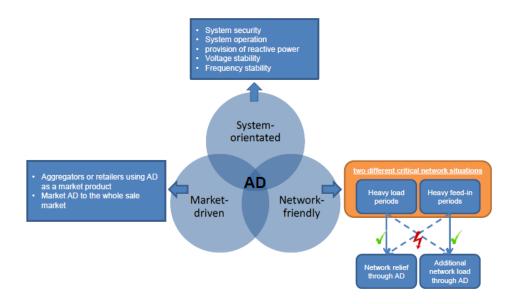


Figure 6: Benefits of DR programs for different stakeholders (Source: FP7 project Advanced 2013)

1.4.1 DSOs and TSOs

Increasing load on distribution substations has been noticed in periods with cold temperatures during winter time in Norway. With an increasing number of EVs and the end of oil and kerosene as sources for heating this tendency is bound to continue. Both TSOs and DSOs must design their networks in an economic and efficient way to meet peak demand. The flexibility provided by DR programs can help manage peaks, working as a cost-effective alternative to grid investments.

A well-designed demand flexibility program can help balance the electricity system, increase the loading capabilities of the transformers and relieve voltage-constrained power

"In order to ensure the effectiveness of DR programs for DSOs and TSOs, it is important to take under consideration the length of the regulatory period and the location of the participant-installations; DSOs can highly benefit from DR programs that target customers at specific locations." transfer problems. Some countries are already investigating such benefits, by moving towards TOU⁴ distribution network tariffs as a first step of getting people to adopt RTP at a later stage. By using DR as a possible substitute for network investments in their network planning strategies, DSOs would be expected to reduce investments and thus reduce their CAPEX (i.e. depreciation and interest) in the short-term. At the same time, it could involve an increased OPEX depending on how the DR program is implemented and remunerated. If the CAPEX is included in the cap already, and the increased OPEX does not surpass this reduction, the DSO could make additional benefits. This would last until the end of the regulatory period, when the financial effects of investing less should be passed through to consumers by means of the update of the allowed revenue and the network tariffs. Therefore, both the incentive to carry out DR investments by DSOs and the transfer of these benefits to DSOs would be dependent on the length of the regulatory period and on the exact costs that were recognised as efficient costs to determine the allowed revenue for that regulatory period. Thus, to ensure the effectiveness of DR programs for DSOs and TSOs, it is important to take under consideration the length of the regulatory period and the location of the participantinstallations; DSOs can highly benefit from DR programs that target customers at specific locations. The value of controlling transmission network through DR programs also depends on the level of existing transmission capacity and generation fuel cost differentials.

1.4.2 Intermediaries: Retailers / Aggregators

In most cases, DR service providers are retailers or third party aggregators as those companies can use the flexibility as a tool to manage their customers' energy consumption more effectively and be financially rewarded by other actors (e.g. DSOs,

"Peak clipping as the main achievement of home automation lowers the need to invest in peak capacity which at the same time lowers the need to construct new power plants." TSOs) for it. At the same time, they can optimise sourcing costs as they will be able to purchase energy more effectively on the wholesale market. They can also save transmission costs by being able to use locally generated

⁴ Dynamic pricing schemes are described in Chapter 2.3.

energy to match local supply and demand. The flexibility provided by home automation can balance the unpredictability of renewable energy power plants, helping to integrate them into the grid. Additionally, peak clipping as the main achievement of home automation lowers the need to invest in peak capacity which at the same time lowers the need to construct new power plants. Although the size of the benefits depends on many uncertain factors, it is reasonable to expect that, as long as the number of consumers they represent is large enough, the commercial role of the retailer/aggregator would make for a positive business case.

1.4.3 Pillars of customer engagement

Research into customer engagement has revealed a set of clear steps that are required as part of the engagement process. These three pillars of engagement are summarised in Figure 7.

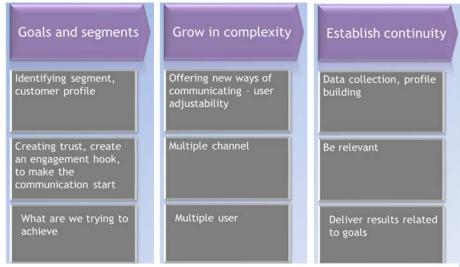


Figure 7: Three pillars of the customer engagement process

In all engagement processes the first step is to make clear what needs to be achieved (goals and segments). It is among the most common errors and misconceptions to skip this step or make some very high level goals which are impossible to meet or measure.

"Grow in complexity", the second critical success factor of consumer engagement is also the hardest. To keep people engaged the communication needs to grow with the consumer's increased understanding and as such deliver a kind of dialogue.

The third critical success factor is related to the ability to sustain the results and collect both consumption data and feedback from end-consumers to ensure they are satisfied and have the ability to improve the product based on first-hand experience. One important aspect in relation to this point is the often overlooked fact that participating consumers should be given regular feedback on the programme they are participating in - even if no event has occurred. Regular communication is key to establishing trust.

Market potential for home automation technology in Norway 1.5

There is no doubt that the past 10 years have seen a rapid development around home automation technology. Six-seven years ago, home automation was the talk of the town and everybody in the utility industry

believed the systems would pop up, plug and play ready, very soon – but it still hasn't happened. Even the largest industry believed the systems would energy event of the year; European Utility Week had its own pavilion for

"Six-seven years ago, home automation was the talk of the town and everybody in the utility pop up, plug and play ready, very soon – but it still hasn't happened."

Smart Homes where small start-ups – as well as the largest corporations – bloomed with promising technology and innovative ideas. By 2012/13 this movement experienced a sudden stop – and in the aftermath, it became clear, that there are a lot of barriers to overcome before home automation becomes a reality for the B2C mass market.



Figure 8: Smart Homes had its own pavilion in European Utility Week 2010 in Vienna

It should be mentioned however, that the business is still seen as having a bright future. As an illustration, market research company Statista expects revenues in the energy management segment of home automation technologies to grow at an annual rate of 20.6% between now and 2021; resulting in a market volume of US\$78m (US\$161 per active household) for Norway alone. The graph below shows projections made by the same company regarding the market penetration of home automation technology in Norway until 2021. 21% of Norwegian households (about 0.5 million households) are

expected to have energy management home automation technology by 2021 up from 5% today.

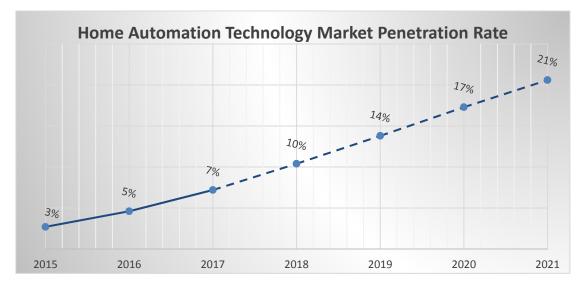


Figure 9: Market penetration of home automation technology in Norway 2015 – 2021 (Source: Statista 2016)

2 Potential of home automation for EE and DR

This chapter investigates the potential of home automation to manage and reduce electricity consumption in the Norwegian context.

2.1 Methodology

VaasaETT keeps an up-to-date database consisting of, at the time of writing, close to 140 EE and DR programs around the world, including 569 samples, and involving over 930,000 residential customers. The database compiles the findings of both feedback and dynamic pricing programs with and without appliance automation. The VaasaETT database is the largest of its kind. It is able to provide statistically robust quantified answers to questions related to the potential of home automation programs to reduce consumption levels and/or to manage consumption in time.

Various scenarios based on the data extracted from the database have been investigated. The relevance of the results was ensured by focusing a) on pilots that took place in conditions comparable and relevant to Norway i.e. high residential consumption and long heating season and b) on pilots that focused on the most electricity consuming appliances found in Norwegian homes. The scenarios comprised three broad features – all of which are important aspects of home automation projects:

Dynamic tariffs ⁵	Home technology	Behavioural change
ТОИ	Electric heating/Heat pump	Consumption feedback
CPP/CPR	Electric water boiler	Engagement and education
RTP	White goods	

To answer the research question, the following information was extracted from the database:

- Change in overall consumption (% kWh);
- Change in consumption during peak hours (% kWh)⁶;
- Change in consumption following peak hours (% kWh).

⁵ Dynamic pricing schemes are described in Chapter 2.3.

⁶ We report average consumption reduction over the whole peak period when peak prices are in force. The duration of the peaks differs depending on the pricing scheme. Peak price periods typically last between 1 and 3 hours for CPP, CPR and RTP pilots and between 3 and 12 hours for TOU pilots.

As can be imagined, not all pilots researched all scenarios and all parameters. This means that the sample sizes on which our results are based vary. To help the reader, the number of household participants and the number of samples are indicated under each corresponding graph.

2.2 Overall pilot results

The graph below shows the impact of home automation technology on three key aspects of EE and DR: overall consumption reduction, peak consumption reduction and consumption immediately following peak hours.

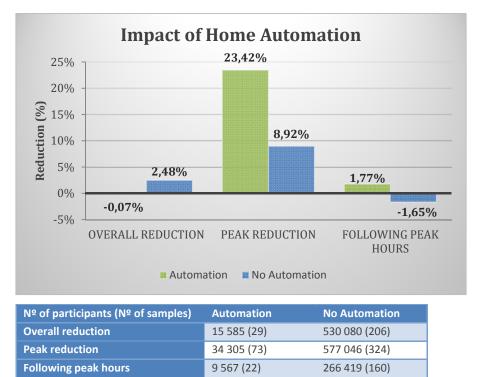


Figure 10: Impact of home automation on electricity consumption (Source: VaasaETT Database 2016)

Interestingly, this graph shows that home automation alone often leads to increased levels of electricity consumption. Pilots with home automation led to a slight increase in overall consumption (-0.07%) whilst

pilots without home automation technology (manual response to dynamic pricing and or consumption feedback) "If automation stands alone, there is a risk of disengaging people and actually increase their overall consumption." led to sizeable reductions in overall energy consumption (2.48%)7.

Pilots with automation are nevertheless clearly more effective at shifting consumption away from peak hours. There are several reasons for it. Even though consumers should always be allowed to overrun the program, automation enables fast reactions as well as controllable levels of reduction and has the advantage of being available during

"Home automation is more effective at shifting peak consumption and managing the pace at which appliances are brought back on line." unplanned system emergencies for instance. In addition, critical situations do not always occur when residential consumers are able to take action (when they are away or asleep for instance). Another important consideration for grid operators is that without automation they risk

seeing millions of appliances come back on line at the same time right after high-pricehours end. Automation can help mitigate this risk by switching appliances back on in cycles. This is also supported by the graph as consumption surrounding peak hours slightly decreases in pilots with automation whilst it increases in pilots without automation.

2.3 Effectiveness of dynamic tariff schemes

Dynamic pricing is one of the most proven ways of enabling demand flexibility. When looking at different dynamic pricing schemes and the added value of home automation, the results are straightforward. As shown by Figure 11 above, ignoring RTP, home automation improves the results of pilots by 75-172%.

⁷ Chapter 2.5 sheds light on why this might be

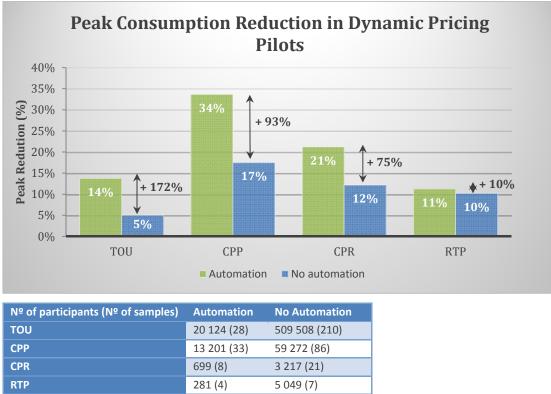


Figure 11: Consumption reduction at peak times (Source: VaasaETT database 2016)

It is important to keep in mind that TOU and RTP peak consumption reductions are the lowest but they occur daily, whilst CPP and CPR produce the highest reductions but only for critical peak periods, typically 12-15 times a year. It is however possible to combine TOU with CPP or CPR.

2.3.1 CPP – Most effective for peak shifting

CPP involves substantially increased retail electricity prices typically triggered by heightened consumption or when the stability of the system is threatened. The number and the length of critical peak periods which the utility is allowed to call are agreed upon in advance, when they are to occur is not. Residential customers are usually notified a day in advance if the next day will be a critical day, but if automation technology is provided, these rates can also be activated on the same day. CPP is very effective at cutting peaks – and it is clear that automated solutions work better.

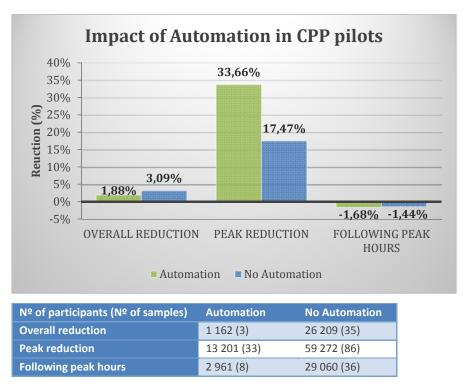


Figure 12: Impact of home automation in CPP pilots (Source: VaasaETT Database 2016)

2.3.2 CPR – More rewarding for consumers but less effective than CPP

CPR are inverse forms of CPP tariffs. Participants are paid in accordance to the amounts that they reduce consumption below their predicted levels during critical peak hours. Participants to CPR pilots usually receive a payment after each critical peak period or a deduction on their next bill. This direct payment or discount is believed to present the advantage of making the reward of participants' efforts more concrete than the concept of savings which might be less easily perceived. As for CPP, the number and the length of critical peak periods which the utility is allowed to call is agreed upon in advance although when they are to occur is not. The graph below shows that CPR is less effective than CPP at shifting consumption away from peak periods both with automation and without automation. However, as consumers are rewarded for decreasing consumption, rather than punished for consuming at certain time, CPR might constitute a more acceptable form of dynamic pricing, thus achieveing greater market penetration and a greater global impact.

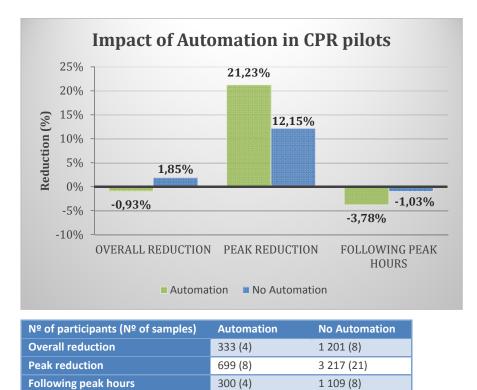


Figure 13: Impact of home automation in CPR pilots (Source: VaasaETT Database 2016)

2.3.3 TOU – Effective but lacks flexibility

TOU tariffs induce people into using electricity at times when consumption is lower. Prices are therefore set higher during the higher consumption periods of the day, and lower during the rest of the day and on weekends. They can have two (peak and off-peak prices) or three (peak, partial peak and off-peak prices) levels of prices per day which

are always the same. This lack of flexibility makes them rather unfit going forward with an ever higher penetration of intermittent generation unless they are coupled

"TOU can be coupled with CPP or CPR to achieve daily peak clipping while maintaining the ability to deal with unforeseen stress on the grid"

with CPP or CPR prices. As is seen from the results below, the impact on peak consumption is the lowest of the tariff schemes analysed; however, unlike CPP and CPR these effects take place daily.

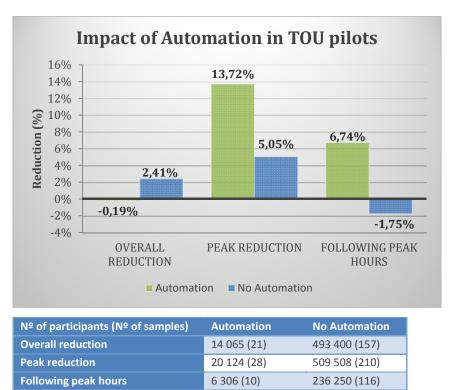


Figure 14: Impact of home automation in TOU pilots (Source: VaasaETT Database 2016)

2.3.4 RTP – a tariff scheme for the future?

With the introduction of smart meters, more advanced tariff schemes have been tested. One such tariff is RTP. Price development on the wholesale market are passed on to consumers – normally by the hour. In order to further encourage reductions during high price periods and reduce risk of high bills, participants are warned when wholesale prices reach a certain threshold decided upon in advance. Unfortunately, only few RTP

"As tariffs become more dynamic, customer involvement becomes more necessary to secure success." pilots have been conducted, hence the results below should be taken with caution. They are nonetheless very important as a vast majority (70%⁸)

of household customers in Norway are already on spot-tied contracts (a basic form of RTP) and it would thus make sense to assume these households will adopt RTP once smart meters are deployed.

⁶ Statistics Norway (2016).

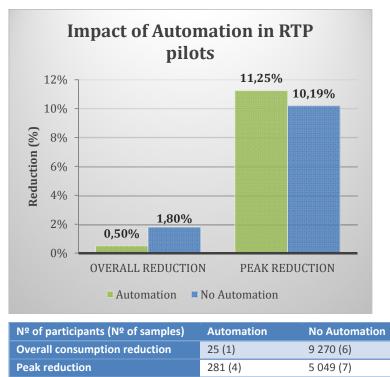


Figure 15: Impact of home automation in RTP pilots (Source: VaasaETT Database 2016)

2.4 Automating the usage of home appliances

The table below shows the breakdown of electricity consumption in Norwegian homes by appliance. Based on this information, we investigated the potential of automated electric heaters/heat pumps, electric water boilers and white goods (e.g. freezer, fridge, etc.) for DR (peak consumption reduction) and EE (overall consumption reduction).

Appliances	Electricity consumption	
	(kWh/year)	
Electric heaters	2,387	
Electric floor heating	1,268	
Individual central electric heater (possibly also oil, wood)	3,304	
Electric water heater	2,955	
Lighting, number of spots > 20	1,289	
Refrigerator	1,076	
Fridge-freezer	1,093	
Freezer	1,509	
Tumble dryer	890	
Washing machine	1,575	
PC	1,626	
Swimming pool etc.	5,967	
Various electrical equipment	3,028	

Figure 16: Appliance Consumption in Norway, kWh per year (Source: Dalen and Larsen 2013)

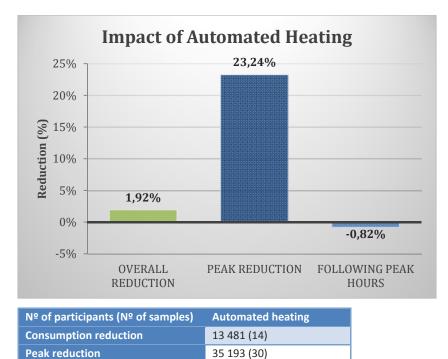
2.4.1 Electric heating and heat pumps

Norway is one of the few countries where electricity is the main heating source for households. According to Statistics Norway, electricity accounts for about 73% of household heating – and air heat pumps alone about 21%. Norway has seen a huge growth in the number of heat pumps which might be due to the fact that conventional electrical heating panels are the most used source for heating. In 2012 conventional heating panels were the primary heating source in almost half of Norwegian households. At the same time 27% of all households had a heat pump (+9% since 2009). Especially detached houses and farmhouses invest in heat pumps.

As heat pumps are driven by electricity, there is rarely a decrease in electricity consumption if a household changes heating source to a heat pump from oil or gas, but households with a heat pump use proportionally less energy than similar homes without a heat pump. According to Statistics Norway households living in 150 m² consume 3,900 kWh less electricity when heated by a heat pump than with other heating sources. For

villas between 100 and 150 m² the difference is around 1,900 kWh. With electricity as the primary heating source, peak consumption is closely related to the weather, it thus makes sense to consider electrical heating and heat pumps as a source of flexibility.

The figure below shows the impact of automated heating on electricity consumption. Pilot results indicate that overall electricity consumption was reduced by 1.9%, peak consumption by 23% and surrounding peak consumption increased by about 0.8%.



11 712 (8) Figure 17: Impact of automated electric heating. (Source: VaasaETT Database 2016)

2.4.2 Electric water boilers

Following peak reduction

Electric water boilers are among the most electricity consuming appliances in Norwegian homes. They are also intuitively very suitable for flexibility as water can be heated during off-peak hours and remain warm as the boiler is switched off during peak hours thus making the loss of comfort almost imperceptible to consumers. This is not a new technology but one that has seldom been put to use. An exception is France where the load of 10 million water heaters (representing 3 GW) is currently automatically shifted away from peak hours to night time (off-peak hours). The figure below shows the impact of automated water boilers on electricity consumption. Pilot results show that overall electricity consumption was reduced by 3.2%, peak consumption by 24% and surrounding peak consumption increased only about 0.6%.

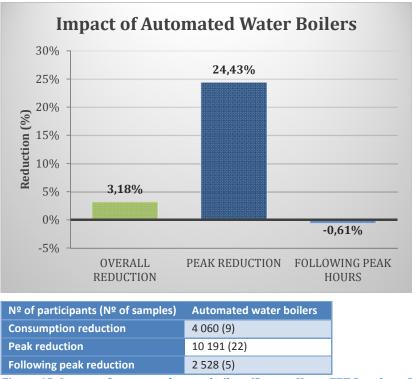


Figure 18: Impact of automated water boilers (Source: VaasaETT Database 2016)

2.4.3 White goods

As shown in Figure 16, a number of smaller appliances that can be grouped in the category of white goods (i.e. refrigerator, freezer, tumble dryer, washing machine, dish washer) represent a significant proportion of electricity consumption in Norwegian homes - especially in rural areas where people don't have access to shared facilities. The figure below shows the impact of automated white goods on electricity consumption; overall electricity consumption increased by 1.7%, peak consumption decreased by 26% and surrounding peak hour consumption increased by about 0.6%.

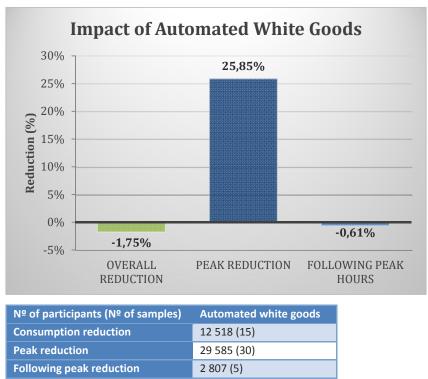


Figure 19: Impact of automated white goods (Source: VaasaETT Database 2016)

The results exhibit one of the fundamental differences between for instance an automated electric heater and an automated washing machine. While the former's consumption can be both shifted

"Automating white goods is well suited for peak clipping, not for energy efficiency."

(turn on or off) and optimised (turn up or down), the latter's can only be shifted (laundry needs done at some other time) which may be why automated white goods seem well suited for demand flexibility but not for EE.

2.5 Education and feedback in home automation pilots

Figure 10 points to a crucial finding: home automation alone tends to have an adverse effect on households' overall energy consumption. Pilots with home automation saw a slight increase in overall energy consumption (+0.07%) whilst pilots without home automation (manual response to dynamic pricing and/or feedback programmes) led to significant reductions (-2.48%). Although it might appear counter-intuitive, this finding is in fact consistent with behavioural science. Indeed, while some would argue that there is no point trying to engage and educate customers who have automated appliances, pilot results show that when efficiency improvements come solely from the technological side, people remain passive actors, leading to low levels of awareness,

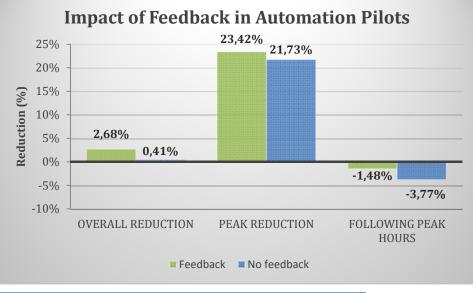
continued inefficient habits and behaviours and well documented rebound effects. In other words, home automation is well suited to shift consumption away from peak hours but not to create reductions in overall consumption. Similar findings were reported for dynamic pricing pilots. (c.f. Figure 4.)

The graph below quantifies the effect of education and feedback (in other words make use of the data generated by the home automation system to reduce overall energy consumption) on pilot results. Pilots

combining home automation and education/feedback are more effective at reducing both peak (23% vs 22%) and

"Education and feedback help reap the full benefits of home automation technology."

overall consumption (2.7% vs. 0.41%). Feedback and education are therefore crucial to reduce the quantity of energy consumed in the home and reaping the full benefit of home automation technology.



Nº of participants (Nº of samples)	Feedback	No feedback
Overall reduction	25 495 (30)	228 (3)
Peak reduction	22 906 (49)	7 278 (17)
Following peak hours	4 901 (11)	1 670 (6)

Figure 20: Impact of feedback on home automation pilots (Source: VaasaETT Database 2016)

A positive business case and an appealing payback time are other fundamental reasons why education and feedback should be part of any home automation package. VaasaETT and Joule Assets, in an upcoming public report, looked at the business case for residential demand side flexibility in 4 EU countries (France, UK, Italy and Germany) and found that between 77% and 87% of end-consumers' financial benefits come from overall consumption reductions (the rest from peak clipping). This can be easily 39 understood if one considers the fact that critical peaks take place for only about 30

"Coupling home automation with feedback is the best way to secure sizeable financial benefits for the grid and consumers both." hours a year whilst benefits from lowering overall electricity consumption take place daily. Offerings with both DR and education/feedback are the best way to secure financial returns for both grid operators and consumers.

Most Norwegian retailers already offer consumers access to granular consumption data in the forms of enhanced bills, IHDs, mobile apps and dedicated web portals as a way to differentiate their offerings, move competition away from prices and establish a trustbased relationship with customers⁹.

⁹ Smart meters are seen as necessary to provide feedback and enable DR. Mass roll out is currently ongoing in Norway and will be completed by January 1st 2019.

3 Impact of home automation on electricity consumption in Norway

This chapter investigates the effects of home automation technology combined with dynamic pricing and feedback on Norwegian household's electricity consumption and their aggregated impact at national level. Impacts were modelled for different household types, time periods and under different scenarios for market adoption.

3.1 Characteristics of household electricity consumption in Norway

According to Statistics Norway, the residential segment of the market consists of 2.3 million households, consuming an average of 16,044 kWh per year (the highest in Europe). Figure 21 shows the electricity consumption by house type. Detached houses are the most energy-intensive house type, with an average energy consumption that is more than twice that for apartment buildings. This is due to a larger dwelling area, more exterior walls and, often, more household members than in an apartment.

Type of housing		Annual consumption 2012
Detached house	*	20 211 kWh
Row house		14 975 kWh
Flat		8 953 kWh
Average household		16 044 kWh

Figure 21: Electricity consumption by type of housing, 2012 (Source: Statistics Norway)

Total net electricity consumption amounted to 120 TWh in 2015, a 2.6% increase compared to 2014 with household and agriculture roughly accounting for a third of it. Electricity is the primary energy source for Norwegian households as shown by Figure 22. It also shows that whilst household energy consumption has decreased since 2006 (mostly due to lower usage of oil and kerosene) electricity consumption has slightly increased.

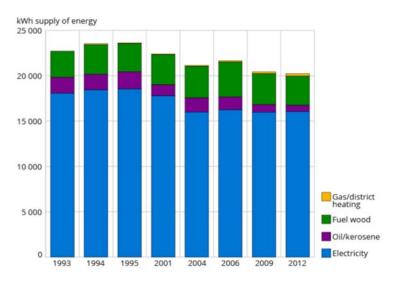


Figure 22: Household's Energy Use in Norway (Source: Statistics Norway 2014)

The high penetration of electric heating (c.f. Chapter 2.4.1) makes national electricity consumption very temperature dependant and high peak consumption can occur on abnormally cold winter days. The graphs below show the hourly load curve (weekdays upper graph and weekends lower graph) month by month. Logically, consumption is highest during winter months.

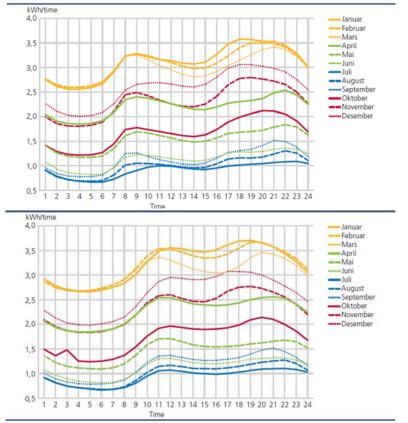


Figure 23: Seasonal Variations in electricity consumption, weekdays and weekends (Source: Statistics Norway 2008)

Figure 24 shows the distribution of the annual electricity consumption of end-use appliances. As can be expected, heating is consistently the largest contributor to daily consumption; 45% of electricity consumption is due to space heating. The rest is divided into hot water 12%, lighting 5%, other appliances 19% and residual 19%¹⁰,

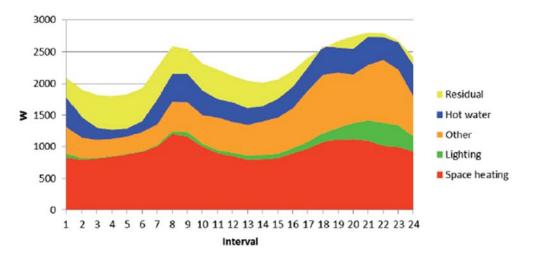


Figure 24: Estimated yearly average demand during workdays segmented into main end-use groups (Source: ECEEE SUMMER STUDY proceedings 2013)

3.2 Methodology and assumptions

The impact of home automation combined with dynamic pricing and feedback on Norway's households and national consumption were based on the following assumptions:

- Consumer feedback and education are crucial to reap the full benefits of home automation. Given that smart meters will be deployed in Norway within 2 years, we assumed feedback and education to be part of home automation offerings and thus took into account their impacts in our analysis;
- VaasaETT's database of feedback pilots (132 samples) shows an average overall electricity consumption reduction of 7%. This number is used to measure the impact of feedback on overall electricity consumption;
- Market penetration rates of 17%, 48% and 78% were assumed for home automation technology corresponding to the years 2020, 2030 and 2040 respectively. These figures were based on projections for the year 2020 (c.f.

¹⁰ Non-identified load that could not be linked to any appliance by the researchers.

Figure 9). A linear regression was performed to extrapolate these predictions to later years;

- Currently about 70% of Norwegian households are on spot-price tied contracts (a basic form of RTP tariffs). It therefore seems safe to assume 70% of household consumers will have RTP once smart meters are deployed. Thus, in our modelling, the impact of automated RTP were assumed for 70% of households with home automation. The combined impacts of TOU (daily) and CPP/CPR (critical peak days only) were in turn assumed for the remaining 30% of households with home automation;
- Peak consumption is defined as high consumption hours at national level during which peak prices would be in force. Reduction in peak hour consumption refers to the reduction in consumption over the duration of the peak;
- To remain conservative in our estimates, we assumed feedback does not influence energy savings during critical peak days for RTP and CPP/CPR schemes;
- Impacts in % were applied to 2015 national consumption levels and 2012 consumption levels for the different house types.

The table below summarises the impact assumptions for each combination of tariff scheme, home automation and consumption feedback based on findings from Chapter 2:

	Peak consumption reduction	Overall consumption reduction	Occurrence
RTP	11.25%	0.50%	Top 100 hours / year
ΤΟυ	13.72%	-0.19%	Daily
CPP/CPR	27.93%	0.20%	Top 30 hours / year
TOU+CPP/CPR	13.72% /	-0.19% /	Daily / Top 30 hours / year
	27.93%	0.20%	
Feedback	7%	7%	Each day for TOU and except critical
			peak days for RTP, CPP/CPR

Figure 25: Impact assumptions of tariff scheme, home automation and consumption feedback.

3.3 Impacts on annual electricity consumption

This subsection presents the results of the modelling on household and national annual electricity consumption.

3.3.1 Household annual consumption

Norwegian households could decrease electricity consumption by an amount equivalent to about 7% of their annual usage thanks to home automation, dynamic pricing, consumption feedback and consumer education. This amounts to 1,065 – 1,104 kWh per year for an average household depending on the dynamic tariff scheme. As can be anticipated, detached houses can save the most in absolute terms (kWh/year) due to higher consumption levels.

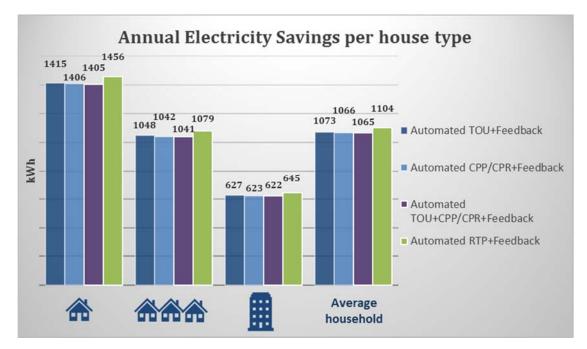
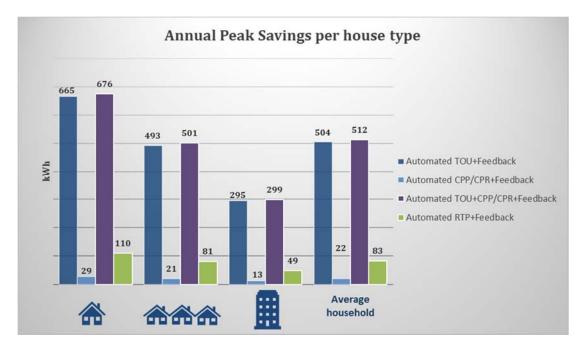


Figure 26: Impact of feedback and automated DR on annual electricity consumption

A similar impact on annual consumption can be observed across pricing schemes. This can be explained by the fact that overall consumption is mostly influenced by feedback and consumer education rather than by dynamic pricing (which targets peak consumption by passing on high wholesale prices or network constraints on to consumers).

When investigating the effects of home automation, dynamic pricing, consumption feedback and consumer education on annual peak consumption, the effectiveness of TOU stands out. An average Norwegian household with automated TOU could reduce consumption by an amount equivalent to about 14% of its annual peak consumption.

This is due to the fact that TOU impacts consumption daily whereas CPP and CPR impact consumption on critical peak days only (12 – 15 times a year). It is important to keep in mind that TOU, due to its rigid structure, lacks the flexibility to deal with extreme prices on the wholesale market or unexpected network constraints. (c.f. Chapter 2.3.3.) TOU and CPP (or CPR) can however be combined to retain the possibility to deal with unexpected events (CPP / CPR prices are triggered on critical days) whilst having a daily impact on peak usage (as TOU are in force every other day). In fact, our results indicate that a pricing scheme combining TOU and CPP/CPR works best at reducing annual peak consumption (512 kWh per year for an average household).





3.3.2 National annual consumption

Based on 2015 consumption levels and assuming 70% of Norwegian households with home automation are on RTP and the remaining 30% on a combination of TOU and CPP/CPR, our modelling shows that Norway's annual electricity consumption could decrease by 414 GWh (1.17%) and annual peak consumption by 85 GWh (2.31%) by 2020 when 17% of households have adopted a combination of home automation technology, dynamic tariffs and feedback. As market adoption of home automation technology increases, these figures could reach 1,142 GWh (3.22%) and 234 GWh (6.37%) by 2030.

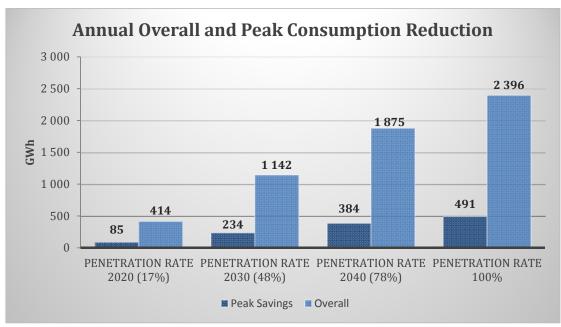


Figure 28: Impact on Norway's overall and peak electricity consumption

3.4 Impacts on the highest electricity consumption month

This subsection presents the results of the modelling on household and national electricity consumption during the highest consumption (also coldest) month of the year 2015; January. Based on national consumption levels, this month alone would have seen 4 critical peak days (triggering CPP/CPR prices) and 33 out of the 100 peak hours assumed for RTP.

3.4.1 Household highest consumption month

An average Norwegian households could decrease electricity consumption by an amount equivalent to 6.57 – 7.75% of its usage on the highest consumption month of the year thanks to home automation, dynamic pricing and consumption feedback. This amounts to 134 - 158 kWh depending on the dynamic tariff scheme. Findings are very similar to the findings detailed in the previous section. Detached houses can save the most in absolute terms (kWh/year) due to higher consumption levels. Impacts are similar across pricing schemes.

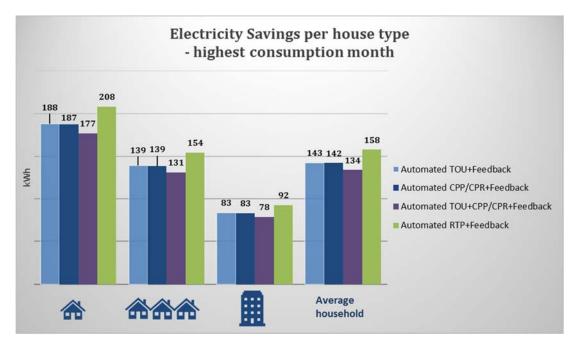


Figure 29: Impact of feedback and automated DR on highest consumption month electricity consumption

Again, the effectiveness of TOU stands out. Norwegian households with automated TOU could reduce consumption by an amount equivalent to about 13.7% of peak consumption during that month. TOU and CPP/CPR combined provides the most flexibility (10 – 67 kWh or 14% for an average customer).

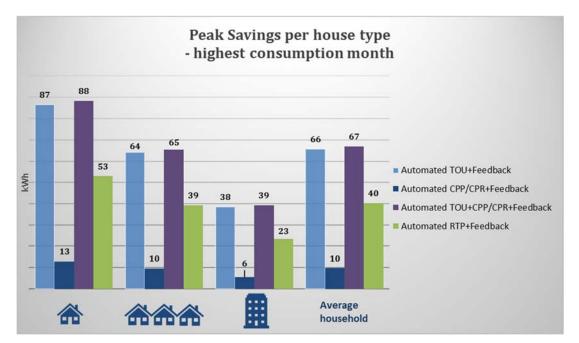


Figure 30: Impact of feedback and automated DR on highest consumption month peak electricity consumption

An interesting finding relates to CPP and RTP. Whilst CPP led to peak consumption reduction of only 0.59% on an annual basis, it led to 2.03% peak consumption reduction during the highest consumption month of the year. The effect is even more pronounced for RTP. Whilst it led to peak consumption reduction of 2.27% on an annual basis, it led to 8.39% peak consumption reduction during the highest consumption month of the year. This again points towards the fact that more flexible dynamic pricing schemes are more effective at dealing with household peak consumption. Chapter 3.5 will make this even more explicit.

3.4.2 National highest consumption month

Our modelling shows that Norway's electricity consumption could decrease by 50 GWh (1.05%) and peak consumption by 20 GWh (4.09%) by 2020 when 17% of households have adopted a combination of home automation technology, dynamic tariffs and feedback during the country's highest consumption month of the year. As market adoption of home automation technology increases, these figures could reach 137 GWh (2.90%) and 54 GWh (11.27%) by 2030. Savings from the highest consumption month alone represent 12% of the annual overall saving potential and 23% of annual peak clipping potential. It would thus be worth considering a special focus and special incentives during this time of year, especially as Norwegians are already aware through their spot-price tied contracts that prices and consumption are higher during winter months.

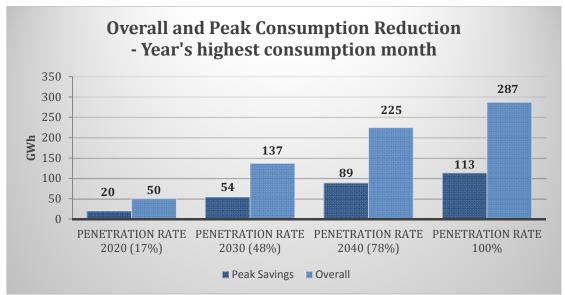


Figure 31: Impact on Norway's highest consumption month of 2015

3.5 Impacts on the highest consumption day

This subsection presents the results of the modelling on household and national electricity consumption during the highest consumption day of the year 2015 - January 2nd 2015. On this day, CPP peak prices and CPR rewards would have been in force and RTP customers would have been informed of high prices on the wholesale market.

3.5.1 Household highest consumption day

CPP involves substantially increased electricity prices during times of heightened consumption or when the stability of the system is threatened. CPR are inverse forms of CPP tariffs in which consumers are paid for the electricity they did not use during critical peak times. By contract, such events can typically occur 10-15 times per year. Although, the impact on annual consumption are limited, CPP and CPR are very effective at lowering critical peak consumption. This is illustrated by the graph below; an average Norwegian household on CPP/CPR pricing could lower peak consumption by 2.37 kWh (28%) on the highest consumption day of the year.

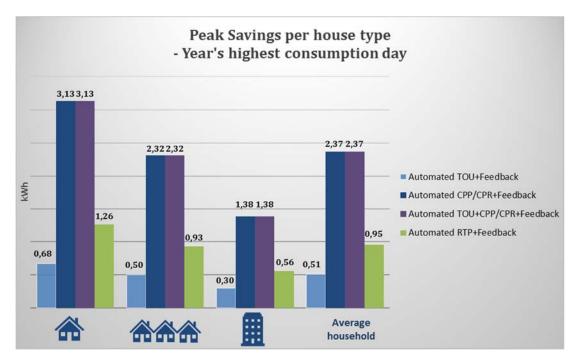


Figure 32: Impact of feedback and automated DR on highest consumption day peak electricity consumption

3.5.2 National highest consumption day

Our modelling shows that home automation technology, dynamic tariffs and feedback could lower Norway's electricity peak consumption by 0.46 GWh (10.65%) by 2020

when 17% of households are equipped during the country's highest consumption day of the year. By 2030, with a market penetration of 48%, peak consumption could decrease by 1.27 GWh (29.36%) on that day.

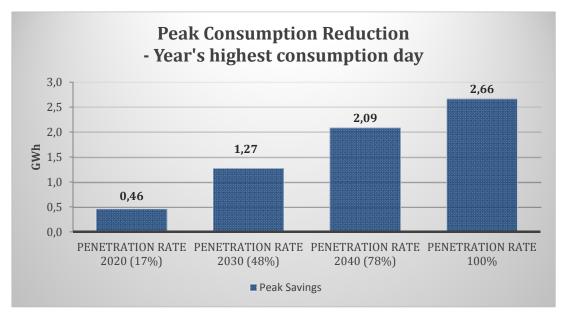


Figure 33: Impact on highest consumption day of 2015

3.5.3 Impact of automated electric heating

The graph below stresses the importance of automated electric heating for managing Norwegian peak consumption. On Norway's highest consumption day, electric heating would account for over 43% of the country's potential for residential peak consumption reduction.

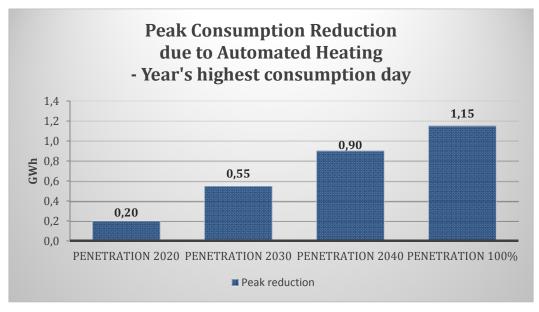


Figure 34: Impact of automated heating - highest consumption day 2015

4 State-of-the-art home automation projects

4.1 New Equipment

Some technologies such as automated heating and AC are well proven. The potential of these technologies is thoroughly investigated in Chapter 2. The industry has recently seen an influx of what we call the 2nd generation of home automation technologies. As the 1st generation was focused on one or two appliances in the home, the 2nd generation addresses many more appliances, which are more complex and have much deeper impact on everyday life. Thus, in order to understand the full potential of home automation going forward, we also need to understand the potential of technologies which are not so well proven yet, but which are undergoing a rapid development.

4.1.1 Geo-fencing – eliminating all stand-by

Geo-fencing is a virtual barrier. It uses different existing technologies like GPS in a mobile phone or an it is likely to enable the elimination RFID tag in a small piece of hardware to locate a person - or more precisely a device - according

"Geo-fencing has many practical uses, in relation to home automation of all stand-by use and ensure that all not intended energy use is cut when nobody is at home."

to positioning it in relation to a geographical location. Programs that incorporate geo-



Figure 35: The VERA geo-fencing home automation app

fencing allow the user or an administrator to set up predefined rules, so when a device enters (or exits) the defined boundaries, an action is triggered. Geo-fencing has many practical uses, with home automation it is likely to enable the elimination of all stand-by use and ensure that all unintended energy use is cut when nobody is at home.

Approximately 6,000 kWh or ¹/₄ of electrical consumption in Norwegian households can be attributed to lighting, PC's and miscellaneous other small electrical appliances (c.f. Figure 19), which geo-fencing would be able to address. In this respect the technology could prove to have the largest impact of all the technologies, since it comprises a lot of "small" uses into one comprehensible load.

4.1.2 EVs, roof top solar and storage – the future is decentralised

With Tesla's acquisition of SolarCity it became clear that solar, storage and Electric Vehicles (EVs) are a very powerful combination. This is even more true in Norway where hybrid and EVs have become very popular. Elon Musk's "master plan", which aims to provide customers with full-stack solutions for owning their own energy production, storage and consumption has also recently been hyped with the introduction of a solar roof tile which, for the first time, brings aesthetics and design into solar power.



Figure 36: Tesla Solar Roof Top designs

With regards to EVs; the latest sales figures for July 2016 show a 17% year-on-year growth rate. EVs made up 28% of new car registrations in Norway for the year through July. (EVObsession.com)

4.1.3 Customer-Led Network Revolution – multiple technologies



The Customer-Led Network Revolution project was a smart grid project led by Northern Powergrid in partnership with British Gas, Durham University, Newcastle University and EA Technology. The project involved monitoring the electricity consumption and generation profiles of around 13,000 domestic and SME customers, both with and without certain technologies (heat pumps, solar Photovoltaics (PVs), micro-combined heat and power, EVs). This is the largest sample of electricity customers' usage to have been undertaken in the UK and Ireland to date.

"EVs or heat pumps can effectively double the domestic load, so there is a strong case for encouraging off-peak EV charging behaviour at an early stage." The project introduced and tested smart meters and different forms of dynamic tariffs. TOU tariffs proved popular; the majority of the customers taking part in the trial saved money and used approximately 10% less electricity in peak

periods than customers on a regular tariff. Household chores such as laundry and dishwashing were the most commonly used to flex the times of electricity usage. Customers with PV were successful at adjusting their electricity usage to take advantage of their own generation and were arguably the most engaged customers of all. The project also concluded, that EVs or heat pumps can effectively double the domestic load,

so there is a strong case for encouraging offpeak EV charging behaviour at an early stage. Last but not least the project also concluded, that if the offered solution is too simple and lacks flexibility for the end-user it can miss the target.

"If the solution lacks flexibility for the end-user it can miss the target."

4.2 Nikola – EVs for Flexibility and Green Energy



Considering the growing number of EVs in Norway Danish project Nikola launched in 2013 may provide useful findings. Vehicle-to-Grid technology – in which EVs communicate with the grid to sell

DR services by either returning electricity to the grid or by throttling their charging rate - was tested to investigate EVs' potential in supporting a cost-efficient and secure power system with a high degree of renewable energy. EVs offer a very good flexibility potential as they are basically batteries offering high-power, fast-response and bidirectional capabilities. These properties can be used for flexibility while at the same time lowering the costs of owning an EV. The pilot shows that a typical nightly plugin lasts for around 13 hours of which only 4 hours are needed for charging. This indicates a high degree of charging flexibility. However, without having the owner connecting it to the power system for sufficiently long durations of times which are predictable and recurring it is hard to make substantial use of the capacity.

"EVs will only realise their full value as an asset for flexibility if owners are involved and willing to accept the automated re- and de-charging."

What is also interesting is that Nikola led to some of the highest financial savings for participants we have seen in a flexibility pilot indicating that DR services based on a high consumption / high flexibility asset (e.g. EV) can be very rewarding for households.

The project concluded that EVs will only realise their full value as an instrument for flexibility if owners are involved and willing to accept the automated re- and de-charging. In other words, the communication and the user interfaces play an important role for the success of such services.

"DR services using high load / high consumption assets (e.g. EV) can be very rewarding financially for household consumers."

THE NIKOLA PROJECT CONCLUDED THAT:

- The owner of the vehicle needs to be able to override any automated settings
- The service should suggest best charging times based on an analysis of user behaviour but any setting should always be accepted by the user.
- Engagement comes only with education. All service offerings need thorough explanations of pros and cons

4.3 Elsa – Energy Local Storage Advanced system



ELSA (Energy Local Storage Advanced system) is an energy storage project addressing local/small scale storage. From 2015 to 2019, ELSA will develop distributed storage solutions to maturity by combining 2nd life batteries with an innovative local ICT-based energy management system.

ELSA storage systems will be applied in six demonstration sites. In this respect the pilot doesn't have any result yet, but it is mentioned here, as it represents a clear trend in the most recent projects to focus on storage technology as part of home automation. Hence, the ELSA project focuses on developing technology that is already close to maturity and will be applied with different application contexts, covering services such as: grid congestion relief, local grid balancing, peak shaving, voltage support and regulation.

4.4 'Car on Toon' – Integrating Home and Car

Over a million smart thermostats have already been installed around Europe. These thermostats provide a natural hub for the integration of home and EVs. Eneco has been one of the most successful utilities in Europe in terms of the uptake of smart thermostats by its customers.



Figure 37: Eneco's Car on Toon integrated solution

Its service, Toon not only provides excellent consumption feedback own-solar generation and smoke alarm information to customers, but also controls smart plugs and lamps and learns customers' preferences and habits to intelligently control the heating of the home. Now it is evolving to incorporate EV, providing insight into consumption and cost and providing the first step towards a home energy management system that extends beyond the home. Integration of car and home into the feedback, control and automation eco-system is imminent.

4.5 WEREL – Bringing it Together

Ultimately the more elements of the future are brought together, the greater the benefits for the consumer. Home energy management, smart home, solar, storage, EV and communities will ultimately all work together through the Internet of Things, mostly discretely in the background through automation and - increasingly - artificial intelligence. One of the first steps towards this integration can be seen in the newly released WEREL offering in Sweden. WEREL provides homes with a financed solar and

storage solution that intelligently works together with other homes to buy energy from and sell energy to those other homes, through the wholesale market. The result is a community of distributed



energy homes that can either use their energy for independence or sharing. The supplier, WEREL also acts as a traditional retailer, providing the homes with energy that they cannot either produce themselves or buy from the others in the community. This is just the first step in a bigger vision of WEREL, but over time, as the community grows, solution efficiency evolves, the homes become ever more automated, and EVs and other community resources become integrated, the automation of the components within this exciting architecture could lead a situation where communities no longer need to buy their energy from retailers at all.

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