ZEB Project report 4 – 2012

William Throndsen (NTNU) and Thomas Berker (NTNU)

Households On The Rebound

Factors Increasing and Decreasing Rebound Effects in Norwegian Households

ZEB The Research Centre on Zero Emission Buildings

A world where buildings do not contribute with greenhouse gas emissions

SINTEF Academic Press

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Norwegian University of Science and Technology
N-7491 Trondheim
Tel: +47 22 73 59 50 00
www.ntnu.no
www.zeb.no

SINTEF Building and Infrastructure Trondheim
Høgskoleringen 7 b, POBox 4760 Sluppen, N-7465 Trondheim
Tel: +47 22 73 59 30 00
www.sintef.no/byggforsk
www.zeb.no

SINTEF Academic Press
c/o SINTEF Building and Infrastructure Oslo
Forskningsveien 3 B, POBox 124 Blindern, N-0314 Oslo
Tel: +47 22 96 55 55, Fax: +47 22 69 94 38 and 22 96 55 08
www.sintef.no/byggforsk
www.sintefbok.no

CONTENTS

SUMMARY

OBJECTIVE

This is a report on a study conducted in the spring of 2011 to examine the cultural and social conditions associated with rebound effects on the household level. The goal of the study was to conduct an empirical, qualitative exploration of the conditions that favour rebound effects. In economics, rebound effects are defined to occur when a measure intended to increase energy efficiency actually contributes to an increase of energy consumption. Examples of conditions that favour rebound effects include using heat pumps for cooling, leaving energy-saving light bulbs on for longer periods or neglecting to shut them off entirely, or driving an energy efficient car more often at higher speed over longer distances.

To shed light on rebound effects occurring on the household level, in this study we aim at contributing to a better understanding of the meanings that households attach to energy-saving investments in general and to examine conditions that result in unexpected reductions of the effect of energy efficiency investments.

The material for this study was gathered through in-depth interviews with the representatives of 17 households in the Trondheim region. Each interview lasted about an hour. The majority of the respondents were drawn from a group of approximately 100 households that had received funding from Enova SF to procure technology for improving energy efficiency. In the interview, we asked respondents about their commitment to the environment, energy practices, energy technologies and their relationship to the energy bill and their energy supplier/utility company. In particular, to identify situations where rebound effects might arise, we examined respondents' reports on their experiences of introducing energy efficient technology into their household, their everyday energy practices, and the ways in which this new technology forced or warranted change in their energy consumption behaviour.

This report consists of three parts: a chapter that proposes definitions and operationalization of rebound effects on the household level, a chapter on observations made about respondents' experiences of investing in energy efficient technology, and a chapter on the factors located within the household that tend to interfere with the effect of the investments. The latter two chapters have their own sections that summarise the respective major findings.

SUMMARY OF FINDINGS

- The meaning of energy saving in everyday life
    - Rising energy prices was the most important reason for increasing energy efficiency.
    - Environmental concerns were balanced against household economy, such that older and higher-income respondents were more likely to make the greatest improvements.
    - Making vast and incremental improvements appeared to result in greater rebounds rather than smaller improvements.

- Making vast and incremental improvements may have led to a feeling of maximum accomplishment, which made behavioural change seem less important.
- Complicated systems, such as centralised control, required periods of breaking in that were crucial for reaching the full potential of the technology. Failed domestication resulted in non-use and, eventually, rebound effects.
- Due to offsetting factors, respondents did not report any tangible cost reduction.
- Instead, respondents said that their investments helped them to keep the status quo between cost and consumption patterns.
- These offsetting factors included investment cost, price elasticity, ratio to general household economy, and the need to reinvest in "the never-ending home improvement project".

- Especially two socio-cultural factors weakened and strengthened the effect of energy saving investments in households (this list is not conclusive)
    - Negotiations between the persistent values of the past and the contemporary possibilities and demands for an active lifestyle resulted in choices that either decreased or increased the level of energy consumption, which decreased or increased the rebound effects, respectively.
    - Energy saving in the household was negotiated among various household members with mixed outcomes for the resulting decisions on energy consumption. Power relations and styles of conflict resolution within the family determined whether the household, as a whole, adopted routines that increased or decreased rebound effects.

RECOMMENDATIONS

Based on our findings, we recommend:

- increasing the visibility of savings,
- encouraging the reinvestment of savings in further efficiency improvements,
- making sure that the energy-saving technology is working as intended after being embedded in the user's everyday life,
- avoiding misconceptions connected to past values and norms, which could be perceived as a resource instead of a rule, and
- supporting within-family negotiations in ways that increase the likelihood of making choices that save energy.

INTRODUCTION

Energy efficiency is an attractive way to battle against climate change because it allows most people to maintain their lifestyle while reducing the negative impact on the environment. This has become part of many energy policies of the last few decades. In Norway, for example, there has been a focus on convincing people to implement efficiency improvements on the household level, often in the form of technological solutions and efforts toward behavioural change. In particular, an important ingredient in the buildings monitored by the Norwegian Research Centre on Zero Emission is to create energy savings that do not compromise the quality of the living or work environment. Energy efficiency is the main means to reach this goal.

Climate change is not the only factor affecting the energy situation in Norway. Due to a more restrictive hydropower development policy and the occasional shutdown of several Swedish nuclear plants for maintenance reasons, certain regions have witnessed the emergence of higher electricity costs for both consumer and industry alike, moving the country into what many perceive as an energy crisis[1]. Motivated by various reasons, political leaders have increasingly focused on energy efficiency, and even the general public has begun to recognise, with some reluctance, the importance of saving energy (Aune & Berker 2007). Thus, energy efficiency is seen as a central solution to problems related to energy provision and consumption.

Since the 1990s, private per capita energy consumption in Norway has stabilised and is even decreasing slowly. The exact combination and relative weight of responsible factors are unknown. However, according to research in other countries, factors that reduce electricity consumption include the improved energy efficiency of electrical appliances and building envelopes, whereas factors that increase consumption include having more households with fewer members and more individual technologies (Simon 2008). An estimate of the relative weight of different factors in Norway was recently proposed by Hille et al. (2011).

Compounding the complexity of these trends are paradoxical effects that have been known as rebound, takeback and backfire effects. These terms, which origins go back to the last century and beyond, were coined by English economist William Stanley Jevons in 1865. Later known as the Jevons' paradox, the idea was based on the assumption that more efficient means to consume and extract coal resources in Britain (in the context of developing efficient steam engines), did not reduce the amount consumed. Rather, it would have been more efficient to increase both the consumption of coal and other economically related resources (Jevons 1865). Today, the paradox has been revived in the debate on climate change and sustainability, and if the paradox is true, it would have weighty implications. Contemporary economist Harry D. Saunders— a theorist with a focus on the paradox— has renamed the paradox the 'Khazoom-Brookes postulate' after two other contemporary economists, Len Brookes and Danial Khazoom, who are closely associated with the idea (Sorell 2009). Saunders (2000) defined the paradox to operate when "with fixed real energy prices, energy-efficiency gains […] increase energy consumption above what it would be without these gains". In general, when describing someone who ends up spending more energy at the levers of an incrementally more efficient machine, the term *rebound* effect is used.

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[1] A Norwegian energy crisis occurs in light of widespread consumer complaints about unusually high electricity prices and newspapers that report the fact extensively, without necessarily an actual shortage in supply

In this report, we take these typically (macro-) economic analyses of rebound effects as a starting point for our own empirical analysis of rebound effects in 17 Norwegian households. Whereas the motivation in previous studies was to prove and measure the effect, we chose another approach. First, we analyse how household members *made sense* of their investment in energy efficiency, looking at why they invested and how they incorporated the investments into their daily lives. We assume that these practices hold the key to understanding why rebound effects vary in strength between different households. Second, based on a conceptual redefinition of rebound effects, we describe cultural factors that have the potential to increase or decrease rebound effects. Both parts contain their own conclusion sections. Toward the end of the report, we describe recommendations in the battle against rebound effects.

DEFINING THE REBOUND EFFECT

Achieving as much as possible within a given frame is a shared ideal within the areas of economics, science, and engineering. Trying to achieve 'more' with 'less' is the essence of many engineering projects. Energy efficiency is an example of this shared ideal. Given an ever increasing political and environmental push towards lowering energy consumption with less energy to yield the same product or service, using the same amount of equipment has become the most important form of efficiency engineering (Berkhout et al. 2000).

REBOUND EFFECTS DEFINED ECONOMICALLY

In economic terms, an increase in technical efficiency makes a service cheaper to consume. Using the example of a conventional domestic heat pump, which typically consumes approximately 1.5 kWh to produce 6 kWh of electric spatial heating, the work cost of producing 6 kWh of heat is considerably reduced, given the absence of other offsetting effects. In theory, this surplus of energy and the cost related to it has been saved and may be allocated to some other need. Alternatively, the heat pump may be used to produce *more* of the same service. In the latter case, we witness a rebound effect. In economics, the rebound effect is expressed as a percentage of the potential of efficiency improvement. For example, for a heat pump that enables a 10% improvement in energy efficiency, we may have a 10% rebound effect. When the take-back exceeds 100%, it is considered a backfire.

Controversy often arises when seeking to define different forms and absolute sizes of rebound effects. According to Sorrell (2009), the rebound effect is "an umbrella term for mechanisms that reduce the potential energy savings of energy efficiency improvement initiatives". Using the earlier example, the extended usage of a heat pump may lead to a higher indoor temperature and result in a reduction of savings potential. This is called a *direct* rebound effect. However, if the usage of the heat pump remains steady with the savings potential (in kWhs) maintained at 100%, the monetary surplus could still be used on goods and services that require energy from other sources. This is called an *indirect* rebound effect. Taken together, the sum of indirect and direct rebound effects result in the so-called *economy-wide* effects that impact the overall economy.

Taking the original Jevons' paradox as an example, figure 1 illustrates the intertwined relationship between the increase in energy efficiency and the situations in which direct, indirect and economy-wide effects may take place. Sorrell (2009) outlines several ways in which the indirect effect may manifest itself. *Embodied effects* refer to the energy consumed in the process of increasing efficiency, with thermal insulation being a good example. *Re-spending effects* (briefly mentioned in the heat pump example) arise when cost savings are redirected to other goods and services that require energy for their provision. An example might money saved by domestic energy efficiency that is then spent on air travel. *Output effects* refer to the situations when improvement in energy efficiency leads to an increase in output and, in turn, an increased consumption of capital, labour and materials that themselves require energy. A good example is an energy efficient car made to go faster or farther.

Energy market effects arise when the large-scale reduction of energy consumption leads to a decrease in energy prices that, in turn, cause an increase in demand, which ultimately results in an increase in consumption. Finally, *composition effects* arise when improved energy efficiency and reduced energy prices lower the price of energy-intensive goods and services, making them a more feasible alternative to low-intensity goods and services (which would not benefit from the decline in energy cost).

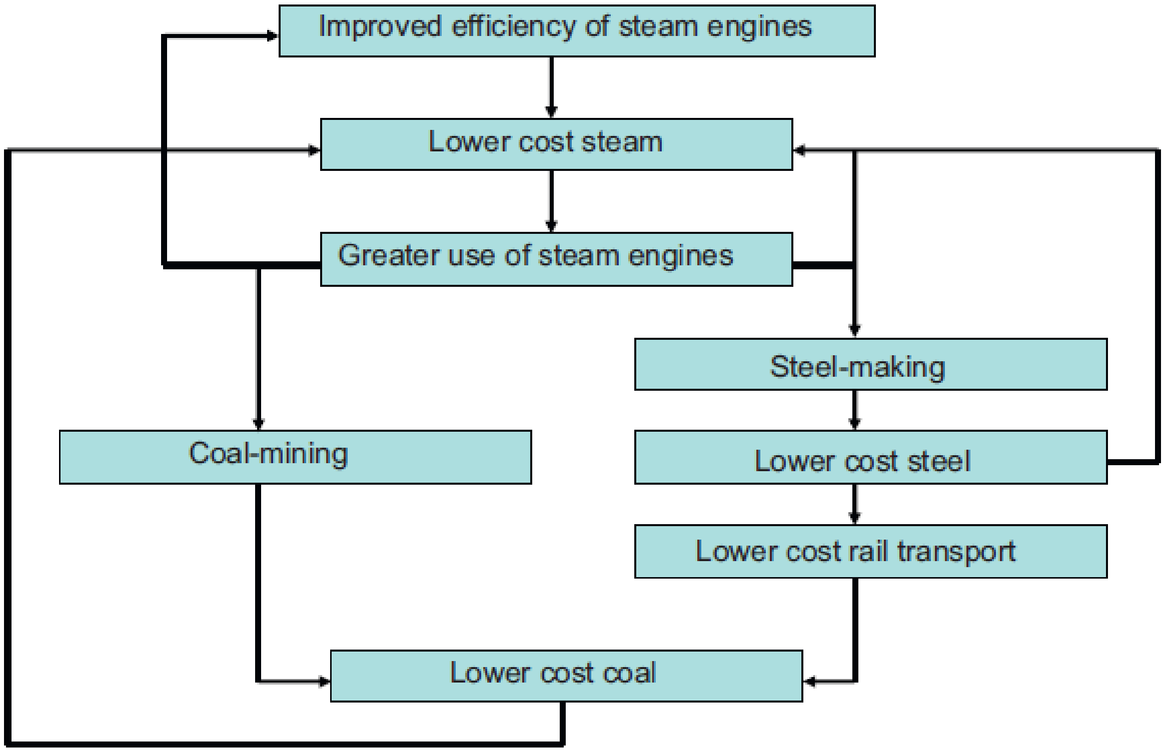

Fig. 1. **Energy efficiency, positive feedback, and economic growth (Sorrell 2009)**

According to Sorrell (2009), rather strong correlations have been observed between economic output and energy consumption, but there remains some controversy as to whether economic growth is a cause or an effect of increased energy consumption. On the one hand, 'conventional wisdom' based on growth theory suggests that growth is typically caused by technical progress and increases in the quantity and quality of capital and labour. On the other hand, ecological economists believe that the economic growth is driven primarily by an increased availability of 'high quality' energy sources. By this account, better access to higher quality energy empowers workers and increases their output, which contradicts the idea that increased productivity results from technical change.

Finally, divergent views can be found concerning the significance of the rebound effect. Sorrell (2009) argues that the use of general-purpose, more energy intensive technologies in a developing setting may pose a greater risk of rebound than the use of non-energy-intensive household technologies in developed settings. Energy focused technologies, such as thermal insulation, may also run a smaller risk for rebound because of their relatively small impact on economic growth.

Although the above quantitative estimates of factors that increase or decrease the rebound effect operate on an economy-wide level, the factors can easily be extended to the economy of individual households. The expected savings from a specific investment in energy efficiency tend to be fixed, but the resultant impact of such investment on a household would differ depending on household income levels. The assumption is that wealthy households tend to have reached a point of saturation at which it is less likely for the fixed money savings to be used for further energy consumption.

HOUSHOLD LEVEL REBOUND EFFECTS AS THE RESULT OF SOCIO-CULTURAL INTERFERENCES

It has been argued that energy in everyday life is invisible in at least two ways (Burgess and Nye 2008). First, energy is invisible due to its abstract nature. The concept of energy is difficult to grasp if not through the services powered by it. This introduces a second layer of invisibility because the exact relation between energy-powered services and the resultant energy consumption tends to be hidden behind the scenes. As a result, end-users in wealthy countries, including Norway, tend to (mis)understand energy as something ubiquitous and always readily available to power any service at any given moment as necessary. As such, energy is not easily associated with its costs (e.g., to the wallet and the environment), but is more often associated with the more or less complex deliberations spanning a broad range of concerns (Wilk and Wilhite 1985; Aune 2007, Sahakian 2010). These alternative meanings of energy and associated practices in everyday life may *interfere* with the actual energy savings achieved by a particular investment in energy efficiency. The consideration of interference yields a new set of empirical questions about rebound effects. The questions no longer concern whether rebound effects exist or how strong the effects are in economic terms, but shift toward *how* different meanings and practices influence the theoretical energy efficiency potential.

In theoretical terms, the redefinition of rebound effects is inspired by actor-network theory (ANT) and its emphasis on the fundamental indeterminacy of 'agency'. With regard to the meanings and practices within the household, how one defines rebound effects leads to fundamental differences in predictions about the direction and size of the effect. Specifically, rebound effects perceived as reliable and quantifiable may be included as a constant in any given energy efficiency calculation, such that meanings and practices "support" or "prevent" energy savings in the household. In contrast, rebound effects perceived as unpredictable may create irreducible uncertainty, resulting in "interference" (Hetherington and Law 2003).

Image 1: Interference patterns (http://preor.net/2011/04/04/%D0%BB%D0%B0%D0%BC%D0%B1%D0%B4%D0%B0/)

In ANT terminology, the difference between quantifiable influences and unpredictable interference of the theoretical energy efficiency gain in a household translates into the difference between having and not having 'agency'. Agency is defined as the ability to make a 'surprising' difference. Are there factors within households that create this kind of agency? Clearly, the meanings and practices related to energy are not completely random. Are there emerging patterns of interference that can be described qualitatively?

When rebound effects are redefined in this way, the economic rebound effect becomes a special case within a larger set of interferences that can influence the actual outcome of energy efficiency investments.

ABOUT THE STUDY

The data in this study come from in-depth interviews with 17 households who had installed energy-saving technologies to replace conventional heating methods. Five of the interviews were collected by a snowball method; the rest were drawn from a list of people who had received economic support from the Norwegian public energy management enterprise Enova SF. Among approximately 100 households who had received support, 12 agreed to take part in in-depth interviews that lasted one hour in length. Initially, the study focused solely on heat pumps owners. As the study progressed, we decided to include participants in any kind of energy efficiency improvement initiative, given that the rebound effect is equally likely to appear regardless of technology type.

Six respondents owned air-to-air heat pumps, two owned air-to-water heat pumps (used for floor and water based heating), and three owned geothermal, earth-to-water heat pumps (water used for both floor and warm water heating). Other respondents had invested in centralised energy control systems (one owned conventional space heaters, one owned centralised heating ovens, and one owned a water-based floor heating system), pellets ovens (2 cases), and one owned a modern wood stove. One respondent also owned two electric vehicles, which were beyond the scope of this study but provided additional insights into rebound effects. Of the 12 interviews, five were conducted with two adult members of the household and twelve were conducted with a single household representative.

In line with the theoretical approach outlined above, the goal of this study was not to adjudicate whether the rebound effect existed or not, but rather to explore the everyday energy practices and meanings ascribed to energy and examine how they interfere with potential energy savings. Due to time constraints, the actual energy consumption of the interviewed households was recorded only qualitatively based on information from the respondents. This information, however, represents the accuracy of interviewee's knowledge rather than the exact consumption level.

Even if the data regarding actual energy consumption were available, they would have to be analysed with care. The complex web of cause-and-effect relationships in rebound effects is too complex to describe in a simple way. Instead, we focus on highlighting conditions in which rebound effects are likely to arise, instead of debating about its absolute size.

To discover the conditions conducive to rebound effects, we asked respondents about their commitment to the environment, energy practices, energy technologies, and their relationship to the energy bill and their energy supplier/utility company.

FINDINGS

In the presentation of our findings, we begin with a description of the ways respondents interpreted the factors relevant to rebound effects defined in economic terms. In a second part, we extend the range of our observations to the social and cultural factors that interfered with the actual energy efficiency of the household on a more basic level.

THE MEANING OF ENERGY-SAVING TECHNOLOGIES

THE PROCUREMENT OF ENERGY EFFICIENT TECHNOLOGIES

In the past years, electricity prices in Norway have been steadily increasing. This increase in prices, combined with the fact that the two previous winters were, on average, much colder than usual, has seen many consumers receive very high electric bills. In response, many consumers began to consider the possibilities of energy conservation. In fact, energy conservation has been a topic in Norway for several decades. In 2001, the Norwegian government appointed a special government enterprise called Enova to improve energy efficiency on the consumer level. Measures included providing support to consumers in the form of funds to implement energy efficient technologies, such as heat-pumps, centralised control systems, and pellets ovens.

In line with an evaluation of the ENOVA program, in which most of our sample had enrolled (ENOVA 2010), the majority of our respondents reported that this support had little or no influence on their decision to invest in more efficient technology. Our respondents would typically learn about the program incidentally after making the investment, and only then did they claim the money.

Increased energy prices constituted the most frequently cited and important reason for our interviewees to turn toward energy efficiency. Other important factors cited almost as frequently included the desire to keep a good conscience regarding the environment while maintaining a comfortable lifestyle. Some of the respondents were quite well off, with an above-average income or were in later, more economically stable stages of life. Consistently, we observed that the older and more economically/socially stable respondents were, the more they invested in energy efficiency measures. Respondents who were not as wealthy[2] were much more concerned with the investment paying itself off, economically speaking. As a family man in his thirties stated, energy saving was about the “ability to afford it, and the economy part was a large obstacle”. The choices for these households usually comprised pellet ovens or wall-mounted air-to-air heat pumps, priced in the range of €2-3000. In comparison, the usual choice for our wealthier respondents (often well-off households of 2 to 4 residents that included parents in their 50s or 60s and some with children still at home) was the geothermal heat-pump, which is the most efficient alternative, but also the most expensive. Respondents with this variant of the heat pump expected to break even in about ten years given current energy prices, which they also expected to rise in the future. In these cases, the need to upgrade an oil-based heating system provided additional motivation to invest in energy efficiency.

When asked whether such a costly investment was motivated by economic or an environmental incentives, most people answered a little of both, depending on their life situation. This quote reflects the typical sentiment:

[2] There was no indication that any interviewee had a below-average income.

"[it's] seventy-thirty [economy-environment]. However, then it's more the environment after a while. Because as you mature, and become better off, you begin to enter a certain stage and you make more than you had earlier, your mortgage is lower, your car loan's been paid off, your student loan's been paid off, all that, you know, you get more money, and it's clear that the more you have, the more the pendulum swings from being just economically related to being more about the environment. You can actually afford to be more environmentally friendly."

SAVING MONEY? OR REALISING OTHER BENEFITS?

Most of the wealthier respondents who implemented the most expensive and efficient measures claimed they had not made any changes to their behavioural patterns after improving efficiency, and most of them reported not using more of the same service despite the reduced cost. However, the vast energy savings (in kWh consumed) that often results from the implemented technology might create a situation where it would be quite easy to take out a greater effect. Still, the energy bill would mostly look the same, a fact related to increased prices and colder winters. As one respondent put it

"Well it makes you angry. When you see that the number of kWhs is reduced by half, but the bill is the same? Then, ok. Thank you very much. As I tell the missus, because she says that well, we aren't getting a smaller bill, no that's right; we aren't getting any smaller bills. But if we hadn't performed that [improving efficiency], then the bill would have been twice as large."

Thus, strictly in monetary terms, the improvement enabled the households only to keep a status quo with regards to heat service consumption in light of the energy prices. Another respondent who also claimed that the installation of a geothermal heat pump reduced his energy consumption by half talked about his electricity bill as follows:

"Well, no, I was disappointed about the electricity bill, but that's because the price of electricity has gone up so much. So no great euphoria, but by a sober-minded analysis that was as a result of high electricity prices, and not the consumption itself"

Most of the informants shared the same opinion. However, the above quoted informant later on blatantly admits that his earlier statement might not be entirely true:

"We do take out an effect, that I can say, we take out an effect in that we keep a slightly higher temperature, and fire up the whole house. Before we used to close off [...] several rooms and such, we closed them off during the winter, just open them for Christmas, you know. However, with these large radiators... when it's like that, then we just keep them open. That luxury we allow ourselves. [...] And my wife is very happy about it. She likes to be bare footed and lightly dressed."

In the example of yet another household, the informant admitted that the efficiency improvement was implemented mainly to *maintain* the high level of comfort in the house *while* using less energy and that economically speaking, saving money (relative to earlier electricity expenditures) was not the real issue.

"Economically, it was pretty much so-so, as we saw it, because we had not actually expected to save that much. However, the environment, I guess, is the winner in our account, and at the same time it [the geothermal heat pump] is a very robust and good solution in the long run for us. [...] We want a high level of comfort, but I don't want to say that we, because of the new system, spend any more, that we increased our level of comfort; we haven't performed it to use more heating energy than before. However, we do get at least the same comfort for half the cost."

In this case, the use of “at least” here suggests that slight increases in heat consumption posed less concern than before, which further reinforced a relaxed attitude with regards to the energy consumption behaviour in the household.

THE ROLE OF THE TECHNOLOGY

One informant who implemented a centralised control system for his heat radiators (connected to a central heating system[3]) had the option of programming his house heating in accordance with household activities and the outside temperature. This, he stated, increased the comfort level in the sense that the heating took care of itself:

“I’m pleased with having installed the new control system. Though I haven’t... I don’t think we’ve seen a very great effect, but at least it... it provides a higher comfort level.”

However, in relation to the electricity bill, the sudden implementation of a new technological system apparently demanded a period of house-breaking, as suggested by the respondent’s comment that energy consumption immediately rose above previous levels.

“Comfort is the greatest effect thus far. What I’ve seen, actually at first [...] the consumption rose. However, we had set the temperature to a comfortable level. And we hardly used fire wood. So we had sort of like a breaking-in period this winter, when we taught ourselves how to use the system. I’d just set it too high. […] instead of heating with wood, everything went on the central heating.

In this case, to accomplish any savings, the informant actually had to reduce the level of the system, complement it with fire wood, and avoid consuming more than before.

This problem was also evident in the case of another informant who had implemented a slightly different centralised control system. This household was in the process of refurbishing the bathrooms. After installing the floor-heating, the respondent wanted to avoid heating the floor unnecessarily (i.e., during the night and daytime). Thus, they installed the control system for the whole house and connected it to the existing panel ovens around the house as well. However, this system was not as maintenance-free as he had expected. On the contrary, the respondent complained that the fluctuation of the outside temperature, in general and in connection with the changing seasons, made it very difficult to predict the optimal temperature level at which he should set the system. Furthermore, it was near impossible to manage the lowering of the system at night, because the time window for switching the ovens back on to make for a comfortable morning temperature would incessantly and unpredictably vary. This also led to a house-breaking period involving experimentation with the system. However, it was not easy to keep the system at an optimal level. When asked how he would resolve his issues, he replied:

“Well no, I don’t then, do I? A lot of this is just physics, so there’s not a lot you can do about it. There are things, as you say, you need to adjust the times for when it switches on, so there’s a lot of trial and error. And it’s not just adjusting it, you need to make some “guesstimations”, and you’d go: well maybe four hours is enough, maybe we can try three? And then it got cold. The other is, well pretty straight forward, that you get up at quarter to seven and throw four or five good logs of birch in the fire-place, and that would lift the temperature,

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[3] Central heating prices per kWh are kept at around the same level as electricity prices.

in about a half hour. But that's not, I didn't buy the control system so I could light the fire place every day, did I?"

Clearly, this was not an optimal solution for this household; despite reductions in the energy cost, it certainly did not make solving the heating issues any easier. Furthermore, given that the optimal functioning of the system requires a constant, manual submission of a rather large amount of data at rather short intervals, making the adjustments may become too cumbersome after a while. One could imagine that the system might simply be left at a rather comfortable but somewhat inefficient level, providing another example of a failed domestication process.

However, in the more successful examples mentioned earlier, the often large perceived savings in energy consumption, though not very tangible in monetary terms, seemingly allowed some of the respondents to conscientiously continue their relaxed, comfort-oriented patterns of energy consumption. In some instances, these patterns was augmented by the technology itself having the ability to adapt based on pre-programmed settings or to automatically maintain the optimal working conditions by taking into account climate variations and household activities. These factors reinforce the feeling that "enough has been performed" with regards to energy consumption and efficiency improvement.

A GENERAL FEELING OF SURPLUS

Still, there were times when a monetary surplus was not diminished entirely by the unusually cold weather, steep prices, or the offset of investment costs and maintenance. In such cases, people could be expected to expend this surplus in other, direct and in-direct, energy consuming ways.

However, according to our respondents, this surplus was often too small to be of any significance, especially in the context of the economic situation of the entire household. The complex everyday patterns of cash flow tended to make the eventual surplus, at least among the households interviewed, all but visible. This was true even of the respondents who reported keeping a relatively tight inventory. The only area in which a tangible surplus was reported was in the case of the respondent who was also an electric vehicle owner (which, strictly speaking, falls beyond the scope of this study). Here, the gap between the fuel costs for the different types of vehicles was just too large to go unnoticed. However, when asked more generally about the everyday situation after implementing a medium-to-large efficiency improvement, it is clear that the investment produced more of a *feeling* that one was better off compared to before the improvement was made. This *feeling* could arise due to a number of reasons. For example, investments are often inevitable in that they replaced older systems that had to be replaced anyway or that they were implemented as part of a general refurbishing process. Additionally, investments in energy efficiency are perceived to increase the value of the property and to fend off ever-growing energy prices (for a while, at least). Furthermore, the technology may seem *so efficient* that it creates a sense of *maximum accomplishment*, which renders the large expenditure on energy costs in the household economy virtually a non-issue, while the significance of the costs for an everyday breadwinner is not to be underestimated:

"We are concerned with keeping it as comfortable as possible, so now when we've got this new system controlling itself, and even correcting for the colder periods, then of course we have achieved a very high level of comfort. And at the same time we might say it's sensible and in any case comfortable, that it manages itself. And we do want a robust system that makes it comfortable for us. And if we at the same time are able to reduce the energy, well that's wonderful I think. Reading the meter has been a pleasure of late."

Without question, although it is difficult to attach any numbers to the cash surplus, it is apparent that the general feeling of economic spaciousness is enhanced somewhat. This feeling, in turn, contributes to the general movement in life that many people in this particular situation have seen happening for a long time (which further complicates the attempt to pin down the rebound effect): people are steadily becoming better off. Because of this increasing income, it is difficult to pinpoint exactly where the surplus arising from energy improvements tends to be spent. However, when asked directly where the surplus from saving energy would go, typical answers included home improvement, travel, and leisure activities, which would most likely represent an economic rebound effects. Nonetheless, there were some examples that involved a surplus used to save even more energy.

For example, when asked where his savings went, one respondent said it went to further improve the energy efficiency of his cabin in the mountains. Specifically, he removed the 240V electricity installation and replaced it with 12V solar electricity and state-of-the-art wooden stoves and was also experimenting with a tubing system in the construction to exploit the heat from underneath the ceiling by funnelling it down into the floor. Furthermore:

"And we will do it with an annex [4] we're building next to the cabin; it's constructed without any other source of electricity than what you get from the sun. And also there will be a wind generator there. A little high-tech, you know, he-he."

In this case, at least some of the surplus has been utilised for lowering the overall spare-time carbon footprint of the entire family. For this respondent, who was a gadget and technology enthusiast, the process was enjoyed as a challenge. In a few other cases, savings were often spent on making the house more efficient, with projects either planned or under way to replace the windows or the insulation.

SUMMARY: THE MEANING OF ENERGY SAVING IN EVERYDAY LIFE

Rising energy prices and colder weather seems to be two of the most important factors that motivate efforts to increase energy efficiency. Respondents reported that Enova funding, despite being a welcome measure, was not substantial enough to become a factor in their decision making. Many respondents claimed the funds after deciding to make the investment. Furthermore, the decision to procure energy efficiency improvements was based on both environmental issues and the economic situation of the household. In this regard, being idealistic often required a solid economy, thus isolating the procurement of expensive technological improvements to our older and wealthier respondents.

In terms of saving money as a result of efficiency improvements, even though respondents could observe that the use of kWhs was reduced on the bill, there was no corresponding reduction in cost. This was even truer of those who implemented the most drastic technologies (e.g., geothermal heat pumps), which reduced energy usage by nearly half in some cases. In these cases, the greatest impact of implementing energy efficiency technologies was to allow households to uphold a status quo of energy cost and energy practice. The less drastic improvements simply contributed to a bill that was "lower than what it might have been". In terms of rebound effects, this might create meagre conditions for squandering away energy-saving potential. Respondents who implemented the most energy efficient technologies, such as geothermal heat pumps, seemed more prone to allow rebound effects, which was likely because the investments had replaced very old systems (e.g., oil heating kettles) that were very expensive to operate in the first place. It is reasonable for a vast incremental improvement, as opposed to replacing an already cost-efficient and newer system, to allow

[4] As the family of a cabin owner grows larger, it is common to construct small annex-houses in the immediate vicinity of the main dwelling to accommodate the increase in the number of family members.

for greater rebound. In terms of energy efficiency, going from bad to good, as opposed to going from decent to good, may create a larger potential for small allowances in behavioural change to create greater rebound effects. Even worse, respondents who implemented the most energy efficient technologies, such as the geothermal heat pump, also seemed to have the most relaxed relationship to their household's energy consumption, perhaps because of higher income, but also because the equipment installed seemed so much more efficient compared to the one replaced. The gain in efficiency created a sense of maximum accomplishment, which made trifle and minute energy-saving behaviour feel pointless and redundant.

With regard to coping with new technology in the household, it was clear that those who had installed centralised control systems often reported difficulties with breakdowns in their equipment. As a result, the systems were not being used to their full potential and there was an increased risk of the systems becoming redundant. In contrast, some of the geothermal heat pumps could be programmed to self-adjust based on outside conditions. The least problematic were the air-to-air versions, which were likely to yield substantial effects even if the user did not make use of the full range of built-in functionalities.

As mentioned earlier, none of the respondents reported that implementing energy efficiency technologies gave them a tangible monetary surplus that they would be able to spend on other things (and, thus, create indirect rebounds). However, a closer inspection of the economies of our respondents may reveal some accumulation of a monetary surplus. After all, the respondents were clearly cutting back on consumption and several respondents reported a feeling of economic wellbeing as a result of their efficiency improvements. To explain this ambivalent scenario, four offsetting factors were discovered:

- Offset by investment cost. The investment cost often takes five to ten years to pay off, which makes monetary savings feel less tangible.
- Offset by price elasticity. Growing electricity prices and colder weather eat up savings.
- Offset by ratio. Compared to the overall household economy, the savings disappear.
- Offset by re-investment. Savings are cycled back into general refurbishing projects that often involve energy efficiency improvement.

Importantly, the last point is not really an offsetting factor but is, in fact, a rebound effect. To be precise and to follow Sorrell (2009), it is a re-spending effect that arises when cost savings are spent by consumers on other goods and services requiring energy for their provision. In this case, savings become invisible as the efficiency improvement is entangled in the typically continuous and more general home improvement projects common to many households, some of which may increase energy consumption, while some may decrease it.

In our sample, these offsetting factors were distributed differently across respondents, and not all of them had to be present at once. Some respondents experienced feelings of hopelessness in the face of the offset; though they had performed everything they could, the electricity bill still looked the same. Others felt more optimistic, that they could have been worse off, with those respondents who invested in the most drastic efficiency improvements more frequently reporting a feeling of economic freedom.

SOCIO-CULTURAL FACTORS INTERFERING WITH ENERGY-SAVING INVESTMENTS

In this section, we provide in-depth descriptions of three factors that are able to both increase and decrease rebound effects.

LIVING PRE-OIL VALUES TODAY

Another set of attitudes towards energy consumption was observed among respondents who conserved energy as a part of their lifestyle, thus developing behavioural patterns that often worked towards saving energy.

In some cases, the energy conserving behaviour was related to a concrete wish to reduce energy cost. In other cases, the causality went the other way. For example, one respondent commented that she simply employed a sober-minded lifestyle due to her strong and inherent belief that wastefulness was bad in general, which allowed her to *enjoy* a relatively ascetic life based on feelings of sensibility and conscientiousness regarding consumption. For this respondent, the success in adhering to her values gave her a sense of accomplishment and well-being. For instance, when tending the garden, the respondent would gather the refuse and use it as fire wood:

"I think it's fun, while tending the garden I gather the wood so I can use something which I have produced myself, I find it satisfying. It feels like a prize, a reward. It feels like being in command, how shall I put it, it strengthens the self-image. To be able to use energy that I have taken part in producing myself. [...] It's as much for the feeling, actually. Because it feels very right, in a value-oriented way. […] in a way I reap what I've sown. That the result of the garden work is not just the garden itself or lots of refuse in a trash bag, but that it leads to something which one can enjoy."

When travelling, the respondent reported enjoying taking the bus to work, which allowed her to peacefully enjoy the morning paper and escape the rush of traffic. She felt that it was "comfortable and practical" and relieved her of the need to own a car. With work-related travel, the respondent (who worked as an energy consultant at an engineering company) admitted that the demands changed in the context of her job and that it was often important to reach destinations quickly and not to risk wasting her employer's time. However, when travelling in her spare time (something that she enjoyed a lot), the respondent liked to travel slowly, and, as she rather poetically described, "allow the soul to come along:"

"Travelling privately, when I'm on vacation in my spare time, I like the journey to be part of the holiday experience. So then I can take the time, and I like to travel so I can see more than I do from a plane when it's clouded over. And the soul is allowed to come along. I love to take the train."

In terms of material consumption, this respondent was quite adamant about not wasting, but admitted that a sense of guilt when she, at times, had to throw away rotten food. However, in this regard, she emphasised that "it would really have to be ruined, I don't throw it away just because the date says it's overdue." To this respondent, wastefulness was irritating and hard to justify. She attributes her values to her upbringing:

"I belong to a generation that's been brought up to not throw away food. Not to throw it away, and not to play with it. It's in the upbringing. So it's a defeat every time I have to throw away food."

When it came to the electricity bill, she saw payment as inevitable. She felt that her sober-minded lifestyle provided her with a stable and robust personal economy and that she never had any problems paying for her electricity consumption.

"That's just how it is living in Norway. [...] and through my work I've learnt that we actually have quite cheap electricity in Norway. And we use a lot of it, and live in quite spacious houses, so I think I just have to live with that, and I have to pay for that. Just accept that it's one of the major items on the budget. That's just the way it is."

With regards to her *energy* consumption, she admitted that the bill encouraged her to "be on the offensive" about substituting electric heating in the coldest winter months with fire wood and to keep temperatures down when she was not at home. She had no qualms about coming home to 15 degrees and putting on a sweater until the house was heated again. She compared herself to her grandfather, who had lived in the same house (at a different point in history) that she was in and commented that "it's a question of what kind of lifestyle you have, and what standards you keep." To sum it up, this respondent was quite confident that her lifestyle, being as ascetic as it was in terms of energy consumption, was quite energy efficient. She had, in a sense, indirectly achieved a feeling of maximum accomplishment by proxy of an inherently carbon-friendly lifestyle.

On several occasions, this respondent referred to the past as an inspiration for energy saving. Practices such as wearing more clothes rather than cranking up the thermostat would likely result in a welcome amplification of the technical efficiency potential of heat pumps or similar investments. References to one's 'upbringing' or to the 'grandparents' in the Norwegian context are implicit references to the poor past of the country before oil exports made it a wealthy nation. Today, these references signal value orientations that influence the amount of energy consumption.

A less beneficial influence of the same poorer past may be observed (as demonstrated in some of the earlier examples) when the surplus is spent on achieving more comfort, which reduces the effect of the energy-saving investment. Being able to 'fire up the whole house' in a cold country like Norway is an immediate and important improvement of domestic life. The idea fits well into an overarching trend of the ever-increasing heated floor area in Norwegian homes, a development closely related to the electrification of residential heating systems in the country since the 1960s. However, the idea also has a special ring within Norwegian culture, which (not surprisingly, given the cold climate) celebrates having a warm and cosy home (Wilhite et al. 1996).

A BUSY EVERYDAY LIFE

Another example that stood out was the lifestyle choices made by a family of four—, choices that were not made necessarily to conserve energy but incidentally led to environmentally friendly outcomes. The direct measures made to improve energy efficiency included re-insulating and installing a wall mounted air-to-air heat pump, which were likely adopted with energy consumption and the resulting electricity bill in mind. More interestingly, however, showing all the signs of keeping with the "waste not" values characterising the previous respondent, this family was concerned with the avoidance of over-consumption. For example, the younger child was allowed to inherit clothes from the older one, and children were encouraged to swap toys or bicycles that were no longer of use with their neighbours. According to both parents, these acts were motivated by values that they had been taught in their own upbringing. In particular, the most striking facet of their everyday life was that even though the family members had an intense level of activity (with different kinds of sports and afterschool activities that went on nearly every day of the week and engaged the whole family at once), the family got by with having just one car. As the respondents did admit, the one car, was utterly necessary and that they were well aware that their lives would be considerably simpler if they had another one. Still, though they could afford a second car, they did not procure it. To function with just one car, the family made a weekly plan every Sunday by planning and coordinating every single movement of the family members during the upcoming week. Unsurprisingly, the respondents talked a lot about *logistics*.

[Him:] "Well, it demands more of us as parents, actually."
[Her:] "Yeah, we need a weekly planner, who picks up, who brings, we need that to be settled on Sundays."
[Him:] "And we've begun to plan our dinners, after New Year's, and we keep a blackboard in the kitchen, where we put up our dinners for each week, and we do our shopping on Saturdays [...]
[Her:] "And we use what's in the fridge, so as not to go shopping all the time [...]
[Him:] "And that simplifies things, in addition to being environmentally friendly. Because you drive a lot less, because you usually need to drive a ways to go shopping, so…"
[Her:] "And we changed our nursery school, to a closer one […] and to be honest, that's not on account of the environment, it's more to make the logistics add up, because we've got one in school and one in nursery. And us at work, so… […] but you need to have the logistics ready, everything has to be prepared on Sundays. Who picks up, who brings, where to, and we have a weekly planner hanging on the wall, bam, bam, bam. That's the way it's got to be. Don't you have kids?

After the above exchange, the parents proceeded to demonstrate how the planner was set up, how clothes for the next day had been already laid out (as the interview was conducted in the evening), and how everything was timed down to the last detail (or, in fact, not, as the planners did not include "regular events", as revealed by the phrase "swimming, handball, soccer, and the like."

This kind of intense planning, leaving nothing to chance and always following the most efficient way of getting through a day's activities, may have its own effect in improving the overall energy efficiency of the family. This way of living, of never going anywhere empty-handed, seemed to have provide the parents with an enormous sense of well-being that resembles, again, a state of maximum accomplishment. Upon receiving their electricity bill, they merely checked the numbers to make sure that that it was not too far off from their predictions based on their gut feeling for that period before proceeding to pay the bill without any further ado. Their point of departure was simply "that we don't waste energy." When pressed further on the question of how they could possibly conserve even more energy, the respondents replied that it would be quite impossible without cutting down on the more vital activities of the household, such as washing clothes and cooking food.

The energy-saving potential resulting from the rigid timetable followed by this family becomes particularly clear if we consider an option that the family did admit to be a tempting (and affordable) alternative. Specifically, a second car would give the family less pressure to plan and create pockets of flexibility.

WITHIN-HOUSEHOLD NEGOTIATIONS

A common story told by families with children is that their children are often introduced to electricity saving and waste sorting at school. Based on the interviews, this influence has had some effect on the household in general, especially when parents agree, in principle, with the need for environmentally sound behaviour but forget to include such behaviour in their daily routines. It is expected for children to have less say when it comes to a real disagreement. For this reason, the influence of the child on household energy saving tends to be limited.

A second kind of story involving within-family negotiations that came up in several interviews related to gender differences in the adult family members. For instance, in one case, we were told that the male interviewee had positioned bulky convection ovens everywhere in the home. Despite agreeing with his wife that they the ovens were 'ugly as hell', he ignored her protests. Another contention revolved around women needing higher indoor temperatures. Nonetheless, our sample contained too few couples interviewed together to confirm the reality of these classical gender stereotypes. Still, we can state that they were reported repeatedly. Regardless of the actual distribution among men and women, it is reasonable to assume that there are different needs and expectations related to aesthetics and indoor environmental conditions that may very well interfere with the energy consumption of a household. The outcome of negotiations between these different positions depends on the power relations within a specific household. For example, one respondent described how he had installed low-flow shower heads to save energy. With a smile, he explained that he was the only person in the house who did not need to wash his hair (because he was bald) whereas his wife and daughters struggled to get their hair clean after the installation. In this case, the domestic power relations apparently allowed him to force an energy-saving option on the other members of the household. An ideal of domestic democracy, which appears to be the norm at least in Scandinavia, creates a completely different situation, as observed in cases in which the need of respondents' teenage children for long and hot showers led to the need for considerably increased boiler temperatures.

A third and final interfering aspect of domestic negotiations that we encountered in the interviews was related to illness and old age. For example, an interviewee who, otherwise, clearly demonstrated the sober pre-oil lifestyle described earlier, found himself needing extraordinarily high indoor temperatures because of his wife who had recently undergone a severe cancer operation. His energy-saving investments were quickly offset by this unforeseen event that trumped every other concern.

SUMMARY: SOCIO-CULTURAL FACTORS IDENTIFIED AS INTERFERING WITH ENERGY CONSUMPTION

We found many examples in which households were the locale of ongoing negotiations, which produced outcomes that interfered with energy consumption. Above all, two types of negotiations stood out:

Tensions between the longue durée[5] and the present: The contrast between the enduring values and needs from the past and the possibilities and demands of the present creates a tension that is resolved in different ways by different households. In two of the cases presented here, our respondents resolved this tension in favour of a low-consumption lifestyle. One of them, the family of four, however, also shows how current demands for an active family life can force household members into sacrificing flexibility that they actually could afford.

Inner-domestic tensions: A second type of negotiations that interferes with energy consumption was observed among household members. We observed children trying to influence adults, divergent demands within the group of adults, and the influence of special groups like adolescents and old members who, in some cases (depending on power relations within the household), led to larger energy use for all household members. We have shown how these negotiations were influenced by the (absent) norms of democracy within the family and gender roles and stereotypes. In this sense, the web of personal relations in a household interferes with energy consumption and creates distinct interference patterns.

[5] The historian Fernand Braudel (1980, 1992) used *longue durée* in reference to structures that show a particular resistance against change. In his history of early modern Mediterranean regions, he found these structures connected to slowly changing climate, geology, geography, and large technical infrastructures.

RECOMMENDATIONS FOR COMBATING THE REBOUND EFFECT

Based on the findings of this study, we believe that the locus of the challenge regarding the rebound effect lies within the black box of what people do with energy in their homes and in their everyday practices. Therefore, most of the suggestions following our glimpse into this black box are based on awareness. However, raising awareness can be achieved using concrete methods, and some suggestions to impact what goes on in the black box are as follows:

- **Making saving visible**: One problem that our respondents often had was that they did not feel that the energy-saving technology provided them with an economic surplus (due to the point discussed earlier). Raising users' awareness of how much *energy* is being saved, and how much they otherwise would *not* save, might help to make investments to improve energy efficiency a more worthwhile experience and the ever-increasing energy prices easier to accept. Making the invisible surplus (provided that it exists) visible is the first step that prevents users from inadvertently using the surplus elsewhere and creating indirect rebound effects.

- **Re-investment in energy efficiency**: Of the responses regarding what economic surplus would be used on if realised, further energy efficiency improvements were the only re-investment item that did not result in immediate rebound effects. Therefore we recommend programs that encourage earmarking money saved for energy efficiency improvement efforts.

- **Technology**: Difficulties with integrating the technology into a user's everyday life can have a catastrophic effect on the intended outcome of the technologies. In the best case scenario, patterns of unintended use may lead to non-use of the energy efficiency investment, but could easily also lead to rebound effects.

- **The past as a resource for savings in the present**: The single largest non-technical way to realise and even exceed technical efficiency potentials was found in the enduring values of low-consumption from the past. However, the past can also interfere in ways that make rebound effects more likely. Energy efficiency investments have focused too much on the new and the future. Persistent structures from the past have not received the attention that they deserve, especially as a resource in the battle against rebound effects.

- **Engaging in inner-household negotiations**: Within-household (often within-family) negotiations should be supported in ways that increase the likelihood of energy efficient choices.

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