Heat Pumps and Household Energy Consumption in Norway

An actor-network and practice theory approach

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Abstract

The aim of this project is to contribute to the research on how heat pumps affect energy consumption in Norwegian homes. It approaches the question by focusing on heat pumps as technical objects, and looking in detail at the use of these objects in home settings.

The study uses actor-network theory in conjunction with practice theory to examine the role of heat pumps in the network of household energy-using practices, with a particular focus on home-heating. The aim is to shed light on how these practices might be shaped by heat pump technology, and vice-versa. The study utilises key concepts from ANT, namely the concepts of technological *scripts* and *agency*, to conceptualise heat pumps. This conceptualisation is then employed in an examination of the role of heat pumps in the network of household activities, which is approached from a practice theory perspective.

Members from 15 households in the Oslo/Akershus area were interviewed about the use of their heat pump and the other methods used for heating their home. The research questions guiding these interviews were: How do heat pumps, as technical objects, influence the way people use them? Are heat pumps used in the ways intended by their design? And, how do homes with heat pumps use other forms of heating?

The interaction between the user and the heat pump is discussed with a focus on how this interaction affects energy consumption. The study also incorporates an examination of the wider context of this energy use, namely the heating related practices taking place in the households studied.

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1 Introduction

Managing levels of domestic energy consumption is one of the major challenges for Norway and other Northern nations wishing to reduce their emissions and improve overall sustainability. Reducing the amount of energy consumed in the domestic sphere has been a focal point for climate and energy policies for decades. In Norway there is a strong focus on space heating in these policies, which is seen as an area with major potential for reducing energy use.

Space heating can account for up to 50% of the energy used in a Norwegian home (Larsen and Nesbakken 2004). Reducing the amount of energy used to heat households therefore presents itself as an obvious area to focus on in strategies for reducing energy consumption. Heat pumps have gained attention as a means for reducing consumption because of their high energy efficiency relative to other methods of space heating. In recent years heat pumps have even been subsidised by bodies like Enova and certain Norwegian municipalities tasked with reducing energy consumption.

Heat pumps' energy efficiency has also helped them to become desirable as consumer items. The number of heat pumps installed in Norwegian homes has greatly increased over the past decade. Over a quarter of households in Norway now own some form of heat pump, the majority of which are air-to-air pumps (Halvorson and Larsen 2013:4).

Despite the theoretical benefits of heat pumps' energy efficiency there is still debate about whether their use in domestic settings actually leads to a net reduction in energy use. A recent study published by Statistics Norway found that the actual energy-savings of homes with heat pumps was close to zero (Halvorson and Larsen 2013), and a study conducted in Denmark produced similar results (Christensen et al. 2013). Studies like these are raising difficult questions regarding the actual, as opposed to theorised, effects of heat pumps on domestic energy consumption.

This thesis aims to address some of these questions about heat pumps and energy consumption by looking in-depth at the energy-use practices of households that own a heat pump. It uses a distinct combination of theoretical concepts to help understand both the role of the user and the role of the technology in the formation of energy-use patterns. By using a focused and in-depth approach this thesis addresses the everyday reality of heat pump use in a way that cannot be adequately examined in macro studies on energy consumption.

1.1 Research Questions

The research questions for this project were developed with the aim of understanding how heat pumps affect energy consumption. In order to achieve this, the question needed to be broken into smaller, more specific parts. I have used three different research questions for this study, all aimed at gaining a better understanding of how heat pumps affect energy consumption on the level of everyday life. These questions draw from concepts in the theoretical framework of this study, which I detail in chapter 3, but I have phrased the questions in the simplest possible terms here for better clarity.

(1) How do heat pumps, as technical objects, influence the way people use them*?*

This question is draws upon the concept of technological *agency*, or the idea that technologies, by nature of their physical and technical properties, have what could be described as a kind of 'will' that acts upon their users. This question examines the role of the agency of heat pumps in shaping the way heat pumps are used.

(2) Are heat pumps used in the ways intended by their design? And if heat pumps are used in ways that were not intended in the design, how does this type of use affect energy consumption?

The aim of this question is to reveal whether, or how often, heat pumps are used 'correctly,' and what affect 'incorrect' use has on energy efficiency. The question is informed by the concept of technological *script*, which is the idea that technologies have a specific program of action inscribed in them that must be followed by the user if the technology's intended function is to be carried-out.

(3) How do homes with heat pumps use other forms of heating like fireplaces and resistance heaters?

Here the aim is to understand the heat pump's place in the wider context of home-heating. Heat pumps are very seldom the only source of heat in a household, so from an energy-consumption perspective it is important to understand how they are used in conjunction with other heat sources. The approach to the question is heavily informed by practice theory, which is discussed in chapter 3 along with the other theoretical concepts mentioned in this section.

1.2 Structure

The next chapter, Background, establishes the research landscape on energy consumption, lays out the relevant information about the energy environment in Norway, and the technical aspects of heat pumps that are relevant for the discussion to follow. This section is designed to inform the reader of the information that is not directly addressed in other chapters, but still bears significance for the findings and analysis.

The next chapter, Theoretical Framework, goes into detail about the theories employed in this study, and outlines how they are used. It also goes further in-depth about the justification for using this particular theoretical framework.

Chapter 4, Methodology, outlines the methods used in this study in more detail and the justification for their use. This includes reflections on the strengths and weaknesses of the approach used here, and details about how the data was collected and analysed in this study.

Findings and Analysis, chapter 5, represents the bulk of the argumentation for this thesis. I have chosen to discuss my findings as I report on them, and have organised the chapter on the basis on the types of findings I discuss in each section. Each finding, and my analysis of it, is discussed in detail, and those findings relate to energy consumption is addressed.

In the final chapter, Conclusion, I reiterate the key findings from of the thesis as they pertain to energy use and space heating in Norway. I then reflect further on these findings, and offer some thoughts on the ways future energy research and policy might help to better exploit the energy-saving potential of heat pumps.

2 Background

In order for the arguments presented in this thesis to be understood as clearly as possible it may be helpful to review some background information that bares relevance. This chapter outlines some relevant technical specifications of heat pumps, including the operating principles that make them an energy efficient space heater. I also review some of the literature on energy consumption that will help clarify the choices of theoretical and methodological approaches that I have made, then move on to a discussion of electricity production and policy in Norway, and finally to a discussion of Norwegian heating practices.

2.1 What is a Heat Pump?

In order to understand the relationship between heat pumps and energy use it is helpful to know some basic things about heat pump technology. Here I focus on the aspects of heat pumps that are most important for a clear understanding of the discussion to follow.

Heat pumps of any variety are a considerable investment. An air-to-air heat pump costs between NOK 15,000 and NOK 30,000 and water-to-water between NOK 90,000 and NOK 200,000, including installation (Norsk Varmepumpeforening 2012a). Despite the cost, however, heat pumps are growing in popularity in Norway, with over a quarter of the population owning one as of 2012 (Halvorson and Larsen 2013:4).

Heat pumps are an energy efficient space-heating technology by virtue of the fact that they do not actually generate the heat that is used to warm a space. Instead a heat pump captures heat from a source – either outside air, or heat from the ground – and transfers that heat indoors. In an air-to-air

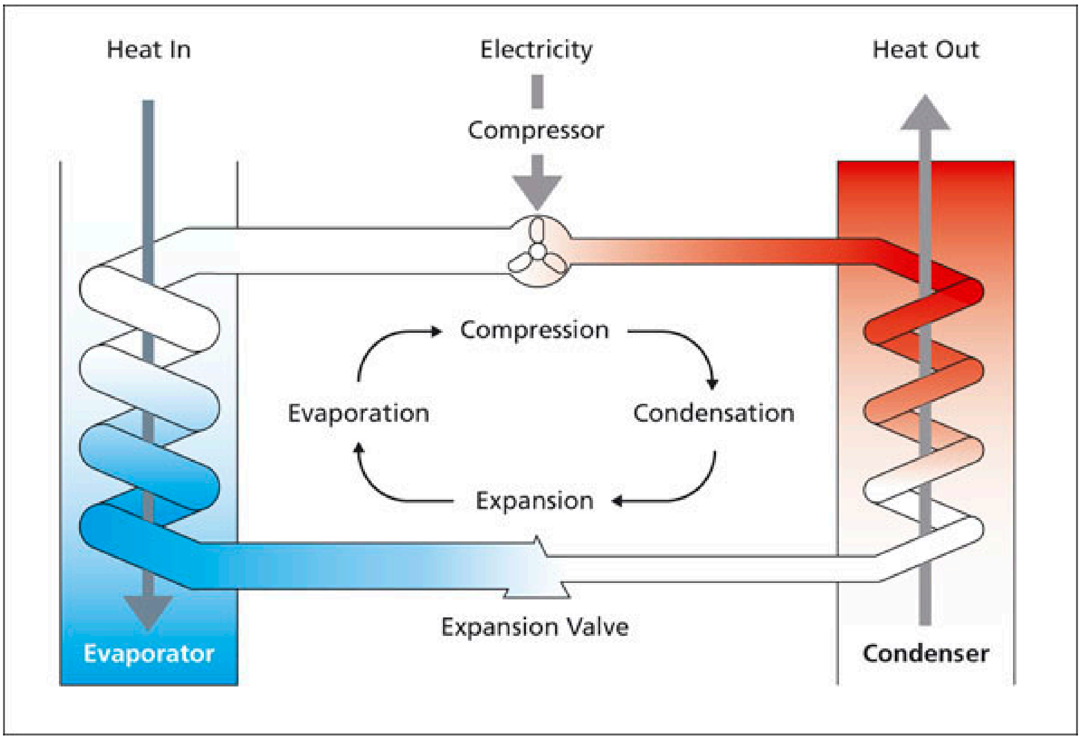

Figure 1. Heat pump compression/expansion cycle (Heat Pump Association 2013)

heat pump, the most common type, this heat is captured by a refrigerant that runs through coils in the evaporator on the outdoor portion of the heat pump.

Refrigerant is used because it can be easily changed between liquid and gas form by increasing or decreasing the pressure it is put under. When this refrigerant is vaporised it easily absorbs ambient heat from the outside air, when it is then compressed the temperature increases as the refrigerant liquefies. An air-to-air heat pump works by exposing vaporised refrigerant to the outside air where it collects ambient heat, even at very low temperatures. The refrigerant is then compressed into liquid form and pumped through coils in the indoor portion of the heat pump (the condenser), where a fan blows over these coils delivering the heat output. The refrigerant is then decompressed by an expansion valve as it is pumped back to the outside portion of the pump to begin the cycle again (figure 1.).

This same basic principle also applies to water-to-water heat pumps, but instead of using heat from the outside air it uses heat from below ground, where temperatures are highly stable. This heat is collected by long underground pipes or coils containing water, sometimes with refrigerant mixed in. The heat source that water-to-water pumps draw upon is usually the ground warmth, though water-to-water heat pumps can also be made to capture heat from underground bodies of water or ocean water. With ground-sourced water-to-water pumps, the kind four of the informants in this study owned, the water-filled pipes that collect the heat have either been bored into bedrock (figure 2), or have been laid as long coils one meter below the ground, spread over a large area. In most cases water-to-water pumps are also used to heat the hot water cylinder of the house, whereas air-to-air pumps are not (Norsk Varmepumpeforening 2012b).

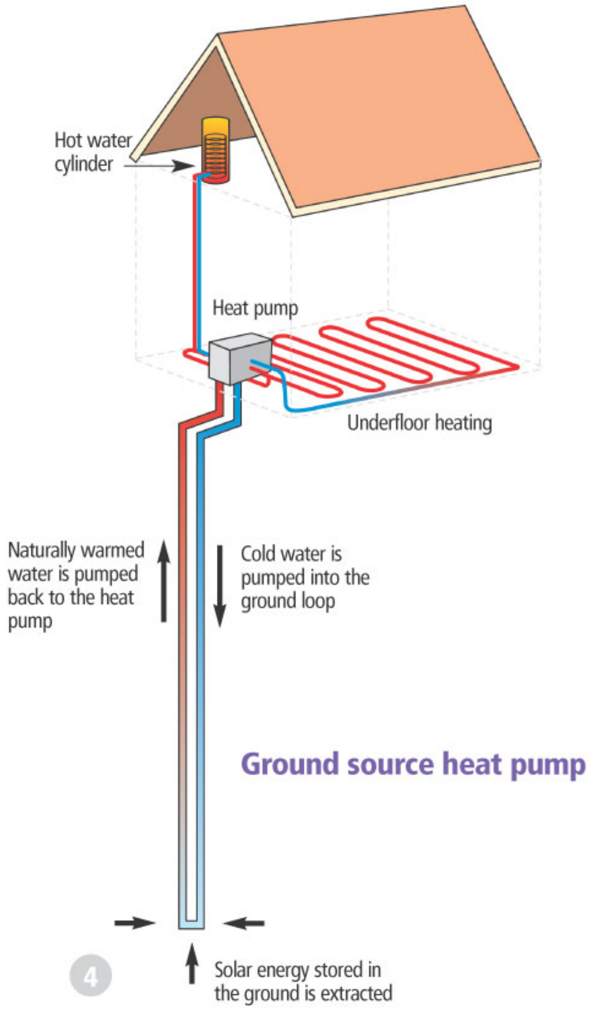

Figure 2. Ground-sourced water-to-water heat pump (building.co.uk 2005)

While water-to-water heat pumps are far more expensive and complex to install they provide almost the exact same level of energy efficiency year-round, due to the consistency of the heat source. Air-to-air pumps, while cheaper and simpler to install, function less efficiently the lower the outdoor air temperature is. At somewhere between -10˚C and -15˚C, a typical air-to-air pump will not provide any added energy efficiency, because it cannot extract enough heat from the outside air.

Air-to-air	Ambient heat is transferred from outside air and delivered inside as warm air.
Water-to-water	Heat from stored in the earth is collected by refrigerant and water mixture pumped through pipes below ground. This heat is delivered through water-filled pipes in the floor of the home.
Air-to-water	Heat is collected from outside air and delivered indoors via water-filled pipes in the floor.
Ground-sourced	Refers to pumps that collect heat from beneath the earth, either from a bedrock from soil.

Table 1. Explanation of heat pump types

Air-to-air heat pumps are also prone to another type of problem in during sub-zero temperatures. Because the temperature of the outdoor coils of an air-to-air pump must be lower than the air temperature in order to absorb heat, these coils collect ice when outside temperatures are below freezing. Air-to-air pumps must therefore go through a defrost cycle to remove this frozen condensation from the outdoor coils. This requires the pumps to temporarily reverse the flow of refrigerant, pumping the warm, liquefied refrigerant from the indoor coils through the outdoor coils to defrost them. This process creates moisture run-off from the defrosted coils which, as we shall see later, can freeze and cause problems in certain contexts.

The final point to note about heat pumps used in Norway is that their high energy efficiency is contingent on them running for extended periods. The heat pump installers that the informants in this study spoke to recommend that the heat pump be left running almost continuously during winter, rather than only turning it on as needed. According to these technicians, if a heat pump is regularly turned off and on its efficiency will be reduced, because the pump must produce heat for a longer time to bring a space up to temperature than it does to maintain a temperature. Norsk Varmepumpeforening, an independent web resource for heat pump information in Norway, also advises that “for the heat pump to have the longest possible lifetime you should avoid turning it completely off"[1] (2013c). This aspect will be relevant later when I discuss the use of heat pumps in more detail, and the implications of how they are used for energy consumption.

2.2 A Brief Overview of Energy Consumption Research

In this sub-section I will discuss some of the more common ways that domestic energy consumption is researched, and the advantages and limitations of these approaches. I take a global approach, focusing on the most prominent types on energy consumption research regardless of the country of origin. The aim of this section is to help frame my study in the wider context of energy research by showing what mainstream energy research focuses on, how this research informs energy policy, and where there is a need for different perspectives in the study of energy consumption.

2.2.1 Intervention and feedback studies

Much of the current research on domestic energy consumption and how to reduce it focuses on "intervention techniques" designed to change people's consumption behaviour. These studies have their roots in social psychology, with most aiming to discover the best strategy to convince people to change their energy-using behaviour. 'Interventions' can come in a variety of forms depending on the specific approach of the study or policy, but generally they all follow the same principle; that if energy consumers are better informed about their energy use they will reduce that energy use. The basic assumption is that there is an 'information deficit' between what electricity consumers know about their consumption and what the most optimal level of consumption actually is. As consumers become more informed, it is hypothesised, their consumption should decrease.

One form of intervention designed to decrease this information deficit, and one that has been favoured by policy-makers in many countries, is the use of

[1] "For at varmepumpa skal ha lengst mulig levetid bør du ikke slå varmepumpa helt av."

information campaigns relating to how to save energy and why energy saving is important. This type of intervention comes in the form of advertising campaigns such as posters, television adverts, and leaflets, usually sponsored by government bodies, providing tips and practical advice on how to save energy. Common advice in such campaigns includes lowering the home thermostat, unplugging appliances when not in use, installing energy efficient light bulbs, and using fans instead of air conditioners for cooling during the summer.

He and Kua (2013) conducted a study of the effect of these types of information campaigns in Singapore, specifically the effect of pamphlets and stickers, to help determine whether they were an effective intervention strategy. As well as the pamphlet and stickers the researchers looked at face to face interaction between consumers and volunteers who provided information and advice about energy saving. The informants were divided into three groups; one which was given pamphlets and stickers with energy saving tips, another group who received the face-to-face consultations and advice from volunteers, and a control group.

For the leaflet and sticker group He and Kua found that, though overall reductions in energy use were observed, the types of energy-saving techniques presented in the pamphlets (such as lowing thermostats and unplugging appliances) were not observed. The authors explain this by saying that

> There is reason to believe that the information given in the leaflet may have prompted households to adopt other measures that are mentioned in the questionnaires [conducted as part of the study] but not explicitly highlighted in the leaflets and stickers. (2013: 112)

Indications from studies like He and Kua's are that information in the form of pamphlets or other kinds of advertising are not particularly effective at reducing consumption. Brandon and Lewis (1999) for example found that the information leaflets did not increase the probability of households reducing their energy use compared to a control group. And in a review of 38 studies on intervention techniques for reducing energy consumption Abrahamse et al. (2005) found that “[g]enerally, information alone is not a very effective strategy” (281). Both Brandon and Lewis (1999) and Abrahamse et al. (2005) did, however, find some indication that providing feedback on real energy use made households more likely to reduce their consumption.

Direct feedback on real energy use is a form of intervention that has been receiving increased attention in the study of energy consumption. Some studies have shown that direct feedback can be successful in reducing energy consumption, at least in the short-term (for example Brandon & Lewis 1999, and Fischer 2008). Wilhite et al.’s (1999) experiment of providing detailed information about energy use on customers’ energy bills in Oslo and Helsinki showed a reduction in energy use by customers that received such information (particularly information that showed historical energy use in the billed household). Customers in their study reported being highly satisfied with this type of billing, and that they paid more attention to their bills than before. The results of that experiment showed that the customers who received the detailed bill saved an average of 10% electricity compared to a control group over the course of one year (Wilhite et al. 1999). This indicates that when feedback on actual consumption is given there is potential for reductions in energy consumption.

What, then, is the most effective form of feedback? Fischer (2008) conducted a review of 22 intervention studies in which she concluded that feedback is most effective in reducing energy use when it is “given frequently and over a long time, provides an appliance-specific breakdown, is presented in a clear and appealing way, and uses computerized and interactive tools” (79). Abrahamse et al. (2005) also found that providing frequent feedback on energy consumption could be an effective strategy for reducing that consumption. Given that feedback may be an effective way to curb energy consumption, if provided correctly, there has been growing interest in discovering the best method for doing so.

Household ‘smart meters’ that measure electricity use and give feedback in the form of a visual display are one such feedback device that is designed to give up to date and on-going information on electricity use, thus fulfilling many of Fischer’s criteria above. These meters are considered by some to hold the best potential for decreasing household energy because of the immediacy of their feedback; users can see exactly how much electricity they are using in real time, and can thereby adjust their usage more effectively. In fact, the UK Department of Energy and Climate Change are convinced enough by the potential for energy meters to reduce domestic energy consumption that they plan to have one installed in every British household by 2020 (Hargreaves et al. 2012: 126).

However, as Hargreaves et al. (2012) point out, very little research has actually been done on the effectiveness of smart meters in reducing electricity consumption. In their study of smart electricity meters (SEMs) these authors did not find a great deal of evidence to support the idea that feedback from meters is effective at reducing consumption *long-term*. They state in their concluding remarks that:

> … [H]ouseholds in our sample appeared to learn what counted as ‘normal’ consumption for their household in quite considerable detail. Whilst the SEMs prompted some initial behavioral changes to cut out unnecessary and wasteful energy use, once this ‘normal’ level of consumption had been learnt, the monitors then appeared to be used only for very specific reasons and provide little or no motivation to reduce energy consumption further – especially in the absence of wider policy and market measures to save energy. (Hargreves et al. 2012: 132)

According to Hargreaves et al. the potential for significant reductions in energy consumption resulting from SEMs alone is limited. Users did not respond by continually aspiring to save yet more energy as time went on, but rather “backgrounded” (Ibid) the smart meter once the initial novelty had worn off and they had made the energy reductions in areas that they considered ‘non-essential.’ No significant long-term changes in lifestyle and general energy consumption by the informants use were observed.

This cursory overview of studies of intervention techniques suggests that the idea that the problem of over-consumption in the domestic energy sector is one of an information deficit is too simplistic. While increasing the information available to users on their energy consumption through various feedback methods has the potential to reduce consumption to some degree, its potential to cause long-term and on-going reductions in energy use appears to be limited. With this in mind I now turn to research that focuses on increased technological efficiency as a potential key in reducing energy consumption.

2.2.2 Efficiency and the rebound effect

The question of whether more efficient technology equals less energy used overall is central in much of the contemporary research on energy consumption. Many economists argue that improvements in energy efficiency may actually not actually reduce energy consumption, and can even increase it in some cases (Herring 1999). This phenomenon is variously referred to as the 'rebound effect', 'take-back effect' or the 'Khazzoom–Brookes postulate'. A central component of this argument is that increases in energy efficiency make the services provided with that energy cheaper to use, and with the savings gained from this increased efficiency an individual, household, or firm, will use those savings for other energy-consuming activities. The reduction in cost to an individual of, for example, driving a more fuel-efficient car, might mean that the individual then chooses to drive that car further or more often. The driver of the car might also choose to use the savings gained from increased efficiency to consume other energy intensive services, for example air travel.

Sorrell (2007) authored an extensive report for the UK Energy Research Centre, which reviewed over 500 studies on the rebound effect. Sorrell's conclusions are that improving energy efficiency will reduce overall energy use and therefore emissions, but that these reductions will be minimal if the rebound effect is not explicitly addressed. If policy measures to reduce greenhouse gas emission are to be effective, he argues, the rebound effect must be taken into account in the formation of those policies.

The difficulty in achieving this is that there is still much that is unknown and disputed about the exact nature of the rebound effect, because it is an extremely difficult phenomenon to measure accurately (Sorrell 2007: v). However, there is wide-spread support amongst economists working with energy consumption for the idea that the rebound effect has a significant impact on overall consumption (Maxwell et al. 2011; Sorrell 2007; Herring 1999, 2006; Hanley et al. 2009; Greening et al. 2000). The question appears to be not whether there is a rebound effect that comes with improvements in energy efficiency, but rather how significant the effect is in each particular case.

Maxwell et al.'s (2011) review of studies on the rebound effect found that the rebound effect for space heating and "other consumer energy services" was between 10 – 30% (11). This means that there is still a net reduction in energy use, but that those reductions were 10 – 30% less than what the improvements in efficiency should have produced in theory.

This finding is consistent with Christensen et al.'s (2011) study of air-to-air heat pumps in Danish households, which found that the installation of heat pumps tended to lead to an increase in indoor temperatures, and thus did not fulfil their full potential for energy saving through increased efficiency. Furthermore – and most significantly for this thesis – Halvorsen & Larsen's (2013) study for SSB, which this thesis was written in cooperation with, found that there was a significant rebound effect associated with heat pumps in Norway.

According to Halvorsen & Larsen the rebound effect almost completely negated the potential energy savings provided by heat pumps' efficiency (2013:19 – 20). They attribute this finding to the increase in indoor temperature and reduction of alternative heating fuels, such as firewood, amongst households that installed heat pumps:

> The results indicate that households with a heat pump have chosen to spend the money they save on heating costs on living more comfortably: raising the indoor temperature, reducing the labor involved in chopping and carrying wood, heating a larger part of their residence, and using air conditioning. (Halvorsen & Larsen 2013:20)

The rebound effect is significant both as a phenomenon and as a theoretical concept that informs energy research and policy. It is therefore important to take the rebound effect into consideration when studying energy consumption or proposing measures aimed at curbing it. Though the aim here is not to study the rebound effect directly, the research on the rebound effect, and especially Halvorsen and Larsen's findings, will be drawn upon in the discussion to follow.

2.2.3 Energy research and policy

The behavioural and technological fields of research discussed above correlate to two different policy approaches to curbing energy consumption. The first type of policy focuses on encouraging people to reduce their energy consumption by changing their behaviour through the use of intervention techniques. The second focuses on reducing the amount of energy consumed by making technologies more energy efficient. Both of these lines of policy thinking have a straight-forward and reductive reasoning to them; 'if people are using too much energy we need to get them to use less. If technologies are consuming more energy than they should, then we should make them more efficient.' As has been argued extensively elsewhere (for example Shove 2010, Aune 2007, Herring 2006, Strengers 2012, Wilhite 2013) neither of these types of approaches fully address the problem of energy consumption in all its complexity, and because of this have been largely ineffective at shaping meaningful and effective policies to reduce energy consumption.

Part of the reason that governments have used intervention and increased efficiency as their main research base for forming policy on curbing consumption is that they involve less political risk. Policies of improving efficiency, for example, present no major cost to the economy, and no reductions in the quality of life or level of consumption for citizens.

Just the word ‘efficiency’ itself has a rhetorical power; it is seen as something good, something to be strived towards, because it means having more by using less; more distance travelled in a car using less fuel; more food brought home from the supermarket for less money. Langdon Winner commented on the power of the idea of efficiency in The United States during the energy crisis in the 1970s by writing:

> Throughout the progressive era and in the decades since, an eagerness to define important public issues as questions of efficiency has been a common strategy … Thus it is not surprising to see efficiency reappear at the centre of today’s energy debate. For Americans, to demonstrate the efficiency of a course of action conveys a sense of scientific truth, political wisdom, social consensus, and a compelling moral urgency. (Winner 1982, quoted in Herring 2006: 16)

Putting policies in place that are aimed at creating better efficiency are therefore a popular way for policy makers to act on sustainability issues, without the need for the public to make personal sacrifices or slowing the economy.

Intervention, or policies that aim to reduce consumption through information campaigns, are less common in the United States but have been widely implemented in other countries such as the UK. Shove (2010), for example, writes that the established policy approach in The UK for reducing energy consumption conforms to what she calls the ABC model. This model, she argues, posits that “…social change is thought to depend upon values and attitudes (the A), which are believed to drive the kinds of behaviour (the B) that individuals choose (the C) to adopt” (Ibid: 1274). The focus on attitudes, behaviour, and choice puts the onus for change on the individual, who must somehow be convinced to change his or her behaviour for the greater good. This all but leaves out, as Shove argues, the importance of contextual factors in how people consume. The focus under this sort of policy model is placed on providing better information to consumers so that they will make the 'right' choice, rather than, for example, on investing in infrastructure more conducive to lower energy consumption.

Again, the reasons for policy makers to take this approach, it could be argued, are to avoid implementing unpopular policies that might, for example, increase the price of energy. An extensive discussion about these types of policies is beyond the scope of this thesis, but Shove's proposed alternative to the 'ABC' approach to policy is highly relevant.

Shove is a major proponent of practice theory as an alternative model to the ABC policy approach, and her research focuses on how people's physical environment, learned behaviours, and social structures and conventions influence consumption.[2] She is one of a growing number of academics (for example Henning 2005, Wilhite 2013, Strengers, 2011, 2012) who are arguing for policy-making to be more informed by practice based approaches. However this has been slow to come about, and policy makers continue to be primarily focused on changing individual behaviour or improving technological efficiency. The reality, as I will show in chapter 5, is that energy consumption cannot be reduced to a product of either behaviour or technical efficiency alone. Addressing behaviour or efficiency in isolation as the drivers of energy consumption ignores important aspects of how energy consumption actually takes place.

2.3 Electricity Generation and Energy Policy in Norway

This chapter has thus far taken a very wide view in its discussion of research and policy relating to energy consumption, but I will now bring the focus to

[2] Practice Theory is discussed in the next chapter

Norway, and briefly outline some of the important characteristics of the Norwegian energy environment that are relevant to this study.

Norway is in the privileged position of having an abundance of hydropower, with approximately 95% of the country's electricity being produced by hydroelectric plants (Statistics Norway 2013). However the hydroelectric plants are vulnerable to variations in rainfall, and Norway must on occasion import electricity from other counties if the plants cannot keep up with demand due to low rainfall. The electricity that is imported is from coal-fired plants, meaning that Norway's electricity use it not as carbon neutral as it appears at first glance (IEA 2011: 8).

Electricity use is Norway is extremely high. According to the International Energy Agency (IEA):

> Electricity use per capita is higher [in Norway] than in any other IEA member country and second only to Iceland in the world. In 2008, average use per capita was more than 23 megawatt-hours (MWh) in Norway, while the IEA average amounted to 9 MWh per capita and the world average to 2.5 MWh. (2011:17)

Part of Norway's energy policy has been to limit the growth of energy consumption, and the government established the agency Enova in 2001 with this aim in mind. Enova's stated goal is "[…] to strengthen the work in converting energy consumption and generation into becoming more sustainable, while simultaneously improving supply security" (Enova 2013a). One of the initiatives that Enova has produced as a part of this goal had been to provide finical subsidies on water-based heat pumps of up to NOK 10,000, but this initiative was discontinued in May 2013 (Enova 2013b). However, there are still several municipalities in Norway that offer financial support for heat pump purchases, including Oslo and Bergen. Oslo municipality offers a NOK 3,000 grant for air-to-air pumps and grants for air-to-water and water-to-water pumps calculated on the basis of projected energy savings for the household (Norsk Varmepumpeforening 2012d).

In sum, Norway's domestic energy landscape can be characterised by high levels of consumption from a well-functioning grid, sourced mainly from hydroelectric plants. Norway's national energy policy includes the stated aim of curbing consumption (IEA 2011). Because the majority of Norway's domestic energy consumption is used for space heating (IEA 2011: 17), reducing the amount of energy used for this is an important part of the policy goal.

In the next section I discuss some of the practices associated with space heating in Norway that are particularly relevant for this study.

2.4 Domestic Heating Practices in Norway

Winters in the south of Norway, where this study takes place, can bring temperatures as low as -25˚C. As such, keeping warm is an important activity in households in these areas. Most households aim to heat the majority of the house, rather than particular rooms. Bedrooms are often left cold, but Norwegian homes are generally quite warm during the winter. Wilhite et al. (1996) described Norwegian households on winter evenings as being like a "heated envelope which allows the occupants to move freely from one room to another without experiencing discomfort" (797). This effect is usually achieved by a combination of central heating of some kind along with electric or kerosene heaters (Ibid.). Wood burners are also a common feature in Norwegian houses, and are often used on particularly cold evenings or on weekends.

In their cross-cultural comparison of energy-use practices in Norway and Japan Wilhite et al. (1996) also found that space heating in Norway has "an important symbolic value" (798). A comfortable temperature indoors is essential, particularly when hosting guests, as a fulfilment of the expectation for 'cosiness', which Wilhite et al. (1996) refer to as "*koslighet*" (from the Norwegian '*koslig'*). The cultivation of *koslighet* goes beyond having a comfortable temperature indoors, it also include how a room is lit. The desired effect in a Norwegian home is for the 'warm' low level light effect created by multiple small light sources. Wilhite et al. found a strong contrast between Norway and Japan when it came to attitudes about lighting, with Norwegians valuing the 'warmness' of multiple incandescent light sources, and Japanese favouring brighter, more illuminating, overhead fluorescent light sources (Ibid: 799). This practice of achieving cosiness has obvious implications for how energy is used in Norwegian homes, which will be discussed in more detail in later sections.

The other aspect of domestic space heating in Norway that appears to be quite significant is the cultural importance of the fireplace or wood burner. On the 15th of February Norway's national broadcaster, NRK, ran a 12 hour television show about firewood, with four hours of normal documentary-style programming followed by an eight hour live broadcast of a fireplace burning. The program received high ratings, with approximately 20 per cent of the population tuning in at some point during the program (Lyall 2013). The popularity of the program, and the fact that it was even made, suggest that firewood and fireplaces hold an important place in Norwegian culture. In fact, every household visited during this study had a working fireplace that the residents maintained and used, even if only occasionally.

There is, to my knowledge, no academic literature on the cultural significance of firewood and fireplaces in Norway, but it is clear that fireplaces are a relevant feature of Norwegian heating practices in detached houses. It would however not be surprising to find that their importance is closely linked to value placed on cosiness. The social convention of heating the entire house combined with the desire for cosiness will be discussed further in chapter 5.

The Norwegian practice of keeping almost all rooms of a house heated has obvious implications for the amount of energy used in space heating. Although fireplaces are still very common they are seldom the primary method for heating a home; devices that require electricity have long since taken precedence as the main space heaters. If electricity is to be relied on to perform this function then the efficiency of the device used is an important factor in determining the amount of electricity consumed. This why heat pumps have received the attention they have from those interested in curbing energy consumption, and why it is important to know about what makes them an efficient space heater.

This chapter has provided some essential background information needed to place the following discussion in context. I have briefly outlined the important features of heat pump technology, of energy production and policy in Norway, as well as some aspects of Norwegian culture that are relevant to energy consumption. I have also given an overview of mainstream energy consumption research, and indicated that there is still a need for other approaches to the problem of energy consumption. The next section deals with my theoretical approach, outlining the two theories I have employed and my justification for their use.

3 Theoretical Framework

The two theories I have used for this study are practice theory and actor-network theory which, as we will see, overlap in some important ways. They are, nonetheless, distinct theories, so before going into how the two are applied in tandem I will discuss each individually, with a focus on the strengths and weaknesses they each have in relation to studying energy consumption.

3.1 Practice Theory

In recent years Practice Theory has been gaining in popularity as a framework for studying energy consumption (see for example, Christensen et al. 2011, Røpke 2009, Scott et al. 2011, Strengers 2012, Wilhite 2008, Wilhite 2013, Winther and Ericson 2013, Winther and de Lesdain 2013). This is in part a response to the perceived inadequacies of the traditional approaches to energy consumption that focus on attitudes, technological efficiency, or economic factors. These approaches are seen by proponents of practice theory as ignoring the reality of how people actually use energy, reducing that use to product of, for example, utility-maximising decision making. Instead, practices theory researchers look at what people use energy for; the 'cultural energy services' that electricity provides (Shove 2003: 9, Wilhite and Lutzenhiser 1999).

Proponents of practice theory who study energy consumption emphasise that it is connected to complex social practices that do not exist only in the mind of the user, nor only in the overarching socio-economic structures of energy production and consumption. These researchers have re-located the social, claiming it exists not in "mental qualities, in discourse or interaction" but in practices (Shove et al. 2007: 12). To explain further it is necessary to first define the important elements of practice theory as it pertains to energy consumption. First, what is the "practice" that practice theory focuses on?

Reckwitz provides what is perhaps the most concise yet authoritative definition of practices, describing them as a combination of:

> […] forms of bodily activities, forms of mental activities, "things" and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge. (2002: 249)

These elements delineate a practice as something that exists in the bodies and minds of the practitioners, *as well as* in the material, and social structures that they are a part of, or which exist around them. This definition overcomes the often assumed dichotomy between the *material* or *technical*, and the *social* or *human*, and treats the social and technical as co-determined (Christensen et al. 2011: 1964).

Practices will manifest differently depending on the exact nature of each of the elements Reckwitz describes, but they will always require some combination of them operating together. The practice of heating a home, for example, requires: Some form of *bodily activity*, such as building a fire; the *know-how* required to carry-out that activity (good fire-building technique); the materials or *things* needed such as wood and a fireplace; *background knowledge* about, for example, how to manage a fire safely; and perhaps the *emotional* element of fire eliciting feelings of comfort and cosiness, which may make it preferable to another method of heating. The point is not that all the elements in Reckwitz must be present during a practice, but that the things people do can only be explained by acknowledging that there is an array of elements that go into a practice.

In order to ground this working definition of Practice Theory it is important to focus a moment on the "background knowledge in the form of understanding," as Reckwitz described it. This phrase alludes to the idea that practices exist outside of their doing. For example, even if I do not have the materials or know-how to heat my home, or simply decide not to heat my home, 'warming a home' still exists as a practice in a set of shared assumptions, which are independent of my own knowledge and actions. Perhaps a better way to illustrate this point is to use sport, as Elizabeth Shove (2012) does by taking the example of football to show how practices exist as 'external entities.' As Shove explains, given the right materials – a ball and a flat space of a large enough size – a group of people could, if they wished, organise something resembling a game of football. This is because football exists as a practice outside any specific settings or specific bodies; one does not need to be a professional player in an officially sanctioned match to play football, only the right materials and know-how. Knowledge of football is so widely disseminated that the basic parameters of the practice, such as the rudimentary rules of the game, are known to enough people that a game could be improvised based on a shared understanding of what it is to 'play football' (Shove 2012).

The term 'practice-as-entity' is used to describe this existence of practices outside of their doing. But in order for a practice-as-entity to be maintained it must be regularly performed (if no one ever played football then it would eventually become extinct as a practice). 'Practice-as-entity' is therefore reproduced by 'practice-as-performance' (Shove et al. 2012: 7). It is this dynamic of being both an entity in itself, and as requiring reproduction through performance that separates the concept of a 'practice' from the more general concept of 'things that people do.'

The next element of practice theory that is important to address here is the "things and their use" that Reckwitz refers to. Practice theory recognises that material elements, whether the simplest household item or a state-of-the-art technology, are integral to social practices. In Schatzki's (2001) words: "understanding specific practices always involves material configurations" (3). So how does practice theory actually handle the material aspects of society?

This question is on-going in practice theory literature. Despite their acknowledgement of its relevance, practice theorists have generally not given a great deal of attention to the material aspects of the social, and those who have often use a conceptualisation of objects and technologies as passive recipients of human agency (Shove et al. 2007, Schatzki 2010). There have been efforts on the part of some practice theorists to incorporate a stronger conceptualisation of 'things', such as Shove et al.'s (2007) *The Design of Everyday Life*, and Schatzki's (2010) *Materiality and Social Life*. The most successful of these efforts, including the examples above, have drawn heavily on select elements from Science and Technology Studies, particularly the work of Bruno Latour on actor-network Theory. Rather than rehash the work that that these practice theorists have done in this regard, I will now discuss actor-network theory as separate tradition, paying particular attention to the elements that deal with material artefacts. I will then bring these elements back to together with what I have discussed about Practice Theory and show how I intended to use these two theories in tandem.

3.2 Actor Network Theory

Actor-network theory was developed primarily in the work of social theorists Bruno Latour, Michel Callon, and John Law. It is based in anti-essentialist ideas about society, and avoids the traditional dichotomies of, for example, knowledge and technology, society and nature, or human and non-human (Crawford 2004:1). ANT borrows from semiotics in its explanation of how the world functions; all things, human or non-human, are only meaningful in as far as their meaning is constructed through their interactions with other things. In describing how 'semiotics' is employed in ANT, Akrich and Latour put it this way:

> [Semiotics is] [t]he study of how meaning is built, but the word "meaning" is taken in its original nontextual and nonlinguistic interpretation; how one privileged trajectory is built, out of an indefinite number of possibilities; in that sense, semiotics is the study of order building or path building and may be applied to settings, machines, bodies, and programming language as well as texts; […] the key aspect of the semiotics of machines is its ability to move from signs to things and back. (1992: 259)

Akrich and Latour's phrasing is typically dense in this paragraph, but there is an important point that can be drawn from it; that "meaning" refers to a privileged trajectory, and is not limited to the linguistic definition of meaning.

If we apply this use of semiotics to a thing or technology, a 'privileged trajectory' refers to how that thing becomes an essential component in a network. One might, for example, examine how the automobile went from a novelty item, strictly within the domain of hobbyists, to the dominant mode of transport. A good example of one type of path-building that allowed this shift to happen is described by Verbeek (2005), when he discusses how cars only became an accepted a means of long-distance transport in The Netherlands after the railroad strike of 1903, when mail could no longer be delivered by train. Automobiles were, at the time, used in The Netherlands only by enthusiasts for health and recreation, but during the strike the post office called upon these enthusiasts to use their cars to deliver the mail that would normally be sent by train. This, according to Verbeek, helped establish the automobile as a legitimate alternative to the railway for long-distance travel (2005: 217). The automobile thus became "meaningful" as a mode of transport via the network of relations it became a part of during and after the rail strike. This meaning was not inherent to the automobile; it was created in the interaction with the postal service and other nodes connected to the rail strike and mail delivery.

Though actor-network theory has been highly influential it has also been the centre of heated debate in the social sciences. Much of the disagreement and confusion has stemmed from the unstable position of ANT as a theory. It is well known that even Latour is not entirely comfortable with the "theory" in actor-network theory (or the "actor-network" for that matter) (Latour 1996). Latour himself thinks of ANT not as a way of explaining but as a way of seeing the social. He uses the metaphor of a guide book to describe how he wants his book on actor-network theory, *Reassembling the Social*, to be understood by his readers. He hopes that *Reassembling the Social*, in describing ANT, will help researchers to navigate the social world they are all accustomed to being in, and to see it in new and more useful ways (Latour 2005: 17). For Latour, ANT is about describing the world in a particular way, and thereby understanding it better; "Explanation does not follow from description; it is description *taken that much further*" (Latour 1991: 121 italics in original). Viewed in this way ANT is closer to a methodology than a theory, and has often been interpreted as such (Crawford 2004: 2).

Latour's misgivings about the "theory" in ANT notwithstanding, it is still provides concepts that are useful as part of a theoretical framework. The way that actor-network theory conceptualises technology fills-in some important gaps in other social theory, such as practice theory. I will discuss how I intended to use ANT concepts in conjunction with practice theory in section 3.3 below, but first I will outline which of those concepts from ANT I will be using.

3.2.1 Actants and agency

The early ANT theorists were motivated in large part by a desire to correct what they saw as the inadequate conceptualisation of technology in sociology. They argued that the role of material things was largely overlooked in social research, and that non-human things are just as relevant in society the human ones. ANT views all things in the world – human, material, and otherwise – as agentive in social reproduction and change, and uses the term *actant* as a way of describing things and people in more equal terms.

Actants can be anything that influence society; bacteria, machines, people, and institutions, all are treated as agentive, but for the purposes of this study I will focus on technologies. In the conventional understanding technologies are used by people to achieve a task and are more or less neutral in this role. A person will use their car to drive to work, and the role that the car plays in this interaction is to carry the person from A to B more quickly. From an ANT perspective the car is viewed as an agentive entity; it acts upon the driver as the driver acts upon the car as they *both* drive[3]. The car may even act upon the driver in a very deliberate and normative way by, for example, sounding an alarm if the driver does not fasten her seatbelt. The driver may choose not to wear the seatbelt, but the consequence is that the car will make an irritating noise for the duration of the drive. The driver is thus compelled to comply with the intended use of the car by fastening their seatbelt (Latour 1992: 151-152).

In this example we can begin to see how technologies become more important in the social world when viewed through an ANT lens. When non-human things are treated as agentive in networks of activity their role in social reproduction and change must be taken more seriously. This perspective has occasionally been misinterpreted as being technologically deterministic, but the point is not that agency of technology is more powerful than that of humans, or vice versa. The point is that both are elements in a network of activity which, if we are to properly understand it, must be viewed as consisting of all types of agents acting upon each other, not just human agents acting upon each other.

Treating technical objects as agentive raises some conceptual issues around what the nature of agency actually is, so some clarification on this point may be useful. Clearly a piece of machinery does not have the same capacity as a human being to make a decision in the capacity as a human and to and carry out an action accordingly, but it does nevertheless have an agenda of sorts. The seatbelt alarm example that Latour used in *Where Are the Missing Masses?* is one case of such an agenda; the alarm ‘wants’ the driver to fasten their seatbelt. Actor-Network theorists use the term *agency* to describe this ‘want’ of technologies, a semantic choice which again furthers the agenda of describing human and non-human actors in equal terms. In cases like the seatbelt alarm the agency that the technology exercises has been *inscribed*

[3] For simplicity’s sake I will avoid a discussion of the wider network of activity taking place in this example, such as the infrastructure required for driving, the rules of the road, other drivers and so on.

into the technology by its designers, their aim being for drivers to fasten their seatbelts.

One of the key contributions ANT has made to the study of technology is a clear conceptualisation of how technologies act on their own. Even though it is the human designers, car manufacturers, and law-makers that have together inscribed the function into the technology, and produced the imperative for drivers to wear their seatbelts, their agency does not act directly upon the driver; they have delegated it to a machine. Once a seatbelt alarm is installed it acts on its own; it is not the law-maker or designer who tells the driver to buckle their seatbelt, it is the technology. Additionally, and perhaps more importantly, the seatbelt still has agency even if it is not of the type intended by its designers and policy makers. If the alarm is faulty and sounds even when the seatbelt is fastened there is still an agentive force in that malfunction. A technology can act upon its user in any number of unexpected or undesired ways, and these are just as meaningful as the ways that were intended in its design. This brings us to the question of the role of designers in how a technological object acts in the world, and a particular use of an object comes about.

3.2.2 Scripts

Technologies are produced with a particular purpose in mind, and their material parameters are designed to facilitate that purpose. In designing technology to carry-out some tasks and not others, the creators of these technologies are favouring some particular pathways of use over others. A standard kitchen knife, for example, is designed with a short handle on one end, encouraging the user to hold it with one hand; only one sharp edge, encouraging the user to cut in one direction; and is sharpened in such a way as to effectively cut meat or vegetables as opposed to, say, wood or plastic. The knife is also designed to be used in a particular setting; the nature of the sharp edge, which is easily blunted, assumes use in conjunction with a cutting board, as well as proper storage in knife block or case. This, in turn, assumes use in the setting of a kitchen where such items are more likely to be available, and where food is usually prepared. Thus a kitchen knife, in being designed for a particular type of use, helps to reproduce certain social conventions and material settings by the nature of its physical properties.

The kitchen knife has a particular way of cutting 'inscribed' into it, and assumes a particular kind of user (a person preparing food) as well as their physical setting (a kitchen). It is in such a way that, in the words of Madeleine Akrich, "[…] technical objects define a framework of action together with the actors and the space in which they are supposed to act" (Akrich 1992:208). The framework of action that the technical object is inscribed with is referred to as its *script*, deliberately conjuring the idea of a film script.

One of the major challenges designers face when inscribing a framework of action into an object is to try to foresee undesired scripts that may arise unintentionally, but are not any less powerful for it. Revolving doors, for example, were designed to allow easy passage in and out of a building without loss of heat from inside, but an outcome of their original design was that they prohibited people in wheelchairs from entering the building (Verbeek 2006: 371). This kind of side-effect from a technology's design can have far-reaching consequences, particularly if a technology becomes widely disseminated.

In addition, designers must foresee the potential for users to deviate from the inscribed framework of action. Like a film's script, a technical object's script does not necessarily have to be followed. Users can re-purpose an object, or interrupt it in different ways that were not intended by the designers. Users read technologies when they interact with them, and in that reading they will hopefully discover the meaning that the designers of the technology have inscribed in it. In these cases the script is followed and the action that is carried-out is consistent with the intentions of the designers. Often, however, a negotiation takes place between the script and the user. This can result in outright rejection of the script in extreme cases – such as holding a kitchen knife by the blade – or in an adaptation of the script for use of the object in a way unforeseen at the design phase, such as using the kitchen knife to cut open packaging. These adaptations of scripts are sometimes referred to as *antiprograms* (Berker 2011: 260).

3.2.3 Domestication

The concept of an antiprogram deals with the kind of negotiation where the user of a technology engages with it in a manner that was unintended at the design phase. The term 'antiprogram' itself connotes a kind of rebellion, in this case the rebellion of a user against the script of a technology. But there is another concept that deals with a different, softer, kind of negotiation between technology and user, which I want to outline briefly here. *Domestication* addresses the user/object negotiation that takes place when a technology is introduced to a home and becomes an everyday item. While domestication is not an ANT concept it is useful for understanding how consumer technologies are integrated into the lives of their owners.

According to Silverstone et al. (1994) domestication consists of four non-discrete stages or elements; *appropriation*; *objectification*; *incorporation*; and *conversion. Appropriation*, the point at which a technical object is purchased, is the stage in which that object becomes "authentic," its meaning changes from a commodity to an object. *Objectification* sees the object finding its (literal) place in the household, displayed, for example, as a signifier of the household's taste or status. This physical placement of the object in the home gives that object another dimension of meaning. *Incorporation* refers to the object's actual use by the members of the household. This is where the negotiation with the object's script will usually take place and patterns of use are established. And lastly *conversion* refers to the public display of ownership of the object, where it is used to express the moral economy of the owner(s).

The concept of domestication illustrates the mundane user/script negotiation that is part of the process of turning a consumer item into an everyday object. The way that this process takes place has implications for the patterns of use of an object that are formed, and therefore the amount of energy it consumes, if it is an energy consuming device. For a heat pump, the patterns of use that are formed during the incorporation phase determine how effective the device will be at saving energy. If the patterns established are not consistent with the script required for energy-saving the device will most likely be less effective than it is designed to be.

Domestication is not only important for patterns of use but also for establishing the meaning of an object, which in turn determines how it, and its functions, are displayed and perceived by its owner(s). For a heat pump – an object designed to save energy – the establishment of its meaning has implications for whether it will function in a symbolic capacity as a "sustainable" or "environmentally friendly" object; as a "luxury" object; as a standard feature of a home or "normal" object; or as something else altogether. The meaning that heat pumps are given has implications for how the technology is adapted on a large scale, and for the kinds of patters of use that developed around it, and thus their impact on energy consumption (Pantzar 1997).

The socio-technical grounding of the domestication concept makes it compatible with an ANT-practice theory framework. Though it is not deployed here as a central concept I will draw upon the insights from domestication studies in my analysis of the interview data obtained in this study. I view it as a tool to explain a specific aspect of the intersection between technology and user, not as an overarching framework for the study. To show in more detail how I have utilised the concepts discussed above I will now outline in more detail how they have informed my data collection and analysis.

3.3 Application of Theory

I argued in chapter 2 that research which focuses singularly on technology, behaviour, or economic drivers of energy consumption, leaves significant gaps in our understanding of how energy consumption really takes place, particularly with regards to how these elements intermingle and the effect of this on energy consumption. As a response to this perceived inadequacy, a number of researchers have been trying to bring practice theory into energy consumption research, because it can fill these gaps in understanding.

Practice theory moves the focus away from economic or psychological theories of consumption by looking at how energy-consuming practices are established, reproduced, and how they might be changed. For example, in his study of consumption in Southern India Wilhite used a practice theory approach in order to "situate the study of consumption in everyday practices and to explore the social, material and discursive contributions to changing consumption" (2008: 6). In this way Wilhite was able to show how the consumption of heavy durables such as household appliances was part of larger processes of social reproduction and change. One example he discusses is how the changing practices relating to food storage and preparation are connected to the wide-spread adoption of household refrigerators in Southern India (Ibid.: 61-65). Wilhite showed that refrigerators are contributing to changes, particularly among younger generations, in the belief that food should always be eaten fresh, and leftovers should never be stored for later consumption (Ibid.). When practices change, as they are in the case of Southern India, there are implications for the amount of energy that is consumed in order to carry out those practices, and these types of changes are often not visible in economic or behavioural studies.

Take, for example, the largest study on heat pumps and energy consumption in Norway, recently completed by Statistics Norway (SSB). The authors of this study, Halvorsen and Larsen (2013) found that, despite the increased efficiency of heat pump technology, these households were not saving as much energy as they hypothetically should have. This is a valuable piece of data, which was obtained by conducting a survey of 1111 households across Norway. However, in a meta-study such as this there is no room for detailed accounts of the practices associated with heat pump use, so Halvorsen and Larsen (2013) were not able to say a great deal about why the predicted savings did not occur beyond attributing it to "behavioural changes" (20) amongst heat pump owners. By treating home heating as a practice I intend to show how heat pumps fit into that practice, in part with the hope of revealing the nature of the changes in behaviour hypothesised by Halvorsen and Larsen (2013).

Setting out on this study I made no assumptions about the shaping of the informants' heating practices being due to financial, behavioural, or other factors, but instead tried to piece together all the relevant aspects of their home heating practices to create a more detailed picture of heat pumps and energy use. However, the fact that there is a technical object at the centre of this research means that a theoretical framework that can adequately conceptualise technology is needed. While practice theory allows for a consideration of technical objects, it is weak on theorising exactly what their role in practices is. This is the reason for incorporating aspects of actor-network theory into the theoretical framework, specifically the concepts of *script* and *agency*. These concepts fill-out the gaps in practice theory relating to technology, and allow for a detailed examination of heat pumps' effect on energy use in the home.

Based on the ANT and practice theory literature I drew upon in preparation for my fieldwork, one of the fundamental assumptions that I held going into this research project was that heat pumps have the capacity to act upon users in ways that will affect the amount of energy used in heating the home. The interview guide was informed by this assumption, and a series of questions were devoted to finding out whether it was justified; to see what, if any, agentive force could be attributed to the heat pumps (see section 3 of the interview guide, Appendix). The guide was also designed to elicit responses that would reveal how the informants' practices were affected by the heat pump (Section 4 of interview guide). The aim was to find where and how 'practice' and 'technology' intersected when informants' used heat pumps to warm their homes.

I decided that the logical place to begin investigating where this intersection occurred was in the physical interaction that took place between the informants and the technology. I kept the concepts of *script* and *agency* in mind when informants described their experiences interacting with their heat pump, such as turning it on or off, setting the thermostat, or cleaning the filters. This yielded some telling data about how the script of the pump helped produce certain kinds of practices while discouraging others. I was able to see both how the heat pumps 'configured their users' (Woolgar 1991) and how the users negotiated with the heat pumps' script.

Although practice theory and ANT were the main foundation of my theoretical framework I did not want to neglect other factors that may have impacted on the informants' energy use practices. The fact that this study was done in cooperation with the SSB study on heat pumps, and with the Partners in the CREE Research program, two projects that focus on the rebound effect, meant that the rebound effect was also relevant to the framework for this study. While not integral to the analytic portion of this study, the concept of rebound did inform lines of questioning related to the financial aspects of heat pump ownership. These questions were mainly for the benefit of the CREE research project, but they also yielded relevant data for my own investigation.

Rebound effect theory underpinned this project's investigation of the informants' finical motivations, or lack thereof, for purchasing a heat pump. It also underpinned the questioning about how informants kept track of their energy consumption and general household expenditure. This line of investigation was useful for understanding the informants' reasoning about purchasing a heat pump, as well as how important they perceived saving money on energy to be. By incorporating an understanding of the rebound effect into the investigation and analysis I was able to better situate the findings in the wider context of the SSB national survey.

Having now outlined my theoretical framework I will move on to a discussion of the methodology I applied in this study. I indicated above that the theories I drew upon were influential in the data gathering phase of my study, but they were also important for my methodological choices. Now that the theory has been outlined I can show how they helped to shape the methodology used, my justification for my choice of methods, how those methods were applied in practice, and reflections on some of the challenges that arouse during the data gathering process.

4 Methodology

To answer the research questions posed in this thesis requires an in-depth investigation into the real practices of the people and the nature of the technologies being studied. I needed to uncover details of how people actually used their heat pumps, and how that use related to the rest of their energy-consuming practices in the home. A written survey or statistical analysis would have been insufficient for achieving this goal, as these are tools designed to observe highly generalizable trends and patters across a large sample base, not to make detailed observations about people's individual practices. In any case, the Halvorsen and Larsen (2013) study for SSB already sheds light on the wider trends relating to heat pumps and energy use in a way that this thesis could not. The aim for my project is to go into detail, to analyse people's use of heat pumps in-depth, and thereby show how this use fits into the wider network of practices and technologies that constitute everyday life in the domestic sphere.

The decision was made early in the planning process to use qualitative research methods in the data collection phase. This was primarily because the research questions required a type of investigation into people's lives that could not be adequately carried-out through a survey or other quantitative method. The following section briefly summarises some of the key aspects of qualitative methodology as they pertain to this project.

4.1 Qualitative Methodology

Qualitative methodology is designed to gain a situated understanding of the object of study rather than facts that can be supported with numerical data. As Willis (2007) puts it, in the qualitative paradigm "[s]ituated or contextual understanding, not truth, is the purpose of research" (215). Researchers using qualitative methodologies draw upon their own understanding of the context in which the information they gathered was obtained, and can thereby better understand the meaning of that information. Data obtained through qualitative methods is not abstracted by being converted into a set but remains inherently connected to the context it was taken from. In seeking situated understanding qualitative methodologies can therefore reveal information about the subject of analysis that would not be made visible using quantitative methods.

People's own thoughts and reasoning about why they do things, and how they make sense of their experiences are one important type of context to be taken into account in qualitative research. An understanding of these thoughts is something that is not easy to achieve using quantitative methodology (Liamputtong & Ezzy, 2005: 5), but such an understanding is especially useful in studies such as this one, where people's own reasoning for, and understanding of, what they do is important for the analysis. In the context of my own study, allowing the informants to explain in their own words, and discussing with them, their home heating practices, gave me a deeper understanding of those practices that would have not have been possible with a quantitative methodology.

Naturally, the fact that qualitative research focuses on situated or contextual understanding does have some drawbacks. Gaining a contextual understanding requires an in-depth – and therefore relatively narrow – investigation of the subject matter. The kind of large-scale generalisations that quantitative studies can make require a significantly larger data-set than a typical qualitative study can manage whilst maintaining this in-depth approach. The comparatively narrow scope of qualitative studies makes it difficult to argue that what is true in one case is also true in others, and these studies therefore have less authoritative claims to universality than quantitative ones.

In the case of this thesis, however, part of the aim is to provide a companion piece to Halvorsen & Larsen's (2013) study. Their project gave a thorough economic analysis of heat pumps and energy use, based on statistical evidence on a scale well beyond that of a Master's thesis. What can be contributed by this thesis is, among other things, the voices of some of the people who make up those statistics, and an in-depth analysis of their energy consumption practices. By seeking an in-depth and contextual understanding of these people's use of heat pumps I hope to contribute to a more complete picture of the effect of heat pumps on energy use in Norway.

4.2 In-depth Interviews

For this thesis I, along with Tanja Winther and Harold Wilhite (partners in the CREE research program), used in-depth, open-ended interviews as the main method for studying domestic heating practices and heat pumps. This decision came about because the nature of the questions we wanted to investigate in this study required first-hand and detailed accounts from people who use heat pumps.

Rubin & Rubin provide a straight-forward summary of the rationale behind choosing qualitative in-depth interviewing:

> You do not need to conduct depth [sic] qualitative interviews to find out how frequently people wash their hair, watch a television program, or buy a particular product. These are matters that can appropriately be counted. But if you want to know what people think about personal hygiene, why they watch so much television, or whether they feel that they gain status by buying a particular product, then qualitative interviewing is the right approach. If what you need to find out cannot be answered simply or briefly, if you anticipate that you may need to ask people to explain their answers or give examples or describe their experiences, then you rely on in-depth interviews. (2005: 2-3)

In the case of this thesis the aim was to gain detailed knowledge about *how* people use their heat pumps, not just how much they use them. I wanted to know how the informants interacted with the machine itself, what they thought about this interaction, and what their reasoning was for using their heat pumps in the ways that they did. A full ethnography designed to answer these questions through observation would not have been practical for this project because of its scale and time-fame, so in-depth interviews were the only logical choice for achieving this study's aims.

The in-depth interview method uses an relatively informal conversation format to get the informant's own descriptions of, and thoughts about, their 'lived world' (Kvale, 2007: 11). An interview guide is used to help the researcher guide the discussion in the direction they want, without strictly adhering to a list of questions that must be asked in a particular order (Ibid.: 57). This gives the researcher enough control over the interview that it does not stray off topic, whilst still allowing the interviewee to answer freely and actively contribute to the discussion.

The flexibility of the open-ended interview format was an advantage for this study. It allowed for follow-up questions that were not pre-designed when an informant revealed information that was unanticipated in the interview guide (Kvale, 2007: 63-69; Rubin and Rubin, 2005: 163). This meant that points raised by the informant in the interview could be discussed the moment they were raised, which often yielded highly interesting and relevant data. This was an important aspect of the methodology for this study, as the aim was in part to unveil the daily reality of the respondent's heating practices, rather than to test a hypothesis about those practices.

Because this study is in collaboration with research being conducted in cooperation with partners in the CREE research program –Winther and Wilhite – most of the interviews were conducted together with one of these two researchers, based on an interview guide that I designed, with additional questions added by Winther. Two of the interviews were conducted by me alone, two were conducted together with Wilhite, and the remaining 11 were conducted together with Winther. Four of the interviews were conducted in Norwegian, as these participants were not comfortable speaking English.

Each interview took approximately 45 minutes to one hour and was conducted at the informant's home. In the cases where the informants were a married couple, and both members where available, the two of them were interviewed together. The questions were divided into eight topics: 1) Background information such as house size, number of residents, and yearly consumption of electricity; 2) Reasons for purchasing the heat pump; 3) How the technology is used by the informants; 4) The heat pump's place in the wider home context; 5) Comfort; 6) Family dynamics relating to heating; 7) Effects on household budget, and; 8) The informant's overall assessment of their heat pump.

The general aim of the interviews was two-fold; to gain in-depth insights into how heat-pumps are used and perceived by the residents of these households, and to uncover the relationship between energy consumption in the household and the heat-pump.

4.3 Selecting Informants

The informants consisted of members from 15 households in the Akershus County, all but one of which were married couples. The respondents were selected from a list provided by SSB of 98 households in Akershus County that were known to have heat pumps installed. A letter was sent to each of the 98 households on the list that had also participated in Halvorsen and Larsen's (2013) statistical survey, offering a 500kr gift card as compensation for those agreeing to a one hour interview. 14 of the 98 people solicited agreed to be interviewed. The 15th informant for this study was recruited though personal contacts.

All but two of the 15 informants had purchased their heat pump themselves, the others having moved into a home with a pump already installed (air-to-air). Of the 15 informants, 11 had air-to-air pumps, 3 had water-to-water, and 1 had air-to-water. The participants varied in age from young couples with pre-school aged children to retired pensioners. All of the respondents lived in either detached or semi-detached houses, which they owned. The size of these houses ranged from 130 – 300 square meters.

This study used 'purposive sampling' to gather informants; a strategy for selecting informants with a particular focus in mind (Punch 2005: 187). In this case the focus was on people with direct experience using heat pumps use in domestic settings; namely heat pump owners. Because of the relatively small number of people in this category, certain variables such as age, household size, or income could not be controlled for. However the differences between households were not so great as to be problematic for the study. All informants lived in detached or semi-detached houses with between 1-4 other residents, exclusively partners and children, and were either retired professionals or working professionals. Although income was not explicitly addressed in the selection process, all informants reported in the interviews that they were not overly concerned with saving money, implying that they had the finical means to live comfortably. All of the informants were born, and had lived at least most of their lives in, Norway, and they all owned the houses that they were living in. These informants cannot, however, be considered wholly representative of the Norwegian population of heat pump owners.

Because of the qualitative method being employed, with the inherent aim of gaining contextual understanding, the differences between informants that did exist could be taken into account in the interviews and in the analysis of the data. I have been careful to only make arguments that can be supported with direct evidence as given by informants in interviews, and have avoided large generalisations of the kind found in macro-level studies. There were, however, many similarities in the information obtained between informants, regardless of other differences between them, and these have been discussed where relevant.

4.4 Addressing Potential Biases

It is important to note that, by necessity, the informants in this study were self-selected, and the possibility of a self-selection bias had to therefore be taken into account in the collection and analysis of the data. There were, for example, four informants who mentioned having a particular interest in research and were especially curious about the study and how it was being carried out, and two informants who were particularly interested in the technical aspects of their heat pump. This means that the sample likely has a disproportionately high number of informants who were interested in such matters, and who may have provided a-typical responses to the questions posed, or used their heat pumps in a-typical ways. The solution to this was, again, to remain highly situated in the data provided in my interviews. I have kept my analysis firmly rooted in the context in which the data was gathered, and have avoided making generalizing claims about heating practices based on data from informants that are not representative of the population at large.

The second issue relating to bias arose during a few of the interviews, and appeared to be associated my, and the other interviewers', role in researching energy from an implicitly environment or sustainability perspective. Before each interview we (I and Winther or Wilhite) introduced ourselves as being based at the University of Oslo's Centre for Development and Environment (SUM). We told the informants that our research was focused on energy consumption, and gave a brief overview of our backgrounds in energy research. Based on this information it would have been clear to the informants that the research they were participating in was part of the wider (general) project of finding more sustainable solutions for domestic energy consumption.

With a handful of the informants the implied environmental/sustainability dimension to their energy consumption seemed to cause some anxiety when they were asked about their energy use habits. Their remarks about their energy use were often apologetic in tone, with comments to the effect of "I probably shouldn't do it this way" or "it's probably not very environmentally friendly." This cast some doubts in my mind as to whether these particular informants were skewing the information that they were providing about their energy use in order to appear more conscientious about the environment.

With only a short period of time with each person it was sometimes difficult to establish an understanding wherein the informant could feel assured that their practices would not be judged by us. One strategy I used to try and establish this understanding was to demonstrate empathy with their perspective (Rubin & Rubin, 2005: 117). I would respond to answers that the informant showed signs of feeling were not the 'correct' ones with phrases like "that's reasonable" or "sure, I can understand that" which seemed to put these informants more at ease.

Exactly to what extent this problem affected the data gathered is difficult to say, but it did not seem too significant. It should also be noted that the majority of respondents did not show any signs of discomfort at their energy use being examined in detail by people concerned with sustainability, and a few even expressed a degree of antagonism towards the sustainability ethos. The informants' attitudes towards the questions and our identity as environmental researchers were taken into account when formulating the questions directed at them and in interpreting their answers.

4.5 Language

Another challenge that occasionally arose was the slight language barrier between myself and the Norwegian informants. This sometimes manifested as a difficulty in informants expressing themselves in English, and, in the case of interviews conducted in Norwegian, as my own difficulty in following the discussion well enough to contribute intelligently. While I am reasonably proficient in spoken Norwegian I did not feel I was not proficient enough to lead the interviews in Norwegian, and therefore relied on the informants' ability to speak English, or on Tanja Winther to lead the interview in Norwegian.

The knowledge I do have of the Norwegian language did prove useful however, as it allowed informants to switch to Norwegian when they could not find the words in English, and for me to at least follow – if not always contribute to – the interviews that Winther conducted in Norwegian. In this way the language ‘barrier’ did not prove to be significantly prohibitive to the study, but did require some compromises in order to overcome.

4.6 Data Collation and Analysis

All interviews were transcribed in full. For the interviews conducted in English I did the transcription myself, for those conducted in Norwegian I hired Norwegian Master’s students from the Centre for Development and Environment (SUM).

Once the transcripts were completed I reviewed each of them in detail and plotted the relevant information obtained from the interviews into a spread sheet (available on request). The spread sheet was organised into colour-coded categories corresponding to the different categories of question in the interview guide (Appendix). The relevant passages in each transcript were also colour-coded in the same way to allow for easy referral to the transcript as needed. Thus, the spread sheet was used to help reveal ‘the big picture’ of what the data showed, such as how many respondents reported an increase in temperature from their heat pump, and fostered new understandings of the data as the coding process went on (Marshall and Rossman 1999: 157). The spread sheet was also used as a reference tool by providing a summary of how each informant responded to the different categories of questions, and if more details were needed I referred back to the original transcript.

In the findings chapter that follows I frequently make use of quotes from the transcript to forward my discussion. All quotes are presented in English, but where I have translated from a Norwegian transcript the original text is referenced with a footnote. When relevant I have provided some background information about the informants, but this is limited both to ensure anonymity and to keep the discussion grounded in what the informants have reported. I have avoided addressing factors such as class and race in my discussion of the findings. These factors are not a part of my framework for analysis and would only serve to detract focus from the real focus of my analysis; the practice of heating a home and the heat pump’s place in this.   I have, however, included the gender of each informant in the quoted transcripts, as including this information does not present either of the issues cited above. It also has the added practical benefit of indicating, in the cases where couples were interviewed, which member of the household is being quoted. And final, though gender is not explicitly addressed in the analysis, the information about the gender of each informant may be useful to the reader in forming their own interpretation of the findings.

This concludes the methodology chapter, and marks the half-way point of this thesis. In the preceding chapters I have established the necessary groundwork for the discussion that follows. The final half of this thesis presents the findings of the 15 interviews, as well as my analysis of these findings.

5 Findings and Analysis

This chapter is divided into three main sections, the first dealing with the acquisition of heat pumps, the second with their use in the home, and the third discussing comfort. Each of these sections focuses on a different aspect of the findings that relates to heat pumps' effect of energy consumption. I draw extensively from the interview transcripts in my discussion in order to base my claims as firmly as possible in the data gathered.

5.1 Reasons for Purchase

If we want to understand more about people's use of heat pumps, knowing why they have one in the first place can be revealing. In the interviews every informant was questioned about why they choose to buy a heat pump, with the aim of uncovering what these informants thought about the utility of the pump, and what their motivations for purchasing one were. Not surprisingly, their answers showed that the decision to purchase a pump was not part of any agenda to be more environmentally friendly. Only two of the informants (#1[Woman] and #8[Man and Woman]) indicated that they purchased their heat pump even partly for environmental reasons. When asked, a few others said that the pump's potential to reduce their carbon emissions was beneficial, and that they felt good about this fact, but this was spoken about as a positive side-effect and not a reason for purchase in itself.

5.1.1 Saving money

What were the reasons then? The energy efficiency of heat pump technology is often cited as its main selling point in literature and advertising (Gustavsson and Karlsson 2002, Elsawaf et al. 2013). The reason heat pumps are even researched from an environmental perspective in studies like this one is that it has been theorised that if people are provided with an efficient means to heat their homes that they will thereby reduce their energy use. The implication is that people will be motivated to acquire a heat pump by the possibility of saving money on electricity. As the following will show, this was not necessarily the case for most informants. The reasons for purchasing that the informants in this study gave were more complex and diverse than simply wanting to save money.

The desire to save money through the efficiency of a heat pump was only mentioned as the main driving factor in a few cases. One respondent (#15[Man]) had installed a water-to-water heat pump to replace an electrical system only after the discounted electricity they were receiving was raised to full-price (#15[Man] was a former employee of a major power provider, and had been receiving a substantial discount from that provider). This was always the plan for the household, as they knew that their electricity would not be cheap forever, so they had installed the necessary infrastructure for a water-to-water pump when they built the house, then installed the pump itself when the price for their electricity increased. Interestingly, even after the installation of the pump, this informant was aware that his household's electricity consumption was still above the average for Norway, but was not concerned about this.

Two other informants mentioned the price of the paraffin they had been using to heat the house being an important factor in their decision to buy a heat pump; they wanted to switch to a cheaper and more convenient system and decided heat pumps were the best alternative. One of these two (#3[Man and Woman]) also said that the smell of paraffin in the house was an additional reason they wanted to replace the old system, and the other (#8[Man]) also cited the fact that their tank was 35 years old and would need to be replaced soon anyway.

Other than the three informants above, reducing the price of heating was not cited as one of the primary reasons for buying a heat pump. Only two informants (#6[Man and Woman] and #8[Man]) were able to give specific information about the payback period for the pump and how much energy they had saved as a result of installing it. However, the reduction in the cost of heating was often mentioned as one of the added benefits of a heat pump.

In a few cases the money-saving aspect of heat pumps was directly cited as an *un*important factor in the decision to purchase. 3 informants (#12[Man and Woman], #10[Man] #5[Woman]) stated overtly that saving money was not a major concern:

> Interviewer 2: But did you expect when you got it that you would save money compared to having [heating] cables for instance? Did you think that it would be an economic thing in the long-term?
>
> #12[Man]: In the long-term, well, um, I don't think we discussed it really much as that "oh we are doing this in order to save money."
>
> #12[Woman]: It's not like a reason. No it's not a reason but it's interesting to look –
>
> #12[Man]: It's one of the co-benefits.
>
> ***
>
> #10[Man]: I didn't think about saving or anything like that, it was not… and the money that I save I don't know where [it is] [laughs]. […] maybe I save 5 or 10 thousand crowns a year or something like that, and yeah I liked that when we did it, but yeah … I think we save a few thousand a year on electricity. […] But of course, I mean, if this house should be more economic we should have windows like this and walls like this [heavily insulated] and so on [laughs] but I don't want to live like this.
>
> ***
>
> #5[Woman]: No, I don't think it will be any cheaper. It's not a cheap solution with the heat pump. Not the way I think about it. It costs 150,000 – 200,000 kr. That takes a bit of time, or actually quite a few years, to earn back, but maybe with about a 10-20 year perspective it is possible to recoup.
>
> Interviewer 2: Yes, so in the long run it might be cheaper, but that was not what was important for you [and your husband] when you chose it?

> #5[Woman]: No. It was comfort and, yeah, that it will always be warm at home.[4]

We can see from this last quote in particular that comfort was an important factor in the decision to purchase a heat pump. Households #5, #7 and #14 said that comfort was the main reason for choosing a heat pump, and #1, #3, #6 and #8 said that comfort combined with energy-saving was their reason. The 3 informants who gave comfort as their main reason for purchase also said that saving money on electricity was not important for the decision.

Some informants had bought a heat pump because it was cheaper than the alternative (for example #15 above), but even in these cases the amount of money saved did not seem particularly important to them. In fact, the informants who had kept track of the money they saved on energy did not have any particular reason for saving this money beyond thrift for its own sake, and could not account for how the savings were used.

These findings indicate that, while the energy efficiency of heat pumps may be a motivating factor for choosing a heat pump over another technology, people who purchase heat pumps are not necessarily motivated to reduce their energy consumption. This lack of desire to actually reduce energy consumption and save money may partly explain the rebound effect observed by Halvorsen & Larsen (2013) and Christensen et al. (2011).

5.1.2 Social networks

Recommendations from friends or family members who either worked with heat pumps or had one installed in their home was cited by 9 of the 14 informants that had purchased a pump (#2, #3, #6, #7, #8, #11, #12, #13 and #14) as a factor in their decision to get a heat pump. A few had also received discounts on their purchase because of a personal relationship with the

[4] #5[Woman]: Nei, jeg tror ikke det blir noe billigere. Det er ikke noen billigløsning nei, med varmepumpe. [Ehh] Ikke sånn som jeg tenker. Koster sikkert 150 000 - 200 000. Det tar jo litt tid, eller det tar jo ganske mange år å tjene inn det, men sikkert 10-20 års perspektiv så er det kanskje tjent inn.
Interviewer 2: Ja, så i det lange løp så blir det kanskje billigere tilslutt, men det var ikke det som var viktig for at dere valgte det?
#5[Woman]: Nei. Det var komforten og, ja at alltid vi kan ha det varmt hjemme.

installer or seller of the pump. The interviews suggest that knowing an expert, or someone who had already installed a heat pump in their home, was an important factor in most informants' decision to purchase one:

> Interviewer 2: How did you get the idea to acquire one?
>
> #7[Woman]: Someone in the family told us, he was involved with that sort of thing.
>
> ***
>
> Interviewer 1: I'm interested in how you decided on a heat pump. Did you talk to other people who had bought one or, how did you find out?
>
> #8[Man]: We did some um… research by one or two people. My brother in law has the year before installed [counts off] one, two, three, four, five, six, heating pumps in his office in Ski, and he was quite convenient with it, because, as he's told me, it was more quiet than he expected. And he has lower heating costs than he had before, because before that they just had electricity panels, heating panels was more expensive than this one [the heat pump]. So he has a loss of expenses for about ten thousand each year, for, I think he said he had twelve hundred square meters on two levels. So it was about ten thousand less in expenses for one year.
>
> ***
>
> Interviewer 1: Did you speak with other people that had heat pumps before you bought one? Who, experts?
>
> #11[Woman]: Yes, my uncle. It was him that installed it. He works with them [heat pumps].[5]

Informants also told us about discussions with heat pump experts that involved decisions on where to place it, how it should be used, its efficiency during winter, and the money they can save on heating. The overall indication was that an experienced and trusted voice – whether a technician or owner from within the social network of the informant, or an expert from

[5] Interviewer 1: Snakket dere med andre som hadde hatt varmepumper før dere kjøpte? hvem? Eksperter?
#11[Woman]: Ja, min onkel. Det var han som satte inn den. Han jobber med det.

outside the network brought in to provide advice about heat pumps – was highly important in the decision-making process about the purchase.

The finding that social networks were important in the decision-making process is consistent with other studies that have examined the decision-making processes behind adopting new technologies (for example Janeesn and Jager 2002; Gilly et al. 1998). Sopha et al.'s (2010) study *Norwegian Households' perception of Wood Pellet Stove Compared to Air-to-Air Heat Pump and Electric Heating* is particularly useful for comparison, as it specifically examined heat pumps in the Norwegian context. The authors of this study carried out a large-scale survey of households across Norway with the aim of uncovering the factors that influenced these households' choice of heating system. They found that in the case of people who chose heat pumps as their next heating system, social comparison was an important factor in their decision-making process:

> The result [sic] suggests […] that those who are likely to choose a heat pump perform a social comparison; a reasoned and socially determined decision. One possible motivation for considering a change could be influence from active promotion of heat pumps as an alternative heating system. Households' use of the social comparison strategy could reflect their dissatisfaction with their current heating systems, and therefore they search for an alternative. Because a heat pump is considered a new technology, uncertainty is relatively high. This motivates households to compare their choices with those of other households. Applying this decision strategy, the examined households should use households in their social network as a means to acquire information. (Sopha et al. 2010: 3750)

The authors make three key points in this quote which are relevant for this analysis: Firstly, that promotion of heat pumps helps trigger the consideration of whether to purchase one; secondly that people may be motivated by dissatisfaction with their current method of heating; and third, that the newness of the technology motivates people to find out more about it from sources they trust, such as friends and family. How do these claims hold-up when viewed in light of the data gathered here?

The promotion of heat pumps was reported as a factor in the decision to buy a heat pump by several informants in our sample. Household #3[Man and Woman] reported speaking to a man promoting heat pumps in a shopping centre, who they happened upon by chance. They talked with this promoter, who also installed heat pumps, about the product, and he gave a consultation at their home where he suggested the location for the pump and provided other information. Another informant, #13[Woman], reported clicking a link on the internet, which lead her to a discount offer on air-to-air pumps. Others mentioned seeing heat pumps discussed in consumer magazines and TV shows, with a few basing the decision of which brand to purchase partly on research they did online about which were the best models of heat pump (#6[Man], #8[Man], #12[Man]).

Clearly promotion does play a role in people's decision-making about heat pumps, though the degree to which it can be attributed as the main catalyst is uncertain. Many people seemed to have already decided to look into buying a heat pump before coming across, or seeking out, promotional material. To get a complete picture of the role of promotional material would require much more in-depth research into that question, which is beyond the scope of this paper, but promotion does appear to be an important factor in the dissemination of heat pumps.

Dissatisfaction with the previous methods of heating was cited by several informants as a reason for "upgrading" to a heat pump. This has been touched upon the section above, but to briefly reiterate; several of the informants wanted to replace their old paraffin heating system for reasons including the cost of fuel, the smell produced by burning that fuel, and the inconvenience of running and maintaining the system. Many of the informants also installed heat pumps as part of larger "upgrading" or renovation projects, discussed below. Dissatisfaction with a previous method of heating would therefore also appear to be an important factor for many people in their decision to buy a heat pump.

The final point raised by Sopha et al. (2010) was that the relative newness of the technology prompted potential consumers to seek advice from a trusted source. Though there is less direct evidence to support this claim, it seems a likely explanation as to why the majority of informants in this study sought advice from friends or relatives. Heat pumps are not yet as common as electric heaters or under floor cables, and are complex enough as a technology to require a higher level of knowledge about how they work in order to make an informed decision about purchasing one. Advice from a trusted source would help clarify what the technology does, what it is like to live with, the relative cost compared to other heating methods, and provide other useful information which may not be readily available through other sources. However it must be noted that the newness factor was not specifically cited by any of the informants as a reason for placing importance on advice from friends and family members. This is most likely due to the fact that informants were not specifically questioned about the newness of heat pump technology, or what their reasons were for placing importance in the advice of their peers.

The newness of the heat pumps means that the level of knowledge needed to make an informed decision about purchasing one is not yet 'common knowledge.' When this is combined with the fact that a heat pump is a sizable financial investment, purchasing one can be perceived as a 'risky' venture, which prompts potential buyers to seek personal advice from trusted sources (Gilly et al. 1998: 1). Advertising and online information play a role in the decision-making process as well, but based on the information gathered from the informants in this study this type of information is less influential than advice obtained via social networks.

Having examined some key aspects of the decision-making process involved in acquiring a heat pump I will now examine the circumstances under which these decisions are commonly made. This will help form a more complete picture of how, when, and why heat pumps are acquired.

5.1.3 Renovation and 'nest-building'

It was very common amongst the informant group for the heat pump to have been installed as part of wider renovations. 8 of the 14 households that had the heat pump installed themselves did so at or around the time they had either done major renovations to the home, or built the home. This is hardly surprising in the case of water-to-water pumps, which require water-filled pipes to be installed under the floors of the house, and 4 out of 4 water-to-water system owners in this study had installed the system during major renovation or when building the house. An air-to-air pump, however, is relatively easy to install without other changes to the house, yet of the 9 households that had installed air-to-air pumps themselves, 4 had installed them around at or around the same time that they did other renovations such as building additions, replacing windows, and replacing old wood burners with newer ones. Thus, the decision to buy a heat pump was, in the 8 cases where renovation also occurred, nested in larger decisions about transforming the home such as making it warmer, larger and more comfortable. It was not simply a matter of replacing or upgrading a heat source; the heat pumps were a part of improving or upgrading the *house*.

The reasons for why people chose to renovate their home ties in again with the question of whether people are financially motivated to invest in energy saving measures like heat pumps or improved insulation. It is tempting to conclude that the main factor in such decisions is a desire to increase the utility of the house and improve the household's finances by increasing its energy efficiency, or to increase the re-sell value by making improvements, but closer examination shows that this is not usually the case. Munro and Leather (2000) conducted a qualitative examination of why people work on their homes and found that people placed more importance on improving the home as site of comfort and family life than as an economic investment. Making the home warmer, creating a more welcoming environment for visitors, and presenting a particular image of the household to the outside world were the foremost that motivated home owners to renovate (Munro and

Lather 2000). When viewed in light of the information gathered in the interviews for this study, Munro and Leather's findings highlight an important element of why people choose to renovate their homes.

The work involved in improving a home is sometimes referred to as 'nest-building.' Wilk and Wilhite (1985) use the phrase to help explain why, in their study, residents of Santa Cruz, California invested in expensive technologies with long payback periods like solar water heaters but did not in weatherising their homes. The authors argue that their informants placed greater importance on the symbolic aspects of their home than on the purely practical aspects.

Weatherising is a relatively simple and inexpensive process of insulating the gaps in doors and windows to improve thermal efficiency, and can lead massive savings on energy used for heating. But Wilk and Wilhite found that the informants in their sample overwhelmingly opted for more visible energy-savings measures such as solar-powered water heaters and efficient wood burners. Part of the reason was that the actual work itself of weatherising was seen by the informants, according to Wilk and Wilhite, as unglamorous 'dirty work' and is therefore not as appealing as other types of renovation or repair (Wilk and Wilhite 1985). In addition, the authors argue that weatherising was so seldom done because it occupies a semantically ambiguous area in people's thinking; it does not fit into either category of 'maintenance' or 'improvement' well enough to been seen as a worthwhile undertaking. To elaborate I will quickly explain the semantic categories of 'maintenance' and 'improvement' as they apply to Wilk and Wilhite's study.

'Maintenance' implies that something is not working and needs to be repaired, but gaps in doors and windows are not seen in this way. 'Improvement' implies something that can be seen, something that has visibly changed the house for the better. Because the results of weatherising are invisible homeowners have nothing to show from the work put into weatherising, and it is therefore not seen as really improving the home in a desirable way.

As with Munro and Leather's study Wilk and Wilhite's informants were engaged in creating a safe and comfortable environment for themselves (nest-building) through making *visible* improvements to the home. This visibility appeared to be an important factor in both studies; people were concerned with how their home was presented to guests and to the outside world, and the work they engaged in to modify their homes was largely in service of crafting a particular image of their home. This is not to say that people are only motivated to improve their homes by a desire to show-off, but rather that the home has a symbolic importance that in most cases seems to out-weigh financial concerns as a motivation for making home improvements.

Turning back to the case at hand, the informants in this study who had installed heat pumps when renovating their homes also appeared to be more motivated by a desire to 'nest-build' than a desire to improve the utility of the home by reducing energy used for heating. In making home improvements like installing heat pumps the informants were working to create the type of home that they felt was desirable in terms of cosiness and aesthetic beauty. These two elements are quite often entangled, as illustrated by case of informant #15[Man], who had installed a water-based heat pump system to warm the house, as well as a fireplace that served a purely aesthetic function. The glass fireplace, as #15 explained, was designed not to give off heat but merely to look nice. The heat pump and ventilation system in the home provided all the heat the household required, but due to its invisibility could not create a cosy atmosphere the way a fire could.

When heat pumps are installed as part of nest-building work their role is primarily one of facilitating the desired type of indoor environment, not of improving the overall energy efficiency of the household. The efficiency aspect of heat pumps is most important as a means to make a house that is always warm (and with a larger area heated to a comfortable temperature) an affordable environment to maintain.

For most of households examined in this study, the idea that heat pumps are primarily installed to reduce consumption or to save money does not apply. Many of the informants were in the process of making much larger changes to their living situation by either building or renovating, and required some form of heat source as part of these changes. These people often received advice from friends or relatives, or found through their own research, that heat pumps were efficient and effective. The energy efficiency of heat pumps was mainly viewed as beneficial in terms of providing good value for money, not as beneficial for reducing energy consumption. The motivation for most of the informants was not to reduce their energy consumption but to improve their home, or nest-build, in the most desirable way.

5.2 User Engagement with the Heat Pump

Because installing a heat pump is done as work on a house, not as a purchase of a stand-alone item, I conceptualise heat pumps not as discrete objects, but as part of the wider network of things, people and activities that make up a household. This conceptualisation borrows from actor-network theory (discussed in chapter 3) by viewing the house, its constituent parts, and its inhabitants all as agentive. With this in mind I will now present and discuss the findings on how people reported interacting with their heat pump.

5.2.1 Placement

The physical placement of the heat pump in the home matters for how an air-to-air heat pump is used and for how effectively it heats a space. The technology's script requires that it be positioned in a location with unobstructed air flow to achieve the maximum possible circulation of air. This is because air-to-air pumps of the kind the informants used have only a single heat output. If the airflow from this output is obstructed the area around the pump will be heated much more effectively than the surrounding space. This will not only leave the rest of the house colder but will also 'trick' the heat pump's thermostat into believing the air temperature is higher than it is in reality, because the space directly around the pump is being warmed more than the rest of the house. The placement of both the pump and the furniture in the house, in the case of air-to-air units, is therefore an important aspect of a pump's functionality.

The placement also has implications for how the pump is used by residents. As discussed in the theory chapter, the literature on ANT often refers to the idea that technologies, by nature of their design, pre-suppose a type of use and a type of user. These assumptions are inscribed in the technology by the designers, and they are part of what constitute the technology's script. Scripts are not completely stable; some uses of a technology are inscribed unintentionally through design elements that facilitate a particular use that was unforeseen by the designers. However, unintended uses can emerge during the process of domestication as the technology is integrated into the routines and settings the owners use it in. During the interviews for this study I observed uses of a heat pump that followed closely to its script, uses that came about through a negotiation of the script, and uses that were directly contrary to the script. Many of the deviations from the scripted use were directly related to where the heat pump was located in the house. Below I discuss these script deviations as well as how choices made early in the domestication process, particularly the decision of where to place the heat pump, can lead to, or discourage, certain types of uses.

In the cases where the pumps had been installed by the current residents of the home, figuring out the best place to put the pump was the first site of negotiation between the residents, the house itself, the heat pump's script, and the installer of the heat pump. Some informants had quite specific demands for the function they wanted their pump to perform, which they sometimes had to compromise on as part of this negotiation. For example informant #8[Man] wanted his pump to heat his basement living area, as well as the dining and living areas upstairs:

> Interviewer 1: I can see where it's located there, what was the reason for putting it there in particular? [The heat pump is located near the floor, under a large window and by the edge of the basement entrance]
>
> #8[Man]: Yeah, actually my idea was to have it there [on the adjacent wall near the celling] because then it would have been more open to have the wind [the air flow from the heat pump] further down to the basement. […] the idea was to have it heat both of the levels; both downstairs and upstairs.
>
> Interviewer 1: Yeah, that makes sense. So why did it end up here instead?
>
> #8[Man]: Ah, the…
>
> Interviewer 1: …Was it the installer that said?
>
> #8[Man]: Yeah the installer said to me that it should stay there.
>
> Interviewer 1: Ok.
>
> #8[Man]: And the outside section is more convenient, it's just outside, for three or four meters down on the outside, and then you have a shorter way – an easy instillation. So if it had been up to me, maybe it would have stayed there [adjacent wall] after all but, it stays there [where it is].

In this particular case the logistics of the installation process played a pivotal role in the final location of the heat pump. To put the pump in the location that the informant had wanted would have required installing the outside portion several meters off the ground, and would have therefore been a more difficult and dangerous process for the technician. The technician apparently persuaded the informant that the best course of action was to install the pump nearer to the ground on the adjacent wall.

Informant #8[Man] seemed to be satisfied with the location the heat pump ended up in. He also indicated that its location was appropriate for the type of use he wanted to make of it, but that a different type of usage would have required it to be in the location he originally suggested:

> #8[Man]: […] I know some people say that "it's so convenient, you can put it on cold and you can use it as a cooler in the summertime" but that wasn't the idea. If it had been, then it wold have been up there [on the adjacent wall].
>
> Interviewer 3: Sure.
>
> #8[Man]: But that was one of these situations where we considered [this] lower location of the heating pump because I didn't want to use it as an air conditioner in the summertime.

Though #8[Man] never intended to use his heat pump as an air conditioner, its position near the floor further reduced the likelihood of it being used that way. Had the pump been installed near the ceiling, this may have opened up possibilities for experimentation with the cooling function during summer.

In this case the material layout of the house (providing only two possible locations where the pump could heat the areas desired by the informant); the physical characteristics of the pump (its size and weight meant that an installation above a certain height wold be more difficult); and the technician's requirements of a safe installation (not wanting to install the pump at a difficult height), combined to inhibit the scripted function of the pump as an air conditioner. Thus a particular use, deliberately inscribed into the technology, was effectively removed as an option for the user due to the demands of these other actants.

The placement of furniture was also an important factor in some cases for how the pump was used and how effectively it heated the space. Household #9 had moved into a house with an air-to-air pump already installed. They set up their living space with the husband's favourite chair next to the heat pump. This meant that, on occasion, if he was using the chair to watch TV the heat and noise from the pump could become distracting:

> Interviewer 1: Did you have to think a little bit about the heat pump when you decided where you were putting the furniture in the house? … Or did you just put the furniture where it felt…

#9[Woman]: Yeah I… I don't like it being there but we – it has to be there so, yeah.

Interviewer 3: Someone sitting in that chair would be pretty warm then?

#9[Woman]: Yeah, yeah. Sometimes you can sit there and be warm but ah…

Interviewer 1: Do you use this chair?

#9[Woman]: No.

Interviewer 1: No?

#9[Woman]: No my husband does. I hate it!

[laughter]

[…]

Interviewer 1: Does he use it to read or, what does he…?

#9[Woman]: Yeah he sits there and reads and watches TV and…

Interviewer 1: And will he ever turn this off because it's too distracting while he sits there?

#9[Woman]: Yeah, yeah.

Interviewer 1: And then what happens in the rest of the house?

#9[Woman]: Sometimes then I come in and he has turned it off, and I take my blanket because it gets chilly and…

In this case the informant is describing the placement of the pump relative to the furniture as affecting the practices of household members, and therefore the warmth of the house. If the husband wants to sit in his chair the placement of the heat pump nearby can sometimes mean that he turns it off, lowering the temperature of the house.

In this case the scripted element of the heat pump ‘always on’ was in opposition to the resident’s desired use of the living space. The ‘always on’ element of the heat pump’s script presupposes a user that does not regularly occupy a space near the heat pump’s output, and presupposes a physical set-up where the pump can be placed out of the way to avoid competition with the residents for space. But in the case of household #9 two things were working against these presuppositions: 1) the heat pump was installed in an area of the house that was a natural choice for these residents to set up their living space, and 2) the informants, having not purchased the heat pump themselves, were unaware of the ‘always on’ requirement. This example illustrates the fragility of ‘the always’ on script of air-to-air heat pumps, a design element which is integral to the technology’s high energy efficiency. It also shows how important the location of an air-to-air heat pump is in terms of how effectively it can be used.

There was another case where furniture placement also appeared to be affecting the indoor temperature. The furniture in household #7 was set up so that their air-to-air pump was blowing directly into the back of one of the sofas:

> Interviewer 2: Right. Can I just see where it is? Because you said it's quite low down.
>
> #7[Woman]: Yes, it could be that it's more practical to have it higher up, but they say that warm air rises, so.
>
> […]
>
> Interviewer 2: But here the air goes right into this sofa, you haven't discussed having the sofa's facing each other or something like that? Not that I'm an expert...
>
> #7[Man]: Well, we can move those [sofas] if we want to, but…
>
> #7[Woman]: We move things sometimes.

> #7[Man]: I like having it like this.
>
> Interviewer 2: Yeah, it's very nice like this... I was just thinking... A lot of people are interested in the air flowing.
>
> #7[Woman]: Yes, it should do that, but it does come out here.
>
> #7[Man]: It will probably impede the flow of air somewhat.
>
> #7[Woman]: That's possible.

It's difficult to say for certain, based on interviews alone, that the placement of the heat pump behind the sofa was impeding the air flow to the point that the household temperature was affected, but once inside the house it was clear that the living room where the pump was located was much warmer than the rest of the house. This was despite the adjoining dining room and kitchen both having large open entryways, which should have allowed for sufficient air flow between all three rooms, and the thermostat on the pump being set to 25˚C at the time of the interview. It certainly appeared that the placement of the pump behind the sofa minimised the heat dispersion from the pump as, despite the thermostat setting of 25 ˚C, the indoor temperature was reported as being approximately 20 ˚C.

The informants seemed very satisfied with the arrangement however:

> Interviewer 2: […] And how would you characterise the warmth from the heat-pump, then? How is that?
>
> #7[Man]: It's completely fine, if you ask me, but…
>
> #7[Woman]: Nice and warm on the feet.
>
> #7[Man]: At least where I am sitting, because it blows from under the sofa and around my legs.
>
> #7[Woman]: We switch places sometimes when my feet are cold [laughs].

Although the heat pump was almost certainly not fulfilling its full potential in terms of the amount of space heated, it nonetheless served a useful function for the residents. For them the comfort of warm air blowing around their feet when sitting on the sofa was a positive benefit, and the living room was adequately heated for their needs. In terms of thermal efficiency, however, the combination of the pump's placement and the location of the furniture does not appear to be an ideal arrangement.

It is interesting to note that both households #7 and #9 were cases where the residents moved into a house where an air-to-air pump was already installed, and in each case the choice of furniture placement ended up being in conflict with the pump's requirements for effective heat output. The nest-building that took place in both cases gave precedence to furniture placement, which impacted upon the effectiveness of the pump. This gives an indication as to how the heat pumps were conceptualised by these informants; the pumps appear to have been viewed as background objects that did not require any special consideration in order to function. This is despite household #7 having prior experience with a heat pump that they had installed in their previous home. The knowledge gained from that prior experience about the space requirements for air-to-air heat pumps was either too distant to be remembered by these informants or deemed less important than having the desired arrangement of furniture in their living room.

In contrast to households #9 and #7, none of the informants who had purchased their air-to-air pumps themselves had obstructed the pump's heat output with furniture. This is attributable to the fact that the informants who had purchased heat pumps would had gone through the process of domesticating it. Domestication involves several stages (described in section 3.2.3) whereby an object, in this case a heat pump, transitions from being a consumer item into being a meaningful and integrated part of the household. For the informants, part of this process would have involved making a number of conscious decisions about the pump, and thus focusing on it as a discrete object. During this direct engagement with the machine; deciding where to place it; reading the manual; and talking with the installer, the script of the heat pump had a much better chance of being successfully conveyed to the informants. The informants who had moved in to a house with a heat pump already installed would not have gone through this process, at least not in the same way, because the heat pump was acquired as a pre-integrated part of the house. These informants' use of the pump developed in a different way, with the heat pump occupying a less prominent place in their consideration of how to create the kind of living-space they wanted in their new house. The script of the pump was thus not conveyed to these informants as successfully as it was to the informants that had purchased a pump.

5.2.2 Negotiating with the heat pump

As I established in my discussion of actor-network theory, the use of a technical object can be thought of as a negotiation between the user and the object, both of whom are actants possessing agency. In order to uncover the nature of the negotiation that was taking place between the informants and their heat pumps I wanted to investigate what kinds of feedback the pump provided and how the informants responded to it. The line of questioning in section 3 of the interview guide was designed, in part, to encourage the informants to describe their interactions with the pump's interface (a remote for air-sourced pumps, a control panel for ground-sourced pumps) in the hopes of discovering ways that the technology was acting upon the user. Some informants described occasions where they found themselves having to adapt to 'quirks' in the machine in order to get the desired use from it. I will focus here on a few examples of such occasions, which illustrate how the feedback from heat pumps can affect how they are used.

The first example comes from household #13 [Man and Woman], who had difficulties when changing the temperature of their air-to-air pump using the remote. Air-to-air heat pump remotes include a temperature display, but there is not a display on the heat pump itself. As the informants described, if the heat pump did not receive the signal from the remote there was no way of knowing if the temperature on the remote's display represented the real temperature on the pump:

> #13[Man]: There is one thing I've always wondered about, because when you regulate the temperature you have an audio feedback that's a "peep." And if it doesn't come that means that it hasn't received a signal, but still it adjusts the temperature on this one [the remote]. So if I…
>
> Interviewer 1: Oh I see.
>
> #13[Man]: So now it says "24" here [on the remote display] but that pump thinks it's 23. So, does that mean that this 24 could be 19, in reality?

Household #13 dealt with this confusion by simply adjusting the heat pump temperature to what felt comfortable:

> Interviewer 2: so it means that you don't always trust that the temperature here is the right one set?
>
> #13 [Man]: Yeah, so it's more of a "what's the comfortable temperature, and what's the display temperature?" It could be some deviation there.
>
> Interviewer 2: But when you want to increase it maybe you feel that "now it's getting cold" do you then turn it up to 26 to have a, you know –
>
> #13 [Woman]: No now we put a fireplace on.
>
> Interviewer 2: Ok.
>
> #13 [Man]: I think I've been up on 24 but not higher than that.

This is consistent with what the other informants with air-to-air pumps said about temperature adjustment; the degrees Celsius displayed on the pump remote was not relied upon to give an accurate representation of the actual temperature indoors. Informants reported adjusting the thermostat according to what produced a comfortable temperature rather than trying to produce a specific temperature as measured in degrees Celsius.

It is clear from the discussions that, even regardless of the type of problem household #13 had with their pump, the temperature displayed on the remote was not considered by the informants to be an accurate representation of the indoor temperature. This thinking appeared to be well justified; the temperatures on the pump display versus the actual indoor temperature at the time of each interview varied as much as 7˚C in one case (informant #2 [Man] had his pump set to 27˚C and reported an indoor temperature of 20˚C on his home thermometer). None of the informants with air-to-air pumps had the same temperature on the pump display as the indoor temperature measured on their home thermometer.

The indication from all informants was that temperature cultivation was as much an intuitive activity as a rational one. The aim was never to achieve a specific temperature but rather to achieve a comfortable temperature. For most informants this meant using the heat pump to maintain a base temperature and adding other heat sources, such as a fireplace or electric heaters, to warm the house further if it began to get too cold for comfort. If the temperature outside fell to around -5˚C to -10˚C the informants were especially reliant on other heat sources to keep comfortable, and generally did not adjust the pump temperature more than one or two degrees up. One informant (#14[Woman]) reported that they would turn the pump off altogether at around -10 ˚C.

Another interesting negotiation between the members of a household and the heat pump was described by the members of household #12[Man and Woman]. This household had their air-to-air pump installed in a downstairs living area. In order for the pump to heat the rest of the house effectively the informant [Man] stood in the doorway of this living area and adjusted the angle of the air output of the pump so that it was blowing air directly out the door and into the rest of the house. This negotiation was only brief, but it is indicative of these informants' intention to give their pump the best chance they could to for it heat their home effectively (in contrast to #7 and #9 above, who both prioritised furniture placement).

The placement of the pump also required some of the habits of younger family members in the household to be monitored. #12[Man] described how the door to the downstairs living room needed to be managed in order for the heat to be distributed throughout the house:

> #12[Man]: […] our daughter [12 years old] comes here [the downstairs living room] and when she has her friends here they tend to close the door. And that you will notice, after a while at least, that 'hm, there's something wrong here.' First of all you don't hear them, and the other thing is that you can sense a difference in the temperature. So – but this door is always open, so he [toddler] tries to close it, that's when we are here as well, so then we try to learn him to keep the door open but you can see it's [laughs] not always easy to learn.

In this case keeping the house warm was at odds with the daughter's desire for privacy when her friends were visiting, and also required the parents to manage their toddler's impulses to close the door. The example illustrates the vulnerability of an air-to-air heat pump's effectiveness to the space it inhabits, and to the people it shares that space with. It shows how the users, the technology and the space must all engage with each other in a way that allows for the scripted function of the heat pump to play-out uninhibited. Without the right knowledge and active engagement from the users that is needed to cultivate the best circumstances for this function a heat pump will not provide the kind of energy efficiency for space heating that it is supposed to.

The negotiation between the residents of a household and the heat pump's script involves a number of elements all acting upon each other. If these elements do not interact in the precisely right way the script can potentially be weakened to the point of a major loss in efficiency. The apparent inability of air-to-air heat pumps to give a reliable representation of the actual indoor temperature that they will produce appears to push informants towards setting higher temperatures on their pump to give an indoor temperature that feels comfortable to them. This appears to be largely irrespective of how high they might be setting the thermostat on the pump, such as the extreme case of informant #2[Man] setting his heat pump to 27˚C, though there is usually a point at which the informants will no longer rely on the pump entirely and begin adding extra heat. The average temperature on the air-to-air pump displays of the houses we visited was 23.4˚C, versus an average indoor temperature of 21.5˚C as measured by home thermometers. With such a large dissonance between the display temperature and the actual room temperature it is easy to see how the degrees Celsius displayed on the heat pump remote could lose its connection to actual temperature and become merely an indication of whether the pump is set higher or lower than previously, such as a 1-10 scale would provide. We can see in the extreme case of informant #2 how this might lead to increasingly higher pump settings, which require much more energy.

5.2.3 Dealing with freezing temperatures

The main problem that was mentioned by several informants was ice build-up on the outside of air-to-air units caused by the defrost cycle. Dealing with this ice can often be a challenge, depending on the location of the outdoor portion of the pump. For one household, #14[Man and Woman], the ice build-up was enough to discourage use of the pump altogether. They described how in the first year of owning the pump they used it every day in winter, but it made so much ice that the pumps began to be pushed off of its fixtures. To try to solve the ice problem they bought a warming cable to keep the ice from forming. Though the cable helped it required a lot of maintenance, more than the elderly couple wanted to deal with: “I had to look at it, and crawl around in the snow and it’s not so convenient” (#14[Woman]). They also worried about melt-water getting into the power outlet and causing a fire. These problems with ice, along with the fact that they did not feel the pump was heating their house very effectively, was enough cause this couple to eventually abandon use of their heat pump.

Other informants also had ice problems which required some creative improvising to deal with. Household #6[Man and Woman] dealt with the problem simply by placing a plastic bucket under the outside part of the unit to collect the water as it condensed (figure 3). This would then have to be emptied periodically once the water froze (figure 4.)

Figure 3. Bucket household #6 used to collet water run-off from heat pump defrost cycle.

Household #12 sought a different solution to the ice problem. They built a drainage pipe into the ground designed to collect the water and avoid ice build-up on the ground. This did not function entirely as intended however, and the informants were still in the process of figuring out how to deal with the ice more effectively when we spoke to them.

The ice problems that these informants experienced are indicative of the fact that these air-to-air heat pumps were not dimensioned for winters as cold as those in the south of Norway. Many informants spoke about the fact that they had been told by the installer that their pump would not function effectively in temperatures of around minus 10-15 ˚C and below. When the temperature dropped low enough they would use other means to heat their homes and not rely on the heat pump, and some households turned their pump off altogether.

Figure 4. Ice emptied from bucket in figure 3.

5.2.4 Always on

Every informant that had bought their heat pump themselves had been told by the installer that the pump would be most effective if it was never turned off during the coldest months of the year. This advice applied to both air-to-air pumps and ground-sourced pumps. Heat pumps run most efficiently when they are maintaining a constant temperature, and use more energy when brining a space up to temperature. This is the logic behind the 'always on' advice; keep the pump running at maximum efficiency, rather than creating spikes in energy use from turning it on and off as needed.

All of the informants reported not thinking about their heat pumps very much, most likely because the pumps did not need to be interacted with in order for them to function. The common exceptions to this were if the pump started making unusual noises, or if the temperature in the house was either too warm or too cold. The rest of the time informants reported ignoring the pump and simply letting it run.

The fact that heat pumps are easily left on and forgotten about may be conducive to less energy-conscious practices. People who reported previously having paraffin-based heating, for example, said that they had to be aware of how much fuel they were using and when they might need to get more, as well as maintaining it and making sure it wasn't left on longer than it was needed:

> #4[Woman]: […] it [the paraffin heater] was effective. But then we had to constantly make sure to fill kerosene and do this and that.
>
> ***
>
> #10[Man]: […] this oil heating system you had to watch them more carefully than we do with this [heat pump] and also you had to have a service every autumn to check that everything is ok. You had to shift these burners now and then, and so on. So, it's more to worry about […].

Heat pumps on the other hand could be 'trusted' and more or less left alone. This is of course one of the benefits from the user's perspective because it means less time negotiating with the technology, fewer concerns about safety, and less time spent thinking about and managing the fuel supply. The side effect, however, is less awareness about the amount of energy being used by the pump.

The switch to a heat pump system often meant a longer heating season as well. Informant #4[Woman], for example, described being mindful of turning off the paraffin tank when the weather got warmer, but with the heat pump system she or her husband could simply turn it down when it began to feel too warm. They also did not consider it important to be aware of when the heat pump was on because it was supposed to always be on. When asked, #4[Woman] agreed that her house was probably warmer with the heat pump than it was with the paraffin, due to this change in practice.

If household #4 is a typical example of how peoples' practices change when they switch from a paraffin system to heat pump system it explains at least a portion of the rebound effect observed by Halvorsen & Larsen (2013). As they describe in their introduction:

> […] the full energy-saving potential of an energy-efficiency measure, as measured by the reduction in energy needed to produce the same amount of goods and services, will only be reached if consumers or producers do not change their behavior when the new and more energy-efficient technology is introduced. (Halvorsen & Larsen 2013:4)

The behaviour of, in this case, the consumers, clearly changed when they switched from paraffin to a heat pump, and this did in fact lead to a reported increase in temperature. Halvorsen & Larsen's explanation this kind of change sticks closely to economic theory, attributing the change in behaviour to the reduction in the cost of heating provided by the heat pump:

> Based on economic theory […] we expect behavior to change since increased energy efficiency will reduce the unit cost of producing a good or a service. This will result in a partial increase in demand for the energy source that has become more efficient in use due to both substitution and income effects. The full energy-saving potential of an energy-efficiency measure will thus only be reached if the demand for energy does not respond to changes in the unit cost of production. (Ibid.)

There appears, however, to be more at play in this change in behaviour than just the income effect. Although the more affordable cost of heating that a heat pump provides is implicitly correlated to an increase in demand for that heat, the differences in the ways the technologies function also play an important role in the changes in behaviour. As established above, the reduction in cost given by the efficiency of the heat pump was seldom cited by the informants when they spoke about their reasons for purchasing or their changes in heating practices. What was more often cited was the increased convenience of the pump and the improved comfort it provided. Heat pumps warm space very consistently when left alone for extended periods, unlike paraffin, wood burners and panel heaters, which all need to be monitored and managed in order achieve the desired temperature. By automating their functions, and by providing an even and consistent temperature in the space when left on, heat pumps encourage users to leave them running without interference.

The change in behaviour hypothesised by Halvorsen & Larsen is partly an effect of the heat pump's script. The way that heat pumps are supposed to be used is fundamentally different to that of other methods of heating, such as panel heaters or paraffin heaters, so a change in behaviour could reasonably be expected even if running costs were the same across all devices. Heat pumps are promoted as energy efficient devices, which they are, but they are also devices that are made to heat larger spaces, or heat for longer periods, than many of the devices they replace in the Norwegian context.

5.2.5 Efficiency and behaviour

The two studies on heat pumps conducted in Scandinavia (Halvorsen and Larsen in Norway, Christensen et al. in Denmark) found a significant rebound effect associated with heat pump use. However, in their study of heat pumps and energy efficiency, Elsawaf et al. (2013) found a marked *decrease* in energy consumption when air-sourced heat pumps were installed in factory-produced houses in North Carolina. A comparison between Elsawaf et al.'s findings and the Scandinavian studies' findings illustrates some key aspects of heat pump use in Norway and Denmark that can produce a rebound effect.

Elsawaf et al. took detailed measurements of the temperatures inside and outside the 132 houses in their sample over a period of two weeks during the heating season, and collected energy use data from the gas and electricity providers. They found that the households with heat pumps used 47.5% less electricity on average during one month than the control houses, with indoor temperatures of all households adjusted to 22˚C. This drop in energy use cannot be easily attributed to differences in behaviour between the residents because "[i]n all measured houses the occupants [operated] their heating systems continuously" (Elsawaf et al. 2013: 189). Comparing Elsawaf et al.'s study with Halvorsen et al.'s (2013) and Christensen et al.'s (2011) studies may therefore help in hypothesising why heat pumps provide large reductions in energy use in some cases but almost none in others.

There are some important differences between the sample bases in Elaswaf et al.'s (2013) study and those conducted in Scandinavia. Elaswaf et al. studied factory-produced homes that were designed to have an integrated heating system. This integrated system is normally based on forced air electric furnaces connected to a duct network. Elaswaf et al. (2013) compared houses with furnaces connected to these ducts to houses where the furnaces had been replaced with air-sourced heat pumps (188). This means that the heat was distributed through the house in the same way in both samples, unlike in the Scandinavian houses where installing a heat pump meant a fundamentally different way of distributing the heat. The second important difference between the two samples is the difference in climate between the two locations. Temperatures in North Carolina during winter average around 5 ˚C (Current Results 2012), whereas the average temperature during the coldest months of winter in the Oslo area is around -4˚C (Bolstad et al. 2013). Heat pumps run less efficiently in colder weather, so the reduction in energy use resultant from air-sourced heat pumps is likely to be less in a colder climate such as Norway's. Halvorsen and Larsen's findings did in fact show that households in Norway that relied only on heat pumps and other electric sources for space heating saved the least energy, which they attribute to the pumps' reduced efficiency during very cold weather (2013: 18).

These differences may well account for much of the discrepancy in results between Halvorsen and Larsen (2013) and Christensen et al. on the one hand, and Elaswaf et al. (2013) on the other. The households in Elaswaf et al.'s sample kept their heat on regardless of the type of heating system, but the same cannot strictly be said for the Danish and Norwegian households. The Scandinavian households would have also been exposed to lower temperatures than those in North Carolina, potentially reducing the comparative efficiency of their air-sourced heat pumps. And finally, the temperature that each house was heated to was the same for both the homes with heat pumps and those without in Elaswaf et al.'s study, but this was not controlled in the Scandinavian studies; both of the Scandinavian studies attribute the loss of efficiency from the heat pumps to an increase in indoor temperature.

The fact that heat pumps are not used in the same way, and do not function the same way, as these other heating methods means that the economic principle of *ceteris paribus*, 'all other things being equal', cannot be realistically applied when comparing the two. Elsawaf et al. (2013) showed that in more controlled comparison – when heat pumps replaced furnaces in integrated heating systems in mobile homes, and were used in exactly the same way – that heat pumps were far more energy efficient. The problem in the Norwegian context is that there are too many other extraneous factors which also change when a heat pump is installed.

In the case of air-to-air heat pumps specifically, the efficiency of the device depends largely on a specific set of physical circumstances that allow for the heat to be distributed effectively. When these circumstances are not met the efficiency is reduced, as in the example of household #7 whose heat pump thermostat was set at 25˚C but had an indoor temperature of only 20˚C. In Elsawaf et al.'s (2013) study the distribution of the heat was the same for both the furnaces and the heat pumps, removing the variable of placement of the heat output. But in the Norwegian context air-to-air pumps need to be in a physical arrangement that allows for optimal heat distribution; they must be installed in an appropriate location and must be unobstructed by furniture. As was evident from even our small sample of 15 informants this type of ideal setup is not a given.

5.3 Comfort

Much of the evidence presented above indicates the importance of ideas about, and desires for, comfort in both the acquisition and use of heat pumps. This section examines comfort in more detail, looking first at how the informants reported their heat pump's effect on their comfort. This section also discusses how comfort has been formed as a commonly understood concept, and examines what it actually means to be 'comfortable'. This will help to frame the evidence provided by the informants about their uses and perceptions of heat pumps, and show how comfort relates to energy consumption.

The informants for this study mostly reported an improvement in their level of comfort, things like less dryness in the air (compared to wood burners) no smell from the dust on electric heaters, and more even heating throughout the house. 4 informants specifically reported an increase in indoor temperature compared to when they did not have the pump, and one informant reported having a longer heating season.

The average indoor temperature reported by the informants in this study was 21.5 ˚C. This is consistent with Halvorsen & Larsen's finding that the "mean reported living temperature [was] slightly above 21˚C" (2013: 9). Halvorsen and Larsen also found that this temperature was "significantly higher" (0.4˚C) than that of homes without heat pumps (Ibid: 14).

Heat pumps also appear to provide a much more consistent and even indoor temperature, whilst also heating a larger portion of the house. Several informants commented on the fact that their house was always warm as a result of the heat pump, for example:

> #12[Man]: Before we got this heating pump, I mean, we just all went into the kitchen, closed the door so it can get really warm, and it could

be like 16, 17 degrees in the living room in the morning. And we didn't heat it up and it was the same temperature, more or less, when we came home from work in the evening, and then we really had to put a lot of logs into the fireplace and heat. But now we have a constant temperature more or less, because of this [heat pump].

***

#14[Man]: I thought at least that when we were away during the day that it will be warm when we come home, and when we get up.[6]

The fact that the house is never cold is one of the obvious advantages of a heat pump, from a comfort perspective. Heat pumps also appear to lead to a higher indoor temperature in most cases, which could also be said to be an advantage. However we should not assume that higher temperatures indoors equates to an increase in comfort. As we shall see below, comfort is a somewhat slippery concept, and what does or does not make for a comfortable environment is not clear-cut.

In her book *Comfort, Cleanliness and Convenience* (2003) Shove argues against the notion that comfort is an empirically definable sate determined by biology. In her discussion she cites research that showed people have reported being comfortable in temperatures from anywhere between 6˚C and 31˚C depending on the environment (Shove 2003: 35). She also draws an interesting insight from the field of ergonomics, which shows that technical definitions of comfort and what people actually find comfortable do not necessarily match:

> Anatomical and ergonomic analyses of posture and position, twinned with medical research into the causes and characteristics of back pain, has resulted in a wealth of data relevant for the specification of 'comfortable' seating (Cranz 1998). The trouble is that what ergonomic researchers recommend does not translate into chairs that people find comfortable, leading Cranz to reach the ergonomically unhappy conclusion that 'People seem to respond more to their ideas about

[6] #14[Man]: Jeg tenkte i hvert fall på at når vi var borte på dagen at vil ville har det varm når vi kommer hjem, og når vi står opp.

> comfort than to their actual physical experience of it' (Cranz 1998: 113). (Shove 2003: 25)

Shove's claim is essentially that the ideas we hold about comfort are more important than the objective conditions of comfort. She argues for a way of viewing comfort that sees it not as a condition or state of being, but rather as an achievement. Comfort requires a type of work to achieve, which is connected to the norms and expectations held by a person about what it is to be comfortable.

These norms and expectations are not fixed and can vary across time, environment and culture. The Wilhite et al. (1996) article discussed in Chapter 2, for example, showed how norms for comfort differ significantly between Japan and Norway, as demonstrated by the way people in each country heat and light their homes. The authors showed that Norwegians placed great importance on heating the whole house, except for the bedroom, whereas Japanese used *kotatsu* body heaters which warmed people individually, leaving the air temperature relatively cool. Additionally, there were major differences in the ways in which people from each culture preferred to light their homes, Norwegians preferring multiple light sources to create what they described as a "warm" atmosphere, and Japanese preferring a single overhead fluorescent light which provided good visibility (Wilhite et al.: 1996). Both the Japanese and Norwegians were producing the types of comfort that were the norm for their culture, and this involved work on their part to cultivate that particular type of comfort.

The above examples show how the definition of comfort is largely determined by cultural norms. Integral to definitions of comfort in Norway is the concept of cosiness. Wilhite et al. (1996) used the term *koslighet* to describe this particularly Norwegian definition of a comfortable environment. The informants in this study all appeared to have a good understanding of how to create a *koselig* atmosphere, an important part of which is having a fire when at home during the coldest parts of the year. Many informants described how they enjoyed having a fire not just for warmth but because it also made the house feel cosy. One Informant even installed a fireplace intended purely for ascetics which did not effectively give off heat:

> Interviewer 2: Do you have any other kind of alternative sources? You have this one [fireplace]
>
> #13[Man]: We have this [fireplace], but we installed it because it's – it doesn't give any heat.
>
> […]
>
> #13[Man]: Yeah. And that's all part of a plan, because when we – you know the problem often, in the places we've lived before we moved here, is that when you light the fireplace it gets too hot, you know.
>
> Interviewer 2: Mm, nettopp.
>
> #13[Man]: You see?
>
> Interviewer 1: Yeah.
>
> #13[Man]: So we can have guests and we can have a cosy fireplace and you don't – you can still wear your clothes.
>
> Interviewer 2: So this is just for the atmosphere?
>
> #13[Man]: Yeah, right. Of course it heats, but when it's locked like this it doesn't heat too much, we need to open it and then the heat…

Though #13 was the only household in our sample with this type of fireplace several other informants also spoke of the cosiness they felt a fire provided (#2[Man], #4[Woman], #7[Woman], #9[Woman], #10 [Man]). Clearly fireplaces are deeply integrated into Norwegian concepts of a comfortable winter environment.

Although Halvorsen and Larsen (2013) found a reduction in the use of fireplaces associated with heat pump use, the evidence gathered here suggests that they are still an important part of everyday life, even for heat pump owners. All of the informants reported using their fireplaces at least semi-regularly during winter. One requirement for a heat pump to be successfully domesticated into a Norwegian home must therefore be that it can function well in conjunction with a fire. The pumps seemed to achieve this integration in every case; fires were often used to boost the indoor temperature on especially cold days, and to help create a cosy atmosphere in the evenings and on weekends. The pump was not adjusted in most cases and the informants simply allowed their houses to become warmer, sometimes very warm, as we shall see below. This is according to the informants themselves, several of whom indicated that they were cultivating a temperature above what was considered necessary for a Norwegian house.

An understanding of the comfort norms for Norwegians can be observed in some of the comments made by informants in this study. Every household we visited kept a thermometer indoors to track the temperature in the house (itself is a kind of cultural norm relating to comfort). The informants also seemed have a clear idea of what a 'normal' indoor temperature for winter is. Two of the informants illustrated this point particularly well; #4[Woman] and #6[Man and Woman] both had indoor temperatures of between 24 and 25 ˚C at the time of their respective interviews. These informants had presumably been comfortable with the indoor temperature, having not reported any discomfort during the interview, but when asked what the temperature currently was inside each commented that it was 'probably too warm':

> #4[Woman]: [24˚C] that is actually very warm.[7]

***

> #6[Man]: It's 24, 25 degrees [inside now]. Too much, we know.

[7] #4[Woman]: "Det er jo kjempevarmt"

In the first case (#4[Woman]) the temperature of 24˚C was described as being unusually high, which the informant attributed to the wood burner having been on for several hours prior to our visit. In the second case (#6[Man and Woman]) however, 24 – 25˚C indoors was reported as being around the norm for winter in their household, yet they still described it as “too much”. Both of these responses indicate an understanding of a normal indoor temperature as being somewhere below 24˚C, and both informants saw themselves as deviating form that norm, yet neither of these informants reported feeling too warm or uncomfortable at these temperatures.

If shared understandings of an ideal temperature range for good comfort are culturally determined then it is possible, even inevitable, that they will change. The increase in temperature and the ability to keep houses warm day-round that have come with heat pumps has implications for how social standards of comfort are reproduced. It is not unlikely that as heat pumps become more widely adopted in Norway that the cultural standards for indoor temperature will change in favour of higher indoor temperatures for longer periods of the day, as well as producing longer heating seasons.

A detailed examination of the social reproduction of comfort goes beyond the scope of this project. What this discussion of my findings has focused on is 1) the reasons people purchase heat pumps, and 2) how heat pumps are used. I have highlighted and discussed some of the complexities inherent in both of these processes and showed their relevance for energy consumption. In the next chapter I will summarise the key points raised in this discussion, and reflect on their relevance for policy and future research.

6 Conclusion

6.1 Heat Pumps and the Rebound Effect

Much of my discussion has been framed as a response to the findings of Halvorsen and Larsen (2013), which showed a rebound effect connected with heat pump use. Halvorsen and Larsen use economic theory to hypothesise that the rebound effect was caused by a rationalisation on the part of the users, namely that they used the savings gained by their reducing energy consumption to increase their comfort by having a higher indoor temperature, and by using non-electric heating sources less (2013: 20). I have tried to give more depth to these findings and to highlight the complexities inherent in the changes in energy use patterns that come with heat pumps. By using a combination of actor-network theory and practice theory as the framework for my analysis I showed that the rebound effect can largely be attributed to the complex interplay between the heat pump's technical properties and the practices of its users.

Halvorsen and Larsen's study found that households with heat pumps had a warmer average indoor temperature than those without. They reported that the average indoor temperature of houses with heat pumps was "just above 21˚C" (Halvorsen and Larsen, 2013: 9), which is consistent with my own findings, and claimed that houses with heat pumps had a temperature "almost 0.4˚C higher" than other households (Ibid.: 14). I have argued that, particularly in the case of air-to-air pumps, the script of the technology greatly contributes to this rise in temperature, and thus a rebound effect.

One of the key aspects of the script which leads to higher temperatures is the 'always on' requirement. Heat pumps are most efficient when they are left running without interference, and heat pump owners are usually instructed by their installers to leave the heat pump alone and to let it maintain the indoor temperature. This is fundamentally different to the types of heating that heat pumps usually replace in the Norwegian context, such as paraffin and panel heaters, which must be monitored and adjusted according to outside temperature, and which are usually turned off or down when residents leave the house. Heat pumps can easily be forgotten about, and the fact that they are, in most cases, always on, produces a higher average temperature when compared to systems that are turned off and on. The 'always on' script also appears to produce longer heating seasons, again, because the heat pump will function unproblematically when left alone.

Another factor I discussed in relation to the rebound effect was how the unreliability of temperature displays on air-to-air heat pumps created a disconnect between the indoor temperature as displayed by the pump and the temperature as experienced by the residents. This disconnect, I have argued, is conducive to higher thermostat settings on heat pumps, and therefore lower energy savings. When a user does not consider the displayed temperature on their pump to be indicative of the actual temperature it will produce that display begins to lose its meaning. I showed one extreme example of this in informant #2[Man] who had his pump set to 27˚C, but had an indoor temperature of only 20˚C. This informant was not aiming to heat his house to 27˚C, he reported being quite comfortable at 20˚C, but he had nevertheless set his pump to that temperature. This informant's reaction, and that of the others with large temperature discrepancies, was not to try and make adjustments so that the pump would heat more effectively, but was rather to turn the thermostat up and add other heat sources until a comfortable temperature was achieved. The example of informant #2, though extreme, was not the only case of a large discrepancy between display temperature and indoor temperature,[8] and it illustrates the vulnerability of air-to-air heat pumps' efficiency to anything other than an ideal set of operating circumstances.

These points show that the rebound effect is not just the result of an economic rationalisation on the part of the users. How these issues might be addressed

[8] Households #7 and #11 had temperature differences of 6˚C and 4˚C respectively.

will be discussed in section 6.3, but first I will briefly summarise the findings relating to the motivations behind the purchase and use of heat pumps.

6.2 Motivations

In the first section of chapter 5 I discussed the reasons that the informants gave for purchasing a heat pump. I highlighted the complexities of the decision-making process that these informants went through in deciding to get a heat pump, and showed that it was not as simple as wanting to save money on heating costs. A desire to get good value for money from their heating system was apparent in many of the comments made by the informants, but I have argued that this is different than a desire to actively reduce household energy expenditure adopting a more energy efficient means of heating. Good value for money, plus the desire to improve comfort, and in many cases the desire to replace out-dated systems such as paraffin-based heating, were all important factors contributing to heat pump purchases. I also showed that social networks were important to almost all the informants in their decision-making process, and that advice from a trusted source, such as a friend or family member, was highly valued by these informants. Promotion and advertising also played a part, but appeared to be important mainly in the early stages of investigating new options for home-heating. And finally, I showed that heat pumps were most often acquired as part of wider renovations to a home, and were seldom installed under circumstances other than a renovation or building process.

The responses from the informants in this study clearly showed that the motivations behind buying a heat pump were not primarily to reduce consumption, for either economic or environmental reasons. This indicates that heat pumps are not generally conceptualised as conservation technology. On the one had this means that heat pumps may have the potential to improve energy consumption as a background technology that does not require an active desire to conserve energy on the part of users in order for it to reduce energy consumption. On the other hand, if heat pumps are not conceptualised as a sustainable technology they are less likely to reproduce practices conducive to reducing energy consumption. Heat pumps do not require a sacrifice in comfort or convenience; they can in fact improve both of these things for owners. Heat pumps therefore have the potential to take on a meaning of a luxury item that improves comfort, rather than a sustainability item that reduces environmental impact. The indications from the data gathered here are that heat pumps are already trending towards the category of 'luxury item,' as opposed to 'sustainability item.'

More research would be needed to determine exactly how heat pumps do, or do not, reproduce energy-saving attitudes, beliefs or behaviour. What we can say from the findings here, however, is that heat pump ownership does not in itself indicate a desire to reduce energy consumption. Therefore, I posit that if heat pumps are to be an effective means of reducing household energy consumption *en masse* they must be able to do so without a concerted effort on the part of the residents to operate it in a highly specified way. In the case of water-based heat pumps (air-to-water or water-to-water) this seems to have been achieved; there were no major discrepancies between thermostat settings and indoor temperature with water-based systems amongst the informants in this study. The informants with water-based systems had fewer additional heat sources than those with air-to-air systems, with most using only fireplaces to boost the temperature on particularly cold days or when a cosy atmosphere was desired. The efficiency of air-to-air heat pumps on the other hand appears to be far less stable, as it requires more active engagement by the users and installers to create the best conditions for it to operate in, and these conditions are not always achieved.

6.3 Reflections on the Findings

From a sustainability perspective, the main benefit of heat pumps is that they reduce the amount of energy used for heating. I have already argued that because people who own heat pumps are not usually motivated by a strong desire to save energy that heat pumps, particularly the air-to-air variety, must be made less vulnerable to circumstances that will reduce their energy efficiency. How exactly this can be achieved is a question further research should address in more detail, but I will nevertheless offer some reflections on this problem based on my findings in this thesis.

One of the challenges in improving the real efficiency of heat pumps is addressing the disconnect between air-to-air heat pumps' temperature display and the actual temperature as experienced by their users. Because the temperature display is not considered by users to be accurate, high temperature setting are less likely to be viewed as out-of-the-ordinary. If a high temperature setting with low actual temperature is considered the norm then there is a greater chance that problems that can reduce the efficiency of the pump – such as dirty filters, or use in spaces that the pump is not dimensioned to handle – will go unnoticed by the users.

This disconnect might be remedied by changes in the designs of the thermostat and information displays on heat pumps. Of course, because I am not a technician, the kinds of recommendations I can give for improving the technology are limited, but I will nevertheless comment on a few hypothetical changes in the technology design that I believe could help users operate heat pumps more effectively.

In Norway indoor temperature is typically measured with a home thermometer; the thermometer indicates the real air temperature, and the heat pump display indicates the temperature that the heat pump will try to produce. A display showing the real indoor temperature *as measured by the pump*, as well as the temperature *setting* of the pump, may give the user an a better idea of how well the pump is actually heating the space, and whether adjustments need to be made. When the user can see what temperature the heat pump 'thinks' the indoor space is they will have a more complete picture of how hard the pump is going to work to achieve the temperature they have set. This could also trigger awareness in the users about the need for air circulation for the pump to work effectively. In the case of the couple who had their air-to-air heat pump behind their sofa, for example, the air temperature directly around the pump would almost certainly have been higher than in the rest of the room. A temperature display on the pump would help to demonstrate this discrepancy in this type of situation, and perhaps trigger a reconsideration of the furniture arrangement.

Failing a redesign of the heat pump technology itself, this same effect may be achievable through the placement of a home thermometer near the heat pump's output. This could be included as a recommendation on heat pump web-resources such as varmepumpeinfo.no, and from installers. The findings of this thesis showed that installers in particular are in a prime position for influencing the future patterns of use of the heat pumps they install, and their recommendations for particular types of use may be highly affective shaping user practices. This brings me to my next observation about the role of installers in affecting heat pump use patterns.

If we approach the rebound problem from the angle of the user's practices, rather than the machine's design, the findings in this thesis indicate that the best opportunity to form good use practices is in the early stages of the heat pump's domestication. Every informant in this study that had purchased their heat pumps themselves learned much of what they knew about the device and how to use it from the installer, during the installation process. These informants demonstrated a use of their heat pumps that was more closely in-line with its scripted function than those who had not bought a pump themselves. However, even these informants reported practices that were not conducive to the best efficiency, including high thermostat settings. This shows that there is potential for improvement in the ways that air-to-air heat pumps are used, and that installers are well-placed to teach better kinds of use.

Improving the information given out by installers does not, however, solve the problem of users who have moved into houses already equipped with heat pumps. This is the group that appears to be deviating the most from the scripted use of heat pumps, but how best to bring their use back into line with the script is a difficult question to answer. The two informants in this study that had not purchased their heat pump reported being uninterested in the device and had not read the manual or sought other information, and the logic of the heat pump as an technical object was evidently not strong enough foster the kind of use intended by its script. Current air-to-air heat pump designs mean that they require some amount of user training in order to achieve the best possible efficiency. However, air-to-air pumps are still easy to operate without this training.

The problem of how to ensure that the appropriate training takes place for users that have not purchased a heat pump themselves raises larger questions about how to make people's practices, in general, more sustainable, questions that have been on-going in environmental research for decades and are far too large to be addressed here. More research on users that have moved into houses with air-to-air heat pumps already installed is needed in order to establish how exactly such users think about and operate their pump. This may help determine how either re-designs of the technology or targeted intervention strategies could bring these users operation of heat pumps more into line with the technology's script. Without such efforts the energy efficiency of air-to-air pumps is likely to be reduced further as they are passed-on to new owners that acquire them as part of a house, owners who have not received the appropriate training for how to use them.

In contrast to the finding that air-to-air heat pumps' efficiency is vulnerable to improper use, there appears to be little reason to doubt the efficiency of ground-sourced heat pumps, based on the data gathered here. It would be helpful, however, to have research focused specifically on water-to-water heat pump households, to delve into more detail about these households' levels of energy consumption and home heating practices. The indication from the small sample of water-to-water heat pump owners in this study is that these owners do indeed reduce the amount of energy they use for heating, relative to alternatives for heating the same space. There was no indication from these informants of increases in thermostat settings, or use of the pump that significantly deviated from its script. These informants also reported using other heating devices such as resistance heaters less than previously. By nature water-to-water pumps' high level of integration into a house, and the relatively fixed nature of their level of heat output, they provide far fewer opportunities for deviation from their script. They also very consistent in the level of energy they use due to the stability of the heat source, and are safer and cheaper to run and maintain than paraffin-based heating while producing fewer emissions. Water-to-water heat pumps are thus an excellent option for efficient space heating, especially as a replacement for paraffin-based systems or as a new house's primary heat source.

Policy targeted at reducing domestic energy consumption should therefore continue to encourage and facilitate the installation of water-to-water heat pump systems in new and renovated houses. It must be repeated, however, that informants in this study did not consider the subsidy for water-to-water heat pumps an essential factor in their decision to purchase one, citing the relatively small financial contribution the subsidy made to the cost of the pump. As outlined in section 5.1, the reasons that people gave for purchasing heat pumps related to advice given from friends or family members, and were closely nested in larger decisions about building and renovation that were in turn related to desires to create more comfortable environments. The informants' responses indicated that the greatest advantage of heat pumps as space heaters – and the reason that their adoption has been so successful thus far – is that they provide a high level of comfort and convenience, as well as good value for money in terms of running costs. Therefore, a strategy of convincing people to buy heat pumps for environmental reasons, while not detrimental, is not likely to be the most effective way to increase sales. Promoting the instillation of water-based heat pumps is probably best achieved by increasing general awareness about the technology and its advantages on the one hand, and making them more attainable (reducing cost and increasing availability) on the other.

6.4 Final Remarks

Water-based heat pumps hold a great deal of potential as a tool for reducing domestic energy consumption. The data gathered here showed that water-based pumps functioned as intended, and that the informants that used these pumps did not carry out the type practices connect with the rebound effect that were observed in air-to-air heat pump owners. The highly integrated and fixed nature of the technology means that water-based heat pumps is far less susceptible to deviations from their scripted use, and are therefore more reliable in their efficiency.

Air-to-air heat pumps, on the other hand, are not highly integrated into a house, and their delivery of heat is far more susceptible to variations due to extraneous factors such as high thermostat settings; their placement in a space; and being turned off by a user. Air-to-air pumps are also vulnerable to losses in efficiency due to extreme cold, which is not ideal for the Norwegian climate. These factors all make their efficiency as space heaters much more unstable than that of integrated water-based systems. However, given the right set of operating circumstances, air-to-air pumps still provide better energy efficiency than resistance heaters and produce fewer emissions than paraffin heaters; the problem is ensuring that they are installed and used in a manner that adheres to their script.

If heat pumps are to be a part of large-scale efforts to reduce energy consumption in Norway this should be done with an awareness of their limitations as energy-savers. Heat pumps are not a 'silver bullet' for domestic energy consumption, but simply technologically efficient devices, which must operate in highly specific circumstances in order to be effective as energy-savers. The task of reducing energy consumption will not be achieved by simply adopting energy efficient technologies; it requires that these technologies are used in the right ways and in the right settings; that the complex interplay between social practices and technologies produces outcomes that are less energy-intensive than what came before. Understanding the complexities of this process is a difficult task, but it is an essential step towards finding effective ways to reduce energy consumption.

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Appendix

Interview Guide

1 Background

- (Date, name of interviewee, type of house (detached/flat), outdoor temp)
- How many people live in this house?
- How big is the house?
- Approximate yearly consumption of electricity?
- Other heating sources than el?
- Do you own or rent?
- How long have you lived here?
- When did you get the heat pump?
- What kind is it? (Air sourced, ground sourced, water sourced? + brand/type)
- Where is it located? What considerations led to this location?

2 Why have they purchased a heat pump in the first place?

- What were your reasons for purchasing a heat pump?
- Did you talk to other people before deciding to buy it?
- Did knowing that they had/did not have one factor into your decision?
- Did you receive a subsidy?
- Was the subsidy important in your decision to buy the heat pump?
- How did you hear about it?
- How did you decide to get this particular type of heat pump?

3 How is the heat pump actually used?

- Can you tell me how the heat pump works?
- How did you learn how to use it (during installation, manuals, friends etc)?
- Does it heat the entire house?
- How many months of the year would you say you use the heat pump?
- Do you also use it for cooling?
- At what temperature do you set the heat pump (various seasons, day/night)
- How much do you actually interact with it?
    - When you do interact with it what do you usually do?
    - Do you interact with it in ways other than for just "normal usage"?
    - How often do you adjust the settings?
    - What are those adjustments, usually?
- What can you tell me about its usability?
- Does it work the way you want it to?
- To what extent do you feel that you know how to use it in an optimal way?
- Is there anything about the design that you would change if you could?
- Are they any features you particularly like?

4 How does the heat pump fit into the wider home context?

- How did you heat your house before?
- What are the differences, if any, between your life before you had the heat pump and after?
    - Did you change anything about physical set-up of the house or furniture after the pump was installed?
    - Have you noticed any changes in the indoor temperature or the way you close/open doors, keep windows closed/open since getting the heat pump? (diff temperature diff rooms, seasons, social gatherings vs everyday life)
    - Have you noticed any changes in the way you do household activities since

getting the heat pump?
    - Has having a heat pump changed your household routines in any way?
- Do you use any other means to regulate the temperature in your house? (e.g. opening windows, wood fire)
- Have you done anything else to try and reduce your energy use or make you house more energy efficient?

5 Comfort

- What is important when you decide to set the temperature (heat pumps) and other heating devices as you do? Do family members "negotiate" on what temperature is optimal? Examples of situations/discussions? What kind of clothing do you usually wear around the house during winter?
- Do you have under-floor heating in your bathroom or other rooms?
    - Do you turn them on and off and are there different requirements for comfort here than in other rooms?
- Generally, are the family's requirements for comfort different in different rooms

6 Peers/family dynamics

- Do you know anyone else who has a heat pump?
- Do you ever talk to other people about heat pumps?
- Does the family talk about the pump? In what kind of situations? Examples?
- Who in the family interacts most with the heat pump? (link to the phase when it was installed, knowledge about how it works, who is paying bills)
- Do various generations or genders have different views on comfort and/or the way the pump should be used?

7 Potential affects; budget and costs

- Does this family make a budget and keep account of costs? (who)
- To what extent do you think you're saving energy and costs by using the heat pump? (if possible: estimation of amount in NOK)
- [Explain the rebound effect.] If you think that the pump has made you save energy/money on one level, has this lead you to i) use "more of the same": more energy on heating/cooling perhaps leading to a higher indoor temperature or ii) the saved costs are used for other purposes (which) or iii) you do not know?
- Do you regularly save money? What do you do if you discover that you have more extra money than normal? (Examples?)

8 What is their overall assessment?

- What is your overall assessment of the heat pump in your home?
- Heat pumps are becoming common in Norway, what do you think are the reasons for this?
- In your opinion, what are the most important effects of the wide spread of heat pumps?
- Do you have anything else you'd like to add?
- May we contact you again in case we wish to ask follow-up questions, or are you satisfied with having helped us today?
- Do you wish to receive information about the results of this research project? (in a years' time)
- (Explain again anonymity and thank them.)