# The Wrench in the Works: Household Behavior and Why Energy Efficient Buildings are not Enough

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## ABSTRACT

In many countries around the world there is a shift towards constructing more energy efficient buildings. Research shows that the buildings have better energy performance but still are not reaching the overall targets of reduced energy consumption. Household electricity use in low energy buildings is similar to that in conventional buildings. If the buildings are getting better, then what is missing from the equation? The aim of this study is to introduce a model called *energy order* which can be used to analyze how people living in low energy buildings actually conduct their everyday activities. A more specific objective is to look at the use of household appliances and their role in everyday life.

Interviews have been conducted with people living in low energy apartments classified as passive houses. The passive house concept focuses on a tight building envelope, appliances and people's activities in the home as important means of maintaining a comfortable indoor temperature. The interviews concentrate on the use of household appliances, in particular white goods. Results show that reducing energy consumption is usually not a priority in the households studied, and hence low energy buildings are not as successful energy wise as anticipated. The main reason is that the household members rarely think actively about lowering energy consumption and thus fail to recognize their own role in the system. Also, various restrictions prevent people in these households from making better energy choices.

## Introduction

Low energy buildings are becoming more popular all around the world. One type of low energy building is the passive house, a building concept that is gaining popularity in many countries and has proved successful in its country of origin, Germany. Passive houses have also been built in cooler climates and are currently getting a great deal of attention in Sweden. However, there are skeptics who state that passive houses do not reach their over-all energy goals and that it would be better from an energy systems perspective to build houses according to conventional methods and focus instead on the energy supply (Joelsson, 2008).

When comparing energy use in passive houses to that in conventional ones, the passive houses have indeed not proven to use less energy overall if household electricity use is considered (Isaksson, 2009; Green, 2006). This has been the case in many newly built passive house apartment blocks in Sweden, and the question is, why does overall energy use not decrease as anticipated? The building constructions are of high quality and they perform better energy wise compared to conventional buildings, but household energy use does not go down in them, despite of the more energy efficient appliances and energy systems. One reason could be that the predictions on energy use have been too optimistic regarding the role of the household. Calculations are therefore based on some form of standard household energy behavior that might not correspond to household energy use in reality (Ruud & Lundin, 2004; Green, 2006). For example, household energy use in two newly built apartment blocks where one was of passive house standard and the other of regular building standard was measured. The household electricity use was basically equal in the two buildings, at 50 $kWh/m^2$ in the passive house and 52 $kWh/m^2$ in the regular one over one year (Finnvedsbostäder, 2008).

Another reason that could explain why household electricity use in passive houses is not lower than that in regular houses is the increasing number of appliances in the home, particularly appliances used for entertainment and information (Swedish Energy Agency, 2011). A third and more intriguing reason is that, when designing the houses, the builders did not realize that the energy concept itself does not encourage energy efficient behavior and that the people living in the houses do not know how their own activities affect the indoor climate. In other words, people do as they have always done, and the passive house energy concept provides only a better building envelope.

This paper is a first step towards creating a model for analysis of household activities and is part of an ongoing project on household behavior in passive houses. This model will be further developed and the results are so far tentative. The idea is to offer a suggestion on how household activities may be observed and what new insights this might bring to builders and suppliers of low energy housing. The material is based on households in passive houses but should apply equally well to any building, whether of low energy or conventional design.

## The Passive House Concept - A Socio-Technical Solution

The passive house energy concept is a way of constructing energy efficient buildings where energy losses are reduced through the creation of an air tight building envelope. Because of the well insulated building envelope, the demand for additional heating becomes low enough to make it possible to exclude a conventional heating system with radiators. Instead, solar radiation and the surplus heat generated by home appliances and the people in the household are the main sources of heating (Karresand, Molin, Persson & Åberg, 2009). Normally an air-to-air heat exchanger is used in the mechanical ventilation system of the house to extract the energy from the exhaust air and use it to heat the supply air. Due to the well insulated and air tight building envelope and the heat recovery in the ventilation system, it is possible to provide space heating with the ventilation system alone (Janson, 2010).

The passive house, in other words, is not just a technical solution, but requires human presence and activity to keep it warm. This method of building distinguishes it from the traditional way of dimensioning heat supply in a house. In an ordinary house radiators compensate for any deficiencies in air-tightness and insulation or the absence of people; the buildings are provided with as much heat as the household requires. In a passive house, however, the majority of the heating requirements are met through the interaction between appliances and people. This means that there must be some activity in the house in order for it not to become cold. In other words, a kind of balance point between activities, equipment, and people is required to maintain a comfortable indoor climate. If some appliances are on for a long time and generate heat, the indoor temperature may become too high and difficult to control without opening windows and doors to let in fresh air. The opposite may also occur, in that the air in a house that is left unattended for an extended period of time will cool down. In that case there is no quick way of getting the house warm again if no additional radiators are available, because the ventilation needs time to circulate air, and heat must first be generated before it can be recycled. The most practical behavior from a thermal comfort point of view is therefore to maintain a steady level of activity with a moderate number of appliances, and just enough activity to keep fluctuations as small as possible.

It is important to emphasize in this case that energy use where passive houses are concerned means electricity use. In colder climates additional heating in the form of district heating or pellet stoves is often used, but the general idea of the concept is that these are not needed.

## What Do We Know About Energy Use in Households?

Household energy behavior has been the focus of many studies ever since the oil crisis in the 1970's made energy awareness a topic of interest. In sociology many studies have focused on what factors and circumstances create certain types of energy behavior, for instance, attitudes towards energy efficient behavior and ecofriendliness. Since household energy use has remained at a higher level than the more energy efficient technologies of consumer goods make possible, these factors and circumstances have been studied quite extensively in recent years, including by Lutzenhiser (1993); Wilhite, Nakagami, Masuda and Yamaga (1996); Gram-Hanssen (2003); Aune (2007); and Lindén (2008). Broadly speaking, one can say that energy use varies greatly between different households, even among households that are similar. It is therefore difficult to implement energy conservation measures that are suitable for all households. The amount of electricity consumed in a household depends on many factors, and the above studies point out the various parameters that are of interest, such as age, generation, gender, socio-economic status, and culture. These have been shown to have an impact on how much electricity is used in the course of a household's daily activities. However, it is evident that people are not thinking primarily of energy saving as they go about their daily activities, probably because energy is not a product used for its own sake but only a means to carry out the activities and routines that make up people's everyday lives.

Changes in daily activities have also been in focus in research. Studies of households have contributed to our understanding of how routines and norms in, for instance, hygiene, cleanliness, comfort, and well-being have changed and evolved throughout history. An example is Mary Douglas's studies of everyday life and her classic study on dirt (Douglas, 1966). Shove (2003) has studied, among other things, the development of the Western world's view of indoor comfort, noting that technical standards often have a major impact on how new technologies are transformed into new needs and create new markets for energy-intensive technologies with associated practices. Shove shows, for instance, that the practice of washing clothes has undergone changes that are now hard to alter. We wash clothes more often, but the water is not as hot as before. The development of different elements in the practice of washing goes in opposite directions, some towards more energy consuming practices such as washing often, and some towards less energy use, such as washing in cooler water. Hence, these days, clothes are being washed based on what is considered socially acceptable (having fresh clothing) and not necessarily because the clothes are dirty. This means that practices can change, hopefully to less energy consuming ones.

## Aim of This Study

The aim of this study is to introduce a model called *energy order* which can be used to analyze household energy behavior in low energy buildings. The idea is to contextualize energy use in everyday life and find out how people within households reason when they perform daily activities. How do the inhabitants, activities, and appliances within a household together create energy orders that constitute the energy system in the passive house?

## Theoretical Framework

Household activities in relation to energy have been studied from many theoretical standpoints, among them practice theory (Shove, 2003; Gram-Hanssen, 2008). In this study the time-geographical approach has been used to illustrate household activities in relation to energy. The core of the time-geographical approach is the relationship of the individual to his or her surroundings. The physical embeddedness of various processes is important, as well as the view in which the world is regarded as a physical and concrete time-space context (Hägerstrand, 1985, 1991; Åquist, 1992). I will focus on the time-geographical concepts of *project, activities,* and *restrictions*.

The project is a central concept in time geography. In this study, examples of everyday projects are "having access to clean clothes," "making dinner," and "relaxing in front of the TV." Projects control individuals' plans or activities. Projects and activities are not the same thing, even if they sometimes coincide. A project leads to a goal and consists of a series of activities performed until the project's objective is reached. At the same time, activities can be projects and can thus be seen as projects on another level of detail. A project can exist at multiple levels and is interspersed with various tasks (Andersson, 2009). Activities in one project may also be included in other projects. The terms *project* and *activity* can be used to identify patterns of activity in everyday life and they help us see how activities are related to each other in everyday life (Ellegård & Wihlborg, 2001). This, I believe, can be used to identify how people reason about activities, and how the appliances are important in this context and in the indirect use of energy.

Restrictions are not limited to the time-space constraints that are basic in time geography; there are additional types of constraints that influence individuals' activities and projects. The *steering constraint* is based on an organizational level where rules, regulations, etc. affect the individual's access to resources; an example is the requirement to get permission to make changes in an apartment. *Coupling constraints* concern the interplay between individuals or between individuals and objects, and are affected by when, where, and how individuals need to find themselves simultaneously at the same place. These are governed by agreements, commitments, and negotiations; they may occur, for example, in a family where different family members have different tasks to perform. The last type of constraint is called a *capacity constraint* and deals with restrictions arising from humans' biological needs for food, sleep, shelter, etc. This also includes the potential of material and psychological resources such as knowledge, living conditions, etc. (Hägerstrand, 1985).

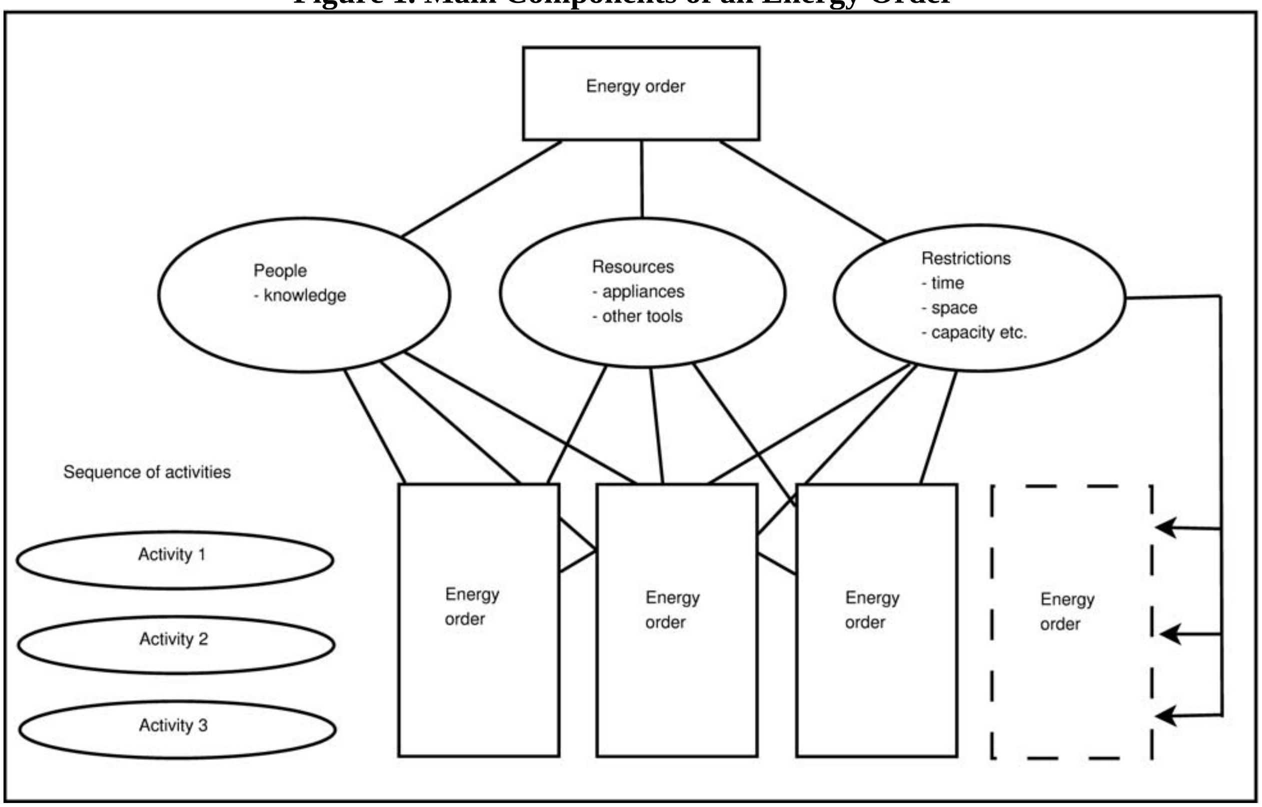
Restrictions are not the only factor influencing activities and projects; there are also opportunities connected to them, such as any options available for acting differently and the resources required to do that.

### Energy Orders

Based on project, activity, and restrictions, an energy order is an analytical model created for understanding how different activities and appliances together form routinized behavior, and what circumstances create obstacles or possibilities for changed behavior related to energy. The focus is on energy, or in this case on electricity use. However, some energy orders may in fact not include any appliances at all, which indicates that the way some projects are carried out has an impact on energy use.

Activities performed in a household are often related to each other in logical sequences so that they can be regarded as projects. For instance, the project of “cleaning the house” can consist of several different activities: clearing away items, dusting, getting out the vacuum cleaner, vacuuming, wiping off furniture, etc. Depending on the resources available, such as the type of vacuum cleaner you have or the other appliances you use while cleaning (steam cleaner, floor polisher, etc.), energy use will vary from one occasion to another and from one household to another. Resources may include appliances that run on electricity and other tools that do not require electricity, such as a dust cloth. Time may be considered both a resource and a restriction. Different types of restrictions will affect how these activities will be accomplished. Restrictions may include inadequate space for beating the rugs (should that be preferred) or physical limitations, for example back pain that makes vacuuming impossible, prompting the use of an automatic vacuum cleaner as an alternative. An energy order thus describes how activities in projects are organized by the use of appliances. Of course, not all activities necessarily involve the use of an appliance (washing clothes by hand, for example, although heating the water used does require energy), but this material has been limited to activities where appliances are used. Figure 1 illustrates this, showing the different ways of doing the same project.

**Figure 1. Main Components of an Energy Order**




People’s decisions about what appliance to use, and how to use it, will be affected by their knowledge, resources and restrictions. They decide what activities to perform in a project and how to perform each one. The different ways of realizing the project is called an energy order. Some energy orders (such as vacuuming and dusting using the vacuum cleaner) are more dependent on electricity than others (such as dusting with a cloth and cleaning floors with a mop). Restrictions will have an impact on all of the activities and on the amount of energy the particular energy order will require in the end.

An energy order may be related to a project, where a project may consist of several different energy orders. The energy order may also be seen on a higher level. If all of the different energy orders on a lower level are combined you get an energy order for the entire household.

On a more descriptive level, the project “care of clothing” will be presented below to give examples of various ways of performing household activities and what an energy order might look like. The material is based on interviews about household activities in 14 different households in passive house apartments.

### Method

The material in this study is part of a case study conducted on two public housing companies in eastern Sweden that have built passive house apartments for rent. The informants are tenants in these apartments and were first contacted via an information letter about the study and were soon afterwards contacted by telephone. A selection of apartments was made based on size of the apartment and location in the building. A total of 14 households responded positively and qualitative interviews were conducted with them. A semi-structured interview guide was used where different themes concerning every day household activities were discussed. Such themes included cooking, washing clothes, and relaxing at home. Questions asked included the following: How do you normally cook dinner? How do you prepare dinner? What appliances do you use when cooking? How many times a week and for how long do you use this appliance? All interviews took place in the informants’ homes and all household members over the age of 18 participated in the study. The interviews lasted from approximately 30 to 90 minutes. All interviews were recorded and transcribed.

The analysis has been inspired by the time-geographical approach and the analytical model or concept of energy order has been created to illustrate the variety in activities and restrictions and opportunities for changed behavior related to energy. The concept is also used to provide a structure for the themes found in the material.

## Preliminary results

The results from the study are presented in the form of energy orders. Three examples of energy orders for the project “care of clothing” are presented here to show the variety of different activities and their possible influence on energy consumption.

### Care of Clothing

The project “care of clothing” may consist of a number of different energy orders. They can be about washing clothes made of delicate fabrics, white laundry, heavily soiled laundry, drying, ironing, mangling etc. Every such order involves both activity and at least one appliance. In the case of taking care of clothes, the most frequently used appliance is the washing machine; another appliance is the clothes dryer. The following sections present some examples of activities involved when washing and drying laundry. In these examples the washing machines and dryers had been installed by the housing company that owns the apartments. They are all of the same brand and have the energy efficiency label A.[1]

**High efficiency, high energy consumption.** Maria works full time as a nurse. She has a family of three young children and a husband, who also works full time. The family lives in a two-storey, four-room passive house apartment. Maria works shifts and wants house work to run efficiently. Laundry has to be done often since one of the children is still in preschool and the two older ones are in school and are also involved in various after-school activities, such as sports. Every other day the washing machine has to be loaded and run. To supplement the pre-installed machines, Maria has bought a drying rack for clothes that cannot be tumble dried.

A normal washing routine, according to Maria, involves filling up the washing machine, always to full capacity, and choosing the hot water cycle. This means that a full load of clothes has to be dried at once, so Maria puts everything in the dryer and chooses the hottest possible cycle until all clothes are dry. She does not choose the less energy intensive eco cycle because she does not want to wait the extra time it would take to get the clothes dry. When the clothes are ready they are immediately put away.

Maria is fully aware that this highly intensive way of drying the clothes is energy consuming and probably expensive. But it is practical in her daily life, where things have to run efficiently in order to get the household organized. The family mainly uses clothes that are easy to wear and also easy to wash and dry. Maria says that all clothes have to be of the sort that can withstand tumble drying because there simply is not enough time and place to keep clothes drying on racks inside. In the summer, when the weather is nice, she does occasionally take the drying rack outside on the balcony instead. Maria notes that one advantage to drying clothes in the dryer is that it keeps the apartment warm in the winter.

**Modest energy consumption.** Will and Barbara have been retired for many years and live on the bottom floor in a three-room apartment in one of the passive house buildings. They are, in spite of old age and ailment, still very active with their hobbies and social life. They spend a lot of time at home and actively try to save energy. The washing machine and dryer have been installed in the bathroom, and both appliances are energy efficient.

The washing routine varies a lot in the household. As there are only the two of them, Will and Barbara only have to do laundry once or twice a week. The laundry is sorted according to fabrics and color, and different washing cycles are selected accordingly. The couple always chooses the eco cycle to save energy. Most of the laundry (with the exception of delicate fabrics), is dried in the dryer; the eco cycle is used here as well. In order to save energy and preserve the clothes, Will and Barbara stop the dryer halfway through the cycle and remove the clothes and hang them on a drying rack to air-dry. In summer, they always dry clothes on the drying rack on the patio.

This work-intensive way of drying laundry does save some energy but is not really their own choice, according to Will. They have to use the dryer in order to prevent the apartment from getting too humid. They would prefer not to use the dryer so much, but they feel they have to because other options are not really available.

[1] The European Union energy efficiency label classifies appliances, mainly freezers, refrigerators, washing machines, dishwashers, and TVs from A to G according to how energy efficient they are. A is the highest and most energy efficient level.

**Low energy consumption.** Jill and Dave are a young couple. Both have just finished their university degrees and started their careers as therapist and environmental engineer. They live in a two-room apartment on the top floor of a passive house building.

They do laundry two or three times a week and they always wash full machine loads. Dave has figured out that the warm eco cycle requires more energy than the regular cold water cycle, so the couple usually chooses that for normal washing. Jill, though, sometimes thinks the cold cycle is not enough to get certain items clean and occasionally runs the warmer eco cycle.

They do not use the dryer at all unless there is no space to air-dry items. Sometimes sheets and towels are tumble dried using the eco cycle, but never clothes. Jill thinks the tumble dryer wears out the clothes, and they shrink, too. The couple has a drying rack standing on the floor and another one hanging from the ceiling, where most of the wet clothes are dried.

Using less energy is the motive behind not using the dryer very much and it is fairly unproblematic for the couple. The couple has not reflected much on whether the dryer affects the indoor climate because they seldom use it. Jill says that on the few occasions she uses it she always opens the door to the bathroom in order to spread the heat to the rest of the apartment.

## Different Energy Orders, Different Energy Use

The above examples show the different ways of washing and drying clothes that are being conducted in the same block of passive house buildings. They can be seen as different energy orders and they result in different levels of energy use. Using the energy order model, the energy use for washing and drying clothes could look like Figure 2.

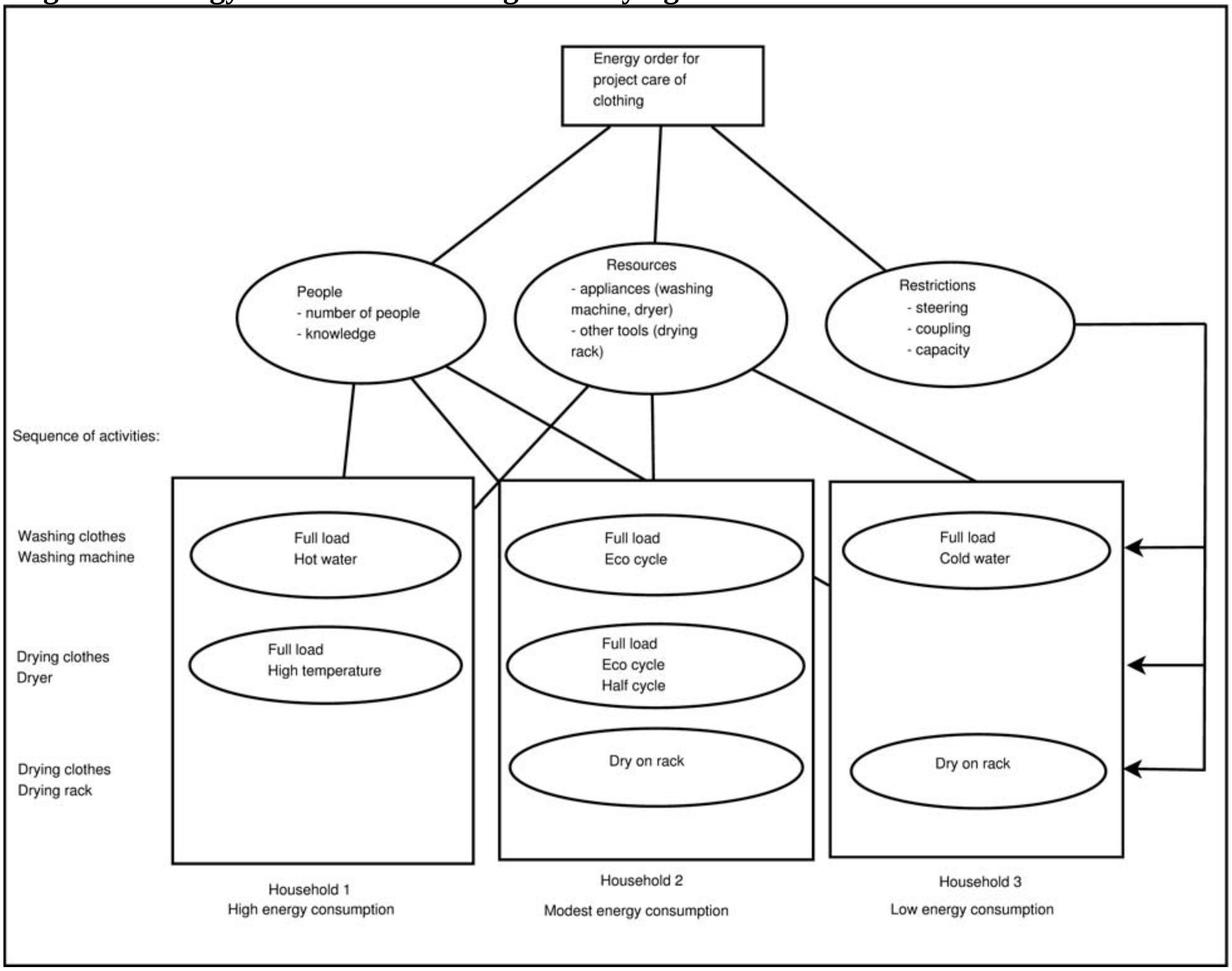
There are clearly different motives behind the various modes of action and the choices to do things in certain ways. Energy awareness does exist, particularly in connection to drying clothes in a dryer, because people generally know that the dryer requires a lot of energy. But this is not always enough to alter people's behavior in a more energy-efficient direction if other factors are more important. In the case of the household in which everything was dried in the drier, the fact that there was no space to air-dry a large number of items made it impossible to do otherwise. Also, the Swedish climate makes drying clothes outdoors impossible during most of the year.

But there is also evidence that being energy aware also results in better energy use habits. The elderly couple used a combination of the clothes dryer and air-drying, but they also felt they made that choice out of necessity. They want to limit their use of the dryer because they wanted to avoid high energy bills. On the other hand, they did not want the humidity to spread, either, so they opted for a mix. This option would never have occurred to Maria, who wanted everything done quickly.

The young couple also rarely used the clothes dryer, but for environmental reasons rather than economic ones. They also had a pragmatic view of using the eco cycle when washing since they realized that the eco cycle was not as energy efficient as the cold water program, which did the job just as well.

These energy orders are all influenced by different forms of restrictions. The most obvious restriction is lack of space to dry clothes in other ways than by using the tumble dryer. Air-drying is considered the best way by all because it does not wear out clothing, but it is also hard to do in reality. The apartments are not designed for such convenience and hence form a type of steering restriction where drying clothes is concerned. A typical coupling constraint is also the sequence of doing things. In order to have clean clothes for the children to wear, Maria has to first wash the clothes and then dry them. The washing machine also has to be available for washing.

**Figure 2. Energy Orders for Washing and Drying Clothes in Three Different Households**




In another sense the appliances installed in the apartments are of good quality energy wise, which offers possibilities to save energy. The way people choose to act within given frames, then, greatly depends on individual capacity constraints. Knowing how to act in alternative ways is an opportunity for changed behavior.

When considering the energy orders and their effect on the energy system in the passive house, it is notable that all of the households kept the bathroom door open when using the clothes dryer. The dryer generates a lot of spill heat and has a noticeable effect on room temperature in a passive house. No one used the dryer specifically to warm up the apartment, but all were aware of the effect it had. The heat, once it was there, was much appreciated. If the households, on the other hand, started using the appliances specifically to regulate the indoor temperature, then much of the main idea of the concept of energy efficient living would be to no avail. The risk still exists, though, especially during winter when extra heating is usually required.

## Concluding discussion

This paper has dealt with household activities and their variations in passive house apartments. The aim was to study how different energy orders are created from the inhabitants' point of view and what implications they have on overall energy use. Looking at the use of appliances in this way may contribute to greater understanding of the variety in behavior that exists in households.

There are a number of restrictions that prevent people from making better energy choices, but these restrictions may also provide opportunities for change. In this paper only a few examples have been presented. Energy orders appear in many more household projects; cooking and food storage, for example, comprise one such project that consists of a number of energy orders. Also, activities connected with relaxation, such as watching TV and playing video games, all have their own energy orders.

An important restriction is space and how rooms, storage, etc. are laid out in an apartment. The lack of proper space to dry wet laundry is one such restriction. In the past, multi-story buildings in Sweden had common laundry rooms in the basement. This shared arrangement is gradually disappearing due to individualization trends, and nowadays many newly built rental apartments are equipped with their own washing machines and dryers. This is also in line with other research, for instance studies on practice theory where the combination of new appliances and changed practices results in changed behavior, either towards less use of energy or the opposite. Also, the trend towards individual metering of household energy use is quite new in Sweden and further supports individualistic solutions, which may actually result in less energy use for the individual household. Housing companies have not yet realized, or do not take into account, that the new conditions also require new thinking when planning space. Steering constraints in the form of rigid planning should be changed towards more flexible solutions that allow for alternative ways of doing things. It is important that energy efficient behavior be supported by the surrounding infrastructure as well.

The role of appliances in a passive house is fundamental to how the energy concept is designed. Household members rarely notice that the use of appliances raises to the indoor temperature; the only appliance in this example that seems to have a direct effect on the indoor climate when it is running is the clothes dryer. People also seem to take the opportunity to spread the heat by opening the door to the bathroom, where the dryer is. Even if the tenants do not consider the appliances per se to be heat generators, they do not limit their use because they live in a passive house and the heat will be used for heating the apartment anyway. There is a risk of rebound effects on energy use even if people do not actively use appliances for heating purposes. Looking at it another way, appliances may in fact make the apartments warmer than necessary during summertime, since the tight building envelope keeps the heat inside as well.

The results from this study show that reducing energy consumption is usually not a priority in the households, mainly because the household members rarely think actively about lowering energy consumption. The passive house concept only makes it a little bit easier on an individual level to live energy-smarter; the highly insulated building envelope may help in some ways, but the concept does not require any real changes in behavior. Even when household members want to make better choices from an energy point of view, they do not always have the opportunity to choose better alternatives because of various constraints that prevent them from doing things differently. If household members were able to change their energy behavior in ways that reduce electricity use, the energy saving potential of the concept would be greater.

Using the concept of energy orders may be helpful in illustrating how people actually use their household appliances. The energy orders help pinpoint where the actual obstacles to changed behavior lie, whether it has to do with life situation, material context, or the appliances themselves. Since the ideal would be to have a fairly stable level of activity and appliances running in the passive house to keep it comfortable, the energy orders could also be used to identify where the gaps between the ideal and reality lie.

The concept of energy orders will be further developed and extended to include more typical household activities such as cooking, TV watching, using computers, etc. Also, restrictions in the form of steering constraints will be further studied, particularly the role of the housing companies and their influence on how apartments are designed and developed.

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