NTNU
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Sustainable Smart House Technology Business Models

An Assessment of Rebound Effects

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Master of Science in Communication Technology
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Problem Description

Implementing smart technologies can introduce a number of difficulties, including the environmental rebound effect. Smart house technology and other life-enhancing ICTs have good support in literature for being effective with regards to the rebound effect. If these technologies are to be deployed in a rebound-minimizing way, there is a need for new business models. This assignment will look into effective and sustainable business models with regards to rebound effects from user adaption, e.g. by using suggested and existing smart house technologies as cases and incorporating rebound effects into sustainable business models.

More specifically, the student will:
- Gather relevant knowledge on business modeling, rebound effects, and smart house technologies
- Construct a relevant case for the use of smart house technologies
- Study how different business modeling influences rebound effects for the constructed case

Assignment given: 15. January 2010
Supervisor: Leif Arne Rønningen, ITEM

A business that makes nothing
but money is a poor business

Henry Ford

Abstract

Smart House Technologies have in earlier research been put forward as an effective measure to reduce CO2-emissions. A rebound effect is defined as the change in energy demand caused by changes in consumer behavior. This behavior occurs when energy efficient technology such as Smart House Technology is introduced. Energy efficient technology has been found to stimulate increased usage through the appearance of new services and usage areas. This leads to an increase in overall energy demand, causing a take-back in energy efficiency called a rebound effect. This thesis has conducted an analysis on potential rebound effects from Smart House Technologies. The analysis is based on a constructed case study and interviews with users. This research shows that people tend to react positively to feedback on energy consumption. By incorporating this into business models wanted rebound effects towards increased environmental awareness by the users can be enhanced. Another finding was that measures should be taken by Smart House Technology providers to prevent direct cost-savings to reach the users and cause unwanted rebound effects from wealth maximization. The results have been discussed at micro- and macro-economic levels. A suggestion for a sustainable business model at the micro-level is presented. The suggested business model is an environmentally friendly bonus point scheme. The scheme can be utilized to capture the free cash from energy savings achieved with Smart House Technology. Customer relationships, partner networks and revenue models were identified as the three elements in Osterwalder's business model ontology that considerably influence rebound effects arising from the use of Smart House Technologies.

Preface

This thesis is submitted to the Norwegian University of Science and Technology (NTNU) as a part of my Master of Science in Communications Technology. The work presented here has been performed at the Department of Telematics, under the supervision of supervisor Harald Øverby and professor Leif Arne Rønningen.

I would like to thank both Harald and Leif Arne for invaluable guidance and fruitful discussions throughout the working process. You have undoubtedly helped made the idea I had in the fall of 2009, become this fulfilled project. It has been a long, but valuable journey.

Last, but not least, I would like to thank my beloved boyfriend who patiently has corrected and discussed this work with me.

Oslo, June 10 2010

Line Rød-Knudsen

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Definitions[1]

Consumer Electronics (CE) Electronic equipment intended for everyday use. Consumer electronics are most often used in entertainment, communications and office productivity. Some products classified as consumer electronics include personal computers, telephones, MP3 players, audio equipment, televisions, calculators, GPS automotive navigation systems, digital cameras and playback and recording of video media such as DVDs, VHSs or camcorders.

Graphical User Interface (GUI) A type of user interface item that allows people to interact with programs in more ways than typing, such as computers; hand-held devices such as MP3 Players, Portable Media Players or Gaming devices; household appliances and office equipment. The interaction is with images rather than text commands. A GUI offers graphical icons, and visual indicators, as opposed to text-based interfaces, typed command labels or text navigation to fully represent the information and actions available to a user. The actions are usually performed through direct manipulation of the graphical elements.

Local Area Network (LAN) A computer network that covers a small physical area, like a home, office, or small groups of buildings, such as a school, or an airport. The defining characteristics of LANs, in contrast to wide area networks (WANs), include their usually higher data-transfer rates, smaller geographic area, and lack of a need for leased telecommunication lines. Ethernet over twisted pair cabling, and Wi-Fi are the two most common technologies currently in use.

Power Line Communication (PLC) Systems for carrying data on a conductor also used for electric power transmission.

Radio Frequency (RF) A type of radiation that is a subset of electromagnetic radiation with a wavelength of 100 km to 1 mm, which is a frequency of 3 kHz to 300 GHz, respectively. This range of electromagnetic radiation constitutes the "radio spectrum" and corresponds to the frequency of alternating current electrical signals used to produce and detect radio waves. RF refers in this thesis to radiation through air.

Radio-Frequency Identification (RFID) The use of an object (typically referred to as an RFID tag) applied to or incorporated into a product, animal, or person for the

[1] All definitions are based on information from http://en.wikipedia.org

purpose of identification and tracking using radio waves. Some tags can be read from several meters away and beyond the line of sight of the reader.

Residential Gateway (RG) A home networking device, used as a gateway to connect devices in the home to the Internet or other wide area networks (WAN).

Universal Plug and Play (UPnP) A set of networking protocols promulgated by the UPnP Forum. The goals of UPnP are to allow devices to connect seamlessly and to simplify the implementation of networks in the home (data sharing, communications, and entertainment) and incorporate environments for simplified installation of computer components.

Voice over IP (VoIP) A general term for a family of transmission technologies for delivery of voice communications over IP networks such as the Internet or other packet-switched networks.

Acronyms

Chapter 1

Introduction

1.1 Scope

The scope of this thesis is Smart House Technologies (SHTs) and their rebound effects. These technologies have for a long time been foreseen to change the home and its activities, but have not yet been very successful in reaching their full potential [21]. In the Smart 2020 report released in 2008 [43], it was stated that Information- and Communication Technologies (ICTs) in the buildings sector could substantially contribute to reduce CO_2-emissions[1]. Global building emissions of CO_2 were 8% of total emissions in 2002. Figure 1.1, page 2, shows that in a Business As Usual (BAU) case, total emissions from the buildings sector will be 11.7 giga tons CO_2 equivalents in 2020. The figure also illustrates that Building Management Systems (BMS)[2] could reduce emissions from the sector by 15% by 2020. The report, however, does not take into account rebound effects. Rebound effects occur when implementation of ICTs frees up capital, e.g. time or costs. This often results in an increased overall energy demand because of changed consumer behavior. The overall result from the implementation is a "take-back", i.e. a rebound effect [30]. The scope of this thesis is thus to address the topic of rebound effects and especially from SHTs, more thoroughly.

This thesis aims to identify efficient ways of assuring environmental benefits of SHTs by taking rebound effects into account. The goal is to reduce overall CO_2-emissions from the buildings sector by use of efficient business models that includes rebound effects.

[1] This thesis will focus on the reduction of CO_2 emissions from energy consumption, not other environmental threats such as pollutants and overpopulation

[2] Categorized as Smart House Technology (SHT)

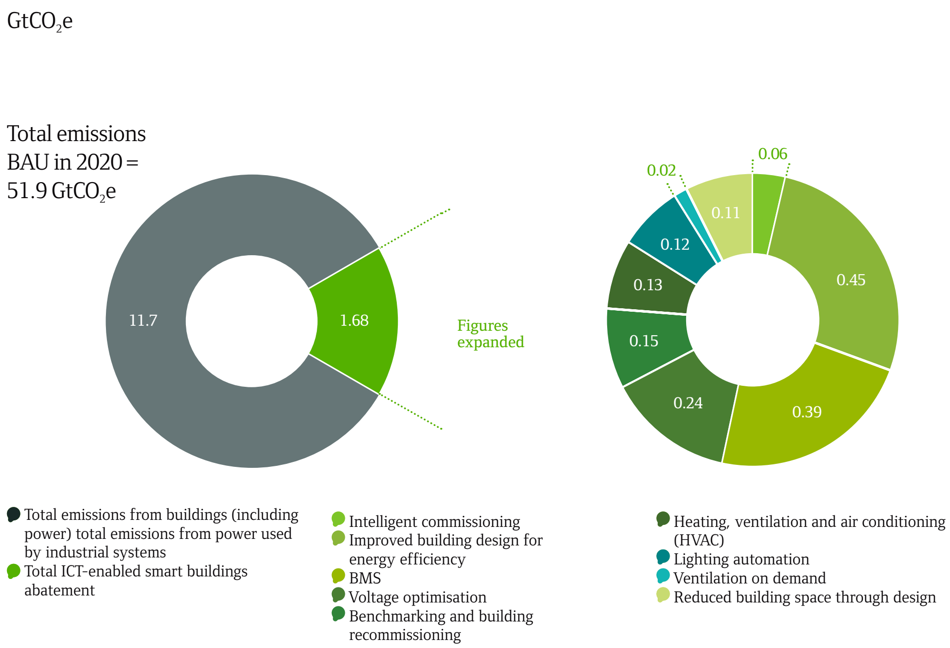

Figure 1.1: SMART buildings: The global impact 2020 [43]

1.2 Problem Definition

This work will address the project scope with three research questions:

1. *What are the most evident rebound effects from Smart House Technologies?*
2. *How can unwanted (or wanted) rebound effects from Smart House Technologies be minimized (or maximized)?*
3. *How does different business modeling influence rebound effects from Smart House Technologies?*

1.3 Limitation of Scope

In this thesis smart houses will be defined as residential homes, not institutional or commercial buildings. In addition, smart homes will be explored with focus on entertainment and normal living. Systems developed for medical and other types of care will not be relevant, other than as a limited part of a "normal" family life. This is important since the scope of this thesis will focus on rebound effects related to normal living, and their effects on personal behavior. Business modeling will be limited to the definition and ontology of Osterwalder [25] and with a focus on how rebound effects can be applied in business modeling. That is to say that the scope does not include a complete business model for Smart House Technologies (SHTs), including business models for potential providers, e.g. electrical utility companies.

1.4 Motivations and Current Interest

The increased focus on the climate challenge in later years has lead to an increased push for finding solutions that can decrease CO_2-emissions and at the same time stimulate economic growth. Recently, Information- and Communication Technologies (ICTs) have been put forward as a major contributor for realizing this goal. More specifically, Smart House Technologies (SHTs) have been found to be effective in the transformation towards a low-carbon society [30].

As already mentioned, SHTs have been predicted to change our daily lives and reduce the carbon footprint from the buildings sector. This has not yet been the case and a lack of standardization is a likely reason for the low degree of smart buildings implementation [18]. SHTs also seem to have failed to provide the consumer with the services needed to create strong demand. New faith is however put into SHTs as “fiber to the home”[3] is becoming more wide spread and as the demand for more bandwidth accompanies the growth of new multimedia technologies [5, 14]. Another hope for SHTs is the increasing demand for security and everyday effectiveness of standard solutions as washing, cooking and shopping.

The Royal Norwegian Ministry of Petroleum and Energy founded the public enterprise Enova SF in 2001, which has as its main mission “to contribute to environmentally sound and rational use and production of energy, relying on financial instruments and incentives to stimulate market actors and mechanisms to achieve national energy policy goals” [10]. Enova works with different sectors and offers subsidies and information on, among others, energy efficiency and the environment. The buildings sector and implementation of new technologies are among Enova’s focus areas. Another initiative is “Grønn IT” by IKT-Norge, which focuses on the environmental benefits of ICT [22]. This shows that the Norwegian government and business actors in Norway are interested and motivated in working towards energy efficiency through ICT. Home automation or SHTs could be forceful tools for achieving these goals. If rebound effects are addressed properly in this matter, solutions found in this thesis could be helpful in directing a sustainable path forward.

[3] Large-scale optical fiber network deployment to residential homes

1.5 Related Work

Key literatures within this field include environmental reports such as the Smart2020 [43] and World Wide Fund for Nature (WWF)'s strategy documents [28]. These have addressed environmental gains from Information- and Communication Technologies (ICTs), and has established a good fact base for decision-makers. Other relevant research addresses the general rebound effect in energy economics, for example [33, 35].

Rebound effects from ICT have been explored to some extent for both academic and commercial purposes. Hilty et al. [21] have conducted a system dynamics simulation study. It revealed strong rebound effects in the transport sector in a time-horizon until 2020. The rebound effects occurred when ICT applications led to time or cost savings for transport, which resulted in increased use of transportation. The Institute for Prospective Technological Studies (IPTS) of the European Commission funded in 2003–2004 a study called "The Future Impact of ICT on Environmental Sustainability". The study group developed a system dynamics model and revised the findings described in [11]. The Japanese telecom-firm NTT has presented a concept for evaluating the rebound effect through the use of life-cycle analysis (LCA) and a method based on user questionnaires of videoconferences [38]. Results from the work show that rebound effects were estimated to be around 10% of the total environmental burden of videoconferences. Herring & Roy conducted an empirical research project "People-centered eco-design" with the aim to identify how consumers may avoid rebound effects. In addition, it analyzed how manufacturers, service providers and governments might design and promote these products to achieve their optimal benefit. The results indicate that there is a need to combine innovative technology with a sustainable lifestyle to ensure a future low-carbon economy with a high quality of life [19]. Ha et al. have created a "method to analyze user behavior in home environments". The study has analyzed users' behavior in ubiquitous computing environments within the home. It suggests a method consisting of five steps to analyze user behavior effectively with the aim of using it in personalized ICT services [16].

This thesis addresses rebound effects from Smart House Technologies (SHTs), which has not been widely studied. Rebound effects can be looked upon as social phenomena [32], and this thesis will use a qualitative research approach for identifying them. Thereafter, the findings will be used in business modeling to show how companies can utilize knowledge of rebound effects to ensure sustainable environmental benefits of their products or services.

1.6 Report Structure

This thesis is structured into the following chapters:

- **Chapter 2** presents the concept of Smart House Technologies (SHTs). A definition of the "Smart Home" and the evolution of smart homes are described.
- Rebound effects from Information- and Communication Technologies (ICTs) are defined in **Chapter 3**. The chapter ends with two tables presenting possible rebound effects from SHTs.
- A constructed technical case study for a "Smart Home Management system" is presented in **Chapter 4**. The case study will be used in this research to identify rebound effects from SHTs.
- Research methods and the chosen method, semi-structured interviews, are described in **Chapter 5**. The chapter also describes the research procedure used in this thesis.
- **Chapter 6** summarizes and evaluates the findings from the conducted semi-structured interviews in this research.
- In **Chapter 7**, research findings are used to discuss implications for sustainable business models for SHTs based on the case study.
- Discussion of the research findings, and weaknesses and strengths of this thesis is presented in **Chapter 8**.
- **Chapter 9** concludes the findings in this thesis and suggests topics for further work.

1.7 Summary

The scope of this thesis is the assurance of environmental benefits from Smart House Technologies (SHTs) by taking rebound effects into account when designing business models. Existing literature in the field consists of system dynamic models and social research. This thesis extends the literature in this field by elaborating on SHTs with the use of qualitative research. It also extends the field into the usage area of business modeling with the aim of including commercial companies as important actors in the battle for CO_2 emissions reduction.

The next chapter introduces the evolution and concept of SHTs.

Chapter 2

Smart House Technology

It was as early as in the 1950's, with the arrival of electrical home appliances such as the refrigerator, that Smart House Technologies (SHTs) were first predicted to change the living environment of the residential home. An illustration from 1956 proves that the idea of the smart home has been around for a while. Figure 2.1, next page, shows Three Dimensional Televisions (3DTVs) and house-control panels as future technologies in 1956. These technologies are available on the market today, but still not common in most homes. This indicates that many Smart House Technologies have been "just around the corner" for over 50 years. Today many social structures in the home are changing and technology is becoming more and more ubiquitous in peoples' lives. These changes, combined in trends like men and women sharing more of the household chores, new forms of social networks, increased focus on the climate challenge and a high degree of mobility, may be factors that can accelerate the implementation of Smart House Technologies (SHTs). This chapter introduces the evolution and current technology behind the concept of "Smart Homes".

2.1 Evolution of Smart House Technology

Household appliances were introduced in the 1950's and made domestic activities more effective. Four stages of evolution in Smart House Technology (SHT) have been identified by Venkatesh et al. [41] and are shown in Table 2.1 on the next page. The table categorizes these stages and lists the common technologies believed to be seen in that stage of development. The author asserts that we are today facing Smart Home 2, Home Automation/ Intelligentification: "World of Thinking Machines". This implies that the next stage is Human Substitution and "World of Artificial Intelligence and Artificial Life".

Figure 2.1: An illustration of the future home by Fred McNabb from 1956

Table 2.1: The evolution of Smart House Technologies, based on [41]

Home Electrification	**Home Communication** **(Smart Home 1)**	**Home Automation/ Intelligentification** **(Smart Home 2)**	**Human Substitution** **(Smart Home 3)**
"World of Energy" • Home Appliances • Radio	"World of Simple Programmable Machines" • Telephone • TV • VCR • FAX Machines • Security	"World of Thinking Machines" • Computers • Smart Appliances • Remote Sensors	"World of Artificial Intelligence and Artificial Life" • Bio-Tech • Home Robotics

Even though SHTs are increasingly available and largely affordable, they are still not common in normal houses. Some authors point at the lack of common standards in the industry and difficulties in developing the one appliance or application that can solve this. Another problem is the difficulties for normal people to set up and operate the complex systems SHTs represent. Developing a "plug-and-play" solution, i.e. a solution customers can buy, set up and use without any specific technological knowledge or skills, could solve the general operating problem. The problem of people not realizing the need to cut energy use and the cost of implementing them is a more fundamental problem. One suggestion is to implement SHTs incrementally, e.g. to make appliances with the ability to interconnect.

In this way, users would realize that many of their appliances already support connection and power saving measures, and that all they would need is the backbone system. Another solution is to provide SHT backbone systems through technologies that people would buy or invest in even if the backbone option was not part of the package. This could be entertainment systems like multimedia centers, music systems or smart energy meters. From an economical point of view there is also a lack of sustainable business models for providers of Smart House Technologies, which will be the focus of this thesis [2, 5, 18, 41].

2.2 The Smart Home

The terms "smart home", "intelligent home" or "home automation" generally refer to the same concept and are often used interchangeably. The concept is used to "classify the technologies that shape the use of the home" [5]. These classifications are twofold:

1. The idea that the material environment and domestic tasks of the home can be automated
2. The notion of the "informational home", where existing and new information services are used to improve the management of family and professional life

Venkatesh et al. [41] state that a house or a home can be looked upon as a living space of different functional centers, such as an activity center, learning center, working center, communication center, shopping center and entertainment center. These centers can be embedded as organic elements into three subdivisions of the living space: *the social space*, *the physical space* and *the technological space*. This division of the home will be used in Tables 3.2 and 3.3, pages 16 and 17, when outlining possible rebound effects from Smart House Technologies (SHTs).

Accordingly, we can see the smart house as a place where different human needs are met through different types of technology. The evolution of smart houses has introduced an interoperability of these technologies that increase the usefulness of each separate appliance or solution.

"The networked home" is another name for SHTs. It denotes that, in the future, every appliance in the home will have a network address and have the possibility to be managed centrally or remotely from any type of client connected to the Internet. This will allow the appliances to communicate with each other and make decisions that make our lives easier, e.g. dimming the lights, choosing a TV program or locking doors and windows. Another example of the practicalities offered with smart appliances is that the refrigerator does the shopping itself by using Radio-Frequency Identification (RFID) tags [23] or, in the future,

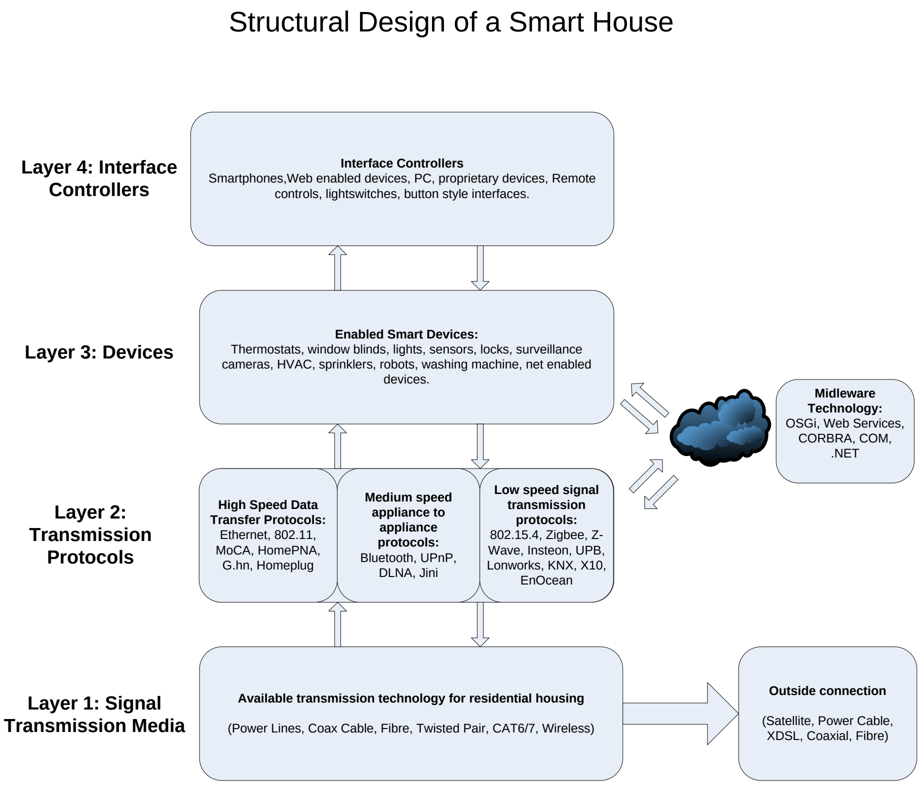

Figure 2.2: Structural design of a smart house [18]

robots taking chores, cuddling and socializing with us, and integrated 3D environments being the basis for entertainment, learning, communicating and working [42].

One scenario for the future home is the adaptive, context-aware, intelligent home that “learns” the patterns and preferences of its inhabitants. This scenario is in line with “the networked home”, but uses a network of sensors around the house to design patterns and modes according to user behaviors. The home can thus be seen as a system adapting to user needs and preferences, learning through artificial intelligence [31, 41].

Haugen [18] presents in a technical report a structural design of a current smart house and the technologies involved, see Figure 2.2, above. SHTs are divided into four layers: Signal Transmission Media, Transmission Protocols, Devices (and Appliances) and Interface Controllers. The cloud on the right represents the middleware technology that facilitates the interoperability between smart devices and appliances. We will in this thesis focus on the two topmost layers: Interface Controllers and Devices. The technical specifications of

SHTs are beyond the scope of this work and will not be further discussed.

2.3 Time-saving versus Time-consuming Technologies

Smart House Technologies (SHTs) can be divided into *passive or time-saving* and *active or time-consuming* technologies [2, 17]. Passive technologies have little or no direct interaction with humans and work in the "background" to facilitate energy saving and comfort without being visible. These technologies save time and energy for the users without interaction. An example is a smart refrigerator that turns of the cooling process to save energy in peak energy consumption hours of the day. One or two minutes without power are sufficient to ease the demand on the grid in these periods. This energy saving measure is unnoticeable for the users, since the refrigerator is capable of keeping the temperature stable in this short period of time. Energy providers get a more stable grid during peak hours and the owner of the refrigerator saves energy when the energy prices are at their highest.

Active or time-consuming SHTs interact directly with humans to enhance their lives through for example entertainment: High Definition Televisions (HDTVs), computer games and stereo/ audio sets. Time-consuming technologies are smart technologies that interact and entertain people. These technologies are made to take up time and are therefore called "time-consuming".

2.4 Summary

The "Smart Home" is a concept used to explain how domestic tasks can be atomized and new information technology is used to improve the management of the home. Smart House Technologies (SHTs) define *the technological space* of a Smart Home and consists of technologies used to improve efficiency in the home. There are today several reasons for why SHTs are not common in residential houses. One is the lack of common standards for interconnection and another is the complexity of the technologies, which makes it difficult for the average person to handle them. SHTs are generally divided into *time-saving* or *time-consuming* technologies. This refers to technologies that either make household activities more efficient or interact with the inhabitants to take up time such as a PC or TV.

The next chapter focuses on rebound effects from Information- and Communication Technologies (ICTs) and introduces rebound effects from SHTs.

Chapter 3

Rebound Effects from ICT

Information- and Communication Technologies (ICTs) have become ubiquitous and they are becoming increasingly wide spread. Human interaction and reaction to these technologies are interesting, not only because of the potential rebound effects. They can also profoundly change many aspects of modern human life. This is interesting from a psychological and sociological perspective, but it also affects the development of these technologies. The environmental impact of technologies naturally comes from human reactions to them. It is therefore important to look at ICTs and especially smart houses as socio-technological environments. This chapter gives an overview of rebound effects, focusing on ICT and Smart House Technologies (SHTs).

3.1 Definition of Rebound Effects

"The rebound effect" is a phenomenon that occurs when more energy efficient technology is introduced, i.e. more output for the same amount of energy input. This introduction can lead to the appearance of new services and usage areas for the technology. Further, this can stimulate to an increase in energy usage and demand, called a "take-back". That is to say, that even though the technology itself was more energy efficient and one would expect a decrease in energy usage, users' behavior reduce the overall efficiency of the new technology through new usage areas. The greatest problem arises when this new behavior accumulate and lead to an overall increase in energy demand. That is to say that overall energy demand after, is higher than before the new technology was introduced. This is what we call "the rebound effect" [30].

The rebound effect is a well-known phenomenon in energy economics[1] and can be divided into three orders of effects: first, second and third order effects, shown in Table 3.1, next page:

First order effects are *direct effects*, i.e. effects that directly stems from the technology itself. For example when a new PC is used for longer periods because the cost is the same as using an older PC for a shorter time.

Second order effects are *indirect effects* that affect other sectors indirectly. For example, if a PC is faster it can be used for more purposes, such as communicating or games. This leads to higher incomes in these sectors, not only the PC manufacturer-sector.

Third order effects are *economy wide effects* that stimulate the whole economy and have the ability to change paradigms. This is for example, what has happened in the "information age" that we experience today. Information is extensively available at any time from any place. In this way, technology has changed the way we live, learn and socialize.

Classic economic theory sees humans and consumers as rational agents, aiming to maximize their economic profit or personal welfare. The rebound effect phenomenon originates in this field of thought, which means that we can expect the users to maximize their profit when energy prices fall or they gain efficiency [35]. Other theories and research areas also support the rebound effect, but take different approaches. One example is the field of Industrial Ecology, which focuses on the fact that not all environmental impacts create internal costs, and thus do not impact the consumer behavior directly [20]. This means that the classic economic theory on value maximizing consumers becomes obsolete. Using methods from the social sciences are thus seen as better ways to explain and examine rebound effects from Information- and Communication Technology (ICT), since consumer behavior is influenced by a variety of outside factors and personal preferences.

Figure 3.1, page 14, shows how rebound effects "eat" up the potential energy savings from a new technology in a waterfall diagram. This clearly visualizes the take-back effect that may result from changed behaviors as a consequence of new technology. Table 3.1 on the next page, shows this classification of rebound effects with conceptual examples. Both classifications are based on [35] and originally presented in [30].

As mentioned in Chapter 2, Smart House Technologies (SHTs) are divided into *time-saving* and *time-consuming* technologies. Time-saving technologies are often related to household chores and efficiency, while time-consuming technologies are usually entertainment and work. It can be assumed that time-consuming technologies have the greatest rebound effects because they imply more use. This need not necessarily be the case, since time-saving technologies often saves both time and money that can result in substitution

[1] See for example "Jevons Paradox" or "Khazzoom-Brookes postulate" from classic economic theory

Table 3.1: Classification and examples of rebound effects [30]

Estimate of energy savings potential: The savings in energy usage that is equal to the energy efficiency potential of a technological improvement that increases energy efficiency (i.e. a technology that uses energy is improved so that it uses less energy per unit output)	**Actual energy savings:** The remaining energy saved after the sum of negative rebound effects has decreased the energy efficiency gains from a technological improvement	
	System-wide rebound effects: Rebound effects that are due to long-term changes in society structures (third order effects)	**Time effects:** How people behave (choose to do) when they get more spare time as a result of more energy efficient technologies. *Positive:* Low-carbon activities such as mountain climbing or reading *Negative:* High-carbon activities such as air plane travel or computer gaming
		Preference changes: Changes in consumer preferences *Positive*: Preference for more energy efficient / time saving solutions, low-carbon commodities *Negative*: Preference for higher quality and high-carbon luxury goods
		Structural changes: Changes in institutional and organizational structures. Characteristic of a pre phase to a paradigm shift. Example: a current structural change of the world economy is globalization *Positive:* Emergence of new business models and governmental solutions that stimulate low-carbon activities and behavior *Negative:* Network effects of high-carbon activities and environmentally adverse behavior
	Indirect rebound effects: Changes in demand and behavior in other sectors and areas than where the technological improvement was introduced (second order effects)	**Secondary effects:** Increased consumption of other products or changed behavior in other areas than directly influenced by the initiating technology *Positive:* A more energy efficient service, such as digital music, stimulate the emergence and demand of other energy efficient services, such as digital movies. *Negative:* Increased production outputs (because of lower input costs from energy) that create higher consumption/demand of this and other products in other sectors. May lead to an increase of production in other sectors
		Embodied energy: Indirect energy consumption that is included in the production of products that is substituted with the efficiency improved product or service *Positive:* nonexistent *Negative:* The energy required to produce insulation
	Direct rebound effects: Reflects the direct impact on a consumer as a result of the technological improvement, changes in income or substitution of saved energy	**Income/output effect:** Income/output increases because costs related to energy decrease and income increase *Positive:* Increased income is used to invest in new energy efficiency measures. *Negative:* Production output increase because energy prices is reduced. Higher consumption of goods and services caused by higher incomes
		Substitution effect: A commodity is substituted by another commodity or more of the same because energy efficiency has reduced the price of the commodity *Positive:* The freed capital is used on low-carbon commodities or other activities *Negative:* The freed capital is used on more units or other high-carbon commodities

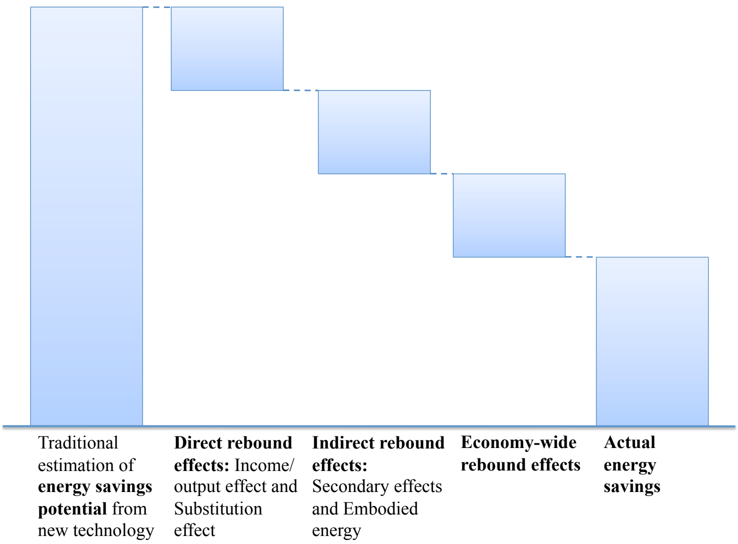

Figure 3.1: Classification of rebound effects [30]

and income effects. How these "extra" resources are used, and what this implies of second and third order effects are of high significance.

3.2 Rebound Effects from SHTs

There is today a wide range of Smart House Technologies (SHTs) available on the market. Some technologies are provided in new homes through contractors and architects, examples include Xcomfort building automation from Moeller, Siemens Building Technologies and numerous others[2]. Home automation or building automation is today a common type of technology and can be considered as the first step toward Smart Homes. Energy information and digital sustainability services are also becoming numerous. Many of these technologies, such as Make Me Sustainable[3] and AlertMe[4] suggest measures to save energy and money. For example provides AlertMe a meter to monitor the electricity usage in your home and Make Me Sustainable utilizes user information to provide information on how to become more sustainable.

[2] An extensive list is provided on http://home-automation.org
[3] http://makemesustainable.com
[4] http://www.alertme.com

Tables 3.2 and 3.3, page 16 and 17, respectively, present some SHTs according to their physical and social spaces explained below. Possible direct, indirect and economy-wide rebound effects from user adaption of the technologies are also suggested and presented in the tables. The tables have been constructed on the base of SHT and rebound effect literature. The technologies and rebound effects presented in the tables are consequently neither extensive nor based on calculations.

The Physical Space The spaces we occupy are usually labeled with names related to their social function. Examples are "bathroom", "dining room", "ball room" and "playground". A home, as every other physical space, is divided into different rooms and/ or spaces with different social functions and containing different technologies.

The Social Space The social space consists of social functions and activities in the home. These functions and activities are usually connected to a physical space and include different types of technologies to assist inhabitants. The home is seen as a shelter from the outside world and consists of spaces of personal and private spheres. It is also a place to socialize and connect with others, for example through a telephone or the Internet. A home encompasses a number of social functions such as learning, relaxing, eating and shopping. Traditionally, the home has been a private zone deconnected from the world, but as Information- and Communication Technologies (ICTs) have developed, it is today also a place to reconnect and maintain connections though social networks online.

The Technological Space The technological space in a home is a collective term for all technologies in the home. Today this may include several PCs, TVs, refrigerators and freezers, washing and dishwasher machines and other Consumer Electronics (CE). Technologies have different purposes according to their social function and physical placement in the home. For example, a PC that serves as a multimedia center in the living-room serves other means than a PC in the office. Another example is the refrigerator, which delivers a very different service than the intercom system. The divide between current and future technologies is not very clear, therefore current technologies are defined as technologies that are in use today and that the average consumer can buy in a store or get hold of if he is interested.

An example of rebound effects from Table 3.2 is from the physical space *kitchen* in a **modern home**. The social functions in this space are listed to be *making food, eat* and *socialize*. Smart House Technologies (SHTs) in a modern kitchen would be *PC/ Internet* and *smart kitchen appliances*. The latter are appliances such as smart refrigerators that keep the temperature, but shuts off the power in short periods during peak demand hours. The refrigerator could also have an integrated Radio-Frequency Identification (RFID) tag-reader that keeps a list of the food inside. Other examples of smart appliances include programmable coffee-machines and dishwashers with timers. A *direct rebound effect* from these appliances would be that *home cooking* becomes easier and less time-consuming.

Table 3.2: Possible rebound effects from SHTs in a modern home

THE MODERN SMART HOME			POTENTIAL REBOUND EFFECTS		
The Physical Space	**The Social Space**	**The Technological Space**	**Direct Effects**	**Indirect Effects**	**Economy-wide Effects**
Kitchen	• Make Food • Eat • Socialize	• PC/Internet • Smart kitchen appliances	• More home cooking • Better food mgmt[1]	• Less take-away, restaurant visits • Less food disposal • Increase in food-related services such as recipes	• Decrease in restaurant sector • Healthier population
Bathroom	• Relax • Recreation • Cleaning	• Media mgmt • HVAC mgmt • Water mgmt • Lights mgmt	• Better HVAC usage • More use of spa facilities • Better water mgmt	• More at home • Increase in cosmetic sales	• Increase in cosmetic disposal (pollutants)
Office	• Work • Plan • Shop • Learn • Banking • Telephone	• PC/Internet • Videoconference • Home server & thin clients (local and secure remote data storage) • VoIP	• Home office • Internet shopping • E-learning • Social networks online • Internet banking	• Food travels longer • More parcel shipping • Moving to the country • More spare time	• Increase in transport sector • More travel • Increase in ICT service sector
Living room	• Relax • Socialize • Entertainment	• Multimedia center • HDTV • Multi room music system • Universal remote control • HVAC mgmt • Lighting mgmt • Portable screens/ clients (kindle, iPad, smart phone, PDA)	• More home entertainment > more time at home • Better home mgmt • More use of energy	• More use of electricity • More investments in the home • More electronic waste	• Bigger market for home & Consumer Electronics (CE) • Decrease in cinema/entertainme nt/parks etc
Laundry room	• Cleaning • Washing • Drying & ironing	• Smart washing machine & tumble-dryer • Robotic vacuum cleaner & floor washing machine	• More washing and cleaning • More effective washing • Time-saving	• More chemical pollutants to local environment • More spare time	• Increase in spare-time activities (travel, shopping, workout, hobbies)
Workout room	• Work out • Fitness	• Fitness appliances • Online consultation	• Time-saving (home workout) • Healthier & fitter people	• More spare time • People live longer	• More travel • More entertainment • More public expenses on elderly
Bedroom	• Relax • Entertainment • Wardrobe • Sick-care	• Electrical bed • HDTV • PC/Internet • Basic medical monitoring and aid	• Better & faster medical aid	• Less patients at hospitals (better time mgmt for doctors)	• Healthier people > live longer > use more resources (denser population)
Garden	• Recreation • Socialize • Relax	• Robotic lawn mower • Water mgmt/ lawn sprinklers	• More use of electricity • Tidier garden	• More at home • Happier people	• More home investments > increase in home market (interiors, holiday houses)
Garage	• Storage • Work	• Electrical shelves	• More space	• More shopping	• More travel • More shopping transport
House generally	• Security • Weather shield • Home/private place	• Energy mgmt • Surveillance cameras • Sensors (indoor & outdoor: window, door, temperature, movement, light etc) • Electrical locks • HVAC mgmt • Lighting mgmt • Water mgmt • Control panels • Electrical widows, shields & blinds • Solar panels • Other energy generating equipment • Safety/fire protection • Metering • Equipment monitoring	• More use of electricity • Better energy mgmt • Self-generation of energy • Less fires and housebreakings	• Increases security needs for the whole neighborhood • Increase in serious crime • Less CO2-intensive energy usage	• Increase in security services • Increase in public spending due to crime

[1] mgmt = management

Table 3.3: Possible rebound effects from SHTs in a future home

THE FUTURE SMART HOME			POTENTIAL REBOUND EFFECTS		
The Physical Space	**The Social Space**	**The Technological Space**	**Direct Effects**	**Indirect Effects**	**Economy Wide Effects**
Kitchen	• Make food • Eat • Socialize	• PC/Internet • Smart kitchen appliances • RFID system • Kitchen robots	• More home cooking • Better food mgmt[1] • Robot uses energy • Time-saving	• Less take-away, restaurant visits • Less food disposal • Increase in food-related services such as recipes	• Decrease in restaurant sector • Healthier population
Bathroom	• Relax • Recreation • Cleaning	• Media mgmt • Water mgmt – sensors • Touchless fittings • Lights mgmt	• More use of spa facilities • Better water mgmt • Less bacteria infections	• More at home • Increase in spa services • Healthier people	• Increase in cosmetic disposal (pollutants)
Office	• Work • Plan • Shop • Learn • Banking	• PC/Internet • 3D-conference • Identity online, clients at home • Portable screens (paperless office)	• Home office • Internet shopping – more shopping • E-learning • Social networks online • Internet banking	• Food travels longer • More parcel shipping • Moving to the country • More spare time • Change in social relations (virtual not physical)	• Increase in transport sector • More travel • More entertainment • Increase in ICT service sector
Living room	• Relax • Socialize • Entertainment	• Interactive multimedia center • 3DTV • Multi room music system • Pet robot	• More home entertainment > more time at home • Better home mgmt • Happier with robot pets	• More electricity usage • More home investments • Change in social relations	• Bigger market for home electronics • Decrease in cinema/entertainment /parks etc • Increase in virtual life services
Laundry room	• Cleaning • Washing • Drying & ironing	• Robot maid • More effective washing machine	• More effective washing • Robot uses energy • Time-saving	• More spare time • Scrap handling of old robots	• More travel • More entertainment services
Workout room	• Workout • Fitness • Health	• Fitness appliances • Online fitness consultation • Body analysis	• Time-saving (home workout) • Healthier people	• More spare time • People live longer • Longer work-hours/ more efficient work	• More travel • More entertainment services
Bedroom	• Relax • Entertainment • Dressing room	• Smart bed • 3DTV • PC/Internet • Electrical/digital wardrobe RFID system	• Better sleep • More efficient dressing	• Longer work-hours/ more efficient work • Need for less clothes (because of better mgmt)	• More efficient work • Less clothes/material production
Garden	• Recreation • Socialize • Relax	• Robot gardener • Sensors • Water mgmt/ water sprinklers	• More use of electricity • Tidier garden	• More at home/in the garden •	• More home investments • Less travel
Garage	• Storage • Work	• Electrical shelves • Car/transport medium maintenance online/robot	• More living space • Less car maintenance & expenses	• More shopping • More living space for other people • Car/transport medium lives longer	• Less mechanical disposal • Less chemical disposal
House generally	• Security • Weather shield • Home/private place	• Cameras • Sensors (indoor & outdoor: window, door, temperature, movement, light etc) • Smart locks • HVAC mgmt • Lights mgmt • Water mgmt • Electrical shields & blinds • Electrical windows • Control panels • Solar panels • Power generating floors • Touchless fittings and controls • Identity recognition/ customization	• Zero sum energy consumption and generation • Better energy & water mgmt • Higher security • Better home mgmt	• Increases security needs for the neighborhood • Less need for energy suppliers • Less maintenance on houses	• Increase in serious crime • Increase in security services • Increase in public spending due to crime

[1] mgmt = management

In addition, the household could achieve *better food management*. That is to say, the household can get control over the food stored in the refrigerator and use less time cleaning out old food. *Indirect effects* could be that people eat less at restaurants because it is easier to eat at home. With smart applications on the *"kitchen PC"*, recipes and portion measures could be improved, leading to *less food disposal*. This could also lead to an increase in home-cooking related services such as cookbooks, kitchenware, etc. *Economy wide effects* are hard to predict, but from the other two types of effects, one can assume that new consumer behavior can accumulate in a total *decrease in the restaurant sector*. Another, but more wanted third order effect could be that people become healthier since they eat more at home and have better food management.

An example from Table 3.3 is from the physical space *living room* in a **future home**. The social functions here are *relaxing, socialize* and *entertainment*. The possible SHTs listed to realize these social functions are *interactive multimedia center, 3DTV, multi-room music system* and *pet robot*. *Direct rebound effects* from these technologies could be that people use *more time on entertainment and at home* because they have better management of the systems in the home. *Better home management* reflects the idea that when the systems are interconnected they are easier to manage and use. Research has been done on the social and psychological benefits of human interaction with pets. With pet robots there is no longer an excuse to not have one, since it can be turned off, does not need food or exercise and lives longer. A pet robot can thus make people *happier*. One *indirect effect* of these technologies is *more energy usage* for the pet robot and entertainment devices, which is an unwanted rebound effect. Another indirect effect is *more home investments*. A third effect can be a *change in social relations* since one is more at home and communicates though social networks online and other digital entertainment services. A third order, *economy wide effect* could be an increase in the *market for home electronics and Consumer Electronics (CE)*. A *decrease in the cinema and other entertainment sectors* could also be an economy-wide effect because people are entertained and social at home. The last listed third order effect is an *increase in virtual life services*. This means that a change in social relations due to increased entertainment usage from smart entertainment devices can make an overall increase in demand for virtual life services such as movies, games and chatting.

3.3 Summary

"The rebound effect" is defined as the change in energy demand due to consumer behavior when new technology is introduced. More energy efficient technology has been found to stimulate increased usage of technology and thus increasing the overall energy demand. This behavior is part of why the world is facing a resource and energy crisis today. Rebound effects from Smart House Technologies (SHTs) have not been calculated, but possible effects have been suggested in Tables 3.2 and 3.3, pages 16 and 17.

The next chapter presents a case study of a possible SHT implementation for a residential home. The technical case will be further used in semi-structured interviews with a goal to identify rebound effects.

Chapter 4

Case Study: "Smart Home Management system"

This chapter describes a case study that is constructed for use in research on rebound effects. The case is a Smart House Technology (SHT) for a modern home. The technology presented is called "Smart Home Management system" and is a system designed to control most devices and appliances in a home. The system is designed with current technologies and with a purpose to lower the house's energy consumption and to ease the daily lives of the inhabitants. The described case is based on Table 3.2, page 16. The table lists modern SHTs, their social functions and potential rebound effects. The case system has four interconnected control areas:

1. Energy consumption metering and statistics generation
2. Appliance control and surveillance
3. Entertainment provision and personalization
4. Security systems and services

A potential system architecture for a "Smart Home Management system" can be described as in Figure 4.1 shown on the next page, consisting of:

1. **Centralized domestic server** located in the home with a "Smart Home Management" system application running on it. The centralized home computer can be connected to other centralized computers belonging to, for example, the energy

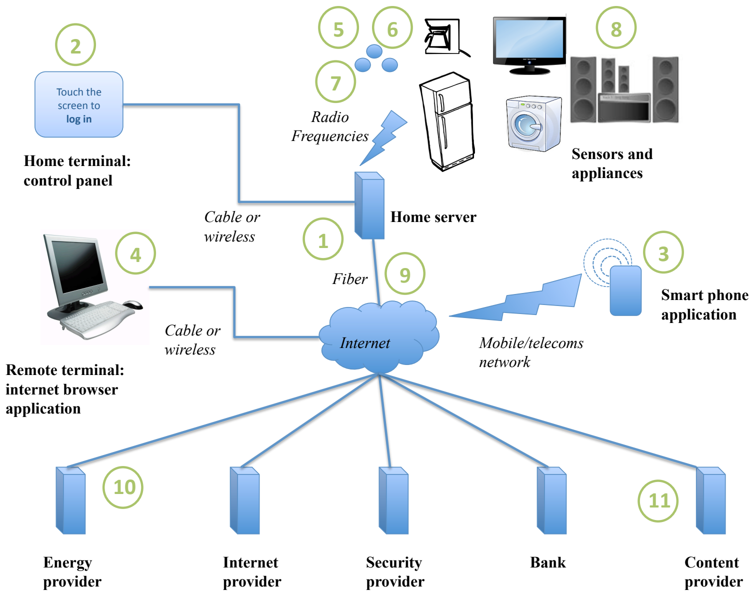

Figure 4.1: Technical end-to-end architecture of a "Smart Home Management system"

provider. A scenario is that an *energy provider* obtains information on energy consumption from many households. This can be done with for example smart meters, for the purpose of adapting the grid load to this information or real-time pricing. Information on energy usage can also be distributed to the households so that they can conform to less energy consumption. The energy provider would be responsible for the maintenance of the system and benefit from an increased management of the grid or new pricing methods. In this way, the energy provider would update the software of the home computer/ server regularly, and the end-user would get a maintenance-free solution to his home.

2. **Domestic control panel**, which is the standard login screen and operational human interface of the system. It is located at a central place in the home, e.g. the hallway. The control panel displays the Graphical User Interface (GUI) of the system application and serves as the communication channel between the inhabitants and the system, see Figure 4.2, page 23, for an illustration of a user-to-server architecture.

3. **Remote application**, which is a GUI for the system application. It is downloadable to smart phones and accessible through an available high-speed telecoms network such as 3G/4G or Wi-Fi. This application interface is an alternative to the domestic control panel, but has the same functions.

4. **Remote Internet-based application**, which also is a GUI for the system application. It is accessible with an Internet browser and connected to the home server. This application interface is an alternative to the domestic control panel and has limited control options due to security reasons.

5. Multiple **temperature, motion, sound and lighting sensors** in every room. They are connected to, and controlled by, the home server through middle-ware technology (Radio Frequencies (RFs)). The sensors are used to change temperature and lighting according to a time schedule.

6. Multiple **water sensors** in plants together with small water cables that have to be installed manually in every flowerpot.

7. Multiple **cameras** both indoor and outdoor for surveillance and security purposes.

8. **RF transmitters, smart cards or Radio-Frequency Identification (RFID) tags** in every electrical appliance, e.g. TVs, refrigerators, coffee-machines and washing machines. We here assume that this is a standard feature from the manufacturers (for example Electrolux, Siemens and Sony) and that the devices only need middle-ware technology and protocols to communicate with the centralized, domestic computer/ home server.

9. High-speed **Internet connection** to/ from the server, optical fiber or Power Line Communication (PLC)

10. Secure high-speed Internet connection to/ from a centralized computer owned by the **energy provider**. Energy consumption information and energy saving schedules and tips are also exchanged.

11. Secure high-speed Internet connection to/ from a **service/content provider** for entertainment access. This can be charged at a monthly basis as it is by many cable companies today, or at a per use-basis

In addition, the “Smart Home Management system” also controls:

- Electrical locks, shields and blinds equipped on windows and doors, which can be opened or closed from a GUI application
- Heating, Ventilating and Air Conditioning (HVAC) system
- Safety, water-leakage and fire protection and detection system
- Audio- and video entertainment. The TV and stereo will have a great range of possibilities for operation such as for example, taping TV-shows and broadcasting sound or music in multiple rooms

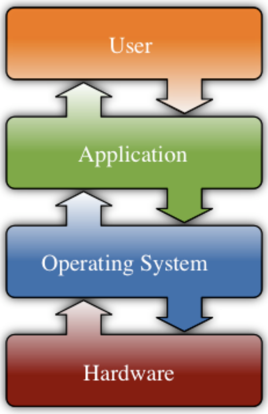

Figure 4.2: Communication layer architecture between user and server (from http://commons.wikimedia.org/)

The above-mentioned functions and technologies can be controlled and are visible through a control panel. The "Smart Home Management system" application is thus an intermediary between the smart electronics in the house and the inhabitants. The system's domestic server and application is in this case example, provided through a utility company (energy provider). This type of system can be a new way for utility companies to earn money as an incentive to sell less energy and more services due to the increased focus on energy reductions.

Background on the case house:

- The case house is newly built and it meets normal residential building requirements for a modern home
- The house is located in a suburban environment and is approximately 200m^2
- The house in this case uses electricity for all appliances, lighting, devices et cetera delivered by a utility company directly to the premises by underground cables from the publicly owned grid
- The house uses waterborne heat in the floors for heating and is insulated and built according to new Norwegian regulations [36].
- The users of the system are a normal family with two adults in the age 40–45 and two children in the age of 8–12
- In Norway, 99% of electricity generated and sold comes from hydropower and is hence renewable. Hot water and heating amount to about 75% of a household's energy usage [9]

4.1 System Requirements

4.1.1 Functional Requirements

A *functional requirement* describes a specific behavior or function of a software or system. Functional requirements are also called *capabilities* [1]. A table of functional requirements for the Smart Home Management system is listed in Table 4.1, below.

Table 4.1: "Smart Home Management system" : functional requirements

Functional Requirement	Description
Handle different users	The system should have different user accounts with different needs
Generate system status	The system can generate an overall system status
Get equipment status	The system has access to the status of a specific equipment and its location
Change equipment status	The system has access to changing equipment behavior or status
Keep a system schedule	The system saves and plans a system schedule based on all equipment
Monitor equipments	The system can monitor changes and status of equipments
Collect and save data	The system saves data on energy usage and other relevant system and user data
Communicate with energy provider	The system communicates information with the energy provider
Be remotely accessible	The system is accessible from any Internet-equipped device
Energy metering	The system monitor detailed energy consumption
Away-mode	The system should have a function that puts all units into sleep-mode when possible
Maintain network equipment	The system should assign and update network addresses for all equipment when necessary

4.1.2 Nonfunctional Requirements

A *nonfunctional requirement* describes the qualities and constraints of a software or system. These are testable, observable requirements such as security, usability, scalability etc. of the system [1]. A table of nonfunctional requirements for the Smart Home Management system is shown in Table 4.2, next page. The networked "Smart Home Management system" has nonfunctional system requirements in the following topics [4] (continued after the table on the next page):

Usability The system must be as easy as possible to use so that there are small learning and transactional costs. The average user has no or little knowledge of maintaining complex technologies such as a Smart Home; this should be kept in mind through the whole design process of the system. This requirement is the most fundamental of all requirements. If the system does not meet adequate "ease-of-use" standards,

Table 4.2: "Smart Home Management system" : nonfunctional requirements

Nonunctional Requirement	Description
Usability	The system acts as a "plug-and-play" application with automatic software updates and a familiar user interface, for example as an application in Windows
Connectivity	The system is connected to the Internet and must serve multiple remote connections to other access technologies as well as intra-home connections on RF
Quality of Service (QoS)	The system must support both upstream and downstream QoS and prioritize intra-home traffic; maximum 500 ms response time for intra-home traffic
Scalability	The end-user can add and remove equipment easily
Reliability	The system is remotely monitored and maintained and the reliability should be about 99%
Security	The system uses login and protects personal and sensitive data from other users and the energy provider

the system will be too complex for the users and will not allow for widespread adoption. Therefore, are Universal Plug and Play (UPnP) and an intuitive Graphical User Interface (GUI) labeled as crucial areas for the system design.

Connectivity The physical interconnection of many devices and equipment is one of the most challenging tasks in designing a Smart Home. A shared home network (Local Area Network (LAN)) and a Radio Frequency (RF) network can act in parallel to meet the high capacity requirements of the network. The networks must cover the whole physical house area, both inside and outside and meet necessary QoS demands. The most demanding QoS devices might require cable wiring or access on the LAN to function properly. All remote devices (smart phones, PCs and multimedia centers) are wirelessly connected to the LAN. To ease demands on the LAN, RFs are used for the "Smart Home Management system" intercommunication.

Quality of Service (QoS) Today's QoS based on "best effort" is adequate for some devices in the system such as connectivity to the refrigerator, coffee-machine, temperature sensors etc. For security and ease-of-use reasons, other parts of the "Smart Home Management system" must meet a higher level. These parts include streaming of high quality video and end-to-end entertainment services that require high bandwidth and little jitter. It also includes fire and water surveillance systems, which have high requirements on uptime and security. With optical fiber access network to the home and wireless LAN connection inside the home, QoS for these services should be satisfied through standard network protocols. The Residential Gateway (RG) is responsible for controlling the traffic in and out of the system and reserving the necessary resources without compromising on security and energy demands. It is important that the users get a high quality service that does not make them wait for entertainment services or fails to connect to the user terminals. It is also important that the protocol between the equipment and the system works properly and has regular updates to find devices that are new in the network, "down" or faulty. SNMP is for example a protocol that encompasses some of these network management issues.

Scalability and Reliability (setup, operation and management) Since users are not required to understand the technology, the setup, operation and management of the system should be simple or nonexistent. Components in the system should be automatically discovered and maintained with the use of UPnP. The main server should be maintained by the energy provider and receive automatic updates. Easy operation is important to meet customer satisfaction and can contribute to the breakthrough for Smart House Technologies (SHTs). An intuitive GUI is mandatory and the UPnP setup should be standard for the whole system.

System Security The home network and the RG hold all private and sensitive data and statistics of the users and must meet high security demands. Unwanted intrusions can have fatal consequences such as loss of privacy, damaged or deleted data or devices. Hence, access control must be mandatory for all users, devices and services. Authentication and security for the users must be facilitated and easy to use while accessing and using the system. The system should support different user classes to differentiate the level of usage and access rights. The RG must also act as a firewall for the entire system and hide the local network and end-devices for outsiders. Security is a high demand in a system that operates on a wide variety of users' lives and that has such a great impact on privacy and sensitive information. It is therefore necessary to focus on security issues when designing the system, but the ease of use for the users must not be compromised. All parts of the wireless communication system should be encrypted, both inside the home and when sent over the Internet. The users should have their own personal passwords or they should be recognized with biometrics, to meet a high security level. The information stored in the home server should also be encrypted to make intrusions more difficult. A firewall in the RG is mandatory.

4.2 Detailed System Description and Functionality

The "Smart Home Management" system application has four main functions that are accessible through a user interface: *Entertainment*, *System and Equipment Status*, *Security* and *System and Equipment Schedule*. These functions will be described in detail in Section 4.2.2, next page. The user interface exists in three versions: the domestic control panel, a downloadable smart phone application and an Internet browser application. The screen shots viewed in Section 4.3, page 32, are based on the domestic panel application's Graphical User Interface (GUI). The centralized domestic computer (home server) is the heart of the "Smart Home Management" system and is described in Section 4.2.1 on the next page. The server acts as an intermediary between the users, service providers and smart house technology equipment implemented in the home. The server communicates with the users through GUI applications, with the service providers through the Internet and with the appliances through middle-ware technology, in this case Radio Frequencies (RFs). Figure 4.1, page 21 shows a technical architectural overview of the system, and Figure 4.3 on the next page, shows an example implementation of the system in a residential home.

4.2.1 The Domestic Server

The "Smart Home Management system" is built up with equipment and appliances present in a modern home. All appliances have integrated network functionality and they can be added to a centralized computer/ server that acts as the "brain" of the system. A US patent application by Schoettle [34] is used as a basis for the server design in this system and is showed in Figure 4.4, page 29. In addition, an example of a user-to-server architecture is illustrated in Figure 4.2, page 23.

The domestic server is connected to its environment as shown in Figure 4.1, page 21. The server also acts as a Residential Gateway (RG) between the home network (RF between Smart House Technology (SHT) equipment and cables/ Wi-Fi between user devices) and the access network (Internet). The server runs an application with a GUI that is shown on the domestic control panel screen. The screen is directly connected to the server with a twisted-pair cable, and integrated in the wall with hidden infrastructure. The server is also connected to the Internet through optical fiber and can take commands from the two other Internet-connected applications (smart phone application and Internet browser application). The server is connected to a RF broadcaster/ receiver that transmits and translates the signals to and from the smart house technology equipment. The server is placed in a room where it can be easily accessed, and where there is enough air-conditioning for the server to be active 24 hours of the day, seven days a week. The server receives commands from one of the three user applications. All appliances and sensors are stored in the server database with their current status and other relevant equipment information such as type and capabilities. The server is also connected to service and content providers through the Internet.

4.2.2 Application and Graphical User Interface Functionality

The domestic control panel application requires a login and has a touch-screen. The remote, downloadable application for smart phones requires login the first time, but saves the user information and does not require login after the first time. The remote Internet-accessible application is available from any Internet browser and always requires a login. The front screen on the domestic control panel allows the user to log in by simply touching the screen and typing a password. This is shown in Figure 4.5, page 29. An "Emergency" button is placed on the front screen and serves the same purpose as the emergency call-

Figure 4.3: Physical overview of a "Smart Home Management system", background illustration from [3]

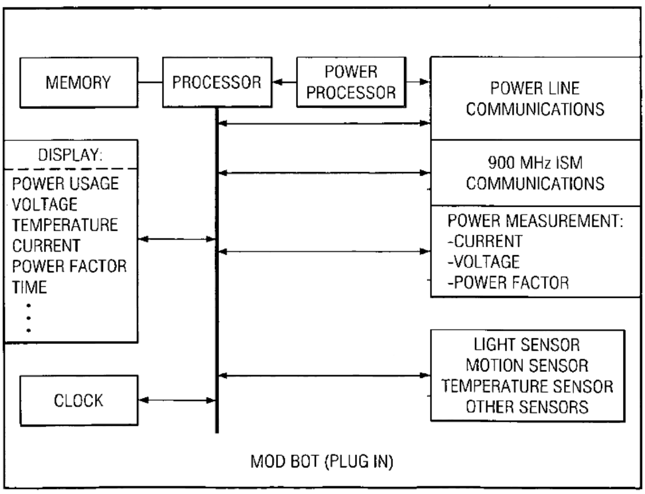

Figure 4.4: Architecture of a “Smart Home Management system” server, from [34]

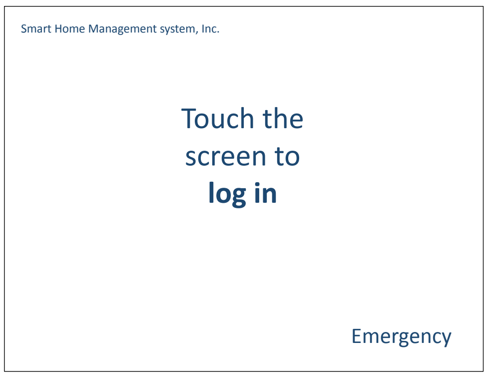

Figure 4.5: Screen shot of “Smart Home Management system” application: Login

function on a mobile phone. If there is an emergency with the system and there is no time or possibility to login, the emergency function offers to shut down the system, turn off electricity or water and alert security providers. Ideally it should also have direct connections to the police, medical staff and firearms.

Figure 4.6, on the next page, shows a screen shot of the main menu in the system application. The functions are described in more detail below. More screenshots and user scenarios will be described in Section 4.3, page 32.

Figure 4.6: Screen shot of “Smart Home Management system” application: Main functions

Entertainment All entertainment equipment (audio- and video system, online gaming, multimedia center etc.) in the house is connected to the domestic server. The entertainment equipments have smart cards that communicate with the server through middle-ware technology, in this case with Radio Frequencies (RFs). Entertainment content is provided through the Internet or is stored on the main home server. Section 4.2.3, page 31, lists and explains the broadband entertainment services available.

System and Equipment Status The house is equipped with multiple motion, lighting and temperature sensors that senses and communicates relevant information to the home server. The system can be set in an “away”-status indicating that no one is at home. The system then turns on all cameras, turns down the temperature to a pre-defined minimum threshold and turns off all equipment and appliances as well as lighting. All smart equipment and appliances in the house are connected to the domestic server and the application running on it. The equipments and appliances have smart cards that communicate with the server through RFs. The smart cards hold information about current status and equipment/appliance information and capabilities. The capabilities of an appliance can range from being turned on and off, to scheduling washing and tumble-drying and watering of plants. The system collects information on the connected equipments and keeps statistics and current system status. System statistics and other information, such as energy usage for each room, time schedule and equipment category are stored and used to inform the users of helpful measures that can be taken to decrease energy usage. For example, energy could be cheaper at certain times of the day and washing of clothes and dishes should therefore be scheduled to these times. It could also be that keeping the TV on when cooking food uses unnecessary energy, or turning down the temperature in the shower results in wanted savings. These statistics are sent to the energy provider regularly and new schedule changes and suggestions for energy saving measures are provided to the users in return. These changes and suggestions for further energy savings must be approved by the users and appears at regular intervals as a popup when the user logs in. This is shown in Section 4.3.2, page 34

Security Services The house is equipped with multiple indoor and outdoor cameras that the users can access with the different user applications. The motion sensors also register if there is someone outside or inside the home at all times. The sensors can only trigger an alarm when the system is in the "away"-status. The alarm is directly connected to a security provider's network. The security function "View camera/location" can be activated when the system is in the "away" system status. The function is accessible through all interfaces and can be triggered from there. The system also senses if a person is in a room through sound and movement sensors. The system will keep the current status of the room as long as the person does not leave the room, even if the person is not moving. The "Recognize motion" function uses motion sensors to discover if there are people in a requested room or area, independent of if the system is in the "away"-status or not. This function gives the current status of a requested room or a list of active rooms as a system status.

System and Equipment Schedule Since all smart house technology equipment, appliances and sensors are connected to the domestic server and maintained locally, the users can program the application to schedule equipment activity. The system schedule is programmed by the users, but receives updates and changes from the utility company, e.g. real-time price information and energy saving measures.

4.2.3 Broadband Internet Services

While future broadband services are difficult to predict, some example services that are common today and have an impact on this case in the form of "time-consuming technologies" are described below.

Voice over IP (VoIP) Telephony via the Internet is becoming increasingly common and it can be assumed that the service will become better and more widespread when optical fiber networks are available to residential homes. Internet applications such as Skype, which provides video chatting through the Internet, can be expected to be common in future Smart Homes.

Online gaming Gaming and other interactive entertainment are already very popular and with better televisions and higher bandwidth these can be expected to increase in use and become standard features in Smart Homes.

Online entertainment provision (HDTV, IPTV, music- and video-on-demand) HDTV is already available to most homes and IPTV services, streaming and other types of entertainment on-demand can be expected to be common features in residential entertainment systems.

Security systems and services (alarm and surveillance) Both security and health related services could be common services provided through the Internet and enabled by the backbone network provided by a Smart Home.

4.3 Use Cases

A use case is a description of a system's behavior to outside requests. For the purpose of this research, we have constructed three scenarios, or use cases, including example screenshots that illustrate how the system works. This will hopefully make the system more real and help respondents in this research to relate to the system and its functions.

4.3.1 Use Case One: Playing Music and Watering of Indoor Plants

The user logs in through the login screen shown in Figure 4.5, page 29 and the main menu shown in Figure 4.6, page 30 appears. Now, the user wants to **play music** in her room and the hallway, so she chooses *Entertainment* on the main screen. The following steps, shown in Figure 4.7, next page, from left to right, top to bottom, are:

1. Press "music" and then "choose music" to choose what kind of music to play
2. Press "view stored music" to find music stored on the local server
3. Choose the artist you want to listen to from the selection of stored music
4. Choose what or which rooms to play the selected music in

In cases where one can choose two or more alternatives, such as the room list to play music in, one can press a choice once to mark it, and then again once more to release it. Pressing a finger down at a choice for at least two seconds chooses the entire list. In these cases, a button marked "OK" will appear at the lower right side on the screen that can be pushed when the selection is finished. The "back" and "forward" buttons can be used to easily navigate recent history in the same way as in a browser.

Suppose the user wants to view the automatic **watering function** in the system to check how the plants are doing. The system has sensors and automatic watering, but different plants have different needs, so the user will need to regulate the watering. To do this, the user logs in through the login-screen, then chooses "system and equipment status". The

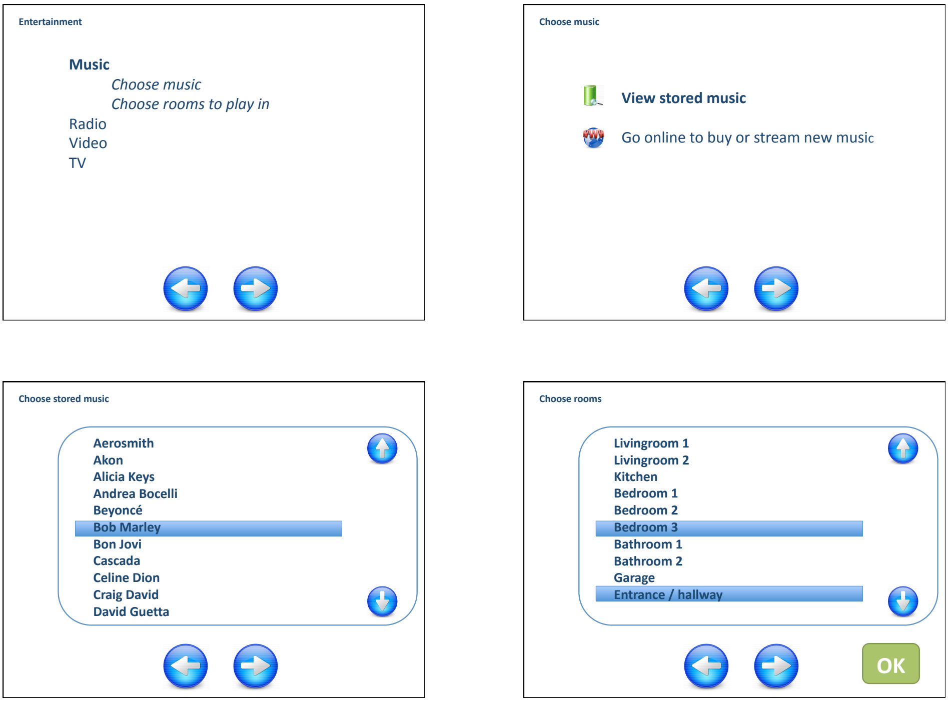

Figure 4.7: Screen shots of "Smart Home Management system" application: Play music

screenshot at the top left in Figure 4.8, next page, appears. The user goes through the following steps, illustrated in Figure 4.8 from top left to bottom right:

1. Press the "view or change system status" icon
2. Choose in which room to see registered equipments from the list
3. Choose the function available for the selected room
4. Tap the water status bar representing one of the plants to view change options. Press "water more" or "water less" according to the plant's needs.

A Message Sequence Chart (MSC) for the "watering of plants"-function is presented in Figure 4.9, page 35. An MSC shows how the system exchanges messages and executes methods to serve a user's needs. In Figure 4.9 we see that the "User" logs in through the "Control Panel" and is authenticated by the "Home Server". The "Control Panel" views the main menu and the "User" chooses what she wants to do, in this case: change the plant's water status. The time is from top to bottom on the chart and each instance

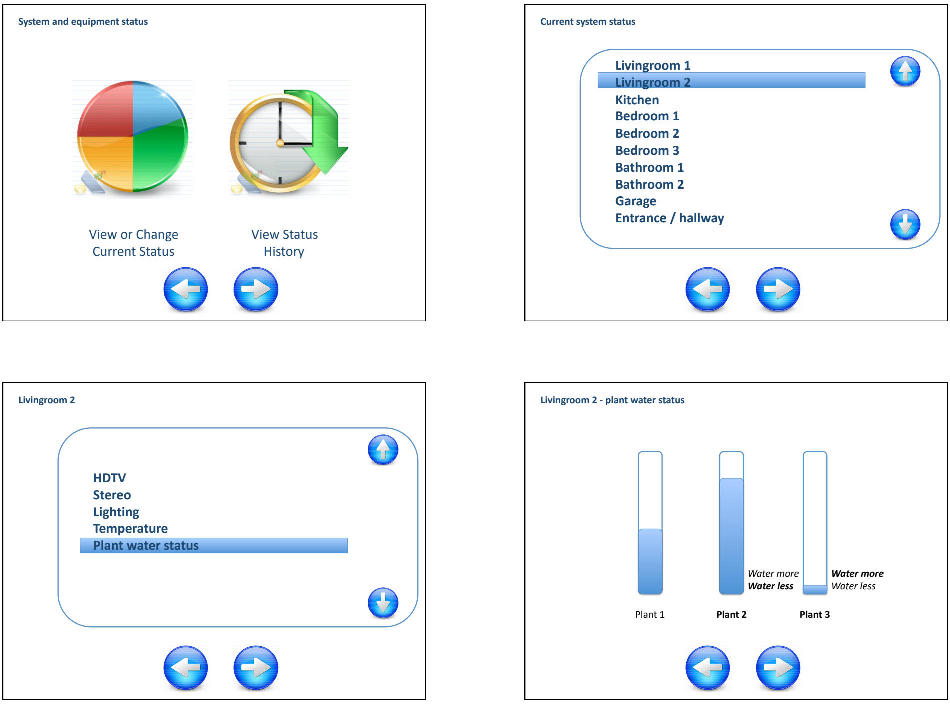

Figure 4.8: Screen shots of “Smart Home Management system” application: Watering of indoor plants

(“User”, “Control Panel”, “Home Server” and “Water Sensor”) is illustrated with a time-line. Arrows from the instance that triggers the messages to the instances where they are to be handled illustrate the messages/ methods exchanged/ executed in the system. Two additional MSCs for the “Smart Home Management System” can be found in Appendix A.

4.3.2 Use Case Two: Information and Energy Control

The system provides the users with weekly energy statistics[1] for the household as shown in Figure 4.10, page 36.

In addition to the weekly statistics in numbers, the statistics are also compared to others and shown graphically at the top of Figure 4.11, page 37. The bars on the screen show:

[1]Statkraft.no provides an energy calculator for hours spent on different household activities, from heating frozen pizzas to watching TV. This calculator has been used in this use case.

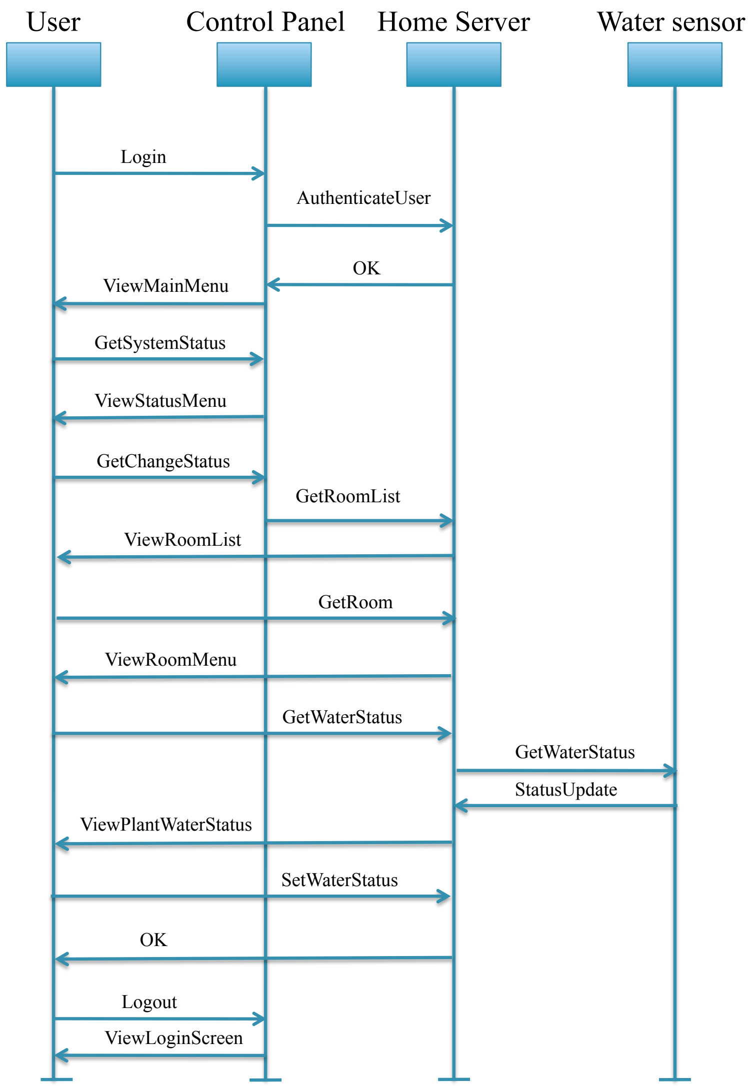

Figure 4.9: Message Sequence Chart (MSC): Watering of indoor plants

Weekly household statistics

Week 12, 2010

Activity	Total minutes	Sessions	kWh	Water in L	Cost in €
Shower	66	10	5,28	1320	1,06
Hair drying	17	7	0,51	-	0,08
TV	720	10	1,56	-	0,25
Cooking	480	7	10,00	1000	2,53
Washing clothes	240	4	3,60	80	1,09
Tumble dryer	240	2	3,60	-	0,59
Dishwasher	540	6	6,6	114	1,56
Heating	-	14	1,40	1500	0,23
Lighting	3360	-	3,36		0,55
PC	10080	-	42,00		3,42

Figure 4.10: Screen shots of "Smart Home Management system" application: Weekly energy statistics

1. The suggested weekly consumption for the household (white bar)
2. The percentage of suggested consumption for that week (dark blue bar)
3. The aggregated percentage of suggested yearly consumption that has been consumed by the household up until this week (light blue bar)

The system also provides information on governmental regulations and means for energy savings to the end-user. In this case, the government has set a limit on how much energy is "normal" usage and the system will automatically take actions to maintain this goal. This could be to lower the temperature or switching off appliances or dim the lights. If the user would then choose to override the system, the system will inform the user of the consequences of its actions on the system's screens. To lower the energy usage even more, if these measures are not enough, the system suggests means for the user to lower his or her energy usage as shown in the second screen shot in Figure 4.11 on the next page. Here the user can choose one of the recommendations and the system will remind the user when he or she is about to exceed this choice.

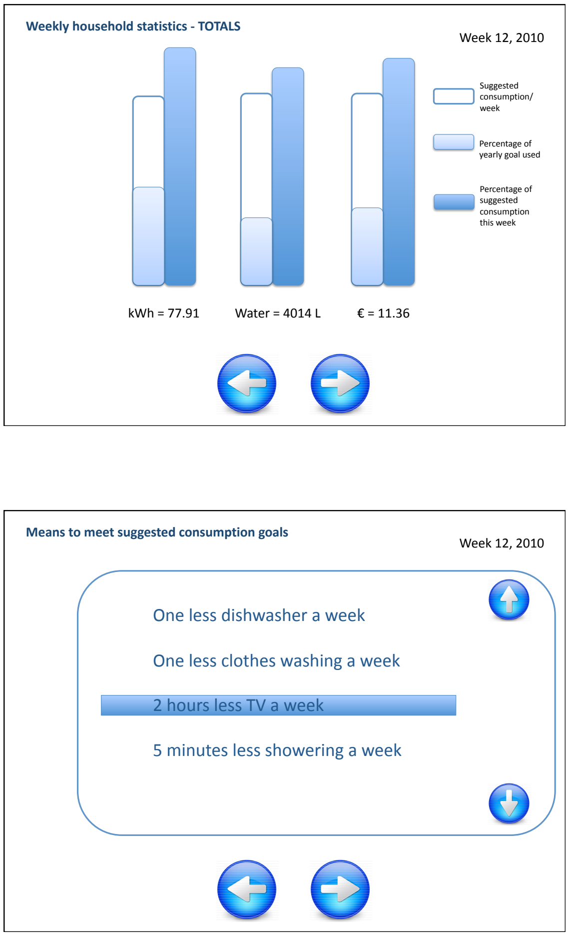

Figure 4.11: Screen shots of “Smart Home Management system” application: Energy reduction recommendations

4.3.3 Use Case Three: Social Entertainment Network

This use case has no screen shots, but is described as a crossover between Facebook[2] and Amazon.com[3], only the “Social Entertainment Network” provides entertainment and

[2] Famous social networking site on the Internet (www.facebook.com) that allows users to make personal social profiles, add friends to their network, keep social contact with friends by making events, send messages and get updates, upload pictures and tag friends in them

[3] An (originally) American online bookstore that allows users to rate and write reviews of books they have read or own. This is used, in addition to the users’ previous buying history, to recommend new book titles. Amazon.com is famous for earning most of its revenues on niche sales (commonly known as “the long tail”)

knowledge personalized to the user. The user makes a personal profile and adds people to their network. The profile keeps information on what TV-shows and films, books and news the user prefers in addition to other interests. Every time the user logs on, he or she gets recommendations on what might be interesting for them to see or buy. The user can also "follow" other users that have similar interests and see what friends or family is interested in or likes. The network is made for providers to earn extra money and to make entertainment more efficient for users. In this way they do not have to swap around on the TV, they can see something they want to see and then turn it off. This service can on the other hand, create unwanted rebound effects towards *more* entertainment usage. In this case, the energy usage related to digital entertainment could increase instead of decrease.

4.4 Issues with the Smart Home Management system

The "Smart Home Management" system is designed to assist the private lives of humans in their homes. To assist them in the best possible way, seamlessly and failure free, there are several issues involved. The problems that arise when a system is integrated in such a detailed way as in this system description, can be complex and have domino effects on the rest of the system. For example can a power outage be severe if there is no back up information stored elsewhere to reconfigure the home after a black out.

4.4.1 Human Issues

Privacy issues are obvious when considering surveillance cameras and other sensitive information. These must have the ability to be shut off by the residents when they sleep or do not want to be seen. The purpose is solely for security and information. For this reason the cameras in the house are not active during the day, but is turned on when the system status is set to "away".

Humans (both users and intruders) can also, intentionally or unintentionally, tamper with the system and its functions and must be robust enough to handle this. A normal radio transmitter can for example be used to tamper with Radio Frequencies (RFs), and there must be a technological solution to prevent these human interruptions from occurring.

4.4.2 Technological Issues

In case of a power outage, caused by either a grid failure or users unintentionally detaching the electric plug, the system has a recovery mode to come back online without significant

from specialized, narrowed recommendations to its users intervention from the user. After a power outage the system enters the “away” status and must be woken manually by a user through one of the interfaces. The server will also have to reboot after a sudden loss of power and reset parts of the system.

In case of a system failure such as a hard disk crash or in cases where the server is lost, in for example a burglary, the system has a back-up at a remote server provided by the utility company. The back up is only taken once a night and it updates schedule changes and other important system changes such as newly added equipment and configurations, but not equipment statuses.

The system must also be secure against threats such as hacking and privacy issues related to the home. As a resident in a private home one wants to feel secure and when all equipments, sensors and cameras are available online, there is a great deal of sensitive information that can be obtained by others if the network security and privacy issues are not properly dealt with.

In cases where equipment falls out or fails to connect to the server, the user applications trigger a silent alert on the display. In cases of major failures, information is sent to the energy and security provider of the system or relevant service provider.

4.5 Summary

This chapter described a technical case study with the use of Smart House Technologies (SHTs). The case system is a “Smart Home Management system” designed to interconnect all electrical appliances in a modern home. The system operates four technological areas in the home: energy consumption metering and statistics generation, appliance control and surveillance, entertainment provision and personalization and security systems and services. An energy provider is suggested as the provider of the system.

The next chapter outlines the research method chosen to identify rebound effects from this technical case study.

Chapter 5

Research Method

The main purpose of this thesis is to recognize rebound effects from Smart House Technologies (SHTs) with the goal of identifying critical areas in business modeling related to this phenomenon. To identify rebound effects as realistically as possible we have constructed a smart house technology case study: the “Smart Home Management system”. The technical case study has been constructed to give the research subjects an experience of how smart house technologies work and give them an opportunity to relate to this. This is essential to get relevant research results, as will be explained below.

5.1 Qualitative and Quantitative Methods

When performing research on social phenomena such as the rebound effect, one might choose between two general methods of research: qualitative and quantitative. *Quantitative methods* involve surveys and questionnaires, and gives quantitative and numerical results that can be statistically interpreted. The method requires many, representatively and randomly chosen respondents, normally around 500, for the results to be statistically significant. *Qualitative methods* on the other hand involve, among others, semi-structured interviews, observations and group discussions. This method requires less, but more qualified respondents, highly dependent on the case or phenomena under study. The method takes use of few cases, but many variables to distinguish and clarify complex phenomena [29, 39, 15].

5.1.1 Choice of Method: Semi-structured Interviews

Ideally, without monetary or time constraints, this research would gain the most from using a physical house and implementing the described technical solutions from Chapter 4 in it. The research would in that case consist of observations or field studies of real people living in a "Smart Home" with the technology presented. We would then be able to passively observe the subjects' behavior and more accurately calculate the rebound effects. The Michigan Institute of Technology (MIT) does for example have a house called "House_n[1]" on their campus that is a project at the Department of Architecture. The house is used in Smart House Technology (SHT) research on how the design of a home and its related technologies, products, and services should evolve to "better meet the opportunities and challenges of the future". However, they have not yet done research on rebound effects and the possible impacts of these effects on the design of the Information- and Communication Technology (ICT) systems. Telecom operators such as Telenor in Norway and Orange in the United Kingdom constructed "future homes" for business related research in the beginning of the 2000's. These houses unfortunately no longer exist.

This work has no test facilities available for real-life testing. To be able to do research on rebound effects from SHTs we have constructed a "real life like" case study and chosen to present it to a number of technically qualified people. To capture the complexity and uncertainty concerning the rebound effect phenomenon, semi-structured interviews were considered as the best method to "identify and observe" rebound effects from the case study. The chosen qualitative method allows for a choice of people that have a knowledge of, or insight in, technology. Hopefully, the respondents will be able to reflect upon their relationship to these technologies. This is believed to be easier with a group of technology-interested people. It is significant for this work that we get information that can help recognize rebound effects from SHTs. The negative aspect of using a qualitative method is that it is difficult to draw statistical significant conclusions from the results as the respondents are biased and not representative for the population in general. This indicates that the results will be rather limited to the specific case presented in this thesis.

5.2 Validity and Reliability

The interviewees participating in the semi-structured interviews will be presented below and the results will be discussed according to the biased selection of respondents. *Validity* in this report is dependent on *construct validity*, which refers to the relationship of accuracy between the responses and the reality the responses were intended to capture. There are several reasons for why the responses given do not necessarily represent the real opinion of the respondent [15]:

[1] http://architecture.mit.edu/house_n/

Co-operation bias The respondent does not know the right answer, but gives an answer anyhow

Self-serving bias The respondent gives an inaccurate answer that he thinks is accurate or believes is accurate according to a preferred belief about himself

Social desirability bias The respondent knowingly gives an inaccurate answer in order to present a favorable impression

Acquiescence bias The respondent is unwilling to give the right answer, but gives another he thinks the interviewer wants

Refusal The respondent refuses to give an answer

Interpretation fault The respondent fails to interpret the answer in the way it was intended and he gives an answer according to his interpretation, unbeknown of the researcher

Reliability refers to consistency of approach in the research. For example can the answers be influenced by the circumstances of which the questions are asked. Suppose that one interview takes place in a quiet, private place and another in the hearings of relatives. These circumstances will influence the responses considerably and the unreliability to the research increases. Differences recorded between respondents may be due to differences between the given response and the reality or due to differences in the circumstances. This way it is difficult to distinguish between unreliability and validity in a qualitative interview research.

5.3 Research Procedures

To be able to test rebound effect theory on smart house technology, semi-structured interviews have been conducted. For the interviews to give the best possible results we have constructed a realistic case the interviewees can relate to. This is to make the reactions and answers as realistic as possible. Each use case presented to the respondents describe the software and Graphical User Interface (GUI) of the "Smart House Management system" presented in Chapter 4. The technical case study describes both a *time-consuming* and *time-saving* technology. The system has been designed so that the users can relate to both aspects of the technological solution presented. This means that the technology encompasses two types of technology that the users (interviewees) probably will react differently to.

Four people were chosen to participate in the interviews. They were chosen based on age, knowledge of and interest in SHTs. It is essential to the research results that the interviewees can relate to their behavior as consumers and understand the impact of technology to their everyday life to minimize unreliability and increase the validity of this research.

The interviewees were asked and agreed to participate through e-mail and telephone contact. Because semi-structured interviews often lead to longer conversations and are aimed at understanding the "world" of the subject and a high level of sensitive information may come forth, the interviewees were given a statement of consent to sign, see Appendix B. This statement of consent declares that the person who agrees to the interview can withdraw his or her statements at any time and that he or she is promised anonymity in the final report.

A voice recorder was used during the interviews in addition to hand-written notes. All interviews were conducted in a private room without the hearings of others. The interviews took place between April 13 and May 1 2010. Each interview lasted between 1,5 – 2 hours and of this, the recordings were around 50 minutes per interview.

The course of the interviews were as follows:

- Interviewees were given the *statement of consent* (Appendix B) to read and sign
- Interviewees were presented with the "fact sheet" (Appendix C) for the case technology presented in Chapter 4
- Interviewees were presented with two possible "use cases" with the help of several printed screenshots of the system, see Sections 4.3.1 and 4.3.2
- The interviewees were given the opportunity to ask questions about the technology before the interview started
- The interview was conducted semi-structured by the "interview guide" (Appendix D) and recorded with a voice recorder. In the course of the interview an entertainment use case was presented that involved social networking, see Section 4.3.3
- The interview finished up and the recorder was stopped. Interviewees were asked how they felt it went and if they had any comments to the interview or case study

In general, the interviewees were first presented with the statement of consent and the general information about the "Smart Home Management system". The subjects were able to ask clarifying questions before the voice recorder was turned on and the interview began. It was purposely waited until the subjects had understood the purpose and functioning of the system before turning on the recorder. This was done to make the interviewees more comfortable, since they could ask "stupid" questions without knowing that it was recorded. In that way it was ensured that the system was properly understood before starting the questioning. The recorder was placed on the table between the interviewee and interviewer, but often on the side so it would not distract or disturb too much.

To more easily understand the rebound effects that can occur from different reactions we defined some research questions based on Chapter 2 and 3. These were intended to clarify the goals of this research and were used to construct the interview guide presented in Appendix D. The research goals defined were:

- Do the interviewees react economically rational when they save money with the system?
- How do the interviewees react to the information/ feedback given by the system?
- What are the possible rebound effects from these reactions?

5.4 Summary

In this chapter we looked at research methods and the chosen method *semi-structured interviews*. Semi-structured interviews were identified as the best method for understanding the complex phenomenon rebound effects, with the constraints present in this work. This research is based on the technical case study presented in Chapter 4. The research procedures were also presented.

The next chapter reviews the conducted interviews and summarizes the findings.

Chapter 6

Research Review and Findings: Smart House Technologies and their Rebound Effects

Four semi-structured interviews were conducted in the time-period between weeks 15 – 17 of spring 2010. The course of the interviews was presented in Chapter 5. All interviewees were chosen because they had a background or good understanding of technology. Three men and one woman were interviewed. Two were master students and two were working in private companies. Their age ranged from 25 to 53 and the yearly income range were from less than NOK 100.000,- to more than NOK 1.000.000,-.

Only one of the interviewees stated that he was especially environmentally aware. The three others stated that the environmental awareness that comes through media was important and meant something to them. They would however, not choose environmental measures above their own comfort. All the respondents were positive towards the technology and felt it would be of value to them. Saving money was generally seen as the main driver for implementing the system, and the greatest incentive for all parts of the system and its usage areas. However, the means for pressure and usage were very individual, ranging from the desire to save the planet to avoiding extra costs.

6.1 Reaction to the Time-saving Technology

None of the respondents believed they would wash clothes or dishes more often with the system. It seemed to be a general understanding that clothes washing and other household chores are already performed as effectively as possible. For example does one respondent state that the technologies presented as time-saving in the case “have already been made as effective as possible without the help of a robot-maid”. Thus, the respondents did not feel that even smarter washing machines etc. could help them save time considerably. When they were asked what they would do if they imagined that they saved time with such a system, everyone stated that they would enjoy having more spare time. No one expressed a desire to get more work done. One person expressed a preference for traveling more; the three others wanted more time with family, friends and to do workout activities. Two respondents specifically mentioned wanting to take up new hobbies and explore new things, one of them labeling this extra spare-time as “self time” and “quality time”.

The sensors and surveillance system that was introduced were of importance to two of four respondents. The two others would not invest in this extra feature, if it was not part of the system package. Main reasons for wanting this function were the ability to control the house at a distance and security against fire, water leakage, burglary and other security issues in the home. All respondents however, marked network and computer security as a high-risk area of the technological solution. This implies the risk of other people getting hold of the sensitive information held in the system and control of the home. An example was the risk that someone could get into the system and for example unlock doors. Another example was someone getting into the system to watch the cameras and obtain other sensitive user information such as names and daily user-patterns.

6.2 Reaction to the Time-consuming Technology

The use-case scenario “Social Entertainment Network” was met with very positive reactions. This part of the system was the next most wanted part for three of four respondents (75%). Two meant that they would watch less TV with this system since it gave them the opportunity to watch what they wanted when they wanted it, knowing it was of good quality. This would lead to more spare-time that they could use on other things, as discussed in the previous section. The two others thought that this system would be in competition with other things they wanted to do, like go to the movies, meet friends and work out, since it presented an opportunity to do more of a thing they enjoy. This means that the entertainment function in the system could lead to a zero-sum game in the long run, since it is a 50/50 chance respondents use more time on entertainment than before. A possible effect of being provided with suggestions for entertainment and other forms of information that suits your preference is that one can get onto a “track” and loose the breadth in information that is provided with “traditional TV”. Two respondents were asked if they believed this type of “specialized” information would contribute to a sociological distinction between people who prefer reality shows and other types of “low level” entertainment and people who prefer knowledge information. The respondents saw how this could happen, but both suggested that the system should provide both information of current interest and specialized information. This implies that the system should not have the ability to shut off “important” information and information that contribute to a breadth of knowledge. This third order rebound effect has a social distinction and does not have directly impact on energy usage. However, it shows that rebound effects from technology can have third order effects of a social character that are unpredictable at first sight.

6.3 Reaction to the Provided Energy Information

The information provided by the system on the user’s energy consumption and areas of improvements were seen as the most valuable part of the system. All respondents thought that this definitely would reduce their energy usage and that it would contribute to a change of attitude towards energy efficiency. One of the respondents stated that it should be possible to view the information as visual art or other forms of visibility on the house’s environmental “health”. Just making the information visible could be helpful, but the respondents said that if they were provided with detailed information on their energy usage and given suggestions for change, this would be very useful in their everyday lives. It was a general apprehension that the system should provide statistical information on the same type of houses to avoid discrimination of old houses etc. It was important to three of four respondents that the information provided showed how they contributed in the big picture. They were generally not interested in changing their behavior or lifestyles if they did not know that what they did actually contributed in some way. It was also important that the system did not degrade the comfort of their lives and homes.

6.4 Incentives for Usage and Most Important Parts of the System

Saving money was put forward as the strongest incentive for using the system. One of the respondents expressed that the incentive to *avoid* costs, on for example taxes, was bigger than the incentive to save money. The respondents were negative to the idea of not receiving compensation for the energy saved with the system. This came forth when they were introduced with the idea to, for example, give the money they saved on energy to charity or receiving lottery tickets. They saw the lottery or statistical comparison, as additional incentives and a way to get “even better”, but the monetary reward was more important. The statistical significance and comparison to other households were especially successful with the respondents. They all reacted very positively to this, and said that this information was the most valuable to them. However, as already mentioned, it was only appreciated if they received some sort of compensation for their efforts. When confronted with how they would use the money they saved, three of four said they would use it on themselves or family, Consumer Electronics (CEs) or travel. One said he would save the money. This respondent had comparable, the best income of the four, and it can be considered that spending versus saving is sensitive to income. This can denote that if a person has an income above a certain level, he will save, rather than use the money saved by using the system.

Social status and comparability to others were seen as important incentives to use the system and conform to the measurements suggested by the system. The fact that being environmentally conscious is in fashion was significant for two of four respondents. Being compared to others and receiving statistical information about their energy usage, were significant for all. Participating in a contest was significant for one of four respondents. This low response number on competitions could be higher in reality, because being competitive can be seen as a negative quality. This can lead to people answering that they would not react to a competition, even though they would do so in real life. This is called a *social desirability bias*, introduced in Chapter 5. For example, in this case, 100% would like to be compared to others, and 50% would be interested in the system because it is trendy to be environmentally conscious, but only 25% say they would react to a competition. This implies a higher real number of people who would react positively to a competition, since other competitive behaviors were identified.

Generally, it was also very important for the respondents to have the ability to override the system, i.e. have the possibility to change the behavior of the system. As one of the respondents said: "people must feel a personal connection to the system. If not, they will not trust nor use it". In addition, it was important that the system provided a mixture of "self saving" and conscious user saving. This means that the respondents wanted the system to do most of the saving for them, without them noticing. Examples of this are the refrigerator that is turned of in small intervals, lowering of temperature and lighting control. In addition, they all saw the information given by the system, e.g. measures they could do to decrease their energy usage, as important to help change behavioral patterns and attitudes. However, they wanted the system to help them remember when they should turn off the TV or stop showering. Again, the continuous information provision is a strongly wanted feature.

Of importance to all respondents was the ability of the system and its functions to be trustworthy. They wanted to be able to troubleshoot and fix simple things in the system, for example if one of the system parts "fall out" they wanted to be able to set it up again themselves. It was a general wish that the system should be reliable and easy to use, but also secure. Energy providers were by all respondents seen as trustworthy of providing such a system. An energy provider was in more than one case seen as a more credible provider than if the government were to provide and maintain the system.

6.5 Interview Findings: Rebound Effects from SHTs

Based on the previous section the most significant results from this research are as follows:

The system must make people aware of their energy usage and make it visible This was the strongest positive element in the system for increasing environmental consciousness and behavior. The information should be based on statistics and made easily accessible. The system should make it easy to follow the provided advice from the system.

The system must be easy to understand and use Troubleshooting, overriding the system etc. should be easy and intuitive to increase trust and stimulate usage.

The system must provide added value to the user The added value could be automatically reducing energy usage so that the user saves money. The entertainment functionality was also highly welcomed by all respondents. This could contribute to a more effective use of entertainment as well as an extra income for the provider of the system.

The system must have low costs for the user Both installation and usage must bear low costs so that the threshold for adaption is low. A financial assistance scheme by the government was suggested as a proper mean to help the system penetrate the market. An alternative was introduced where e.g. energy providers take the investment cost, and in return take a fee of the monthly savings achieved with the system.

The security of the system must be highly prioritized All respondents expressed a certain concern for the data security of the system. The security functionality of the system with surveillance and cameras were also seen as important, especially because the system is highly complex and can be a security issue.

There were several parts of the system that came forth as especially sensitive to rebound effects. Four functionalities stood out and Table 6.1, page 51, lists these with possible rebound effects. The rebound effects are based on theory from Chapter 3. As already mentioned, the rebound effects are hard to predict and due to time constraints in this work, detailed modeling of rebound effects has not been conducted. The table thus presents *possible* rebound effects from the most crucial functionalities in the system, revealed by this research. In addition, the table introduces some implications for business modeling that will be further elaborated on in the next chapter.

An example from Table 6.1 is the function *visible information on energy usage*. This function represents potentially **positive** rebound effects. Direct effects could be *increased awareness on energy usage* by the users. Indirect effects could be a more permanent change of behavioral patterns on energy usage in other places than at home. Suppose that you, for example, have been told by the system that you use too much hot water when washing your hands, your clothes and when cleaning. The continued feedback from the system makes you think of how much hot water you use, not only when you are at home, but also at work or on holiday. This reduces your energy consumption for hot water in other areas than just your home. Assumed that the system gives feedback on a range of activities and energy consumption areas, we can also assume that a reduction in energy demand will "spill over" to other areas of the inhabitants' lives. This can create *sustainable changes in attitudes* on energy consumption as third order, *economy-wide effects*. The implication on business modeling, which will be further discussed in the next chapter, is to incorporate a visible information function to a Smart House Technology product. That is to say that a company can include this feature to ensure positive rebound effects from the system. To give the users a good visual experience with this function the firm could also partner with creative designers. This could possibly increase the effect of this function.

6.6 Summary

This chapter reviewed and discussed the semi-structured interviews conducted in this work. The respondents identified five usage areas in the system as important. Four system functionalities were found to give considerable rebound effects. These were: visible information on energy usage, statistical information on energy usage, time-saving functions and cost-saving functions.

The next chapter takes the four results on rebound effects from the interviews and discusses further the implications on business modeling.

Table 6.1: Possible rebound effects identified in interviews

System Functionality	1. order Direct Effects	2. order Indirect Effects	3. order Economy Wide effects	Implications for Business Models
Visible information on energy usage	**Potentially positive:** • Increased awareness on energy usage	• Change of behavioral patterns on energy usage in other places than at home	• Change of attitude towards environmental consciousness in other areas and sectors of life than the home > more environmentally conscious people > less environmental damage	• Include feature in product • Use creative designs for visualization and greater impact
Statistical information on energy usage	**Potentially positive:** • Incentive to try harder • Awareness of local/ regional/ global impact of energy use	• Change of attitude and behavior in a bigger perspective (regional and global)	• Pressure on companies to deliver environmentally friendly products > more environmentally conscious companies and people > less environmental damage	• Include feature in product • Partner with a provider of statistic information & deliver added value to users
Time-saving functions	**Potentially negative:** • More time for personal use	• More spare-time/ increased use on spare-time activities (environmental friendly or unfriendly)	• Sporty people need more food. More travel (short-distance is good, long-distance is bad). Happier people live longer > increase in governmental spending	• Not easily addressed in a commercial business model
Cost-saving functions	**Potentially negative:** • More money for personal use	• Money used on life enhancements such as Consumer Electronics (CE), travel, shopping *or* money saved in a bank	• Increase in consumer goods and transport a*nd/ or* increased investment capital in banks > cheaper loans, more investments > increase of environmental damage (today's situation)	• Offer products for environmentally friendly saving as part of value propositions to customers • Partner with environmentally friendly product or service providers

Chapter 7

Sustainable Smart House Technology Business Models

Why are rebound effects important for businesses? Rebound effects are important because they create unforeseen network effects and spirals of either good or bad environmental consumer behavior. The environment has become an important area for businesses to be conscious about. It also introduces a business opportunity for companies to earn money and at the same time fight the climate challenge. Smart House Technologies (SHTs) have been endorsed as a way to lower carbon emissions and change human behavior without introducing severe and long-standing rebound effects that reduce the overall potential of these technologies. A sustainable smart house technology business model must incorporate rebound effects and a way of handling the most significant ones to realize this potential.

This chapter will first give a formal definition on business models and then introduce a business model ontology developed by Osterwalder [25]. Thereafter, a discussion on micro- versus macro-economic measures for the system functionalities identified with rebound effects in Chapter 6 is given. Lastly, a business model for a micro-level measure for rebound effects from cost-savings is developed.

7.1 Business Models

There are many definitions and usage areas for the term *business model*, but no formal definition. The term is not new, but encompass a great variety of understandings, most of them at a high level of abstraction. One of the most cited authors on Information- and Communication Technology (ICT) business models in later years is Alexander Osterwalder who wrote his PhD-thesis on the development of an ontology and formal definition of business modeling.

Osterwalder understands a business model as “the conceptual and architectural implementation of a business strategy and as the foundation for the implementation of business processes” [27]. This means that a business model describes the logic behind the processes that a business creates value from. In other words is a business model a representation of how a company buys and sells goods and services. What the company offers, to whom and how it accomplishes this are all parts of a business model.

7.1.1 Business Model Ontology

To be able to present business modeling in a structured and accurate way, we have chosen Osterwalder’s ontology to describe a business model. This business model ontology, originally presented in [25], is founded on *four main pillars* as shown in Figure 7.1 on the next page, with nine building blocks. The four pillars are:

1. **Products and services** offered by a company and which represents a value to the customer, shown in “OFFER”
2. **Infrastructure and the network of partners** that the company needs to create value is shown in “INFRASTRUCTURE MANAGEMENT”
3. **Relationship capital** that is created and maintained with customers to ensure sustainable revenues is illustrated in “CUSTOMER INTERFACE”
4. **Financial aspects** that can be found in all the other three components and transverse the model is shown in “FINANCE ASPECTS”

The four pillars in Osterwalder’s ontology incorporate *nine building blocks* that are used to characterize the business model of a company (see Figure 7.1).

Core capabilities represent the range of capabilities a firm needs to posses in order to deliver value to customers

Partner network is the voluntary initiated collaboration between two or more companies to make value for the customer

Value configuration describes the organization of the company’s activities and resources needed to make value for the customer

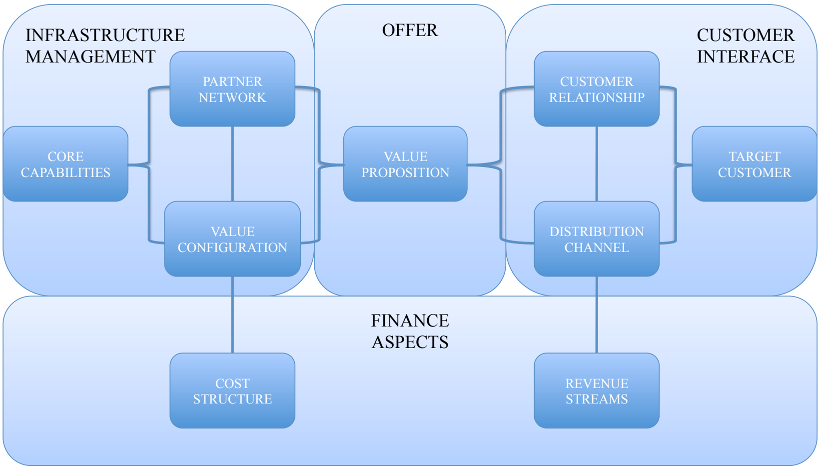

Figure 7.1: Business model template illustrating the four pillars and nine building blocks in Osterwalder's business model ontology [26]

Value proposition is an overall overview of the company's bundled offers that is of value to customers

Customer relationship describes the type of connection the company establishes with its customers

Distribution channel is how the company communicates with its customers

Target customer is the segment of customers that the company wants to offer value to

Cost structure is the representation in money of all the resources employed in the business model

Revenue streams is represented by a revenue model that describes the way the company earns money through a variety of revenue flows

The ontology is comprehensive and an abbreviated version will be used here, since the scope of this thesis is mainly focused on rebound effects. However, an extended version of the business model ontology can be found in Appendix E. The templates for the elements in the ontology presented in the appendix will also be used in the business model constructed later.

7.2 Micro- versus Macro-level Measures

Generally in economics, activities and results are divided into micro- and macro-level. The **micro-level** concentrate on what single actors can do and how they interact with other actors on their level. Microeconomics study how the individual parts of the economy, e.g. households and firms, make decisions to allocate limited resources. It also examines how these decisions and behaviors affect the supply and demand for goods and services, which determines prices, and how prices, in turn, determine the supply and demand of goods and services. **Macro-level** activities and results focus on what happens on an aggregated level, i.e. what happens when many actors work together or many factors influence each other. Macroeconomics usually deals with the performance, structure, behavior and decision-making of the entire economy, be that a national, regional, or the global economy [37].

In Table 6.1, page 51, four functions in the case study on Smart House Technology (SHT) were identified with possible rebound effects. Two functions, *visible information on energy usage* and *statistical information on energy usage*, were identified to give positive/ wanted rebound effects. *Time-saving* and *cost-saving* functions were identified to stimulate negative/ unwanted rebound effects. According to this, rebound effects affect business model design in two ways:

- Customers have an ability to change behavior and attitudes with the right information. This means that if customers are given personal and statistical information on their usage of, for example, a technology, they can change their usage accordingly, further enhancing the impact.
- Customers have the tendency to reduce the effectiveness of an energy efficient technology through other means. That is to say, that customers use what they gain (time or money) on other things that often increase the aggregated carbon footprint of the initial measure (e.g. energy efficient house).

This can be formulated as value propositions to be included in a business model:

1. Provision of visible and statistical information on energy consumption to stimulate wanted rebound effects
2. Provision of measures that prevent time- and cost-savings from being used on high-carbon substitutes creating unwanted rebound effects

7.2.1 Micro: Visible and Statistical Information Provision

The first point presented above, is rather straightforward for businesses and is a *micro-level* solution to enhance wanted rebound effects. It was clear in this research that information provision was a strong incentive for people to get aware of their behavior and change attitudes. With smart house technologies and other information channels where people roam, companies have a unique opportunity to utilize the power of information. What came forth in this research, and that is of special interest, is the significance of specialized or personalized information. All the respondents said that knowing how their actions made a difference in the world or in their region, was interesting. If they did not know the statistical significance of their efforts, it was not so interesting to change behaviors or attitudes. Making information personal and statistically accurate has thus in this research been shown to have an ability to change how people act and think. This can be utilized on many types of rebound effects, correcting for unwanted behavior. That is to say that if an unwanted behavior from a user rises, a company can provide personalized information on how and why to change this behavior. This will in time, compliantly correct the user's behavior. To do this, the company can use its *partner network* element as described in Osterwalder's business model ontology to get statistical and personal information on the users. It can also use its *distribution channel* element to get the information through in a credible way, and its *customer relationship* element so that the information will be taken in by the users.

7.2.2 Macro: Time-saving Functions

Preventing or controlling what people use the time they obtain or save with a technology is difficult. At a *macro-level* the government could stimulate *longer work hours* or *provide information* on healthy and environmentally good use of the time, but there is probably little a company can influence here. Both of these measures to reduce unwanted rebound effects are beneficial to employees, customers and companies. Employees get better offers on healthy spare-time activities and companies could get a part of the profit for promoting these activities. Customers also receive better services or products if the work-hours are increased. In addition, people would be healthier and thus happier, which could reduce governmental and company expenses on sick leaves, illnesses and other physical or metal problems. Figure 7.2 on the next page, shows an illustration of rebound effects from a time-saving function and the *macro-level measures* that can be taken to prevent them.

7.2.3 Micro: Cost-saving Functions

Saving money was seen as the most important incentive for using a SHT system in this research. This function also results in the greatest and most severe rebound effects. It

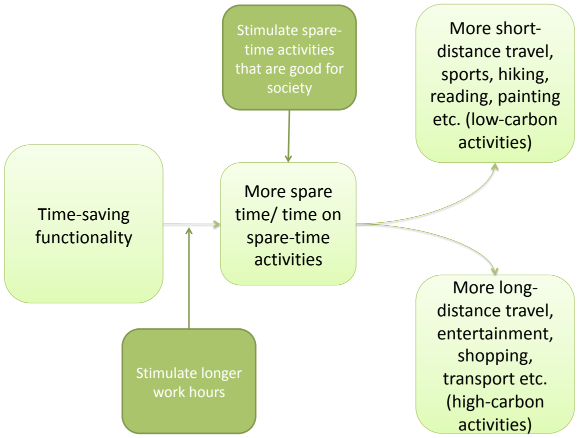

Figure 7.2: Rebound effects from time-saving functions and macro-level ways to prevent them

can be said that we today are in a bad spiral of cost-saving rebound effects from energy efficient technology. When we save money, we go and buy new material goods or save the money in funds, so that investors can invest them in potentially high-carbon investments. This is the money-spiral that drives our economy and that has driven us into a network of environmentally adverse consumer behaviors. It would be ignorant to believe that it is an easy way out of these problems. We nevertheless suggest some simple means that a company can do to reduce the rebound effects that arise from cost-saving functions for their customers and make economic profit of it. Figure 7.3, next page, illustrates three such measures: *payments by other means than money, stimulation of low-carbon investments* and *increase information on environmental impact* on increased consumption.

In this research it was found that the respondents were positive to the option of saving the money they gained from increased energy efficiency. The respondents intended the extra money to be used on investments, travel and other spare-time activities. There are two offers a firm can give to its customers, in addition to the information-function presented above, to prevent money from being used on high-carbon activities. Both include finding alternative payback mechanisms to the user:

1. Offer the saved money (or a self-chosen amount of it) to be placed in eco-friendly funds. This would include the actor (e.g. energy provider) to partner with an investment bank.

2. Offer bonus points to be saved and used on other environmentally friendly products, appliances and services. This would include a personalized website for shopping and maintaining points, and a partner network to offer the products and services.

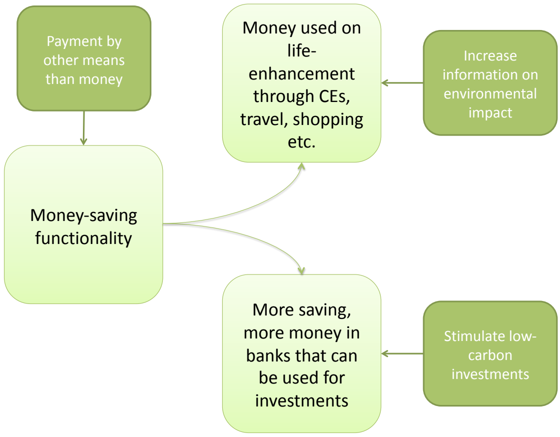

Figure 7.3: Rebound effects from cost-saving functions and micro-level ways to prevent them

The first measure would include a partnership with an investment bank to set up and ensure environmentally friendly funds where the customers could invest the money saved by using the SHT system. The offer could be that the energy company directly transfers the difference in costs on a normal energy invoice compared to the lowered energy invoice achieved with the system, to an environmentally friendly fund.

The second measure the energy company potentially can implement is to give the customer "bonus points" or "credits" instead of reduced costs, in cases where it would be normal to reduce the invoice or give "offers". This means that a company can add a new offer to their business model by including a bonus system instead of only regular billing. This revenue system is also a known form of "lock-in" already in use by most airlines and chain stores today. The scheme locks the customer into spending more money at the same company, thus the company increases its revenue. In this case, the customer gets his share by receiving good offers on environmentally friendly services and products without paying directly for them. This business idea of a bonus point scheme will here be applied to Osterwalder's business model ontology, introduced in Section 7.1. The templates for the elements in the ontology used in the next sections are provided in Appendix E. We will show how the case actor, which in this case is the energy provider and provider of the "Smart Home Management system", can adapt to meet the challenges related to rebound effects from cost-saving technology functions.

7.3 Case: A Sustainable Business Model for the "Smart Home Management system"

General outline of the business idea:

- Customer's are given the choice between a reduced energy invoice, or a monthly fee with the possibility to earn points for saved energy compared to "normal usage"
- Points that equal a higher value than the difference in costs on a reduced invoice are given to the customers. This makes the bonus point scheme a preferred alternative for the users.
- The customer can manage its "points account" through an online service
- The online service provides the opportunity to use points on guaranteed environmentally friendly products and services. This way the customer can for example save points for new, more energy efficient appliances, e.g. a washing machine or refrigerator. Hopefully, the customer will "earn" enough points to replace all appliances in the house within a limited time-period. This will contribute to further abatement in energy consumption and thus more points for the user.

This section proposes a business model for the introduction of a **bonus point scheme** in the "Smart Home Management system" described in Chapter 4. It is important to notice that it is the *partner network*, *customer relationship* and *revenue model* that are affected the most when this new business idea is introduced in the company.

7.3.1 Offer

The first pillar, *"offer"*, in the business model ontology by Osterwalder [25], consists of one element: **value proposition** in Table 7.1, next page.

Value proposition attributes:

- The **reasoning** attribute describes why the offering is valuable to the customer. The following three values are used to categorize the reasoning attribute: *{use, risk, effort}*, i.e. the offering is valuable to the customer through its usage or because it reduces the user's risk or effort.
- The **value level** (or customer utility) attribute measures the utility of the product for the customer and can be used to compare the offering against competitors. The

Table 7.1: Value proposition for the “Smart Home Management system”

VALUE PROPOSITION Name:	Bonus point scheme
Description	Customers are offered to receive savings on energy consumption with the “Smart Home Management system” in bonus points instead of a lowered energy invoice. The bonus points received can be used on eco-friendly products, appliances and services. This way, customers can transfer an eco-friendly attitude to other areas of their lives. The bonus point scheme offers good “prices” on products that will lower the customer’s energy consumption even more. This can lead to virtuous circles in energy reduction for the customer.
Reasoning	{effort}: The bonus system reduces the user’s efforts in obtaining environmentally friendly products and home appliances. It also reduces the effort to be environmentally friendly in other areas of personal life: low-carbon holidays and spare-time activities such as workout and sports.
Value Level	{innovative imitation}: The bonus system imitates already existing bonus systems such as e.g. the “Trumf” system by grocery chain “Norgesgruppen” and “Eurobonus” by airline company SAS. The bonus system is innovative since it promises to only offer environmentally friendly products.
Price Level	{economic}: The bonus system is based on saved costs on energy consumption. In this way, it “costs” the customers their savings on energy, but they get more for their bonus points than if they were to get a reduced invoice instead.

levels used are: *{me-too, innovative imitation, excellence, innovation}*. These categories represent the level of utility, i.e. product not differentiated, but competitive in other areas (e.g. price), product is an imitation of an already existing product, but adds innovative elements, the product is made as a luxury good or the product is a complete new innovation, respectively.

- The **price level** attribute compares the price of the offering with competitors’ prices. To categorize the levels *{free, economic, market, high-end}* are used. The price levels are self-explanatory.

7.3.2 Customer Interface

The customer interface is separated into three elements: **customer relationship** in Table 7.2, **target customer** in Table 7.3 and **distribution channel** in Table 7.4 on the next page.

Relationship attributes:

- The **customer equity** attribute has three categories: *{acquisition, retention, ad-on selling}*. The attribute defines whether the relationship to the customer is made to

Table 7.2: Customer relationship for the "Smart Home Management system"

RELATIONSHIP Name:	**Increased integration and loyalty**
Description	The bonus system increases the personal relationship to the customer with a personalized website and a trustworthy partner network.
Reasoning	{risk}: The relationship reduces the customer's risk in buying environmentally friendly products.
Customer equity	{add-on selling}: The bonus system relationship involves selling additional products and services to current customers of the "Smart Home Management system".
Function	{personalization}: The bonus system contributes to personalizing the relationship between the customer and the actor.
Customer buying cycle	{after sales}: The bonus system is offered as an "after sales" mechanism or a "lock-in", i.e. it is an additional offer that gives value to the customer after he has invested in the "Smart Home Management system" and creates an incentive for the user to stay with the actor.

acquire new customers, keep customers or sell additional products and services to them, respectively.

- The **function** attribute describes the function of the relationship with the customer. The three categories are: *{personalization, trust, brand}*, which indicate a personalization of the relationship, increased trust between actor and customer or brand building for the actor.
- The **customer buying circle** attribute is described with four categories: *{awareness, evaluation, purchase, after sales}*. These categories indicate in which stage of the customer's buying process the relationship takes place.

Table 7.3: Target customer for the "Smart Home Management system"

TARGET CUSTOMER Name:	**Existing customers**
Description	The target customer for the bonus system is the already existing customer of the "Smart Home Management system".

Table 7.4: Distribution channel for the "Smart Home Management system"

CHANNEL Name:	**Online website and partner's distribution chains**
Description	The "Smart Home Management system" will need an online website with personal pages for the bonus system. Offers from partners are presented, ordered and billed, through this site. The customer receives the products via the partner's distribution networks.
Reasoning	{effort}: The online website that links the actor and partner's offers reduces the customer's effort when buying new products or services.

7.3.3 Infrastructure Management

Infrastructure management is in the ontology divided into three elements: **core capabilities** in Table 7.5, below, **partner network** in Table 7.6 and **value configuration** in Table 7.7, both on the next page.

Table 7.5: Core capabilities for the "Smart Home Management system"

CAPABILITY Name:	**Collect and manage bonus points electronically**
Description	The actor must use its existing energy metering system to calculate customer's bonus points. They should also have an Internet page where the users can login, see their "savings" and receive offers from the actor's partners.
Resource types	{tangible} and {human} The system needs an Internet page and the existing access network of the actor. It also needs human resources to maintain the system services and partner network.

Capability attribute:

- The **resource type** attribute describes the sources needed by the company to create its capabilities. Capabilities are again used to provide the *value proposition*, see Figure 7.1, page 54. The resource types are categorized into: *{tangible, intangible, human}*. That is to say, we distinguish between resources that are physical such as property and equipment (tangible), nonphysical resources such as intellectual property, brand names and copyrights (intangible), and human skills, work-capacity and knowledge (human).

Partnership attribute:

- The **reasoning** attribute describes the company's motivation to conclude a partner agreement. Three reasons are distinguished: *{optimization and economies of scale, reduction risk and uncertainty, acquisition of resources}*. The reasons are self-explanatory.

Value configuration attributes:

- The **configuration type** attribute describes how the value is composed within the company. There are three types of configuration: *{value chain, value shop, value network}*. The categories indicate whether the value is made by activities for creating output of input, resolving customer problems or linking customers, respectively.

Table 7.6: Partner network for the "Smart Home Management system"

PARTNERSHIP Name:	**Appliances and services partnership**
Description	The partner network of the actor consists of several providers of environmentally friendly products, appliances and services. This could be an electronics store such as (Norwegian examples) "Elkjøp" or "Expert", travel agencies such as "Ticket" or "Ving", or workout centers ("SATS"), tourist associations ("DNT") etc.
Reasoning	{optimization and economies of scale} The actor enter into income sharing partnerships to profit from it's partners products, services and distribution channels, which it can not achieve on its own.
Strategic importance	{5} Collaboration with partners to deliver environmentally friendly products, appliances and services is vital for the bonus system to be successful.
Degree of competition	{1} The partner companies are not seen as competitors since they supply other forms of value (products and services such as home appliances and holidays) for the customer.
Degree of integration	{3} The companies need to be integrated at some degree, since our actor needs to use the partners' supply chains for the products offered.
Substitutability	{4} Since there are many firms that deliver environmentally friendly products and services, the substitution of a partner firm is not seen as difficult.

Table 7.7: Value configuration for the "Smart Home Management system"

VALUE CONFIGURATION Name:	**Bonus system and partner network**
Description	The bonus system is based on the actor's metering and maintenance of the customer's energy consumption. In addition it provides a channel (online website) where it links customers and its partner network to increase sales and prevent the customer from using money on high-carbon products and activities.
Configuration type	{value network} Value is created by linking customers and partners.
Activity level	{primary} The activities related to maintaining the bonus system, and acting as an intermediary between customers and partners are essential to make the bonus system successful.
Activity nature	{service provisioning} The activities needed to make the bonus and partner system work, are associated with establishing, maintaining and terminating links between customers and billing for the value received. The actor maintains a bonus system based on its already existing customer base. It distributes and maintains value transactions between customers and partners.

- The **activity level** attribute distinguish between the firm's *{primary}* and *{secondary}* activities.
- The **activity nature** attribute is dependent on the *configuration type* and in the case of the *{value network}*, the categories are: *{network promotion and contract management, service provisioning, network infrastructure operation}*. The categories define whether the activities consist of inviting and maintaining customer contracts,

delivering and billing for value received, or maintaining and running a physical and informational infrastructure.

7.3.4 Finance Aspects

Consists of two elements: **revenue model** in Table 7.8, below and **cost structure** in Table 7.9, next page.

Table 7.8: Revenue model for the “Smart Home Management system”

REVENUE MODEL Name:	**Bonus points and partner network**
Description	Customers are invited to collect bonus points instead of receiving a reduced energy invoice. The actor (energy provider that provides the “Smart Home Management system”) receives a monthly fee for the energy and “Smart Home Management system” services that are provided to the customer. The customer saves points on reduced energy consumption with the system and uses the points on “buying” other products and services that the actor takes a small fee for providing.
Stream type	{transaction cut} and {advertising}: The bonus points can be used on offers provided by the actor’s partners, which the actor takes a small fee for providing and/ or advertising.
Percentage	If the actor takes a 20% transaction fee towards the partners, and gives 10% more value on offerings when the customer chooses the bonus point scheme, they will make approximately 10% in revenue from the scheme.
Pricing method	{differential pricing}: The prices are set dependent on volume and product characteristics.

Revenue model attributes:

- The **stream type** attribute describes the type of economic activity with which a company generates a revenue stream. The categories are: *{selling, lending, licensing, transaction cut, advertising}*, and are self-explanatory.
- The **pricing method** attribute differentiate between three main categories of pricing mechanisms: *{fixed pricing, differential pricing, market pricing}*, and indicates if the prices on the value is priced according to fixed rates (pay-per-use, subscription), differentiated on volume, product features or customer characteristics, or based on real-time market conditions (supply and demand).

Table 7.9: Cost structure for the “Smart Home Management system”

COST Name:	**Bonus system services and partner network maintenance**
Description	The actor will need to invest in a good online service and use resources on maintaining a good partner network. This includes human resources (key account managers, service desk personnel) and tangible resources (servers).
Sum	No estimations made

7.4 Summary

This chapter discussed the four system functions identified with rebound effects from Chapter 6 in a business-modeling context. The functions were discussed as micro or macro-economic measures. A micro-level business idea was presented with the use of Osterwalder’s business model ontology.

The next chapter will discuss the general findings in this thesis as well as findings according to the research questions defined in Chapter 1. Weaknesses and strengths in this thesis will also be discussed.

Chapter 8

Discussion

This thesis has taken a user perspective to Smart House Technologies (SHTs): presented current and future technologies, how they interact with users and identified rebound effects through qualitative research. These findings have been connected to business modeling in order to realize the environmental potential of SHTs in a commercial setting as a mean to further accelerate implementation of the technology.

8.1 General Results

The general results of this thesis is the identification of functions in a Smart House Technology (SHT) case that can lead to rebound effects. In addition, several suggestions for handling these rebound effects have been presented, from both micro- and macro- economic perspectives. Another result is the business model developed as a suggestion for handling rebound effects from cost-saving functions.

The findings from the interview research were summarized in Table 6.1, page 51. Generally, the main result from the conducted interviews was that people seem to react on information provided directly to them. This was found to potentially stimulate wanted rebound effects. The other result was that time- and cost-saving functions can lead to unwanted rebound effects. These results on rebound effects are interesting in light of the case study presented, but as introduced in Chapter 5, the results are only valid for the specific case presented here. In addition, they become tentative because the method used limits the statistical significance of the results. The results, however, are reasonable and in line with other literature in the field as will be discussed in the next section. This strengthens the significance of the results and suggests that the topic should be pursued as further work.

So, what is changed in business modeling because of rebound effects? Rebound effects mainly affect businesses that have an environmentally friendly profile and wish to contribute in the battle for CO_2 emissions reduction. This is because the rebound effect is known to "take back" some of the environmental gains introduced by energy efficient technology. In this case, rebound effects affect how the company relates to the customer and gains trust through information and partner networks. Without thinking of rebound effects we will find ourselves at the same point where we are today: in a vicious circle of environmentally adverse behavior, generally caused by increased efficiency from technology. A general problem with the rebound effect is that not all environmental impacts are internalized to the user or consumer and can thus not be corrected for accordingly. Most literature on the field suggests governmental measures such as taxes and guidelines, for coping with rebound effects. This thesis has tried to show an alternative route by including the commercial company as a main actor for addressing rebound effects at the micro-level. If this is successful at a macro-level, is too early to say, but indications from the research conducted here are hopeful in this respect. Regarding businesses, the main problem is the constant strive for earning money through value creation and resource usage. Changing this way of thought from products to services can give companies greater incentives for joining the fight against the climate change.

8.2 Results According to Research Questions

In Chapter 1, we started out with three research questions that have lead this research process.

1. *What are the most evident rebound effects from Smart House Technologies?*

   As mentioned, the interviews conducted identified two particularly significant rebound effects. The first was that users were interested in changing behaviors causing high energy usage when presented with visual and/ or statistical information on energy usage. This is a rebound effect because it affects the initial energy efficiency measure, namely the implementation of a smart house technology system designed to reduce energy consumption. It is a *positive* or *wanted* rebound effect because the users tend to further decrease their energy usage when information on this is provided.

   The other significant rebound effect confirms classic economic theory on rebound effects; the users wanted to spend additional money or time on potentially energy intensive commodities and activities, e.g. Consumer Electronics (CEs) and travel. This rebound effect is *negative* or *unwanted* since it leads to a take-back in the lowered energy consumption achieved with the smart house system.

   The most important result from the interviews was that people reacted positively to information on their own energy usage. The strongest result was the ability and desire to conform to detailed and personalized energy consumption information. The respondents also had the understanding that it would help them reduce their own energy usage and increase their awareness on general energy usage. It can also, if utilized by companies in a sensible way, lead to greater environmental awareness in other areas of personal life, hence a wanted rebound effect. This means that a company could exploit the ability of people to perceive statistically relevant information to increase sales in other sales departments as described in Chapter 7. A problem with the provision of personal information is the risk that companies will exploit this type of information provision, or that too many will start giving information in this way so that people no longer react to it. For example do TV-commercials no longer have the same impact on people as when it started, but it obviously still works since it is as popular as ever as a way to market products. Another problem is that people receive too much information all over, so that it is hard for them to conform to it all. An obvious obstacle to this provision, that is not available to all companies, is the direct channel into people's homes. The home is a very sacred place, and people are vulnerable there. This is why companies that are trustworthy and credible will have the most to gain on this type of information provision and way of correcting rebound effects.

The finding on information provision of energy usage is also consistent with literature found on energy feedback [7, 12, 40]. This literature reveals that feedback and information given to users also reduce energy usage for other appliances in addition to for those where direct energy feedback is given [7, 40]. This strengthens the finding in this report and also some of the proposed rebound effects from this function, see Table 6.1, page 51. On the other hand, what this study has not been able to test is the durability of the information. That is to say, how long the users will need to receive energy consumption information to change attitudes and behaviors permanently. Two studies [7, 12] accentuate that information and feedback must be available over a certain time period to become "tacit knowledge", and thus contribute to a lasting change of attitudes and the wanted rebound effects we suggest in this report. Exactly how long is not stated, but the longer the feedback is present, the more durable the knowledge and new behaviors become. This also needs to be balanced with the amount and frequency of information provided such that the user does not become overloaded with information and annoyed by the functionality.

The fact that people seem to act economically rational when faced with an increase in time or money, is a result in line with theory on rebound effects presented in Chapter 3, and confirmed by this research. But will people always substitute savings with other commodities? As mentioned earlier, the field of Industrial Ecology calls for new ways to examine rebound effects that also take other factors into account, not just personal gains [20]. This is because not all influences on how a consumer behaves can be measured and calculated directly. These questions are in need of further elaboration and other scientific methods than the ones originating in classic economic theory.

2. *How can unwanted (or wanted) rebound effects from Smart House Technologies be minimized (or maximized)?*

   Measures to handle rebound effects could be facilitated at either a micro- or macro-economic level. Technologies that increase time efficiency (and that cause unwanted rebound effects) were found to be most easily addressed at a macro level. Cost-savings and information provision could more easily be addressed at the micro-level by companies. At a micro-level we found that to *minimize unwanted rebound effects* the company that provides an energy efficient technology should inspire to prevent cost-savings from reaching the users of the technology. If the user is not aware of the environmental damage the increased consumption causes and how it can be prevented, it is better to provide other alternative uses of the savings achieved. To *enhance wanted rebound effects* the provider could present visible, personal and statistical information on users' energy consumption or other unwanted behavior. This feature was suggested in the technical case study and gave positive reactions from the respondents. This reflects a willingness to learn and change behaviors if information on how this can be done is provided. A specific suggestion on how to minimize unwanted rebound effects from cost-saving functions in the form of a business model for a bonus point scheme was presented in Chapter 7.

3. *How does different business modeling influence rebound effects from Smart House Technologies?*

   Rebound effects generally affect all main pillars of a business model. There are however three building blocks or elements that stand out as especially effective for handling rebound effects. Rethinking *value propositions* with new additions to the business' *partner network* and/ or changing the *customer relationship* are suggestions for influencing wanted rebound effects. This reflects that a company should have a fully extended environmentally friendly profile, and search for partner companies that can complement its offers in this area. To reduce unwanted rebound effects, we have suggested rethinking payment methods and alternatives for time- and cost-savings for customers. This generally changes a business model's *revenue model*, but can not be done without the interference of one or more other elements, for example the *partner network* or *customer relationship*.

   As outlined in the technical case example in Chapter 4, a utility company was used as the provider of the SHT case system and in the business model proposition. A problem with utilities being providers of technologies for energy efficiency is that they have few incentives for lowering users' energy consumption within traditional business models. As described in [6], a shift towards service based business models would probably be needed. In such a business model, energy could be provided as a service, not a volume-based product. Alternatively, it could be a third party who installs and provides the SHT system described in the technical case example. This third party would act as an intermediary between the customer and the energy provider, making their revenues out off the energy savings or additional services provided. This new actor will have incentives for providing services that enhance rebound effects towards less energy consumption. Examples of service based utility and third party business models have been implemented in California and Texas, and discussed in other literature [6, 8, 13, 24]

Business modeling with rebound effects is difficult because of the uncertainty related to nondeterministic systems and human behavior. The proposed focus areas in business models are based on assumptions. This could be further tested and quantified through designed experiments to verify and increase the reliability of the results. A study from Japan made calculations based on social research. This was to measure how much rebound effects amount to of the total environmental impact of a service [38]. This is a suggestion for further work.

8.3 Weaknesses

Rebound effects from Smart House Technologies (SHTs) and other omnipresent Information- and Communication Technologies (ICTs) have not been comprehensively studied in earlier literature. Rebound effects are of a sociological nature, and should be studied as such, even though it is of most interest to technologists. A good example of interdisciplinary research collaboration is the MIT "House_n" introduced in Chapter 5. This leads us to a discussion of the method used in this research, semi-structured interviews. A case study and semi-structured interviews cannot uptake the full reactions from a technical system. This makes the results tentative. The method chosen was the best available and gave reasonable results, but observations of actual use of such a system over time would be the preferred method if time, resources and money were not constraints.

What concerns the design of the case study, the time-saving function was given little credibility by the respondents in this research because they did not believe that the system would allow them to save considerable time. Looking back, this was a weakness in the design of the system technology and should have been better planned for. Most household chores are today made as efficient as possible, and few services or technologies available today can make these tasks substantially more time-saving. It was still important to ask the questions concerning the use of extra spare-time. This because time-saving and increased effectiveness is one of the main drivers of rebound effects in existing theory, as described in Chapter 3. The results, however, made it clearer that effects from time-saving functions are hard to stimulate or prevent at the micro-level for businesses and are best addressed at a macro-level by, for example, governments.

8.4 Strengths

The research conducted in this thesis is characterized by the background knowledge on rebound effects from the technical autumn report by the same author [30]. This thesis is a continuation of findings in this report and has elaborated on Smart House Technologies (SHTs) and the potential environmental effects of their implementation in residential homes. In addition, this work has given a base for further work and new ways forward related to research on rebound effects. It has also given some concrete guidelines for business modeling with rebound effects. Lastly, the research findings have been examined on both micro- and macro-economic levels.

Considering the resource constraints, a strength in this research was the type of interview-method chosen. It gave good insights into the sociological phenomena of rebound effects. The case study presented gave a realistic perspective to the interviews because we were able to construct the technology according to what we were interested in testing. This implied that we did not need to test with an already existing technology with other features that for example were not suited for identification of rebound effects.

The data material was of good quality and no biases were experienced related to the interview process. It was also taken notes during the interviews, and in addition to the good quality of the recordings, this was valuable in the research evaluation. This also made it possible to transcribe the interviews in a good manner, which was very helpful in the later work.

With the chosen method, time was generally not a constraint and good planning has made the working process successful.

8.5 Summary

This chapter presented the main findings of this research; people have an ability to react positively to feedback on energy consumption and that measures should be taken to prevent direct cost-savings to cause unwanted rebound effects. Customer relationships, partner networks and revenue models were presented as the three elements in a business model that is relevant for by rebound effects. Main weakness in this thesis is a lack of test-facilities for social research. Main strength was the constructed technical case study together with the chosen method. This resulted in reasonable results that have been confirmed in other literature and can be taken into further work.

The next chapter concludes this thesis and suggests topics for further work.

Chapter 9

Conclusion

To conclude this thesis we will summarize the findings from the discussion in the previous chapter:

1. The most evident rebound effects from the technical case study on Smart House Technologies (SHTs) were:
   - The desire for people to change environmentally adverse behavior when information is provided
   - The tendency for people to spend extra money and time on high-carbon activities or increase comfort or material wealth
2. Wanted rebound effects from SHTs can be maximized by:
   - Visible, personal and statistical information on energy consumption

   Unwanted rebound effects from SHTs can be minimized by:
   - Prevent time- and/ or cost-savings from reaching the customers
3. The elements in a business model that have the greatest influence on rebound effects are *customer relationships*, *partner networks* and *revenue models*, in addition to the *value proposition* that consists of offers to customers. The *revenue model* can be rethought to reduce unwanted rebound effects, e.g. by providing an alternative payment scheme. Generally, a strengthening of the *customer relationship* can contribute in maximizing wanted rebound effects since users react to personal information. These measures can both be realized with the help of a *partner network* to ensure its impact and success in the firm.

Because a weakness in this work is the statistical relevance of the results, some topics for further work to address this are suggested in the next section.

9.1 Further Work

Calculating rebound effects for business models The work would consist of finding "rules" that can be applied to models for rebound effects. To find such rules, a social research should be conducted in such a way that patterns of rebound effects from Information- and Communication Technologies (ICTs) could be identified. The work would aim to find patterns applicable to modeling rebound effects in a dynamic system or different economic models (classical and community economic models). The results from the economic analysis can be used to calculate the impact on different business models.

Testing energy consumption feedback This work should consist of developing a technology (e.g. an application for a smart phone). The technology should give visible information on environmentally adverse behavior, such as energy consumption levels. The research would consist of examining the impact of such an application on the users' behaviors and the rebound effects it may stimulate.

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Appendix A

Message Sequence Charts (MSCs) for the “Smart Home Management system”

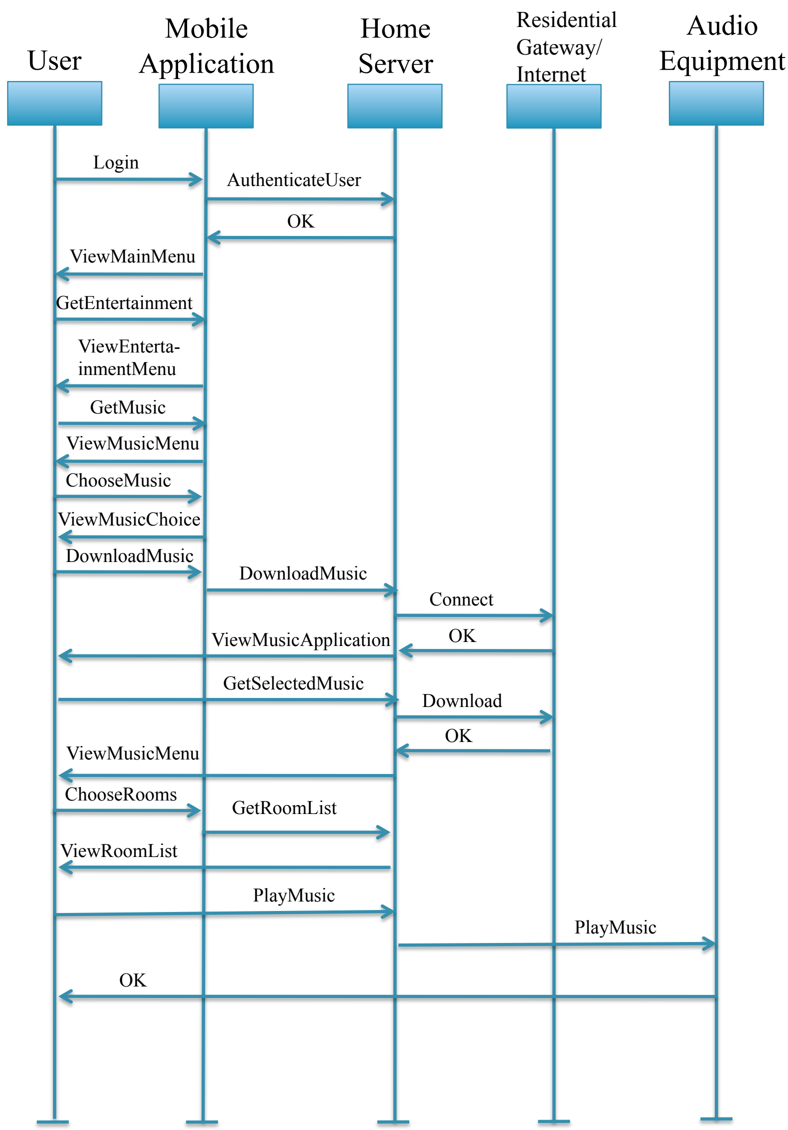


Figure A.1: Message Sequence Chart (MSC): Download music from Internet and play in selected rooms

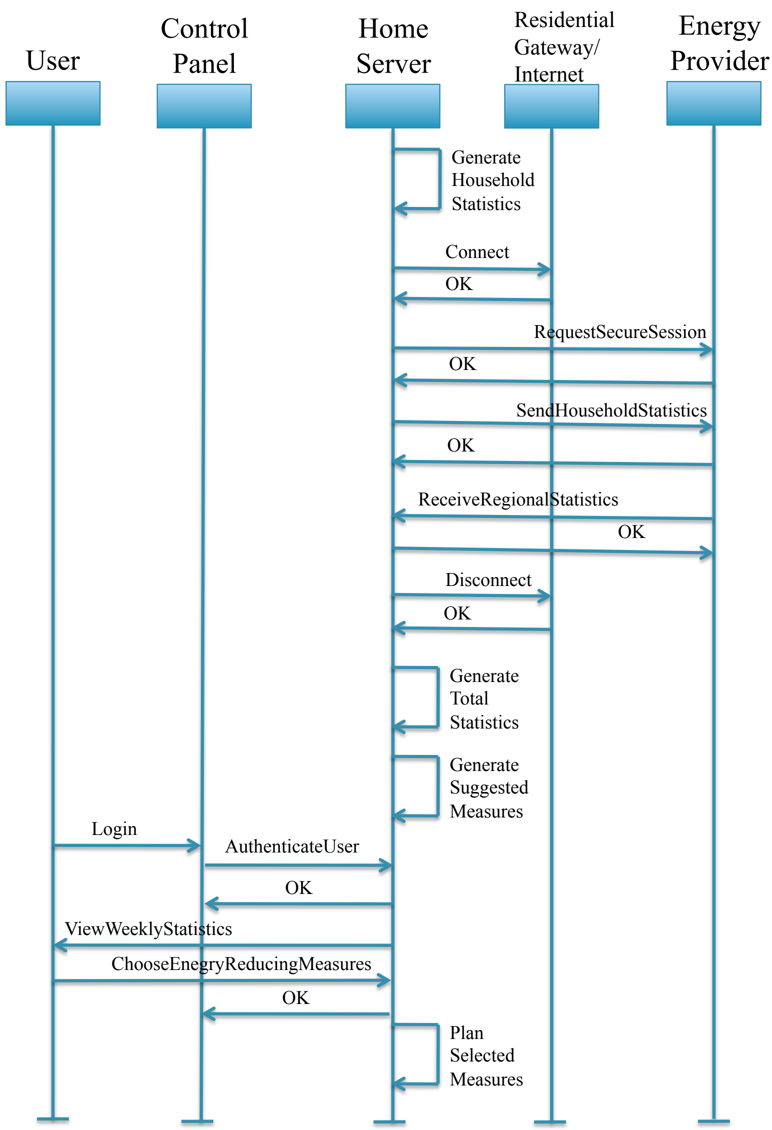


Figure A.2: Message Sequence Chart (MSC): Generation of household statistics, exchange of energy statistics with energy provider and selection of suggested energy reducing measures

Appendix B

Statement of Consent

NTNU
Det skapende universitet

Samtykkeerklæring

Bærekraftige forretningsmodeller for smarthusteknologi
Jeg skriver våren 2010 masteroppgave om hvordan mennesker forholder seg til smarthusteknologi og hvordan dette kan brukes i forretningsmodeller. For å kartlegge meninger og oppfatninger om slik teknologi vil du bli presentert for en konstruert teknologi som du skal svare på noen spørsmål rundt.

Oppgaven gjennomføres ved institutt for telematikk ved NTNU, i samarbeid med professor Leif Arne Rønningen.

Under intervjuet vil det bli brukt en båndopptaker slik at jeg kan gå gjennom intervjuet og svarene senere for tolkning og resultater. Ved å skrive under på dette arket samtykker du til at all informasjon du gir, om ikke annet avtales, kan brukes senere i prosjektet. Du kan imidlertid når som helst trekke deg fra intervjuet når som helst og velge å få slettet data om deg uten begrunnelse.

Du er ikke forpliktet til å gjennomføre intervjuet og en avbrytelse vil ikke få noen konsekvenser. Du kan også kontakte meg senere for å legge til eller trekke informasjon hvis du skulle ønske det. Dataene som samles inn vil bli behandlet konfidensielt og kun undertegnede vil ha tilgang til den. Eventuelle resultater fra intervjuene vil behandles anonymt.

Det er viktig at du svarer ærlig og oppriktig i forhold til deg selv og din oppfatning av teknologien og situasjonen. Det er ingen riktige eller gale svar, alt du tenker er nyttig informasjon for meg. Prøv å sette deg så godt du kan inn i en situasjon hvor teknologien er en daglig del av livet ditt og svar på spørsmålene i forhold til dette. Du må allikevel gjerne nevne utfordringer eller stille spørsmål om teknologien underveis.

Line Rød-Knudsen

Jeg har lest informasjonen over og samtykker til å delta i prosjektet.

…………………………..	…………………………..	…………………………..
Sted	Dato	Underskrift

Appendix C

Fact Sheet "Smart Home Management system"

Faktaark – Smart Home Management system

"Smart Home Management" (SHM) systemet er et smarthusteknologisystem som er installert samtidig som huset bygges. Case-huset er nybygd i en forstad i Norge og møter alle nye energikrav. Alt elektronisk utstyr er nytt og det beste innen markedet på energibruk. Huset har elektrisitet som hovedenergikilde og bruker vannbåren varme som oppvarming. Smarthussystemet SHM består av en sentralisert datamaskin som er koblet til Internett og som fungerer som systemets "hjerne". I huset er alle elektriske apparater som kaffemaskin, stekeovn, vaskemaskin, stereoanlegg og TV koblet sammen via et trådløst nettverk og opp mot hoveddatamaskinen. I tillegg er huset utstyrt med sikkerhetsfunksjoner som kameraer, sensorer for temperatur, lyd, lys og bevegelse, elektroniske låser, elektroniske dører og vinduer. Alle elementene som er koblet til systemet kan styres via systemets brukergrensesnitt via pålogging. Elementene kan vises på systemet med status (av/på) og eventuelt andre funksjoner som å ta opp TV-programmer eller bestille en video fra Internett som kan sees på TV-en med en gang. Alt det elektroniske utstyret kommer med tilkoblingsmuligheter fra produsenten. Systemet har i hovedsak to statuser: "Aktiv" og "Borte". "Borte"-statusen slår av alt lys, alle apparater og senker temperaturen i huset. Statusen kan forhåndsprogrammeres og kobles inn via brukergrensesnittene eller tidsplanleggeren i systemet. Systemet tilbys og vedlikeholdes av strømleverandøren. Oppdateringer skjer automatisk og statistikk blir sendt til strømleverandøren sikkert over Internett. Informasjon om sentral statistikk og tiltak for økt sparing kommer tilbake. Systemet er i hovedsak beregnet på energieffektivisering og effektivisering av oppgaver i hjemmet som vasking og matlaging.

En bruker kan koble seg til systemet på tre måter:

- via systemets kontrollpanel som er en touch-screen plassert i gangen i huset
- via en applikasjon på en smart phone (iPhone)
- via en nettleser på datamaskin som er koblet til Internett

Systemet har fire hovedfunksjoner:

1. Underholdning
    a. Spille musikk i ett eller flere rom
    b. Kjøpe musikk eller video på Internett
    c. Planlegge opptak av TV-programmer
2. Sikkerhet
    a. Se kameraene i huset når systemet er i "Borte"-status
    b. Se temperatur, bevegelse og lys i "Borte"-status
3. System- og utstyrsstatus
    a. Se status på alle enheter koblet til systemet
    b. Endre status på alle enheter koblet til systemet
    c. Se informasjon om husstandens energibruk
    d. Se informasjon om tiltak for å senke energibruket
4. System- og utstyrstimeplan
    a. Legge til eller endre aktiviteter i timeplanen som vasking av klær, oppvarming, TV-opptak og lignende
    b. Se på og endre systemets eller en enkelt enhets timeplan
5. Statistikk og forslag til endringer
    a. Ukentlig statistikk over energi- og vannbruk
    b. Forslag fra energileverandør for senking av energibruk

Appendix D

Interview Guide “Smart Home Management system”

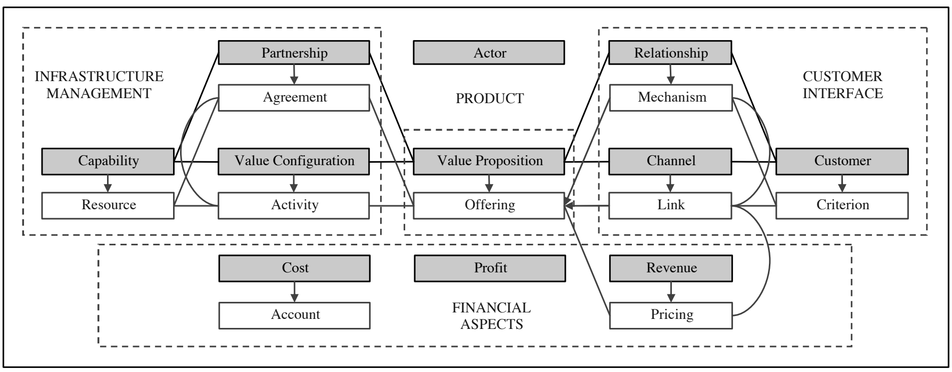
Intervjuguide, dybdeintervjuer om smarthusteknologi

Mål/tema	***Spørsmål***
Forhold til og bevissthet rundt teknologi/miljø	Hvorfor kunne du tenke deg å bruke denne teknologien, ev. hvorfor ikke? Hvordan vil du beskrive forholdet ditt til teknologi og miljøet (energieffektivitet, tidseffektivitet, miljøholdning/miljøbevissthet)?
Reaksjon på tidsbesparende	Hvis du tenker at du sparer tid/penger på teknologien fremlagt, hva ville du brukt den tiden/pengene på? Ville du vasket tøy eller vannet planter mer eller tror du at du ville for eksempel ville spart energi og vaskemidler på teknologien? Hvordan tror du dette hadde påvirket økonomien og tiden din?
Reaksjon på tidsbrukende Prioriteringer ved sparte midler (penger/tid)	Hvordan ville du forholdt deg til de tids/ressursbrukende delene av teknologien (enklere tilgang til underholdning, sosiale nettverk, e-læring, interaktiv matlaging)? Hvordan tror du denne delen av teknologien vil påvirke økonomien og tiden din?
Reakson på informasjon Holdningsendringer eller gjerningsendinger ved økt informasjon	Hvordan tror du informasjonen som blir gitt deg av systemet om din energibruk og metoder for å senke den vil påvirke deg? Ville det vært annerledes om et visst energibruk var statlig regulert?
Tilleggs-informasjon	Hva ser du på som de største fordelene og/eller ulempene med denne teknologien? Hva ville du investert i hvis du fikk velge funksjonalitet selv/hva er viktigst for deg? Hvordan ser du for deg distribusjonen og vedlikeholdet av et slikt system? Hvem burde betale for de ulike delene av systemet? Har du noen tanker om hvilken rolle smarthusteknologi vil ha i fremtiden?

Appendix E

Business Model Ontology

Osterwalder defined a methodology for accurate presentation of business models. This appendix gives an overview of the ontology used in the business modeling in Chapter 7. All elements and sub-elements are presented here for a thorough understanding of the modeling language, though not all are used in the thesis. The first figure is an overall overview of the elements and their relationship. This is an extended version compared to Figure 7.1, page 54, used in the thesis.



E.1 Building Blocks and Elements

The first nine building blocks are the base for the business model presented in Chapter 7. The rest of the elements are only presented for informational purposes.

Name of BM-Element	TARGET CUSTOMER
Definition	A TARGET CUSTOMER segment defines the type of customers a company wants to address.
Part of	CUSTOMER INTERFACE
Related to	*Receives* a VALUE PROPOSITION (1-n)
Set of	CRITERION(s)(0-n)
Cardinality	1-n
Attributes	Inherited from CRITERION

Name of BM-Element	VALUE PROPOSITION
Definition	A VALUE PROPOSTITION represents value for one or several TARGET CUSTOMER(s) and is based on one or several CAPABILITY(ies). It can be further decomposed into its *set of* elementary OFFERING(s). A VALUE PROPOSITION is characterized by its attributes DESCRIPTION, REASONING, VALUE LEVEL and PRICE LEVEL and an optional LIFE CYCLE.
Part of	PRODUCT
Related to	*Value for* TARGET CUSTOMER *Based on* CAPABILITY(1-n)
Set of	Elementary OFFERING(s) (0-n)
Cardinality	1-n
Attributes	Inherited from elementary OFFERING

Name of BM-Element	CHANNEL
Definition	A distribution CHANNEL describes how a company *delivers* a VALUE PROPOSITION to a TARGET CUSTOMER segment. Normally a firm disposes of one or several direct or indirect CHANNEL(s) that can be decomposed into their LINK(s).
Part of	CUSTOMER INTERFACE
Inherits from	LINK
Related to	*Delivers* VALUE PROPOSITION (1-n) *Delivers to* TARGET CUSTOMER (1-n)
Set of	LINK(s)(0-n)
Cardinality	1-n
Attributes	Inherited from LINK

Name of BM-Element	RELATIONSHIP
Definition	The RELATIONSHIP element describes the relationship a company establishes with a TARGET CUSTOMER segment. A RELATIONSHIP is based on customer equity and can be decomposed into several RELATIONSHIP MECHANISMs.
Part of	CUSTOMER INTERFACE
Inherits from	relationship MECHANISM
Related to	A RELATIONSHIP promotes a VALUE PROPOSITION (1-n) A RELATIONSHIP is maintained with a TARGET CUSTOMER (1-n)
Cardinality	1-n
Attributes	*CUSTOMER EQUITY* {ACQUISITION, RETENTION, ADD-ON SELLING} All other attributes are inherited from the RELATIONSHIP MECHANISM

Name of BM-Element	CAPABILITY
Definition	A CAPABILITY describes the ability to execute a repeatable pattern of actions. A firm has to dispose of a number of CAPABILITYies to be able to offer its VALUE PROPOSTION. CAPABILITYies are based on a set of resources from the firm or its PARTNER(s).
Part of	INFRASTRUCTURE MANAGEMENT
Inherits from	RESOURCE
Related to	A CAPABILITY(ies) allows a firm *to provide* its VALUE PROPOSTION (0-n)
Cardinality	1-n
Attributes	Inherited from RESOURCE

Name of BM-Element	VALUE CONFIGURATION
Definition	The VALUE CONFIGURATION of a firm describes the arrangement of one or several ACTIVITY(ies) in order to provide a VALUE PROPOSITION.
Part of	INFRASTRUCTURE MANAGEMENT
Related to	The VALUE CONFIGURATION relies on a set of CAPABILITIES (1-n) The VALUE CONFIGURATION makes VALUE PROPOSITIONs possible (1-n)
Set of	ACTIVITIES
Cardinality	1-n
Attributes	*CONFIGURATION TYPE* {VALUE CHAIN, VALUE SHOP, VALUE NETWORK} Other attributes inherited from ACTIVITY

Name of BM-Element	PARTNERSHIP
Definition	A PARTNERSHIP is voluntarily initiated cooperative agreement formed between two or more independent companies in order to carry out a project or specific activity jointly by coordinating the necessary CAPABILITIES, RESROUCES and ACTIVITIES.
Part of	INFRASTRUCTURE MANAGEMENT
Related to	Concerns a VALUE CONFIGURATION (1-n) PARTNERSHIPS are developed to provide a VALUE PROPOSITION (1-n)
Set of	AGREEMENT(s)
Cardinality	*0-n*
Attributes	Inherited from AGREEMENT

Name of BM-Element	REVENUE MODEL
Definition	A REVENUE MODEL describes the way the company makes money. It can be composed of one or several REVENUE STREAM AND PRICING elements.
Part of	FINANCIAL ASPECTS
Related to	A REVENUE MODEL is built on and depends of the firm's VALUE PROPOSITIONs (1-n)
Set of	REVENUE STREAM AND PRICING(s) (0-n)
Cardinality	*1-n*
Attributes	Inherited from REVENUE STREAM AND PRICING

Name of BM-Element	COST
Definition	The COST element measures all monetary costs incurred by the company
Part of	FINANCIAL ASPECTS
Inherits from	ACCOUNT
Set of	ACCOUNT(s) (0-n)
Attributes	Inherited from ACCOUNT

Name of BM-Element	OFFERING
Definition	An elementary OFFERING is a part of an overall VALUE PROPOSITION. It is characterized by its attributes DESCRIPTION, REASONING, LIFE CYCLE, VALUE LEVEL and PRICE LEVEL.
Element of	VALUE PROPOSITION (1-n)
Cardinality	0-n
Attributes	*NAME* {abc} *DESCRIPTION* {abc} *REASONING* {USE, RISK, EFFORT} (0-n) *VALUE LEVEL* {ME-TOO, INNOVATIVE IMMITATION, EXCELLENCE, INNOVATION} *PRICE LEVEL* {FREE, ECONOMY, MARKET, HIGH-END} *LIFE CYCLE* {CREATION, PURCHASE, USE, RENEWAL, TRANSFER}

Name of BM-Element	CRITERION
Definition	A CRITERION defines the characteristics of a TARGET CUSTOMER.
Part of	TARGET CUSTOMER
Cardinality	0-n
Attributes	NAME {abc} DESCRIPTION {abc}

Name of BM-Element	LINK
Definition	A channel LINK is part of a CHANNEL and describes a specific channel role. It may be part of the VALUE PROPOSITION and it may be related to another LINK.
Element of	LINK
Inherits from	OFFERING
Related to	A LINK can be *connected to* another LINK (0-n)
Cardinality	0-n
Attributes	Inherited from OFFERING *CUSTOMER BUYING CYCLE* {AWARENESS, EVALUATION, PURCHASE, AFTER SALES} (overwritten by *VALUE LIFE CYCLE* if the LINK element is also an OFFERING.

Name of BM-Element	AGREEMENT
Definition	An AGREEMENT specifies the function and the terms and conditions of a partnership with an ACTOR
Element of	PARTNERSHIP
Related to	An AGREEMENT is always made with an ACTOR (1-n)
Cardinality	0-n
Attributes	*NAME* {abc} *DESCRIPTION* {abc} *REASONING* {OPTIMIZATION AND ECONOMIES OF SCALE, REDUCTION OF RISK AND UNCERTAINTY, ACQUISITION OF RESOUCES} *STRATEGIC IMPORTACE* {0-5} *DEGREE OF COMPETITION* {0-5} *DEGREE OF INTEGRATION* {0-5} *SUBSTITUTABILITY* {0-5}

Name of BM-Element	relationship MECHANISM
Definition	A RELATIONSHIP MECHANISM is part of a RELATIONSHIP and describes the function it accomplishes between the company and its customers. It may also be a channel LINK or a part of the VALUE PROPOSITION.
Element of	RELATIONSHIP
Inherits from	LINK
Cardinality	0-n
Attributes	Inherited from LINK *FUNCTION* {PERSONALIZATION, TRUST, BRAND}

Name of BM-Element	ACTOR
Definition	A business model ACTOR is an outside organization that is involved in the firm's business model and is integrated through a partnership
Attributes	NAME {abc} DESCRIPTION {abc}

Name of BM-Element	RESOURCE
Definition	RESOURCEs are inputs into the value-creation process. They are the source of the CAPABILITIES a firm needs in order to provide its VALUE PROPOSITIONs.
Element of	CAPABILITY (1-n)
Related to	A RESOURCE can be provided *by* an ACTOR (0-n)
Cardinality	0-n
Attributes	*NAME* {abc} *DESCRIPTION* {abc} *RESOURCE TYPE* {TANGIBLE, INTANGIBLE, HUMAN}

Name of BM-Element	ACTIVITY
Definition	An ACTIVITY is an action a company performs to do business and achieve its goals.
Element of	VALUE CONFIGURATION
Related to	An ACTIVITY is executed by an ACTOR (1-n) An ACTIVITY {fits}, {flows} to or is {shared} by one or several RESOURCE(s) (0-n)
Cardinality	0-n
Attributes	*NAME* {abc} *DESCRIPTION* {abc} *ACTIVITY LEVEL* {PRIMARY ACTIVITY, SUPPORT ACTIVITY} *ACTIVITY NATURE* (0-1) - for Value Network {NETWORK PROMOTION AND CONTRACT MANAGEMENT, SERVICE PROVISIONING, NETWORK INFRASTRUCTURE OPERATION}

Name of BM-Element	REVENUE STREAM AND PRICING
Definition	The REVENUE STREAM AND PRICING element describes an incoming money stream from the value offered by the company. Furthermore, it defines what mechanisms is used to determine the price of this value offered. The element is characterized by its attributes STREAM TYPE and PRICING METHOD
Element of	REVENUE MODEL
Related to	A REVENUE STREAM AND PRICING is for one or several OFFERINGs (1-n) Every channel LINK can have one or several REVENUE STREAM AND PRICING elements (1-n)
Cardinality	0-n
Attributes	*NAME* {abc} *DESCRIPTION* {abc} *STREAM TYPE* {SELLING, LENDING, LICENCING, TRANSACTION CUT, ADVERTISING} *PERCENTAGE* {123} *PRICING METHOD* {FIXED, DIFFERENTIAL, MARKET}

Name of BM-Element	ACCOUNT
Definition	An ACCOUNT is a registry of pecuniary transactions (expenditure) of a certain category
Element of	COST
Cardinality	1-n
Attributes	*NAME* {abc} *DESCRIPTION* {abc} *SUM* {123} *PERCENTAGE* {123}