From energy efficiency to efficiency of consumption?

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Abstract
In the debate on reducing the consumption of energy, the main focus tends to be on the (technological) energy efficiency of devices and appliances. In this, the everyday life surroundings' and contexts' influence on the final or actual energy use often seem to be neglected. The important issue should not be the mechanically derived energy efficiency of appliances, but the resulting, "actual" energy efficiency. It is perfectly possible to use an energy efficient appliance in an inefficient way: Better efficiency is fine, but as a means and not an end. Economists describe and explain the discrepancy between the potential and actual energy savings with the term "the rebound effect". Is this appropriate and useful in a change perspective? What would be the main determinants of the households' final efficiency of consumption? A renewed focus on the framework, limitations and possibilities everyday life put on the households' energy use is vital for any policy aiming to achieve reductions in the households' energy use. We propose the term efficiency of consumption to address this rather neglected but crucial factor - truly a result of the dynamics of consumption. Regarding the dynamics of consumption, it remains an open question whether it drives or is driven by the development of modern societies.

Introduction
In a Directive from the European Commission in 2003 on household refrigerators and freezers, it is stated that these appliances account for "… a significant part of total Community household energy demand. The further scope for a reduction of energy use by these appliances is substantial". The "success" of the labelling scheme of these products is based on the "rise of the efficiency index of new refrigerators and freezers by over 30% between 1996 and 2000" (European Commission, 2003). This seems to indicate that energy savings follows from efficiency measures on a 1:1 scale: 10% increased energy efficiency results in 10% reduction in energy use. We believe there are strong reasons to question this assumption.

The assumption of an equal or near equal saving from efficiency measures has strong connections to what we call the "techno-optimist" tradition. Central here is the belief that the developments in technology alone can solve the environmental challenges we face today. Implementation and actual use of the developed products is given little or no consideration, and not much attention is given to our present consumption patterns. Principal in this tradition is the well-known book "Factor Four: Doubling Wealth, Halving Resource Use", where the authors claim: "Or to put it another way, it means we can accomplish everything we do today as well as now, or better, with only one-quarter of the energy and materials we presently use" (Weizsäcker et al., 1997). In this frame of understanding, technology will do "the dirty work" of reducing the environmental load, so there will be no need to change consumption patterns, and accordingly no need for consumer restraint or self-sacrifice.

In a book reporting from the Dutch national research programme Sustainable Technology Development, you can read in the foreword : "one of the main responsibilities of the present generation to future generations is to work today to find technological breakthroughs with the potential to deliver eco-efficiency improvements of the needed scale within the relevant time constraints." (Jansen and van Grootveld, 2000). This can be seen as a continuation of the line of thought in factor four, that technology will solve the problems. The task for consumers is merely to buy the new refined products.

Technological development is an important factor when we envision a sustainable society, but we should not rest on it exclusively. Certain measures and important choices must in all probability still be made regarding our consumption patterns or lifestyle.

This paper discuss the limitations of the rebound effect scheme, and suggests a possible framework to account for or understand how the everyday life of household does interfere with the energy efficiency of appliances. The objective of the paper is not to conclude on the issue, but to raise the question and come with a tentative suggestion on how to address this transformation.

Three empirical examples that challenges to the rebound effect are presented: washing machines, cars and refrigerators/freezers. These examples point to weaknesses in the concept of the rebound effect, and a new direction is proposed where there should be an increased attention on how appliances (and services) actually are used in households, in surrondings that are hardly laboratory-like. They (i.e. the appliances and services) are often included in settings with other appliances, and properties that were considered central by the producer, may become inferior and minor properties become more central. From this it follows that the performance of the appliances may change, and one aspect of the performance is energy use.

Energy efficiency

In a number of areas, energy efficiency efforts have paid off, and technological developments have resulted in great savings. The problem is that too often "other developments" occur in parallel that tend to delay or reduce the resulting savings. Is this the result of economic forces? Could it be explained by saved fuel costs being used in new areas, so that without the improvements of the engines, the safety devices would not have come about? This argument is applied by economists first and foremost, and they call it "The Rebound Effect".

THE REBOUND EFFECT

The rebound effect can be quantified as the difference between the mechanically derived energy saving resulting from an increase in efficiency and the actual energy savings (Musters, 1995; VTPI, 2002). In other words:

Rebound Effect = Potential savings – Actual savings

Khazzom (1980) describes the effect in a well-known article, although he does not actually introduce the term "rebound effect". He criticizes the idea that energy savings of mandated efficiency standards can be derived mechanically: If standards raise the efficiency of a car with 1%, fuel demand is expected to drop 1%.

Those who expect such one-to-one relationships overlook that changes in energy efficiency of appliances have a "price content", according to Khazzom (1980). If you buy an appliance that is twice as efficient as your old one, the effective price of fuel is reduced to a half. As long as the elasticity of energy demand with respect to energy price is not zero, there will be a pressure on energy demand. This pressure will at least partly offset the mechanically derived energy savings.

In a response to a paper in the journal Energy Policy, concerning nuclear energy and energy efficiency, Len Brookes writes an answer on the issues of energy efficiency, The greenhouse effect: the fallacies in the energy efficiency solution (Brookes, 1990). Here he repeats and develops Khazzoms arguments:" …there is no evidence that using energy more efficiently reduces the demand for it" (Brookes, 1990). The conversion factor of fuels to useful energy has improved drastically over the last 100 years, he claims, and yet we now consume more energy both in total and per capita. A simple explanation to this is that the implicit price for the commodity "energy" have been reduced due to the efficiency development, and the demand have responded to the falling prices.

In a survey of the rebound effect, Greening et al. (2000) claim that an increased demand for an energy service, not countered by an increase in the fuel price, can diminish technological efficiency gains. Although this is firmly rooted in neoclassical economic theory, which is controversial in itself, the real controversy concerns the identification of sources and the size of the rebound effect, say the authors. The authors conclude that although efficiency improvements are partially offset by increases in consumption, they will result in an overall reduction in the consumption of energy.

In many ways the debate concerning the existence and size of the rebound effect presuppose or contain the debate on technology's role and ability in solving environmental problems. To those who argue that the rebound effect is small or non-existent, the following claim from Factor Four sounds familiar: "Or to put it another way, it means we can accomplish everything we do today as well as now, or better, with only one-quarter of the energy and materials we presently use" (Weizsäcker et al., 1997). Some claim that in this line of thinking energy efficiency programs are the ultimate "free lunch" for politicians, not only enabling them to meet environmental targets but also to do that in a costless or even profitable way without politically unpopular measures (Brookes, 2000).

So far, it is the economic understanding of the rebound effect that has been presented, but it seems quite clear that the term "rebound effect" is very much confined to the economic sphere. Several non-economists discuss similar features; where potential eco-efficiency gains are offset by growth in consumption, without the authors using or referring this term (McDonough and Braungart, 1998; Náray-Szabó, 2000; Uiterkamp, 2000). Uiterkamp (2000), a professor of the Environmental Sciences, refer to the phenomenon: "This seems to be a common finding: technological improvements are offset by volume effects resulting from behavioral, social or demographic factors", suggesting a more complex connection between improvements and succeeding growth in consumption. In an extensive review of the literature on energy consumption in the years preceding 1997, Aune (1998), a sociologist, makes no reference to the rebound effect. This might be explained by the fact that she was looking for literature on energy consumption, rather than energy conservation. But again it looks like the rebound explanation is confined to the economists' sphere.

It seems likely that growth in consumption can occur without being a response to a change in the effective price of a consumer good or service. In line with this thinking it is suggested that energy efficiency measures can be offset by growth in consumption through other mechanisms than a "pure" price mechanism.

BEYOND THE REBOUND EFFECT: HOUSEHOLD DYNAMICS

An example of this would be how the growth in the number of households we witness especially in the Western world (Liu et al., 2003), at least partly offset eco-efficiency measures on household goods and home insulation. As growth in household numbers globally is more rapid than population growth on a global scale, it means that the numbers of persons per household is shrinking (ibid.). This is probably an even clearer trend on Western countries. This poses a challenge since smaller households have a higher per capita resource consumption (ibid.; Kok et al., 2003; Throne-Holst et al., 2002).

Some of the reasons for the growth in household numbers/ reduction in household size are listed in Liu et al. (2003; 532): "Proximate causes of a reduction in household size include lower fertility rates, higher per capita income, higher divorce rates, ageing populations, and a decline in the frequency of multi-generational families living together".

This growth in the number of households has a twofold environmental effect:

1) Increased living area: this is a combined effect of greater prosperity – increased comfort and bigger houses – and a tendency towards a greater number of households or fewer persons per household. In Norway the average living space have increased almost 50% from 1980 to 1999, from 36 m^2 to 53 m^2 (Throne-Holst, 2002). Greater living space increases the demand for heating or cooling: Between 1972 and 1992, the total amount of energy used for space heating in Denmark (national aggregate) fell with more than 30% (Meyer et al., 1994). But it turns out that per square meter living area the reduction was actually more than 50% (ibid; 93). This means 20% of the improvement or more was eaten by other factors. The reason for the discrepancy is (of course) an increase in the number of square meter living area per person in the same period.

More living space also fosters the need for area on where to build, as well as building materials (Liu et al., 2003).

2) More household appliances are sold: This goes especially for the items that comprise the common standard/basic appliances: washing machine, refrigerator, cooker (stove), television set etc. Furniture would also be included in such a standard. The numbers of cars could also be expected to increase for the same reason. All these products contribute to increase the indirect energy use of households. Indirect energy use is the energy needed to produce and transport the products to the households (Throne-Holst et al., 2002).

CHALLENGES TO EFFICIENCY FROM EMPIRICAL MATERIAL

How do developments in other areas actually influence our consumption levels and patterns? What are the mechanisms that reduce the real gross energy savings from efficiency measures?

Washing machines

Currently there is a rising interest in clothing care and washing machines, and a number of authors have noted the rapid growth in washing (Shove, 2003; Klepp, 2003; Weaver et al., 2000; Vezzoli, 2000). The different authors have different explanations, and have to some extent contrary focuses, but it seems rather clear that the increased use of washing machines has its roots in developments in other areas:

Clothes: introduction of new textile fibres that have to be cleaned separately and sometimes more often, as well as a shift in consumers' fibre preferences – most notably from wool to cotton. This is important since cotton is more care-intensive than wool. There is in addition a growing number of coloured textiles, that at least should be washed separately, to avoid cross-colouration (Klepp, 2003: 96-97). At the same time hygienic standards have changed: The question of why we wash has two main reasons (ibid.: 209-213): there are social reasons that mean avoiding social exclusion. In addition we have aesthetic reasons, where smell has a prominent place. Both factors tend to increase the number of washing cycles per household.

So the technical development of washing machines and washing powders that have resulted in a lower environmental load per washing cycle, have not delivered a smaller aggregated environmental load from clothes washing, at least not in the scale to be expected when looking at the efficiency improvements of each machine or cycle. It has been disturbed and reduced by changes in clothing habits and washing habits.

Cars

Much has been gained in fuel efficiency of car engines since their invention, and this progress has especially speeded up in the last 20-30 years. So most of today's car engines are very efficient, and do have very low fuel consumption per km/mile. But this changes if we shift the focus from fuel use per weight unit of car, to fuel use per car:

In an overview of energy use per passenger-km for the total car fleet in European countries, for 1980-1999, (EEA, 2001) find that the energy efficiency has improved only slightly over this periode: "Technological improvements in fuel efficiency have largely been offset by traffic growth and low occupancy rates (ibid; 39)".

One of the worlds most sold car models is the Volkswagen Golf. It was introduced in 1974, and on the 25th of June 2002 it surpassed the Beetle in sales, when Golf Number 21.517.415 left the assembly line (Volkswagen 2002). Over the years the model has evolved, and reflects many of the technological changes the automobile industry has been through in this period. The Golf is a notion in itself, and a reference point for a whole class of Compact family cars.

We find that the fuel consumption is reduced with less than 6% from 1975 to 2003 (Throne-Holst, 2003). In the same periode the weight of the Volswagen Golf has increased by 50% since 1974, and by 35% since 1985 (ibid.). This makes the weight of the car a great challenge, and according to Dresselhaus and Thomas (2001): "Further great challenges lie in making the substantial improvements in materials that are needed to increase efficiency in the generation, conversion, transmission and use of energy. For example, the most effective way to increase fuel economy in automobiles is to lower their weight, and we are starting to see more vehicle components being made of lightweight, tough and strong composite materials."

So, parallel to the development in engine performance, car designs have changed as well, resulting in the increased weight of most cars. During these years the demands on comfort and especially safety measures have increased significantly. Steel beams and air bags are installed to reduce damages if cars collide. Air conditioning and servo control are more typical comfort measures. These contribute both by their weight, and some also increase the direct energy demand (to run the air conditioning, for instance).

Freezers and refrigerators

Norwegian material indicates that new, energy efficient household appliances do not necessarily substitute old ones, but are rather added to the "machine park". That is, when you buy a new refrigerator or freezer, the old one regularly is not thrown away or disposed off, but rather moved out into the garage, basement or cabin (Strandbakken, 2005). Here it is plugged in, and continues to be in use, most likely as a "back-up" cold appliance for sodas, beers and pizzas, and situations where there is an extra need for capacity, like parties. Hence the households total energy use for refrigeration purposes increases as a result of the purchase of a new energy efficient device. Of course would this be even worse if your new refrigerator was less energy efficient. But our point here is to show how energy efficiency gains may be delayed.

ARE WE HAUNTED BY THE REBOUND EFFECT?

The three examples we just have described, can obviously be "forced" or reduced into an economic framework, and accordingly be explained by the rebound effect. The real price of energy is shrinking, and our demands for energy use are therefore increased. Electricity is so versatile, the demand for it is very flexible, and it can be used for satisfying "endless" needs:

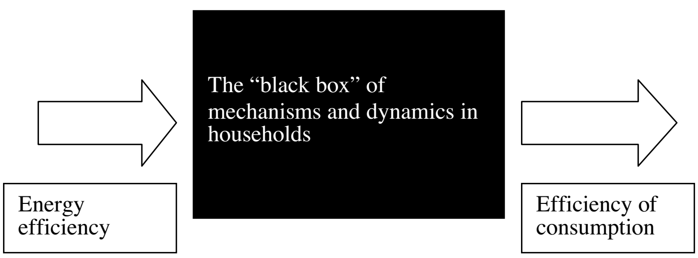

Figure 1. The (energy) efficiency of consumption

- It is because the real price of energy is getting lower that we have the second refrigerator still running in the basement.
- The washing machine is used more, because the price per washing cycle is cheaper
- The low real price of fuels makes us able to demand greater security and comfort in our cars

So, are we just witnessing the Rebound effect at play once again? In socioeconomic models societal matters tend to be reduced to economic considerations only. To this we would claim otherwise: in a rather rhetorical fashion we could ask: are all everyday actions the result of economic considerations? In Norway the societal focus appear to be that although approximately 10% of total consumption expenditure income is used for food, many households use more than 10% their available time trying to cut back these costs. Much more money could probably been saved in their remaining 90% of consumption. Of these 90%, much is probably more or less taken for granted, and energy expenditures are probably one of these. From this we may deduct that changes in energy prices do not necessarily have a great impact on consumption patterns, within reason of course. Regarding energy prices, we believe there is need to separate between effects on consumption from rapid or sudden changes, and changes in the long term.

When changes in lifestyle and consumption patterns occur, for instance due to an increased concern for environmental issues or as results of reduced number of adults per household we believe that the purely economic approach offers a too narrow explanation of consumer behaviour. Basically, I do not drive the extra kilometres because of lower fuel prices, but because I try to meet challenges of career, family and social-cultural belonging. Economy obviously is a constraint, but fuel prices do not explain my increased mobility after divorce or job change. Neither will reduced price per washing cycle explain changing hygiene standards.

The transformation of energy efficiency

Although the Rebound Effect seems to describe or explain certain aspects of the fallacy of energy efficiency, we believe that there are other important aspects that not are covered. Among them is the idea that not all decisions and actions by households are based on economic consideration alone.

Other authors (e.g. Throne-Holst, 2003; Norris and Segal, 2002) have proposed the term "efficiency of use" to address to apparent problems with "energy efficiency". Here we propose the term "efficiency of consumption". It can be illustrated as follows:

On the consumption side, households are an appropriate unit, as most of consumption takes place in this context. Household consumption is also considered "the very basis of economic activity" (Kok et al., 2003). This is because choices on the households' spending to a high degree affects activities on the production side, and associated environmental loads.

Consumption can be considered as consisting of seven phases (Throne-Holst, 2004):

- Planning of purchase
- The moment of purchase
- Use
- Durability
- Repairs
- Purchase of supplements
- Disposal

These seven phases will constitute the main part of the "black box". In addition the interaction with other appliances in the household is important. With this in mind, we believe that the new term "efficiency of consumption" frame more of the actions performed by households that are relevant to get a clearer picture of the final savings from efficiency measures. It also embraces the products' complete presence in the household. Each of the seven points above should, where relevant, be included in an evaluation and analysis of households' energy use. Through such an approach we will get closer to the real energy use in households. How such an analysis can be performed, will be one of the scopes for futher work on this concept.

It should be noted that we by this do not exclude a possible "rebound effect", it may well be one of the dynamics in the households, and together with others participate in determining the shifting of the energy efficiency. Although the rebound effect has its shortcomings, it may still come as a valuable contribution to determine the energy efficiency of consumption.

As we can see from this illustration the mechanical energy efficiency is a very important input and determinant of the efficiency of consumption, but the two are not equal. Energy efficiency is moulded and shifted in the meeting with the "black box" of the household and the activities and choices made there. Developments in the energy efficiency is therefore crucial to improve the efficiency of consumption, but the transformation of energy efficiency in the everyday life of households must be taken into consideration when calculating expected savings in energy use from efficiency measures.

There is a need to find more effective and potent ways of changing consumption patterns to reach sustainability. We hope that others see this term and the developments of appropriate methods as a fruitful and fertile way of getting to grips with the problems of realizing efficiency efforts into actual energy savings.

Especially we hope to achieve a greater understanding what mechanisms and forces that are at play when products and services are chosen and used by the households.

What we have presented here is a tentative way forward on how to investigate the transformation of energy efficiency. There are reasons to believe that energy efficiency measures are delayed, disturbed and reduced in the everyday life of households. It is too early to give any estimates to what degree energy efficiency is transformed, but we believe there are strong evidence that it is indeed happening, nad that these mechanisms are so important that ther should be further development of our tentaive model, to get closer to quantifying the effects. At the preset stage we can merely give an qualitative measure, as outlined above: energy efficiency is transformed, so by applying energy efficiency indexes alone to calculate final energy savings will certainly exaggerate the effects of energy efficiency measures.

Conclusion

This paper has presented the rebound effect that by many, especially economists, is considered to be the chief explanation of the discrepancy between anticipated and realised energy savings. Emprircal examples have been presented that highlights the weaknesses of the rebound effect scheme, and a alternative scheme has been presented, although tentative. Understanding the discrepancy can help in bridging the gap, and both provide more accurate anticipation of measures, and hopefully more effective ways of saving energy, which is imperative to reach sustainability.

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