An evaluation of local authority social network interventions for the promotion of energy-efficiency measures in the domestic sector

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Abstract
Local governments at city and regional level have a key role in promoting the uptake of energy-efficiency measures by households through schemes such as the UK's Green Deal financing mechanism. However, there is little understanding of the role that social network interactions between householders play in ensuring the successful diffusion of energy-efficiency measures. In this paper we explore the role of local authorities in using interventions designed to use interactions on social networks to promote uptake of energy-efficiency measures in the domestic sector.

Both the individual preferences of households and the influences that they experience from peer groups and the wider population (through social norms) are important factors in the adoption of energy innovations, and local authorities have the means to harness these influences to their advantage in encouraging increased adoption. The role of social networks in the spread of information on energy-efficient technologies and behaviours is a relatively new area for research, but one which draws on evidence of success in other areas, such as health.

To investigate this, we use results from modelling work recently conducted by the authors, and examples of methods used in practice by local authorities in the UK and elsewhere to promote uptake of energy-efficiency initiatives. This enables us to appraise the potential utility of different types of social network interventions for promoting uptake, including interventions aimed at individuals, groups, and the network structure itself.

In conclusion, we present the resulting insights into the use of network interventions by local authorities for promoting uptake of energy-efficiency measures in the domestic sector, and examine current UK and EU policy to see to what extent it supports implementation.

Introduction
Social network interventions have recently attracted much interest as a means of using social networks to accelerate behaviour change (Valente, 2012). These ideas have been used most widely to tackle health-related issues (Valente, 2010). However, little attention has been given to applying these ideas to the area of energy. While local authorities appear to have been incorporating some of the ideas about the use of social networks in influencing household decision-making into local initiatives aimed at encouraging uptake of energy-efficiency measures in the domestic sector (as we go on to discuss later), this has largely been done in an *ad hoc* manner without a systematic understanding of the mechanisms by which network interventions work and the benefits that they may bring.

We define network interventions as purposeful efforts to use social networks to accelerate progress towards a goal (Valente, 2012), which in this case is the adoption of energy-efficiency measures in the domestic sector. By 'social network', we refer to all inter-household interactions that are relevant to energy, with friends, neighbours, colleagues and family, either face-to-face or online. We use the term 'energy-efficiency measures' to broadly cover measures that are either behavioural or technology-based (such as a one-off decision to install insulation, for example).

The aim of this paper is to draw together evidence from existing literature regarding network interventions, recent survey

and modelling work undertaken by the authors, and examples from local authority initiatives to examine how network interventions can be used to encourage increased adoption of energy-efficiency measures in the domestic sector.

The structure of the paper is as follows. We first set out the background and rationale to this work. We then discuss in turn insights from existing literature, survey work on who households talk to about energy, and modelling work looking at scenarios for local authority roll-out strategies. We then draw this together and examine whether current UK and EU energy-efficiency policy does enough to maximise the benefits of harnessing social networks.

Theoretical background

BARRIERS TO ADOPTION OF ENERGY-EFFICIENCY MEASURES IN THE DOMESTIC SECTOR

The barriers to adoption of energy-efficiency measures in households are well documented (Jaffe and Stavins, 1994, Dowson et al., 2012, Weber, 1997) and include both financial (e.g. the cost of up-front investments) and non-financial (e.g. hassle, lack of awareness/information, convenience etc.) considerations.

In addition, domestic actors operate in a strongly social context which affects their habits, behaviours and decisions with regard to energy. Previously, quantitative analysis has been focussed on individual behaviour and has tended to assume rational choice or reflect only individual psychological motivations (Nye et al., 2010). Approaches that address the social context of decision-making tend to be more qualitative (Shove, 1998). This suggests a need for methods that can combine quantitative and qualitative approaches to analysing the effects of social context on individual behaviour, in order to support measures to achieve increased adoption.

LOCAL AUTHORITY ROLE IN DOMESTIC ENERGY EFFICIENCY

Local authorities have a significant role to play in meeting national carbon and energy-efficiency targets through the services they deliver and their role as social landlords, community leaders and major employers (in addition to their regulator and strategic functions) (Committee on Climate Change, 2012). In these roles they maintain influential relationships with residents, tenants and employees across their area of responsibility, in a way that national government does not. In this way, local authorities are able to harness social networks that operate at the community level.

The Committee on Climate Change (2012) notes that one of the key areas for local authority action is in improving energy efficiency by supporting the adoption of energy-efficiency measures in the domestic sector. This local authority role can be either direct, by provision of free installation programmes (e.g. Wrap Up Leeds (Leeds City Council and Yorkshire Energy Services, 2012)), or indirect, through energy advice services (e.g. Actio2n Woking (Woking Borough Council, 2012)). They can also offer advice and support for behavioural changes to save energy and support national programmes such as the Green Deal (Department of Energy and Climate Change, 2011b). Often, initiatives are tailored in an *ad hoc* manner to suit a given funding scheme, and are limited by available finance (Bale et al., 2012a). For a simple intervention such as offering free or reduced cost insulation, local authorities enjoy the freedom to choose from a range of roll-out strategies, each of which may deliver different adoption rates.

SOCIAL NETWORKS

The importance of social network influences on behaviour is well recognized in the literature that exists outside of the energy-policy domain, and network interventions can be used to accelerate behaviour change (Valente, 2012). Adoption of energy-efficiency behaviours has much in common with adoption of other behaviours or innovations (as we shall illustrate), yet the insights from social network theory have so far been under-exploited in the area of energy policy. The role of social networks (and network interventions or marketing) in the spread of information on energy 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) and Darley and Beniger (1981), and in relation to climate change (Maibach et al., 2008)).

DIFFUSION OF INNOVATIONS

Diffusion of innovations (Rogers, 1983) describes the social communication process that influences individual adoption of a specific innovation; the theory has been applied in the context of domestic energy consumption (Wilson and Dowlatabadi, 2007). The spread of ideas or technologies has been widely studied across different domains as diffusion on networks (Valente, 2005). Diffusion models usually consider only the social aspects of spreading, which in many cases is appropriate. However, the decision to adopt a technology may be based on a combination of factors, including ability to install/use the technology and willingness to purchase, as well as social influence from peers and the wider population. Modelling therefore needs to take into account ability or willingness to adopt as well as the personal usefulness of the item, as perceived by the householder, alongside word-of-mouth recommendation and the benefits of aligning with the social norm (Valente, 1996, Delre et al., 2010, Deffuant et al., 2005). In recent modelling work (Bale et al., 2012b, McCullen et al., 2012), the results of which we discuss later, we included both personal and social aspects of diffusion in the model. Similar multi-parameter models for diffusion of innovations have been investigated by Choi et al. (2010) and Lee, Lee and Lee (2006).

SOCIAL NETWORK INTERVENTIONS

There are various ways in which network interventions can be used to accelerate the diffusion of innovations through social networks. For the purposes of this discussion we use the typology defined by Valente (2012), whereby network data can be used to design effective behavioural change interventions (in this case aimed at increasing adoption of energy-efficiency measure in the domestic sector). The four intervention types are individuals, segmentation, induction and alteration. We will briefly describe them here.

- *Individuals*: Influential individuals on the network are identified to act as champions or opinion leaders.

- *Segmentation*: Influential groups or communities of individuals are identified and approached to change their behaviour at the same time.
- *Induction*: Peer-to-peer interactions are encouraged in order to persuade others to adopt; so-called 'word-of-mouth' interventions.
- *Alteration*: Deliberate modification of the network. This can be done by adding or deleting nodes or links, or re-wiring existing links.

Network interventions for promoting energy efficiency

In the following three sections we examine what can be learnt from: the application of network interventions in other domains and its relevance to the adoption of energy-efficiency measures; the information available about social networks for sharing energy information and their influence; and modelling work exploring scenarios for local authority network interventions. It is our aim to draw insights from all three areas in order to inform the approach to local authority use of network interventions in enhancing energy-efficiency initiatives at the local level.

NETWORK INTERVENTIONS IN HEALTH

In this section we consider how network interventions have been used with regard to health-related issues and consider whether it is likely to be appropriate to use similar approaches to promote the adoption of domestic energy-efficiency measures.

Network interventions have been used successfully for tackling health-related issues (Valente, 2010, Luke and Harris, 2007). However, it does not necessarily follow that they could successfully be applied to the adoption of energy-efficiency measures. The majority of studies of network diffusion processes in the health domain concern the spread of infection by limited contact with other individuals. In this type of diffusion only a single contact is typically required for a transmission to occur from one individual to another; this is therefore not useful when thinking about the diffusion of energy-efficiency behaviours. Instead we turn our attention to studies that are concerned with the diffusion of health-related behaviours.

Empirical studies show that many people wait for a proportion of their social group to precede them before adopting a new behaviour or product (Granovetter and Soong, 1983, Valente, 1996). Threshold models have been developed to account for this phenomenon (Grönlund and Holme, 2005, Watts, 2002) and can be used to study the diffusion of behaviours. In these models, an individual's adoption is a function of the behaviour of others in the network. Empirical examples of this type of behavioural 'contagion' of innovations can be found in Valente (1996) and include a case on the adoption of family planning methods.

If we consider the barriers to adopting energy-efficient behaviours and the barriers to adopting a healthy diet (as an example in the health domain where experimental results exist), a number of common areas can be identified. These are outlined in Table 1 and include those related to cost, convenience and social support.

In addition, there are certain post-adoption characteristics that are similar for energy-efficiency measures and certain health behaviours. For example, the adoption behaviour may not be visible to a household's wider social network.

A successful example of a network intervention related to healthy diet is given by Sorensen et al. (2007), who show that the presence of strong social ties supports fruit and vegetable consumption; this highlights the need for interventions that directly build social support.

These insights suggest that initiatives to promote energy-efficiency should be amenable to the use of network interventions in a similar way to those trialled for tackling health-related behaviour. Arguably, some health-related behaviours, such as smoking, have a more significant social influence element than energy-efficiency behaviours. In this case we might expect network interventions to have a stronger influence in tackling health issues, but we know that there is a strong social and cultural element to domestic energy use (Lutzenhiser, 1992, Lutzenhiser, 1993) and there is evidence to suggest that peer influence is also important, as we shall discuss further in the next section.

SOCIAL NETWORKS FOR ENERGY INFORMATION

In this section we consider the question 'Who do people talk to about energy use in the home?' in order to identify how social networks might work in relation to domestic energy use, and therefore how they might be used more effectively. Although there has been a considerable amount of research and analysis of social network structures, this has mainly been conducted for networks for which the data is relatively easy to obtain, such as either moderately small systems or online social networks. There is limited empirical data available on the networks that may operate between households in relation to energy technologies or behaviours, and this remains a challenge to understanding the influence of social networks on the adoption of energy-efficiency innovations. Information is needed on the following aspects of the system:

- The structure of the network — Who do people exchange information with regarding domestic energy technologies?
- The density of the networks — How many others do people communicate with about energy?
- The weight of the links on the networks — What influence do certain links to individuals or groups have on adoption decisions?

We first give a brief summary of some survey work recently conducted and the specific insights into the social networks operating in a city with regard to energy information. This is compared with work conducted elsewhere that provides additional data with regard to the questions above. We have noted elsewhere the limited availability of network data relating to energy innovations and the need for further information in this area (Bale et al., 2012c).

In May–June 2011 a survey of residents in Leeds in the UK was undertaken. 1,068 valid responses were received, which represents 0.34 % of the total number of households in the metropolitan district of Leeds. Further details of the sampling method are given elsewhere (Bale et al., 2012b, Bale et al., 2011). 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

Table 1. Barriers to adoption of energy-efficiency behaviours compared with adoption of a healthy low-fat diet.

Barrier	Adoption of energy-efficiency behaviours[1]	Adoption of a low-fat diet[2]
Cost – Additional upfront cost.	Upfront cost of measures such as insulation.	Belief that a healthy diet is more expensive.
Perceived benefits – Long-term pay-back period and may not be immediately visible.	Pay back period may be several months to years. Savings on energy bills are not apparent to the consumer (since billing is usually complex). Wider benefits to local environment and economy are impossible to see.	Weight loss occurs over a long period of time. Wider health-related benefits may not become apparent.
Convenience/Lifestyle	Behaviours do not always align with lifestyle e.g. desire for new appliances and technologies in the home.	Perceived belief that low-fat diet will be less tasty.
Family support	Lack of family/household support for changes e.g. children leaving appliances on.	Lack of family/household support for changes e.g. individuals would eat more healthily if their whole family did.
Information – Trusted, independent and informed information sources are needed to navigate complex choices.	Difficult to find reliable information on the benefits of installation e.g. expected cost savings. Poor understanding of domestic energy issues e.g. how much is used and what can be saved.	Difficult to find reliable information on the content of some food items. Poor understanding of what comprises a low-fat diet.

[1] *(Pelenur and Cruickshank, 2012)*

[2] *(Lloyd et al., 1995)*

of pro-environmental behaviours (Thornton, 2009)). However, the difficulties in reaching certain sectors of the population resulted in under-sampling of the unemployed, the retired and those on lower incomes. We present here a selection of the results from the data that are pertinent to the operation of social networks for sharing information about energy.

The results from our survey indicate that friends, family and work colleagues are trusted sources of information on energy use. The local authority (Leeds City Council) is also seen as a trusted source of information.

Although it would not have been possible to conduct a full social network analysis of the city, these figures can provide useful information on the number of connections and clustering found. In this way we can build up a picture of the social network.

In general accordance with our findings, Southwell et al. (2012) found that one third of a sample of people in the US reported sharing information about energy use. Importantly, they also found that, of those households, 85 % shared information verbally and only 3 % reported sharing through online social networking sites, indicating that face-to-face interactions are the predominate method of communication. Using 2011 national survey data from U.S. residents they also predicted energy information sharing as a function of objective knowledge, perceived understanding and other variables, and found that both objective energy knowledge and perceived understanding were equally predictive of energy information sharing frequency.

Furthermore, recent work conducted in the USA indicates significant empirical evidence for a peer-influence effect in the diffusion of solar photovoltaic panels (Bollinger and Gillingham, 2012). The authors conclude that their evidence is suggestive of the pathways by which peer effects work: visibility of the panels, and word of mouth. While not all energy-efficiency measures have the visibility of solar panels, some, such as external wall insulation, may do.

In work concerning the role of social capital in the diffusion of energy innovations, McMichael (2011) reports that social networks can help to increase information diffusion and that personal referrals are more likely to make people feel confident in their decisions, particularly if there is a high degree of uncertainty around an innovation (e.g. new smart meters).

Taken together, these findings suggest that, although sharing energy information is not nearly ubiquitous, there is a significant proportion of the population that can be targeted by the local authority and their existing social networks utilised. Additional data is needed to fully understand and characterise the social networks operating in the sharing of energy information.

MODELLING NETWORK INTERVENTIONS

In this section we consider how modelling could be used to assess the effectiveness of network interventions on adoption of energy-efficiency technologies. In recent papers (McCullen et al., 2012, Bale et al., 2012b), the authors have described the development of a modelling method to investigate the diffusion of energy innovations on a social network. Crucially, our model combines personal and social factors influencing adoption of domestic energy innovations. We have used the model to demonstrate its potential use in evaluating local authority roll-out strategies that harness existing social networks (Bale et al., 2012b). This new interdisciplinary modelling work dem-

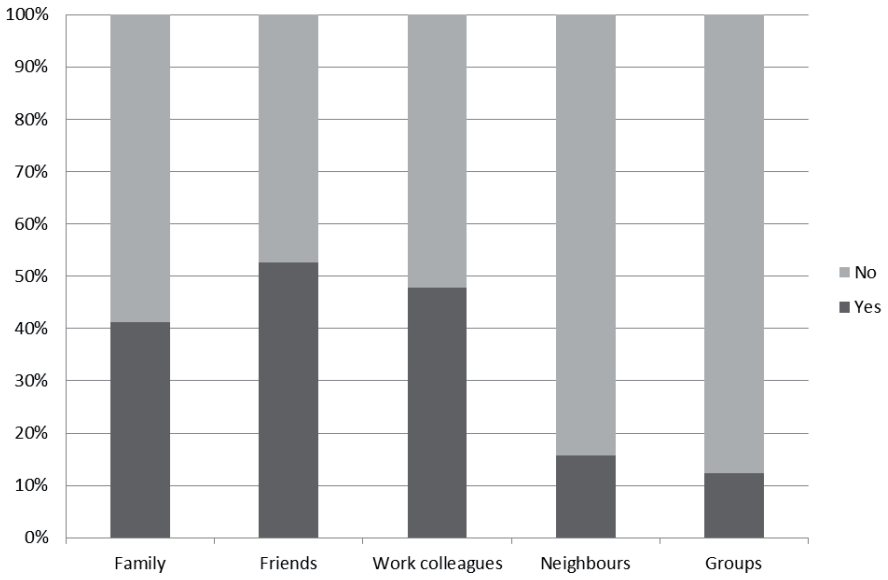

Figure 1. Who do people talk to about energy? Responses to the question 'Do you currently talk to any of the following people about energy use and/or saving money on energy?' from 1,068 households in Leeds (valid percentage, excluding missing values 3–7 %).

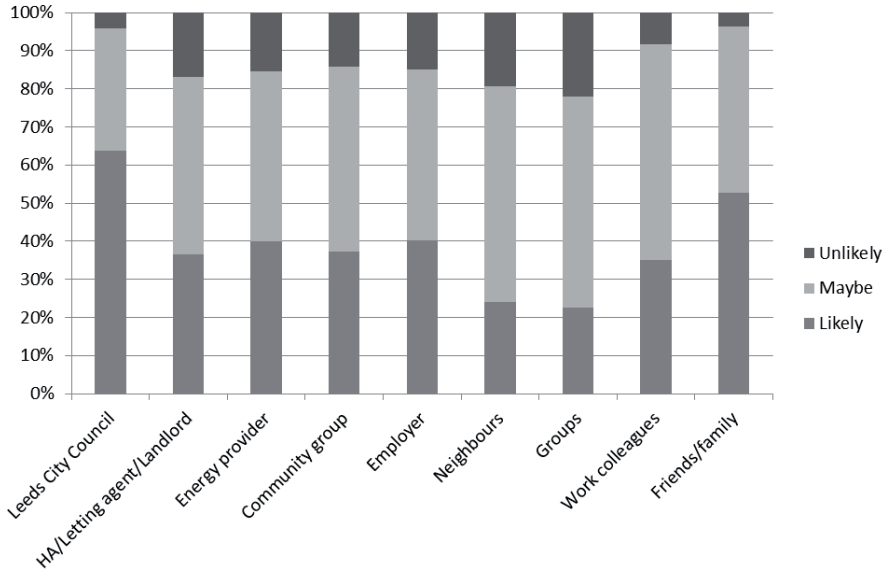

Figure 2. Who do people trust for advice about energy? Responses to the question 'Would you trust advice on energy/money saving given to you by the following people/organisations?' from 1,068 households in Leeds (valid percentage, excluding missing values 3–15 %).

onstrates the value of a quantitative approach that combines personal and social motivation factors and better characterises the heterogeneity of households in a city and their decision-making processes. We briefly summarise this work and the key findings.

The model analyses the adoption decisions of households as dynamical systems interacting on social networks. In the model, households are represented as nodes on a network, with the links between the nodes representing lines of communication between householders, for example between individual households or at workplaces or other group environments. The total perceived usefulness or utility of a product to a household is a combination of factors, broadly divided into personal and social benefit (Delre et al., 2010). Personal benefit is a measure of the perceived benefit of acquiring the technology to the household. Total social benefit is the utility derived from the perceived benefit of fitting in with others, which can be divided into two parts: the influence from a household's personal social links (peer-group) and the influence from society in general (population) (Valente, 1996). The model we have developed thus has three factors, which can be given relative weightings, to account for different preferences of the household. The

weightings are given to the factors of the perceived personal benefit to the household, the perceived benefit gained from following the influence of adopters within the household's social network neighbourhood, and the perceived benefit of aligning with the mainstream social norm. Different household types will weight these factors differently; we are able to introduce different archetype groups to reflect this.

The decision to invest in a technology is determined at each time-step, and if the perceived total utility to the household outweighs the barriers to adoption, seen as a combined utility threshold, the node will become an adopter.

We use the model to investigate different roll-out strategies for a generic local authority initiative, including those that alter the threshold to adoption and those that use network interventions. Of those where the network is altered we try to effect an intervention targeted at individuals, or using the 'segmentation' and 'induction' types, as defined in Table 2. We found that all the network interventions investigated increased uptake over the baseline case, by different amounts. There was little difference to the overall average final uptake whether seeding to the same fraction of the total population of individual households (randomly) versus those connected to one community group or workplace. We concluded that this is because there was no significant overlap between communities on our network, and thus even once each cluster is seeded there is no mechanism for adoption to propagate socially across the whole network and the results are therefore similar to those in the randomly seeded case.

We found that our scenario to induce new active connections on the network (our snowball scenario, where new adopters were giving an incentive to recommend a friend) gave a significant increase in the average uptake across the network and could provide a cost-effective means for a local authority to promote uptake.

The results of the simulations revealed the qualitative dynamics of the uptake in response to various alternative strategies (which were in some instances counter-intuitive on first thought) and provided a strong motivation for using this type of network model-based thinking to inform policy decisions.

In summary, the three perspectives we have discussed in this section show: 1) that adoption of energy-efficiency measures may be amenable to network interventions as shown to be successful in adopting healthy behaviours, 2) that social network connections do operate among households and energy information is both shared and trusted between friends, family, work colleagues and the local authority and 3) that results from abstracted modelling of local authority interventions (where households adopt based on personal and social preferences) indicate that network interventions could give enhanced uptake. In the next section we consider how social network interventions might be applied by local authorities.

Local authority use of network interventions

As we have described, there are many examples of the use of network interventions with the aim of supporting health-related initiatives. There are far fewer in the energy domain; nevertheless, there are some examples which show how different types of network intervention can be applied to encourage uptake of energy-efficiency measures in the domestic sector. In Table 2 we have drawn examples from recent local authority-led initiatives and shown how these relate to the typology of network interventions given by Valente (2012). We also show how social network data could have been used to improve the design of these interventions. Unfortunately we have no way of knowing whether the initiatives were designed with network intervention principles in mind based on social network data, although we believe that this is unlikely.

The initiatives shown in Table 2 are likely to have achieved mixed success depending on the exact design of the intervention. It would be useful to collect data from these types of intervention in order to help understand how network interventions can be successfully made in future initiatives drawing on social network data, where available (as proposed in Table 2).

It would potentially be possible to conduct an intervention that could be used as a two-way experiment; to collect information on the social network as well as assessing the success of the intervention itself. This could lead to iterative policy design whereby new data leads to improved success of the initiative.

It is also worth noting that local authorities usually do not have the tools or resources available (Bale et al., 2012a) to make informed decisions on the design of interventions that incorporate social network features and would be useful in harnessing their potential for domestic energy-efficiency initiatives. Modelling tools using a method similar to that developed by these authors (McCullen et al., 2012, Bale et al., 2012c, Bale et al., 2012b) could be used in this respect to aid policy design. In addition, policy support at a national/regional level for initiatives that use social networks may be helpful. This is discussed in the next section.

Discussion

In combination, the literature in the health domain, new data on energy information sharing through social networks, modelling results, and pilot local authority-led initiatives show the potential for utilising social networks in the promotion of energy efficiency in the domestic sector. Although further research in this area is clearly warranted, in light of the 'energy-efficiency gap' (Jaffe and Stavins, 1994) we suggest that insights from social network theory and the application of network interventions would require a different approach than is currently being taken. To support new local authority approaches to promoting energy efficiency, action must be supported at the national and international level. In this regard we review the two key strategies at the EU and UK level to assess what provision there is currently for supporting local-level social network interventions.

The EU Energy Efficiency Directive (European Commission, 2012) establishes a framework of measures for the promotion of energy efficiency within the EU in order to ensure the achievement of the 2020 20 % target on energy efficiency. The directive lays down rules designed to remove barriers in the energy market and overcome market failures that impede efficiency in the supply and use of energy. As we have mentioned, there are several non-financial barriers to implementation of energy-efficiency measures in the domestic sector, and we have proposed that the social influence and the use of network interventions may be one route to overcoming these barriers.

Table 2. Examples of the use of network interventions in local authority energy-efficiency initiatives.

Type	Local authority-led example in the energy-efficiency domain	Similar initiatives that have already been implemented (where found)	Comments/Suggestions for improvements to the initiative using social network theory
Individuals	*Local energy champions* Certain trusted households are targeted to act as energy advisors or 'champions'.	*Energy Champions* – Bath & North East Somerset Council, UK[1] *Energy Champions* – Nottingham Energy Partnership, UK[2]	Use of social network data to identify and target those 'champions' that are likely to be the most successful opinion leaders. This would require a more detailed picture of the social network as well as information on what type of individual is influential in this context.
Segmentation	*Community energy programmes* Retrofit programmes are undertaken in certain segments. This could be geographic (for example, all those within a certain area) or on some other basis (for example, those in council-owned properties).	*Community Energy Saving Programme* (CESP) – DECC, UK[3]	Use of social network data to identify overlapping clusters on the network and target those that are well connected, in order that propagation spreads to other communities. Again, this would require more detailed social network date. However, results from modelling work suggest that in a network where communities are not overlapping this is no more successful than targeting individuals.
Induction	*Referal elements in programmes* Recommend-a-friend schemes for energy audit and retrofit programmes.	*Wrap up Leeds* – Leeds City Council, UK[4] *EnergySmart* – Boulder County Council, USA[5]	Use of household segmentation data to identify and target pro-environmental households who even if they are not be able to act themselves (e.g. cannot install equipment if in a rented property) are more likely to have a desire to do so, and can therefore be used to encourage others in the network who are able to act.
Alteration	Use of advocacy groups, targeted social media, energy auditors and public commitments to enhance communication and visibility about energy-efficiency issues in a targeted manner.		Alteration of the network is usually harder to implement and cannot be done by mass media campaigns alone. Increasing the visibility of adoption to alter the network by providing peer influence in geographic neighbourhoods where social network connections may not currently exist could help e.g. peer influence seen for solar panel adoption.

[1] *(Bath & North East Somerset Council, 2012)*

[2] *(Nottingham Energy Partnership, 2012)*

[3] *(Department of Energy and Climate Change, 2012a)*

[4] *(Leeds City Council and Yorkshire Energy Services, 2012)*

[5] *(Beckel, 2012)*

We have briefly reviewed the directive in order to assess what provisions have been made to support these types of intervention. We found only one explicit mention of the role for local authorities working with citizens:

> Article 17. 4. Member States shall, with the participation of stakeholders, including local and regional authorities, promote suitable information, awareness-raising and training initiatives to inform citizens of the benefits and practicalities of taking energy efficiency improvement measures. (Page 24)

In addition, we have found that the UK's recently published Energy Efficiency Strategy (Department of Energy and Climate Change, 2012b) largely overlooks the role of social influences in domestic energy decision-making, except for one mention in Annex B relating to the information barrier.

> B.68 Third parties such as charities, consumer groups, community organisations, local authorities, housing associations and friends and family will also have an important role as 'trusted messengers'. (Page 104)

The strategy suggests that engagement with these trusted third parties should be coordinated. While our evidence from the survey shows that these types of communication channel can play an important role, we propose that the strategy should go further in its aims for the use of these social network channels.

The Green Deal (Department of Energy and Climate Change, 2011a) is the UK's flagship policy, and one of the key policies under the UK Energy Efficiency Strategy, aimed at promoting retrofit of domestic energy-efficiency technologies. The Green Deal, coupled with the Energy Company Obligation (ECO), aims to achieve a large-scale reduction of carbon emissions from existing buildings in the UK. It offers a market-led scheme that provides a financing mechanism for householders to install a number of energy-efficient measures and make the repayments on their energy bills, without the need for upfront capital investment. In theory, this will remove one of the major barriers to uptake, that of the upfront cost of installation. However, there has been speculation from industry and the wider community that the Green Deal will not achieve its expected outcomes (Rosenow and Eyre, 2012) and that, while the policy may help overcome financial barriers to adoption of energy-efficiency measure, it will not address those that are non-financial. Rosenow and Eyre also assert that 'the "conversion" of non-interested to interested [households] remains a key problem'. It is with regard to this conversion that we suggest that social influence, and in particular the role of social networks, could be used to promote adoption.

It is very likely that local authorities will have a significant role to play in the implementation of the Green Deal (Department of Energy and Climate Change, 2011b), but at this stage it is up to each individual authority to decide how it will do this. There are three broad approaches that a local authority may adopt: as a provider (directly coordinating finance and delivery), as a partner working with other providers to facilitate delivery, or as a promoter to advocate the scheme to residents. We suggest that, whichever of these approaches is adopted, the local authority and its partners will need to use social influences in order to promote uptake of the Green Deal. As we have found from our survey, local authorities appear to be a trusted source of information with regard to energy and their brand can be leveraged to promote confidence in the policy. Local authorities are also able to work directly with communities and businesses in the ways shown in Table 2 to use network interventions. We propose that these types of intervention be considered when designing local-level initiatives in support of the Green Deal.

National strategies need to include local authority-led trusted information and the influence of peers and the population in decision-making when designing initiatives aimed at encouraging uptake of energy-efficiency measures.

Conclusions

Drawing on existing literature and empirical survey evidence, we have highlighted that social influences can and will likely have an impact on adoption of energy-efficiency measures in the domestic sector. We have also summarised initial results from modelling of social network interventions, which combines quantitative and qualitative insights. While there are still gaps in our understanding of the mechanisms of diffusion for specific innovations, the benefits to network interventions are becoming clearer.

However, both EU and UK energy-efficiency strategies overlook the important role that local authorities play in encouraging the households under their remit to adopt energy-efficiency measures, as well as the significant social network influences on uptake between households.

We propose that these ideas be developed further; research to collect new data, evidence and monitoring drawn from current local-level strategies is clearly warranted. These insights should also be considered in national policy in order that local initiatives, where local authorities hold trusted relationships, can be enhanced and supported in order to achieve energy-efficiency targets.

References

Bale, C. S. E., Foxon, T. J., Hannon, M. J. & Gale, W. F. 2012a. Strategic energy planning within local authorities in the UK: A study of the city of Leeds. *Energy Policy,* 48, 242–251.

Bale, C. S. E., McCullen, N. J., Foxon, T. J., Rucklidge, A. M. & Gale, W. F. 2011. Local authority interventions in the domestic sector and the role of social networks: a case study from the city of Leeds. *Energy & People: Futures, complexity and challenges conference.* Oxford: UKERC.

Bale, C. S. E., McCullen, N. J., Foxon, T. J., Rucklidge, A. M. & Gale, W. F. 2012b. Harnessing social networks for promoting adoption of energy technologies in the domestic sector. *Submitted to Energy Policy*.

Bale, C. S. E., McCullen, N. J., Foxon, T. J., Rucklidge, A. M. & Gale, W. F. 2012c. Modelling diffusion of energy efficiency measures on a social network: Integration of real world data *Complexity Science and Social Science at the Interface to the Real World.*

Bath & North East Somerset Council. 2012. *Local Energy Champions* [Online]. Bath. Available: http://www.bathnes.gov.uk/services/environment/sustainability/community/local-energy-champions [Accessed December 2012].

Beckel, B. 2012. EnergySmart Social Marketing: Lessons from Boulder County. *Behaviour Energy and Climate Change conference.* Sacramento.

Bollinger, B. & Gillingham, K. 2012. Peer Effects in the Diffusion of Solar Photovoltaic Panels. *Marketing Science.*

Choi, H., Kim, S.-H. & Lee, J. 2010. Role of network structure and network effects in diffusion of innovations. *Industrial Marketing Management,* 39, 170–177.

Coltrane, S., Archer, D. & Aronson, E. 1986. The social-psychological foundations of successful energy conservation programmes. *Energy Policy,* 14, 133–148.

Committee on Climate Change 2012. How local authorities can reduce emissions and manage climate risk London.

Darley, J. M. & Beniger, J. R. 1981. Diffusion of Energy-Conserving Innovations. *Journal of Social Issues,* 37, 150–171.

Deffuant, G., Huet, S. & Amblard, F. 2005. An Individual-Based Model of Innovation Diffusion Mixing Social Value and Individual Benefit. *American Journal of Sociology,* 110, 1041–1069.

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.

Department of Energy and Climate Change 2011a. The Green Deal: A summary of the Government's proposals. London.

Department of Energy and Climate Change 2011b. Local Authorities and the Green Deal. London: DECC.

Department of Energy and Climate Change. 2012a. *Community Energy Saving Programme (CESP)* [Online]. DECC. Available: http://www.decc.gov.uk/en/content/cms/funding/funding_ops/cesp/cesp.aspx [Accessed Jan 2013].

Department of Energy and Climate Change 2012b. The Energy Efficiency Strategy: The Energy Efficiency Opportunity in the UK. London: DECC.

Dowson, M., Poole, A., Harrison, D. & Susman, G. 2012. Domestic UK retrofit challenge: Barriers, incentives and current performance leading into the Green Deal. *Energy Policy,* 50, 294–305.

European Commission 2012. Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. Official Journal of the European Union.

Granovetter, M. & Soong, R. 1983. Threshold models of diffusion and collective behavior. *The Journal of Mathematical Sociology,* 9, 165–179.

Grönlund, A. & Holme, P. 2005. A network-based threshold model for the spreading of fads in society and markets. *Advances in Complex Systems,* 08, 261–273.

Jaffe, A. B. & Stavins, R. N. 1994. The energy-efficiency gap What does it mean? *Energy Policy,* 22, 804–810.

Lee, E., Lee, J. & Lee, J. 2006. Reconsideration of the Winner-Take-All Hypothesis: Complex Networks and Local Bias. *Management Science,* 52, 1838–1848.

Leeds City Council & Yorkshire Energy Services. 2012. *Wrap up Leeds* [Online]. Leeds. Available: http://www.wrapupleeds.co.uk/ [Accessed November 2012].

Lloyd, H. M., Paisley, C. M. & Mela, D. J. 1995. Barriers to the Adoption of Reduced-Fat Diets in a UK Population. *Journal of the American Dietetic Association,* 95, 316–322.

Luke, D. A. & Harris, J. K. 2007. Network Analysis in Public Health: History, Methods, and Applications. *Annual Review of Public Health,* 28, 69–93.

Lutzenhiser, L. 1992. A cultural model of household energy consumption. *Energy,* 17, 47–60.

Lutzenhiser, L. 1993. Social and Behavioral Aspects of Energy use. *Annual Review of Energy and the Environment,* 18, 247–289.

Maibach, E. W., Roser-Renouf, C. & Leiserowitz, A. 2008. Communication and Marketing As Climate Change–Intervention Assets: A Public Health Perspective. *American Journal of Preventive Medicine,* 35, 488–500.

McCullen, N. J., Rucklidge, A. M., Bale, C. S. E., Foxon, T. J. & Gale, W. F. 2012. Multi-parameter models of innovation diffusion on complex networks. *SIAM Journal on Applied Dynamical Systems* Submitted.

McMichael, M. 2011. Household energy efficiency and information-seeking: the value of social networks in the diffusion of innovations. *'Buildings don't use energy, people do' conference.* University of Bath.

Nottingham Energy Partnership. 2012. *NEP's search for 'energy champions'* [Online]. Available: http://www.nottenergy.com/News/nep_in_the_news/neps_search_for_energy_champions [Accessed January 2013].

Nye, M., Whitmarsh, L. & Foxon, T. 2010. Sociopsychological perspectives on the active roles of domestic actors in transition to a lower carbon electricity economy. *Environment and Planning A,* 42, 697–714.

Pelenur, M. & Cruickshank, H. 2012. The social barriers towards adopting energy efficiency measures and behaviours in the home: a Manchester and Cardiff case study. *Retrofit 2012 conference.* Salford Quays.

Rogers, E. M. 1983. *Diffusion of innovations,* New York; London, Free Press ; Collier Macmillan.

Rosenow, J. & Eyre, N. 2012. The Green Deal and the Energy Company Obligation – will it work? *9th BIEE Academic Conference – European Energy in a Challenging World: The impact of emerging markets.* Oxford.

Shove, E. 1998. Gaps, barriers and conceptual chasms: theories of technology transfer and energy in buildings. *Energy Policy,* 26, 1105–1112.

Sorensen, G., Stoddard, A. M., Dubowitz, T., Barbeau, E. M., Bigby, J., Emmons, K. M., Berkman, L. F. & Peterson, K. E. 2007. The Influence of Social Context on Changes in Fruit and Vegetable Consumption: Results of the Healthy Directions Studies. *American Journal of Public Health,* 97, 1216–1227.

Southwell, B. G., Murphy, J., Dewaters, J. & Lebaron, P. 2012. Energy information sharing in social networks: The roles of objective knowledge and perceived understanding. *Behaviour, Energy and Climate Change Conference.* Sacramento.

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.

Valente, T. W. 2005. Network models and methods for studying the diffusion of innovations. *In:* Carrington, P., Scott, J. & Wasserman, S. (eds.) *Models and methods in social network analysis.* Cambridge University Press.

Valente, T. W. 2010. *Social Networks and Health: Models, Methods, and Applications,* New York, Oxford University Press.

Valente, T. W. 2012. Network Interventions. *Science,* 337, 49–53.

Watts, D. J. 2002. A simple model of global cascades on random networks. *Proceedings of the National Academy of Sciences,* 99, 5766–5771.

Weber, L. 1997. Some reflections on barriers to the efficient use of energy. *Energy Policy,* 25, 833-835.

Wilson, C. & Dowlatabadi, H. 2007. Models of Decision Making and Residential Energy Use. *Annual Review of Environment and Resources,* 32, 169–203.

Woking Borough Council. 2012. *Actio2n Woking* [Online]. Available: http://www.woking.gov.uk/environment/climate/canyoudo/actio2nwoking [Accessed November 2012].

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