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Home Energy Management Systems

A Research Study on the European and Nordic Market

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Abstract

Global energy consumption has more than doubled since the year of 1990, leading to energy efficiency and management becoming increasingly important topics on the sustainable development agenda. Home Energy Management Systems (HEMS) is a solution combining hardware and software for managing, measuring and analyzing residential energy consumption and in effect addressing the issue of increased energy expenditure. This report aimed to assess the current market for HEMS in Europe and in the Nordics, and how these markets might develop in the future, to enable KTH Live-in Lab to be in the forefront of smart building development by providing them with potential strategic business partners.

With a literature review of earlier research on HEMS as a basis, a market study was conducted in combination with qualitative interviews with key market operators. Active companies, regulatory institutions and ongoing industry initiatives were identified, showing a large number of different available HEMS solutions provided by companies of varying sizes, and a number of market operators and ongoing initiatives affecting the current and future market. Porter's Five Forces Model was applied, exhibiting an intense threat of new entrants to the market and currently high market profitability. A number of drivers of market development were identified, such as the roll out of smart electricity meters and environmental consciousness, as well as barriers to market development, such as lack of financial incentives and data privacy issues. Moreover, the market for HEMS was predicted to grow, especially in the Nordics, due to the region being in the leading edge of sustainable development, electric vehicle deployment and local electricity production. Lastly, KTH Live-in Lab is proposed to collaborate with market operators across the value chain and from all parts of the ecosystem, to fully leverage the potential benefits and energy optimizing possibilities of HEMS.

Sammanfattning

Den globala energikonsumtionen har mer än fördubblats sedan år 1990, vilket har medfört att energieffektivisering och energiförvaltning har blivit allt viktigare punkter på agendan för hållbar utveckling. Home Energy Management Systems (HEMS) är en lösning som kombinerar hårdvara och mjukvara för förvaltning, mätning och analys av energianvändning i hushåll och därmed adresserar problemet med ökande konsumtion av energi. Denna rapport syftar till att kartlägga och bedöma den rådande marknaden för HEMS-lösningar i Europa och i Norden, och hur dessa marknader kan komma att utvecklas i framtiden. Detta för att möjliggöra för KTH Live-in Lab att vara i framkanten av utvecklingen av smarta byggnader, genom att förse dem med potentiella, strategiska samarbetspartners.

Med en litteraturstudie av tidigare forskning om HEMS som utgångspunkt, har en marknadsstudie genomförts i kombination med utförande av kvalitativa intervjuer med nyckelaktörer på marknaden. Aktiva företag, reglerande institutioner och pågående branschinitiativ identifierades, vilket påvisade flertalet tillgängliga HEMS-lösningar från leverantörer av varierande storlek, samt ett stort antal marknadsaktörer och pågående initiativ som påverkar den rådande och den framtida marknaden för HEMS-lösningar. Porters femkraftsmodell applicerades, vilket påvisade ett stort hot från nya marknadsaktörer samt god lönsamhet på den rådande marknaden. Ett antal pådrivande aspekter till marknadsutveckling identifierades, bland andra utrullningen av smarta elmätare och miljömedvetenhet, samt hinder till marknadsutveckling, bland andra brist på finansiella incitament och bristande dataintegritet. Dessutom förutsågs marknaden växa, framför allt i Norden, till följd av regionens starka ställning inom hållbar utveckling samt framväxten av elbilar och lokal elproduktion. Slutligen föreslås KTH Live-in Lab samarbeta med aktörer från alla delar av värdekedjan för att maximera potentiella fördelar och energioptimerande möjligheter med HEMS.

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List of Figures

Table of Contents

1. Introduction

1.1 Background

The resources of the world are being consumed at an unsustainable pace and increased carbon dioxide emissions and rising temperatures are clear signals that overall climate change is an urgent matter. Due to the dramatic development, sustainability has risen on the world agenda during the last centuries, even more so when the global journey to sustainability was accelerated in 2015 as the Sustainable Development Goals (SDGs) were agreed upon. The 2030 Agenda for Sustainable Development[1], divided into the 17 SDGs, provide a clear path for achieving ecological, social and economical sustainable development on a global level. In order to work towards more sustainable processes in industries, societies and in everyday life, a responsible usage of resources is central. This includes both reducing the usage of resources and utilizing resources in a smart and sustainable way. For both matters, a well-managed energy system with a clean energy-mix is crucial. Two of the 17 SDGs, *Affordable and Clean Energy* (SDG 7) and *Sustainable Cities and Communities* (SDG 11), are therefore highlighted in this study.

During the last decades, overall technical evolution has gradually increased the human energy consumption. Both the everyday life for a majority of the world population and an overall future of sustainable solutions are fully dependent on electrical supply. Manual solutions are being replaced with digital solutions, and an increasing number of products and industries are being electrified. As a result, the total energy consumption in the world has more than doubled since 1990.[2] While the demand for energy has grown at such a rapid pace, optimization and energy management are subjects that have developed into central aspects of the energy sector. The goal has been to optimize the energy flow including both production and consumption, which has lead to Energy Management Systems (EMS) having a key role in the end-to-end value chain of the electricity network.

EMS is a set of hardware and software used to measure, monitor, control and analyze energy usage, and has existed in various energy markets for more than a hundred years. During the first years of the 20th century, the usage of night thermostats was present in many homes and can be considered as the first phase of EMS products. However, the true evolution began in the beginning of the 1970s[3], as limited energy supply and rising energy costs had become a concern for an increasing number of residents. During this time, the evolution of EMS was embraced by various companies such as General Electrics, Toshiba, Siemens and Hitachi, creating multiple products and solutions within the segment. Many of the products developed were in the segment of energy management within residential buildings, which came to be accumulated under the name of Home Energy Management System (HEMS).

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[1] UN. Sustainable Development Goals. 2015. https://sustainabledevelopment.un.org/sdgs (Accessed on 2020-03-31).
[2] IEA. Electricity final consumption, World 19*90-2018.* *https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20consumption&indicator=Electricity%20final%20consumption.* n.d. (Accessed on 2020-03-27).
[3] B. Asare-Bediako, et al. *Home Energy Management Systems: Evolution, Trends and Frameworks*. Eindhoven University of Technology. N.d.

In later years, HEMS has started to become the very intersection between the energy market and digitalization. Since the beginning of HEMS, the five main areas within HEMS have been and are to this day the possibility for a consumer to monitor, log, control, manage and alarm energy usage in its home. Following a rapid technical progress, HEMS systems have resulted in various functionalities ranging from demand management to peak shaving and load management.[4] As previously mentioned, companies have developed their respective offerings and the industry has grown significantly, resulting in 50+ companies offering HEMS products on the European market.[5]

Residential energy consumption makes up a substantial part of a nation-wide energy consumption. As an example, residential energy in the US is approximately 22% of the nation's consumption.[6] Therefore, measuring and optimizing energy usage is becoming an increasingly relevant topic for growing parts of the population. In addition, the overall HEMS market is estimated to have a strong growth and in Europe specifically, the annual growth over the next 5 years has been estimated to 25% by Delta-EE[7]. Even though the market growth points out a bright future, the question remains whether the power grid infrastructure, legislation and end users are equipped for an upscaling of the HEMS market.

1.2 Objectives

The aim of this report is to study and analyze the current Nordic and European market for HEMS, to be able to predict the future development of the market. By categorizing different products, applying an industry analysis tool and mapping out key players and ongoing initiatives, valuable insights and potential strategic business partners are to be provided for KTH Live-in Lab. The goal is to provide information of such kind that will enable KTH Live-in Lab to be in the forefront of smart building development.

The study will be carried out through a split approach combining a business and market analysis, with a technical approach addressing the components and features of HEMS. By combining the two, the aim is to provide an overall estimation on whether the HEMS market is ready to go live or not.

1.3 Research Questions

With regards to the aforementioned objectives, this study aims to answer the following research questions:

- What are the different types of HEM systems and products and their respective functionalities which exist on the European market, and more specifically in the Nordics, today?

[4] B. Asare-Bediako, et al. *Home Energy Management Systems: Evolution, Trends and Frameworks*. Eindhoven University of Technology. N.d.
[5] A. Jouannic, et al. *Accelerating the energy transition with Home Energy Management*. Delta-EE. 2020.
[6] J. LaMarche, et al. *Home Energy Management: Products and Trends*. Fraunhofer Center for Sustainable Energy Systems. 2012.
[7] Ibid.

- How might the HEMS market develop in the future and what are the drivers and barriers to this development?

- Which actors would be potential strategic business partners for KTH Live-in Lab, in order for them to be in the forefront of smart building development?

1.4 Scope

The scope of this study is limited to the European and Nordic market for HEMS, due to KTH Live-in Lab requesting potential business partners in the near geographic region. This report is also limited to electrical energy and its consumption, which puts topics such as water consumption of households, outside the scope of this study.

2. Methodology

The overall methodology of this study was based on the approach described in section 1.2, combining a business and market analysis with a technical approach. This combination is the common thread through all methodologies presented in this section.

2.1 Literature Review

The main part of this paper was built on a literature study of relevant material addressing HEMS. The literature study was carried out in four steps in line with a common literature review strategy, for instance applied and presented by the University of Guelph[8]. The first step was to narrow down the specific research area of this paper which resulted in a slimmed focus on HEMS, with primary focus on electrical energy usage in the home. The second step was a collection of scientific papers within the subject, and focusing on different aspects of HEMS, such as:

- Components of HEMS and their respective functionalities
- The effects of consumption feedback from HEMS
- Drivers and barriers to the advancement of HEMS
- HEMS trends and market development

The third step of the literature study was a systematic review of the papers with an evaluation of material presented and conclusions made. As a final step, the articles were clustered into categories as trends were identified and patterns found. By clustering the articles, a stronger foundation was built to enable a stable theoretical ground for the paper.

[8] University of Guelph. Write a Literature Review. https://guides.lib.uoguelph.ca/c.php?g=130964&p=5000948 (Accessed on 2020-03-18).

2.2 Qualitative Interviews

The research questions of this paper are to a large degree a snapshot of the current market and movements of HEMS. While a literature study capture a large portion of the previous and ongoing development of the market, interviews with actors on the market were considered value-adding, in terms of experience and insights into the HEMS market. Therefore, it was decided to conduct interviews where questions covering the current and future state of the market were asked. The parties included in the qualitative interviews were found through general research of the market, and subsequently added to a shortlist. Both operational and regulating actors, such as Tibber and the Swedish Energy Markets Inspectorate respectively, were included. As the shortlist was finalized, contact was taken with all actors included by finding contact details through websites or with help from our KTH supervisors. As a result, a total of four interviews were conducted, with interviews ranging from 30 to 60 minutes. The knowledge gained from the interviews formed a basis for this paper along with the material collected in the literature review. The interview results are summarized in section *5.2 Interviews*. All of the questions answered by the interviewees can be found in the appendix.

2.3 Market Study

Apart from reviewing earlier research on HEMS and conducting qualitative interviews, a market study was carried out. With the list of companies active on the HEMS market compiled by Delta-EE in their whitepaper *Accelerating the Energy Transition with Home Energy Management*[9] as a basis, the respective websites of the different companies were searched. Information was gathered regarding smart home solutions and associated functionalities, geographical market availability and other relevant information. Additionally, different regulatory institutions influencing the HEMS market and industry initiatives were researched. The collected results were structured in two different geographic regions, Europe and the Nordics, and are presented under section *5.1 Market Study* of this report.

2.4 Industry Analysis

Lastly, an industry analysis was performed by applying Porter's Five Forces Model[10] on the HEMS market. The analysis tool was applied to give a holistic business and strategy perspective on the current HEMS market and its potential development. The theoretical framework for the industry analysis is presented in section 4.1 of this report, and the results of the application of the model on the HEMS market is presented under section *5.3 Industry Analysis*.

[9] A. Jouannic, et al. *Accelerating the energy transition with Home Energy Management*. Delta-EE. 2020.
[10] M.E Porter. *The Five Competitive Forces that Shape Strategy.* Harvard Business Review. 2008.

3. Literature Review

The following literature review gives the reader a broad presentation of the individual components of HEMS and their respective technical functions, earlier research on the effects of HEMS with regards to consumption feedback, motivation, benefits and disadvantages as well as previous studies of the current market for HEMS and its development.

3.1 Components of a Home Energy Management System

The HEM system consists of a few key components; the central HEM unit, sensing and measuring devices, smart appliances as well as information and communication technology (ICT). These components are presented in the scientific papers *Home Energy Management: Products and Trends*[11] and *Home Energy Management Systems: Evolution, Trends and Frameworks*[12] and below follows a description of the individual components.

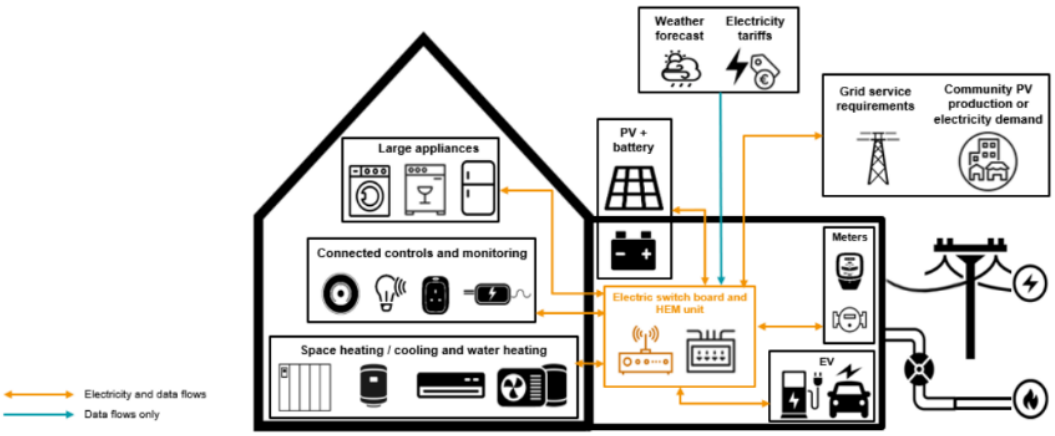

Figure 1 *- An Illustration of HEMS Installed in a Household and its Potential Functionalities.* [13]

3.1.1 The Central HEM Unit

The fundamental part of the HEM system is the central unit which all other components are connected to. The central unit constitutes both hardware and software. Some manufacturers deliver a display which is installed in the home of the customer, providing functionalities such as real-time feedback of consumption and household monitoring. Other manufacturers base their system solely on a mobile application, enabling remote control of your home and its appliances. Most manufacturers however, provide a solution combining the two alternatives. What all HEMS providers have in common is that data and feedback is presented in a visual

[11] J. LaMarche, et al. *Home Energy Management: Products and Trends*. Fraunhofer Center for Sustainable Energy Systems. 2012.
[12] B. Asare-Bediako, et al. *Home Energy Management Systems: Evolution, Trends and Frameworks*. Eindhoven University of Technology. N.d.
[13] A. Jouannic, et al. *Accelerating the energy transition with Home Energy Management*. Delta-EE. 2020.

and informative way, in different forms such as graphs, pie charts and notification alerts, so that the system is as user-friendly as possible.

The software of the central HEM unit is commonly based on artificial intelligence, enabling automated responses and decisions when changes in input parameters are sensed by the installed sensors and measuring devices throughout the house. More advanced systems enable forecasting and scheduling of consumption to avoid the hours when consumption on the grid is at its peak, so called peak-shaving.[14] This can be done from the consumer's perspective to lower electricity costs or from the TSO's perspective as a form of demand-side management activity. Systems with connected solar photovoltaics (PV) and storage units have the ability to optimize self-consumption, in terms of cost and grid distress, and maximize sales to the grid.

3.1.2 Sensing Devices

Sensors, with the ability to detect changes in different parameters, are crucial for the HEM system. Voltage, current, temperature and motion are examples of input for the sensing devices, input which is transmitted to the central HEM unit to act upon. Such input can for instance cause the HEM system to increase the overall temperature of a house when detecting a low temperature or turn on the lights in a specific room when someone is present. Other sensors not related to energy usage, but to health and safety concerns, are for example smoke and epilepsy detectors. Combining sensors ranging from energy usage to security, enables the HEM system to be transformed into an overall supervisor, monitoring all aspects of the home, making it a safe and energy efficient environment.[15]

3.1.3 Measuring Devices

Apart from sensing devices, other vital components of the HEM system are the different measuring devices. By measuring electricity, water and other consumption of energy sources over time, valuable insights on for instance consumption patterns and real-time usage can be presented to the user.[16] One particularly important measuring device for HEMS solutions is the "smart residential electricity meter"[17], which enables real-time communication between the consumer and the electrical utility company. With smart meters, energy consumption data is collected and updated at a higher frequency in comparison to old meters. Thereafter, when displayed to the user, it provides consumption feedback and enables dynamic electricity pricing models such as time-of-use tariffs or real time pricing. Such pricing models can be implemented to decrease peak demand and to smoothen daily energy consumption.

[14] ABB. Peak Shaving. N.d. https://new.abb.com/distributed-energy-microgrids/applications/energy-storage-applications/peak-shaving (Accessed on 2020-03-23).
[15] B. Asare-Bediako, et al. *Home Energy Management Systems: Evolution, Trends and Frameworks*. Eindhoven University of Technology. N.d.
[16] Ibid.
[17] J. Carrol et al. *Reducing Household Electricity Demand through Smart Metering: The Role of Improved Information about Energy Saving*. Energy Economics, 45, 2014. 234-243.

3.1.4 Smart Appliances

Sensing and measuring devices are main components of HEMS as they secure the ability to gain valid feedback, control and draw conclusions based on the information provided.[18] An essential condition to any smart home however, are smart appliances that are possible to integrate with sensing and measuring devices that form a HEM system.

The definition of smart appliances are typical in-home appliances such as refrigerators, ovens, dishwashers and TVs with a "smart" software. By retrofitting smart plugs to standard appliances, these can also be turned into smart appliances. The software enables the appliances to communicate with the system, enabling residential customers to monitor and remotely control devices.[19] One aspect is sending and receiving signals to and from the central HEM unit, which forms the feedback loop of the system, such as displaying the energy usage of the appliance. The extension of such feedback systems, is to use the data to form energy consumption patterns as a result of different household actions.[20] Another built-in capability of smart appliances is the possibility to communicate directly to the end user. One example is alerts via text messages or email, to notify the end user when energy consumption has exceeded a certain level.

Smart appliances of this type often require smart meters, however there are examples where appliances are able to take part of a HEMS setup without the usage of a smart meter. One example is a "smart dryer" produced by Whirlpool, which has an integrated communication system that enables the dryer to sync its heating and cooling cycles with the grid.[21] Concretely, the dryer executes heating cycles when the grid distress is low and cooling cycles when the grid distress is high. The result is load shifting which in a larger scale contributes to avoiding spikes in the electricity consumption.[22] Further functionalities enables scheduling for the appliance to run at desired periods.[23] The market has developed with time and for each year that passes new smart appliances are launched on the market. The result is that multiple appliances, from coffee machines to heat pumps, are available to integrate into a HEMS.

3.1.5 ICT (Information and Communication Technology)

The infrastructure of a HEMS is the communication between the components of the system. In the general case of HEMS, all the functions are handled through a software platform, where the Information and Communication Technology (ICT) is the bridge connecting the central

[18] J. LaMarche, et al. *Home Energy Management: Products and Trends*. Fraunhofer Center for Sustainable Energy Systems. 2012.
[19] Y. Liu, et al. *Review of Smart Home Energy Management Systems*. Energy Procedia, 104, 2016. 504-508.
[20] J. LaMarche, et al. *Home Energy Management: Products and Trends*. Fraunhofer Center for Sustainable Energy Systems. 2012.
[21] Ibid.
[22] Next Kraftwerke. What does Peak Shaving Mean? https://www.next-kraftwerke.com/knowledge/what-is-peak-shaving (Accessed on 2020-03-23).
[23] Y. Liu, et al. *Review of Smart Home Energy Management Systems*. Energy Procedia, 104, 2016. 504-508.

HEM-unit, measuring and sensing devices and smart appliances.[24] In addition, all communication between the user and the system is handled by the ICT which enables the user to take actions based on energy usage. In smart systems where patterns, optimal load scheduling and peak shaving is central, the ICT also plays a key roll to deliver the data to the central unit to optimize the system.

3.2 Earlier Research on the Effects of HEMS

Several attempts have been made to assess the effects of HEMS on energy consumption of households and to gain insight on motivation and consumption behaviour of users. There are numerous scientific papers on obstacles to adopting HEMS and what benefits of such adoption can be observed. Here follows a summary of the findings from reviewing earlier research on the subject.

The overall life cycle impact of HEMS has been studied by van Dam et al. in the paper *Do Home Energy Management Make Sense? Assessing their Overall Lifecycle Impact.*[25] Three different types of HEMS with increasing levels of automation and functionalities were analyzed, based on assumptions regarding production costs, potential savings and technical lifespan. The results showed that all three types of HEMS could reach net energy savings within their technical lifespans. However, this was dependent on how the user responded to consumption feedback, if the HEMS became obsolete during its lifespan and other factors which needed to be studied further. Whether HEMS was a good investment from a financial perspective was thus somewhat unclear according to the study of van Dam et al.

A one-year field study conducted by Nilsson et al.[26], on the influence of real-time feedback from HEMS in 154 households in a newly-built sustainable city district in Stockholm, Sweden, is yet another study which showed ambiguous results. After the introduction of a HEM system, electricity consumption decreased but simultaneously water consumption increased.[27] In comparison to many other studies, this particular study focused on a relevant population segment, high-income and highly-educated households, who were considered as early-adopters of new technology. This should have lead to more apparent positive effects of HEMS on decreased energy consumption according to the researchers, however this did not seem to be the case in this paper as there were differing results. The study also showed a wide variation between the participating households, implying highly individual response to feedback from HEMS.[28]

Additionally, interviews with the study respondents conducted by Nilsson et al. reported both benefits and obstacles with HEMS. Positive effects included increased awareness of standard energy consumption levels, increased understanding of unnecessary consumption and

[24] J. LaMarche, et al. *Home Energy Management: Products and Trends*. Fraunhofer Center for Sustainable Energy Systems. 2012.
[25] S.S. van Dam, et al. *Do Home Energy Management Systems Make Sense? Assessing their Overall Lifecycle Impact*. 2013. Energy Policy, 63, 2013. 398-407.
[26] Nilsson, et al. *Smart Homes, Home Energy Management Systems and Real-Time Feedback: Lessons for Influencing Household Energy Consumption from a Swedish Field Study*. Energy & Buildings, 179, 2018. 15-25.
[27] Ibid.
[28] Ibid.

increased home comfort. However, many of the respondents reported obstacles to behavioural change. Firstly, the respondents experienced a lack of knowledge of economic and environmental outcome of their energy consuming behaviour and alternatives to lower energy consumption. Secondly, the respondents reported a lack of sense of control, mainly due to consumption already being as low as possible, giving the respondents the feeling of not being able to do anything about their consumption. Lastly, the individual values and attitudes of the respondents were deeply rooted in their behaviour, for example justifying a well-deserved but highly energy-consuming bath.[29]

Another study conducted on some 5000 households in Poland, Portugal and the Netherlands by Kowalski and Matusiak[30], combined quantitative and qualitative research with a financial simulation of HEMS installation. The study showed that the dominant motivating factors for installing a HEM system were financial benefits and more specifically "guaranteed significant reduction of energy bills" as well as free installation and maintenance of the system. Ease of use and automatic control of household appliances were also reported as highly motivating for installing the system. Moreover, the study reported a high discrepancy between user's expected savings on energy bills and the actual savings simulated by the researchers. Users expected a much higher financial compensation compared to actual savings, which was one of the challenges to adoption of HEMS on a greater scale according to the authors of the paper.

Schwartz et al.[31] are yet another group of researchers who have studied the effects of consumption feedback on people's behaviour, by carrying out a living lab study of HEMS in seven households in Germany for 18 months. By developing an own HEMS for this specific study, with feedback provided through TV, PC, smartphone and tablet-based interfaces, the researchers explored "what people do with HEMS in daily life", which resulted in a discussion divided into nine different categories on the impact of HEMS on domestic life and its future design. The nine categories of the study are presented below.

The first category highlighted that the study participants were curious about their energy usage and named "real-time local information of energy consumption at point-of-use"[32] as the most important benefit to increased energy awareness. The second, third and fourth categories covered more social aspects of the impact of HEMS. Two different types of usage were observed; there was either one main user of the HEMS, the "energy expert", or there was a more collective use of the system, resulting in more communication and collaboration with regards to energy usage. The study also found that the HEMS educated the participants and made them more expressive and explicit when talking about energy usage, as well as identifying with the system and proudly demonstrating it for visitors. Category five and six of the study included a more functional approach to HEMS, where an overview of consumption and individual adaptation were reported as important tools to increase energy awareness. In

[29] Nilsson, et al. *Smart Homes, Home Energy Management Systems and Real-Time Feedback: Lessons for Influencing Household Energy Consumption from a Swedish Field Study*. Energy & Buildings, 179, 2018. 15-25.
[30] J. Kowalski, B.E. Matusiak. *End Users' Motivations as a Key for the Adoption of the Home Energy Management System*. International Journal of Management and Economics, 2019, 55(1). 13-24.
[31] T. Schwartz, et al. *What People Do with Consumption Feedback: A Long-Term Living Lab Study of a Home Energy Management System*. Interacting with Computers, 2015, Vol. 27 No. 6. 552-576.
[32] Ibid.

the seventh category of the discussion, the TV was named as the main display for monitoring energy usage of the household, mostly in connection to daily TV watching of the participants. The last two categories covered the challenges of misleading and misinterpreted data as well as how the HEMS actually caused energy-saving changes in the daily lives of the participants, such as replacing energy-wasting appliances and avoiding energy-inefficient behaviour. The future design of HEMS according to Schwartz et al., has to address the observed issues presented in the categories, and build on the observed benefits.

3.3 The Current HEMS Market and its Development

The current market for smart home technology has been outlined by for instance Ford et al.[33] and by B.K. Sovacool & D.D. Furszyfer Del Rio[34], on a US and European level respectively. The US study of Ford et al. from 2017 focused on HEM technologies specifically and data was collected from reviewing websites of key actors, internet searches of online markets, from personal contacts as well as media sites and newsletters. 308 different products were identified between November 2015 and April 2016, and the majority of the products were different types of smart plugs, lights and thermostats (100, 56 and 61 products respectively) and a number of in-home displays and load monitors were classified (19 and 11 products respectively). One limitation stated by Ford et al., is the rapidly changing HEMS market, as some 80 products disappeared and another 120 products were introduced to the market during prior studies from 2014 up until the current study.

The European study by B.K. Sovacool & D.D. Furszyfer Del Rio, covering 13 categories of smart home technology, identified 267 products available from 113 companies by conducting expert research interviews and UK-retailer site visits. Energy gas and utilities, safety and security as well as lighting were the largest product categories, with 51, 52 and 33 classified products respectively. Apart from collecting data on products and categorizing them, the study also provided a framework for assessing the level of smartness of a home, from a basic home without any smart technology (level 0), to an aggregated level where smart homes are interconnected into smart neighbourhoods, societies or cities (level 6). The development of smart homes is expected to go through these seven levels of smartness. Additionally, the study gathered opinions on benefits and risks with smart home technology from the conducted expert interviews. The most frequently mentioned benefits were energy savings as well as convenience and controllability. Among the most mentioned risks were privacy, security and hacking in addition to technical reliability and usability.

Furthermore, there are several researchers and institutes who have studied the HEMS market and identified different drivers and barriers to market growth and given their predictions on the future of HEMS. One of those institutes is Delta-EE, a leading research institute within the new energy industry, who provides clients with consultancy services such as expert advice and in-

[33] R. Ford, et al. *Categories and Functionality of Smart Home Technology for Energy Management*. Building and Environment, 2017, 123. 543-554.
[34] B.K. Sovacool, D.D. Furszyfer Del Rio. *Smart Home Technologies in Europe: A Critical Review of Concepts, Benefits, Risks and Policies*. Renewable and Sustainable Energy Reviews, 2020, 120.

depth analyses.[35] Delta-EE recently published a whitepaper on why the HEM-market is at a tipping point in Europe[36], where they give five explanations justifying this statement.

Firstly, there is a growing number of large electrical loads in European homes, such as EV charging points, solar PV systems and electrical heating solutions, increasing the self-consumption optimization and energy-saving potential of HEMS. Secondly, there is rapidly evolving legislation favouring HEMS usage. Smart meters with higher frequency readings, giving the consumer real-time consumption data, are being rolled out and time-of-use tariffs are gaining popularity, meaning dynamic electricity prices and thus incentives to shift consumption loads. Moreover, governments are gradually removing solar PV subsidies, which will benefit self-consumption as selling electricity to the grid will be less profitable, and the opening of flexibility markets, meaning consumers can momentarily decrease their electricity usage as a support service to the electrical grid, will further benefit the features of HEMS. Thirdly, access to value streams across the energy industry is increasing, where HEMS has the potential to harness the home values of self-consumption, dynamic electricity pricing (i.e time-of-use tariffs) and consumption within local energy communities. Fourthly, there is an increasing number of innovations within the long and complex value chain of HEMS. The value chain can be divided into three parts: a customer facing side, interoperability and communication as well as optimization of energy flows. Within each area, the number of active companies is growing and Delta-EE have identified at least 50 companies currently active in the overall HEMS market.[37] Lastly, Delta-EE predicts more than 2 million new installations of HEMS in European homes before 2023. Retrofitted systems are believed to be the key contributor to sales, as well as bundling new technologies (i.e EV charging points or solar PV systems) with the installation of a HEM system.

Besides Delta-EE, there are a number of researchers who have studied the development of the smart home market within specific geographic regions, one of which is the work of N. Balta-Ozkan et al.[38], who studied public views on technical and economic aspects of smart homes in the United Kingdom, Germany and Italy. Worth noting is the broader definition of a “smart home” used in the study, where energy management is one of the services delivered by the smart home, together with safety and lifestyle support.[39]

N. Balta-Ozkan et al. focused on a few distinct challenges with smart homes market development: retrofitting existing homes, interoperability (with different vendors and existing infrastructure), reliability, privacy and security, costs and lastly usability. By conducting a total of six workshops with participants from cities of different sizes, in different stages of life (pre-family, family and post-family), different income groups and different types of property (owners and renters of flats and houses) in the UK, Germany and Italy, the views on the different challenges posed by the researchers were gathered and a number of drivers and barriers to the potential of development of the smart home market were observed.

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[35] Delta-EE. About Delta-EE. https://www.delta-ee.com/aboutus (Accessed on 2020-04-07).
[36] A. Jouannic, et al. *Accelerating the energy transition with Home Energy Management*. Delta-EE. 2020.
[37] Ibid.
[38] N. Balta-Ozkan, et al. *European Smart Home Market Development: Public Views on Technical and Economic Aspects across the United Kingdom, Germany and Italy*. Energy Research & Social Science, 2014, 3. 65-77.
[39] Ibid.

Drivers observed in all three countries were the potential to reduce costs through energy savings as electricity prices increase and the potential of practical services and their ability to increase quality of life. In the UK and Germany, the environmental aspect of saving energy was highlighted and in Germany and Italy, transparency to gain additional information regarding energy and money saving was pointed out as a driver. Examples of barriers observed were regarding the operational difficulties of the technology in the UK, the reliability of the technology in the UK and Germany, and a lack of knowledge and acquaintance with high tech products was reported in Italy. Smart home products were also regarded as luxurious items in Germany and the UK, and concerns about costs of installment, operation and maintenance of smart home technology were raised in the UK and Italy. In all three countries, privacy and security issues (i.e invasion of privacy and misuse of personal data) were also regarded a barrier to market development. According to the authors of the study, the most important finding was that energy monitoring and control does not seem to be an adequately strong driver for consumers and that benefits improving wellbeing in daily life need to exist.

4. Theoretical Framework for Industry Analysis

To provide further understanding of the HEMS market, this section presents the theoretical framework for the industry analysis which is applied in the results section of this report. Porter's Five Forces is the model of choice. It provides a holistic business perspective of the HEMS market and its development due to two primary reasons. Firstly, the model considers customers, suppliers, potential entrants as well as substitute products and therefore goes beyond the competition from existing rivals. Secondly, the model recognizes the dynamic processes of the HEMS industry and its development over time. Michael Porter states that "understanding the competitive forces, and their underlying causes, reveals the roots of an industry's current profitability while providing a framework for anticipating and influencing competition (and profitability) over time".[40] The industry analysis enhances the understanding of the HEMS market and contributes to an improved prediction of the market development.

4.1 Porter's Five Forces Model

Porter's Five Forces is a market analysis model which is used to understand the underlying structures of a certain industry. The structure is defined through identifying the industry's five forces, which form the competitive landscape of the market, and thereto profitability. In the Porter's Five Forces model, the *nature* of each force also impacts the market competitiveness and profitability. An industry where each force is *intense*, will generate return on investments that are generally low. One such example is the airline industry. On the contrary, markets where the forces are *benign,* such as the software industry, will to a larger extent generate profitable companies.[41] The five forces of Porter's model presented below are: *Threat of New Entrants*, *Bargaining Power of Suppliers*, *Bargaining Power of Buyers*, *Threat of Substitute Products or Services* and lastly *Rivalry Among Existing Competitors*.[42]

[40] M.E. Porter. *The Five Competitive Forces that Shape Strategy.* Harvard Business Review. 2008.
[41] Ibid.
[42] Ibid.

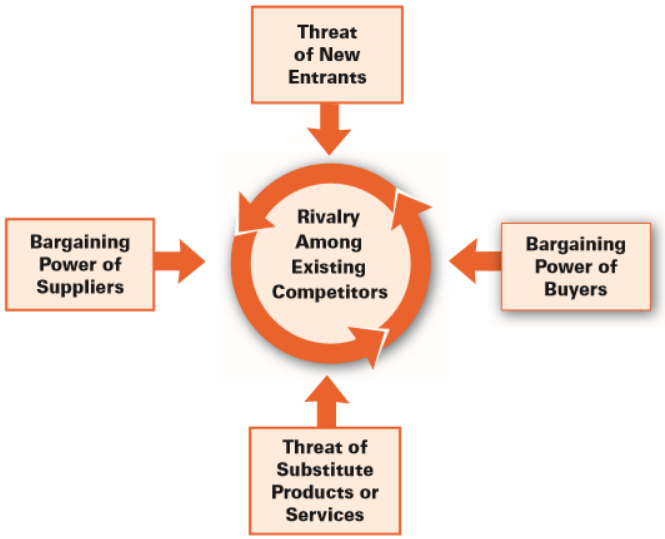

Figure 2 *- The Five Forces that Shape Industry Competition.* [43]

New actors on the market have a desire to expand their market share which allow new actors to put pressure on competitive factors such as price and costs. This phenomenon is captured in the force *Threat of New Entrants.* The threat is dependent on entry barriers to the market, and to which extent established competitors choose to fight back when a new actor enters the market. The second force, *Bargaining Power of Suppliers,* is the force that measures how powerful suppliers are, and how their way of acting can affect the market. If companies are considerably dependent on specific suppliers, those suppliers could raise prices and in other ways take advantage of their strong position. The result is a substantially lower profitability. *The Bargaining Power of Buyers* is the third force, which highlights powerful customers. Customers in this position are, just like powerful suppliers, able to demand a certain quality or service while demanding lower prices. Powerful buyers are often present in markets where there are few buyers, standardized products, and easy for actors to replace suppliers with a competitor or an in-house solution. The result of strong buyers that utilize the possibility, are lower margins and therefore lower profitability.

The fourth force, *The Threat of Substitutes,* refers to substitutes that achieve similar values as the original product. The threat becomes considerable due to three main reasons; if the pricing of the substitute is favorable, if the costs for a buyer to switch to a substitute is low, and if competitors have diverse competing strategies and goals. When the threat is high, the profitability undergoes great pressure. Lastly, *The Rivalry of Competitors* is the fifth force mainly based on two factors; the intensity of rivalry and based on which factor actors compete. The intensity depend on the number and size of competitors, market growth, overall dedication and goals of rivals and exit barriers of the market. The factors could for instance be price or quality. Profitability is most likely to suffer if the main competing factor is price, while the risk is lower if the factor is quality, service or others. Price is most likely to be the factor if substitutes are similar, products are perishable, if there are high fixed costs and low margins, and if large capacity is needed to stay efficient. The result could be both positive and negative since rivalry could amount to more efficient operations and addressing the customers' needs to a higher

[43] M.E. Porter. *The Five Competitive Forces that Shape Strategy.* Harvard Business Review. 2008.

degree. Contrary, rivalry could also lead to suffering profitability and overall negative industry development. All in all, the five forces are used together to map out and identify underlying structures of the market, and how they affect competitiveness and profitability.[44]

5. Results

5.1 Market Study

The following market study is divided into two geographical regions; Europe and the Nordics, as well as two categories of market operators; companies and regulatory institutions. The two markets have been studied with regards to energy usage and consumer behaviour differences and scanned for interesting HEM-operators and industry initiatives. Below is a comprehensive list of the key findings.

5.1.1 The European Market

According to an article from Berg Insight, around 10% of all European households contained a smart home system of some kind in 2017.[45] It could be a smart speaker or simply any appliance connected to an app or a digital user interface. In estimations from the same source, the market is said to have potential to grow at an annual growth rate of 30%. Apart from a strong market growth and a bright future, the European Commission has also considered "Smart Homes" an increasingly important topic. In a report from 2019, the current Smart Home situation is mapped out, with suggestions on how to proceed to support continuous development.[46]

The development of the European market is highly individual for different countries, depending on numerous aspects ranging from climate targets, to the stage of the roll-out of smart meters in the respective countries. In the UK, there is an ambitious long term goal to reduce greenhouse gas emissions in 2025 by 50% of 1990 levels, and 80% by 2050.[47] Thereto, the UK has a voluntary smart meter roll-out initiated in 2007, which has estimatedly lead to installments of 53 million new smart meters which is a great enabler to grow the HEMS market in the UK. Germany also has a comprehensive energy strategy, with an aggressive changeover to renewable energy and vast focus on energy efficiency which is closely related to HEMS. One main goal is a decrease of energy consumption by 50% of 2008 levels by 2050. Germany also has the largest total capacity of solar PV installed in Europe.[48] A clear setback for the HEMS market in Germany is however that there has not been a large scale roll-out of smart meters yet. On the contrary, Italy was the first European country to roll out smart meters on a large scale which took place in around year 2005. There is also a main focus on rolling

[44] M.E. Porter. *The Five Competitive Forces that Shape Strategy.* Harvard Business Review. 2008.
[45] M. Bäckman, et al. *Smart Homes and Home Automation.* Bergs Insight. 2017.
[46] T. Ribeiro Serrenho, et al. *Smart Home and Appliances: State of the Art.* European Commission. 2019.
[47] N. Balta-Ozkan, et al. *European Smart Home Market Development: Public Views on Technical and Economic Aspects across the United Kingdom, Germany and Italy*. Energy Research & Social Science, 2014, 3. 65-77. (Accessed on 2020-04-17)
[48] SolarPower Europe. *EU Market Outlook for Solar Power 2019-2023*. 2019.

out a demand response market platform which would further increase the rise of the HEMS market in Italy. Similar to previously mentioned countries, Italy has an energy policy highlighting energy efficiency and a changeover to renewable energy.[49] All in all, the different strategies and actions taken by the governments of each country has a remarkable impact on the development of HEMS.

5.1.2 The Nordic Market

Although the Nordic market is a submarket of the European market, one can observe discrepancies between the two regions. A remarkable distinction between the Nordic and European markets is that the Nordics is the pioneering region for sustainable development. Firstly, the Nordic countries has a high share of renewables, ranging from 32 to 73% in 2016, in comparison with the EU average of 17%.[50] Variable renewable energy capacity increased from 4.8 GW in 2008 to 16.6 GW in 2017, where the majority of the capacity comes from onshore wind power.[51] Secondly, the region has very ambitious greenhouse gas (GHG) emission goals, and current carbon intensity of electricity in the Nordics is at 60 gCO_2/kWh, 88% lower than the global average.[52] Thirdly, GDP growth is highly decoupled from CO_2-emissions, meaning simultaneous economic and ecological sustainable development is achievable.[53]

Aside from being leaders within sustainable development, the Nordic countries has a considerable fleet of electric vehicles (EVs). The region accounted for 8% of the global fleet of EVs with almost 250,000 vehicles at the end of 2017 and one can find the highest ratios of EVs per person in the region. The fleet is projected to grow to a number of 4 million cars by 2030 according to the *Nordic EV Outlook 2018* by the International Energy Agency (IEA) and the charging of the EVs is expected to account for 2-3% of projected electricity demand. The rapid deployment of EVs has been driven by strong policy support and ambitious GHG emission goals.[54]

Lastly, the electricity grids and markets of the Nordic countries are highly interconnected and the overall Nordic electricity system is “one of the world’s most secure, affordable and renewable”.[55] Sweden and Finland have long been pioneers in rolling out smart meters, with Norway, Denmark and Iceland following close behind.[56] Furthermore, a report on distributed electricity production and self-consumption in the Nordics by Sweco and Oslo Economics[57],

[49] SolarPower Europe. *EU Market Outlook for Solar Power 2019-2023*. 2019.
[50] Nordic Energy Research. *10 Insights into the Nordic Energy System*. The Nordic Council of Ministers. 2018.
[51] Nordic Energy Research. *Tracking Nordic Clean Energy Progress*. 2019.
[52] Nordic Energy Research. *10 Insights into the Nordic Energy System*. The Nordic Council of Ministers. 2018.
[53] Nordic Energy Research. *Tracking Nordic Clean Energy Progress*. 2019.
[54] International Energy Agency. Nordic Region Offers Valuable Lessons for Rapid EV Deployment Worldwide. 2018-03-08. https://www.iea.org/news/nordic-region-offers-valuable-lessons-for-rapid-ev-deployment-worldwide (Accessed on 2020-04-18).
[55] Nordic Energy Research. *10 Insights into the Nordic Energy System*. The Nordic Council of Ministers. 2018.
[56] Nordic Energy Research. *Tracking Nordic Clean Energy Progress*. 2019.
[57] Sweco, Oslo Economics. *Distributed Electricity Production and Self-Consumption in the Nordics*. 2019.

shows an increase in renewable distributed electricity production for self-consumption by 46% from 2005 to 2017 in the Nordics, mostly due to increases in solar PV capacity. The same report shows that the Nordic countries have regulatory frameworks in place promoting and supporting distributed electricity production and self-consumption and that there are few barriers to "sound development" of said technology. HEMS can potentially be a key component in the optimization of such self-consumed electricity production.

5.1.3 Regulatory Institutions

Regulations and infrastructure of the energy market sets the premises of how the HEMS market is able to develop. Even though the HEMS market has a history that goes back more than a hundred years, a lot has happened in the last decades. The main trends indicate a decentralization of the energy market and consumers becoming increasingly active market operators. To support development of the HEMS market, regulations have to be implemented in a way that enables and benefits HEMS, such as supporting energy flexibility, small scale electricity production and general incentives for customers to support peak shaving and sustainable usage of resources. In each country, different institutions bears the responsibility. All national regulatory authorities in Europe share the mutual responsibility to ensure that the country as a whole meets targets and regulation policy set by the EU. In the Nordics, each country has its own regulatory institutions and in Sweden, the responsible institution is the Swedish Energy Markets Inspectorate (Ei).[58]

Ei points out two main areas for its work; supervising compliance with regulations, and participating in international work on Sweden's behalf. A majority of the authority's actions are taken to ensure functioning markets and strengthening the position of the customer. Back in 2010, a report was released by Ei where a restructuring of the power grid was identified to meet the future needs of a more sustainable energy market.[59] The four main aspects identified were:

- ➢ Simplify the upscaling of renewable energy
- ➢ Enable power reduction during load peaks
- ➢ Improve incentives for more sustainable energy usage
- ➢ Create conditions for more active customers

All four aspects are relevant from a HEMS perspective, and especially the last aspect, where active end customers is a central prerequisite to scale up the HEMS market. The actions mentioned included increased incentives to build smart grids and investigate in pricing structures to favour peak shaving.

In 2018, the Nordic energy regulators reached an agreement to move to 15 minutes imbalance period settlement instead of 60 minutes, as a result of an EU decision.[60] Therefore, the

[58] Swedish Energy Markets Inspectorate. More about us. https://www.ei.se/en/About-Ei/About-us/ (Accessed on 2020-05-07).
[59] Energimarknadsinspektionen. *Anpassning av elnäten till ett uthålligt energisystem*. R2010:18.
[60] Energimarknadsinspektionen. Nordiska tillsynsmyndigheter eniga om tidplan för införande av 15 minuters avräkningstid. 2018-12-20. https://www.ei.se/sv/nyhetsrum/nyheter/nyhetsarkiv/nyheter-

Swedish government alongside the governments of the Nordic countries, made the decision to change all electricity meters in the country into a smarter generation of meters. Features required for the meters are the possibility to measure electricity usage every 15 minutes and user interface that enables the user to see its own usage data.[61] The intention was to ensure a more active position for electricity customers. The decision is a prime example of how regulations and governmental policies can push the market into different directions, which makes regulations and legislation very important factors in the development of HEMS.

In addition to Ei, the Swedish Energy Agency is also a regulatory institution on the Swedish market. The distinction between the two are that the Swedish Energy Agency strives to lead the energy transition into fossil free energy supply as its primary mission.[62] This is certainly a highly important task in developing a more sustainable energy market. One such example is initiatives to promote intelligent energy management, which is mentioned in section *5.1.5 Industry Initiatives*. Therefore, the Swedish Energy Agency can be considered a main driver of development within the energy management sector in Sweden, which ultimately affects the overall development of HEMS.

5.1.4 Companies

There is a multitude of companies active on the HEMS market according to Delta-EE as previously mentioned, and listed below are some of the interesting players with their respective products and solutions. Large global energy companies such as Schneider Electric and Bosch have been researched, in addition to smaller nische-startups within the HEMS ecosystem such as Watty and Tibber.

Schneider Electric
Schneider Electric is a global provider of energy and automation digital solutions for efficiency and sustainability, with more than 135,000 employees worldwide and a wide portfolio of products and solutions for industries and consumers. The smart homes department provide two different HEM solutions: *Wiser* and the *KNX Home Automation System.*[63]

The Wiser solution lets the user control heating, lighting, shutters and other appliances via the Wiser mobile application or the Home Touch digital monitor. With Wiser comes the option to install sensors which can detect water leakages, motion, open doors and windows as well as temperature and humidity to provide a comfortable and secure indoor climate. The Wiser solution is available for any building situation, as sensors can be retrofitted and controlled by the mobile application and no changes are necessary for the user's electrical wiring. Wiser is available throughout Europe, Asia and North America.

2018/nordiska-tillsynsmyndigheter-eniga-om-tidplan-for-inforande-av-15-minuters-avrakningstid/ (Accessed on 2020-04-03).
[61] Energimarknadsinspektionen. Beslut om nya funktionskrav för elmätare. 2018-08-22. https://www.ei.se/sv/nyhetsrum/nyheter/nyhetsarkiv/nyheter-2018/beslut-om-nya-funktionskrav-for-elmatare/ (Accessed on 2020-04-02).
[62] Swedish Energy Agency. *About us*. 2020-02-04.http://www.energimyndigheten.se/en/about-us/ (Accessed on 2020-04-03).
[63] Schneider Electric. Smart Homes. https://www.se.com/ww/en/home/inspirations/smart-home.jsp (Accessed on 2020-04-02).

Figure 3 *- The Schneider Electric Wiser App and the Home Touch Digital Monitor.* [64]

The KNX Home Automation System is recommended for new buildings and renovations as the connections in between the individual components require hard-wiring and the system can be tailor-made for each unique project with its unique requirements and needs. With functionalities such as time and energy saving automated routines for specific home scenarios, watering scheduling based on weather forecasts and the ability to monitor usage and production of a photovoltaic installation, the KNX Home Automation System is a more advanced smart home solution compared to Wiser. KNX is available in many European and Asian countries.

Bosch

With more than 400,000 employees worldwide, Bosch is a leading IoT company and supplier of technology and services, offering solutions for smart homes and cities as well as connected mobility and manufacturing. Bosch offers an intelligent home control solution called “Bosch Smart Home System”.[65] The centerpiece of the system is the “Smart Home Controller” in combination with the application which enables the communication between different HEMS devices and displaying generated data to the user. The “Smart Home Controller” and software could therefore be categorized as the central HEM unit.

[64] Schneider Electric. Smart Homes. https://www.se.com/ww/en/home/inspirations/smart-home.jsp (Accessed on 2020-04-02).

[65] Bosch. Smart System Solutions. https://www.bosch-smarthome.com/uk/en/categories/smart-system-solutions (Accessed on 2020-04-10).

Figure 4 *- The Bosch Premium Room Climate Starter Kit.* [66]

The two categories related to the smart home offering of Bosch are climate and security. Within the category climate, multiple smart devices controlled by the central HEM unit enable cost saving and comfort-enhancing energy management. Examples of such devices are smart radiator thermostats as well as door and window detectors.[67] Bosch also has collaborations with Smart Home Partners including Philips Hue[68], a smart lighting product, and Amazon Alexa[69], a digital assistant. As of the security solutions, there are various features such as the "presence simulator", which is a lighting system to simulate presence and prevent burglary. Other features are smoke and motion detectors to prevent fire and ensure safety in the home.[70] The products and solutions presented above form a cluster of HEMS technologies which makes Bosch one of the primary actors within the global HEMS market.

EON

EON is a global energy supplier with over 70,000 employees.[71] EON is based in Germany but is operative across the whole Nordics. EON has a HEMS product called EON Home. The EON Home app provides the possibility to monitor energy generation and consumption including smart metering, electric vehicle charging as well as solar PV energy production and storage. It is also possible to overview your own energy ecosystem to determine export to or import of electricity from the grid and to control your appliances.[72] EON Home also has an integrated intelligent management control, allegedly enabling cost and energy savings. All features mentioned require smart appliances that are able to integrate with EON Home.

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[66] Bosch. Premium Room Climate Starter Kit. https://www.bosch-smarthome.com/uk/en/products/smart-system-solutions/room-climate-premium (Accessed on 2020-04-21).
[67] Bosch. Indoor Climate. https://www.bosch-smarthome.com/uk/en/categories/smart-system-solutions/indoor-climate (Accessed on 2020-04-10).
[68] Philips. Hue. https://www2.meethue.com/sv-se (Accessed on 2020-04-10).
[69] Amazon. Amazon Echo & Alexa Devices. https://www.amazon.com/Amazon-Echo-And-Alexa-Devices/b?ie=UTF8&node=9818047011 (Accessed on 2020-04-10).
[70] Bosch. Security. https://www.bosch-smarthome.com/uk/en/categories/smart-system-solutions/security (Accessed on 2020-04-10).
[71] Eon. About us. https://www.eon.com/en/about-us/profile.html (Accessed on 2020-04-06).
[72] Eon. Eon Home Application Demo. https://app.home.eon.com/demo (Accessed on 2020-04-06).

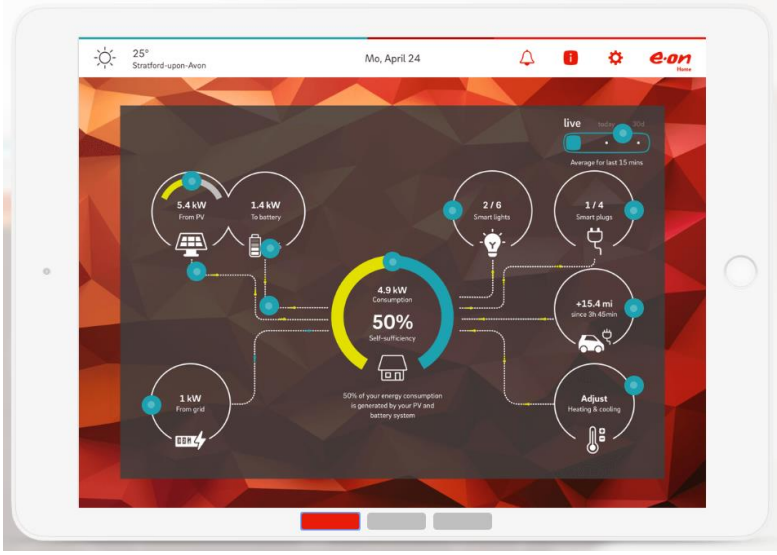

Figure 5 *- The EON Home App.* [73]

Watty

Watty is a Swedish startup that was registered in 2013. Today the company's product offering consists of a so called "duo" of hardware and software. The hardware is the Watty box which is an AI driven device that could be considered the central HEM-unit of the system. A Watty box is installed in the home's fuse box.[74] The software is the Watty app which monitors real time data communicated from the Watty box. This data concerns electricity usage resulting from kitchen appliances such as a kettle or a microwave, or other household appliances. Later on, the data can be used to get an overall look of the household's energy consumption to optimize the usage and save energy, or simply to get notified when leaving an appliance on for too long. All in all, Watty provides a solution to easily monitor the energy usage in the household.

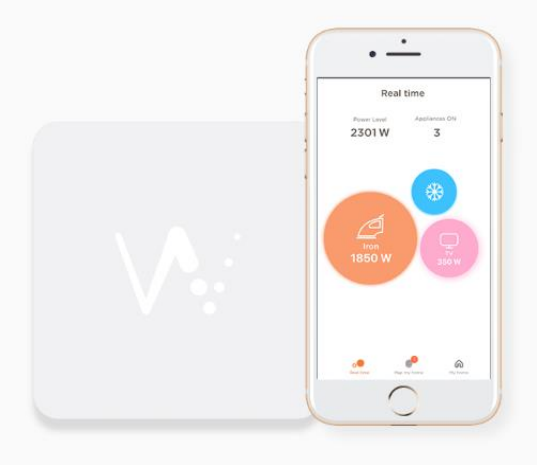

Figure 6 *- The Watty Box and the Watty App.* [75]

[73] Eon. Eon Home Application Demo. https://app.home.eon.com/demo (Accessed on 2020-04-06).
[74] Watty. Watty. https://watty.io/ (Accessed on 2020-04-06).
[75] Ibid.

Tibber

Tibber is a Swedish startup that was established in 2016. The company describes itself as a "digital electric utility" and provides two main services, a platform to buy electricity directly from producers, and an app to create a smarter home that allows a lower and more sustainable electricity consumption.

Figure 7 *- The EV Charging Feature of the Tibber App.* [76]

Broadly, the app focuses on four main aspects; optimizing heat control for household heating, electric car charging, solar power generation and various smart home solutions. The heat control solution is enabled through a connected thermostat or heat pump, which makes it possible to control the temperature of the house, as well as optimizing the heating of the house from a cost perspective.[77] The electric car charging also enables load balancing, and cost efficient charging, as it uses most electricity when the price level is as low as possible.[78] The smart solar power functions enables smart real-time production data and the possibility to sell excess electricity.[79] Apart from the three nisched functions mentioned, there are also overall features in the app to ensure a smart home. A number of the features require a so called smart hub and others do not. Depending on the features of the appliances, it is possible to monitor the home energy usage and weather data such as temperature and humidity with the help of sensors. Apart from monitoring your usage, a Tibber certified hub also enables the app to control various appliances to ensure an energy efficient usage.[80] As an example, the previously mentioned Watty box is a Tibber certified hub that could be integrated with Tibber.[81]

[76] Tibber. Ladda elbil. https://tibber.com/se/losningar/ladda-elbil (Accessed on 2020-04-21).
[77] Tibber. Värmestyrning. https://tibber.com/se/losningar/varmestyrning (Accessed on 2020-04-05).
[78] Tibber. Ladda elbil. https://tibber.com/se/losningar/ladda-elbil (Accessed on 2020-04-05).
[79] Tibber. Solenergi. https://tibber.com/se/losningar/solenergi (Accessed on 2020-04-05).
[80] Tibber. Tibber. https://tibber.com/se/ (Accessed on 2020-04-05).
[81] Tibber. Watty - Smart energimätare. https://tibber.com/se/store/produkt/watty-smart-energimatare (Accessed on 2020-04-06).

5.1.5 Industry Initiatives

In addition to product development of individual companies and market development activities of regulatory institutions, there are also ongoing initiatives such as strategic alliances striving for standard protocols and interoperability between different connected devices. An example of such an initiative is the Zigbee Alliance[82], consisting of member companies such as Google, Amazon, Apple, Ikea and Schneider Electric among others. The alliance was established in 2002 and has since then been working on creating universal open standards for IoT-solutions to accelerate innovation within the industry on a global scale. Two of the alliance's solutions are notably important for the HEMS market. Smart Energy is a standard for interoperable products which control, monitor and automate delivery and use of energy and water, creating greener homes for consumers.[83] JupiterMesh is a Neighbourhood Area Network (NAN) standard, enabling communication between devices outside the home, such as smart meters and distribution automation devices, which are key components of the future smart grid.[84] These open standards developed by Zigbee have benefits such as getting to market quicker, access to a large amount of interoperable devices as well as stable and tested technology.[85]

One example of a HEMS initiative in the Nordics is the Intelligent Energy Management Challenge[86] arranged by the Swedish Energy Agency in 2017. The project aimed to promote new flexible solutions for local solar energy consumption and storage by adapting the energy systems of buildings. The solutions of the four global winners were implemented in five municipalities in Sweden for real-life testing. Another example of an initiative in the Nordics is the Swedish Smart Grid Forum[87], with the main task of promoting dialogue about the smart grid among industry actors. The forum has for instance published reports on strategy for increased flexibility in the electricity system as well as on internationalization of the Swedish smart grid. The forum has also published examples of Swedish smart grid solutions and the section "Customer-Side Systems" is particularly interesting for the HEMS industry, where the forum has gathered solutions for innovative energy management, smart optimization and control with battery storage as well as energy usage planning, among others.

Yet another initiative driving the HEMS market development is KTH Live-In Lab. Live-in Lab is a full-scale test environment where it is possible to conduct research on areas related to building technologies and property management. The initiative is driven by KTH Royal Institute of Technology since 2016. The full-scale test environment consists of over 300 beds in Stockholm with student residents, and the test beds are equipped with over 9,000 sensors

[82] Zigbee Alliance. About us. https://zigbeealliance.org/about/ (Accessed on 2020-04-16).
[83] Zigbee Alliance. SmartEnergy. https://zigbeealliance.org/solution/smart-energy/ (Accessed on 2020-04-16).
[84] Zigbee Alliance. JupiterMesh. https://zigbeealliance.org/solution/jupitermesh/ (Accessed on 2020-04-16).
[85] Zigbee Alliance. Why Standards? https://zigbeealliance.org/why-standards/ (Accessed on 2020-04-16).
[86] Energimyndigheten. Intelligent Energy Management. 2017-03-10. http://www.energimyndigheten.se/en/innovations-r--d/intelligent-energy-management/ (Accessed on 2020-04-16).
[87] Swedish Smart Grid. The Swedish Smart Grid Forum. http://swedishsmartgrid.se/in-english/ (Accessed on 2020-04-16).

and measure points that ensures ambitious data collection of residents who live there.[88] As a frontrunner in building technology and data collection related to energy management, KTH Live-In Lab has great possibilities to collaborate with actors on the market to take part in bringing forth HEMS value offerings and drive the development of the HEMS market in the Nordics.

5.2 Interviews

In this section, the results of conducted interviews with operators within the HEMS ecosystem and associated areas are compiled. The interviewees were selected to represent the various market stakeholders, to provide their individual perspective and knowledge of HEMS and its future, and collectively contribute to a comprehensive representation of the market.

5.2.1 Marielle Lahti, Senior Adviser at the Swedish Energy Markets Inspectorate

The Swedish Energy Markets Inspectorate (Ei) was contacted to answer questions regarding the current and future energy market situation in Sweden and Europe (please see appendix 1 for questions asked during the interview). Marielle Lahti, Senior Adviser at Ei, was subject to the interview. Marielle Lahti has 14 years of experience at Ei and was recently the director of the Swedish Smart Grid Forum, a national forum appointed by the Swedish Ministry of Environment and Energy, with the main goal of promoting “dialogue about the possibilities of smart grids, and to help create international business opportunities and partnerships within the smart grid field”.[89]

Marielle began the interview by pointing out that Ei only regulates the energy market up until the point of consumption (ie. the electricity outlet point) and Ei does not specifically operate in the field of HEM. However, as the HEM-market is part of the bigger ecosystem of the energy market and smart grids, the work of Ei touches upon HEM occasionally and she does herself have some knowledge of the topic. The key takeaways from the interview are summarized in the following bullet points:

- According to Ei, the overall trend of the energy market is one of more decentralisation and an increasingly active consumer.

- So called “citizen energy communities”, a form of micro grids, are being discussed as a way of strengthening the consumer and making them more active in the market.

- The energy market is simultaneously becoming increasingly digitized and technology is a driving factor for change on the market.

[88] KTH. KTH Live-In Lab i korthet. https://www.liveinlab.kth.se/om-kth-live-in-lab/kth-live-in-lab-i-korthet-1.965607 (Accessed on 2020-04-16)
[89] Swedish Smart Grid. The Swedish Smart Grid Forum. http://swedishsmartgrid.se/in-english/ (Accessed on 2020-03-29).

- ➢ As of today, there is a lack of regulatory framework when it comes to energy flexibility, home energy management and the smart grid. The process of legislation is slow and one way of dealing with this issue would be to implement so called “regulatory sandboxes”, where market players are temporarily allowed to bypass laws in order to support innovation.

- ➢ Smart meters are being rolled out in Sweden, with two-way communication requirements and more frequent readings (an hour to 15 minutes). This is another way of making the consumer more active.

- ➢ Studies on energy flexibility incentives show that consumers want a large compensation for making changes in their consumption patterns, especially regarding household appliances. Consumers tend to be a bit more flexible when it comes to heating.

To summarize, Marielle provided insights on the current Swedish energy market and how it might develop in the future, as well as comments on HEMS enabling technology such as smart meters and how the consumer is becoming an increasingly active and important stakeholder of the energy market.

5.2.2 Christer Boberg, Market Developer at Stockholm Exergi

Stockholm Exergi (formerly Fortum Värme), co-owned by the city of Stockholm and Fortum, is the local energy and district heating company of Stockholm, providing heating and cooling for residents, businesses and other facilities across the city.[90] Christer Boberg, Market Developer at Stockholm Exergi, has an academic background within Mechanical Engineering at KTH and has been employed at Stockholm Exergi for close to 12 years. He began his employment as Product Manager for 9 years and he has now 3 years of experience in his current role as Market Developer. Stockholm Exergi and Christer Boberg specifically, were asked to take part of an interview to answer heating and electricity-related questions regarding their smart homes solution Intelligy[91], as well as the current and future HEMS market (please see appendix 2 for questions asked during the interview). Christer Boberg’s answers to our questions are summarized below:

- ➢ Intelligy provides a smart home solution for the customers of Stockholm Exergi, mainly housing cooperatives according to Christer Boberg. Key features are heating and electricity optimization, heating system monitoring as well as the integration of solar cell production and electric vehicle charging. By connecting the households of customers, benefits such as peak-shaving, less over-usage of energy, cheaper electricity as well as cheaper and cleaner heating, can for example be achieved by tweaking the heating load and allocating available energy in a smart and efficient way

[90] Stockholm Exergi. Fortum Värme is Stockholm Exergi. https://www.stockholmexergi.se/fortum-varme-is-stockholm-exergi/ (Accessed on 2020-04-02).
[91] Stockholm Exergi. Smarta fastigheter. https://smartafastigheter.stockholmexergi.se/intelligystart (Accessed on 2020-04-02).

to avoid the usage of more expensive and polluting power plants. As of today, only a small share of the customers of Stockholm Exergi has Intelligy installed in their homes.

- There is a growing trend towards “fun” and practical solutions, such as remote temperature monitoring of ones summer house, mostly demanded by tech-enthusiasts. Regarding housing societies, it is usually the board of the cooperative which has an interest in monitoring the consumption of the members of the housing society.

- The development of the HEMS-market is difficult to predict according to Christer Boberg, as there are a vast amount of available solutions: “it all depends on what the customer encounters”. Existing providers of energy solutions might start to cross-sell HEMS products, much like Stockholm Exergi.

- Christer Boberg points out Stockholm Exergi’s HEMS market advantage as an energy provider compared to stand-alone HEMS solutions. An energy provider has more knowledge of the individual customer, has full control of production and thus insight in the energy system as a whole, more consumption data and can better integrate a HEMS solution in the homes of customers as there are no intermediaries. Additionally, if one is to use environmental effect (i.e CO_2-emissions) as means of control for energy management and optimization, it is crucial to base such calculations on real-time marginal production effects and not on an average calculated from historic data, due to an average being very misleading at times. Such data on marginal effects might not be available for the stand-alone HEMS provider.

5.2.3 Love Thyresson, Product Manager at Tibber

Tibber is described as a digital electric utility, a mixture of an electrical utility and a tech-startup. Tibber provides a platform to buy electricity, and an app with various HEMS features. Love Thyresson, Product Manager at Tibber has a bachelor and masters within Computer Engineering. Love has an extensive product management background within Redback Networks and Ericsson, proceeding with Internet Media Transport at Netinsight. For the last 3 years, Love has chosen an entrepreneurial path and since 2019 he is working at Tibber. The interview mainly focused on Tibber’s products and solutions, and the development of the HEMS market as a whole (please see appendix 3 for questions asked during the interview). Answers given by Love Thyresson during the interview is summarized in the bullet points below:

- Love identified two main aspects of Tibber: the electric utility service allowing the customer to buy electricity, and the features to smart home heating and smart car charging. A more detailed description is available in section 5.1.4.

- Tibber is originally a Swedish company. Today the company is operating in Norway and Germany as well. Quite few direct competitors, but actors such as Bulbee, Inspire Energy and Greenly were mentioned. Indirect competitors mentioned were traditional electric utility companies such as Vattenfall, Fortum and Eon.

- ➢ Within Tibber's customer base, three larger segments can be identified. Firstly, the tech-interested segment that enjoys being able to monitor and control energy usage. Secondly, the price-conscious customer which main goal is to minimize electricity costs. Thirdly, the environmentally-conscious segment that is starting to grow bigger and bigger. This segment focuses primarily on sustainability and to make environmental choices, independent of the cost. In summary, the three main driving forces to invest in HEMS is tech, costs and sustainability, according to Love Thyresson.

- ➢ Why should a customer choose to invest in HEMS? Two primary aspects were raised. The first aspect is the fact that Tibber offers the cheapest electricity rates on the whole market.[92] The second aspect is based on the development of solar power generation, electric car charging and many other features in our homes. As a result, our electrical systems at home are growing more complex, which amounts to more complicated optimization problems that Tibber is well fit to solve.

- ➢ Positive trends/aspects for the HEMS market: Transition to smart electricity meters, and the increasing complexity and number of components in the energy system which advocates for a HEMS solution of some kind.

- ➢ Negative trends/aspects in the HEMS market: Time aspect as any extensive decision, such as deciding to roll out smart meters, involves government which generally means longer turnaround time. For actors on the HEMS market, scaling the business and varying market structures across different countries was mentioned as a negative aspect.

5.2.4 Linda Thell, Electricity Market Analyst at Svenska Kraftnät

Svenska Kraftnät (SvK) is the transmission system operator (TSO) of Sweden, responsible for the national transmission grid with the objective to deliver a reliable, cost-efficient and sustainable electrical system.[93] Examples on the activities of SvK are: ensuring the continuous balance between consumption and production of electricity in Sweden, working towards energy and climate goals, in addition to reinvesting in and extending the current national grid to meet the demands of the future. The interviewee, Linda Thell, has close to five years of work experience at SvK and an academic background within Sociotechnical Systems Engineering. Her current role as Electricity Market Analyst has given her the opportunity of studying the field of demand response, which was the main topic of the interview, in addition to questions regarding the current and future electricity grid and associated areas (please see appendix 4 for questions asked during the interview). Below are the key takeaways from Linda Thell's answers:

- ➢ Linda Thell quickly pointed out that SvK are technology neutral and therefore could not directly comment on a specific technology (i.e HEMS) and how it might be incorporated and affect the future electricity grid. However, SvK are positive to new technologies, how they might support the electrical system and are actively researching different

[92] Tibber. Smarta elavtal. https://tibber.com/se/smart-elavtal (Accessed on 2020-04-06).
[93] Svenska Kraftnät. About us. https://www.svk.se/en/about-us/ (Accessed on 2020-04-07).

support services such as consumption flexibility and energy storage.

- Support services are required to quickly be able to deliver support (i.e increase/decrease consumption or production) to the electrical system and during a certain amount of time. Traditionally, hydropower has been providing such a service.

- A pilot project during 2017 conducted together with Fortum, where a hundred Swedish households provided the frequency control via flexible energy consumption for their respective boiler units, had a positive result. The households were able to maintain the system frequency, but more households would have been necessary to increase how much of a frequency difference the system could handle.

- As things stand, there is a market for consumption flexibility. SvK are currently developing their IT-system to enable facilitation of support services from resources with limited support capacity. Since the pilot project in 2017, both energy storage and demand flexibility have been approved for delivering support services to the grid.

- SvK is involved in implementing new EU-legislation that will facilitate new technologies. SvK is also harmonizing the Swedish electricity market with the European market, simplifying cross-border cooperation and electricity trade.

5.3 Industry Analysis

5.3.1 Porter's Five Forces Analysis

As the Porter's Five Forces method is applicable to evaluate entire markets, the method will be applied to the HEMS market according to the theoretical framework presented for Porter's Five Forces in section 4.1. The HEMS market stands at quite an early stage and different aspects such as customers, suppliers and value chains are non-constant and the role of these market operators and the relationships between them, may change significantly as the market develops. In the scope of this market analysis, the products in the HEMS market are defined as the core technology of HEMS. This includes measuring devices, sensors and the central HEM unit. Other devices such as smart appliances and car chargers are not included in the scope. The geographics of the scope of competition is set to the Nordics.

The buyers of the HEMS market are characterized by a quite low bargaining power. One noticeable reason is that the HEMS market is a B2C-market, meaning that the businesses (i.e the HEMS companies) are appealing to household consumers. As a result, the market consists of innumerable customers that are uniquely powerful. Traditionally, the position of the customer has been less active on the energy market than today. As mentioned in the interview with the Swedish Energy Markets Inspectorate in section 5.2.1 of this report, the market is becoming increasingly decentralized. In a long-term perspective where customers become more active and informed about energy usage and costs, there is a possibility that the buyer position will grow stronger. Another important aspect of the buyer's power, is the differentiation of the product. The HEMS products on the market are currently differentiated. Certain products are part of overall solutions from larger corporations, and others are additional services to existing home electricity infrastructure. Differentiability is also a factor that can develop over

time as the market becomes more stable. Thereto, the market seems to still be at such a stage where a big part of all customers are people that are truly interested in energy management. For the average customer, the step to change vendor and integrate new solutions into current home systems may be too large to take. In that sense, the difficulties with switching between vendors also demonstrates that the power of buyers in the HEMS market is quite low.

The force *Bargaining Power of Suppliers* is not crucial in the HEMS market since a wide range of actors, from large corporations to smaller companies, use their own internally developed software solutions. Therefore, the core of the HEMS product is non-dependent of certain suppliers, unlike for example airlines that depend on few aircraft suppliers. Components that are central to enabling HEMS, for example smart meters, are rolled out widely in the European Union[94] and therefore not controlled by a small number of influential suppliers. All in all, the *Bargaining Power of Suppliers* is not considered to be high in the HEMS market, and accordingly has no considerable effect on profitability or competitiveness.

The HEMS market is characterized by corporations of different sizes. When mapping out the European and Nordic market, there are massive corporations such as Bosch and EON who are making great investments to gain market shares in the HEMS market. In parallel, there are also smaller corporations and even startups such as Tibber and Watty that have business models entirely developed around HEMS technology. Tibber is an example of a company that has built its business model on adding no margins when buying electricity, which in the long run could put pressure on established actors when competing to be the electric utility with the most favorable pricing. But when analyzing the market today, many of the established actors are developing HEMS products as part of a bundled solution. Smaller actors and startups on the other hand, could be seen as additional services to optimize energy usage in the home. Therefore, the *Rivalry of Competitors* can be analyzed in different segments of the HEMS market.

One segment is the larger actors who aim to create a bundled solution for the home including HEMS technologies, appliances and so on. In this segment, price discounting and frequent new product introductions could take place, as the market leaders battle to gain market shares. The other segment in the HEMS market are the smaller actors who focuses primarily on HEMS, examples of which are Tibber and Watty mentioned in section 5.1.4 of this report. Although companies of such kind often fight to gain new customers from the same customer segments, they may also collaborate to develop and grow their value propositions and the market as a whole. There is one such example where a smart meter from Watty is available to buy via the Tibber-store, in order to integrate the Watty-meter into the HEMS of the Tibber-app. Other typical factors that intensify rivalry among competitors are slow market growth, and numerous competitors of the same sizes. Both aspects are non-existent on the HEMS market, which indicates a diverse market from a competitive point of view. The HEMS market may contain both tough rivalry among certain main competitors that aim to be market leaders, and more collaboration among other segments of the competitors.

The *Threat of Substitutes* is difficult to evaluate within the HEMS market as many products are still in a development stage. Due to the early phase of the market, there is no clear

[94] European Commission. Smart Grids and Meters. https://ec.europa.eu/energy/topics/markets-and-consumers/Smart-grids-and-meters_en?redir= (Accessed on 2020-04-13).

"standardized" HEMS product, since software and appliances are used differently in varying solutions. Thus, finding a substitute which will deliver the same value as a certain product is difficult. With that in mind, the threat of substitutes has good prerequisites to grow stronger at a later state of the market. As an increasing number of actors take steps towards the HEMS market, a growing number of products with similar functionalities will make their way into the market and in effect intensify the threat of substitutes in the future.

Furthermore, the HEMS market has grown and is expected to grow annually the following years.[95] The growth indicates that new actors on the market have the possibility to expand the market share rather than winning shares from competitors. Therefore, new actors on the market could expect quite little reaction from incumbents which is favorable for an intense *Threat of New Entrants.* Another major aspect of new entrants are the entry barriers within the market. As the HEMS market is quite complex, there are multiple barriers to consider. But when looking into the pure technology of measuring and monitoring energy usage, the technology barriers are considered to be quite low since some solutions only require a gadget of some kind that is integrated to existing home technology. One example is Watty, were the only gadget needed is a box that is installed in the home's already existing fuse box.[96] On the other hand, HEMS products often benefit from large amounts of customer data. Accessing vast amounts of data is one aspect where established actors will gain considerable advantages in comparison to new actors. In addition, larger corporations may also have an advantage in distribution channels, as HEMS solutions could be offered to existing clientele. All in all, there is however no massive legislation or supply chain barrier from a Nordics perspective, which is favorable for a high threat of entry. This could differ among countries, since aspects such as legislation and technology are likely to vary, but *Threat of New Entrants* is considered to be high in the HEMS market and continues to be so as the market is at a growing stage.

Due to the early stage of HEMS, it is difficult to assess the market based on raw numbers. Profitability of big companies that have entered the HEMS market can't be decided as the HEMS products make up such a small portion of the revenue. When looking into smaller actors, most are startups or young companies that tend to struggle with profitability the first years in business. But when taking all forces into consideration, the threats of suppliers, buyers, substitutes and rivalry are relatively low. In contrary, the threat of entrants is considered quite high. With that information taken into consideration, the market should show a relatively high level of profitability in the long run.

Based on the above analysis, the controlling forces for profitability will be the threat of entrants as it is currently the force with the highest intensity. Moreover, the threat of entrants has great potential to grow stronger, since the competition is likely to grow as HEMS becomes increasingly common in European and Nordic households. Another consequence is that the market may pass the stage of aggressive growth, meaning that new actors will fight to win market shares from other competitors. In such a scenario, the force of rivalry among competitors may also grow stronger. When products get more and more standardized, one possible factor that actors may compete on is pricing, either by lowering prices or by offering

[95] A. Jouannic, et al. *Accelerating the energy transition with Home Energy Management.* Delta-EE. 2020.
[96] Watty. Watty. https://watty.io/ (Accessed on 2020-04-06).

special bargains to win customers. If that scenario becomes reality, profitability may also take a hit.

In summary, the five forces will affect actors to different extents. Lower prices may benefit larger actors with larger numbers of customers. The rivalry of competitors and threat of entrants is also likely to disturb larger companies less, since such companies frequently offer overall solutions. Such value offerings will likely raise the barriers for customers to change to a competing HEMS solution which is in favor for larger actors. Strength of suppliers and strength of customers are not considered to have any specific aspects that will disturb certain actors more than others. Lastly, the HEMS market is a relatively novel market and most forces have not yet grown intensive enough to affect the market extensively. The five forces do however have great potential in growing stronger and therefore might have a considerable impact on the future of HEMS.

6. Discussion

The following discussion is divided into two parts; the current HEMS market and the future of HEMS. Firstly, the current HEMS market is discussed with regards to similarities and differences between active companies and their products, success factors for the Nordic market, ongoing initiatives as well as current drivers, barriers and trends. Secondly, the future of HEMS is discussed with regards to current and future market development in the Nordics and Europe, who might become key market players, what factors will determine the growth of the market and finally, who KTH Live-in Lab should collaborate with to be in the forefront of smart building development.

6.1 The Current HEMS Market

Currently, there are numerous companies active on the global HEMS market, as exhibited in the literature review and the market study of this report. The research of Ford et al., B.K. Sovacool & D.D. Furszyfer Del Rio as well as Delta-EE, indicate that there are a vast number of different products and solutions available on the market from a large amount of different providers. In addition to the many active companies, there are also regulatory institutions, energy providers and TSOs who are working with development of the HEMS market in various ways. In Sweden specifically, the Swedish Energy Markets Inspectorate is implementing energy flexibility into the legislative system, Svenska Kraftnät is promoting and working with demand response activities and a large energy provider such as Stockholm Exergi has its own HEMS solution. The large number of different market operators implies that the market is already live and that several parties see great potential in the market.

As presented in the market study, the active companies in Europe and the Nordics range from niche startups such as Tibber and Watty, to large corporates such as Schneider Electric, Bosch and EON. Keep in mind that these are only a few of the active companies on the market. Both differences and similarities can be observed between the solutions of the respective HEMS providers. All of the companies along the spectrum from startup to large corporate, have a customer-centered solution with a mobile application either as the main feature (Tibber and Watty) or as an extra feature (Schneider Electric, Bosch and EON). This indicates that the smaller startups are more app-focused and digital, whereas the larger corporates provide

an overall solution with different sensors and measuring devices as key components. One explanation for this is that the larger corporates already have an extensive portfolio of physical products along with vast in-house competence and knowledge of such components, which can be applied to their HEMS products. The niche startups on the other hand, start from scratch with the HEMS solutions as their main product, are more data-driven and quite possibly even more customer-centered.

Which type of solution the customer prefers most likely differs between individual customers, and is difficult to determine without conducting an extensive market research, but one aspect which speaks for the larger corporates is the value of the brand. As HEMS solutions rely on monitoring and gathering data on households and their energy consumption, a trustworthy brand could be crucial for the customer to disclose such information, as privacy and security issues are reported as fundamental barriers to adoption of HEMS, according to the work of for example N. Balta-Ozkan et al. presented in the literature review of this report. New businesses might find it difficult to build such trust. However, one aspect which speaks for the smaller companies is the fact that they are perhaps even more customer-centered and that their business models are built solely on HEMS. Consequently, it is in such solutions which their core competencies lie and these companies can focus all their resources on HEMS development. The fact that the startups are small in size, could also be beneficial as a smaller size could make them more innovative and flexible as market conditions change.[97] With these aspects in mind, the niche startup could be the prefered HEMS provider, in comparison to the larger corporates mentioned earlier.

Another element to consider is the actual smartness of the different solutions. Schneider Electric, Bosch and EON all provide solutions which monitor energy consumption and indoor climate. Automation is however achieved by predetermined scheduling or preferences. On the contrary, Watty and Tibber are artificial intelligence (AI) based solutions which enables “smart” management of energy, and the systems can make decisions which over time improve as the systems learn from past experiences. This is a competitive advantage which can be crucial for achieving net energy savings and in effect cost savings and lower CO_2-emissions. The smartness of the system could also prove to be crucial because of the ambiguous results on the effects of feedback from HEMS. The study of Nilsson et al. presented in this report have shown that energy consumption, in terms of electricity and water, can both decrease and increase after HEMS installation, even for a group of people who are considered early-adopters of new technology which HEMS should have the most positive effect on. This indicates a discrepancy between the expected feedback effect and how consumers actually answer to and act upon such feedback. This is something manufacturers need to consider and incorporate into their solutions for HEMS to be effective, or the decision-making with regards to energy consumption and management needs to be automated with AI or similar technology, which speaks in favour for companies like Tibber and Watty.

To assess which functionalities are key for success on the Nordic market, one should try looking at what distinguishes the Nordic market from the European market. As mentioned in the market study of this report, the Nordics are in the forefront when it comes to sustainable development, EV deployment and its electricity system. One could argue that for a company to truly succeed on the Nordic market, the company needs to build on these market properties.

[97] M.A. Schilling. *Strategic Management of Technological Innovation*. McGraw-Hill Education. 2017.

Sustainability can be incorporated into the HEMS solution by providing feedback on climate footprint from energy consumption of the customer's household and the effects of energy saving actions. Such feedback need to be easily understood to have effect and energy savings need to be compared with for instance the CO_2-emissions of an average flight trip, for the customer to truly grasp his or her environmental impact to avoid misinterpretation of data, a barrier to adoption mentioned in this report. In addition, the large fleet of EVs in the Nordic region require in-home charging, something which a HEMS solution can optimize in terms of minimum cost and minimum grid distress. In this sense, Tibber and EON are ahead of their competitors. Lastly, to fully utilize the potential of the superior electricity system of the Nordic countries, the companies need to collaborate with the national TSOs and other affected parties, in order to leverage the demand response advantages HEMS can provide. Such collaboration is yet to be seen.

Furthermore, this paper has presented general drivers and barriers to market development among its different stakeholders. From the customer's perspective, there are numerous drivers to invest in a HEMS solution. Generally, the drivers seem to apply to different customer groups. The most common driver for a customer to invest in a HEMS solution is the willingness to reduce electricity costs and therefore save money in the long run. This customer group mainly live in stand-alone houses, and will stand a good chance to lower the costs during cold winters and other periods where an extensive amount of electricity is used. As studies show that net energy savings and therefore cost savings are possible to achieve, this is a customer group that has potential to grow. However, literature studies also highlights that the user must take actions and adapt oneself with regards to the HEMS feedback. If the market and its products are to explode and be used by the vast majority, more clear economical incentives are needed. In addition, the HEMS products must also develop in a direction where economical savings can easily be achieved without sacrificing comfort among its users. The comfort factor applies to an even larger extent in the Nordics and on the European market, as end users have a generally high standard of living that has to be upheld after the implementation of a HEMS solution.

Another driver and a customer group are the environmentally conscious users who are willing to pay a higher price and adapt quite heavily if the result is a more environmentally friendly way of living. This group was said to grow stronger at Tibber, and generally this group show good potential to do so, as the global environmental movement is flourishing. If the HEMS solutions available are able to monitor and lower electricity usage and in parallel track environmental effects of energy savings, the value offering can become increasingly popular for environmentally conscious customers.

An additional customer group are the tech-interested customers. These are somewhat the early adopters of the HEMS market and can be important to establish the market at an early stage. However, at the stage of the current European HEMS market, this group isn't crucial to an extensive growth of the HEMS market, since it is a quite limited share of the market. If the market is to grow further, larger customer groups need to be targeted.

Another driver for the market as a whole is the Zigbee Alliance's ongoing initiative of promoting standardization of IoT-communication between household appliances and devices. If the SmartEnergy standard becomes widely used, the result will be that an increasing number of household products will be able to communicate and in turn lead to even more possibilities

with HEMS. A standard also means that it is easier for early stage companies to develop new products compatible with the existing pool of products, most likely causing market growth. The JupiterMesh standard in turn, might enable the communication between the HEMS of different households, which means that we might in the future reach B.K. Sovacool & D.D. Furszyfer Del Rio's sixth level of smartness of interconnected smart neighbourhoods. What sort of possibilities which could develop from these two standards is outside the scope of this discussion, but it is likely to cause market growth.

From the viewpoints of electricity producers and legislative institutions, one main driver to promote the development and up-scaling of the HEMS market, are the possible peak shaving effects of HEMS. If an increasing number of people start using HEMS, there will be larger demand flexibility, for example flexible EV charging or flexible usage of heavy load appliances such as ACs and boiler units. As a result, it will be easier to avoid effect peaks and prevent grid distress. If HEMS is shown to be a well-functioning tool for peak shaving, it could be a driver that grows stronger. As power deficit has become an issue to consider on the Swedish market[98], the HEMS market could benefit if the power deficit issue develops further.

When considering overall trends, both drivers and barriers are observed. The development and decentralisation of the Swedish electricity market were mentioned by several interviewees and in literature. This should be considered a driver for the HEMS market as increasingly active end customers will raise awareness about electricity prices in more and more households. Thereto, more active end customers will also raise the willingness and the demand to monitor and control energy usage in the home. The decentralization trend of the energy market should therefore be considered a powerful driver of the HEMS market development. An overall trend that has already shown to be a barrier for the HEMS market is the growing issue of data privacy. As HEMS companies will gain massive amounts of data regarding each customer's personal behaviours, data privacy and integrity are on top of many customers' minds. HEMS actors could therefore face resistance among customer groups where data privacy and integrity is of high importance in the same way Facebook and other data intensive companies have faced similar challenges. This could however benefit bigger companies with strong brands as higher trust in the company is central in data privacy issues. The issue could also lead to other established actors entering the HEMS market, such as security companies and other operators that are already trusted to handle sensitive data. However all in all, data privacy is a matter that could hinder many customers from investing in HEMS, and should therefore be considered a barrier for future development of the HEMS market.

6.2 The Future of HEMS

With the current HEMS market and its development as a basis, the following section aims to predict the outcome of the future of HEMS. As the future is unforeseeable, one must consider that the following segment is speculative with respect to the findings of this paper.

[98] Ellevio. Effektbrist eller kapacitetsbrist - eller både och? Vi reder ut begreppen. 2019-03-22. https://www.ellevio.se/om-oss/Pressrum/newsroom/2019/mars/effektbrist-eller-kapacitetsbrist--eller-bade-och-vi-reder-ut-begreppen/ (Accessed on 2020-04-30).

The HEMS market has great potential for future growth as there are already many active players on the market. The number of companies show that many see potential in the product and Delta-EE predict an annual market growth of 25% for the next couple of years due to for example an increase in large electrical loads in households, evolving HEMS-enabling legislation and an increase in market innovations. Other researchers identify drivers of market development such as cost savings, improved indoor climate and energy consumption awareness. This report has identified drivers such as environmental consciousness, EV deployment and the development of product standards. As the market grows, we will most likely see an increase in companies providing HEMS solutions of different kinds, both hardware and software based. If incumbents such as Bosch or niche-startups such as Tibber will gain the largest market share is impossible to predict, but the market in terms of customers, companies and products will surely grow significantly.

Another aspect which might affect the market development of HEMS is the increasingly complex energy systems of residential households. The emergence of such more complex households is already taking shape as EVs, EV chargers, solar PVs, smart appliances and smart meters are part of an increasing number of households. As the advancement is likely to continue, components such as multiple smart appliances and complex features such as battery storage units could be part of many residential households. If that is to be the case, individual residential households will have very complex energy systems where energy management, cost optimization and demand control will be central. In such circumstances it is likely that the system will be too overwhelming to make manual decisions, which will increase the need of a HEMS solution to take the most optimized actions from an energy and cost perspective.

The Porter's Five Forces analysis of this report provides yet another perspective on future market growth. The threat of new entrants was identified as having the largest impact on market profitability and in effect market growth, as the number of market operators is predicted to increase. As the barriers to entry were considered low, one can assume that many small actors might enter the market, but on the other hand, the incumbents might grow stronger as they can better handle decreasing prices and in turn lower profitability. Apart from an intense threat of new entrants, the four other market forces were identified as less intense, resulting in high market profitability. With that in mind, one can assume that the HEMS market will attract more companies, causing the market to grow in the future.

When continuing to review the development of HEMS in a long term perspective, it is likely that overall economic development and increasing socioeconomic standards will influence the main drivers for the HEMS market. The customer group driven by sustainability has great potential to expand, as there may be an increasing number of customers who want to, and more importantly, are able to pay an extra amount of money to make a sustainable choice. Similar to EVs and solar PVs becoming trendier in the sense that it is a sort of status symbol to make conscious choices, the same development may lay ahead for the HEMS market. Yet an additional factor following from growing prosperity among the population is consumption behaviours. If today's electrification trend continues to develop in the same manner, even more electricity dependent products will be bought and used. In parallel with industries reconverting from non-renewable fuels, the electricity prices are likely to go up. A natural effect of higher electricity prices are more price-conscious customers which is in great favor for the HEMS market and its overall growth. If sustainability will continue to be on top of the global

agenda, it will have vast impact on the development of the energy market, hence it will also be one of the main HEMS market drivers. Given that situation, one could argue that the Nordic market will grow substantially in comparison to the European market, since many Nordics countries have come a long way from a sustainability point of view. In addition, respective markets of HEMS related components, such as electrical vehicles and solar panels, have already grown substantially in the Nordics. In the previously mentioned interview with Tibber, section 5.2.3, the electrical car boom in Norway was mentioned as the main market driver in Norway. The emergence of solar and wind power is another argument in favor of the Nordic HEMS development, since the early development has brought existing infrastructure and good possibilities for local production of electricity to grow. Therefore, Nordic countries are more likely to develop its microgrid infrastructure than the European countries that haven't come as far within the microgrid development. If the current sustainability pattern and transformation is to be continued in all Nordic countries, there will be substantially better prerequisites for the HEMS market to grow in the Nordics compared to other European countries.

In addition to technological and behavioural readiness for the emergence of the HEMS market, legal and regulatory decisions are also main aspects of impact. As the HEMS market has come to expand quickly, regulatory institutions are gradually adapting. On an EU level, regulatory adjustments are slow but as mentioned in the interview with the Swedish Energy Markets Inspectorate, regulatory sandboxes are developing to temporarily enable the advancement of markets as HEMS. By-and-by laws and regulations are therefore likely to be implemented in a way that supports the development of HEMS as aspects such as energy efficiency, peak shaving and flexibility of demand is of high importance for the electricity infrastructure in each country. There are also many countries that have rolled out smart meters nationally just as the Nordic countries. Following that development, it is very likely that an increasing number of countries will do so in the future, which will enable more companies to invest in developing HEMS solutions for a global audience which can result in global market growth. Furthermore, the trend of decentralization in the electricity market also indicates that regulations as a whole will be adapted to facilitate HEMS solutions, which also indicates favorable future circumstances for the HEMS market to flourish.

Lastly, associated with the research questions of this paper, there are numerous potential strategic partners for KTH Live-In Lab to collaborate with in order to proceed in its HEMS development. To develop the HEMS market and bring forth a value offering that recognizes requirements from the whole market, it is recommended that KTH Live-In Lab seeks strategic partners throughout the whole value chain of HEMS. Such potential partners could be both operative companies within the HEMS segment as well as regulatory institutions. Operative companies of interest could be companies of different sizes, such as larger actors such as Bosch and EON, and smaller actors such as Tibber and Watty. Bigger companies can bring forward knowledge about hardware and tangible components that are needed in a home energy management system, while smaller actors tend to have a vast focus on software and customer-centric app solutions. With both type of actors included as strategic partners, there are favorable possibilities to research issues that are important both with respect to the hardware and software aspects of HEMS. Additionally, it is suggested that KTH Live-In Lab seek to include regulatory institutions such as the Swedish Energy Markets Inspectorate and Svenska Kraftnät, to ensure that the development and value offerings that are being researched and supported, are compatible with current regulations and possibilities on the Nordic electricity market. Another benefit with including regulatory institutions is that

conducted HEMS research can be tailored to solve energy related problems that are acknowledged by regulatory institutions, such as power deficit or peak shaving. In addition, KTH Live-In Lab could also have a say in affecting the aspects developed on a regulatory level. All in all, it is recommended that KTH Live-In Lab include competencies covering as many aspects of the HEMS market as possible, to fully utilize and leverage the many benefits of the solution.

7. Conclusion and Suggestions for Further Research

7.1 Conclusion

With regards to the findings of this report, it can be concluded that the market for HEMS is already live, based on the many active companies and available products, as well as ongoing initiatives for development of the market. The available products are mainly all-in-one solutions with physical sensing and measuring devices in combination with a mobile application. Typical functionalities are energy consumption overview, live feedback, historical consumption data, optimization of EV charging and solar PV production as well as security related features. The HEMS market is predicted to grow further as new companies enter the market and incumbents develop their existing value proposition. Observed drivers of market development is the roll out of smart meters, increased environmental consciousness and the boom of electric vehicles as for example observed in Norway. Barriers to development are for example issues concerning data privacy and lack of financial incentives for end users. Additionally, it is predicted that the Nordic market will grow faster than the European market, due to the region's position in the forefront of sustainable development and its superior electricity system which is adapting to local production and consumption, which could potentially be optimized by HEMS. Lastly, it is proposed that KTH Live-in Lab collaborates with varying market operators across the complex value chain and ecosystem of HEMS, to fully leverage its potential for enabling energy efficient residential households.

7.2 Suggestions for Further Research

To ensure continuous growth of the HEMS market, several topics are interesting to consider for future research. Firstly, further extensive research on energy and cost savings as a result of HEMS is essential to clarify and potentially strengthen the incentives of using HEMS. Today's existing research gives no clear answer to how much energy and money can be saved, which is critical when putting forward clear incentives and advantages of using HEMS. One such measure could be to test different HEMS products in the existing test beds provided by KTH Live-In Lab. Secondly, it is suggested to thoroughly investigate customer behaviours and key drivers that would attract larger masses to invest in HEMS. By doing so, future HEMS products can be developed to meet the desires and needs of the market, which could result in a remarkable expansion of the HEMS market.

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9. Appendix

Appendix 1 - Interview Questions for the Swedish Energy Markets Inspectorate

The following questions were asked and answered during the interview with Marielle Lahti, Senior Adviser, at the Swedish Energy Markets Inspectorate (Ei):

- Please introduce yourself and Ei shortly.
- Does Ei work with Home Energy Management, and if yes, in which ways?
- Which current trends are possible to identify on the energy market?
- Which changes on the market are drivers of HEMS?
- In addition to smart meters, which instruments can be used to strengthen the position of energy market customers and to make them more active?
- Are there enough regulations and laws to enable HEMS? If no, which regulations and laws are needed?
- Who owns all the data that is generated through HEMS, and has there been a discussion about the topic?
- Ei highlighted several challenges that the energy market is facing in a report from 2016. How can HEMS help solve the challenges mentioned?
- Which are the main drivers and incentives needed for a customer to start using HEMS?
- Which future trends do you see coming within the energy market?

Appendix 2 - Interview Questions for Stockholm Exergi

The following questions were asked and answered during the interview with Christer Boberg, Market Developer, at Stockholm Exergi:

- Please introduce yourself and Stockholm Exergi shortly.
- How do you work with smart buildings and home energy management at Stockholm Exergi?
- Explain more about your HEMS solution “Intelligy” and aspects such as; functionalities, customer base, possibilities, barriers and peak shaving.

- How do you think the HEMS market will develop over time?

- Is current legislation and infrastructure on the market sufficient to scale up the usage of HEMS? If not: Which are the barriers, challenges and possibilities with HEMS and its future market?

Appendix 3 - Interview Questions for Tibber

The following questions were asked and answered during the interview with Love Thyresson, Product Manager, at Tibber:

- Please introduce yourself and Tibber shortly.

- Explain more about the products and solutions that Tibber offer, including functionalities and customer base.

- Which are the main drivers for a customer to invest in a HEMS solution?

- How do you act to broaden Tibber's customer base?

- How "smart" is the Tibber App? Is it capable of making optimized energy management decisions, or is it the bundled solution itself that form the main value offering?

- Which countries is Tibber operating in?

- Which are your main competitors?

- How is Tibber different from other HEMS solutions on the market?

- Explain more about your collaborations with other actors.

- How has the market reacted to your solution?

- How do you think the HEMS market will develop over time?

- How do you think your product will develop over time?

- Which are Tibber's main possibilities/challenges in the future?

Appendix 4 - Interview Questions for Svenska Kraftnät

The following questions were asked and answered during the interview with Linda Thell, Electricity Market Specialist, at Svenska Kraftnät:

- Please introduce yourself and Svenska Kraftnät shortly.

- What is Svenska Kraftnät's viewpoint on demand flexibility with regards to HEMS? How can it affect the electricity market and aspects such as distribution and production? Do you see any challenges?

- Are there any limitations in the power grid with related to a growing proportion of local production (wind power, solar power etc.)

- Have you observed any movements on the market towards HEMS solutions?

- What are your responsibilities to support the emergence of the HEMS market and what actions do you take to do so?

- Which challenges on today's electricity market can be resolved as a result of HEMS solutions?

- Is current legislation and infrastructure on the market sufficient to scale up the usage of HEMS?

- How do you view the Swedish electricity market in the future and what major movements can you see?

TRITA -ITM-EX 2020:115