Rapid energy savings in London's households to mitigate an energy crisis

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1. Key words

Rapid energy savings, energy crisis, behaviour

2. Abstract

This paper reports on research on the potential for the voluntary and rapid curtailment of energy use in London's (United Kingdom) households in response to a short term energy crisis. The work investigates whether such a crisis could be mitigated through voluntary means. The measures considered include: lower thermostat settings, shorter showers, and reduced use of lighting and electrical appliances. This paper presents the results of a postal survey of Londoners' behavioural intentions toward adopting specific energy saving measures. The potential energy reductions through behavioural change have then been quantified using an approximate evaluation of possible savings. Further development of the work involving a more detailed model of energy savings will be conducted using a stock model based on the English Housing Survey and calculations based on SAP.
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Introduction

The issue of security of energy supply is receiving increasing attention around the world and in the UK, due to North Sea and global natural gas and oil reserve depletion, the impending closure of a number of power stations, and a variety of other factors (Bird 2009). Many of the strategies which address energy shortages are focused on geopolitical or technological solutions. However, energy resilience can also be strengthened through short term, voluntary behavioural changes. Rapid reductions in energy use can be promoted through advertisement campaigns and calls from governmental authorities (IEA 2005a). This has most recently been seen in Japan (BBC News 2011) where the government has called for citizens to save energy to alleviate the deficiency in electricity supply following the recent crisis (earthquake and tsunami, March 2011). This work looks at the energy savings that could be achieved in London's households in a crisis.

3. Background

"Energy Security" in the UK is mostly thought of in the context of reducing natural gas and oil reserves in the North Sea and the impending closure of a number of power stations. In addition to this, new concerns are arising in relation to possible terrorist attacks on energy infrastructures (in the US see for example Rose (2007) and Greenberg et al. (2007)), the escalating occurrence of severe weather causing energy disruptions, the potential political consequences of shrinking oil reserves, and finally the reliability instability that renewable energy may cause (Yergin 2006).

In December 2009, a part of London had its natural gas supply cut due to a technical failure (BBC News 2009). Last winter, the UK's newspapers announced that the UK could "run out of gas" within hours. Natural gas as supply had been interrupted to some businesses that had "interruptible" natural gas supply contracts (Webb 2009, Macalister 2010). This work looks at alternative or supplementary solutions to interrupting business contracts.

Energy security is threatened when supply is not sufficient to respond to demand, and most discussions concentrate on the supply side (particularly, on the external supply sources) (Bielecki 2002). Many of the strategies attempt to improve the capacity of production, transformation, transmission or storage, to diversify sources (both in terms of energy type and location), to increase relative domestic production to energy use, or, to establish energy supply interdependencies between countries. Whilst the strategies that aim at improving energy security through upstream solutions are important and essential, they can also be complemented by downstream, or demand side measures. Automated demand-side peak load reduction is receiving much academic attention (for example in the context of Smart Grids and dynamic demand systems (Wood & Newborough 2003, Albadi & El-Saadany 2008) as well as the response to variable energy prices to mitigate peak demand. Yet, as pointed out by Godschalk (2003), urban hazard mitigation practices must include both technical and social approaches, and this could apply to energy crises – the mitigation potential of user behaviour could also be significant in the context of energy emergencies.

Saving energy in a hurry

Measures and policies aiming at rapidly reducing energy use have been used as a crisis prevention tool around the world for many years. 'Rapid' demand response or demand restraint, also commonly called 'saving energy in a hurry', is an approach by which the energy customers are asked to reduce consumption through rapid changes in their energy consumption behaviour, generally on a temporary basis, but the time scale vary depending on the length of the shortage. Such programmes are usually voluntary, or more rarely, compulsory (meaning that a penalty is implemented to non-compliant consumers), and they are promoted through advertisement campaigns, such as press, television, posters, and more recently internet media. These measures are adapted to 'shortfalls' in electricity supply but will not prevent sudden and unexpected accidental blackouts, due to the time such measures take to implement (IEA 2005a).

Well known examples are the campaigns during the 1970s with the oil crisis and World War II with the "Save Fuel for Battle" campaign in the UK. Perhaps less noticeably, such approaches have also been used in the past ten years in New Zealand, California and Japan in response to energy shortages.

'Saving electricity in a hurry' measures are often surprisingly cheap, effective, and can support more general (not crisis related) energy saving measures (IEA 2005a).

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Table , which was compiled from different documents, illustrates some examples of electricity shortage events when rapid demand response measures have been implemented, with an indication of the savings that have been achieved and whether actual electricity blackouts were experienced.

Table : Table of electricity energy savings through saving electricity in a hurry measures - sources: adapted from (IEA 2005a, Meier 2006, Chen 2008, Blackwell 2009)

Location, date	Cause and trigger	Savings achieved
Chicago, USA 1995	Heat wave caused high electrical demand on over-taxed transformers. Failure to renew infrastructure	Not Known (NK)
Southern Australia, 1998	Explosion at natural gas production facility limited natural gas supplies to power plants. Possible market manipulation	Not Known (NK)
Brazil, 2001	Drought and economic upturn causing increased demand Partial de-regulation failed to increase electricity supplies	20%*
Sweden, 2001	Anticipated cold wave combined with expected high demand on Monday. De-regulation led to mothballing of peak plants	4%*
California, 2001	High number of plants out of service, reduced imports Incomplete de-regulation, shortage of natural gas, drought in nearby areas, market manipulation by independent generators	15%
New Zealand, 2001	Drought	10%*
Auckland, New Zealand 2001	Transmission line cut	Not Known (NK)
Tokyo, 2003	Nuclear plants shut down - Utility admits to preparing inaccurate safety reports. Severely limited connections to neighbouring utilities.	3%*
Presque Isle, USA, 2003	Flood damages cooling system of power plant Remote location prohibits substitution via transmission	Not Known (NK)
New Zealand, 2008	Drought Uncertainty surrounding de-regulation discouraged construction of new generation capacity	Not Known (NK)
Norway, 2003-2004	Drought, early and unusually cold winter Reduced oversight of supplies after deregulation	8%*
Ontario, 2003	Slow re-start of nuclear power plants following US/Canada blackout. Occurred during situation of long-term supply shortfall	17% in industrial buildings
Italy, 2003	Heat wave combined with unexpected reduction in imports Failure to build new generating capacity for many years. Coincided with reduced availability of power from Germany wind farms	Unknown -probably very small
France, 2003	Heat wave and drought led to increased demand and reduced output Occurred during period when many nuclear plants were shut down for maintenance. Other plants could not operate because thermal limits in rivers had been exceeded.	Not Known (NK)
Southern California, 2003	Forest fire interrupted transmission	Not Known (NK)

Juneau, Alaska, 2008	An avalanche damaged a major electrical power line which had carried inexpensive hydroelectric power that supplied 85% of electricity of the line	40% (not academic source)

* With no major blackouts

Despite the focus of this paper not being about oil, it is worth noting that 'Saving Oil in a Hurry' measures have also been used at many occasions in the past, the most well known example being the measures taken by governments to curb oil demand during the seventies energy crisis. The IEA's "Saving Oil in a Hurry", (IEA 2005b) gives very broad quantified estimates of the possible impacts of different measures for different regions of the world and based partly on past experience and educated guesses.

The examples given above clearly illustrate the potential in implementing measures that aim at saving energy in a hurry. However, the potential of such measures implemented in the UK in the event of a natural gas or/and electricity crisis, has never been evaluated. Hence we propose to investigate to potential of such measures implemented for the UK, using London's households as a case study.

4. Overall method

The metropolitan area of Greater London has been selected as a case study, due to the convenience to access and analyse information regarding energy use, and as London uses 7% of the UK's natural gas consumption and 13% of the UK's electricity (DECC 2010a). The work is composed of two parts:

- A mail survey which investigates Londoner's willingness to adopt a range of specific energy saving actions in the context of a natural gas shortage;
- A numeric evaluation of the energy savings this could result in.

5. Preliminary discussion on the use of survey to predict actions

Using a survey to predict energy savings presents a significant assumption: it assumes that the respondents of the survey effectively will put into practice the actions that they declare they intend to implement. This assumption presents is broadly based on the 'Theory of Reasoned Action' (TRA) advanced by the Fishbein & Ajzen (Figure), which suggest that attitudes precede intentions, and that such intentions are predictors of behaviour, as shown in Figure . If a person intends to have certain behaviour then it is likely that the person will do it. Furthermore a person's intentions are themselves guided by two things: the person's attitude towards the behaviour and subjective norms (Fishbein & Ajzen 1975).

Figure : The theory of reasoned action (Fishbein & Ajzen 1975)

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However, this theory has been widely debated, with conflicting results.

It was found that attitudes had less influence on energy consumption than non-psychological, structural variables (i.e. temperature, income and house size), which were all positively correlated with energy consumption (Ritchie et al. 1981). Hale and al. (Hale et al. 2003) further pointed out that the aim of the TRA is to explain volitional behaviours. It therefore excludes behaviours which are mechanical, spontaneous, and impulsive for example. In addition to this some consumers that might want to change their behaviour might not be able to do so. In relation to energy efficiency this may be due to economical constraint, social pressure, or lack of physical opportunity (Kaiser 1999). Hence, it is possible to overestimate ecological behaviour – or even more specifically energy efficient behaviour (Wood & Newborough 2003). A number of characteristics present a stronger link, such as for example, taking into account all household members or attitudes towards specific energy actions as opposite to general attitudes (Shipworth 2000).

Sheppard et al. (1988) reviewed a total of 87 studies – not specifically related to energy saving- and found a correlation of 0.53 for the Behavioural Intention- Intention relationship and 0.66 for the Attitude + Subjective Norm - Intention relationship. This suggests a relatively strong support for the 'Theory of Reasoned Action'. The authors suggested some necessary refinement, and concluded that the model performed extremely well in the prediction of goals and in the prediction of activities involving an explicit choice among alternatives.

Hence the use of a survey to predict behaviour is adequate but presents some limitations; as stated behavioural intentions may differ substantially from actual actions for the following reasons:

- the low correlation between attitude, behavioural intention and actions.
- the subjective norms and attitudes at the exact time of the survey may be different to those observed during a crisis.

In order to improve the quality of the response, the survey questionnaire will on specific behaviours as opposite to general attitudes, and the respondents will be presented with a list of precise options for saving energy.

6. Survey method

A mail survey of Londoners' intentions with regards to adopting specific energy saving measures was carried out. In this survey, sent to 1,800 households in London, participants were asked which energy saving actions they currently take, and which they believe they would be willing to take in the event of an energy crisis. Other questions were related to personal attitudes toward energy use, personal and household social characteristics, and some information about the dwelling energy characteristics.

Figure : Sample stratification

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The sample selected was a stratified probability sample using 3 stratifiers: geographical (local authority), dwelling type (flat in a bloc or other), and tenure (occupier owned or not), as shown in Figure . These stratifiers were selected using a simple statistical analysis of a survey of energy saving behaviours. The sample was extracted from the UK's Postcode Address File, which is the sample frame available in the UK presenting the least bias (Lynn 1995). The resulting spread is shown in Figure below.

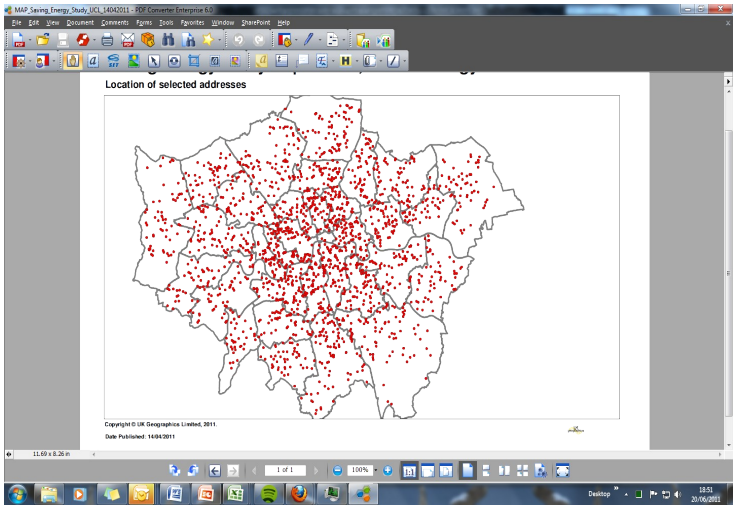

Figure : Stratified probability sample of households

In order to achieve a good response rate, the survey was partly based on Dillman's method (Dillman 2007, Dillman et al. 2008). Four different mails were sent: a forewarning letter, the questionnaire with a covering letter, a reminder postcard and an additional and final questionnaire. A token incentive was added, the format and wording were made personal and friendly. The questionnaire was developed in three stages: a workshop, cognitive interviewing and a pilot study.

7. Survey Results

A response rate of 29% was achieved; this was relatively successful in the context of a large city like London. Early analysis shows that the respondents are somewhat unbalanced, with for example, an unrepresentatively large number of respondents being retired. Consequently, it is suggested that non-response needs to be accounted for. This will be carried out in a further exercise.

The initial results from the survey are presented in Figure . These results are from the raw data.

The most popular changes that people are willing to take in the context of a crisis, and that they are not currently taking are: to use candles instead of electric lighting, to heat only one room, to eat food that doesn't need cooking, to take shorter showers, and to watch less television.

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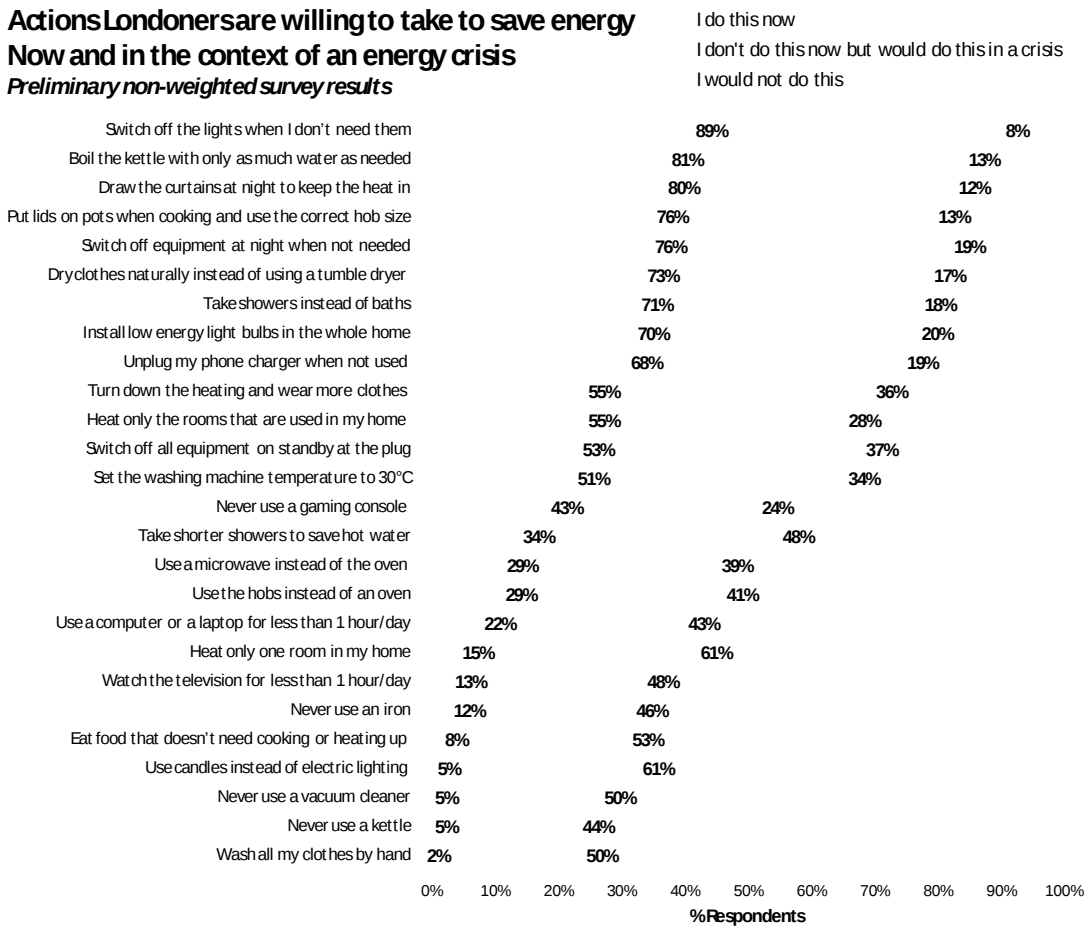

Figure : Actions Londoners are willing to take to save energy in the context of a crisis

8. Calculation of energy savings

The energy savings in a typical UK household through the range of measures suggested was evaluated using national statistics (DECC 2010,DEFRA 2011). Figure 3, below, shows the wide difference in energy savings. Measures aiming at reducing space heating are generally the most effective options to save energy.

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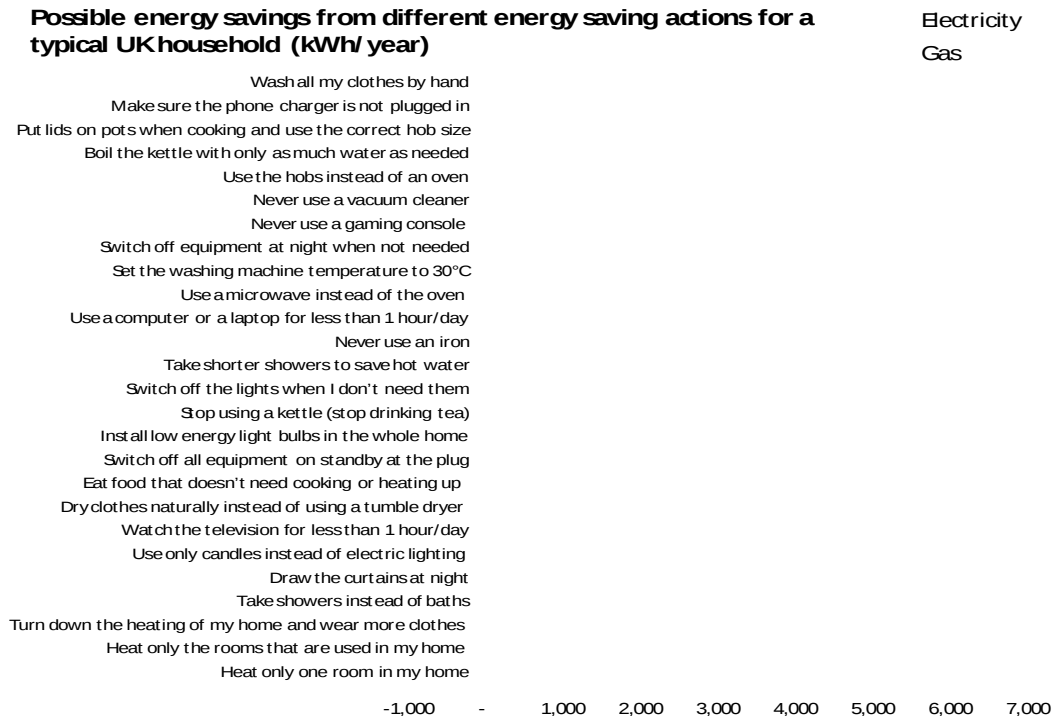

Figure : Savings achievable in a typical UK household from the different measures proposed

9. Preliminary results and conclusions

Some measures were found to be substantially more effective than others in reducing energy use. For example, the impact of heating only one room in the household is very high, as both the rate of adoption and the energy savings achievable are very high. Many other actions are found to be extremely ineffective, due a combination of their individual low impact and a low rate of adoption amongst the respondents to the survey.

Using the approximate values above and the results of the survey, the following savings can be calculated:

- An average natural gas energy saving of up to about 30% may be achieved, most of which comes from heating only one room in the home.
- Electricity energy savings of about 20%, half of which is due to reduced television usage combined with substituting candles for electric lighting.

A preliminary approximation of the savings achievable suggests that the measures may be effective in substantially reducing the energy demand of households in the context of an energy crisis. In addition, it is suggested that concentrating energy saving efforts in only a very few actions could give substantial results whilst also giving a relatively simple message to residential energy consumers. It should be noted that these results are preliminary and will be refined in future development of this work.

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10. Discussion

As discussed previously, the use of a survey to predict behaviour presents some significant limitations. The exact prediction of savings that can be achieved through rapid energy use curtailment, in households or by individuals as discussed earlier, is not straightforward. At best we can evaluate the overall impact of the actions people think they would take in such an event. Therefore, the conclusions of this work relate to the current inclination of the sample of respondents.

In addition, the implementation of the "saving energy in a hurry" approach is a complicated as it involves a large number of people. A strong, credible, leadership by responsible authorities is necessary for successful implementation (IEA 2005a).

Finally, this work needs further refinement, including a weighting of the data, more detailed calculation of energy savings and statistical analysis of the results.

Despite these uncertainties, the option of rapid energy savings may still be an attractive alternative to much more severe economic dislocation and disruption caused by curtailments in supply of electricity or natural gas.

11. Further and on-going work

The results of the survey will be analysed statistically, and weighting factors may be applied to compensate for non-response.

In a further development of the study, the potential energy reductions through behavioural change will then be quantified with a more detailed model of London's households energy use.

In addition further work needs to be carried out in relation to the validity of the Theory of Reasoned Action' model in this context.

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