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Exploring the Links Between Energy Efficiency and Resource Efficiency

Contents

This Thematic Issue is written and edited by the Science Communication Unit, University of the West of England (UWE), Bristol
Email: sfep.editorial@uwe.ac.uk

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EDITORIAL

Energy efficiency and resource efficiency: a key relationship

Energy efficiency is one of the key components of strategies to tackle climate change and to improve the security of energy supply as well as resource efficiency.

Increasing energy efficiency involves using a reduced quantity of energy to generate the same or improved product, process or service. It is generally measured in a physical unit as the ratio between energy output (Eo), and energy input (Ei). Similarly, resource efficiency refers to the ability to use a reduced quantity or volume of resources to produce the same or an improved service or product and it is measured as the ratio between useful material output (Mo) and material input (Mi), both measured in physical terms (Dahlstrom and Ekins, 2005).

The purpose of this Thematic Issue is to provide an overview of new research on the linkages between energy and resource efficiency to help to inform policymaking in this area. The selection of research presented here offers insight into three key policy-relevant areas: 1) the relationship between energy efficiency, resource efficiency and economic growth and wellbeing; 2) market and system barriers to energy efficiency and lessons learnt for resource efficiency in the area of demand-side management; and 3) the opportunities and challenges of improving resource and energy efficiency in the building sector, which is among the sectors with the greatest potential for efficiency improvements.

The Europe 2020 strategy includes a headline target of a 20% increase in energy efficiency by 2020, which derives from the EU's 2009 climate and energy policy — and resource efficiency has been one of its 'flagship initiatives'. Recent EU Energy commitments[1] have set a target of at least 27% for renewable energy and energy savings by 2030, while the EU's Energy Union Communication[2] places energy efficiency at the centre of its policy for achieving a fundamental transformation of Europe's energy systems by 2030. In fact, significant increases in energy efficiency are a key prerequisite for decarbonising the EU's energy system and achieving the target of a 80–95% reduction of GHG emissions by 2050 (cf European Climate Foundation *et al.*, 2013, and as reflected in EU energy efficiency targets for 2020 and 2030). The European Resource Efficiency Platform (EREP), a high-level group, provided guidance to the European Commission in the area of Resource Efficiency between 2012 and 2014. One of the EREP policy recommendations concerned the need to increase resource productivity from current levels (measured as GDP divided by Raw Material Consumption) by an order of magnitude of at least 30% by 2030, and to integrate this approach into the Europe 2020 strategy.

One limitation of current analyses of energy and resource efficiency is that they normally only compute one of the issues: either energy or resource efficiency. It is generally assumed that increasing energy efficiency will lead to improved resource efficiency and vice versa, but combined analyses are still scarce. The first article, **'Resource-efficient Portuguese packaging waste management system brings multiple benefits'**, provides an example of such analysis, describing how the packaging waste management system in Portugal brings not only important benefits in terms of material savings but also avoidance of CO_2 emissions through a strict application of the waste hierarchy. The study takes into account the energy needs for different waste processing methods. Although the collection, sorting and recycling processes consume energy and produce CO_2 emissions, these are offset by the impacts avoided due to material and energy recovery processes, while also generating added value for the economy.

The second article, **'Tools to reduce resource consumption identified by analysis of historical resource efficiency'**, presents an historical analysis that looks at the relationship between energy and resource efficiency improvements and resource consumption across a number of different sectors of activity, including iron and steel production, electricity generation from coal, oil and natural gas, and motor

1. *COM(2014) and October 2014 Council Conclusions*
2. *COM(2015) 80*

vehicle travel. The analysis produces somewhat mixed results. While in the long run, resource and energy efficiency improvements did not seem to lead to an overall reduction in the use of resources, the study also identified shorter, decade-long periods where increases in efficiency in the use of energy and materials exceeded or matched those in resource consumption. Although, in many cases, these periods were characterised by economic recession or structural changes, the research also suggested that policy could play an important role through two main types of policy measures: efficiency mandates and price pressure.

The next article, **'Energy efficiency measures in some EU countries could be backfiring'**, tries to estimate the magnitude of **rebound effects** for household energy consumption in the EU 28 plus Norway by correlating household energy consumption with an averaged energy efficiency index. Just under half of the countries show a rebound effect of over 50% while six countries have rebound effects over 100%. Nonetheless, it is unclear how much energy consumption would have risen without energy efficiency policies. The group with lower rebound effects is mainly made up of northern and western EU countries with advanced energy-efficiency policy frameworks, including Sweden, Belgium, France, Luxembourg, Germany, Austria, Ireland, the Netherlands and the UK, and also Austria. This seems to suggest that policy interventions are crucial factors in reducing the magnitude of rebound effects. However, two Scandinavian countries, Denmark and Finland, with strict environmental and energy efficiency standards and relatively high GDP per capita, also experienced rebound effects of over 100%. By looking more closely at one country, Germany, the paper points to factors that seem to have an effect on the magnitude of the rebound effect, such as changes in fuel prices, income, environmental awareness, demography and lifestyle.

The article **'Improving resource efficiency: new method identifies key areas of product improvement'**, concentrates on resource efficiency and focuses on how to communicate complex resource efficiency issues effectively to consumers. The article proposes a five-step method to assess the resource efficiency of a product with a focus on materials recovery at the end of its life. The method is said to provide information that is easier to interpret than complex Life-Cycle Analysis (LCA) data, which can assist designers to create more resource-efficient products.

The next two articles explore issues related to demand management and **social and behavioural barriers** to energy efficiency in the housing sector. Research points to the gap between the actual level of investment in energy efficiency measures and the level at which it would actually be cost-beneficial to the home owner. The so-called efficiency gap (Brown, 2001) has been explained as a combination of market and behavioural barriers resulting in actors not taking full advantage of energy efficiency measures (Kemp *et al.*, 2014). The article **'Energy efficiency policies for home renovations and retrofitting should consider the social factors'** is a qualitative investigation of the decision-making process guiding house renovation projects. The analysis is based on a sample of homeowners who have undertaken renovation projects that include the improvement of energy efficiency among their objectives. The findings suggest that energy efficiency considerations in renovations are frequently overruled by those of aesthetics, costs and convenience. The study also found that there was little evidence that overall energy use was reduced by the renovation projects as these projects also commonly entail extensions and additional bedrooms or bathrooms. Policy implications derived from the analysis point to the need to design policy programmes that tackle not only technological issues but also the social practices associated with the use of technology.

Awareness and behavioural change are the focus of the next article, **'Energy efficiency in low-income households: study explores the role of feedback information on energy consumption in reducing energy consumption'**. Research has suggested that feedback and detailed information may be effective ways to influence behaviour. However, this feedback needs to be tailored to the specific needs and characteristics of the household. The research presented in this article explores the role of feedback to increase energy efficiency and reduce energy consumption in low-income households in Sweden. The study of two groups of residents, with average ages in their 50s and 60s, showed that although residents were concerned about energy consumption for environmental and economic reasons, upfront costs rather than life-cycle costs were considered more important when, for example, buying appliances. The residents also showed a preference for receiving feedback on their energy consumption by post and through electronic home displays of real-time consumption. The article concludes that energy awareness campaigns should include both environmental and economic information.

The construction sector, and within it the housing sector, is the most material-intensive sector of the economy. In addition, buildings consume around

40% of Europe's energy (Odyssee-Mure, 2012). Two articles in this issue look at energy efficiency in the housing sector from a different perspective. The article **'Household energy efficiency could help boost the economy'** uses a general equilibrium model to analyse the economy-wide impacts of improving the energy efficiency of homes in the UK. The authors model a scenario where a 5% increase in energy efficiency in households is assumed, due to technological improvements. The findings suggest that these improvements result in a 0.10% increase in GDP and a 0.40% decrease in unemployment. The model takes into account both direct and indirect rebound effects — that is, increased energy consumption due to the monetary savings from greater efficiency being spent on other goods and services that involve energy use — with the overall rebound effect reaching almost 60%.

The focus of the second housing-related article, **'Overcoming the tendency of those living in energy efficient buildings to use more energy'**, is the rebound effects for Zero-Emission Buildings (ZEBs). The author argues that ZEBs are viable means to achieve energy efficiency but their potential savings may be reduced as a consequence of the rebound effect. In fact, the impact of rebound effects has generally been overlooked in the calculation of the energy balance of ZEBs. Using a case-study approach, the research identified three factors that can help to reduce or offset rebound effects in ZEBs:

1) Feed-in tariffs may stimulate the take-up of low-emission technologies, but should not be so high as to boost incomes excessively, thereby increasing energy consumption.

2) Choosing the most effective renewable technologies for the building and its site can increase the amount fed back into the grid, thereby dampening any rebound effect.

3) Policy that increases the prices of non-renewable fuels may dampen the CO_2 impact of the rebound effect directly, but also encourage investment in renewable technologies, which can reduce carbon emissions further.

In conclusion, the studies presented here give an idea of the complexity of the issue of energy efficiency, its links with resource efficiency and the wide range of factors influencing it, from technology to social practices. However, integration of energy efficiency and resource efficiency is still an area where substantial research gaps exist. The studies portrayed seem to suggest that energy and resource efficiency can have a positive impact on some economic indicators, and also suggest the key role of policy in facilitating the move to a more energy and resource efficient system. But there are uncertainties with regards, for example, to the resource implications of increasing energy efficiency and the material requirements for a low-carbon economy. Increasing energy efficiency in buildings may increase resource requirements of the sector, although little research has been undertaken to better understand the relation between energy and resource efficiency in the built environment. Given the issue's complexity, it is not surprising that policy impacts are not always in the desired direction and that special attention needs to be paid to both intended and unintended consequences of policies. The rebound effect is a good example of the need to monitor interventions carefully and to introduce flexible instruments that can be corrected and amended to achieve the desired outcomes. The studies indicate that there are policies which can be effective in counteracting rebound effects.

The studies featured in this Thematic Issue have pointed to the relevant role of pricing policies and market instruments to promote the adoption of more energy efficient solutions. These instruments may also have a role to play in promoting resource efficiency. Limited evidence exists with regards to, for example, aggregate levies and taxes applied in a number of European countries. Hence, further research into the role of market instruments in promoting resource efficiency is needed.

Unsurprisingly, another key issue highlighted by the research presented here is the relevance of social practices and behavioural issues. The studies have confirmed that there is a need to better assess behavioural issues, as interventions based purely on technical or technological solutions have not delivered the energy savings expected. Values and embedded social practices are shown to be as relevant as the technology itself in determining energy and resource consumption and consequently need to be addressed — if the greater levels of energy and resource efficiency required for the absolute decoupling of economic wellbeing from resource and energy consumption are to be achieved.

Dr Teresa Domenech Aparisi, Research Associate in Policies for Resource Efficiency, University College London

Professor Paul Ekins, Professor of Resources and Environmental Policy, and Director, University College London Institute for Sustainable Resources

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Kemp, R., Dijk, M., Domenech, T., Wieser, H., Bahn-Walkowiak, B., Weaver, P. (2014). Synthesis report and conclusions about barriers and drivers to resource efficiency. Report elaborated as part of FP7 POLFREE for the European Commission. Available online at www.polfree.eu/publications

Odyssee-Mure (2012). *Energy Efficiency Trends in Buildings in the EU.* Available online at: http://www.odyssee-mure.eu/publications/br/Buildings-brochure-2012.pdf

Contact: pribeiro@3drivers.pt
Read more about: Climate change and energy, Resource efficiency, Sustainable development and policy assessment, Waste

Resource-efficient Portuguese packaging waste management system brings multiple benefits

A Portuguese waste management system for packaging has brought a range of environmental, economic and social benefits, according to a recent study. One of the scheme's main achievements was that it avoided around 116 kilotons (kt) of CO2 equivalent emissions in a single year, equal to the emissions associated with the electricity use of 124 000 households. These emissions were largely circumvented because the system recovers large amounts of energy and materials from the waste packaging.

"Anything that cannot be recycled is composted, incinerated for energy recovery, or landfilled if there are no other options."

The Sistema Integrado de Gestão de Resíduos de Embalagens (SIGRE) (English translation: Integrated System for Packaging Waste Management) was set up in Portugal by a non-profit organisation in response to the EU Directive on Packaging and Packaging Waste. SIGRE organises and manages a loop for collecting, recovering and recycling non-reusable packaging waste from households and businesses.

Importantly, it is based on the waste hierarchy: recycling is prioritised as the main form of waste treatment. Anything that cannot be recycled is composted, incinerated for energy recovery, or landfilled if there are no other options. In 2011, 711 kt of the 1198 kt of waste it managed was recycled.

The study assessed the environmental, economic and social impacts of SIGRE. For environmental impacts they used life-cycle assessment methods that track how much energy and materials are used and produced by all its waste management processes, including collection, sorting and treatment (e.g. recycling, landfill). Data for this assessment were generated within the project itself or were taken from earlier studies, for example, those which have estimated the energy needs associated with waste processing.

Overall, the scheme brought clear benefits in terms of reduced emissions of greenhouse gases (GHGs) and air pollutants in the form of volatile organic compounds (VOC). It also reduced acidification of water and soil, water consumption and pressure on resources.

Its climate impacts were particularly striking: in 2011 it avoided the emission of 116 kt of CO_2 equivalent (i.e. a sum of GHGs with the same combined global warming impact as 116 kt of CO_2) by replacing virgin materials with recovered materials from the waste. The avoided emissions are a net calculation, based on direct and indirect impacts of the scheme. For example, the emissions produced by waste in landfill are a direct impact, and the emissions from the electricity needed for the waste sorting process are an indirect impact.

The study also calculated that for every €1 of gross value added (GVA) generated in SIGRE itself, €1.25 is generated for the wider Portuguese economy.

These economic impacts are realised in terms of direct impacts, such as payment for labour and resources, but also indirect impacts. The latter occur when companies which directly serve the scheme need to purchase goods or services from other companies. Thus the second-order, third-order and other companies also indirectly benefit from SIGRE, which is estimated to generate over 2300 jobs in companies and organisations associated with the scheme.

As well as demonstrating SIGRE's environmental benefits, this study's results support the European Environment Agency's claim[1] that moving up the waste hierarchy — away from landfill and towards greater resource efficiency through recycling — creates jobs and boosts the economy.

Source:
Ferrão, P., Ribeiro, P., Rodrigues, J., *et al.* (2014). Environmental, economic and social costs and benefits of a packaging waste management system: A Portuguese case study. *Resources, Conservation and Recycling.* 85: 67–78. DOI:10.1016/j.resconrec.2013.10.020.

1. *EEA. (2011) Earnings, jobs and innovation: the role of recycling in a green economy. EEA Report No 8/2011. Copenhagen, Denmark: European Environment Agency. www.eea.europa.eu/publications/earnings-jobs-and-innovation-the*

Contact: jdahmus@alum.mit.edu
Read more about: **Sustainable development and policy assessment, Resource efficiency, Environmental economics**

Tools to reduce resource consumption identified by analysis of historical resource efficiency

Improving the efficiency of industries and products has not led to overall reductions in the consumption of goods and services, a new study has found. The research looked at the historical relationship between efficiency improvements and resource consumption across 10 different activities, including electricity generation and passenger air travel. However, shorter decade-long periods, where efficiency improvements outpaced resource consumption, suggested that legislation and price pressures could be effective at reducing resource consumption.

"The analysis showed that historical efficiency improvements in the production of products or services, in general, did not reduce overall consumption of energy resources."

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Improving the energy efficiency in processes and technologies is often considered one of the most effective and least obtrusive ways of reducing resource consumption and the associated environmental impacts. However, while energy efficiency improvements can lead to social and economic benefits, it is not so clear whether they actually lead to long-term reduced resource consumption.

To better understand this, new research has examined the historical relationship between efficiency improvements and the consumption of different resources across ten different activities. These included: pig iron (an intermediate product in smelting iron ore) production (analysed between 1805–1990), aluminium production (1905–2005), nitrogen fertiliser production (1925–2009), electricity generation from coal, oil and natural gas (1925–2009), freight rail travel (1955–2009), passenger air travel (1955–2009), motor vehicle travel (1940–2009) and residential refrigeration (1960–2009).

For each activity, the quantity of goods or services provided was measured, and the efficiency recorded as the quantity of goods or services provided per amount of resource consumed, e.g. the number of miles flown per litre of aircraft fuel or the kg of pig iron per unit gigajoule of coke. This was done mainly using data gathered from US agencies and organisations, such as the Air Transport Association. The analysis was mainly limited to the US, however, for activities with integrated global markets (pig iron, aluminium and nitrogen fertiliser), global data were used.

Additionally, the study only focused on a single measure of resource efficiency, which may not take account of increases or decreases in the consumption of other resources for each industry.

The analysis showed that historical efficiency improvements in the production of products or services, in general, did not reduce overall consumption of energy resources (e.g. litres of fuel or amount of coal burned). However, this overview obscures shorter, decade-long periods in which efficiency improvements either outpaced or matched the consumption of resources for some activities.

While many of these periods of improved efficiency compared to consumption of goods or services were driven by turbulent economic times within an industry, as production shifted across continents or recessions affected markets, two practical measures were identified. These were government 'efficiency legislation' and 'price pressures'.

The effectiveness of government efficiency legislation was most clearly illustrated by US residential refrigeration, which had an overall decrease in resource consumption following the introduction of government rules setting limits on the efficiency of home refrigerators. However, the author cautioned that the 'rebound effect' — when consumers respond to an increase in energy efficiency and reduced cost by increasing their consumption — should be considered.

US passenger air travel was one example where price pressures, in this case partly due to rising jet fuel prices, drove longer term efficiency improvements and reduced resource consumption. As jet fuel prices rose, companies were forced, in the short term, to find other ways to reduce costs, such as passing them on through fuel surcharges, which resulted in a reduced number of flights and people flying. In the longer term, technological changes for more efficient use of fuel were employed.

While the price pressures identified were mostly driven by market forces, legislation also provided a route for achieving the same effect, for example through revised tax policies.

A final key message identified by the researcher, was that without external pressures, such as market forces or legislation, efficiency improvements rarely lead to reductions in resource consumption.

Source:
Dahmus, J. B. (2014). Can Efficiency Improvements Reduce Resource Consumption? *Journal of Industrial Ecology*, 18 (6): 883-897. DOI:10.1111/jiec.12110

Contact: RGalvin@eonerc.rwth-aachen.de
Read more about: Climate change and energy, Sustainable development and policy assessment

Energy efficiency measures in some EU countries could be backfiring

Policy efforts to decrease energy consumption by improving efficiency may be lessened by rebound effects. New research on household energy consumption indicates just under half EU countries (plus Norway) have rebound effects above 50%, and six are over 100% which means the efforts to increase efficiency backfire, i.e. they increase, rather than reduce, overall household energy consumption. There is a need to think critically about a policy response to the rebound effect and gain a better understanding of why it occurs.

"Rebound effects of policy measures occur when savings from energy efficiency are eliminated by increases in energy consumption."

Rebound effects of policy measures occur when savings from energy efficiency are eliminated by increases in energy consumption. Recently, energy policy has focused on improving energy efficiency of appliances as a means to reduce energy consumption and associated CO_2 emissions. However measures to promote better insulation or more efficient domestic appliances can suffer rebound effects. This occurs because improved efficiency allows people to save money previously spent on energy, enabling them to consume more overall, including energy services.

To inform EU policy in this area there is a need for a country-by-country estimate of the rebound effects, using centralised data and consistent definitions of rebound effects. The research calculated general rebound effects in each of the 28 EU countries, plus Norway, using figures on energy efficiency and consumption of energy services from 2000–2011 from the EU's Odyssee database[1].

Rebound effects were calculated as the percentage increase in use of energy services that occurs for every percent increase in energy efficiency over the time period 2000–2012. In a more general context, energy services are the 'product' derived from consuming energy such as warmth, cooling and air quality.

The study estimated that 13 of the 29 countries had rebound effects of less than 50% during this period. Economists consider these to be in the 'weak' rebound effect zone as more than half the gain in energy efficiency is being effectively utilised to reduce energy consumption. These countries were mainly north-western European countries, which have implemented advanced energy-efficiency programmes such as Sweden, Belgium, France, Luxembourg, Germany, Austria, Ireland, the Netherlands and the UK. Cyprus, Croatia, Portugal and Romania also fell into this category.

Eleven countries suffered strong rebound effects that were over 50% and six of these had effects of over 100%. When effects exceed 100% this is called a 'backfire' since an increase in efficiency increases rather than decreases energy consumption. The most dramatic rebound effects were in Lithuania (380%) and Hungary (552%), but two Scandinavian countries, Denmark and Finland, also suffered backfires. Nonetheless, it is unclear how much energy consumption would have risen without energy efficiency policies in place.

Negative rebound effects were seen in five countries: Slovakia, Slovenia, Spain, Greece and Norway. Here, consumption reductions cannot be explained by improvements in energy efficiency alone, indicating other factors are at work. In these countries, with the exception of Norway which had only a small negative rebound effect of -4%, economic hardship could be a driving factor for decreases in consumption.

It was not in the scope of the study to identify specific causes of rebound effects but, to gain some insight into this area, it considered the case of Germany more closely. Here it identified four likely factors that affect rebound effects: changes in fuel prices, in income, in environmental awareness and in demography and lifestyle.

The study suggests that rebound effects could present a barrier to the effectiveness of energy efficiency measures. Research focusing on these four factors could provide valuable insight into why energy efficiency measures do or do not work and help policy to improve effectiveness.

Source:
Galvin, R. (2014) Estimating broad-brush rebound effects for household energy consumption in the EU 28 countries and Norway: some policy implications of Odyssee data. *Energy Policy* 73:323–332 DOI: 10.1016/j.enpol.2014.02.033

1. *The Odyssee website (http://www.odyssee-mure.eu/) is co-funded by the Intelligent Energy Europe Programme of the European Union.*

Contact: fulvio.ardente@jrc.ec.europa.eu

Read more about: Resource efficiency, Sustainable development and policy assessment

Improving resource efficiency: new method identifies key areas of product improvement

A new five-step method has been developed for assessing the resource efficiency of products and improving the reuse, recycling and recovery of material at a product's end of life. The Resource Efficiency Assessment of Products (REAPro) method allows the identification and testing of practical measures to improve resource efficiency at both the product and policy level.

"Some Life Cycle Assessment results, which take the form of numerical environmental scores, can be difficult for product designers to interpret and do not necessarily provide useful information to develop design features which improve resource efficiency."

The Roadmap to a Resource Efficient Europe[1] aims to "transform Europe's economy into a sustainable one by 2050". The roadmap identified the use of waste as one of the EU's key resources to lower dependence on imports and reduce environmental impacts.

Life Cycle Assessment (LCA) is a commonly used tool to measure a product's environmental impacts, such as associated waste and damage to human health or ecosystems, from raw materials to disposal. However, some LCA results, which take the form of numerical environmental scores, can be difficult for product designers to interpret and do not necessarily provide useful information to develop design features which improve resource efficiency.

To respond to this shortcoming, researchers from the Joint Research Centre[2] of the EC have developed a method to assess the resource efficiency of a product, with a focus on the end-of-life phase of the product's life-cycle. The REAPro method uses five steps to improve resource efficiency and is illustrated here using a 20-inch (50.8 cm) LCD screen television as an example, though the approach could be used for a wide range of different products.

1) Characterising the product — including data on materials, disassembly information and possible environmental impacts over the product's lifecycle.

For the LCD screen, data on materials and recycling were obtained from a number of sources, including recycling plants, the manufacturer and the scientific literature. This included identifying precious metals in the printed circuit board, content of indium (a metallic element) in the screen and mercury used in the fluorescent back light.

2) Assessing the product's resource efficiency — in terms of recycling, reuse and recovery of the product and product parts, their environmental impacts or benefits and content of hazardous substances.

The LCD screen contained no reusable parts. The researchers examined two different treatments for the end-of-life stage: manual dismantling and mechanical shredding. The recovery of recyclable materials was much higher with manual pre-processing, and resulted in better quality materials for some materials and components.

3) Identifying product 'hot-spots' — key parts of the product which can provide the greatest improvements in the product's resource efficiency.

The printed circuit board, LCD panel and large plastic parts, such as the television frame, were identified as hot-spots for recycling. The circuit board, LCD and backlight were all considered hot-spots for hazardous substances. Currently, the recycling of some hot-spots, such as plastic frames with flame retardants and LCD panels, is not compatible with the shredding scenario.

4) Analysis of 'hot-spots' to identify practical measures which could improve the product's lifecycle resource efficiency. These measures are then tested again through steps 1 to 3, to see if they produce lifecycle benefits.

Three measures were identified. Firstly, decreasing the manual dismantling time of individual components, to help keep this process economically competitive with the faster, but less environmentally friendly, mechanical shredding option. Secondly, increasing the recycled plastic contents of frames to 20% or more. Thirdly, declaring the content of indium, for which recycling processes are currently being developed.

5) Assessing policy measures which could improve the resource efficiency of the product group.

The two possible policy options identified included the introduction of minimum thresholds for the recycled content in large plastic parts, and the mandatory declaration of indium content to help drive recycling when methods become available.

Source:
Ardente, F., & Mathieux, F. (2014). Identification and assessment of product's measures to improve resource efficiency: the case-study of an energy using product. *Journal of Cleaner Production*, 83: 126–141. DOI:10.1016/j.jclepro.2014.07.058

1 http://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm
2 http://sa.jrc.ec.europa.eu/?page_id=143

Contact: ellis.judson@rmit.edu.au
Read more about: **Sustainable development and policy assessment, Climate change and energy, Environmental technologies**

Energy efficiency policies for home renovations and retrofitting should consider the social factors

Policies and programmes providing technological solutions to improve household energy efficiency alone may be insufficient to actually reduce overall household energy consumption, finds new research. The research examined home renovators' motivations, behaviours and use of green technologies. Overall, reduced energy consumption was often undermined by other considerations, such as installation and maintenance costs, aesthetic considerations and daily or social routines.

"...policies and programmes focusing solely on technical innovations, such as improved insulation and solar power/heating, are likely to have a limited effect on overall energy consumption by homeowners where they occur alongside living space expansions."

To meet environmental objectives, such as reduced CO_2 emissions, many governments have put in place policies and programmes aiming to encourage households to improve their energy efficiency and to reduce their environmental 'footprint'.

Initiatives like 'The Green Deal' in the UK and the German 'CO_2 Building Rehabilitation Programme' provide loans for homeowners to overcome the upfront investment barrier in renovating or retrofitting their homes. However, how the resources provided by such initiatives are actually used by people will influence how well their ultimate environmental goals are achieved.

Understanding people's objectives when taking the decision to renovate, together with reasons behind their selection and use of specific energy efficient technologies as part of the renovation will be important for evaluating and understanding the outcome of these policies.

This study examined, through interviews and home 'tours', the motivations for renovation decisions and how day-to-day living shaped, and was shaped by renovations. A total of 36 owner-occupiers in Australia, categorised in two groups (self-identified 'green renovators' and owners of older 'heritage' houses), were interviewed. Their renovation objectives included improving their houses' energy efficiency and other aspects of environmental performance.

In some cases cost and convenience were found to overrule environmental considerations leading to lower quality renovation works. For example, one interviewee indicated that the installation and maintenance of wood windows was too expensive, instead opting for cheaper, less efficient, aluminium frames.

Aesthetic considerations were also often found to trump environmental concerns. For example, one interviewee reduced their renovation's thermal efficiency by installing multiple windows in order to create a lighter and open — more modern — living space.

Both groups undertook similar renovation projects, with 14 of 18 renovators in the 'green renovators' group adding an extension to their property, and 17 of 20 in the 'heritage' group also adding an extension. A quarter of both groups added at least one new bathroom.

Even in a case where a homeowner regarded improved energy efficiency as crucial to their objectives — by researching and investing in a range of 'green' technologies — there was little evidence at the time this study was carried out that household energy consumption had reduced following installation. Again, the renovation included expansion of the property, with additional bedrooms and bathrooms, reflecting the changing daily practices of the family.

The changing nature of people's everyday lives, such as providing an improved space for socialising or accommodating guests, both now and in the future (e.g. preparing for old age) were found to be the factors most affecting renovations, rather than concerns regarding environmental costs alone.

This suggests that policies and programmes focusing solely on technical innovations, such as improved insulation and solar power/heating, are likely to have a limited effect on overall energy consumption by homeowners where they occur alongside living space expansions.

Instead, it may be necessary to re-frame or re-think policies and programmes in a way which considers not just the technologies used, but how homeowners intend to and actually do use them in their daily lives following renovations. For example, examining and challenging typical household practices which have a significant effect on energy consumption, such as what is considered a 'comfortable' temperature for heating or cooling.

Source:
Judson, E. P., & Maller, C. (2014). Housing renovations and energy efficiency: insights from homeowners' practices. *Building Research & Information*, 42(4): 501–511. DOI:10.1080/09613218.2014.894808

Contact: iana.vassileva@mdh.se iana.vassileva@gmail.com

Read more about: Climate change and energy, Environmental information services, Resource efficiency, Sustainable consumption and production

Energy efficiency in low-income households: study explores the role of feedback in reducing energy consumption

Although low-income households consume less energy than wealthier households, they are still keen to learn how to save energy, for both economic and environmental reasons. This is the conclusion of a recent Swedish study which explored the energy-related behaviour of residents on low incomes. It provides insights which could help inform energy-awareness campaigns targeted at this section of the population.

"...a significant percentage (of respondents) said they are interested in saving energy for both economic and environmental reasons..."

Three quarters of European citizens take climate change very seriously, according to a 2008 Eurobarometer survey. However, consumers are often unaware of the link between their individual actions and emissions of CO_2, and tend to place responsibility for climate action with governments and industry.

This study considered how feedback on individual energy consumption could be given to households in Sweden. A number of earlier studies have shown that feedback is an effective way of raising consumers' awareness of their personal energy use that leads to behavioural change and cuts energy consumption — by 15–25% in some cases.

To help make this feedback effective, however, it should be specific to the type of household, this study proposes. It therefore focused on low-income households as a target group. Low-income households typically have fewer appliances than high-income households, but may be deterred from buying energy-efficient products due to higher upfront costs.

The researchers surveyed 35 households in the city of Växjö and 28 in Gothenburg through a questionnaire. Interviewees were asked about household characteristics, their energy-related behaviour and knowledge, and their preferred way of receiving feedback on their energy use. Although this is a fairly small number of interviewees, the results provide insights that could help guide the implementation stages of sustainability measures targeted at low-income groups.

The Växjö residents were more likely than the Gothenburg residents to prefer feedback by post — 26% of those in Växjö chose this option, compared with 12.5% in Gothenburg. The most popular choice for Gothenburg residents, on the other hand, was in-home displays (smart meter digital displays showing real-time consumption), chosen by 13% of respondents.

This difference can probably be explained by age, the researchers suggest: the slightly older residents of Växjö (average age 63, compared with 55 for the Gothenburg households) may be less familiar with technologies. No respondents chose text message or smartphone apps as their preferred option.

The residents were asked about specific energy-related behaviours in order to better understand their awareness and attitudes. For example, the results show that most residents loaded washing machines fully before use, which saves energy (although the study notes that most did not have their own machine and used shared laundry facilities).

In contrast, they appeared to make a limited effort to avoid leaving appliances on stand-by. Consumers should therefore be made more aware of the energy-saving benefits of turning off their appliances completely, the researchers suggest.

Product price was the respondents' main concern when buying new appliances, rather than efficiency. However, a significant percentage said they are interested in saving energy for both economic and environmental reasons (35.3% in Växjö and 46.5% in Gothenburg). Future energy awareness campaigns targeted at low-income households should thus include both environmental and economic messages, the study recommends. It suggests that consumers who would like to save energy for economic reasons should be given advice and information on energy prices, costs of current and future consumption and how much money they could save if they were to adopt energy-efficient practices.

Source:
Vassileva, I., Campillo, J. (2014) Increasing energy efficiency in low-income households through targeting awareness and behavioral change. *Renewable Energy.* 67: 59 –63. DOI:/10.1016/j.renene.2013.11.046.

Contact: karen.turner@strath.ac.uk
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Household energy efficiency could help boost the economy

Improving the energy efficiency of homes could have positive economy-wide impacts, recent UK research suggests. It would allow householders to spend the money they save on energy on other products and services. Although this additional demand and the associated production in non-energy sectors would partly offset the energy saved in the home, this 'rebound effect' is not shown to completely outweigh the household energy savings.

"...in the long-run, industry and householders adjust their behaviour and capacity in response to changes in energy consumption triggered by the efficiency savings..."

This study explored the links between increased energy efficiency of UK households and the wider UK economy using 'general equilibrium' modelling. In particular, the researchers investigated a potential 5% improvement in energy efficiency, which they assumed would occur as a result of technological improvements (e.g. more efficient appliances) that allow a household to continue operating at the same capacity, but using less energy.

Financial savings from this lower energy use will probably mean that householders use their appliances more than before, creating 'direct rebound effects'.

This study also considered 'indirect rebound effects'. These occur because the cost savings allow householders to spend more money on goods and services other than energy. The energy used by other sectors that provide these goods and services can reduce the overall benefits of the initial improvement in household efficiency.

To understand these rebound effects, the researchers assessed the energy usage of 21 economic sectors. These included four energy sectors: 1. coal; 2. refined oil (and also nuclear fuel that goes to the electricity generation sector —analysed together with oil, as these two sectors were integrated in the study's source of data); 3. gas; 4. electricity, and 17 other sectors, including food, textiles/clothing and finance.

The model's results suggest that the 5% improvement would have positive effects on the national economy, because increased real income and spending on non-energy sectors has a greater economic impact than the same amount of spending on energy.

The effects would change over time; in the long-run, industry and householders adjust their behaviour and capacity in response to changes in energy consumption triggered by the efficiency savings; for example, although energy companies will drop their prices in the short term in response to reduced demand, they may increase them in the longer run in order to restore company revenues.

In the long term, the national GDP could increase by 0.10% in response to the household expenditure changes. Total household consumption of goods and services would increase by 0.25% in value and national investment by 0.10%, results suggest. There could also be a corresponding 0.40% fall in unemployment rates and average wage increases of 0.07%.

Household energy consumption would fall by 1.62% and overall energy demand, from all 21 sectors, by 0.22%. Large amounts of energy are required to produce useable energy itself, for fuel extraction and processing, for example, which makes the energy sector more energy-intensive than most other sectors. The transfer of demand from energy to other sectors thus translates into an overall drop in energy use.

The overall rebound effect is calculated to be 59.3%, including direct and indirect effects. In other words, 59.3% of the initial 5% household energy efficiency savings will be offset by resulting changes in the UK's total energy usage.

The study also considered another possibility: householders may feel financially better off thanks to energy savings, and consequently apply less pressure on employers for higher wages. If this occurred, the economic impacts would be even greater because suppressed wages reduce labour costs per worker, and so have an economic effect that is similar to greater industrial productivity.

Thus, under this scenario, although wages could fall by 0.11% in the long run, this is in nominal terms, not real terms, i.e. average wages drop, but so does the cost of living, as judged by falling prices for a wide range of products, including energy, in the Consumer Price Index. Lower costs of living could effectively allow consumers to afford more than previously.

Unemployment rates could drop by 0.99%, GDP would increase by 0.24%, household consumption by 0.29% in value and investment by 0.24%. More energy is consumed under this scenario than under the first, but the rebound effect is only modestly higher at 63.9%. Moreover, the greater growth comes with a drop in the price level, triggered by the fall in wage levels. The resulting increased competitiveness would lead to a 0.06% rise in exports.

Source:
Lecca, P., McGregor, P. G., Swales, J. K., & Turner, K. (2014). The added value from a general equilibrium analysis of increased efficiency in household energy use. *Ecological Economics*. 100: 51–62. DOI:10.1016/j.ecolecon.2014.01.008.

Contact: julien.bourrelle@ntnu.no julien.bourrelle@monda.no
Read more about: Resource efficiency, Environmental economics, Climate change and energy

Overcoming the tendency of those living in energy efficient buildings to use more energy

Zero Energy Buildings (ZEBs) are a viable means to reduce global energy demand, a new study suggests. However, in response to the drop in energy costs for the household due to better energy efficiency, people may begin to consume more energy than they otherwise would. These 'rebound effects' can undermine emissions reductions, the study says, and it proposes possible approaches that could lessen these impacts.

"Rebound effects occur because better efficiency reduces the cost of energy in a household, hence increasing people's income and inducing them to consume more, including more energy."

ZEBs are gaining policy support in the EU as a means to reduce CO_2 emissions. The buildings have high energy efficiency and aim to offset any remaining emissions from the everyday running of the ZEBs together with those created by the construction by generating or investing in renewable energy. This can be done on site if the building is situated in an appropriate place, for example by fitting roof solar panels on a house that receives plenty of sunlight, or by investing in renewable energy that is generated off-site.

Although improving the energy efficiency of households is a popular approach to reduce emissions, rebound effects can undermine the savings made. These effects occur because better efficiency reduces the cost of energy in a household, hence increasing people's income and inducing them to consume more, including more energy. This can be through using energy within the house itself, purchasing other services or goods that consume energy or investing the saved money which is then re-spent by financial institutions in activities that increase energy use.

In the past, rebound effects in ZEBs have been neglected in the calculation of the energy balance but they should be considered, the study says, when making policy decisions in this area. The study plotted non-renewable energy usage for the different building stages, such as manufacture of materials, construction and demolition, against the cost of these stages. This was done for both ZEBs and conventional buildings in a northern heating-dominated climate and the comparison allowed an analysis of money available from ZEBs to potentially re-spend on energy.

The research identified three major ways to influence rebound effects in ZEBs:

Feed-in-tariffs: Many EU countries encourage the generation of renewable energy with tariffs that pay people for the renewable energy they 'feed in' to the national grid. High feed-in tariffs will encourage renewable generation early on but, if they are too advantageous, ZEB owners will be able to offset their emissions, pay off the cost of the building and still earn from renewable generation. This will mean they will have money to spare to potentially consume more energy in the house or engage in energy consuming activities, such as air travel. As such, advantageous feed-in tariffs should be limited to the technology adoption phase in ZEBs to encourage investment in renewable energy technology. Once the owners are 'earning' money from the ZEB then the tariffs could be lessened to reduce their spending. However this reduction must not be so severe that it discourages people from investing in ZEBs in the first place.

Choice of effective renewable energy: Rebound effects can be dampened through adopting the most effective renewable supply option, i.e. producing the most energy for least cost. For example, for ZEBs in the northern climate, investing in wind power is likely to be more effective than installing photovoltaic (PV) systems. The rebound effects on energy use are dampened because, with more effective renewable energy, the ZEB feeds back more energy into the grid than is used to construct the building, giving it a negative energy balance. So, although there may be some re-spend of cost savings on energy-consuming activities, the ZEB has an energy credit which it can use before the impact of any rebound effect kicks in, therefore acting as a form of buffer against the rebound effect. This approach is especially effective when combined with incentives to spend additional cost savings in renewable energy.

Controlling energy prices: Rebound effects can be reduced through energy prices, for example if prices for non-renewable fuels are increased while incentives for renewables are improved, this can encourage greater re-spend of cost savings in the renewables sector.

Both the building sector and policymakers need to be aware of possible rebound effects associated with ZEBs. More research is needed to quantify these effects so they can be included within the energy balance of ZEBs and clarify the real emissions savings.

Source:
Bourrelle, J.S. (2014). Zero energy buildings and the rebound effect: A solution to the paradox of energy efficiency? *Energy and Buildings* 84: 633–640. DOI: 10.1016/j.enbuild.2014.09.012

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News Alert articles

Buildings' future heating and cooling needs are predicted with new method

Which types of buildings will require the least energy for heating and cooling under climate change? A study in Vienna, Austria, looked at the balance between heating and cooling demand in four different types of buildings. The research provides a method that could be useful for other European cities trying to adapt to climate change.

http://ec.europa.eu/environment/integration/research/newsalert/pdf/buildings_future_heating_cooling_needs_predicted_395na3_en.pdf

Refurbishment of Italian homes could provide energy savings of 85%

Simple measures to upgrade buildings by improvements to insulation or heating systems could result in energy savings of up to 85% in Italian homes, according to recent research. Across Europe, such measures could potentially provide energy savings of more than 40% on average, say the researchers.

http://ec.europa.eu/environment/integration/research/newsalert/pdf/378na6_en.pdf

Rising energy demands could see the energy sector's water footprint increase by 66%

Increases in global energy requirements could lead to a rise in the energy sector's water footprint of up to 66% in the next 20 years, new research suggests. As part of a sustainable future, any energy mix must enable a reduction in greenhouse gas (GHG) emissions. However, some renewable sources, such as biofuels and large-scale hydropower, have large water footprints, a factor which must also be considered in energy policies, the researchers say.

http://ec.europa.eu/environment/integration/research/newsalert/pdf/366na1_en.pdf

Concrete and asphalt's green credentials could be improved through changes to production

Concrete and asphalt's environmental impact could be reduced by over a third through changes to manufacturing processes and the use of alternative raw materials, according to research. A scenario study based on life cycle analysis has indicated that using alternative types of cement in concrete and producing asphalt at lower temperatures could substantially improve the green credentials of these two common building materials.

http://ec.europa.eu/environment/integration/research/newsalert/pdf/364na4_en.pdf

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http://ec.europa.eu/environment/integration/research/newsalert/pdf/38si_en.pdf

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This Thematic Issue reports on research which helps guide the way to a more resource-efficient society.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/26si_en.pdf

Future Briefs

Green Behaviour (October 2012)

The role that policy can play in supporting and encouraging the public's pro-environmental behaviour is examined in this Future Brief. The report explores different policy methods to reward green behaviour, such as financial incentives.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/FB4_en.pdf

In-depth Report

Resource Efficiency Indicators (February 2013)

Resource efficiency forms a vital part of Europe 2020, the EU's growth strategy towards a smart, sustainable and inclusive economy. This In-depth Report examines the progress in resource efficiency indicators, building on the EU's Resource Efficiency Roadmap.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR4_en.pdf

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