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Strategies for household energy conservation

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Abstract

The energy consumed by households for space heating and cooling, water heating, cooking and running appliances is a major component of national final energy use. Along with private transport, it is the only energy use (and corresponding greenhouse gas emissions) directly under householders' control. Accordingly, many researchers have examined ways of reducing household energy use, using either monetary or non-monetary measures. We find that although case studies suggest only a limited role for energy pricing, our comparative study of domestic energy use by different nations suggests otherwise. Energy researchers have also examined various social science approaches, but again their effectiveness in case studies is limited. We argue, however, that householders, taking their cue from political leaders, do not presently take climate change very seriously. This attitude could well change over the next decade or so, and with it the scope for non-monetary approaches to energy and thus carbon reductions.

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Key words: Climate change; energy pricing; household energy conservation; non-monetary incentives; pro-environmental behavior.

1. Introduction

Domestic energy use represents an important share of total energy consumption in OECD households, and in middle and high income households outside the OECD. For example in the US in 2013, it accounted for 21.7% of total primary energy, and 37.7 % of all US electricity use [1]. Along with private transport, domestic energy use is one of the few means available to households to directly reduce energy use and the corresponding GHG emissions. Following the Paris Conference in 2015, it is widely agreed that GHG emissions must be drastically reduced if the planet is to avoid a temperature rise of more than 2 °C above

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the pre-industrial figure. Indeed, one prominent climate scientist, James Hansen [2], has argued that even 2 °C will set the Earth on a path to multi-meter sea level rises. Given both the gravity of the problem, and the short time available to take decisive mitigation action, all energy consuming sectors, including the domestic sector, will need to make large reductions. (In this paper, the terms 'household energy' and 'domestic energy' will be used interchangeably.)

Domestic energy use is known to vary with a number of factors, including household income, local climate, household size, and dwelling floor area. Domestic energy use is greater for households with higher incomes, higher household occupancy rates and larger floor areas, and for residents of colder regions [1,3]. Although air-conditioning energy is greater for residents of warmer climates, this increase is more than compensated by lower winter heating energy use [4]. This paper, however, only examines the extent to which policy levers readily available to energy planners, including increased energy costs and various non-monetary approaches, can reduce domestic energy consumption. It also is restricted to non-technical measures—it excludes energy efficiency improvements.

Why is domestic energy reduction important, if the urgent problem is climate change and thus GHG emissions reduction? After all, many researchers believe that a variety of technical solutions such as a shift to non-carbon sources, mechanical and biological carbon sequestration, and even geoengineering (in the form of solar radiation management) can be implemented that will remove any need for energy reductions [5]. We, however, have previously argued that deep GHG reductions inevitably mean deep energy cuts [6,7]. In brief, the present shift to non-carbon energy sources is proceeding far too slowly [8] to make much difference in the time-frame available for serious climate mitigation [9]. The scope for feasible biological CO2 removal by afforestation and forest management is too small when compared with annual CO_2 emissions [10]. Mechanical CO_2 capture and sequestration is both energy intensive and costly, and may run into limits on both possible annual rates of secure sequestration and storage capacity. Geoengineering, although it could be rapidly implemented technically, faces both major known and possibly unknown environmental risks, as well as serious political obstacles, since the benefits and costs (such as reduced precipitation) will be unevenly distributed between regions.

Nomenclature

EU	European Union
GHG	greenhouse gas
GNI	Gross National Income
GJ	gigajoule (10^9 joule)
OECD	Organisation for Economic Cooperation and Development

2. Monetary incentives and information provision

Two approaches to domestic energy conservation are often implicit. One approach, increasing energy costs, can often be evaluated by before-and-after analyses of energy use after a price rise, and is discussed in Section 2.1. Section 2.2 examines the role that energy *information* provision can play in cutting energy use.

2.1. Monetary incentives

Some researchers (e.g. [11]) have argued against using monetary incentives to promote household energy conservation. They argue that appeals to monetary motives run the risk of any energy reduction effects becoming undone if costs fall, as has happened to some extent with gasoline prices since 2014. Better to be 'green' rather than 'mean' [12]. Asensio and Delmas [13] have likewise argued for the superiority of non-price incentives over cost-savings information. However, statistical energy data at the international level provide a 'natural experiment' which seems to contradict this assumption. Table 1 presents the unit costs for domestic natural gas and electricity for a number of OECD countries covering the full range of domestic energy costs [14]. Further, the UK Office for National Statistics [3] regarded price increases as one reason for the fall in average UK household energy use between 2005 and 2011.

In final energy consumption terms, per capita domestic energy use in Europe and Japan, with their high-priced energy, is lower than in the US (Table 1). For year 2013, final domestic consumption for Denmark, Germany and Sweden was appreciably lower than that of the US, despite having generally colder climates. (The centre of population for the US is at 37.5 °N, compared with about 51.5, 55.5 and 59.0 °N for Germany, Denmark and Sweden respectively [15].) As can also be seen from Table 1, per capita incomes in the three EU countries are comparable to that for the US. In Japan it is some 20% lower than in the US, but per capita domestic energy use in the US in 2013 was over twice as high. (Japan's centre of population is comparable to the US, at 35.5 °N [15].)

Table 1. Domestic energy prices ($US/GJ), use (GJ/capita) and GNI/capita, various countries

Country	Natural gas price ($/GJ)[1]	Electricity price ($/GJ)[1]	Final domestic energy use (GJ/capita)[2]	GNI per capita (2014 $US)
Denmark	32.8	112.0	32.0	61,310
Germany	26.3	109.7	30.4	47,640
Japan	NA	70.4	15.8	42,000
Mexico	9.8	25.0	NA	9,870
Sweden	42.8	59.6	30.4	61,610
US	10.0	34.7	37.7	55,200

[1] 2014 prices; [2] 2013 energy use

Sources: [1,14,16-18].

Given the aspirational targets set at the December 2015 Paris Agreement, and the increasing number of countries that have either introduced carbon taxes [19], or are planning to do so, it is inevitable that the real unit costs of domestic energy will rise substantially in future. The International Monetary Fund [19] believes that carbon taxes (or carbon trading schemes that would have a similar effect) should be 'front and center' of climate change policies. Others worry about the equity aspects of carbon taxes. However, the equity problem will be much less of an issue in relatively egalitarian countries like Denmark (which has already introduced a carbon tax) than in less egalitarian countries like the US. And, as already discussed, the high energy priced countries of the EU have significantly lower domestic energy use per capita, which helps offset the burden of higher prices. Nevertheless it is still the case that non-monetary approaches should be used in preference—if they can deliver the necessary energy savings.

2.2. Energy information provision

Householders have long had basic information on domestic energy and gas use from their utility bills. Nevertheless, research has recently shown that householders typically hold erroneous ideas about the power consumption of various household appliances, believing for example, that the size of the appliance is a reliable indicator of its power consumption [12]. Attari et al [20] found that householders were very poor at estimating the power consumption of various appliances, over-estimating for low energy-intensity appliances, and under-estimating for high energy-intensive ones. Overall, they markedly underestimated power consumption.

Delmas et al [21] conducted a meta-analysis on field studies of the impact of electicity use information programs on conservation, and found an average reduction of 7.4%. They concluded that 'strategies providing individualized audits and consulting were comparatively more effective for conservation behavior than strategies that provide historical, peer comparison energy feedback'. It seems that under present circumstances at least, the enhanced potential for information provision provided by smart meters will have limited impact. In Section 4 we will re-assess the potential for this approach.

3. Behavioural change approaches for energy conservation

In general, social psychology researchers are optimistic that applying their latest findings to household energy use can effect big savings. For example, Dietz [22], in the context of climate mitigation, has claimed that even modest interventions could reduce *overall* US CO_2 emissions by 7%. Surveys in OECD countries also consistently find that a high proportion of respondents claim that environmental protection is important to them, which should at first glance make them responsive to GHG reduction messages. This section looks at the potential for social science to motivate change in domestic energy use.

It is important to stress that pro-environmental *behaviour* is more important than pro-environmental *attitudes*, which often do not translate into energy savings. Higher income households are often found to display positive attitudes [23], but national energy surveys consistently show that such households also have higher household energy use. However, the public has been led to believe that the climate change problem can be solved by the mix of technical fixes already discussed, including increased use of non-carbon energy sources and carbon sequestration, with geoengineering as a backstop technology. It may even be that pro-environmental attitudes and high energy use are seen as consistent, given the belief in technical climate and energy fixes. Lower income households, may consume less energy simply because energy costs represent a higher proportion of their budget than is the case for higher income households. They are *involuntary environmentalists* [4].

Asensio and Delmas [13] examined the household electricity savings potential of information designed to raise awareness of health-related problems of electricity production. They concluded that: 'Environment and health-based information treatments motivated 8% energy savings versus control and were particularly effective on families with children, who achieved up to 19% energy savings.'

Visual feedback to grasp otherwise invisible information may provide effective results compared with information-only methods. For example, Goodhew et al. [24] suggested that householders provided with both thermal image and energy (and carbon footprint) audits were more likely to save energy compared with householders with only energy audit information. Dixon et al. [25] concluded that, due to pre-existing attitudes, an attitude-based campaign only can have a limited influence on behaviour. However, a comparative feedback campaign can motivate those with strong pro-environmental attitudes to produce stronger energy conservation.

This brief survey of the recent literature on both information provision on energy use and social science approaches to household energy reductions suggests that they can only produce modest savings, especially compared to the depth of reductions climate scientists think are needed. But it may be the case that the households, in the case studies examined, are not fully aware of the challenge climate change will pose for all Earth's people. Powerful voices—many associated with the fossil fuel industry—still argue against climate change, and even in the media that recognize climate change, readers will often come away with the impression that change will be both linear and gradual, and that in any case, a plethora of technical solutions are available which will require no real lifestyle changes, apart from some adaptation. However, if the general population is convinced of a serious danger, social practices can change rapidly, as happened in the UK during the Second World War. Climate scientists believe that the changing climate will soon impact with rising severity on the everyday lives of more and more of the world population [26]. Such rises in extreme events could well shift attitudes toward climate change over the next decade or so, making households much more susceptible to carbon reduction information and motivational messages.

4. Discussion and conclusions

Although average energy use reductions found to date from information or behavioural interventions have been small, the *potential* for domestic energy reductions through changes in occupant behaviour appear large, as indicated by extreme changes. Pilkington et al [27] examined six terrace dwellings in the UK, and found that demand for space heating (normalised by occupant number) varied by a factor of 14. A later German study [28] likewise concluded that for EU countries at least, occupant behaviour was much more important than the energy efficiency rating of dwellings in determining heating energy use. The problem is to motivate all householders into realising this conservation potential.

This paper has argued that the scope for behavioural approaches to household energy and GHG reductions, while seeming modest today, could be large in the future. For monetary approaches, the *context* for reductions seems important. Countries with low fossil fuel reserves—such as many EU countries and Japan—usually have the highest domestic energy (and also petrol/diesel) prices, in contrast to resource-rich countries like the USA and Australia. Low or zero fossil fuel reserves also means that business pressures for down-playing or denying climate change are lessened, and fears about energy security heightened, so that the electorate is more willing to accept such high prices and the need for energy conservation. Even for resource-rich countries, the rising frequency predicted for extreme climate events could well be the trigger for a sense of urgency about household energy/carbon reductions.

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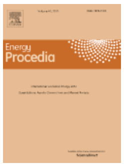

Biography

Stephen Jia Wang (research: Tangible Interaction Design, behavioral changes for sustainability) is Senior Lecturer, Director of ITIDLab and Program Director in Interaction Design; Patrick Moriarty (research: energy, transport, global futures) is Adjunct Associate Professor, both in the Department of Design, Monash University, Australia.