An ecological economics perspective on energy efficiency

Abstract

Energy efficiency programmes have experienced a revival as part of the attempts to reduce green house gas emissions. However, total energy demand has not fallen so far and is projected to increase even further. This paper argues that the failure of energy efficiency programmes to achieve lasting reductions has to do with a misconception of energy efficiency in general. The two prevalent schools of thought in energy efficiency, neoclassical economics and ecological modernisation, are unlikely to reframe energy efficiency programmes with the aim of reducing total energy demand. This paper draws on the ecological economics literature arguing that an ecological economics approach is better suited to address energy efficiency in such a way that it can deliver long-term reductions of energy demand. A framework based on the principles of ecological economics is introduced which can be used to assess energy efficiency programmes. Finally, this framework is applied to a prominent energy efficiency policy, the energy savings obligations in the UK. The paper then concludes that assessing energy efficiency programmes with such an approach is more likely to deliver energy demand reductions than the current mainstream view of energy efficiency as a panacea.

1 Introduction

In the last decade energy efficiency has received increased attention. Across the globe new energy efficiency programmes have been put in place with the aim to reduce carbon emissions and, more recently, to reduce dependence on volatile fossil fuel markets. There remains, however, a big question mark to whether these laudable aims can actually be achieved and the progress made so far is far from sufficient. In most industrial countries the long-term trends point to a different direction: For example, in the UK domestic energy consumption has increased by 19% from 1970-2007 (BERR, 2008), in Germany households consume now about 20% more than 1970 (based on DIW and ISI, 1997, AG Energiebilanzen, 2008), and American households consume now >50% more energy as in 1970 (Energy Information Administration, 2009). Energy savings achieved via energy efficiency measures have been offset by an increasing energy demand related to larger dwellings and in particular a higher number of appliances in households contributing to significantly higher electricity consumption. Although in more recent years domestic energy consumption seems to have plateaued in countries like the UK, there is still no indication of a lasting downward trend.

This paper argues that the failure to achieve significant reductions in energy consumption has to do with a misleading public policy approach to energy efficiency. Most energy efficiency programmes are still pursued from a perspective that puts technological efficiency and finance aspects centre stage – it, intentionally or unintentionally, aims at improving nominal efficiency of energy services leading to relative savings. This helped to trigger remarkable technological innovations with regard to efficiency in many areas. However, at an aggregate level enhanced efficiency just doesn't seem to add up. In order to employ energy efficiency as a means (rather than an end in itself) to reduce carbon emissions on a large scale, a wider perspective as offered by ecological economics is needed. While it is unlikely that the focus on efficiency as it stands will change significantly in the foreseeable future, there is potential to re-calibrate existing policy instruments with an increasing orientation towards achieving total energy savings. Similar thoughts have been explored by others, who also highlighted the need to realign energy efficiency efforts with total energy savings (Harris et al., 2008, Wilhite and Nørgård, 2004). This paper presents a simple framework to assess energy efficiency programmes from an ecological economics perspective and suggests policies that would be in line with such an approach, focusing on residential energy efficiency policies. It looks at one example of a well-known energy efficiency programme, namely the energy saving obligations in the UK.

The structure of the paper is the following: First, the origins of the energy efficiency literature will be summarised. It will be shown how the academic argument was mainly about the so called energy efficiency gap and has been polarised between technological optimists, who claim that there are numerous cost-effective energy saving opportunities, and economic pessimists, who claim the contrary. This is useful for the later analysis, because energy efficiency policy has evolved within a context characterised by controversies that are still prevalent today. Second, this paper will briefly review the evidence on the extent to which energy efficiency savings are offset by rebound effects, which refer to increased energy consumption as the result of lower energy service costs due to energy efficiency improvements. Third, this paper will present how different schools of thought take conflicting viewpoints on the role that public policy has to play in energy efficiency and argue for an ecological economics perspective on policy intervention. Finally, this chapter will present a framework to assess energy efficiency programmes from an ecological economics perspective and discuss a policy example in light of its suitability for an ecological economics approach to energy efficiency.

2 Origins of the energy efficiency debate

In the aftermath of the 1973 OPEC Oil Embargo a number of prominent books and articles were published advocating investment into energy efficient technologies (e.g. Hayes, 1976, Leach, 1979, Lovins, 1976, Lovins, 1977). The focus at the time was very much on energy conservation, a term that is rarely used these days. Since then, numerous engineering-economic studies have highlighted the potential for cost-effective energy reduction opportunities by using modelling tools assuming replacement of existing technologies with more energy efficient equipment, usually based on expected energy savings, lifetime, and cost data (e.g. Carlsmith et al., 1990, Fickett et al., 1990, Hirst and Hannon, 1979, Interlaboratory Working Group, 1997, Interlaboratory Working Group, 2000, Rohmund et al., 2008, Sant, 1979, Williams et al., 1983).

Another focal point of the debate has been the economics of energy efficiency. Even though there seem to be plenty of opportunities for cost-effective energy savings, the potential is far from being exploited. This discrepancy has been termed the 'energy efficiency gap' or the 'energy paradox' (Jaffe and Stavins, 1994b). There is a long and fierce debate about the existence (or non-existence) of the energy efficiency gap stretching back more than 30 years but remaining largely unresolved (Hayes, 1976, Hirst and Brown, 1990, Howarth and Andersson, 1993, Howarth and Sanstad, 1995, Jaffe et al., 1999, Jaffe and Stavins, 1994b, Jaffe and Stavins, 1994a, Levine et al., 1995, Metcalf, 1994, Sanstad and Howarth, 1994, Sorrell et al., 2004, Sutherland, 1991, Sutherland, 1996, Tietenberg, 2009, Weber, 1997).

The two poles of the discussion can be stylised as the 'technological optimists' and the 'economic pessimists' (Sorrell et al., 2004). Some attempts have been made to better understand the energy efficiency gap by analysing the barriers that prevent the uptake of energy efficiency measures.

2.1 Technological optimism

Technological optimists claim that there is a vast untapped potential for energy efficiency and that 'energy efficiency can displace costly and disagreeable energy supplies, enhance security and prosperity, speed global development, and protect Earth's climate - not at cost but at a profit' (Lovins and Cleveland, 2004). Some of the most prominent technological optimists are von Weizsäcker et al. (1996), Hawken et al. (1999) and Lovins (1976) who emphasise the no cost and/ or negative cost opportunities for saving energy by using more efficient technologies. In this context Lovins (1985) coined term 'negawatt' i.e. energy that is not produced due to savings achieved via energy efficiency. The key message of technological optimists is that there is plenty of energy saving opportunities, which are cost-effective, and that it is crucial to bridge the energy efficiency gap in order to reduce energy consumption and make profits.

2.2 Economic pessimism

In contrast, the economic pessimists either reject the idea of an energy efficiency gap entirely or take the position that the gap is much smaller than suggested by engineering-economic studies. Orthodox economists like Sutherland (1991, 1996, 2006) adopt the standpoint that if, in a competitive market, (rational) consumers are not willing to pay for energy efficiency measures that is an indication that those measures are economically not efficient. Higher discount rates used by end users as a result of uncertainty of future energy prices and actual savings, illiquidity and the irreversibility of investments into energy efficient technologies have been put forward as possible explanations for the energy efficiency gap (Metcalf, 1994, Sutherland, 2006, Sutherland, 1996, Sutherland, 1991). Those high discount rates are supposed to reflect real costs in a competitive market, not market barriers and are a normal characteristic feature of functioning markets.

It is, however, remarkable that the implicit discount rates used when deciding about implementing energy efficiency measures are much higher than those applied for other similar purchasing decisions (Gately, 1980, Hausman, 1979, Ruderman et al., 1987).[1] This is not consistent with the model of rational choice and utility maximisation applied by neoclassical economists (Howarth and Sanstad, 1995). As Jaffe and Stavins (1994b) have pointed out quite rightly, the observation that consumers apply high discount rates when making energy efficiency decisions is simply a restatement of the energy efficiency gap and does not explain *why* consumers use such high discount rates. There

[1] Hausman found average discount rates for purchasing room air conditioners of 20%. Gately estimated discount rates of 45-300% for refrigerators. Ruderman reports implicit discount rates of up to 800% for heating and cooling equipment and for residential appliances.

have to be other factors that can actually explain the energy efficiency gap and it is useful to think of those factors as barriers that prevent individuals from making decisions that are economically not disadvantageous.

2.3 Barriers to energy efficiency

The energy efficiency gap can explained with obstacles that need to be overcome by public policy intervention - engineering-economic studies frequently use the term 'barrier' and/ or 'market barrier' to explain the low uptake of cost-effective measures (e.g. Blumstein et al., 1980, Carlsmith et al., 1990, Howarth and Andersson, 1993). As a result of the controversial debate with neoclassical economists some energy efficiency scholars also started to use the term ‘market failure’ (Brown, 2001, Levine et al., 1995), although this was heavily criticised as window dressing by neoclassical economists such as Sutherland (1996).

There have been numerous attempts to develop taxonomies of barriers to energy efficiency (Brown, 2001, Eyre, 1997, Hirst and Brown, 1990, Jaffe and Stavins, 1994b, Sanstad and Howarth, 1994, Sorrell et al., 2004, Tietenberg, 2009, Weber, 1997). The barriers commonly named are:

- imperfect information to energy consumers;
- perverse incentives (e.g. the landlord/tenant barrier);
- limited availability of capital;
- price volatility;
- externalities are not internalised and reflected in energy prices; and
- bounded rationality (individuals do not have the cognitive ability to assess the costs and benefits appropriately).

2.4 Rebound effect

There has been a long lasting debate about the potential contribution energy efficiency can make to reduce total energy demand effectively. Some scholars criticise the results of engineering-economic studies for not acknowledging the macroeconomic effects and claim that energy efficiency measures make the consumption of energy cheaper and hence more attractive to consumers resulting in an increase of total energy demand at the macroeconomic level (Brookes, 1990, Brookes, 1979, Brookes, 1993, Brookes, 1992, Inhaber and Saunders, 1994, Khazzoom, 1987, Khazzoom, 1980, Sutherland, 1996, Sutherland, 1991). This is called the rebound effect, the Khazzoom-Brookes Postulate (Saunders, 1992), and sometimes the take-back or snap-back effect (Nadel, 1993). It goes back to the ideas of Jevons (1865), who argued that 'it is a confusion of ideas to suppose that the economical use of fuel is equivalent to diminished consumption. The very contrary is the truth.'

Often historic data has been used to prove the point that in spite of the fact that energy intensity of one unit of production has declined total energy demand has increased. However, Grubb (1990, 1992) contests such a viewpoints and argues that it cannot be concluded from historic data that policy driven measures aimed at generating a higher energy efficiency in an imperfect market do not work. If energy efficiency is a goal in itself and not a means to an end and energy prices rise, real energy savings can be achieved. Grubb does not reject the idea of a rebound effect in general but makes the point that it is much smaller than claimed by Brookes and others. Schipper and Grubb (2000, p. 368) conclude that the improvement in energy efficiency per se is only a small part of the reason why total end-use activities may have increased'. They name increasing population, household formation, and the climb of incomes and sectorial output as key factors that affect total energy consumption.

2.4.1 Definitions of the rebound effect

The rebound effect is frequently broken down in three different types: direct, indirect and economy-wide rebound effects.

Direct rebound effects refer to the phenomenon that energy efficiency improvements make it cheaper for consumers to use an energy service and as a result they use more of that service (Greening et al., 2000, Sorrell, 2007). For example, if driving a car uses less fuel due to a more efficient engine people might simply drive their car more and offset some of the energy savings by doing so.

Indirect rebound effects might occur when consumers spend the money they save due to energy efficiency measures on other energy consuming services. To stick to the previous example, if driving a car becomes cheaper consumers might decide to pay for a flight with the money they saved due to higher fuel efficiency (Barker et al., 2007, Sorrell, 2007).

Economy-wide rebound effects refer to the effects of falling prices for energy services on the economy as a whole. If the cost of energy services decreases the price of intermediate and final goods in the economy goes down. This has the effect that more energy intensive goods become more competitive. Lower cost for energy services might also stimulate economic growth leading to a higher demand for energy services (Barker et al., 2007).

2.4.2 Magnitude of the rebound effect

There are various assessments of the magnitude of the rebound effect such as a research project undertaken for the UK Energy Research Centre (UKERC) that looks at more than 500 studies dealing with the rebound effect (Sorrell, 2007) and an extensive literature review by Greening et al. (2000).

Greening et al. reviewed 75 studies focussing on the US. Most of the studies relate to residential energy use such as space heating, space cooling, water heating and lighting as well as personal automotive transport. For space heating the magnitude of the rebound effect based on the studies reviewed accounts for 10-30% of the energy savings i.e. only 70-90% of the expected energy savings are realised. The figures for space cooling are less reliable and are about 0-50% take back due to the rebound effect. For energy efficiency measure related to water heating and lighting the rebound effect is estimated to be about 5-12% and 10-30% respectively. Economy wide effects are negligible and add up to 0.48%. The results of the survey lead Greening et al. Greening et al. (2000, p. 44) to the conclusion 'that the rebound is not high enough to mitigate the importance of energy efficiency as a way of reducing carbon emissions. However, climate policies that rely only on energy efficiency technologies may need reinforcement by market instruments such as fuel taxes and other incentive mechanisms.'

Based on a review of over 500 papers and reports a study for the UK Energy Research Centre provided estimates of the direct, indirect and economy wide rebound effects (Sorrell, 2007). For household heating, household cooling and personal automotive transport the direct rebound effect is estimated to be less than 30% (closer to 10% for transport). The results for economy-wide rebound effects are based on computable general equilibrium studies and apply only to producers. Sorrel defines the economy-wide rebound effect as the sum of direct and indirect rebound effects and estimates that economy-wide rebound effects may frequently exceed 50%. The economy-wide rebound effects of consumer focused energy efficiency improvements are likely to be smaller. Note that Greening et al. (2000) use a different definition for economy-wide rebound effects. They define economy-wide effects as effects of technology improvements on fuel prices and economic growth and the resulting increase in energy consumption.

2.4.3 Relevance of rebound effects for public policy

As demonstrated above, there is insufficient evidence for the Khazzoom-Brookes Postulate that says that energy efficiency improvements actually lead to an increase of total energy consumption. However, the magnitude of the rebound effect is not insignificant and it is likely that some of the energy savings will be offset. This has two implications for public policy:

First, policy aimed at energy demand reduction by supporting technology innovation needs to take into account that engineering estimates for energy savings cannot simply be used to calculate energy demand reduction. Some of the potential energy savings will be eaten up by the rebound effect if no other measures are taken (e.g. increased taxes on energy).

Second, purchasing decisions and lifestyles of individuals seem to play an important role when it comes to rebound effects. Both the direct and the indirect rebound effect depend on individuals' choices on how to invest the money they save due to energy savings. The magnitude of the rebound effect should therefore not just be taken as a given, but to be seen as the result of particular ways of consumption. A narrowly defined energy efficiency policy only that only concentrates on technology misses the opportunity to address non-technological ways of reducing energy consumption by shifting lifestyle and consumption patterns.

While the rebound effect is indeed an important issue that needs consideration when designing policies, it is not sufficient to just focus on the rebound effect. This is because even if the rebound effect was zero, growing demand for energy services could still easily offset energy efficiency improvements. Public policy that takes energy demand reduction seriously would need to go beyond the rebound effect. However, the role public policy should play obviously very much depends on the perspective one takes and there is disagreement about whether and how public policy should intervene. The following part of this chapter introduces three different perspectives on policy intervention in the context of energy conservation.

3 The case for policy intervention

Three contrasting perspectives on the role public policy should play regarding energy conservation are presented in the following: the neoclassical economics perspective, the ecological modernisation perspective, and an ecological economics approach. Although these perspectives might come to similar conclusions in certain areas (for example the internalisation of externalities), they are based on conflicting assumptions about energy systems and state intervention. Currently, the neoclassical economics and ecological modernisation approach appear to be the prevalent ways of seeing energy efficiency. Ideas based on ecological economics are marginalised in the mainstream debates around energy efficiency.

3.1 Neoclassical economics: correcting market failure

Neoclassical economists justify policy intervention in case of market failures (externalities and public good problems) with the aim to achieve higher economic efficiency (*not* energy efficiency) (Sutherland, 1996, Sutherland, 1991) and thus increased economic welfare. Orthodox economists classify only some of the barriers identified by energy efficiency researchers as market failures. According to Jaffe and Stavis (Jaffe and Stavins, 1994b), market failures in the context of energy efficiency are public good attributes of information, positive externalities of technology adoption, asymmetric information in energy markets, distortions in energy pricing, and environmental externalities. Hidden costs, risk, reduced product performance, and option value of delaying investments are not classified as market failures, but seen as a typical feature of functioning markets that require no policy intervention (Jaffe and Stavins, 1994a, Metcalf, 1994, Sutherland, 1996).

Sutherland (1996) even claims that energy conservation policies may exacerbate *inefficiency* by increasing market or regulatory failures. He could not have put his perspective more bluntly: 'Mandated energy conservation programmes have no more of a sound economic basis than the emperor has clothes' (Sutherland, 1996, p. 369). Other neoclassical economists such as Jaffe and Stavins (1994a) and Metcalf (1994) are less radical and discuss in more detail the most appropriate way of dealing with market failures related to energy efficiency. The neoclassical perspective suggests addressing the source of the market failure directly i.e. greenhouse gas emissions rather than energy consumption as such (Jaffe et al., 1999). In a competitive market individuals are expected to make rational choices following incentives provided by instruments such as a carbon tax or cap and trade systems for GHG emissions leading to Pareto-efficient outcomes.

Such views are very problematic and the notion that individuals are rational human beings responding to price signals and monetary incentives ignores the insights of other disciplines showing that individuals often behave economically irrational. For example, Simon (1959) introduces the concept of bounded rationality and argues that individuals are likely to make decisions diverging from those predicted by neoclassical economists. Bounded rationality assumes that individuals make decisions under the constraints of time, attention, resources, and cognitive ability to process information. As a result, decisions are often satisfactory in contrast to the optimum (Sorrell et al., 2004). Furthermore, the choice of policy instruments is far from being a neutral and rational process, as some neoclassical economists postulate. To the contrary, instrument choice is dependent on politics in the sphere of power struggles of a range of actors as well as the particular context in which this struggle takes place (Varone and Aebischer, 2001).

3.2 Ecological modernisation: incentivising energy efficiency

Decoupling economic growth from resource and energy use is one of the core messages the ecological modernisation literature conveys (Hawken et al., 1999, von Weizsäcker et al., 1996, Lovins, 1976). We can make a profit while saving the environment and creating new jobs – this idea of a new industrial/ green/ efficiency revolution (Jänicke and Jacob, 2009) has been coined 'natural capitalism' by Hawken et al. (1999). The market is seen as the main vehicle for implementing innovative technologies, 'the market logic of modernisation and competition for innovation combined with the market potential of global environmental needs serve as important driving forces behind "ecological modernisation"' (Jänicke, 2008, p. 557).

Ecological modernisation highlights the vast potential for energy efficiency in terms of energy savings and new markets: 'Focusing on energy efficiency will do more than protect Earth's climate - it will make businesses and consumers richer' (Lovins, 2005, p. 74). The role of public policy is to ensure that the energy efficient technologies are implemented on a large scale by using environmental tax incentives (Hawken et al., 1999, von Weizsäcker et al., 1996), tradable efficiency certificates (Lovins, 1985), performance standards (Lovins, 1990), and other innovative forms of regulation that operate within competitive markets.

As appealing as the concept might be, the problems of ecological modernisation are manifold: First, ecological modernisation concentrates mainly on incremental efficiency (e.g. high efficiency radiators), although there is evidence that in the past incremental efficiency gains have been offset by economic growth and will continue doing so in the future (Huesemann, 2004). By focussing on incremental efficiency improvements, 'ecological modernization pushes limits to growth into the background. Limits are not so much explicitly denied as ignored' (Dryzek, 1997, p. 144). However, some ecological modernists recognise that scale effects can offset efficiency gains and that a substantial, more radical change is needed (Jänicke, 2008), although they do not explain in detail how that can be achieved.

Second, the concept of ecological modernisation is very much a concept of production and the issue of consumption is barely problematised in its own right (notable examples are Spaargaren, 2003, Spaargaren and Van Vliet, 2000). In contrast, energy efficiency used as a means to reduce energy demand is all about dealing with consumption. There is now a growing recognition that consumption needs to be addressed as well in order to achieve substantial reductions of GHG emissions (Cohen, 2001), but ecological modernisation falls short on incorporating consumption into its framework of analysis (Carolan, 2004a, 2004b).[2]

3.3 Ecological economics: protecting critical natural capital

In contrast to the ecological modernisation literature, ecological economics generally sees (energy) efficiency as the means to an end and not an end in itself. The ecological economics literature places a lot of emphasis on efficiency, but recognises the limits of it. Hence it should play an important part in a wider context, as a necessary but not sufficient condition with the aim to achieve sustainable development within environmental limits (Daly, 1992, Norgaard and Howarth, 1992).

[2] In a reply to Carolan, Mol and Spaargaren contest this view and claim that ecological modernisation is indeed a concept of both production *and* consumption.

In the case of energy efficiency an ecological economics perspective would suggest that the *scale* of energy consumption and the associated GHG emissions should be the primary focus rather than the energy efficiency of certain types of appliances. Where energy efficiency can contribute to reducing the *total* amount of energy used in the economy and the resulting GHG emissions, it should play an important role (Nørgård, 2006). An ecological economics perspective therefore rightly focuses on energy *conservation* rather than efficiency on its own. A narrow definition of energy efficiency concentrating on the technology level only is at odds with the principals of ecological economics that is based on a whole systems approach and grounded in thermodynamics (Costanza et al., 1997, Daly and Umana, 1981).

The ecological economics perspective justifies policy intervention not with market failures or cost effective energy saving opportunities (although it acknowledges those), but with the importance of energy conservation for radically reducing GHG emissions in order to prevent the depletion of critical natural capital (Ekins, 2003), i.e. those features of the environment we cannot go without.

The ecological economics perspective seems to be the most convincing one from a systems wide perspective and the recognition that there clearly are environmental limits, in this case limits to the amount of carbon emissions and the capacity of the climate system to deal with those. This is not to say that other perspective than ecological economics are not valuable. To the contrary, important insights can be taken from differing schools of thought (for example, data on the technical potential of individual energy efficiency measures as provided in ecological modernisation studies), and the controversies between neoclassical economics and engineering-economic studies are very useful particularly for a better understanding of the costs and benefits as well as the barriers to energy conservation.

However, while ecological economics seems a useful starting point for a more holistic account of energy efficiency, the literature so far doesn't engage with energy efficiency in a public policy context and what an ecological economics approach to public policy could look like. An analysis of 91 articles on efficiency in the journal 'Ecological Economics' shows that the majority of the papers deal with economic efficiency. Of the few papers that actually focus on energy efficiency, most do so purely from a thermodynamics perspective (Jollands, 2006). There appears to be a lack of engagement with public policy from an ecological economics perspective in general. Some have called for ecological economics to get more involved with policy making and to develop it as a 'policy science' (Shi, 2004). David Pearce (1998, p. 40) argues that ecological economists should 'look at how policy may be changed in the real world rather than the world of textbooks and journals, coffee bars and conference rooms'.

One way of getting more involved in the policy making process is by being able to assess whether policy measures are in line with an ecological economics approach or not (Shi, 2004). This paper therefore builds on the ideas on energy efficiency in the ecological economics literature and sketches a (rudimentary) framework to assess energy efficiency programmes with regard to their suitability with an ecological economics approach.

4 An ecological economics framework to assess energy efficiency programmes

In the following, a framework based on ecological economics thinking with the aim to assess energy efficiency programmes is outlined. Such a framework needs to follow the basic principles of ecological economics including the recognition of environmental boundaries, taking a long-term view, acknowledging uncertainty, and a whole systems perspective. Therefore, four criteria are proposed for such a framework, namely scale, persistence, flexibility, and holism. The framework is then applied to one policy for illustration purposes.

4.1 Proposed framework

4.1.1 Scale

In order to adhere to an ecological economics approach, energy efficiency programmes would have to be designed with the aim to reduce total energy consumption levels rather than focusing solely on relative efficiency improvements, i.e. it needs to consider the scale of the savings (Wilhite and Nørgård, 2004). While this includes taking into account the rebound effect and taking measures to counterbalance it, it goes much further than that. The evidence so far suggests that even with a rebound effect <100% energy efficiency measures might not lead to total reduction in energy use simply due to increased demand of energy services in general. For example, a policy that promotes energy efficient fridges usually calculates the energy efficiency of a given fridge by comparing it to other fridges of a similar size. Within one category of fridges the one that uses the least amount of energy is deemed most efficient. However, even if a fridge consumes the least amount of energy in that category, simply using a smaller fridge might be the more sensible option if the objective is to reduce total energy consumption. Harris et al. (2008) have developed the concept of 'progressive efficiency', which captures that idea and proposes that as the scale of energy use or service increases, the level of required efficiency should be higher to make sure total consumption is accounted for. To stay with the example of the fridge, this means that a large fridge would need to be more energy efficient than a smaller one in order to get the same energy efficiency rating. This concept could potentially be applied to buildings, other appliances, heating systems etc. In summary, any policy instrument that passes the total reduction test needs to contain provisions to make sure that it contributes to reducing energy use rather than just using energy more efficiently.

4.1.2 Persistence

While it is important that total savings are achieved, it is also crucial that the reductions last over time. The ecological economics literature highlights the need for long-term improvements and the role public policy can play in this (Costanza et al., 1997). For example, energy efficiency programmes aimed at behavioural change (e.g. education, advice, information) that are one-off may generate some savings in the beginning, but if not retained, the effects of such programmes may not last very long. Furthermore, if a programme encourages the installation of energy efficient equipment, the lifetime over which these measures actually reduce energy use needs to be realistically acknowledged. This includes taking technical degradation into account properly. For example, double or triple glazed windows filled with Argon lose some of the gas over time leading to a reduced insulation effect. Similarly, the insulation material filled into cavity walls may sink to the bottom of the wall over time leading to the appearance of non-insulated areas at the top of the wall. These effects need to be accounted for when evaluating the persistence of energy efficiency measures. Finally, the energy consumption of a building is highly dependent on occupants' behaviour (e.g. closing of insulated windows, proper operation of heating controls). Therefore, energy use in identical homes can vary by a factor of up to 3 (Gram-Hanssen, 2010, Steemers and Yun, 2009). Hence there is a risk of a gap between expected savings and real savings (Gupta and Chandiwala, 2010) which can undermine well-intended policy efforts if not considered.

4.1.3 Flexibility

Ecological economics emphasises the need to account for uncertainty associated with complex environmental and socio-economic systems, i.e. unknown events and unknown consequences. This includes the development of technology and its potential applications in the future (e.g. more efficient lighting technologies such as LEDs), new scientific information (e.g. better data on environmental boundaries of economic activity), and changing socio-economic or environmental conditions. Therefore, long-term sustainability requires that policy instruments and the policy landscape respectively show a high degree of 'adaptive flexibility' (Rammel, 2003), allowing that the set of policy instruments used can be readjusted easily in the light of new evidence or changing conditions. In the field of energy efficiency policy, this means for example that policy instruments need to be adjustable to keep up with technological advancement of energy efficient technologies. One way of doing that could be by regularly reviewing the minimum requirements of those technologies promoted by the policy measure. Or, if more radical reductions in energy use were required, the policy instrument would need to be flexible in the sense that it could be made more stringent.

4.1.4 Holism

By definition, ecological economics takes a systems perspective rather than narrowly focusing on one area (Baumgartner et al., 2001). Therefore, one needs to evaluate how an energy efficiency programme fits with the wider policy landscape and what its potential contribution might be. Obviously this requires assessing how new instruments would interact with the existing ones. For example, if financial support schemes for building retrofits are already in place, how could minimum building standards for existing buildings work alongside those programmes? But this also includes the consideration of knock-on effects in other areas that may be outside the obvious realm of energy efficiency. For example, in the past some insulation materials have been produced with blowing agents that contribute to ozone depletion. In this case by simply focusing on energy savings, carbon emissions are reduced while negatively affecting another area of the environment. This may be unavoidable to some extent, but such effects need to be looked at and carefully weighted.

The framework will now be applied to a prominent energy efficiency programme, namely the energy saving obligations in the UK. While a full evaluation would require a large amount of data, this paper looks at the two policies just briefly in order to illustrate how an ecological economics framework could be used.

4.2 Policy example: Energy saving obligations on energy suppliers

In the UK, energy saving obligations on energy suppliers to save energy at the customer end is the main policy instrument to deliver energy and carbon savings in the domestic sector (OFGEM, 2005). The basic concept of the so called Supplier Obligation (SO) is that Government imposes a savings target on energy companies that has to be achieved at the customer end. The target may relate to energy consumption or carbon emissions. In the UK, the target is set by the Department of Energy and Climate Change (DECC) for a defined period of time. The energy regulator, OFGEM, is responsible for administering the SO and enforcing it. It defines individual savings targets for each energy company. The energy companies then contract installers of energy saving measures that carry out the work in homes according to a defined standard and with a certain benchmark for energy and / or carbon savings. Alternatively, energy companies may choose to work with the occupants directly. In the past, energy companies have for example promoted the use of compact fluorescent lamps (CFLs) via mass mail-outs of free light bulbs, although this is now prohibited. Businesses and industrial end-users are not covered by the scheme; they are covered by other policy instruments such as the Climate Change Levy and Climate Change Agreements as well as the recently introduced Carbon Reduction Commitment.

4.2.1 Scale

The SO imposes a saving target defined in t of CO_2 to be saved in a given period (usually about 3 years) on the large energy suppliers in the UK. Savings are accounted for in a benchmark procedure whereby the energy suppliers prove how many installations and which type of installations they delivered during the obligation period. The target does not require a reduction of total energy in a given period; it only defines a saving target. Since the SO started to operate in 1994 significant savings have been achieved (Rosenow, 2011). Theoretically, however, energy demand could increase by, for example, 5% over the period. If the savings target equates to <5% of total energy use, no total reduction is achieved. The SO does, however, account for the free rider effects, i.e. activity that would have taken place anyway, and explicitly treats some of the theoretical savings as 'deadweight' (Lees, 2008).

In theory, energy saving obligations could be designed to achieve total savings i.e. to reduce energy demand. The recently published proposal for the new EU Energy Efficiency Directive contains a requirement by which all member states have to put in place energy efficiency obligation schemes on all energy distributors or all retail energy sales companies operating on the Member State's territory to achieve annual energy savings equal to 1.5% of their energy sales, by volume, in the previous year. Although member states can opt for alternative measures if similar savings can be achieved, this is a first step towards aiming for total savings.

4.2.2 Persistence

Generally, most of the measures promoted by the SO relate to insulation (cavity wall and loft). Considering that most of the houses that will exist in 2050 have already been built (Killip, 2011), making improvements to the building fabric in terms of energy efficiency will have a long lasting impact on the energy consumption of those dwellings. However, as mentioned above, technical degradation may diminish that effect to some extent. Also, there is evidence that some of the measures promoted may actually not have generated the expected energy savings due to lower usage (e.g. households not using free CFLs). While behavioural measures have only recently been introduced and account for less than 1% of the total savings achieved in the third year of the current obligation period (OFGEM, 2011a)[3], there is uncertainty to whether the expected savings will actually be delivered and last over time. For instance, the lifetime assumed for real time displays (RTDs) is 15 years leading to a projected 3.5% reduction in average household electricity use (OFGEM, 2011b). RTDs may be powered by batteries with the risk that once those run out of energy the RTD is not used any longer. While the SO acknowledges this to some extent, RTDs powered by short-time batteries are assumed to only have a lifetime of 7.5 years, there is a high risk that the expected savings will simply not materialise.

4.2.3 Flexibility

With regard to flexibility, at least three issues deserve attention here. First, the saving target as such: As described above, government sets the saving target for an obligation period of usually around 3 years time. This is put in place by formulating secondary legislation which defines the saving target as well as the specifics of how it has to be delivered by the obligated parties. Due to the time required to put secondary legislation in place, government needs to decide on the saving target for the next obligation period fairly early on in the previous obligation period. While there is the flexibility to increase (or decrease) the saving target from one obligation period to another, once the target size has been decided, it is very difficult to change it again. This happened only once during 2008 when energy prices were increasing rapidly and government was under immense pressure to respond to this by supporting more households to save energy (Rosenow, 2011). Second, the specifics of how the saving target has to be delivered can and indeed have been changed frequently over time from one obligation period to another. This includes modification of the accredited measures and their savings. For example, the direct promotion of free CFL light bulbs by energy companies was banned after it emerged that people had been sent CFLs by multiple suppliers at the same time without using them. Also, new measures were brought into the scheme such as micro-renewables and behavioural measures.

As demonstrated above, there is generally a fairly high degree of flexibility. However, more radical modifications of the scheme may require changes in the primary legislation. For example, the extension of the scheme to other businesses and not just the energy suppliers (like a white certificate scheme) would require a change in one of the clauses in the primary legislation that says that all energy efficiency measures need to be promoted by the energy suppliers. The scheme is therefore not very flexible on that account.

4.2.4 Holism

The SO plays a very important role in UK home energy efficiency policy. However, without other policy measures, there may be limits to what the instrument can actually achieve. Over time, the low-cost measures that can be carried out in the housing stock reach saturation (as happening now with cavity insulation in the UK for example). One might argue that the SO was a very effective scheme to address the 'low hanging fruits', but struggles to deliver the deep retrofits that are required to achieve substantial long-

[3] Behavioral measures are currently capped at 2% of a supplier's target (OFGEM 2011b).

term savings. Increasing attention is now paid to the so called 'whole house approach', but considering the already fairly high contribution of £51 per customer per year to the operation of the SO (DECC, 2010), it is doubtful how far in terms of deep retrofits such a scheme can go. The successor of the current SO will focus particularly on solid wall insulation, which will probably demand even higher contributions from customers. Alongside the SO, the UK government is going to introduce a novel policy measure called the 'Green Deal' in 2012, with the aim of providing loans for whole house retrofits. However, the Green Deal is subject to a 'golden rule' which says that the expected financial savings must be equal to or greater than the costs of repaying the loan. While this makes sense from a household perspective, such an approach will not be able to deliver deep retrofits on the scale needed. While there are other programmes running alongside the SO and the Green Deal, at the moment there is no programme in place to deliver deep retrofits that will lead to long-term savings.

4.2.5 Summary

The SO does fairly well with regard to *scale* and the total savings achieved so far are impressive. However, the savings target is not set in percent reduction terms of total energy use, but in terms of an absolute amount of carbon emissions / energy that has to be reduced. Most of the effects of the SO are likely to be *persistent*, but questions remain about issues such as technical degradation and assumed lifetimes of behavioural measures. In terms of *flexibility*, the SO does fairly well which is reflected in frequent revisions of both the saving target and the technicalities of how it may be achieved. Nevertheless, more radical changes are difficult to achieve due to the legislative framework which upon the SO is based. Finally, the *holism* of the scheme is hampered by its focus on low cost measures and the limitations to achieve deep retrofits. Currently there are no aligning policies that correct for the lack of incentives for whole house retrofits.

5 Conclusion

This paper demonstrated that the current approach to energy efficiency, which is very much based on neoclassical economics and ecological modernisation, is unlikely to reduce total energy demand in the longer term. While the rebound effect received a large amount of attention, there clearly is the need to take the debate one step further. The paper therefore positioned energy efficiency in an ecological economics approach and outlined a potential framework for assessing energy efficiency programmes from such a perspective, which puts energy demand reduction centre stage. Finally, the framework was used to evaluate the energy savings obligations in the UK highlighting both areas where the programme does well and where there is potential for improvement.

As indicated above, the framework sketched is rudimentary as it stands and would need to become much more sophisticated. Future research could identify meaningful indicators and tests that could be used to assess energy efficiency programmes from an ecological economics perspective. It could then be applied to a range of different policy instruments and benchmark those according to their relative performance.

Ecological economics so far falls short of applicable concepts to energy efficiency policy and most of the literature engages with energy efficiency from a thermodynamic perspective. Translating those ideas into policy relevant frameworks can only be a first step. But if energy efficiency is to be taken seriously as a means to reduce energy demand and green house gas emissions, an ecological economics approach offers considerable potential.

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