Local authority interventions in the domestic sector and the role of social networks: a case study from the city of Leeds

C. S. E. Bale[a], N. J. McCullen[b], T. J. Foxon[c^], A. M. Rucklidge[b] & W. F. Gale[a^]

[a] Energy and Resources Research Institute, School of Process, Environmental and Materials Engineering, Faculty of Engineering

[c] Sustainability Research Institute, School of Earth and Environment, Faculty of Environment

[b] Department of Applied Mathematics, School of Mathematics, Faculty of Mathematics and Physical Sciences

[^] Centre for Integrated Energy Research

[abc^] University of Leeds, Leeds, LS2 9JT, UK

c.s.e.bale@leeds.ac.uk

Abstract

Decisions on energy-related interventions (e.g. the installation of an energy-efficient technology in council-owned homes, or a city-wide energy awareness programme) made at the local authority level are usually assessed on the basis of cost-benefit analyses based on the expected savings (cost and CO_2) resulting from implementation of the intervention. Wider social shaping of the energy choices of householders is often overlooked – for example, the influence of other members of their social networks.

We apply complex dynamical models of behaviour and interactions of householders to investigate energy technology uptake or energy-efficient behaviour through the social networks connecting the householders. We can then compare the effectiveness of different roll-out strategies available to Leeds City Council (CC) for the provision of energy efficiency measures – for example, street-by-street installation versus incentives and word-of-mouth propagation.

In this paper, we set out a theoretical and empirical methodology for investigating which roll-out strategies present the most effective routes for the delivery of energy-reduction interventions to households within the city of Leeds. We present the insights resulting from the Leeds case study into the links between the local authority and domestic energy users and the social networks in which the latter operate.

1. Introduction

With the UK's heavily urban population, cities have a major impact on energy sustainability. Local authorities have traditionally regarded energy as being outside of their area of competence. However, they have been identified as having the potential to play a key role in measures to manage energy efficiency and reduce greenhouse gas emissions whilst also helping to alleviate fuel poverty (Allman et al., 2004).

Energy policies implemented by local authorities and targeted at the domestic sector have focussed on either the direct deployment or the indirect promotion of various energy-efficient and renewable technologies (referred to here collectively as 'interventions'), which are usually selected after cost-benefit analyses. These analyses are generally derived from the expected savings (in terms of both cost and greenhouse gas emissions) of these technologies assuming certain user behaviours (e.g. Cheng and Steemers (2011) and Clinch and Healy (2001)). However, this type of analysis makes (often implicit) assumptions about the socio-technical aspects of an intervention, without evidence that these assumptions are appropriate to the intervention. It is widely accepted that understanding and evaluating the interaction of the householders with the installed technology is critical to the success of such policies and work is currently being undertaken in this area (Kok et al., 2011, Keirstead, 2006, Natarajan et al., 2011, Gill et al., 2010).

Another aspect that our discussions with key local authority staff suggest is often overlooked when developing local energy polices is the design of the roll-out strategy, used for implementing a given intervention, such that this is appropriate for domestic energy users. The role of social networks in the spread of information on energy-efficient technologies and behaviours, and the subsequent adoption rates of both, is a relatively new area for research (although there are some early examples of such ideas, e.g. Coltrane et al. (1986)). As far as we are aware, there are no studies comparing the success of a single intervention via a number of different roll-out strategies.

Recent developments in complexity science allow study of the effect of social influences on the diffusion of new innovations (Delre et al., 2010), as well as the importance of network structure and the role played by the overlapping communities to which people belong (Palla et al., 2005).

We have applied methods in complexity science, namely dynamical systems models on networks, to look at the various roll-out strategies available for one local energy intervention, specifically that of installing loft insulation in suitable domestic properties. This intervention was chosen because it has the potential to offer a large emissions reduction return on a relatively small capital investment and because the technical features of the intervention are simple and well established. We wish to assess the varying success (or otherwise) of this intervention when it is implemented in each of four different ways. The four different roll-out strategies we propose to compare are:

- **Seeded**: Street-by-street free installation of insulation in certain geographic areas.
- **Communities:** Focus on use of influential community hubs (e.g. groups that are identified as being trustworthy) to provide information and induce a critical mass of adopters.

- **Random**: Random assignment of installation (e.g. households respond to a city-wide incentive campaign).
- **Snowball**: Word-of-mouth propagation (coupled with an incentive to recommend the scheme to a friend).

These models have been populated with information gathered through an online survey of the residents of Leeds that sought information on both energy behaviours in the household and networks of influence on these behaviours.

The underlying aim of the work presented here is eventually to evaluate whole city adoption rates after a certain time period, and estimate the benefits brought about in terms of cost savings and CO_2 reduction, for each different roll-out strategy. Whilst we ultimately intend to produce a tool that could be used by an LA to assess different roll-out strategies, initially we wish to address the question of whether it is meaningful and beneficial to use complexity science methods in this way to tackle these questions regarding local energy policy. In this paper we present our methodology and some early results from the work and provide insights into the networks that exist between Leeds City Council and city residents with regard to the spread of energy information.

2. Methodology

In order to investigate the effects of social interactions on the take-up of energy efficiency measures, we are undertaking both theoretical modelling and empirical survey data collection. We model the energy behaviour of the households as dynamical systems interacting on social networks. In these models, households are represented as nodes on a network. The links between the nodes represent lines of communication between householders, for example between neighbours or at workplaces or other group environments.

These links are then weighted according to the likelihood of information on energy issues being exchanged. This generates, particularly through the dropping of inapplicable links, a sub-network that is specific to energy information exchange. The energy network is then used to model the propagation of ideas relating to efficient energy use or technology itself.

In the dynamical models the nodes are assigned states relating to their level of adoption of a particular technology (or energy-efficient behaviour), and behaviour rules dictate transitions between these states. These transition dynamics are governed by both the householders' own preferences and social influences transmitted via their personal networks (Valente, 1996, Delre et al., 2010).

Having developed a network representation of the city based on empirical evidence, we intend to simulate the different roll-out strategies that could be implemented by the local authority. The different roll-out strategies are simulated by altering different parameters in the model and can have effects in the following ways: a) seeding different initial conditions for the households who already have the technology; b) strengthening the weights of the links on the network; or c) lowering the threshold over which people choose to invest in the new technology. The roll-out strategies will be modelled according to the scenarios outlined in Table 2.

Table 2 — Roll-out strategy scenarios for simulation.

Scenario	Incentive/Action taken by LA	Initial adopters	Propagation/diffusion through network
Do Nothing	None.	Those who already have insulation.	Word of mouth about benefits of insulation to those in their social networks that they already talk to about energy.
Seeded	Street-by-street installation of insulation in certain areas identified as high impact.	Those identified by LA and given free insulation.	Word of mouth about benefits to those in their social networks that they already talk to about energy.
Communities	Use of influential community hubs (e.g. groups that are identified as being both trustworthy and central to the network) to provide information and advice on installation.	Those who exhibit pro-environmental behaviours (therefore lower barrier to adoption) and are likely to trust community groups they are already connected to.	Word of mouth about benefits to those in their social networks that they already talk to about energy.
Random	City-wide advertisement campaign to offer voucher to refund part of the cost of installation.	Those who exhibit pro-environmental behaviours and are likely to trust information from LA. Voucher lowers the barrier to adoption.	Word of mouth about benefits to those in their social networks that they already talk to about energy.
Snowball 1	City-wide advertisement campaign to offer voucher to refund part of the cost of installation and additional refund voucher when participant recommends the scheme to a friend.	Those who exhibit pro-environmental behaviours and are likely to trust information from LA. Vouchers lower the barrier to adoption.	Word of mouth about benefits to those in their social networks that they already talk to about energy as well as 5 additional closest networked contacts, encouraged by the second voucher.
Snowball 2	City-wide advertisement campaign to offer voucher to refund part of the cost of installation and additional refund voucher for both parties when participant recommends the scheme to a friend.	Those who exhibit pro-environmental behaviours and are likely to trust information from LA. Vouchers lower the barrier to adoption for both parties.	Word of mouth about benefits to those in their social networks that they already talk to about energy as well as 5 additional closest networked contacts, encouraged by the second voucher.

A major aspect of our research is determining whether the insights and tools of complexity science can be useful for understanding energy interventions at the city level. It is, therefore, useful to understand the degree of complexity to which we need to represent the system in our models, and the degree of accuracy that is required to represent the model parameters.

It has been shown that the properties and structure of a network can have an influence on the spread of information (or technology) through it (Palla et al., 2005, Newman et al., 2006). As a consequence, we are interested in looking at varying network structures and seeing what difference these make to the outcome of the model simulations. Determining the degree to which a correct representation of the statistical properties of the network is critical to the outcome of any intervention will give us an understanding of the data requirements needed to produce such models. We will also investigate the sensitivity of the model outputs to the values we assign to the parameters of the model of householder choices and behaviours. In this way, we will be able to test the usefulness of complex systems approaches to adoption of energy-efficient technology or behaviours.

To collect empirical data with which to populate the model, a survey of Leeds residents was undertaken in May – June 2011. Two sampling methods were used: 1) convenience sampling through an online collection method whereby participants were recruited by advertising via large organisations in Leeds (e.g. the university, council, NHS and other large businesses) and 2) attending a twice-weekly drop-in centre for residents in the east Leeds area of Burmantofts to encourage participation by low-income households without access to the internet. Burmantofts is an area with a large proportion (> 50%) of council-owned homes and has a high score on a number of socio-economic deprivation indices (Office of National Statistics, 2011). Leeds CC, therefore, has significant capacity and motivation to intervene is this area. The questionnaire sought information on attitude and behaviours with regard to energy use in the home as well as demographic information (including income level, employment status, and geographic area). A series of questions was also asked about the respondent's social network, current sources of information about energy and likely organisations that they would trust to provide energy advice. 1068 valid responses were received, which represents 0.34% of the total number of households in the metropolitan district of Leeds. The sample was found to be broadly representative of the population in terms of tenancy and house type as well as pro-environmental behaviour (as benchmarked to the Defra Survey of pro-environmental behaviours (Thornton, 2009)). However, because of the difficulties in reaching certain sectors of the population, we have under-sampled the unemployed, the retired and those on lower incomes.

3. Preliminary results and insights

Data was collected in the Leeds-based survey about who people currently talk to about domestic energy issues, which organisations people have previously contacted for information about energy, and which organisations would be trusted to provide information, among other topics. The responses to these questions offer some interesting insights into the spread of information and provide the empirical data for the networks discussed later; the results are presented in Figures 1, 2 and 3.

Figure 1 — Responses to the question '*Do you currently talk to any of the following people about energy use and/or saving money on energy?'.*

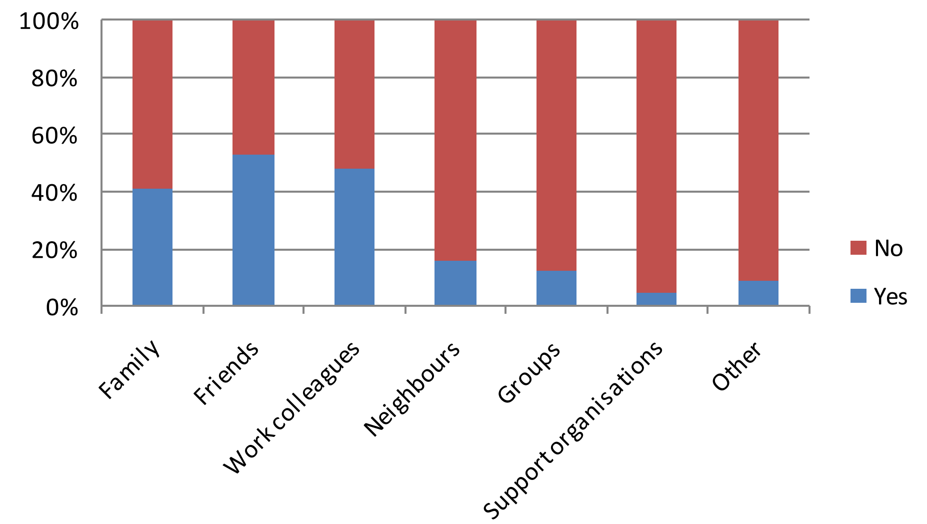


Figure 2 — Responses to the question '*Have you ever sought energy advice from any of the following organisations (this can include calling a phone line or accessing a website for information)?'.*

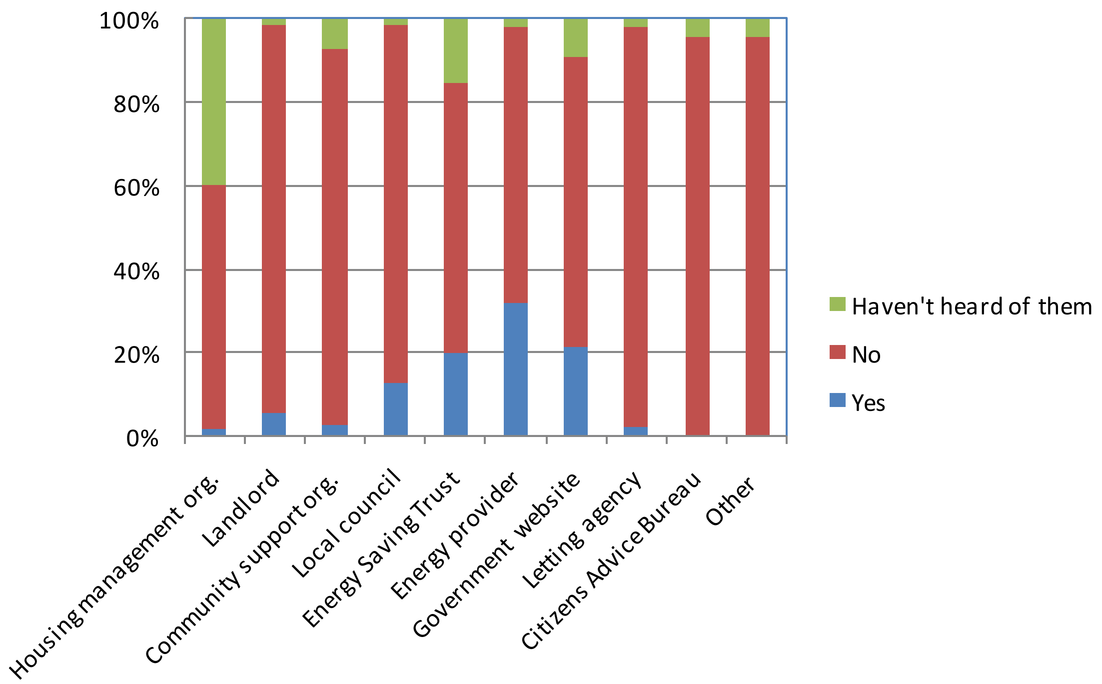


Figure 3 — Responses to the question *'Would you trust advice on energy/money saving given to you by the following people/organisations?'.*

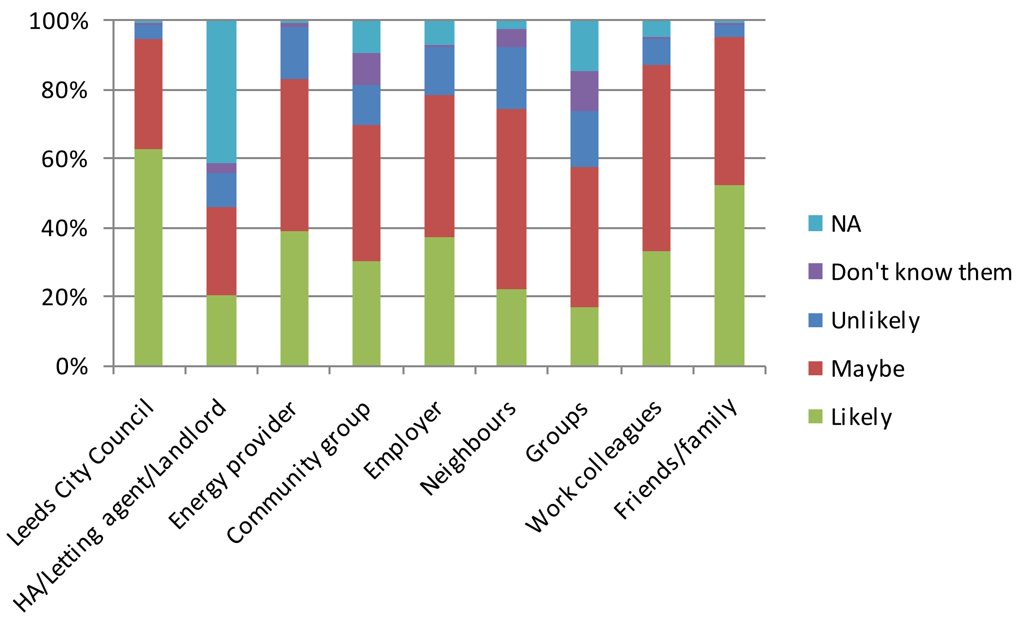


Figure 2 shows that currently the most widely-used route to information about energy-saving options is through the energy provider (32%). Nearly a quarter of all respondents said that they had not previously sought any advice about energy. This indicates that a significant proportion of people take a passive approach to accessing information on energy.

However, looking at the responses shown in Figure 3, it becomes apparent that in theory people would be potentially receptive to information from a variety of sources (notably the council and individuals in their social networks). This result indicates that there are routes open to a local authority for encouraging technology adoption if the social networks of its residents are harnessed and the right incentives to act on information are provided.

These survey questions were used as a basis for mapping the network of households; one question provided information on the number of social groups attended by the respondent, and others, as presented earlier, asked questions related to energy links. From this information, coupled with geographic information about the city, we have developed models of the energy networks operating in the city of Leeds (shown in Figures 4 and 5).

The network representations shown in Figure 4 give an illustrative example of households on a street-like layout for a hypothetical portion of the city. Figure 4C, which represents the network with regard to flow of energy information (based on probabilities obtained from the survey), shows this energy network to be sparse. In this scenario there is no chance of diffusion of information across the full network. Figure 4D shows the potential network for energy based on the probability of households who would trust neighbours, friends and family to supply energy information. This creates many more connections in the network and illustrates that it could be worth enhancing potential lines of communication using incentives.

We have then looked at the effect that various social or work-related groups could have in bridging the gaps in the network, which act as a barrier to the spread of energy-efficient technology or behaviours. These ideas are geographically represented in the graphs in Figure 5.

Figure 4 — Illustrative examples of networks of households:
(A) households are all connected to their nearest neighbours and no others.
(B) the "small world" property arises when long-distance connections are added such as to friends or family who do not live in the immediate locality. These are assigned with a random probability (shown with narrow lines). Links to nodes outside of the notional boundary of this small representation are omitted here, for clarity.
(C) the network only shows current reported communication about energy between households using probabilities taken from the survey data (shown in Figure 1).
(D) indicates lines of trust with regard to energy in the network links using probabilities taken from the survey data (Figure 3).

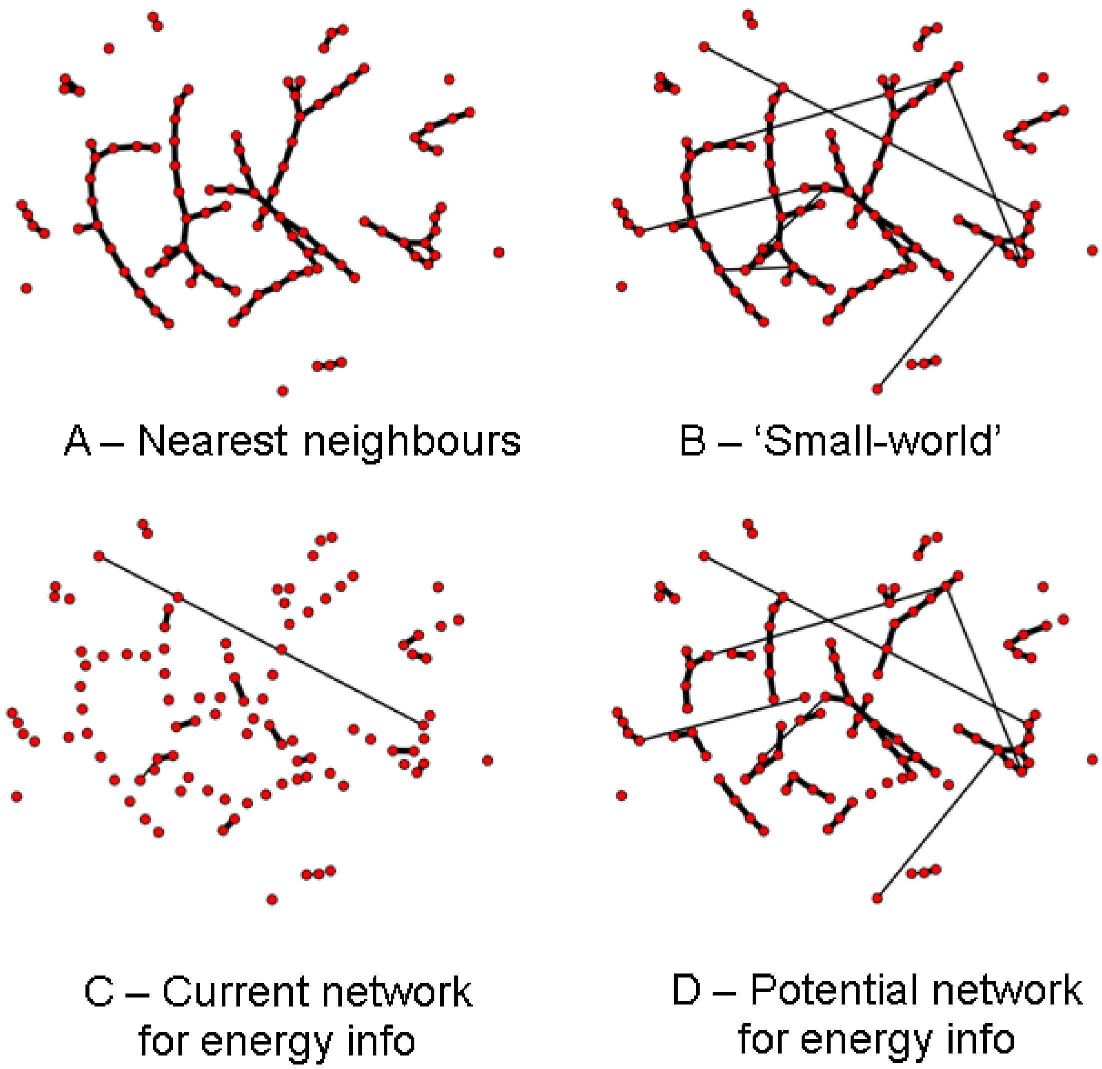
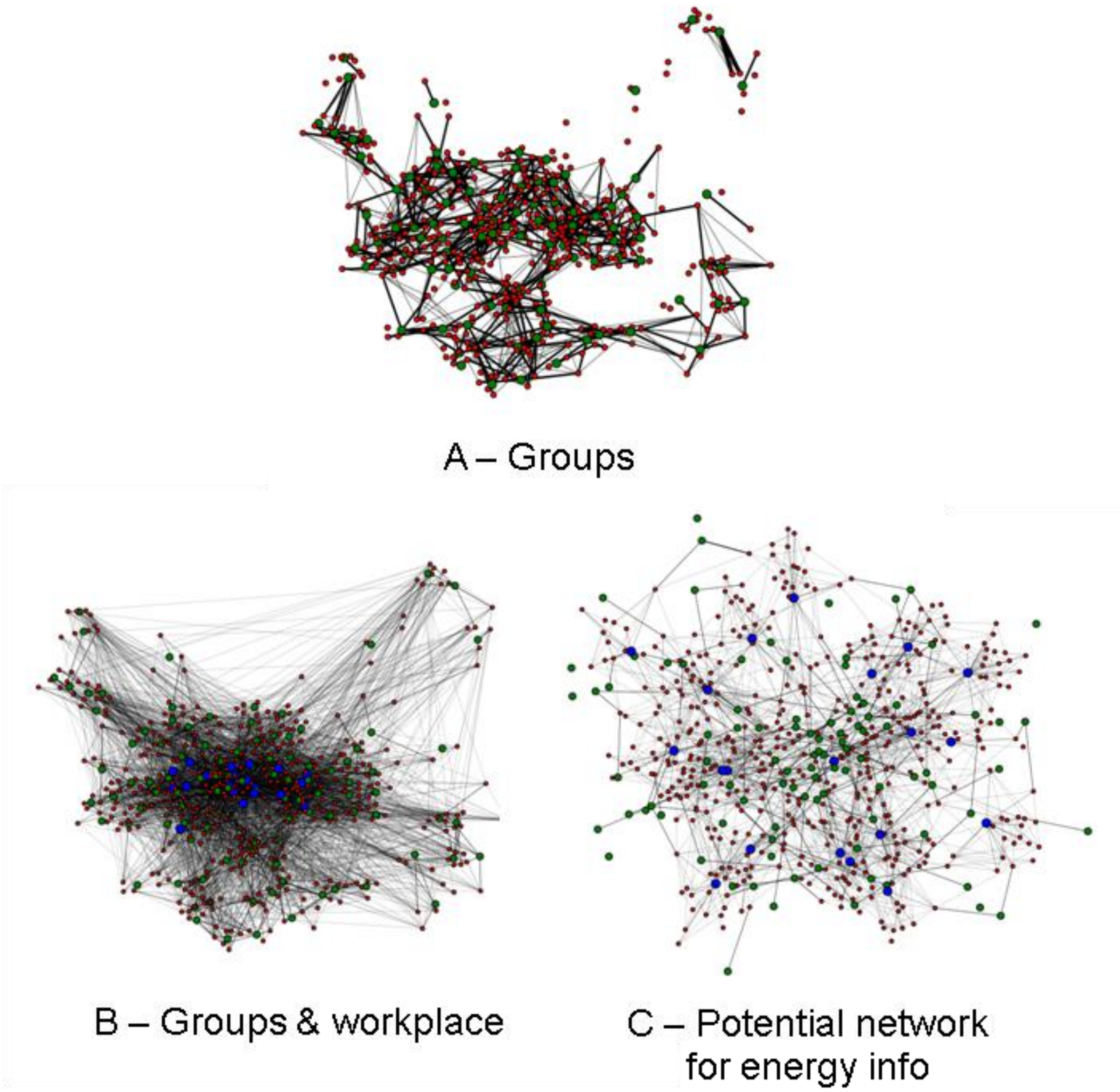


Figure 5 — Simplified graphs of Leeds city area represented by assigning one household (red) to each Lower Layer Super Output Area (SOA; census area) and one group (green) to each Mid Layer SOA:
(A) households are linked to a group according to probabilities obtained from the survey as well as a random number of other group members.
(B) households are linked via hypothetical workplaces (blue) in the city centre and to several other households at the same workplace.
(C) includes inter-household links and probabilities from the survey to show a likely structure of the network for energy information (the graph has been rearranged to show the group nodes more clearly).



It can be seen, in comparing the small-world network representations (Figures 4B and 4C), that many of the connections with regard to exchange of energy information become zero when incorporating the responses given in the survey. In Figure 5 it can be seen that the role of both groups and organisations becomes important for the flow of energy information.

The combination of the network representations and the survey data shows that the strongest potentially influential routes that could be exploited by the local authority to promote a specific energy intervention involve groups that have a high degree but that are also trusted sources of information. In this case, workplaces (a combination of information from both work colleagues and employer) meet both these requirements and could provide an effective way to promote an energy intervention. Further modelling is currently being carried out, as discussed in section 2, to further explore this outcome.

4. Implications for energy policy

Local energy policy design is beginning to include the effects that the behaviours and decisions of the individuals can have. However, the influence of social networks between these actors is likely to be significant and must also be incorporated in assessment of possible interventions.

The structure of the network can have a significant influence on the propagation of an intervention made by a local authority. With the need to increase the rate of uptake of energy-efficient measures and distributed renewable generation options to meet low carbon targets, local authorities face an exceptional challenge. We suggest that, if local authorities wish to harness the power of this influence, then the different roll-out strategies available need to be considered when thinking about policy implementation.

The main government policy for promoting the take-up of energy-efficiency measures, the Green Deal, is predicated on individuals choosing to take advantage of the proposed favourable financing arrangements, as in our Random roll-out strategy. A greater role for local authorities in pursuing energy policy goals could enable social influences to be harnessed through complementary or alternative measures to the Green Deal. In related work, the authors are investigating the potential for UK local authorities to develop a strategic energy planning function to enhance their capacity to support the roll-out of energy efficiency measures and low-carbon generation projects within cities (Bale et al., 2011).

5. Conclusion

We have discussed the importance of considering the role of social networks in understanding the spread of influences on adoption of energy-efficient technologies and behaviours. We have suggested a theoretical and empirical approach to investigating the impact of social networks in the different roll-out strategies available to a local authority implementing an energy-saving intervention. We have highlighted, with evidence from Leeds householders, the importance of highly central and trusted groups for the spread of energy information in a social network. It is intended that this method be developed further for use in informing real decision-making processes for local energy policies.

6. References

ALLMAN, L., FLEMING, P. & WALLACE, A. 2004. The progress of English and Welsh local authorities in addressing climate change. *Local Environment: The International Journal of Justice and Sustainability,* 9**,** 271–283.

BALE, C. S. E., FOXON, T. J., HANNON, M. & GALE, W. F. 2011. Making the case for strategic energy planning within local authorities: a study of the city of Leeds.

CHENG, V. & STEEMERS, K. 2011. Modelling domestic energy consumption at district scale: A tool to support national and local energy policies. *Environmental Modelling & Software,* 26**,** 1186-1198.

CLINCH, J. P. & HEALY, J. D. 2001. Cost-benefit analysis of domestic energy efficiency. *Energy Policy,* 29**,** 113–124.

COLTRANE, S., ARCHER, D. & ARONSON, E. 1986. The social-psychological foundations of successful energy conservation programmes. *Energy Policy,* 14**,** 133-148.

DELRE, S. A., JAGER, W., BIJMOLT, T. H. A. & JANSSEN, M. A. 2010. Will It Spread or Not? The Effects of Social Influences and Network Topology on Innovation Diffusion. *Journal of Product Innovation Management,* 27**,** 267-282.

GILL, Z. M., TIERNEY, M. J., PEGG, I. M. & ALLAN, N. 2010. Low-energy dwellings: the contribution of behaviours to actual performance. *Building Research & Information,* 38**,** 491 - 508.

KEIRSTEAD, J. 2006. Evaluating the applicability of integrated domestic energy consumption frameworks in the UK. *Energy Policy,* 34**,** 3065-3077.

KOK, G., LO, S. H., PETERS, G.-J. Y. & RUITER, R. A. C. 2011. Changing energy-related behavior: An Intervention Mapping approach. *Energy Policy,* In Press, Corrected Proof.

NATARAJAN, S., PADGET, J. & ELLIOTT, L. 2011. Modelling UK domestic energy and carbon emissions: an agent-based approach. *Energy and Buildings,* In Press, Corrected Proof.

NEWMAN, M., BARABÁSI, A. & WATTS, D. 2006. *The Structure and Dynamics of Networks*, Princeton University Press.

OFFICE OF NATIONAL STATISTICS. 2011. *Neighbourhood Statistics* [Online]. Office of National Statistics,. Available: http://www.neighbourhood.statistics.gov.uk/
[Accessed March 2011].

PALLA, G., DERENYI, I., FARKAS, I. & VICSEK, T. 2005. Uncovering the overlapping community structure of complex networks in nature and society. *Nature,* 435**,** 814-818.

THORNTON, A. 2009. Survey of public attitudes and behaviours towards the environment: A report to the Department for Environment, Food and Rural Affairs. London: Defra.

VALENTE, T. W. 1996. Social network thresholds in the diffusion of innovations. *Social Networks,* 18**,** 69-89.