Goodwin, S. & Dykes, J. (2012). Geovisualization of household energy consumption characteristics. Paper presented at the GIS Research UK 20th Annual Conference (GISRUK 2012), 11 - 13 Apr 2012, Lancaster University, Lancaster UK.

Geovisualization of Household Energy Consumption Characteristics

Sarah Goodwin[1] and Jason Dykes[1]

[1]giCentre, School of Informatics, City University London, EC1V OHB
Tel. 020 7040 8370
sarah.goodwin.1@city.ac.uk, j.dykes@city.ac.uk

Summary: A vast amount of quantitative data is available within the energy sector, however, there is limited understanding of the relationships between neighbourhoods, demographic characteristics and domestic energy consumption habits. We report upon research that will combine datasets relating to energy consumption, saving and loss with geodemographics to enable better understanding of energy user types. A novel interactive interface is planned to evaluate the performance of these energy-based classifications. The research aims to help local governments and the energy industry in targeting households and populations for new energy saving schemes and in improving efforts to promote sustainable energy consumption. Energy based neighbourhood classifications will also promote consumption awareness amongst domestic users. This poster describes the research methodology, data sources and visualization requirements.

KEYWORDS: Energy Consumption, Classification, Geodemographics, Visualization, Evaluation.

1. Introduction

Energy consumption is of growing interest to individuals, organizations and government due to EU energy consumption and carbon footprint reduction targets set for 2020 and 2050. In 2004 the household sector represented 27% of the UK's total carbon dioxide emissions and approximately 30% of total energy use (HM Government, 2006 in Druckman & Jackson, 2008). Achieving a large reduction at the domestic level is therefore imperative to meeting these targets. Over recent years there has been an increasing amount of research related to energy consumption, carbon reduction and potential energy saving opportunities; however, there is still limited knowledge of the relationship between energy consumption and measurable characteristics of population. Druckman and Jackson (2008) report that domestic fuel consumption in the UK is strongly related to disposable income levels with other highly influential factors being dwelling type, household composition, property tenure and rural/urban location. This work indicates that energy consumption patterns correlate to socio-economic and geographic characteristics and continued research in this field is needed in order to better target new low-carbon policies.

Within the energy industry there is a substantial amount of energy consumption data and the introduction of modern smart meters will increase this data quantity exponentially (Computer Weekly, 2009). Smart meter technology allows for consumption to be recorded at frequent intervals and communicates this information to both consumer and energy supplier allowing for near real-time feedback of energy use. Smart meters form a major component of 'Smart Grids', which are estimated to reduce annual EU household energy consumption by 10% and carbon dioxide emissions by 9% (European Commission, 2011). Many EU countries have started to introduce smart meter technology into households, with Italy reaching 85% household coverage in 2010 (Clastres, 2011). In 2009 the UK Government announced the intention to introduce smart meters into all households by 2020 (Faruqui *et al.*, 2010).

Smart meters are expected to greatly improve user awareness and allow for the regulation of energy consumption at the household level (Darby, 2010). A study of early adopters (Hargreaves *et al.*, 2010) reports improved awareness, but further studies are needed to identify whether changes in behaviour are long term and to understand the differences across household types. Traditionally household energy consumption feedback is provided through standard utility bills, which are usually vague, uninformative and do not invite householders to think about their consumption patterns. It is rare for utility suppliers to provide benchmarks or comparison target groups for improving consumer awareness (Ehrhardt-Martinez *et al.*, 2010). Räsänen *et al.* (2008) acknowledge the need for neighbourhood level comparisons to provide consumers with understandable and concrete reasoning for saving energy as well as to encourage discussion of energy saving techniques amongst neighbours. Energy usage profiling and online visualization tools are now available for individuals to track their consumption over time, with some of these allowing for comparison at the neighbourhood or community level - such as iMeasure (Environmental Change Institute, 2011). While providing the opportunity to explore household energy consumption patterns in greater detail than the standard utility bill, these profiling tools are often time consuming and require some technical understanding in order to achieve a reduction in energy consumption. Ehrhardt-Martinez *et al.* (2010) review recent research and compare the success of different usage feedback schemes.

Electricity distribution deregulation has enabled electricity providers to formulate dedicated tariff types based on customer characteristics (Stephenson *et al*., 2001). Energy providers and market analysts would benefit from consumption classifications as this would enable tariffs to be targeted based on typical consumer traits. Chicco *et al*. (2006, p.933) describe the need for electricity customer classifications for service providers:

> *"For the purpose of defining suitable tariff structures, the existing customer classifications based on the type of activity are scarcely correlated to the actual evolution of the electrical consumption and, as such, give poor information to the distribution providers".*

A new geographical clustering of energy characteristics at the neighbourhood level is necessary for energy companies, local governments and residents to allow realistic comparisons, understand complex consumption variations and enable better targeting of services and schemes to encourage more sustainable energy use.

2. Geodemographics and Energy Consumption

There is a body of relevant research correlating energy consumption with household or population variables (Semenik *et al*., 1982); however, little research directly investigates the classification and evaluation of energy related variables with geodemographics. Druckman and Jackson (2008) compare energy consumption with the seven ONS Output Area Classification (OAC) Super Groups showing clear correlations with household disposable income and property tenancy. This draws parallels with other literature (Dillahunt & Mankoff, 2011; Dillahunt *et al*., 2009) indicating that low-income families and tenant households have difficulties and additional barriers to reducing energy consumption.

Large multivariate dataset classification is ideal for residential energy consumption as previous research shows that human populations with similar characteristics and behaviours tend to cluster together. Some topical research by Chicco *et al.* (2003, 2006) evaluates techniques and methods for classifying characteristics of non-residential electricity use. In 2008, Experian introduced a data product '*GreenAware*' (Experian, 2008) responding to demand to characterise populations based on energy behaviour. A case study of the use of this data by Haq and Owen (2009) demonstrates the potential for using population classifications to understand the geographical variations in energy consumption, however, the thematic map examples offered also highlight the difficulty in visualizing such abstract classified datasets. In classic thematic maps the areas of interest with the largest populations are frequently least visually salient due to the limited geographical area of the most densely populated areal units. Slingsby *et al.* (2011; 2010) show that well designed and novel visualization methods can be used to effectively visualize local and national multivariate datasets to overcome some of the problems associated with the kinds of thematic maps that are more routinely used.

3. Data Visualization and Energy Consumption

While data classification radically reduces data volumes and enables trends and clusters in large datasets to be identified with greater ease, they can be misinterpreted (Harris *et al.*, 2005). Data visualization can be both useful in helping gain access to and traction with such abstract but potentially informative information as well as providing insight into some of the detail lost during the classification process. OAC Explorer (Slingsby *et al.,* 2010; Slingsby *et al.,* 2011) shows that exploratory visualization methods can be effective in helping organizations understand local populations and their characteristics through geodemographic classifications. The public facing *placeSurvey* application (LSR, 2011) and related means of providing timely information for citizens demonstrate how visualization can be used to engage the public in exploratory analysis of information about local issues.

Technological advances in data visualization offer real opportunities for research into energy consumption awareness with techniques that may provide personal views and interactive exploration of energy data – potentially in real time. Recent research highlights new ideas to encourage awareness and behavioural changes through tools and visualizations designed to make the user aware of their current energy use through non-intrusive and subtle visual stimuli (Jönsson *et al.,* 2010; Rodgers *et al.,* 2011).

4. Research Plan and Status

The academic literature in the field highlights a continued need to classify UK energy user groups as well as provide the ability to explore such a classification through interactive visualization techniques. Our research therefore has two objectives:

a. To create neighbourhood energy consumption classifications by combining datasets such as energy consumption, energy loss and saving potential with geodemographic variables
b. To provide user groups such as energy suppliers, local government and citizens with the possibility to visualize this information through innovative and interactive geovisualization techniques that enable the data to be explored, understood, evaluated and acted upon.

The proposed classification and visualization of energy consumption related data will enable the private household energy market to be better understood, allow for energy profiles at the neighbourhood level and give local government and the energy industry better targets for potential energy saving schemes.

Having established a need for geodemographic energy profile geovisualization we are currently in the process of defining the classification system to be used, collecting datasets that may contribute to it and establishing visualization requirements. Our poster presents a description of our classifier and some initial visualization requirements that form the first stage in moving us towards our research objectives.

5. Acknowledgements

This work is funded by a Vice Chancellor's Scholarship from City University London and Betternest Ltd UK.

6. References

Chicco, G, Napoli, R & Piglione, F 2003, "Application of Clustering Algorithms and Self Organising Maps to Classify Electricity Customers.," in *Power Tech Conference Proceedings*, Bologna, p. 7.

Chicco, G, Napoli, R & Piglione, F 2006, “Comparisons Among Clustering Techniques for Electricity Customer Classification.” *IEEE Transactions on Power Systems*, vol. 21, no. 2, pp. 933-940.

Clastres, C 2011, “Smart Grids: Another Step Towards Competition, Energy Security and Climate Change Objectives.” *Energy Policy*, vol. 39, pp. 5399-5408.

Computer Weekly 2009, “Smart Meters Multiply Data Loads.” Retrieved November 22, 2011, from http://www.computerweekly.com/news/2240089669/Smart-meters-multiply-data-loads

Darby, S 2010, “Smart Metering: What Potential for Householder Engagement?” *Building Research & Information*, vol. 38, no. 5, pp. 442-457.

Dillahunt, T & Mankoff, J 2011, “In the Dark, Out in the Cold.” *XRDS: Crossroads, The ACM Magazine for Students - Green Technologies*, vol. 17, no. 4, pp. 39–41.

Dillahunt, T, Mankoff, J, Paulos, E & Fussell, S 2009, “It’s Not All About ‘Green’: Energy Use in Low-Income Communities,” in *Proceedings of the 11th international conference on Ubiquitous computing*, Ubicomp ’09, ACM, New York, NY, USA, pp. 255–264.

Druckman, A & Jackson, T 2008, “Household Energy Consumption in the UK: A Highly Geographically and Socio-economically Disaggregated Model.” *Energy Policy*, vol. 36, pp. 3177-3192.

Ehrhardt-Martinez, K, Donnelly, K & Laitner, J 2010, *Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities*, Retrieved November 22, 2011, from http://www.aceee.org/research-report/e105

Environmental Change Institute 2011, “iMeasure: Home Energy and Carbon Monitoring Calculator.” Retrieved November 30, 2011, from http://www.imeasure.org.uk/

European Commission 2011, *Next Steps for Smart Grids: Europe’s Future Electricity System will Save Money and Energy*, Brussels. Retrieved November 30, 2011, from http://ec.europa.eu/energy/gas_electricity/smartgrids/smartgrids_en.htm

Experian 2008, “GreenAware: A Segmentation of Environmentally-Relevant Behaviours, Attitudes and Carbon Footprint.” Retrieved November 19, 2011, from http://www.experian.co.uk/assets/business-strategies/brochures/GreenAware_factsheet[1].pdf

Faruqui, A, Harris, D & Hledik, R 2010, “Unlocking the €53 Billion Savings from Smart Meters in the EU: How Increasing the Adoption of Dynamic Tariffs Could Make or Break the EU’s Smart Grid Investment.” *Energy Policy*, vol. 38, pp. 6222-6231.

Haq, G & Owen, A 2009, “Green Streets The Neighbourhood Carbon Footprint of York.” Retrieved January 25, 2011, from http://publicsector.experian.co.uk/Products/~/media/CaseStudies/FinalGreenStreetsReportOct2009.ashx

Hargreaves, T, Nye, M & Burgess, J 2010, “Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors.” *Energy Policy*, vol. 38, no. 10, pp. 6111-6119.

Harris, R, Sleight, P & Webber, R 2005, *Geodemographics: GIS and Neighbourhood Targeting*, Wiley-Blackwell.

Jönsson, L, Broms, L & Katzeff, C 2010, "Watt-Lite: Energy Statistics made Tangible," in *Proceedings of the 8th ACM Conference on Designing Interactive Systems*, DIS '10, ACM, New York, NY, USA, pp. 240–243.

LSR Online (Leicestershire Statistics & Research) 2011, "PlaceSurvey." Retrieved November 30, 2011, from http://www.lsr-online.org/placesurvey.html

Räsänen, T, Ruuskanen, J & Kolehmainen, M 2008, "Reducing Energy Consumption by Using Self-Organizing Maps to Create More Personalized Electricity Use Information." *Applied Energy*, vol. 85, no. 9, pp. 830-840.

Rodgers, J, Bartram, L & Woodbury, R 2011, "Challenges in sustainable human-home interaction." *XRDS*, vol. 17, no. 4, pp. 42–46.

Semenik, R, Belk, R & Painter, J 1982, "A Study of Factors Influencing Energy Conservation Behaviour." *Advances in Consumer Research*, vol. 09, pp. 306-312.

Slingsby, A, Dykes, J & Wood, J 2011, "Exploring Uncertainty in Geodemographics with Interactive Graphics." *IEEE Transactions on Visualization and Computer Graphics*, vol. 17, no. 12, pp. 2545 - 2554.

Slingsby, A, Dykes, J, Wood, J & Radburn, R 2010, "OAC Explorer: Interactive Exploration and Comparison of Multivariate Socioeconomic Population Characteristics," in *Proceedings of the GIS Research UK*,pp. 167-174.

Stephenson, P, Lungu, I, Paun, M, Silvas, I & Tupu, G 2001, "Tariff development for consumer groups in internal European electricity markets," in *Electricity Distribution, 2001. Part 1: Contributions. CIRED.*, IEE, Amsterdam.

7. Biography

Sarah Goodwin is a first-year PhD candidate at the giCentre, City University London. She has an academic and professional background in Geographical Information Science. After being awarded a distinction for her MSc at City University in 2007 and presenting her findings at GISRUK 2008 she was employed in Germany to analyse and map geographical variations in energy use characteristics.

Dr. Jason Dykes is Professor of Visualization at the giCentre, City University London undertaking applied and theoretical research in, around and between information visualization, interactive analytical cartography and human-centred design.