“Feedback in energy demand reduction: Examining evidence and exploring opportunities”

ECCI, Edinburgh, 4-5 July 2016

FULL PROGRAMME & PAPER ABSTRACTS

- What can energy feedback do to alter energy use in the home or workplace?
- How best can feedback data be disaggregated, portrayed or displayed?
- How can feedback relate to community energy action or gaming approaches?
- What can insights from theory, different disciplines and industry tell us about feedback?
- What is the future of feedback?
INTRODUCTION

Energy feedback – the provision of energy-consumption information to energy-users – forms a core component of many initiatives that aspire to shift or reduce energy demand. It features in both domestic and non-domestic settings and takes many forms including utility bills, in-home-displays, phones apps, emails from facilities managers, advice from friends and guidance from consumer and business support centres.

In recent years, the world-wide roll out of smart-metering has led to a surge in feedback-related initiatives with academics, policy-makers and those in industry keen to identify if and how it can promote energy efficiency and reduction. With this in mind, this symposium seeks to bring together all those with an interest in energy-feedback to share the latest empirical evidence in this arena and to use insights gained from this knowledge-sharing exercise to influence and contribute to innovation, future research, and policy and practice in this field.

Over 40 speakers will provide insights from academia, industry and policy and we are pleased to be joined by key note speakers Sarah Darby (University of Oxford), Karen Ehrhardt-Martinez (Navigant) and Tom Hargreaves (University of East Anglia).

This booklet includes the symposium programme, a full participant list and extended abstracts for all the presentations made during the two days. We hope that participants at the event, as well as those unable to make it in person, will find the extended abstracts a valuable permanent resource. We hope to also be able to share slides of the presentations made during the event through the TEDDINET website in due course (www.teddinet.org).

Many thanks in advance to all those who are speaking and attending the event for sharing your expertise, your experience and your enthusiasm, and for helping to make this a memorable and useful event. We of course also thank the EPSRC for the funding to make this event possible.

All the best,
Kathryn Buchanan (University of Essex) and Sam Staddon (University of Edinburgh)
HELP!

If you need any help at all during the symposium, here are the people you can turn to!

Convenors

Kathryn Buchanan  
Sam Staddon

TEDDINET

Dan van der Horst  
Tom Kane

University of Edinburgh

Lynda Webb  
Evan Morgan

Elaine Farrow  
Jonathon Kilgour
PROGRAMME

Monday 4th July 2016

12.00 – 13.00: Registration & Lunch *(Venue: ECCI, Conference Room – see map below)*

13.00 – 13.30: Welcome & KEY NOTE 1 Sarah Darby, University of Oxford


- Vanquishing Energy Vampires: The Failure of Feedback Riccardo Russo & Kathryn Buchanan, University of Essex
- Nat Consumers: Natural Language Feedback Caitlin Bent & Greg Shreeve, Energy Saving Trust
- iBert: Intelligent Support System for Energy Behaviour Change Nataliya Mogles, University of Bath
- Mental Model Interface Design: Putting Users in Control Kirsten Revell & Neville Stanton, University of Southampton
- Investigating Smart Metering in the Home: How Users Comprehend Graphic Representations of Residential Electricity Feedback System Melanie Herrman, University College London
- Designing Successful Feedback Interfaces for Home Energy Systems: the Aging Population Perspective Bruce Stephen & Mike Danson et al., Heriot Watt University

14.45 – 15.10: Refreshment Break

15.10 – 15.30: KEY NOTE 2 Karen Ehrhardt-Martinez, Navigant


- Does Disaggregated Electricity Feedback Reduce Electricity Consumption? A Critical Review of the Literature Jack Kelly, Imperial College London
- Utilising Disaggregated Energy Data in Feedback Designs – The IDEAL Project Martin Pullinger & Nigel Goddard et al., University of Edinburgh
- Energy feedback enabled by load disaggregation Lina Stankovic et al., University of Strathclyde
- Visualising Scale-Invariant Comparative Energy Use Gerard Briscoe, Glasgow School of Art
- Lessons on Visual Feedback from the Eviz Project: The Evidence for Using Thermal Images as a Visual Intervention Matthew Fox, University of Plymouth

- Exploring Energy Feedback at Community and Household Level through Thermography, Carbon Mapping, Online Platform and Home Energy Visits Rajat Gupta & Laura Barnfield, Oxford Brookes University
- The Effect of Real-Time Context-Aware Feedback on Occupants’ Heating Behaviour and Thermal Adaptation Marika Vellei et al., University of Bath
- Quantifying Likely Energy Reduction Opportunities in Family Homes Paula Cosar-Jorda, University of Loughborough
- Between Empowerment and Alienation: How Feedback Technologies Can Harm the Prospects of Successful Energy Transitions Marianne Ryghaug et al., Norwegian University of Science and Technology
- Why Eco-Manager is Not Brilliant? Máté Lőrincz, University of Keele

17.30 – 17.50: KEY NOTE 3 Tom Hargreaves, University of East Anglia
17.50 – 18.00: Close

19.00: Evening meal for all participants & networking opportunities (Venue: South Hall, Pollock Halls)

----------------------------------------

Tuesday 5th July 2016

(Venue: ECCI – see map below)

*** Please note Session 4 consists of two parallel sessions ***

09.00 – 10.20: SESSION 4 A – ‘Beyond Domesticity: Feedback Outside of the Home’ (Conference Room)

- GENIE (Goal-setting and ENergy Information Engagement) in the Workplace Alexa Spence et al., University of Nottingham
- Energy Feedback in the Workplace: Effects of Display Units Caroline Leygue & Alexa Spence, University of Nottingham
- An Interactive and Diagnostic Energy Use Analysis Interface for Facilities Managers Paul Shabajee et al., University of Bristol
- Household Energy Saving Behaviour and Smart Grid Communication between Utilities and Customers Josephine Munene et al., Clark University, USA
- Challenges of Feedback in Organisations- Can We Foster Partnerships not Projects? Richard Bull, De Montfort University & Kathryn Janda, University of Oxford

"Feedback in energy demand reduction: Examining evidence and exploring opportunities" Edinburgh, July 2016 Page 6
09.00 – 10.20: SESSION 4 B – ‘Linking to Theories & Disciplines’ (The Pod)

- The role of non-numeric feedback in reducing domestic energy consumption: Lessons from Freiburg and Besançon Arian Mahzouni, Royal Institute of Technology, Sweden
- Energy feedback: Place, Policy and Mobility Heather Lovell, University of Tasmania, Australia & Gareth Powells, Newcastle University
- Advances in Understanding Energy Consumption Behaviour and the Governance of its Change – Outline of an Integrated Framework Annika Sohre, University of Basel, Switzerland
- Beyond Calorie Counting: What Can Energy Feedback Learn From Weight Loss Programs? Michelle Shipworth, University College London

*** Please note Session 5 consists of two parallel sessions ***

10.30 – 11.15: SESSION 5A – ‘Communities & Collectives’ (Conference Room)

- Householder Engagement with Energy Consumption Feedback: The Role of Community Action and Communications Kevin Burchell et al., University of Westminster [presenting remotely]
- Raising Awareness of Energy Collectively Lara Picollo, Open University
- Social Media and Smart Phones Andy Stephenson et al., National Energy Action
- 7 Families - 7 Solar PV panels, 7 Pre-Payment meters - 1 Estate Nicolette Fox, University of Sussex [not presenting in person]

10.30 – 11.15: SESSION 5B – ‘Gamification of feedback’ (The Pod)

- Reflections on designing an engaging in-home energy dashboard using participatory design and gamification Georgina Wood, University of Birmingham
- Exploring the Challenges and Opportunities of Eco--Feedback Technology for Shifting Electricity Use at Home Nervo Verdezoto, University of Leicester
- Feedback in electricity demand reduction: Examining evidence and exploring opportunities through community-level game mechanics Roberta Castri, University of Applied Sciences and Arts of Southern Switzerland
11.15 – 11.45: Refreshment Break

11.45 – 13.00: SESSION 6 – ‘Insights from Industry & Policy’

- Energy Efficiency Advice: A Toolkit for Engaging Consumers at Smart Meter Installation Visits Andrew Charlesworth, DECC
- Improving participation in the energy market Dan Walker Nolan, Citizens Advice
- The surge of energy data: What does it mean for EDF Energy employees and householders? Christopher Weeks, EDF/University of Bristol
- Existing commercial business activities: why and how feedback on energy consumption is being delivered to customers Scott Bryant, Delta EE
- Energy-feedback services provided by utilities: Lessons learnt from the Empowering project Stoyan Danov, CIMNE
- Waiting for Data: Market Adaptations to Poor Smart Meter Policies in America Michael Murray, Mission.Data

13.00 – 13.45: Lunch

Interactive session hosted by David Shipworth (UCL) with panel discussants Andrew Charlesworth (DECC), Paolo Bertoldi (European Commission), Daniel White (Behaviouralist), and Simon Anderson (Green Energy Options)

14.45 – 15.00: Close
### PARTICIPANT LIST

<table>
<thead>
<tr>
<th>First name</th>
<th>Surname</th>
<th>Institute/Organisation</th>
<th>Email</th>
<th>Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashely</td>
<td>Ahearn</td>
<td>National Public Radio, USA</td>
<td><a href="mailto:aahearn@gmail.com">aahearn@gmail.com</a></td>
<td>Session 7</td>
</tr>
<tr>
<td>Simon</td>
<td>Anderson</td>
<td>Green Energy Options</td>
<td><a href="mailto:simon.anderson@geotogether.com">simon.anderson@geotogether.com</a></td>
<td>Session 7</td>
</tr>
<tr>
<td>Nazma</td>
<td>Bandali</td>
<td>British Gas</td>
<td><a href="mailto:Nazma.Bandali@britishgas.co.uk">Nazma.Bandali@britishgas.co.uk</a></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><a href="mailto:alexander.belsham-harris@citizensadvice.org.uk">alexander.belsham-harris@citizensadvice.org.uk</a></td>
<td></td>
</tr>
<tr>
<td>Alexander</td>
<td>Belsham Harris</td>
<td>Citizens Advice</td>
<td><a href="mailto:caitlin.bent@est.org.uk">caitlin.bent@est.org.uk</a></td>
<td>Session 6</td>
</tr>
<tr>
<td>Caitlin</td>
<td>Bent</td>
<td>Energy Saving Trust</td>
<td></td>
<td>Session 1</td>
</tr>
<tr>
<td>Paolo</td>
<td>Bertoldi</td>
<td>European Commission</td>
<td></td>
<td>Session 7</td>
</tr>
<tr>
<td>Sivapiya</td>
<td>Bhagavathy</td>
<td>Northumbria University</td>
<td><a href="mailto:sivapiya.m.b@gmail.com">sivapiya.m.b@gmail.com</a></td>
<td>Session 4A</td>
</tr>
<tr>
<td>Magdalena</td>
<td>Boork</td>
<td>SP Technical Research Institute of Sweden</td>
<td><a href="mailto:magdalena.boork@sp.se">magdalena.boork@sp.se</a></td>
<td></td>
</tr>
<tr>
<td>Frank</td>
<td>Boyle</td>
<td>Construction Scotland Innovation Centre</td>
<td><a href="mailto:fboyle@cs-ic.org">fboyle@cs-ic.org</a></td>
<td></td>
</tr>
<tr>
<td>Gerard</td>
<td>Briscoe</td>
<td>Glasgow School of Art</td>
<td><a href="mailto:g.briscoe@gsa.ac.uk">g.briscoe@gsa.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Paul</td>
<td>Brown</td>
<td>Centrica</td>
<td><a href="mailto:paul.brown@bgch.co.uk">paul.brown@bgch.co.uk</a></td>
<td>Session 2</td>
</tr>
<tr>
<td>Scott</td>
<td>Bryant</td>
<td>Delta EE</td>
<td><a href="mailto:scott.bryant@delta-ee.com">scott.bryant@delta-ee.com</a></td>
<td>Session 6</td>
</tr>
<tr>
<td>Kathryn</td>
<td>Buchanan</td>
<td>University of Essex</td>
<td><a href="mailto:k.bucha@essex.ac.uk">k.bucha@essex.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Justin</td>
<td>Buck</td>
<td>British Gas - Centrica</td>
<td><a href="mailto:justin.buck@bgch.co.uk">justin.buck@bgch.co.uk</a></td>
<td></td>
</tr>
<tr>
<td>Richard</td>
<td>Bull</td>
<td>DeMontfort University</td>
<td><a href="mailto:rbull@dmu.ac.uk">rbull@dmu.ac.uk</a></td>
<td>Session 4A</td>
</tr>
<tr>
<td>Kevin</td>
<td>Burchell</td>
<td>University of Westminster</td>
<td><a href="mailto:k.burchell@westminster.ac.uk">k.burchell@westminster.ac.uk</a></td>
<td>Session 5A</td>
</tr>
<tr>
<td>Danielle</td>
<td>Butler</td>
<td>Salford University</td>
<td><a href="mailto:D.E.Butler@edu.salford.ac.uk">D.E.Butler@edu.salford.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Roberta</td>
<td>Castri</td>
<td>SUPSI, Switzerland</td>
<td><a href="mailto:roberta.castri@supsi.ch">roberta.castri@supsi.ch</a></td>
<td></td>
</tr>
<tr>
<td>Andrew</td>
<td>Charlesworth</td>
<td>DECC</td>
<td><a href="mailto:andrew.charlesworth@decc.gsi.gov.uk">andrew.charlesworth@decc.gsi.gov.uk</a></td>
<td>Session 6+7</td>
</tr>
<tr>
<td>Paula</td>
<td>Cosar-Jorda</td>
<td>Loughborough University</td>
<td><a href="mailto:p.cosar-jorda@lboro.ac.uk">p.cosar-jorda@lboro.ac.uk</a></td>
<td>Session 3</td>
</tr>
</tbody>
</table>

"Feedback in energy demand reduction: Examining evidence and exploring opportunities" Edinburgh, July 2016  Page 9
<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Email</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stoyan Danov</td>
<td>CIMNE</td>
<td><a href="mailto:sdanov@cimne.upc.edu">sdanov@cimne.upc.edu</a></td>
<td>Session 6</td>
</tr>
<tr>
<td>Mike Danson</td>
<td>Heriot Watt university</td>
<td><a href="mailto:m.danson@hw.ac.uk">m.danson@hw.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Sarah Darby</td>
<td>University of Oxford</td>
<td><a href="mailto:sarah.darby@eci.ox.ac.uk">sarah.darby@eci.ox.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Peter Davies</td>
<td>Green Running Ltd</td>
<td><a href="mailto:p.davies@greenrunning.com">p.davies@greenrunning.com</a></td>
<td></td>
</tr>
<tr>
<td>Karen Ehrhard-Martinez</td>
<td>Navigant</td>
<td><a href="mailto:karen.ehrhardt.martinez@navigant.com">karen.ehrhardt.martinez@navigant.com</a></td>
<td>Keynote</td>
</tr>
<tr>
<td>Elaine Farrow</td>
<td>University of Edinburgh</td>
<td><a href="mailto:Elaine.Farrow@ed.ac.uk">Elaine.Farrow@ed.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Michael Fell</td>
<td>University College London</td>
<td><a href="mailto:michael.fell@ucl.ac.uk">michael.fell@ucl.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Matthew Fox</td>
<td>University of Plymouth</td>
<td><a href="mailto:matthew.fox4@plymouth.ac.uk">matthew.fox4@plymouth.ac.uk</a></td>
<td>Session 2</td>
</tr>
<tr>
<td>Nicolette Fox</td>
<td>University of Sussex</td>
<td><a href="mailto:N.Fox@sussex.ac.uk">N.Fox@sussex.ac.uk</a></td>
<td>Session 5A</td>
</tr>
<tr>
<td>Kathleen Gaffney</td>
<td>Birmingham City University + Walsall Housing</td>
<td><a href="mailto:kathleen.gaffney@navigant.com">kathleen.gaffney@navigant.com</a></td>
<td></td>
</tr>
<tr>
<td>Jesus Garcia</td>
<td>Group</td>
<td><a href="mailto:Jesus.Garcia@whgrp.co.uk">Jesus.Garcia@whgrp.co.uk</a></td>
<td></td>
</tr>
<tr>
<td>Nigel Goddard</td>
<td>University of Edinburgh</td>
<td><a href="mailto:nigel.goddard@ed.ac.uk">nigel.goddard@ed.ac.uk</a></td>
<td>Session 2</td>
</tr>
<tr>
<td>Rajat Gupta</td>
<td>Oxford Brookes University</td>
<td><a href="mailto:rgupta@brookes.ac.uk">rgupta@brookes.ac.uk</a></td>
<td>Session 3</td>
</tr>
<tr>
<td>Tom Hargreaves</td>
<td>University of East Anglia</td>
<td><a href="mailto:tom.hargreaves@uea.ac.uk">tom.hargreaves@uea.ac.uk</a></td>
<td>Keynote</td>
</tr>
<tr>
<td>Melanie Herrmann</td>
<td>University College London</td>
<td><a href="mailto:melanie.herrmann.14@ucl.ac.uk">melanie.herrmann.14@ucl.ac.uk</a></td>
<td>Session 1</td>
</tr>
<tr>
<td>Tom Kane</td>
<td>Loughborough University</td>
<td><a href="mailto:t.kane@lboro.ac.uk">t.kane@lboro.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Jack Kelly</td>
<td>Imperial College London</td>
<td><a href="mailto:jack.kelly@imperial.ac.uk">jack.kelly@imperial.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Jonathon Kilgour</td>
<td>University of Edinburgh</td>
<td><a href="mailto:Jonathan.Kilgour@ed.ac.uk">Jonathan.Kilgour@ed.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Caroline Leygue</td>
<td>University of Nottingham</td>
<td><a href="mailto:caroline.leygue@nottingham.ac.uk">caroline.leygue@nottingham.ac.uk</a></td>
<td>Session 4A</td>
</tr>
<tr>
<td>Richard Lorch</td>
<td>Building Research &amp; Information (journal)</td>
<td><a href="mailto:richard@rlorch.net">richard@rlorch.net</a></td>
<td></td>
</tr>
<tr>
<td>Mate Lorincz</td>
<td>University of Keele</td>
<td><a href="mailto:m.j.lorincz@keele.ac.uk">m.j.lorincz@keele.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Heather Lovell</td>
<td>University of Tasmania</td>
<td><a href="mailto:heather.lovell@utas.edu.au">heather.lovell@utas.edu.au</a></td>
<td></td>
</tr>
<tr>
<td>Arian Mahzouni</td>
<td>Royal Institute of Technology, Sweden</td>
<td><a href="mailto:arian.mahzouni@abe.kth.se">arian.mahzouni@abe.kth.se</a></td>
<td></td>
</tr>
<tr>
<td>Bernard McKeown</td>
<td></td>
<td><a href="mailto:bernard.mckeown@informato.eu">bernard.mckeown@informato.eu</a></td>
<td></td>
</tr>
<tr>
<td>Helen Melone</td>
<td>Energy Action Scotland</td>
<td><a href="mailto:helen.melone@eas.org.uk">helen.melone@eas.org.uk</a></td>
<td></td>
</tr>
<tr>
<td>Nataliya Mogles</td>
<td>University of Bath</td>
<td><a href="mailto:n.m.mogles@bath.ac.uk">n.m.mogles@bath.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Saeed Mohammadi</td>
<td></td>
<td><a href="mailto:saeed121m@yahoo.com">saeed121m@yahoo.com</a></td>
<td></td>
</tr>
</tbody>
</table>

“Feedback in energy demand reduction: Examining evidence and exploring opportunities” Edinburgh, July 2016 Page 10
<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Email</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johanna Moore</td>
<td>University of Edinburgh</td>
<td><a href="mailto:j.moore@ed.ac.uk">j.moore@ed.ac.uk</a></td>
<td>Session 4A</td>
</tr>
<tr>
<td>Evan Morgan</td>
<td>University of Edinburgh</td>
<td><a href="mailto:e.morgan@ed.ac.uk">e.morgan@ed.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Josephine Munene</td>
<td>Clark University</td>
<td><a href="mailto:jmunene@clark.edu">jmunene@clark.edu</a></td>
<td></td>
</tr>
<tr>
<td>David Murray</td>
<td>University of Strathclyde</td>
<td><a href="mailto:david.murray@strath.ac.uk">david.murray@strath.ac.uk</a></td>
<td>Session 6</td>
</tr>
<tr>
<td>Michael Murray</td>
<td>Mission.Data</td>
<td><a href="mailto:murraym@fastmail.fm">murraym@fastmail.fm</a></td>
<td></td>
</tr>
<tr>
<td>Gene Palencia</td>
<td>Coventry University</td>
<td><a href="mailto:palencig@uni.coventry.ac.uk">palencig@uni.coventry.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Yi Xuan Peng</td>
<td>Discovery (German)</td>
<td><a href="mailto:pyx@discovery.com">pyx@discovery.com</a></td>
<td></td>
</tr>
<tr>
<td>Lara Piccolo</td>
<td>Open University</td>
<td><a href="mailto:larapicc@gmail.com">larapicc@gmail.com</a></td>
<td>Session 5A</td>
</tr>
<tr>
<td>Gareth Powells</td>
<td>Newcastle University</td>
<td><a href="mailto:gareth.powells@ncl.ac.uk">gareth.powells@ncl.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Louise Reed</td>
<td>University of St Andrews</td>
<td><a href="mailto:lar9@st-andrews.ac.uk">lar9@st-andrews.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Kirsten Revell</td>
<td>University of Southampton</td>
<td><a href="mailto:k.m.revell@soton.ac.uk">k.m.revell@soton.ac.uk</a></td>
<td>Session 1</td>
</tr>
<tr>
<td>Rosie Robinson</td>
<td>Anglia Ruskin University</td>
<td><a href="mailto:rosie.robinson@anglia.ac.uk">rosie.robinson@anglia.ac.uk</a></td>
<td>Session 4B</td>
</tr>
<tr>
<td>Riccardo Russo</td>
<td>Essex University</td>
<td><a href="mailto:rrusso@essex.ac.uk">rrusso@essex.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Marianne Ryghaug</td>
<td>Norwegian University of</td>
<td><a href="mailto:marianne.ryghaug@ntnu.no">marianne.ryghaug@ntnu.no</a></td>
<td></td>
</tr>
<tr>
<td>Oscar Sanchez</td>
<td>University College London</td>
<td><a href="mailto:oscar.sanchez.15@ucl.ac.uk">oscar.sanchez.15@ucl.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Paul Shabajee</td>
<td>University of Bristol</td>
<td><a href="mailto:paul.shabajee@bristol.ac.uk">paul.shabajee@bristol.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Harshitha Shetty</td>
<td>Centrica</td>
<td><a href="mailto:harshitha.shetty@bgch.co.uk">harshitha.shetty@bgch.co.uk</a></td>
<td></td>
</tr>
<tr>
<td>David Shipworth</td>
<td>University College London</td>
<td><a href="mailto:d.shipworth@ucl.ac.uk">d.shipworth@ucl.ac.uk</a></td>
<td>Session 7</td>
</tr>
<tr>
<td>Michelle Shipworth</td>
<td>University College London</td>
<td><a href="mailto:m.shipworth@ucl.ac.uk">m.shipworth@ucl.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Karen Smith</td>
<td>Centre for Sustainable Energy</td>
<td><a href="mailto:Karen-Smith@cse.org.uk">Karen-Smith@cse.org.uk</a></td>
<td></td>
</tr>
<tr>
<td>Annika Sohre</td>
<td>University of Basel, Switzerland</td>
<td><a href="mailto:annika.sohre@unibas.ch">annika.sohre@unibas.ch</a></td>
<td></td>
</tr>
<tr>
<td>Alexa Spence</td>
<td>University of Nottingham</td>
<td><a href="mailto:alexa.spence@nottingham.ac.uk">alexa.spence@nottingham.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Sam Staddon</td>
<td>University of Edinburgh</td>
<td><a href="mailto:sam.staddon@ed.ac.uk">sam.staddon@ed.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Lina Stankovic</td>
<td>University of Strathclyde</td>
<td><a href="mailto:lina.stankovic@strath.ac.uk">lina.stankovic@strath.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Vladimir Stankovic</td>
<td>University of Strathclyde</td>
<td><a href="mailto:vladimir.stankovic@strath.ac.uk">vladimir.stankovic@strath.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Nikolaus Starzacher</td>
<td>Discovery (German)</td>
<td><a href="mailto:ns@discovery.com">ns@discovery.com</a></td>
<td></td>
</tr>
<tr>
<td>Bruce Stephen</td>
<td>University of Strathclyde</td>
<td><a href="mailto:bruce.stephen@strath.ac.uk">bruce.stephen@strath.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Andy Stephenson</td>
<td>National Energy Action</td>
<td><a href="mailto:andy.stephenson@nea.org.uk">andy.stephenson@nea.org.uk</a></td>
<td></td>
</tr>
</tbody>
</table>

“Feedback in energy demand reduction: Examining evidence and exploring opportunities” Edinburgh, July 2016 Page 11
<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Email</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dan van der Horst</td>
<td>University of Edinburgh</td>
<td><a href="mailto:dan.vanderhorst@ed.ac.uk">dan.vanderhorst@ed.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Marika Vellei</td>
<td>University of Bath</td>
<td><a href="mailto:m.vellei@bath.ac.uk">m.vellei@bath.ac.uk</a></td>
<td>Session 3</td>
</tr>
<tr>
<td>Nervo Verdezoto</td>
<td>University of Leicester</td>
<td><a href="mailto:nervo.verdezoto@leicester.ac.uk">nervo.verdezoto@leicester.ac.uk</a></td>
<td>Session 5B</td>
</tr>
<tr>
<td>Lynda Webb</td>
<td>University of Edinburgh</td>
<td><a href="mailto:Lynda.Webb@ed.ac.uk">Lynda.Webb@ed.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Christopher Weeks</td>
<td>EDF/University of Bristol</td>
<td><a href="mailto:christopher.weeks@edfenergy.com">christopher.weeks@edfenergy.com</a></td>
<td>Session 6</td>
</tr>
<tr>
<td>Dan White</td>
<td>Behaviouralist</td>
<td><a href="mailto:dan@avalonbehaviour.com">dan@avalonbehaviour.com</a></td>
<td>Session 7</td>
</tr>
<tr>
<td>Colin Whittle</td>
<td>University of Sheffield</td>
<td><a href="mailto:cgwhittle1@sheffield.ac.uk">cgwhittle1@sheffield.ac.uk</a></td>
<td></td>
</tr>
<tr>
<td>Georgina Wood</td>
<td>University of Birmingham</td>
<td><a href="mailto:g.v.wood@bham.ac.uk">g.v.wood@bham.ac.uk</a></td>
<td>Session 5B</td>
</tr>
</tbody>
</table>
TRAVEL, ACCOMMODATION & DIRECTIONS

Venue

The Symposium will take place at the Edinburgh Centre for Carbon Innovation (ECCI), winner of the Guardian Sustainable Business Awards 2016.

ECCI is a 10 minute walk from Edinburgh Waverly train station and the centre of Edinburgh where buses from the airport arrive. For more details see http://edinburghcentre.org/contact-form.html

- ECCI, High School Yards, Infirmary Street, Edinburgh EH1 1LZ
- t: +44 (0)131 6505326 e: info@edinburghcentre.org
Evening meal

All participants at the Symposium are invited to an evening meal on Monday 4th July (Day 1), from 7pm. The meal will take place in the University of Edinburgh’s Pollock Halls campus, at the South Hall complex (see map over page). Pollock Halls are 20 minutes walk from ECCI.

- 18 Holyrood Park Rd, Edinburgh EH16 5AY
- t: +44 (0)131 650 1000
Accommodation

Speakers at the Symposium are being accommodated in the **Pollock Halls of Residence**. The reception is staffed 24 hours a day and can be contacted on +44(0)131 667 1971.

Other participants at the event are invited to stay here too and can book their own rooms online at [http://www.book.accom.ed.ac.uk/](http://www.book.accom.ed.ac.uk/) or by calling +44 (0)131 651 2007. A range of rooms are available at varying cost. Other accommodation is available throughout the city.
SESSION 1 - ‘Delivering Feedback’

p.20 Vanquishing Energy Vampires: The Failure of Feedback Riccardo Russo & Kathryn Buchanan, University of Essex

p.27 Nat Consumers: Natural Language Feedback Caitlin Bent & Greg Shreeve, Energy Saving Trust

p.35 iBert: Intelligent Support System for Energy Behaviour Change Nataliya Mogles, University of Bath

p.42 Mental Model Interface Design: Putting Users in Control Kirsten Revell & Neville Stanton, University of Southampton

p.53 Investigating Smart Metering in the Home: How Users Comprehend Graphic Representations of Residential Electricity Feedback System Melanie Herrmann, University College London

p.60 Designing Successful Feedback Interfaces for Home Energy Systems: the Aging Population Perspective Bruce Stephen & Mike Danson et al., Heriot Watt University

SESSION 2 - ‘Advanced Feedback: Disaggregation & Visuals’

p.65 Does Disaggregated Electricity Feedback Reduce Electricity Consumption? A Critical Review of the Literature Jack Kelly, Imperial College London

p.74 Utilising Disaggregated Energy Data in Feedback Designs – The IDEAL Project Martin Pullinger & Nigel Goddard et al., University of Edinburgh

p.78 Energy feedback enabled by load disaggregation Lina Stankovic et al., University of Strathclyde

p.85 Visualising Scale-Invariant Comparative Energy Use Gerard Briscoe, Glasgow School of Art

p.86 Lessons on Visual Feedback from the Eviz Project: The Evidence for Using Thermal Images as a Visual Intervention Matthew Fox, University of Plymouth

SESSION 3 – ‘Learning Lessons & Limits’

p.96 Exploring Energy Feedback at Community and Household Level through Thermography, Carbon Mapping, Online Platform and Home Energy Visits Rajat Gupta & Laura Barnfield, Oxford Brookes University

p.106 The Effect of Real-Time Context-Aware Feedback on Occupants’ Heating Behaviour and Thermal Adaptation Marika Vellei et al., University of Bath

p.115 Quantifying Likely Energy Reduction Opportunities in Family Homes Paula Cosar-Jorda, University of Loughborough

"Feedback in energy demand reduction: Examining evidence and exploring opportunities” Edinburgh, July 2016
p.123  Between Empowerment and Alienation: How Feedback Technologies Can Harm the Prospects of Successful Energy Transitions Marianne Ryghaug et al., Norwegian University of Science and Technology

p.126  Why Eco-Manager is Not Brilliant? Máté Lőrincz, University of Keele

SESSION 4 A – ‘Beyond Domesticity: Feedback Outside of the Home’
p.127  GENIE (Goal-setting and ENergy Information Engagement) in the Workplace Alexa Spence et al., University of Nottingham

p.134  Energy Feedback in the Workplace: Effects of Display Units Caroline Leygue & Alexa Spence, University of Nottingham


p.149  An Interactive and Diagnostic Energy Use Analysis Interface for Facilities Managers Paul Shabajee et al., University of Bristol

p.155  Household Energy Saving Behaviour and Smart Grid Communication between Utilities and Customers Josephine Munene et al., Clark University, USA

p.167  Challenges of Feedback in Organisations- Can We Foster Partnerships not Projects? Richard Bull, De Montfort University & Kathryn Janda, University of Oxford

SESSION 4 B – ‘Linking to Theories & Disciplines’
p.174  The role of non-numeric feedback in reducing domestic energy consumption: Lessons from Freiburg and Besançon Arian Mahzouni, Royal Institute of Technology, Sweden


p.186  Energy feedback: Place, Policy and Mobility Heather Lovell, University of Tasmania, Australia & Gareth Powells, Newcastle University

p.197  Advances in Understanding Energy Consumption Behaviour and the Governance of its Change – Outline of an Integrated Framework Annika Sohre, University of Basel, Switzerland


SESSION 5A – ‘Communities & Collectives’
p.214  Householder Engagement with Energy Consumption Feedback: The Role of Community Action and Communications Kevin Burchell et al., University of Westminster [presenting remotely]

p.215  Raising Awareness of Energy Collectively Lara Picollo, Open University
p.221  Social Media and Smart Phones  Andy Stephenson et al., National Energy Action

p.229  7 Families - 7 Solar PV panels, 7 Pre-Payment meters - 1 Estate  Nicolette Fox, University of Sussex [not presenting in person]

SESSION 5B – ‘Gamification of feedback’

p.235  Reflections on designing an engaging in-home energy dashboard using participatory design and gamification  Georgina Wood, University of Birmingham

p.243  Exploring the Challenges and Opportunities of Eco--Feedback Technology for Shifting Electricity Use at Home  Nervo Verdezoto, University of Leicester

p.248  Feedback in electricity demand reduction: Examining evidence and exploring opportunities through community-level game mechanics  Roberta Castri, University of Applied Sciences and Arts of Southern Switzerland

SESSION 6 – ‘Insights from Industry & Policy’

p.257  Energy Efficiency Advice: A Toolkit for Engaging Consumers at Smart Meter Installation Visits  Andrew Charlesworth, DECC

p.260  Improving participation in the energy market  Alexander Belsham Harris, Citizens Advice

p.262  The surge of energy data: What does it mean for EDF Energy employees and householders?  Christopher Weeks, EDF/University of Bristol

p.267  Existing commercial business activities: why and how feedback on energy consumption is being delivered to customers  Scott Bryant, Delta EE

p.271  Energy-feedback services provided by utilities: Lessons learnt from the Empowering project  Stoyan Danov, CIMNE

p.278  Waiting for Data: Market Adaptations to Poor Smart Meter Policies in America  Michael Murray, Mission.Data
SESSION 1: Delivering feedback

**Vanquishing Energy Vampires: The Failure of Feedback**

**Kathryn Buchanan** & Riccardo Russo,
Department of Psychology
University of Essex
Wivenhoe Park
Colchester CO4 3SQ
United Kingdom
kbucha@essex.ac.uk; rrusso@essex.ac.uk

**Abstract**

Feedback strategies are frequently employed as a behavioural change strategy. The idea is that presenting people with information about their past behaviour can change their future intentions. Hence feedback strategies appear to rest on the assumption that “if only we knew better we would act differently”. In this paper we assess the validity of this assumption by examining whether feedback can influence pro-environmental intentions and the processes that it involves. Specifically, across 6 different studies we provided over 1000 participants with feedback about the yearly costs of their homes “energy vampires” (appliances such as televisions and laptops that consume energy even when they are not being actively used). We presented feedback in several different ways (e.g., financial losses vs. financial savings, collective costs vs. personal household costs). Yet, regardless of the form in which we presented feedback it did not have a significant effect on behavioural intentions. However, feedback did significantly increase knowledge and awareness. Such findings suggest that while feedback may lead to increases in awareness and knowledge, these factors alone are not enough to influence behavioural intentions.

**Introduction**

“Eco-feedback”, the provision of information to end-consumers about their energy usage, is a strategy often invoked to encourage consumers to curb their consumption. To optimize its effectiveness it is important to know not only if eco-feedback can work (the practical applications) but how it works (the theory behind them). Accordingly, in the present study we used an online calculator to show people the costs of their home’s energy vampires (appliances that use energy even when in a standby mode) and examined both (i) the applications of feedback (i.e., the impact it has on behavioural intentions) and (ii) the theory behind it (i.e., whether it increases knowledge and/or awareness and/or motivations).

**Applications: Can feedback reduce energy consumption? Identifying an effective strategy**

Past meta-analyses have reported that energy savings from eco-feedback range from 5 to 20% (e.g., Abrahamse et al., 2005; Darby, 2006; Fischer, 2008). Such variation can (in part) be explained by differences in message framing of this feedback. E.g., energy consumption
can be framed as economic gains (savings) or economic losses (costs). However, given the tendency for researchers to combine multiple feedback strategies within single interventions it has not been possible to identify the most effective way of framing feedback. To address this challenge, we compared the efficacy of different ways of framing feedback. In Study 1 we varied both the personalisation of the feedback (e.g., participants were shown either their own personal costs or the national average cost) and its granularity (e.g., participants were shown either disaggregated costs vs. the total costs vs. no costs), as past research has found that people respond better to feedback when it is tailored to them (Goodhew et al., 2014) and speculated that feedback may be more effective when it provides disaggregated costs (Buchanan et al., 2014). In Study 2 we manipulated whether the information was presented using positive or negative frames (i.e., potential savings vs. losses). On the basis of prospect theory (Tversky & Kahneman, 1991), we expected that feedback would have a more powerful effect on behavioural intentions when the costs involved are framed as losses rather than as gains or potential savings. In Study 3 we supplemented the yearly costs with socially comparative information (i.e., we told participants if their vampire costs were lower/higher/comparable to the national average). Past findings suggest that people may be more inclined to engage with feedback when social norms are also provided (Harries et al., 2013). In Study 4 we provided participants with collective costs (e.g., details of the country’s annual energy vampire costs). We reasoned that the collective monetary (and environmental) savings may be larger than individuals savings and thus may be more likely to motivate intentions to change behaviour. In Studies 5 and 6 we attempted to increase the appeal of the monetary savings using visualization tasks. We reasoned that if people could relate the outcome of the targeted behaviour (unplugging energy vampires) to the purchase of a desired product then this might influence their behavioural intentions.

**Theory: How does feedback work? Three Typical Assertions**

Typically, the explanations provided for why feedback might reduce consumption are based around the following themes; filling an information/knowledge deficit (e.g., Wilhite & Ling, 1995/Darby, 2006), promoting economical motivations (e.g., McKerracher & Torriti, 2012) and, transforming energy to increase visibility (e.g., Hargreaves et al., 2010). Whilst each of these themes have a different emphasis they all based on the inherent characteristics of energy as something that is abstract, intangible, and invisible - both visually and consciously (Fischer, 2008; Hargreaves et al; 2010).

| Table 1 | An overview of the typical assertions made about feedback according to the commonly adopted perspectives |
|---|---|---|
| View of Consumer | The Information/Knowledge Deficit Perspective | The Economical Perspective | The Heightened Visibility Perspective |
| View of Feedback Device | An information resource/learning aid | A means of linking consumption to cost. | A means of highlighting consumption |
| How feedback device will be used | To gain information/ a better understanding of energy consumption | To micro-manage energy resources. | To direct attention towards consumption. |
| How feedback devices works | Empowers consumers with information/knowledge so that they can make ‘better choices’. | Consumers motivated to maximize efficiency in order to minimize costs. | Increases both physical and conscious visibility. |
In Table 1 we provide a summary of three main perspectives. While these explanations have not been tested quantitatively, qualitative data suggests that feedback may highlight the visibility of energy consumption, increase awareness of the costs associated with energy use and subsequently elicit curtailment behaviours, as well as enhancing knowledge about a home’s energy profile (Buchanan et al., 2014; Hargreaves et al., 2010). To test these explanations quantitatively, in the present study we measured knowledge, awareness, and motivations both before participants received feedback, and again after they received feedback.

The Present Research: Testing Applications and Theory

We investigated feedback using an adapted version of an energy vampire calculator, which provided end users with a personalised estimate of the costs of their energy vampires (appliances in the home that consume energy even when they are not in active use). Before interacting with the calculator, participants completed a questionnaire which measured their motives, knowledge about energy vampire costs and existing habits regarding unplugging energy vampires. After receiving feedback, participants completed a post-feedback questionnaire which measured their; behavioural intentions to vanquish energy vampires, motives, knowledge and awareness about energy vampire costs. The type of feedback that participants received, depended on the condition to which they had been randomly assigned.

Method

In total 1106 American respondents (556 female, aged 18-80, Mean = 33.24, Standard Deviation; SD = 11.48 via Amazon’s Mechanical Turk) participated in this study.

Details of feedback presentation

We presented participants with their vampire costs using the estimates provided by NSTAR’s 2013 ‘Vampire Power Calculator’.

In Study 1, participants were shown one of the following: (a) the personalised total cost of their energy vampires (PT); (b) a PT plus the disaggregated costs per each appliance; (c) PT and advice regarding how to eliminate energy vampires; (d) an explanation about what an energy vampire is (but no PT); (e) generic costs of vampires in the US (but no PT).

In Study 2, participants were either shown a smiling emoticon (😊) stating, “Good news! You could save __$ per year by unplugging your appliances when they are not in use!” or a sad emoticon (😢) stating, “Bad news! You are wasting __$ per year by keeping your appliances plugged in when they are not in use!”

In Study 3, participants were shown their PT along with a statement about whether their energy vampire costs were lower than/comparable to/higher than the average American home.

In Study 4, participants were shown either their PT or their PT and a short paragraph emphasizing the collective costs of energy vampires.

In Study 5, participants were shown their PT and asked either to complete a positive visualization task in which they imagined something they would like to buy with the money saved from vanquishing energy vampires or a negative visualization task where they imagine something that they would not like to buy with their savings.

In Study 6, participants were assigned to complete one of four different variations of the positive visualization task. They either had to imagine what they could purchase with their poten
tial savings that they (a) needed for themselves, (b) needed for others, or (c) wanted for themselves or (d) wanted for others.

**Measures**

We administered the measures listed below which we developed ourselves due to the specificity of the constructs. For each measure participants rating the extent to which they endorsed each item using a 7 point scale ranging from 1 (Strongly Disagree) to 7 (Strongly Agree).

**Pre-feedback questionnaire:**

*Knowledge:* We assessed knowledge of energy vampires using three items, “I know how much it costs me when I leave appliances in standby mode.”, “If I wanted to reduce my energy costs I would know which appliances I should avoid leaving in standby mode.”, and “I can see a clear link between my energy use and my energy bills”).

*Awareness:* In Studies 4 – 6 we examined if feedback increased awareness by asked participants to indicate their agreement/disagreement with the following two statements, “I am aware that appliances that have a standby mode cost me money even when they are not in use” and “I am conscious of the fact that appliances that are plugged in but not in use still consume energy”.

*Motives:* Participants used a 7 point scale to indicate to what extent they were (a) environmentally motivated (“I would like to reduce my carbon footprint”) and (b) financially motivated (“I would like to reduce my energy bills”).

**Post-feedback questionnaire:**

*Behavioural intentions to vanquish vampires:* We assessed behavioural intentions using 7 items (e.g., “unplug some 'energy vampire' appliances?” and “regularly check that appliances are unplugged if they are not in use?”). Participants were asked to indicate the likelihood that they would enact each of the 7 items, using a scale ranging from 1 (“Very Unlikely”) to 7 (“Very Likely”).

*Knowledge:* As per the pre-feedback questionnaire.

*Awareness:* As per the pre-feedback questionnaire.

*Motives:* As per the pre-feedback questionnaire.
Results

Table 2.
Studies 1 to 6: Means Scores for (i) Behavioural Intention to Vanquish Energy Vampires and (ii) Changes in Knowledge, Motives, and Awareness Per Condition

<table>
<thead>
<tr>
<th>Study</th>
<th>Condition</th>
<th>N</th>
<th>Beh Intent</th>
<th>Knowledge</th>
<th>Financial Motives</th>
<th>Environmental Motives</th>
<th>Awareness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Time 1</td>
<td>Time 2</td>
<td>Time 1</td>
<td>Time 2</td>
</tr>
<tr>
<td>1</td>
<td>No PT (Control)</td>
<td>63</td>
<td>4.20</td>
<td>4.51</td>
<td>4.48</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Generic total</td>
<td>83</td>
<td>4.35</td>
<td>4.38</td>
<td>4.90**</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PT</td>
<td>62</td>
<td>4.23</td>
<td>4.24</td>
<td>5.31**</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PT + disaggregated</td>
<td>63</td>
<td>4.46</td>
<td>4.41</td>
<td>5.51**</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PT + advice</td>
<td>52</td>
<td>4.27</td>
<td>4.43</td>
<td>5.48**</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>PT + gain frame</td>
<td>47</td>
<td>4.32</td>
<td>4.23</td>
<td>5.21**</td>
<td>6.28</td>
<td>6.26</td>
</tr>
<tr>
<td></td>
<td>PT + loss frame</td>
<td>49</td>
<td>4.67</td>
<td>4.48</td>
<td>5.64**</td>
<td>6.12</td>
<td>6.14</td>
</tr>
<tr>
<td>3</td>
<td>PT + &lt; average</td>
<td>51</td>
<td>4.29</td>
<td>4.39</td>
<td>5.43**</td>
<td>6.00</td>
<td>5.86</td>
</tr>
<tr>
<td></td>
<td>PT + average</td>
<td>42</td>
<td>4.42</td>
<td>4.38</td>
<td>5.35**</td>
<td>6.12</td>
<td>6.14</td>
</tr>
<tr>
<td></td>
<td>PT + &gt; average</td>
<td>68</td>
<td>4.25</td>
<td>4.32</td>
<td>5.59**</td>
<td>6.16</td>
<td>6.04</td>
</tr>
<tr>
<td>4</td>
<td>PT</td>
<td>72</td>
<td>4.60</td>
<td>4.28</td>
<td>5.48**</td>
<td>5.67</td>
<td>6.18</td>
</tr>
<tr>
<td></td>
<td>PT + collective</td>
<td>56</td>
<td>4.66</td>
<td>4.61</td>
<td>5.64**</td>
<td>5.88</td>
<td>6.07</td>
</tr>
<tr>
<td>5</td>
<td>PT + VD</td>
<td>88</td>
<td>4.65</td>
<td>4.49</td>
<td>5.67**</td>
<td>6.22</td>
<td>6.31</td>
</tr>
<tr>
<td></td>
<td>PT + VU</td>
<td>87</td>
<td>4.30</td>
<td>4.29</td>
<td>5.46**</td>
<td>6.12</td>
<td>6.04</td>
</tr>
<tr>
<td>6</td>
<td>PT + VYN</td>
<td>56</td>
<td>4.53</td>
<td>4.51</td>
<td>4.48**</td>
<td>6.32</td>
<td>6.25</td>
</tr>
<tr>
<td></td>
<td>PT + VON</td>
<td>53</td>
<td>4.45</td>
<td>4.38</td>
<td>4.90**</td>
<td>6.30</td>
<td>6.25</td>
</tr>
<tr>
<td></td>
<td>PT + VYW</td>
<td>58</td>
<td>4.49</td>
<td>4.24</td>
<td>5.31**</td>
<td>6.29</td>
<td>6.22</td>
</tr>
<tr>
<td></td>
<td>PT + VOW</td>
<td>56</td>
<td>4.43</td>
<td>4.41</td>
<td>5.51**</td>
<td>6.14</td>
<td>6.07</td>
</tr>
</tbody>
</table>

Note: PT = Personalised total. VD = visualize desired item(s), VU = visualize undesired item(s), VYN = visualize item(s) you need, VON = visualize item(s) others need, VYW = visualize item(s) you want, VOW = visualize item(s) others want. Time 1 = pre feedback, Time 2 = post-feedback. * denotes where changes between time 1 and time 2 = \( p < .05 \), ** = \( p < .01 \). Standard deviations, standard errors, and confidence intervals are not included in this table due to space prohibitions. However, a full table with information for each variable measured is available on request.

Can feedback influence behavioural intentions to vanquish energy vampires?

Table 2 shows the means, standard deviations for each of the variables we measured. The mean behavioural intention scores (ranging from 4.20 to 4.67) were fairly consistent across the 18 conditions. Planned comparisons between the control condition (in Study 1) and each of the experimental conditions (in Studies 1 to 6) yielded only one significant result. Specifically, participants who had visualized spending the monetary savings obtained from vanquishing energy vampires on a desired item had higher behavioural intentions to vanquish energy vampires than participants in the control condition (4.65 vs. 4.20, \( p = .038 \)). However, this difference became non-significant after applying Bonferroni’s corrections to account for the multiple tests we had run.

Identifying an effective feedback strategy

Our results did not lead us to identify one feedback strategy that was more effective than another. This was not only because there were no significant differences between the control condition and any of the experimental conditions (as per above) but also because there were no significant effects of condition on behavioural intentions in any of the ANOVA’s that we
conducted (Study 1: $F(4, 318) = .42$, Non Significant;NS), Study 2: $F(1, 94) = 1.57$, NS, Study 3: $F(2,158 ) = .24$, NS, Study 4: $F(1, 126) = .06$, NS, Study 5: $F(1, 173) = 3.10$ $p = .08$, Study 6: $F(4,318) = .42$, NS).

**Testing the theory: Can feedback affect knowledge, awareness, and motivations?**

**Knowledge:** In each of the studies we found that feedback significantly increased knowledge (Study 1: $F(1, 318) = 144.74$; Study 2: $F(1, 94) = 82.07$; Study 3: $F(1, 158) = 158.89$; Study 4: $F(1, 126) = 111.84$; Study 5: $F(1, 130) = 154.13$; Study 6: $F(1, 219) = 273.59$, all $p$’s < .01). However, there was only a significant interaction between knowledge and condition in Study 1($F(4, 318) = 12.93$, $p < .01$), such that every condition apart from the control, experienced significant gains in knowledge. In Studies 2-6, the interaction between knowledge and condition was not significant (Study 2: $F(1, 94) = .62$; Study 3: $F(2, 158) = 1.19$; Study 4: $F(1, 126) = .73$; Study 5: $F(1, 146) = .01$; Study 6: $F(3, 219) = 2.21$, all NS).

**Awareness:** In each of the studies that we measured awareness we found that it significantly increased post-feedback (Study 4: $F(1, 126) = 37.15$; Study 5: $F(1, 130) = 25.35$; Study 6: $F(1, 219) = 40.16$. All $p$’s < .01). There were no significant interactions between changes in awareness and condition (Study 4: $F(1, 126) = 3.16$; Study 5: $F(1, 130) = 0.45$, Study 6: $F(3, 219) = .24$ all NS).

**Motivations:** Feedback only significantly increased environmental motivations in 4 out of 13 conditions and only financial motivations in 1 out of 13 conditions.

**Discussion**

Across 6 different studies we provided over 1000 participants with feedback about the costs of their energy vampires. Despite, presenting this information in a variety of ways we failed to find support for the notion that feedback can significantly influence behavioural intentions. In fact, given that behavioural intention scores did not significantly vary between conditions, we were unable to state that any one of the feedback strategies was more successful than any other. As for the theoretical assumptions often made about feedback, we found little support for the idea that feedback can significantly alter motivations. Consequently, there was no strong support for the economic perspective that feedback motivated consumers to rationally micromanage their consumption to accrue financial benefits. Yet, this is not to say that feedback did not have any impact, as we found that feedback significantly increased both awareness and knowledge, thus support was provided for the theoretical assertions made by both the knowledge deficit and heightened visibility perspectives. However, despite the fact that feedback significantly increased knowledge and awareness, these benefits alone were not enough to substantially influence behavioural intentions.

**References**


---

This extended abstract is adapted from our ECEEE contribution:

Natconsumers – A mechanism for natural language feedback

Caitlin Bent, Energy Saving Trust, caitlin.bent@est.org.uk

More information on the Natconsumers project, including all publications, is available at www.natconsumers.eu

Abstract

Natconsumers is an EU Horizon 2020 funded project which is developing a framework for the provision of tailored energy feedback that could be implemented in any part of Europe. The feedback will utilise ‘natural language’ – tailored advice which is emotionally intelligent, easy to understand, and delivered in a natural style. To do so, the project has explored the factors influencing energy use, in order to understand the opportunities and constraints people face in relation to reducing energy consumption. From this, the Energy Saving Trust has created a framework of influencing factors:

- wider context factors, which form the backdrop against which energy use occurs;
- individual context factors, which constrain an individual’s ability to change their behaviours; and
- knowledge and psychological factors, which influence people’s willingness to change behaviours.

Using this framework, we are creating segmentation models to allow for effective tailoring of energy advice. To determine what advice is relevant to a household, the wider and individual context of that household must be understood. This will be achieved using load profile and demographic segmentations. To determine how that advice can be delivered in an interesting, engaging and ‘natural language’ way, a third segmentation will be used in which people are clustered based upon their knowledge, values and motivations.

Introduction

The expanding roll-out of smart metering across the EU provides the opportunity for tailored, detailed, household-specific feedback on energy use to be provided to consumers. This, it is hoped, will give consumers greater awareness and control over their energy use, and will stimulate reductions in energy consumption. Giving households access to their energy consumption data alone is unlikely to stimulate considerable change however. Rather, this information will only be effective if it is utilised to produce relevant, interesting advice that prompts the households to adopt more sustainable energy consumption patterns.

The purpose of the Natconsumers project is to investigate this advice provision, and design a mechanism for generating tailored, relevant advice to householders regarding their energy use. Natconsumers is a Horizon 2020 funded project, which aims to create a system of ‘Natural Language’ energy advice messaging, using emotive content which plays off householder’s unique characteristics in order to stimulate action. Such communication will be designed to be friendly, emotionally intelligent, relevant and clear.
Central to this approach is the tailoring of advice. Advice will be tailored based upon household’s measured electricity usage, their property’s characteristics, the socio-demographics of the residents, and the householder’s knowledge, values and motivations. To achieve this tailoring, Natconsumers will combine electricity data from smart meters with survey data on people’s home and their personal characteristics.

To allow advice to be tailored, we must understand what factors are driving energy consumption: what determines people’s current energy consumption patterns, and what determines their likelihood or ability to change. The first stage of this project therefore investigates the factors which influence energy use. The second stage translates these factors into natural language messaging, using this knowledge to understand both what advice to give people, and how to frame this.

**Stage 1: Identifying factors influencing energy use**

Energy consumption is influenced by a multitude of different factors. These factors are not independent of each other, or of the behaviours they produce. Rather, there are complex interactions between different factors, and cyclical relationships between these factors and behaviours. Social norms, for example, are one factor which may influence behaviour, yet social norms themselves are produced and reinforced by the behaviour in question (Shove, 2009).

Separating out these factors for investigation is therefore difficult. For the purposes of this project, we have created a framework (developed from Wallenborn’s (2007) groupings) based upon three broad categories: wider context factors, individual context factors, and knowledge/psychological factors. These factors are, of course, not independent of each other, and there is interplay and cross-overs between the categories. However, this provides a basic framework through which the different factors influencing energy usage can be investigated.
Wider context

‘Wider context’ encapsulates the broad, landscape-level context within which behaviours take place. Structural and institutional factors at this level act as external constraints on behaviour, and therefore provide the backdrop against which all energy usage decisions are made.

Table 1 below provides a brief outline of some of the wider context factors of relevance to Natconsumers. These factors can vary considerably between countries. Different nations within Europe have different energy systems, building stocks, environmental programmes etc. This means that in different countries people’s behaviours are constrained in different ways, and different behaviours will have varying importance between states. The Natconsumers project aims to create a methodology for energy feedback provision applicable across the EU; understanding and accounting for such variations is therefore essential.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical (climate)</td>
<td>Climate is of particular importance due to its impact upon heating and cooling requirements, but can also impact other areas such as lighting.</td>
</tr>
<tr>
<td>Political</td>
<td>The political landscape influences energy infrastructure and market opportunities for energy efficiency, and therefore indirectly affects individual’s choices. This may occur through a variety of mechanisms, such as direct regulatory instruments, educational mechanisms, or support for new technologies.</td>
</tr>
<tr>
<td>Financial</td>
<td>The financial landscape influences energy use through its impact on income and energy affordability. However, the relationship between energy use and price is not simplistic. Energy demand is relatively inelastic, so is not directly correlated with cost.</td>
</tr>
<tr>
<td>Technological</td>
<td>Technological developments can influence energy use both positively and...</td>
</tr>
</tbody>
</table>
negatively. In some cases they are associated with increased efficiency, in others new technologies may increase energy consumption, or shift consumption from one fuel to another.

### Socio-cultural

Cultural norms can have a significant influence on the way people use energy, through a conscious or subconscious desire to conform to what is deemed as ‘normal’ within a particular society.

### Individual context

‘Individual context’ is the household level context, which explains people’s personal capabilities to act. This incorporates physical factors (such as the size and age of building people live in) and socio-demographic characteristics, both of which act to constrain the choices available to householders.

Building characteristics provide physical constraints upon energy usage. Building size, age, type (detached, terraced etc.) and thermal efficiency can all have a significant impact upon electricity use and the options available for reducing consumption, particularly in households with electric heating or cooling. Technology ownership can also have significant impact on energy use, depending upon the number, type and efficiency of appliances a household owns.

The impact of socio-demographics on energy usage is less straightforward, and different studies often find conflicting conclusions. Three socio-demographic factors however are frequently identified as having an impact on energy use: income, household size and age (see Table 2).

<table>
<thead>
<tr>
<th>Factor</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income</td>
<td>In general, higher incomes lead to higher energy use, up to a saturation point at which additional income does not lead to additional consumption (Hayn et al. 2014; Frederiks et al. 2015). However, this relationship is not always straightforward, for example some middle- to high-income city dwellers often have low energy consumption due to living in efficient, purpose-built flats. Income also influences the energy-saving actions people are willing to take. For example, studies indicate that low income groups are more likely to take on energy saving behaviours, whilst high income groups are unwilling to compromise their comfort and convenience to save energy. By contrast, high income groups are more likely to purchase energy efficient products than those on lower incomes (Frederiks et al. 2015).</td>
</tr>
<tr>
<td>Household size</td>
<td>There is a positive correlation between electricity consumption and household size; the more people there are in a house, the more demand there is for energy services. However, whilst overall energy use increases with household size, per capita usage decreases due to the sharing of energy services such as lighting.</td>
</tr>
<tr>
<td>Age</td>
<td>The impact of age on energy usage is perhaps more related to life stage and length of time spent in the home. For example, retired, older people tend to have higher energy usage due to more time spent in the home. Similarly, households with pre-school children are more likely to be at home during the day, and therefore to consume more energy for heating, lighting and appliance use (Faiella 2011).</td>
</tr>
</tbody>
</table>
Knowledge/psychological factors

The role of psychological factors in influencing energy usage is highly contested. A number of studies find them to be of limited importance, identifying an ‘attitude-behaviour gap’ or ‘value-action gap’. However, it can also be argued that these ‘gaps’ occur where individual and wider contextual factors limit people from following through with actions consistent with their attitudes or intentions; i.e. there are intervening variables between attitudes and behaviours (Steg et al. 2015; Mirosa et al. 2011).

Psychological factors should not be dismissed therefore; they can play an important role mediating between context and behaviour. Context can act to constrain and shape opportunities for changing energy use, but people’s willingness, motivation and intention will be important in determining whether this change occurs. Energy saving advice must therefore be tailored to be in-line with these motivations.

Motivation is dependent upon people’s knowledge and understanding of the action or behaviour, the way in which they cognitively evaluate the behaviour, and whether they behaviour is regarded as in-line with their underlying values and beliefs. To a large extent, knowledge is a pre-requisite for action; for people to intentionally change behaviour, they must be aware of the actions which can be taken and the beneficial consequences of this (Dahlbom et al. 2009). Whilst knowledge is a pre-requisite however, it is not, on its own, sufficient for action. Indeed, many studies have found limited relationship between knowledge and behaviours. In particular, the impact of knowledge on habitual behaviours, which do not require cognitive assessment, is likely to be very limited.

Attitudes are often, intuitively, assumed to have an important influence on behaviours. An attitude is, in its simplest form, the way we perceive and comprehend an object, idea or behaviour, and our emotional evaluation of it (Bergman 1998). However, a number of studies have found that in reality there is little correlation between people’s attitudes and actions (e.g. Ramos et al. 2015). For habitual behaviours in particular, which occur automatically without cognitive evaluation, attitudes have little importance.

Perhaps more important than attitudes are values. Values are relatively stable beliefs which form the guiding principles for people, groups, or social entities (Parkhill et al. 2013). They transcend specific actions or situations; rather, they are general modes of conduct that guide our perception and evaluation (Bergman 1998). They are a deeper, more stable concept than attitudes; whilst attitudes and preferences may change with different contexts, values are entrenched and difficult to change (Bergman, 1998; Parkhill et al. 2013; Mirosa et al. 2011). Both Abrahamse and Steg (2011) and Corraliza and Martin (2000) found that values were a much better predictor of current behavioural practices than attitudes.

Understanding the underlying value systems which steer behaviours is important to the effective framing of Natconsumer’s messaging. People will not act in opposition to their underlying values. Messaging should not try to change people’s values, but should be framed in a way which aligns the advised behaviour change with these pre-existing values (Mirosa et al. 2011). Measuring such values and motivations however is difficult. In this project, we have utilized Schwartz’s (2003) Portrait Values Questionnaire, a set of questions used within the European Social Survey. Whilst this does not provide the depth of understanding which could be gained from qualitative studies, it does allow collection of a large amount of data from
across Europe, which is necessary to produce a framework for advice provision relevant across different EU countries.

Stage 2: Developing and tailoring the advice

Within the Natconsumers project, this understanding of factors influencing energy use will be utilized to create tailored energy saving advice. In order to create relevant, interesting, tailored messages, two key elements must be addressed:

**What the message is:** based on our understanding of the consumer, what type of behavioural change is it appropriate to advise?

**How the message is communicated:** how should the message be framed in order to make it resonate with the consumer?

What the message is will depend upon both the wider context and individual context outlined in Stage 1. These factors determine what energy saving options are available to a household, and therefore what advice is relevant. How the message is communicated will depend on psychological factors – what motivates the household, and how the message can be framed to align with their interests and values.

To answer these questions, Natconsumers is creating three segmentation models: a segmentation of electricity load profiles, a demographic segmentation, and a segmentation model based on psychological factors. These segmentations are currently in development.

**Load profile segmentation**
The load profile segmentation will provide information on the pattern of household electricity consumption over time. From this, we will be able to see common characteristics of consumption patterns between different countries, thereby providing the context for energy-related advice across different areas of Europe.

**Demographic segmentation**
A second segmentation model will be produced based on individual context factors. This involves information on building type and characteristics, technology ownership, and socio-demographic factors. This will further allow us to ensure advice is tailored towards what is relevant for particular households, and will allow for comparison between households of a similar type.

**Psychological segmentation**
The third segmentation model will be used to tackle the second element of advice provision: how the message should be communicated. Based on a survey of 4,000 people conducted across four countries (1,000 people in each of Italy, Hungary, Denmark and the UK), we will segment people based upon their values and motivations. Using these segments, messages will be varied and re-framed for different groups. For example, for a segment with primarily hedonistic values, advice will be focused around personal benefits, in particular increases in comfort or convenience which can be gained through slight changes in behaviour. By contrast, for segments where benevolence or universalist values are strong, messaging may be
more focused on the environmental benefits of reducing energy use, or the cumulative benefits to society.

**Conclusions and next steps**

The Natconsumers project is aiming to develop a methodology for the generation of tailored, natural language messaging on energy consumption, for use across Europe. To do so, we have first investigated the variety of factors which influence energy usage and people’s ability and willingness to reduce consumption. This has identified three broad categories: wider context factors, individual context factors, and knowledge/psychological factors.

Understanding these factors, and how they influence individual householders, is necessary both to define what advice is relevant to a household and how that advice should be communicated. As such, we are creating three segmentation models: load profile segmentation, demographic segmentation, and psychological segmentation. The load profile and demographic segmentations will be utilized to identify advice which will be relevant to a household. The psychological segmentation will determine in what terms that message should be framed to make it resonate with the householder in a ‘natural language’ way.

The next stage of the project, once these three segmentations are developed, will be to investigate how to deliver messages. This requires an understanding of message style – should the messages be funny, serious, confrontational, etc.? How should message styles vary by individual, or change over time? Our early focus group studies into this subject indicate that the sender of the message is important; an appropriate message from a consumer organization is very different to an appropriate message from a utility company. Our focus groups also suggest that message style should vary and develop over time. As trust and knowledge build up, messaging can become more complex and more provocative. As the project develops, Natconsumers will further explore these themes, in order to develop a feedback mechanism which is tailored, relevant and effective.

**References**


iBert: Intelligent Support System for Energy Behaviour Change

Nataliya Mogles1, Ian Walker, JeeHang Lee, Alfonso P. Ramallo-González, Sukumar Natarajan, Julian Padget, Elizabeth Gabe-Thomas, Tom Lovett, Gang Ren, David Coley

University of Bath

Abstract

This work contributes to the debate on the effectiveness of In-Home Displays (IHDs) that convey dynamic information on energy consumption. It compared a conventional IHD and more intelligent energy feedback communicated via a mobile application. We hypothesised that energy feedback framed according to personal values and providing tailored action prompts would have a positive effect on energy-related behaviour. The counterbalanced experimental study, carried out in real homes, tested 4 types of energy feedback displays: a standard commercially available IHD, or the same display with added energy information translated into personal values, tailored action prompts, or both of these together. The results of the study demonstrate that a standard IHD led to significant reductions in internal home temperatures during a heating season but that, surprisingly, adding tailored action prompts reduced this benefit.

Introduction

Human behaviour related to energy consumption is a very complex phenomenon as it is embedded into a broad socio-cultural context and infrastructure and for this reason changing this behaviour is very challenging. One of the foci of research on and aspirations for the reduction of domestic energy consumption lies in inducing occupants behaviour change with the help providing real-time energy feedback with technological solutions: smart meters or ambient displays (Darby, 2001) that are capable of providing continuous daily feedback on household energy consumption. Opinions regarding the effectiveness of such solutions - smart meters and In-Home-Displays (IHDs) - are not unanimous. It can be explained by two main factors: 1) research on the effectiveness of digital energy feedback yields contradictory and divergent results; 2) it is difficult to synthesise and to interpret these results due to the fact that the majority of energy feedback interventions ‘are not systemically designed, documented, implemented, and evaluated’ (Karatasou et al, 2014).

Some research findings suggest that continuous energy feedback might be an effective driver for energy behaviour change (Abrahamse et al, 2005). Energy feedback provided to users with the help of smart meters could save between 5-15% of energy costs (Barbu, 2013). Recent research on energy feedback with the help of advanced IHDs demonstrates that they can help to save up to 20% of energy costs (Darby, 2010), (Pierce et al, 2010). Though these savings seem to be quite moderate, they indicate that computerised energy feedback that offers different feedback options might be an effective means to achieve energy conservation goals (Fischer, 2008).

1 Presenter and corresponding author: n.m.mogles@bath.ac.uk
On the other hand, it is stated that proposed current technological solutions suffer from multiple drawbacks (Buchanan et al, 2014), (Fitzpatrick et al, 2009), (Hargreaves et al, 2010) due to their modest effect and inability to motivate and to engage users. The general problems with the large-scale smart meters and energy monitoring displays deployment are summarised as follows: disinterested users, failure to address users’ personal motivations and needs embedded in daily routines and social practices, information comprehension issues caused by abstract numerical information in kWh and financial costs, inattention to users’ personal characteristics (Buchanan et al, 2014). These statements give a clear indication that users need something more than a plain energy feedback in kWh or costs to engage them.

The findings from the environmental psychology literature postulate that environmental behaviour is highly correlated with four internal values: altruistic, biospheric, egoistic and hedonic (Steg et al, 2012). Internal values are ‘desirable goals, varying in importance, that serve as guiding principles in people’s lives’ (Schwartz, 1992). Values are considered to be relatively stable over time. Values are conceptually different from the goals and attitudes: they reflect which goals people find most important in life in general, while goals reflect what motivates people in a given situation, which not only depends on their values but also on situational cues (Steg et al, 2014).

After having considered all arguments described above, we have taken two perspectives on the improvement of user engagement and motivation while providing an energy feedback via IHDs:

1) Incorporation of internal values;
2) Generation of tailored messages with action prompts based on building characteristics and users behaviour

We incorporated this approach into an intelligent energy feedback system called iBert which was deployed in 43 homes in Exeter during from January 2016 until March 2016.

Method

Using environmental, gas and electricity sensors data, we built an energy behaviour change system called iBert. iBert is an Android application which applies intelligent algorithms to the sensors data and generates a tailored energy feedback to users.

iBert was deployed in 43 homes in Exeter at the end of December 2015 in order to evaluate its effect on energy behaviour change. We tested the effectiveness of four types of feedback in a counterbalanced within-subject study with four experimental conditions (see Table 1): 1) typical numeric feedback in kWhs; 2) numeric information converted into personal values; 3) numeric feedback with tailored messages and action prompts; 4) numeric information converted into personal values and tailored messages translated into personal values plus action prompts.
Table 1. Energy feedback study design.

<table>
<thead>
<tr>
<th></th>
<th>- Value</th>
<th>+ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action Prompts</td>
<td>C1: kWh</td>
<td>C2: kWh converted into values</td>
</tr>
<tr>
<td>Action Prompts</td>
<td>C3: Messages with action prompts</td>
<td>C4: Value messages with action prompts</td>
</tr>
</tbody>
</table>

An example of a value neutral tailored message in condition C3: “I have noticed that the temperature in your home is frequently …°C. This is considered unusually high. This might require … kWh more energy over a whole winter, in comparison to a temperature of 21°C. Advice: Consider lowering the thermostat to 21°C. If you don’t have a central thermostat, adjust your radiators. Alternatively, try changing your heating schedule so your boiler
Figure 1. Screenshots of iBert displays: a) Standard IHD (condition C1); b) Display with additional tailored messages and action prompts (conditions C3 and C4).

An example of a value framed tailored message in condition C4: “I think a lot of heat might be escaping from open windows. The escaping heat results in wasted energy. Repeated regularly over a whole winter, the extra pollution from this wasted energy is equivalent to the destruction of about … trees. This may be because there are too many windows open, they are open too wide or for too long.

Advice: Try changing how many windows you open and for how long to see if this message disappears next week”.

Messages in conditions C3 and C4 addressed four energy related aspects: home internal temperature, heating schedule, electricity consumption and ventilation level. There were 4 different messages per each aspect which resulted in 16 text messages in total: 4 for value neutral condition C3 and 3 for value framed condition C4 (egoistic, altruistic and biospheric values). Tailored messages were generated once a week and a household could receive up to four different messages. Screen shots of iBert displays are represented in Figure 1.

Results

We measured electricity, gas consumption, home internal temperature and CO₂ level before, during and after the experimental phase in order to assess the effect of different types of a feedback on users’ behaviour. Many of the gas data were missing owing to technical issues, so this analysis could not be carried out. The key analysis was of temperature, as heating is the key energy-consuming activity that interests us here and the majority of text messages were targeting heating related behaviour.

We conducted a two-way repeated measures ANOVA with the factors Values (present or absent) and Action Prompts (present or absent).
Figure 2. Home internal temperature distributions and means across the 6 conditions: before the study, during the 4 conditions of the study and after the study.

We found a significant main effect of Action Prompts on home internal temperature, $F(1,22) = 4.47, p = .046$. There was no effect of Values, $F(1,22) = 0.21, p = .65$, and no Action Prompts × Values interaction, $F(1,22) = 0.59, p = .45$. Post hoc pairwise comparisons using Holm-Bonferroni p value correction revealed that a standard IHD (condition C1, $p = .008$) and an IHD enhanced with a weekly energy consumption summary translated according to internal values (condition C2, $p = .003$) were associated with significantly lower temperatures than during the pre-trial phase. Internal temperature distributions with means and standard deviations are depicted in Figure 2. The temperature values are represented on the horizontal axis and the four conditions are represented on the vertical axis. The blue dashed vertical line indicates the baseline condition value which corresponds to temperature observations before the study.

As one can see in Figure 2, a significant action prompts effect indicates that tailored messages might be counterproductive. In Values + Actions and Actions only conditions (C4 and C3 respectively) internal temperature is higher than in Standard state of the art display and Values only conditions (C1 and C2 respectively) and, critically, not significantly different to the baseline temperature ($p = .29$ and .16 respectively).

Our initial hypothesis that the first experimental condition (C1) will demonstrate less effect in comparison to the other conditions was not confirmed, also the hypothesis that the Values+Actions condition (C4) will exhibit highest positive effect was not confirmed either. On the contrary, it appeared that condition C4 did not have any significant effect on home internal temperature.

Discussion and conclusions

In general, we found a positive effect of digital energy feedback on homes internal temperature. Taking into account the fact that during the best iBert condition C2 (standard display with a weekly energy summary translated into values) internal temperature on average decreased by one centigrade compared to the baseline condition, it corresponds to around 8% savings. It was calculated under the assumption that change in internal temperature is proportional to a difference between internal and average external temperature over that period:

$$1/(T_{in} - T_{out})$$

An average internal temperature during the iBert energy feedback phase was 19.98 and the average outside temperature at the same time was 6.93 as observed from an online weather station. This results in: $1/(19.98 - 6.93) \approx 0.08$. One may argue that participants in this study were influenced by the Hawthorne effect. This is a phenomenon where people behave differently when they know they are being observed. Given the fact that multiple sensors sets were installed in these homes two years earlier and they had been monitored for a long period of time prior to the energy feedback intervention study, we believe that the Hawthorne effect was minimal.

Messages with action prompts tailored to participants’ contexts had a statistically significant effect on homes internal temperatures, though the direction of the effect was unexpected and the precise mechanism of how messages influenced participants behaviour is not clear given the
absence of gas consumption data for many homes. It would be most accurate to say, from these data, that the specific action prompts inhibited the temperature-reduction behaviours exhibited by participants given a standard IHD. For future work, gas consumption should be measured as a direct indicator of energy usage behaviour rather than home internal temperature which is an indirect and thus a less reliable measure of energy related behaviour. It was found in this study that tailored messages with action prompts resulted in increased internal temperature during the digital feedback period which can be explained either by limiting the choice of participants’ energy savings actions repertoire while providing only one type of action suggestion, or partially by the effect of action prompts directed at thermal energy conservation measures such as closing windows.

The absence of effect of value framing can be explained by the fact that messages were not tailored to participant’s values and/or were not appropriately framed according to values. Values operationalization is very subjective and messages could address other values than we intended them to do. Another possible explanation might be that people were already motivated to participate in this study, and increasing motivation with values did not add to more motivation.

Our findings suggest that the effect of tailored action prompts and value framing in this form as it was done during this study can be counterproductive as a standard IHD had an even better effect. This brings us to a conclusion that either value framing and action prompts should be done in a much more sophisticated way in order to truly engage and influence users or it is not necessary at all given the amount of efforts required to develop these aspects in a better way. Moreover, energy related behaviour is too complex to address it in a simplistic manner. IHDs have definitely a potential to induce some behaviour change, but in order to achieve a greater effect a more holistic and integrated approach at a socio-political level is needed. Relying only on IHDs is an attempt to solve a social problem with a technological approach (Brynjarsdottir et al, 2012), which is not sufficient.

In future we plan to perform a more detailed analysis of the effect of specific messages and an additional analysis of user experience. We also plan to analyse the effect of a digital feedback on psychological variables: energy literacy and environmental motivations.

Acknowledgements
This work was done under the auspices of the ENLITEN project, EPSRC grant number EP/K002724/1.

References


Mental Model Interface Design – Putting Users in Control

Kirsten M.A. Revell & Neville A Stanton, Human Factors Engineering, Engineering Centre of Excellence, University of Southampton
*Presented by k.m.revell@soton.ac.uk

Abstract
A study was undertaken to test the hypothesis that interface design can influence the achievement of home heating goals, by encouraging appropriate behaviour through the evocation of appropriate user mental models (UMMs). 20 pairs of participants matched by age, gender and home heating experience were tasked with completing set home heating goals using an accelerated home heating simulator. The impact of specific design features presented in a novel interface design were compared to that of a more traditional interface. Evidence that design features contributed to differences in UMMs, intentional behaviour, and goal achievement was observed. A mental model approach to design is proposed as a means of putting users ‘in control’ of their heating system and enabling them to better fulfil their home heating goals.

Introduction
It is easy to save energy in the home - just don’t turn the heating on (Sauer, 2009). The real challenge is using energy effectively and efficiently, not just saving it. Using energy effectively to meet realistic heating goals is no mean feat (Revell & Stanton, 2014). Doing so in a way that minimises waste is rife with difficulties when using devices that were not designed with this emphasis (Sauer, 2009; Revell & Stanton, 2016).

Occupant behaviour is a key variable affecting the amount of energy used in homes (Lutzenhiuser & Bender, 2008; Emery & Kippenham, 2006; Guerra-Santin & Itard, 2010; Dalla Rosa & Christensen, 2011; Raaij & Verhallen, 1983). Kempton (1986) discovered variations in the way occupants behaved with their home heating thermostat could be explained by differences in their ‘mental model’ of its function. There are many definitions of mental models and different perspectives from which to consider them (Revell & Stanton, 2012, Wilson & Rutherford 1989, Richardson & Ball 2009). This paper adopts a combination of the definitions by Norman (1983) and Keiras & Bovair (1984) and refers to a mental model held by a user (UMM) of a specific device, that contains information about the operation and function of that device, and has been accessed and described by an analyst.

Kempton (1986) found that different types of UMMs held by occupants encouraged different behaviour strategies for saving energy overnight and estimated that considerable energy savings could result if specific UMMs of thermostat function were promoted to domestic users. Misunderstandings about how to operating home heating controls remains a present day problem (Brown & Cole, 2009; Revell & Stanton, 2014; 2015; 2016, Shipworth et al., 2010). Kempton’s findings were expanded by Revell & Stanton (2014; 2015) to consider functional UMMs of all home heating controls present in the home, as well as their interactions at a system level. They found incomplete or inappropriate UMMs at a device and system level explained differences in behaviour strategies that either wasted energy or jeopardised comfort goals. This means many users are not, ultimately, in control of their home heating system.
So can technology encourage householders to develop a UMM that helps, rather than hinders, home heating control? Lutzenhiser (1993) argues that human behaviour limits the efficiency of technology introduced to reduce consumption. However, it is often the choice and positioning of technology, as well as usability issues, that impedes discovery and use by householders (Glad, 2012). These issues were also found to contribute to incomplete or incompatible UMMs (Revell & Stanton, 2014; 2015;2016).

Norman (1986) proposed that designers could help users operate technological systems more appropriately by designing interfaces that encourage a ‘compatible’ UMM of the way the system functions. He proposed that a compatible UMM was necessary to enable users to develop appropriate strategies to successfully interact with a system and emphasized the role played by individual goals in observable user behaviour. Figure 1 depicts a simplified relationship between the variables described that have a combined influence on observable user behaviour with home heating systems. It should be noted, however, that the consequence of user behaviour in terms of goal achievement is also subject to variables acting in the broader system (e.g. building structure, infiltration, insulation, thermodynamics of the house, external temperature).

![Figure 1 - Different variables that affect home heating behaviour and its consequences](image-url)

Revell & Stanton (2016) applied Norman’s theory and design principles to the home heating domain to identify the components and structure of a compatible UMM of a home heating system. A home heating simulator was developed to allow manipulation of the home heating interface presented, whilst controlling the broader system variables and user goals. This paper describes the results of a study investigating if the promotion of a compatible UMM through interface design, allows householders to be more ‘in control’ of a heating system, by enabling strategies and behavior that increase goal achievement to be adopted. Whilst a number of different hypotheses were examined during the full study (that will form the content of future papers), this paper will focus on a single theme to illustrate the relationship between design, UMMs, behaviour strategies and goal achievement.
Method

The hypotheses and results described in this paper are tailored to the design features, mental model elements, behaviour strategies and goal attainment that are linked to boiler activation. The design feature emphasised in the experimental condition explicitly promotes understanding of the ‘conditional rule’. This refers to the prerequisite for boiler activation, of the thermostat device to be ‘calling for heat’ at the same time as a programmed ‘on’ period, or boost activation. Whilst statistical tests reported will relate to mental model elements and functions with broader scope than boiler activation, evidence of the ‘conditional rule’ in UMMs will be drilled into to illustrate links between interface design and UMMs. Behaviour strategies pertinent to awareness of the ‘conditional rule’ in the context of this specific simulation environment will be examined to illustrate the link between UMM contents and behaviour. Goal attainment linked to those identified behaviour strategies will be considered to illustrate the cascading effect of design changes, (via UMMs and behaviour) on home heating goals.

Experimental Design

A between-subjects design was adopted. The version of the interface presented to participants (either ‘Realistic’ or ‘Design’) represents the independent variable. The number of: a) appropriate functional UMMs of key controls (Programmer, Boost, Thermostat and Thermostatic Radiator Valve (TRV)); and b) the 18 key UMM system elements (including the ‘conditional rule’) represent the dependent variables to test Hypothesis 1, ‘The Device Design Influences UMMs of those Devices’. Hypothesis 2 states that ‘UMMs of Devices influence the Pattern of Device Use’. The number of set point adjustments that resulted in a change of state of boiler activation, was used as the dependent variable. Finally, Hypothesis 3 states that ‘Strategies of Device Use Influence the Amount of Goal Achievement’. Duration of goal achievement was examined for the dependent variable for hypothesis 3.

Participants

40 participants took part in this experiment, 20 per condition. 10 males and 10 females were in each condition from ages ranging between 23 and 70 years (Mean=38). Pairs in each condition were matched by gender, age category, and the number of years’ experience with central heating (+/-2 years). Experience with gas central heating (with radiators) ranged from 4 to 40 years, with a median of 12 years. Participants were all native English speakers and were recruited from staff, students, and residents local to the University of Southampton. Participants were recruited through posters on University notice boards and websites.

Apparatus & Procedure

Individual participants were presented with a version of the home heating simulation, matched to their experimental condition. The simulation was displayed on a Samsung LE40M67BD 40” TV monitor attached to a DELL Latitude E6400 laptop. This was connected to the internet.
webpage hosting the simulation and controlled with a mouse. The ‘realistic’ version reflected the design of a typical gas central heating system and the ‘design’ interface was constructed to promote a compatible mental model of the home heating system following recommendations from Revell & Stanton (2016) (see figure 2). The ‘conditional rule’ is clearly indicated in the control panel of the ‘design’ interface. The ‘flame’ icon illuminates during boiler activation. Analogous to a circuit diagram, this is only possible when the thermostat control and either the programmer or boost control are also ‘active’. If these conditions are not met, there is a ‘break’ in the circuit and the flame icon remains unilluminated (see figure 2, far right).

Prior to data collection, a consent form, participant information sheet, and participant instructions were provided to each participant. Participants in the ‘Realistic’ condition were asked to imagine they were operating the home heating controls as if they were in their own home. Those assigned to the ‘Design’ condition were asked to imagine they had been provided with a digital interface to control the existing heating controls in their home setting. Participants were then provided with the user manuals for their experimental condition and exposed to a 5 minute practice session with the key elements of the interface indicated by the analyst. The simulation ran for 22 minutes with a home heating goal presented textually at the top of the screen, every 2 minutes. The goals represented typical home heating goals for a family with young children and were matched for each condition. The participant was required to decide what adjustment of heating controls was necessary to achieve the goal, and perform any operation they thought appropriate (even if this resulted in no adjustment). If a subject had not completed their intended adjustments before the next goal was presented, they were to move onto the new goal. At the end of the experiment, participants underwent a semi structured interview based on Revell & Stanton (2014;2016), to capture their mental model descriptions. Subjects were then debriefed and paid £10 for their participation.

**Findings**

This section describes data gathered from users’ mental model description, variables relating to their behaviour with heating controls in the simulation, and goal attainment based on room temperatures. The Mann-Whitney U test for non-parametric data was used to determine the significance of differences in the realistic and design group for hypotheses 1 and 3, and an independent t-test was used for hypothesis 2. Further tests were used as appropriate to drill into the data (e.g. Pearson’s Chi-Square, Fisher’s Exact test).
Hypothesis 1 – The Device Design Influences User Mental Models of that Device.

*Improved Functional Models of Key Devices will be held by participants in the Design Condition.*

Hypothesis 1a) predicted that participants in the Design condition would hold more appropriate functional models of key devices, than those in the Realistic condition. Figure 3 shows a box-plot illustrating the median, interquartile range and minimum and maximum of appropriate functions described by participants to key controls in their UMM diagrams. Results of the Mann Whitney U test, found the number of appropriate functional models of key controls captured in participants’ UMMs was significantly greater in the Design condition than in the Realistic condition ($U=108.00$, $Z=-2.617$, $p < 0.01$) which supports this hypothesis.

Drilling into this data, it was found that, regardless of experimental condition, most participants held an appropriate functional model of key devices linked to boiler activation when considered as separate devices (e.g. the programmer schedule, the boost button and central thermostat control). The differences in functional models at the device (rather than system) level could therefore not be attributed to differences in the design of these devices. It was instead found to be attributable to UMMs of TRV control function, with a statistically significant improvement found in the ‘Design’ condition ($\chi^2=9.60$, $d.f.=1$, $p < 0.01$).

*Improved Number of Key Home Heating System Elements will be described in UMMs of participants in the Design Condition*

Hypothesis 1b predicted that participants from the design condition would describe a greater number of Key Home Heating System elements. Figure 4 shows a boxplot illustrating the median, interquartile range and minimum and maximum of key system elements described by participants in their UMM diagrams. It was found, using the Mann-Whitney test, that the number of key system elements present in UMMs was significantly greater in the Design condition than in the Realistic condition, ($U=124.5$, $z=2.092$, $p<0.05$, $r=-0.33$), supporting hypothesis 1b.
Presence of the conditional rule represented a significant difference between conditions ($\chi^2=5.22667$, d.f.=1, p < 0.05) (along with TRV attributes). This indicates the design condition was effective at increasing the presence of these elements.

**Hypothesis 2 – User Mental Models of Devices Influence the Pattern of Device Use.**

Hypotheses 2 predicted that participants in the Design condition would adopt more appropriate behaviour strategies in line with the content of UMMs. A significant increase in the occurrence of the ‘Conditional Rule’ at the system level was found in the UMMs of participants in the Design condition. Understanding the conditional rule enables deliberate control of boiler activation. In this paper, hypothesis 2 predicts effective boiler control would occur more often in the Design condition. An essential pre-requisite for boiler activation is for the thermostat to hold a higher set point than the hall room temperature, and a lower set point for deactivation. To test the statistical significance of this hypothesis, an independent samples t-test for parametric data was performed to compare the percentage of thermostat set point value changes that crossed the current hall temperature value. The results showed a statistically significant increase in control of boiler activation in the Design Condition ($t=3.296$, d.f.=37, p<0.01), than in the Realistic condition, lending support to Hypothesis 2 (see figure 5).
Figure 5 - Percentage of thermostat set point choices leading to boiler state change

Hypothesis 3 – Strategies of Device Use Influence the Amount of Goal Achievement.

The original intention of the authors was to consider duration of boiler ‘on’ times as the dependent variable for hypothesis 3. Due to the deliberate use of realistic goal types (e.g. mainly comfort goals, with energy saving goals set for when the house was unoccupied), and limitations of the thermodynamic model of the simulation, this variable was unreliable. Goal achievement was instead based on target rooms achieving room temperatures within a target temperature range during a target time period. Where the target related to multiple rooms, the median room was used as the basis for measuring the duration of goal achievement as it reflected central tendency for non-normally distributed data. As target goal durations differed, to prevent this becoming a confounding variable, the proportion of time each goal was achieved was used. These were summed for 18 goals and converted into a percentage of overall goal achievement. Figure 6 shows boxplots illustrating the median, interquartile range and minimum and maximum of goal achievement. A Mann Whitney test was undertaken, showing a statistically significant increase in goal achievement in the design condition (U=125.500, Z=-2.015, p < 0.05), lending support to hypothesis 3.
Discussion

More appropriate mental models
That participants from the Design condition were found to have more appropriate functional models of key heating controls, and key system elements (in support of Hypothesis 2) is particularly encouraging, given the lack of formal ‘training’ provided to promote specific model types. Traditionally studies attempting to manipulate mental models provide extensive training, followed by comprehension & retention tests (e.g. Kieras & Bovair, 1984; Hanish & Moran, 1983). In addition, studies often use novice participants who are not required to overcome an established mental model of the device in question. This study, in comparison, comprised of participants with between five and forty years’ experience of home heating controls, with existing knowledge structures requiring amendment (Johnson-Laird, 1983). Improvements in the presence of the ‘conditional rule’ element following the associated design feature, reflects advice from Keiras & Bovair (1984:p.271) that the most useful information to provide users is “specific items of system topology that relate the controls to the components and possible paths of power flow”. That amendments to existing UMMs of home heating systems can be achieved within a very short period of time (25 minutes of accelerated interaction) without ‘formal instruction’, has favourable implications for using UMM based design for home heating systems, or other systems, where inappropriate UMMs have been shown to result in undesirable behaviour.

Greater control of boiler activation
Hypothesis 2 examined differences in boiler activation predicted from significant differences in the presence of the ‘Conditional Rule’ in UMMs. To intentionally fulfil heating goals and manage energy consumption it is necessary for the participant to have an understanding of the link between the set points of the thermostat, its relationship to sensed temperature in order to ‘call for heat’ and its dependency on the setting of the programmer and boost for boiler activation.
Whilst a static thermostat set point is encouraged in manuals and by expert advice (Revell & Stanton, 2016), this was not observed in either condition in this study, as all participants made adjustments to the thermostat set point throughout the simulation. However, the appropriate set point choice for a household requires an appreciation of the thermodynamics of the house structure. Crossman & Cooke (1974) emphasize that operator control of dynamic systems requires sufficient time for experiment and observation, which was not provided to participants in this experiment. In addition, the (unintended) non-typical thermodynamic model for the simulation resulted in particularly high temperatures in the hall where the central thermostat was located. This meant that far higher set point values would be necessary to activate the boiler, than participants would be used to selecting at home. Expectations for a static thermostat pattern was unreasonable in these circumstances. Results from a t-test supported Hypothesis 2 that participants in the Design condition operated a greater level of intentional control over the boiler. This result supports the findings of Keiras & Bovair (1984) who found that participants with an appropriate UMM of the system engaged in very few ‘nonsense’ actions, favouring behaviours that were consistent with the device model. As the majority of participants in the Realistic condition had an appropriate functional UMM for the thermostat device in isolation, their observed behaviour lends support to Revell & Stanton (2014)’s position that UMMs of home heating must be considered at the system level if effective behaviour is sought.

**Increased goal achievement**

Participants in the Design condition were also significantly more successful at achieving the goals provided, supporting Hypothesis 3. To be as realistic as possible, comfort goals made up a large part of goals and energy conservation was only the focus when the house was to be unoccupied. The proportion of goal achievement was relatively low in both conditions compared to the results of Sauer et al. (2009), who found between 73% and 94%. They tasked participants with choosing set points in advance, to achieve a specific daily profile, allowing greater opportunity for planning and amendment. In contrast this study presented a succession of changing goals that incorporated not only typical planned changes in comfort goals, but a more realistic ‘ad-hoc’ adjustment of goals throughout the day under time pressure. Greater generalisability of the results to everyday behaviour is therefore possible by providing more realistic goals in the simulation. The measure for goal achievement was based on temperature values for rooms rather than energy consumption or deployment of appropriate action sequences with controls. This meant that appropriate choices in behaviour (e.g. programmer settings) was not taken into consideration unless there was an impact on room temperature values within the target time period. Further analysis that matches behaviour strategies to specific goals will be the focus of further work. In addition, an improved thermodynamic model for the home heating simulation, and greater ability to reflect typical behaviour strategies (e.g. opening doors to distribute heat), is required to seek evidence that this approach generalizes to energy saving goals.

**Conclusions**

Differences in the design of an interface have been shown to change the content of mental model descriptions. In this simulation, design features from a novel interface improved the number of key system elements, and the appropriateness of the function of key heating controls, present in UMM descriptions. The increased presence of key system elements, such as the ‘conditional rule’ in participants’ UMMs exposed to the Design condition, explained their more effective ‘control’ of boiler activation, which contributed to their greater goal achievement. From this, it
is concluded that a mental models approach to design can give householders greater control of their heating system to deliberately, rather than incidentally, realise their home heating goals.

References


Investigating smart metering in the home: how users comprehend graphic representations of residential electricity feedback systems

Melanie R. Herrmann\textsuperscript{1*}, Duncan P. Brumby\textsuperscript{1} and Tadj Oreszczyn\textsuperscript{2}

1: Interaction Centre, Department of Computer Science, Faculty of Engineering
University College London, 66-72 Gower Street, London WC1E 6BT
e-mail: melanie.herrmann.14@ucl.ac.uk, web: https://www.ucl.ac.uk/uclic/people/m-herrmann

2: The Bartlett School of Environment, Energy and Resources, Energy Institute, Faculty of the Built Environment, University College London, 14 Upper Woburn Place, London, WC1H 0NN

Abstract
The UK government has committed to rolling out smart meters with in-home displays (IHDs) to all homes and small businesses by 2020. In addition to smart meters and IHDs provided by utility companies, there are various residential energy feedback systems (REFS) on the market that come with mobile apps or websites that give feedback on energy usage information. It is hoped that these technologies will help people better monitor their consumption and so learn how to better manage their usage, save money, and reduce emissions. In my PhD research, I am interested in understanding how people read and interpret the data that is being fed back to them. In particular, I am trying to find out how they relate the feedback to routines in their household, i.e. is if they are able to map the given data to everyday actions. Our methodology comprises both qualitative fieldwork as well as quantitative lab experiments to understand how people understand residential electricity feedback. We present the results of our field study in which nine households were interviewed two weeks after installing a commercial electricity-monitoring device. A critical issue to emerge from these interviews is that people could not make sense of the data visualization. To further investigate this issue, we describe the results of a lab-based experiment that was designed to investigate how people learn from different visualizations.

Introduction
Prior research generally suggests that eco-feedback can help people to reduce their energy consumption [1,2,3,4]. However, governmental reports and meta-reviews find that eco-feedback often doesn’t live up to its intended impact on energy saving [5,6]. Recent studies have also found that the average user’s energy literacy is low [7,8,9,10], i.e. they have a poor ‘understanding of energy concepts necessary to make informed decisions on energy use’ [8].

The Smart Metering Equipment Technical Specifications (SMETS) state that the ‘IHD shall be designed to enable the information displayed on it to be easily accessed and presented in a form that is clear and easy to understand [11]. However, concerns have been raised about how clear and easy to understand energy data is [12]. While most visualisations tend to represent energy data using either a line or bar graph, people may not be trained or might find it difficult to read graphs [13]. Interpreting energy displays takes a lot of cognitive work and few studies have investigated people’s ability to extract information from such representations [14].

A critical issue here is that conventional energy bills often summarize energy usage over an extended period of time (usually one or three months). It has been suggested that this kind of...
aggregated format is not very usable for the consumer. For instance, [15] illustrated that with their analogy of a monthly groceries bill without price information on the individual items. Yet, smart meters still display the household’s total consumption and users ‘have no idea how much energy they consume for a given household task’ [6].

Recent efforts have been directed to disaggregating with the hope to give more detailed information to users. Researchers are working on non-intrusive load monitoring (NILM) and there are tools on the market that use such algorithms to provide usage information on the appliance level. It is assumed that disaggregated feedback will lead to better results in behaviour change and energy saving. However, there is at best only weak empirical evidence from prior research studies to suggest that disaggregated feedback is superior to aggregated energy feedback [16].

Information tracking (e.g. for physical activity or caloric intake) can lead to significant insights and learning [17]. However, there is again limited prior research on how people make sense of such tracking data and how they gain actionable insights that then enable behaviour change. One avenue might be to compare smart meters to other personal informatics tools, such as for physical activity tracking. A pivotal feature of many personal informatics tools is that they show data for specific activities. Similarly, it might be crucial for householders to learn how much energy they use for typical activities at home. [18] describe a theoretic model of personal informatics. The model comprises the stages of preparation, collection of information, integration, reflection, and action. We focus on the intermediary stages of integration (where information is processed and prepared for the next stage) and reflection (where users explore and interact with the information to understand it). The aim is to better understand what it means to be energy literate, and what information householders really require in the stages of integration and reflection, in order to make informed decisions about their energy usage.

Finally, we consider the graphic formats used for energy feedback and information visualization. IHDS and app- or web-based tools typically use bar or line graphs. Graphics enhance cognitive processes. However, unfit representations can impair comprehension and like energy literacy, graphic literacy is a skill that needs development [19,20].

The aim of my PhD research is to examine if smart meters and REFSs increase residential electricity literacy and thus empower householders to make better-informed decisions about how they consume electricity in the home. If usage data is not fed back in an intelligible format, then households will not be able to learn from it and therefore can’t sustainably reduce their consumption. This will be investigated through three interrelated research questions.

First, how much do people know about energy usage at home? We hypothesize that people do not know how much they use for everyday actions in the household.

Second, we examine the effectiveness of aggregated and disaggregated electricity feedback respectively on data comprehension. Activity-related information might be crucial for the understanding which household routines are particularly energy-intensive.

Third, we investigate whether and how certain graphical representations help facilitate data comprehension. A graph that is hard to read won’t allow the user to extract the relevant information. Low temporal resolution for example could make it hard to detect specific events in the data.
First study

Method
In a field study we interviewed 13 participants from nine UK households. The participating households had been provided with a commercial electricity-monitoring device: the Loop energy saving kit, see https://www.your-loop.com. Two weeks after installation we conducted semi-structured interviews and contextual inquiries to explore how users read and understand electricity feedback in a real-world setting. To assess their energy literacy, we asked them which electrical devices in their household they believe consume most electricity and if they could quantify the consumption. In the contextual inquiry, the task was to verbalize what information they see in the recorded usage data (shown in a line graph by Loop, see Figure 1) and to explain which appliances or activities have led to the displayed data patterns. A second follow-up interview with ten of the 13 participants was conducted three months later to find out if participants were still using the Loop electricity-monitoring tool and if they had improved their understanding of their domestic electricity usage. Furthermore, we asked participants to imagine that they could design the ‘perfect’ smart metering feedback to derive user requirements. We asked them to describe what would be important in terms of characteristics and functionality so that the feedback would be easy to understand.

![Figure 1. The historic data feedback of the Loop.](image)

Results
We found that energy literacy differed greatly between participants but was low for most interviewees. The majority of our participants did not have adequate energy literacy, i.e. many of them had no idea how much electricity their individual appliances consume. Only a couple of participants gave accurate estimates. The contextual inquiry revealed that people struggled to make sense of the data and to extract useful information. They were mostly insecure when explaining the highs and lows to us, and several misinterpretations occurred. It was remarkable that they were reasoning ‘top-down’, i.e. they were drawing from memory or even checking their calendars in order to explain their data pattern, instead of being able to extract the information from the graph. By the time of the follow-ups interviews, only three participants were still using the tracking tool and they did not report notable progress in understanding the data and their consumption. The feature that was named most often as a user requirement for an electricity feedback tool was appliance-wise disaggregation.
Second study

Method
Second, we conducted a lab study with a pre-test-post-test between-subjects design (N = 43, 12 males). The independent variable was the graphic representation (see Figure 2). Participants were randomly assigned to one of three conditions. The dependent measure was the increase in energy literacy from pre- to post-test, measured by response accuracy, response confidence, and response time. In this experiment, we define energy literacy as knowledge about the electricity that is being used for carrying out a typical activity in the household (such as washing laundry or watching TV). The first condition shows a line graph in a coordinate system with usage duration on the x-axis and consumption in Watt on the y-axis. It displays the aggregated usage of all appliances that are indicated as being on. The second condition shows the same coordinate system, but every appliance is represented by its own, color-coded graph. The third condition shows a coordinate system where the y-scale shows Watts. The x- is standardized over time and displayed as a smooth stacked line graphs.
Results
Our main finding in the experiment is that participants in condition three performed significantly better in the post-test than participants in groups one and two (p < .01). Group two performed slightly better than group one, but this difference is not statistically significant. These results indicate that the aggregated feedback from condition one does not provide the necessary information to learn how much electricity we use for everyday activities (mind that the graph showed the isolated usage for every individual item at times). From the difference between conditions two and three we conclude that a line graph leaves the challenge to visually integrate the area under the curve, which is a fairly difficult cognitive task. The simplified representation in condition three clearly facilitated the comparison between different actions and yielded the best learning results.

Conclusion
We are currently planning a second field study and a series of experiments. In our upcoming field study we will conduct interviews and contextual inquiries similar to the ones described in our previous field study, this time using a tool that offers disaggregated information on the appliance level. Again, the aim is to see how users read and understand the data and if they can derive actionable insights. To further investigate specific representation aspects and graphic formats we will carry out a series of further lab experiments.

The contribution of this research is to inform the theory of how data tracking and personal informatics may lead to behaviour change. The cognitive processes, that is how users make sense of the collected data and how they learn from it to improve in everyday life, need to be investigated more closely.

In the case of residential energy feedback, we intend to define crucial user requirements. In particular, we want to investigate if disaggregation is indeed the key for users to understand residential energy feedback. Also, we work towards identifying what aspects of ‘energy literacy’ are needed to understand residential usage data and learn from it. For the graphic representation...
of the data we aim at providing design recommendations for electricity feedback. Line, bar, or other graphs might be more or less suited to convey the relevant information.

Finally, we hope to enrich the research in ubiquitous computing and human-computer interaction by grounding our research in theory and by combining both qualitative as well as quantitative methods.

References

change habits and our attitudes towards them.


The Aging Population Perspective on Designing Successful Feedback Interfaces for Home Energy Systems: Beyond In-Home Displays

Bruce Stephen (bruce.stephen@strath.ac.uk), Mike Danson, Stuart Galloway (PI), Greta Barnicoot, Andrea Taylor, Craig Lynn, Craig Whittet, Guy Walker, Catherine Docherty, Edward Owens

Abstract

With many developed countries looking to a future with an aging population, ambitions for future power systems that incorporate participation in flexible demand schemes at the residential level will hinge increasingly on willingness of older age groups to engage. Advancements in metering technology, often hailed as the solution to maintaining demand response participation, require a level of consumer technology in the home that could place additional burden on a generation already alienated by electronics devised for younger consumers. Blanket approaches to energy usage feedback will not be optimally effective given that different people have different objectives to managing energy and different approaches to managing routine. The APAtSCHE project saw local housing association homes equipped with ambient sensing and high resolution metering to understand energy use routines coupled with structured interviews to understand the mental models that underlay these routines and sought to understand the aesthetics, interaction and ergonomics of domestic energy usage and control systems that would optimally engage older age groups. Through co-creative workshops and focus group participation, novel energy feedback interfaces at the extremes of end users’ expectations were prototyped with users to understand their expectations and experiences: an interactive TV based information display and a free-standing, electro-mechanical device.

Introduction

An aging population carries with it many caveats that present additional difficulties for engineering power systems of the future. Flexible demand to support the integration of intermittent renewable generation relies very much on the engagement of the end user. For large industrial customers connected to the medium and higher voltage network this is not new, but at the low voltage level, it requires an aggregation of residential users who are less predictable in terms of their energy usage. Routines and levels of acceptable comfort become progressively less flexible as people age and home automation, often hailed as the solution to maintaining demand response participation (Erol-Kantarci & Mouftah, 2011), requires a level of consumer technology in the home that places an additional burden on a generation already potentially alienated by electronics devised for younger consumers. For example, touch screen interfaces are not necessarily suitable for users with visual impairment and reduced dexterity. Fuel Poverty is defined

---

3 Presentation by Bruce Stephen and Mike Danson
4 Advanced Electrical Systems Group, University of Strathclyde
5 School of Management and Languages, Heriot-Watt University
6 Glasgow School of Art
7 FilamentPD, Glasgow
8 Product Design Studio, Glasgow School of Art
9 School of the Built Environment, Heriot Watt University
10 Journey Associates, Glasgow

"Feedback in energy demand reduction: Examining evidence and exploring opportunities" Edinburgh, July 2016
as the situation where more than 10% of a domestic budget is spent on fuel. Clearly, suggesting a reduction in heating to those whose wellbeing is critically dependent on maintaining a warm and dry dwelling will be neither practically nor socially acceptable. This is as much a social challenge as a design and engineering one: technology is not readily adopted by all regardless of its popularity and interfacing with the end user is particularly difficult. This makes this research on attitudes and behaviour essential for integrating demand and supply solutions into future energy plans.

**Fuel Poverty**

Fuel poverty varies across social/household (age, vulnerable families, single person households, household income) and dwelling (rurality, type of dwelling, age of dwelling, tenure, energy efficiency) characteristics (DECC, 2015). Within Scotland, pensioner households are most at risk with over half (56% in 2011) in fuel poverty, compared with only 20% of pensioner households in England (Hills, 2012). They are also particularly vulnerable to extreme fuel poverty, due to types of residential property, lack of funds to invest in means to reduce their energy use, culture, attitudes and behaviour (SHCS, 2012). Little is known on this and how willing and able the elderly in Scotland would be to change their ways, accepting an automated energy supply, changing when and how they use their energy. The APAtSCHE project (Aging Population Attitudes to Sensor Controlled Home Energy) aimed to address this by examining the cross disciplinary facets of the problem: domestic energy budgets, the needs of distribution network operators (DNOs) in the presence of high penetrations of renewables, contextual sensing and human factors.

**Aesthetic and Ergonomic Considerations**

While the development of demand response technology in the form of home automation is not novel, the needs of vulnerable end-users and direct evaluation of technology in their hands is largely unexplored. APAtSCHE saw local authority housing equipped with ambient sensing and high resolution metering to first build quantitative models of contextualized energy use and then, with the deployment of automation and assistive technology, track the changes in model parameters as a proxy for behavioural change. Product aesthetics and interactions also have a role in the success of uptake, given that a display or interface may disrupt the domestic environment it is placed within or be forgotten completely, where the resident becomes blind to its presence, for example. Ergonomics are open to consideration too as existing interfaces are not necessarily suitable for users with visual impairment, hearing loss and/or reduced dexterity (Barnicoat & Danson, 2015).

**End-user Engagement**

A total of 81 participants aged over 50 years took part in the preliminary review of energy saving technology (48 female, 33 male). A total of 15 social housing tenants aged over 50 years (10 female, 5 male) and five members of social housing staff took part in the subsequent design conceptualisation and development of improved energy saving products (Whittet et al., 2016). Participants were recruited from residential areas of South Western Scotland and via stakeholder organisations such as the housing associations who were part of the APAtSCHE project.
Figure 1 shows two of the feedback concepts that were prototyped for presentation to the social housing tenants and staff.

**Prototype Display 1: TV Interface**

Beginning with a device that almost all consumers are familiar with, Concept Prototype 1 combined an energy monitor, where the householder’s main television is the in-home display unit, with remote controlled appliances such as a lamp or radio. The scenario for demonstration purposes was a menu that popped-up on the TV screen with buttons labelled ‘Hide’, ‘Show’ and ‘Schedule’ selected using the TV remote controller. Workshop participants liked the idea of a home energy system utilising technology and controls that they were already familiar and comfortable with, although there was variation in how often they watched TV. Reaction to the ‘Energy Usage’ screen was also mixed, with some participants finding the information graphics clear and helpful and others finding them complex and confusing, suggesting the need for different levels of information. The most popular feature/functionality was the ‘Tips’ information screen and ability to remotely turn off appliances. Reaction to the ‘Change Supplier’ screen was mixed: all participants saw the benefit, but are distrustful to varying degrees of energy suppliers and advertised tariffs. One participant had a very strong view that his supplier ‘robs people’. It was also observed that more effort is required to access information via the TV i.e. information is not available ‘at a glance’.

**Prototype Display 2: Thermal Printer**

At the other extreme, Concept Prototype 2 provides the householder with a printout of their energy consumption at the press of a button or according to a defined schedule. The scenario for demonstration purposes was a print out of the householder’s weekly energy usage in cost (£), the reduction in cost (£) compared to the previous week, and an energy conservation tip. In contrast to most utilitarian-looking energy monitors, Concept 2 has been designed to offer a
physical interaction with the aim of promoting energy conservation behaviour, through encouraging and evoking a sustainable positive emotional response.

Workshop participants liked the interactions, aesthetics and perceived simplicity of Concept 2, the data that were printed (people were mostly interested in cost) and the tangibility of the print out. The value of paper was observed during the preliminary research and it was apparent that paper was used frequently for notes, prompts and reminders. Therefore, the physical element of this concept and the added value of paper provided the team with a product feature worthy of further exploration. The general view was that a lot of older people do not understand high-tech devices. One participant commented ‘People think we’re just not trying [with technology], but it’s not that’. One participant, whose partner has dementia, speculated that the simpler design might be more appropriate for people with mild cognitive impairment, based on lived experience of her partner not understanding their home energy monitor because it is too complex. It was suggested that the simpler design might be more accessible to children who, as family members, are also responsible for their consumption behaviour, and that the print outs could be filed with other energy and gas utilities documents.

Key Findings

Different users have different needs and these have to be taken into account. For example, there is a need to consider risk issues where a house has to be warm for health reasons. In this case information prompting change, without being in context for the resident, could have a detrimental effect. Familiarity with the TV interface and remote control is a positive element and is imagined by the group that that this would be less daunting than an entirely new device; however, worries existed around the learning and introduction of the service, its maintenance plan and costs, the potential security breaches. The printer was favoured for its novelty of the interaction with paper but participants questioned the longevity of its engagement – “It may end up in the drawer with all the other devices after a few weeks”. Despite this, it was suggested by the group that a persistent reminder of energy use was a positive element as it could be posted on a pinboard or fridge for the benefit of other occupants.

Conclusions

Moving forward, data and analyses will be used to inform the design of smart technologies in the home, suitable and acceptable to older vulnerable people. Ultimately, APAtSCHE sought to identify user centric technical solutions in power systems to address the issue of fuel poverty through a more thorough understanding of this ‘at risk’ growing elderly group, by considering how and where using technology, energy behaviour changes can be made, which lead to improved technical, economic and social outcomes for all.

References


Does Disaggregated Electricity Feedback Reduce Domestic Electricity Consumption? A Critical Review of the Literature

Jack Kelly and William Knottenbelt
Department of Computing, Imperial College London, UK.
Jack presented at the symposium. jack.kelly@imperial.ac.uk

Abstract

We examine twelve studies on the efficacy of disaggregated energy feedback. The average electricity reduction across these studies is 4.5%. However, 4.5% may be a positively-biased estimate of the savings achievable across the entire population because all twelve studies are likely to be prone to ‘opt-in’ bias hence none test the effect of disaggregated feedback on the general population. Disaggregation may not be required to achieve these savings: The four studies which directly compared aggregate feedback against disaggregated feedback found that aggregate feedback is at least as effective as disaggregated feedback, possibly because web applications are viewed less often than in-home-displays (in the short-term, at least) and because some users do not trust fine-grained disaggregation (although this may be an issue with the specific user interface studied). Disaggregated electricity feedback may help a motivated sub-group of the population (‘energy enthusiasts’) to save more energy but fine-grained disaggregation may not be necessary to achieve these energy savings. Disaggregation has many uses beyond those discussed in this paper but, on the specific question of promoting energy reduction in the general population, there is no robust evidence that current forms of disaggregated energy feedback are more effective than aggregate energy feedback. The effectiveness of disaggregated feedback may increase if the general population become more energy-conscious; or if innovative new approaches out-perform existing feedback. This paper is a shortened version of Kelly & Knottenbelt (2016).

Introduction

Electricity disaggregation estimates the energy consumption of individual appliances (or load types or behaviours) using data from a single meter. One use-case is to estimate an itemised electricity bill from a single smart meter measuring the whole building’s electricity demand.

Research into electricity disaggregation algorithms began over thirty years ago (Hart, 1984, 1992). Today, there is a lot of excitement about energy disaggregation. Since 2010 there has been a dramatic increase in the number of papers published on energy disaggregation algorithms and since 2013 there have been over 100 papers published each year (Parson, 2015). Disaggregation is big business: In November 2015 disaggregation provider Bidgely raised $16.6 million USD (Richardson, 2015). There are now at least 30 companies who offer disaggregation products and services (Parson, 2012–2016; Kelly, 2016).

The longer version of this paper (Kelly & Knottenbelt, 2016) discusses four main questions: 1) Can disaggregated energy data help an already-motivated sub-group of the general population...
to save energy? 2) How much energy would the general population save if given disaggregated data? 3) Is fine-grained disaggregation required? 4) For the general population, does disaggregated energy feedback enable greater savings than aggregate data? Due to space limitations, this abbreviated paper only discusses questions 1 and 4.

An introduction to systematic reviews

This paper is, to the best of our knowledge, the first systematic review on the effectiveness of domestic, disaggregated electricity feedback.

Systematic reviews are common in fields such as medicine and the social sciences. Systematic reviews aim to find results which are robust across multiple studies as well as opportunities for future research. The process starts with a search, using predefined criteria, for existing papers. Results and possible biases are extracted from each paper, collated and combined. See Garg, Hackam, & Tonelli (2008) for a discussion of systematic reviews.

There is a distinction between narrative reviews and systematic reviews. Most review articles are narrative reviews. These are written by domain experts and contain a discussion of existing papers. Narrative reviews are often very valuable. But they are rarely explicit about how papers were selected and rarely attempt a quantitative synthesis of the results.

Systematic reviews aim to cover all papers which match defined criteria relevant to a specific research question. Systematic reviews are explicit about how papers were selected and present a quantitative summary of each paper and a quantitative synthesis of the results. Systematic reviews may contain a ‘meta-analysis’ where results from each study are combined into a single statistical analysis which provides greater statistical power than any individual study can deliver.

Systematic reviews are not perfect, of course. Bias can still creep in via the selection process; and different statistical analyses may present different results.

Methodology

Broadly, this paper discusses whether deployment of disaggregation across the entire population is likely to reduce energy consumption. We assume that disaggregated data for a population-wide deployment would be delivered via websites, smart-phone applications or paper bills.

We found twelve groups of studies on the question of whether disaggregated energy data helps users to reduce their energy demand. These studies are summarised in Table 1.

We aimed to do an exhaustive search of the literature although it is not possible to rule out the possibility that we missed studies. We used three search engines: Google Scholar, the ACM Digital Library and IEEE Xplore. The search terms we used were ‘disaggregated [energy|electricity] feedback’ and ‘N[I|A|IA]LM feedback’. These searches produced a huge number of results, many of which were not relevant to our research question. We manually selected papers which test the effectiveness of disaggregated electricity feedback. We accepted experiments conducted either in a laboratory environment or in a field test. We also searched the bibliography sections of papers to find more papers. For example, a review article by Ehrhardt-Martinez, Donnelly, & Laitner (2010) contained references to five relevant studies on disaggregated energy feedback.
<table>
<thead>
<tr>
<th>Study</th>
<th>Feedback presentation</th>
<th>Num. homes in disag. group</th>
<th>Num. homes in study</th>
<th>Num. disaggregation categories</th>
<th>Duration (months of display)</th>
<th>Reduction in electricity use (%)</th>
<th>Feedback delay</th>
<th>Timings: Historic or Concurrent?</th>
<th>Recommendations given?</th>
<th>Controlled for Hawthorne?</th>
<th>Volunteer bias?</th>
<th>Controlled for weather?</th>
</tr>
</thead>
<tbody>
<tr>
<td>“RECS” Dobson and Griffin 1992</td>
<td>dedicated computer</td>
<td>25</td>
<td>100</td>
<td>∼ 8</td>
<td>2</td>
<td>12.9</td>
<td>✓</td>
<td>0.6 sec</td>
<td>0</td>
<td>H&amp;C</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>McCaffrey and Midden 2002 Virtual washing machine</td>
<td>25</td>
<td>100</td>
<td>1</td>
<td>-</td>
<td>0.0</td>
<td>✓</td>
<td>-</td>
<td>0</td>
<td>H&amp;C</td>
<td>✓</td>
<td>✓</td>
<td>L</td>
</tr>
<tr>
<td>Wood and Newborough 1983; Mansouri and Newborough 99 LCD by cooler</td>
<td>10</td>
<td>44</td>
<td>1</td>
<td>≥ 2</td>
<td>12.2</td>
<td>✓</td>
<td>15 sec</td>
<td>0</td>
<td>C</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>“ECOIS-I” Ueno et al. 2006b; Ueno et al. 2006c</td>
<td>Dedicated laptop</td>
<td>8</td>
<td>8*</td>
<td>16</td>
<td>2</td>
<td>9</td>
<td>✓</td>
<td>30 min</td>
<td>next day</td>
<td>H</td>
<td>D. 10D</td>
<td>P</td>
</tr>
<tr>
<td>“ECOIS-II” Ueno et al. 2005; Ueno et al. 2006b; Ueno et al. 2006c</td>
<td>Dedicated laptop</td>
<td>10</td>
<td>19</td>
<td>16</td>
<td>3</td>
<td>18</td>
<td>✓</td>
<td>30 min</td>
<td>next day</td>
<td>H</td>
<td>D. 10D</td>
<td>P</td>
</tr>
<tr>
<td>“EnergyLife” trial 1 Jaccaci et al. 2009; Spagnoli et al. 2011; Gambarenini et al. 2011</td>
<td>iPhone</td>
<td>13</td>
<td>13</td>
<td>7</td>
<td>3</td>
<td>5</td>
<td>✓</td>
<td>?</td>
<td>1-2 min</td>
<td>H&amp;C</td>
<td>D</td>
<td>P</td>
</tr>
<tr>
<td>“EnergyLife” trial 2 Gambarenini et al. 2012</td>
<td>iPhone</td>
<td>4</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>38</td>
<td>✓</td>
<td>?</td>
<td>1-2 min</td>
<td>H&amp;C</td>
<td>D</td>
<td>P</td>
</tr>
<tr>
<td>Home Energy Analytics HEA 2012; HEA 2013; Brown 2014; HEA 2015</td>
<td>Web &amp; email &amp; home visits</td>
<td>1623</td>
<td>1623</td>
<td>5</td>
<td>≤ 44</td>
<td>6.1</td>
<td>✓</td>
<td>hourly</td>
<td>0</td>
<td>H</td>
<td>Y</td>
<td>P</td>
</tr>
<tr>
<td>Bidgely</td>
<td>Web, mobile, email</td>
<td>163</td>
<td>328</td>
<td>≥ 37</td>
<td>-</td>
<td>6</td>
<td>✓</td>
<td>30 sec &amp; 1 hr</td>
<td>0*</td>
<td>H&amp;C</td>
<td>DBY</td>
<td>P</td>
</tr>
<tr>
<td>Chakravorty and Gupta 2013; Gupta and Chakravorty 2014</td>
<td>Web, mobile, email</td>
<td>844</td>
<td>1685</td>
<td>≥ 37</td>
<td>3</td>
<td>21.1</td>
<td>✓</td>
<td>30 sec</td>
<td>0*</td>
<td>H&amp;C</td>
<td>DBY</td>
<td>P</td>
</tr>
<tr>
<td>PG&amp;E Pilot</td>
<td>Web, mobile, email</td>
<td>6</td>
<td>6</td>
<td>10</td>
<td>18</td>
<td>7.8</td>
<td>✓</td>
<td>?</td>
<td>0?</td>
<td>H&amp;C</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Schwartz et al. 2015</td>
<td>Web, mob, TV</td>
<td>12</td>
<td>70</td>
<td>≥ 37</td>
<td>0.75</td>
<td>3</td>
<td>✓</td>
<td>30 sec</td>
<td>0*</td>
<td>H&amp;C</td>
<td>DBY</td>
<td>P</td>
</tr>
</tbody>
</table>

A dash ‘-’ in a cell means ‘not applicable (NA)’ and ‘?’ means ‘not specified in paper’.  
1 Absolute reductions minus reductions for the no-contact control (or the most similar group to a no-contact control available).  
2 Recommendations can be ‘P’ for ‘personalised’ or ‘G’ for ‘general’ or ‘X’ for none given.  
3 Volunteer bias can be ‘H’ for ‘high’ (subjects sought out the intervention) or ‘L’ for ‘low’ (subjects were approached by the experimenters but only a fraction agreed to participate).  
4 H=hourly, D=daily, M=monthly, Y=yearly, B=current billing cycle.  
5 # Paper is silent on this question. Assume the worst.  
6 A dash ‘-’ in a cell means ‘not applicable (NA)’ and ‘?’ means ‘not specified in paper’.  
7 A washing machine control was simulated on a computer. The reported energy reduction is only for the simulated washer. The no-feedback-no-goal condition and the feedback-no-goal conditions achieved the same reduction (11%), hence the difference in energy savings between those two conditions is 0%.  
8 One group received both real-time energy feedback for the cooker and a printed information pack of general recommendations but this group achieved lower energy savings (8.9%) than the group which only received energy feedback.  
9 ECOIS-I started with 9 houses but one house was excluded because it had solar PV installed.  
10 Ueno et al. 2006b report that the “average ambient temperatures before and after installation were 6.4 °C and 6.8 °C, respectively. Generally, the power consumption of the whole household increases with the fall in ambient temperature in winter; hence, it is thought that the true effect was more than this 9% value.”  
11 Aggregate data was displayed real-time. Disaggregated data was not real-time.
Can disaggregated electricity feedback enable to save energy?

The mean reduction in electricity consumption across the twelve studies (weighted by the number of participants in each study) is 4.5%. However, as we will discuss below, this figure is likely to be positively-biased and has a substantial (although unquantifiable) amount of uncertainty associated with it.

Aggregating the results by taking the mean of the energy savings across the twelve studies is a crude approach. It would have been preferable to do a full meta-analysis where biases are identified and compensated for (Garg et al., 2008). But the studies on disaggregated feedback appear to us to be too varied and, perhaps most fundamentally, six of the twelve studies only provided a point estimate of the effect size. At the very least, a meta-analysis requires that each study provides a point estimate and a measure of the spread of the results.

There are several sources of positive bias present in the papers. All twelve studies are prone to ‘opt-in’ bias, where subjects self-selected to some extent and so are likely to be more interested in energy than the general population.

Eight studies did not control for the Hawthorne effect. This strange effect is where participants reduce their energy consumption simply because they know they are in an energy study. For example, Schwartz, Fischhoff, Krishnamurti, & Sowell (2013) conducted a controlled study on 6,350 participants, split equally between control and treatment groups. Subjects in the treatment group received a weekly postcard saying: ‘You have been selected to be part of a one-month study of how much electricity you use in your home… No action is needed on your part. We will send you a weekly reminder postcard about the study...’ Participants who received these postcards reduced their consumption by 2.7%. Hence studies on disaggregated energy feedback which do not control for the Hawthorne effect are likely to over-estimate energy savings attributable to the disaggregated energy feedback.

Six studies used feedback displays which were probably more attention-grabbing than the feedback mediums that would be used in a population-wide roll-out of disaggregated energy feedback. Some studies gave home-visits to some participants to enable additional reductions (e.g. T. Schwartz et al., 2015; Brown, 2014; HEA, 2015). All but two studies were too short to observe whether energy reductions persist long-term. And, finally, eight studies used sub-metered data, hence avoiding any mistrust of disaggregated estimates (Churchwell, Sullivan, Thompson, & Oh, 2014).

Despite these sources of bias, there is evidence that energy disaggregation can enable energy savings for ‘energy enthusiasts’.

**Does aggregate or disaggregated feedback enable greater savings for the whole population?**

Four studies directly compared aggregate feedback against disaggregated feedback. Three of these studies found aggregate feedback to be more effective than disaggregated feedback (Krishnamurti, Davis, Wong-Parodi, Wang, & Canfield, 2013; Churchwell et al., 2014; Sokołoski, 2015). The fourth study found disaggregated feedback and aggregate feedback to be
equally effective (McCalley, & Midden, 2002). Are there any explanations for this counterintuitive result? Two of the four studies (McCalley, & Midden, 2002; Krishnamurti et al., 2013) were synthetic computer simulations and so may not generalise.

The other two studies were well controlled field studies (Churchwell et al., 2014; Sokoloski, 2015). In both field studies, aggregate feedback was displayed on an always-on IHD whilst disaggregated data was displayed on Bidgely’s website (which has since been redesigned (Bidgely, 2015)). Participants in the disaggregation groups did not have an IHD. Sokoloski (2015) found that, on average, participants in the IHD condition viewed the IHD eight times per day whilst participants in the disaggregation condition viewed the website only once per day. Churchwell et al. (2014) found a similar pattern and also reported that some participants did not trust the fine-grained disaggregated data. Perhaps aggregate data is not intrinsically more effective than disaggregated data; instead, perhaps IHDs are more effective than websites or mobile apps.

Perhaps dedicated displays for disaggregated data may help enhance efficacy, although this adds costs. Or, as Sokoloski (2015) suggests, efficacy may be increased by combining disaggregated feedback presented on a website with aggregate feedback presented on an IHD.

Furthermore, a meta-analysis of the efficacy of aggregate energy feedback suggests it alone achieves 3% energy savings (Davis et al., 2013). This analysis adjusted for several (but not all) biases.

**Suggestions for future research**

There are several gaps in the existing literature. Below is a list of potential experiments (more ideas are listed in Kelly (2016)).

No existing field studies compared aggregate feedback against disaggregated feedback on the same type of display. The studies which did compare aggregate feedback against disaggregated feedback used an IHD for aggregate feedback and a website for disaggregated feedback and found that the aggregate feedback was more effective at reducing energy demand. But we cannot rule out that this result is simply because users viewed the IHD more frequently than they viewed the website. Hence it would be valuable to run an experiment where both the ‘aggregate’ and ‘disaggregated’ groups received feedback on the same device (e.g. an IHD with a dot-matrix display to display disaggregated feedback).

A related study would explore the effectiveness of aggregate feedback presented on an IHD combined with access to disaggregated data on a website; compared to just the IHD. The IHD might pique users’ interest and motivate them to explore their disaggregated energy usage on a website or smart phone.

Another study would compare fine-grained disaggregated feedback against coarse-grained disaggregated feedback.

Below is a list of suggestions for how to make future papers on feedback as useful as possible:

If possible, conduct a randomised controlled trial. Publish as much information as possible. How were subjects recruited? Were subjects selected from the general population? Did any subjects withdraw during the study period? Was there a control group? Did the study control for the Hawthorne effect and weather? What sources of bias may influence the result? How exactly
was feedback presented; and how rapidly did the information update? How often did participants view the display? Was disaggregated data available from the very beginning of the experiment or did the disaggregation platform take time to adapt to each home? Publish the results of all the valid statistical analyses performed; not just the ‘best’ result. Crucially, please publish some measure of the spread of the result (e.g. the standard deviation). Ideally, publish online, full, anonymised results so researchers can collate your results into a meta-analysis.

Conclusions

Disaggregation has many use-cases beyond feedback. This paper specifically considers a single use-case of disaggregation: Reducing energy consumption via feedback. Averaged across the population, there is evidence that disaggregated feedback may help to reduce electricity consumption by ~0.7-4.5%. But disaggregation might not be necessary to achieve this saving because aggregate feedback may be equally effective. Amongst ‘energy enthusiasts’, disaggregated feedback might save more energy but fine-grained disaggregation may not be necessary.

We must emphasise that all we can do is report the current state of the research. We cannot rule out the possibility that disaggregated feedback is, in fact, more effective than aggregate feedback. Neither can we rule out that fine-grained feedback is more effective than coarse-grained. All we can say is that current evidence contradicts the first hypothesis and that there is no evidence available to address the second hypothesis.

Importantly, note that the existing evidence-base is heterogeneous and has many gaps. Perhaps a large, well controlled, long-duration, randomised, international study will find that disaggregated feedback is more effective than aggregate.

Perhaps users will become more interested in disaggregated data if energy prices increase or if concern about climate change deepens. Or perhaps users in fuel poverty will be more likely to act on disaggregated feedback in order to save money. Or perhaps users will trust disaggregation estimates more if accuracy improves or if designers find ways to communicate uncertain disaggregation estimates. Or perhaps real-time feedback or better recommendations will improve performance. Or perhaps disaggregating by behaviour rather than by appliance will make disaggregated feedback more effective.

References


Schmidt, L. (2012). Online smart meter analysis achieves sustained energy reductions: Results from five communities. In *Summer study on energy efficiency in buildings*. American Council...


"Feedback in energy demand reduction: Examining evidence and exploring opportunities" Edinburgh, July 2016Page 73
Utilising disaggregated energy data in feedback designs – the IDEAL project

Nigel Goddard, Martin Pullinger, Lynda Webb, Elaine Farrow, Edmund Farrow, Jonathan Kilgour, Evan Morgan and Johanna Moore, University of Edinburgh

Introduction

Conventional energy feedback displays still typically rely on ‘information deficit’ models of energy behaviours, in which users are provided with more detailed or engaging information about their current and historic energy use and associated (financial and carbon) impacts. The underlying assumption is that providing this information will enable users to make more informed, ‘rational’ decisions about energy-using behaviours, with the added assumption that they will then choose to use less energy. This approach to energy feedback is still the standard design as specified, for example, in the minimum feature set for in-home displays in the UK Smart Metering Programme (Pullinger, Lovell, & Webb, 2014). However, there is an increasing interest in processing this energy data in ways that may make it more interesting, engaging and useful for the user. Such designs are being developed and evaluated in academic research and are increasingly appearing in commercial feedback systems.

One new strand of research has taken energy feedback out of the conventional in-home display to incorporate it into a variety of alternative physical artefacts, ranging from artificial trees whose branches light according to energy use (Piccolo, Baranauskas, & Azevedo, 2016) to similarly enhanced clocks and polar bears (Verdezoto, 2016), aiming to render energy use more visible in everyday life as a way to encourage behaviour change (Hargreaves, Nye, & Burgess, 2013).

A second strand focuses on the potential to process energy and other sensor data to produce additional feedback for the end user, whilst still using an in-home display as the main interface. This might involve providing more detailed information displays, such as by disaggregating energy data to present energy use by appliance, or to link energy use to the practices being performed in the home (Goddard, Moore, et al., 2012). In addition, it might involve processing the data further, to provide actionable advice about how best to alter the energy-using practices of households. These approaches aim to automate some of the complex data processing steps that are otherwise left to the end user, i.e. the steps required to transform aggregated data on energy use into a form that makes it clearer to the user what changes in practices they could make to reduce their energy use.

The IDEAL approach to feedback

Our approach to designing the feedback system considers three criteria:

1. Practice theory. We start from the premise that feedback should be considered a form of story-telling or conversation, in which the natural conceptual units for the user are the practices they engage in – doing the laundry; heating/cooling/ventilating for comfort and health; preparing meals for sustenance and sociability; and so on. Feedback systems will be more effective if the communications they engage in are better aligned with the language and conceptualisations of practices natural to the users.
2. Engagement through enablement. A feedback system will be more effective if the information it provides answers directly questions the user has. We select participants who are already motivated to learn about and/or reduce their energy use. An analogy might be an obesity-study which focussed not just on people who are obese, but the subset who are motivated to join a study that aims to help them reduce weight. We are not designing a feedback system to motivate energy demand reduction, but to be of assistance to users who already are so motivated: an enabler.

3. Co-design of the feedback system. The feedback system is a computational artifact for the home, and as such its design should draw upon best practice in software engineering and user experience design. Our approach is informed by the tenets of extreme programming, human-computer interaction, and living labs.

**Practice-based Feedback**

We operationalise practices in the feedback system by organising them into four categories:

- Laundry
- Cooking
- Personal washing
- Thermal comfort

Obviously people engage in many practices (e.g., leisure, entertaining, travel) beyond the ones in these four areas, but these are the ones we identified as (a) being significant in their use of energy and opportunity for participants to modulate that use, and (b) amenable to our intervention given the sources of data and communication channels available to us.

Within each of these areas, there can be multiple sub-practices which may stand alone or be linked. As an example, “doing the laundry” will involve all of “putting an item in the laundry basket”, “washing clothes” and “drying clothes”, and possibly “removing creases”, each of which may be manifest in different non-exclusive ways (e.g., “tumble drying”, “spinning”, “hanging on the drying rack” and “hanging on the washing line”). Our aim is to create and study a feedback system that is aligned, in both form and content of interactions, with practices as we discover them to arise in our study households.

**Engagement through Enablement**

Engagement of participants is a key factor in the effectiveness of advice-giving systems [citation]. We feel that “feedback” is not a good descriptor for the kind of system we are aiming at. The system should engage the participants in an ongoing dialogue that is always under the control of the participants but can be both participant and system driven – more of a consultant or advisor. To structure this dialog, and as a form of engagement, we plan to run “themes” in the four areas listed above (laundry, etc). Theme activities will include:

- announcement and survey of current form of practices
• rating of energy/efficiency tips such as “High-speed spinning makes drying cheaper and faster”

• a practice disruption “game” such as “Can you try wearing some items for once or twice more before washing?”

• in a subset of households, a focus group to explore practices and co-design the user interface (see below).

• personalised information about current practice as observed by the system, with suggestions for making the practice more efficient in energy and cost terms (and often in time as well).

Enabling participants to change practices to make them more efficient can require some detailed knowledge of current practices – for example it is of little use to advise a participant that washing clothes on a low-temperature cycle is faster and cheaper than a high-temperature cycle, if the participant/household is already washing on low-temperature cycles. We identify key aspects of practices that can in principle be inferred from the data available to our system, and use various computational methods to automatically generate advice and responses to participants. One of the great research questions is what are the best inference methods in these kind of tasks, where we have multiple streams of time-series data from diverse sensors, as well as more intermittent but focussed information from participant interaction with the system.

Co-design of interfaces

Several strands of research and practice are converging on the principle that effective computational systems that are embedded in human activities can be best designed, implemented and evaluated with a representative sample of the people who are likely to engage with the system. Extreme programming is a software-engineering process for ensuring that a computational system matches the problem it is trying to solve, through rapid cycles (e.g., monthly) of needs elicitation, design, implementation, rollout and evaluation. Human-computer interaction studies emphasize the need for good understanding through controlled studies of what kind of information presentation and engagement strategies work will in practice (Winterboer, Tietze, Wolters & Moore, 2011). Living labs take these ideas further and engage the users in the actual design processes as well as the evaluation, and can be run in cycles.

We use these approaches in creating our feedback system. One cohort of households (40-50) will be involved in focus groups to explore current practices, and in design sessions to explore possible user interface issues including what questions are of interest (e.g., “I want to understand how much low-temperature washing might save me in a year”), how the answers should be formed (e.g., “icons and graphics” and delivered (e.g. “on the tablet but with a text message alert”), and what sort of dialogue might follow. The designs will be trialled in these households, which have sufficient sensors installed that we will not need sophisticated analytics to infer what is going on. They will then be rolled out (after necessary modifications) to the “treatment” cohort.
Summary

We have designed a process for creating an automated system to engage with users in dialogue about their activities that use energy and how these could be changed to meet users goals. It builds on insights from the literature on practices, engagement and user-interface design. The underlying infrastructure (sensor system, communication channels, database, tablet app) are in place and we have done preliminary work on the analytics and feedback/dialogue components. We are about to start recruiting households to the study, in three cohorts: co-designers, experimental condition, and controls.

References


Energy feedback enabled by load disaggregation

Lina Stankovic, Vladimir Stankovic, David Murray, Jing Liao
Department of Electronic & Electrical Engineering, University of Strathclyde, Glasgow G1 1WX
Presented by Lina Stankovic, lina.stankovic@strath.ac.uk

Abstract
Motivated by recent advances in load disaggregation, we discuss innovative tools for understanding household appliance energy consumption and patterns of appliance use for energy feedback generation, developed as part of the EPSRC REFIT project. We show how analytical tools applied on disaggregated data can lead to a variety of energy feedback ranging from appliance usage patterns analysis, appliance upgrade/retrofit advice, opportunities for load shifting and assessing tariff suitability, and understanding household routines through time use and energy consumption studies of daily activities in the home, such as cooking or laundering. Our analysis is based on the publicly-available REFIT electrical measurements dataset that was populated by a 2-year longitudinal study in UK houses and is supplemented by qualitative data. Namely, we collected electricity data, aggregate data and individual appliance consumption, with an 8-second sampling rate for active power, similar to that provided by a Consumer Access Device that reads measurements from a smart meter directly. This implies that our feedback generation approaches could potentially be used in conjunction with smart meters that will be present in all UK homes by 2020. Furthermore, we summarise the findings collected during exit interviews from the test households about the usefulness of smart metering and energy feedback.

1. Introduction
Smart meter roll-outs have been implemented or planned across the world to better manage residential energy demand, conserve energy, improve billing accuracy, and help users understand the energy implications of their appliance usage habits. Bundled with In-Home Display devices, smart meters will provide real-time aggregate energy consumption information and access to historical aggregate consumption.

In this paper we explore enhanced energy feedback methods, beyond live and historical aggregate consumption, that are only possible from appliance-level consumption data. Non-Intrusive appliance Load Monitoring (NILM) is an attractive load disaggregation option, since it does not require any physical, appliance-level sensors to be installed and can potentially estimate energy consumption of each appliance in a home using only smart meter data. Indeed, up to 20% energy consumption reduction is expected via appliance-feedback and specific appliance upgrade programs (Armel, Gupta, Shrimali, & Albert, 2013).

The extended abstract is organised as follows: firstly, we briefly describe NILM techniques, recently developed specifically by the authors to operate with high accuracy on smart-meter type data; secondly, we demonstrate how to use the disaggregated data obtained from NILM to provide enhanced feedback to customers, such as individual appliance consumption, energy consumption broken down to activity level (e.g., cooking, laundering), appliance mining and upgrade/retrofit advice, and suitability for different variable tariffs; thirdly, we present a summary
of findings from 20 households on their thoughts about the previously discussed feedback methods.

The paper is based on a field study conducted as part of the EPSRC REFIT project, where 20 homes in the Loughborough area were monitored for about 2 years.

2. Load disaggregation: background and summary of approaches

Though founded over 30 years ago (see Hart, 1992), NILM has generated renewed interest recently, due energy conservation programmes and large-scale smart meter deployments worldwide. Recent challenges for NILM are high accuracy disaggregation from smart-meter type low sampling rate electrical measurements, and robustness to noise manifested from the very large number of household appliances in a home, many with similar electrical signatures. Most popular ‘low-rate’ NILM approaches are based on Hidden Markov Models (HMMs) which usually require expert knowledge to initiate appliance state models and a very large ‘noiseless’ training set to build//refine the models.

In order to overcome the disadvantages of HMM-based approaches, we have developed a range of NILM methods that are of low complexity without compromising on accuracy, that work with active power measurements at low sampling rates (in the order of seconds or minutes) - see (Liao, Elafoudi, Stankovic, & Stankovic, 2014), (Elafoudi, Stankovic, & Stankovic, 2014), (Altrabalsi, Stankovic, Liu, & Stankovic, 2016), and (Zhao, Stankovic, & Stankovic, 2016).

Our two supervised NILM approaches are based on adaptive thresholding for event detection with a Decision Tree (Liao et al., 2014) and combined K-means and Support Vector Machine for event classification (Altrabalsi et al., 2016). However, both approaches require a training period, albeit small compared to HMM-based approaches, when each appliance is operating with minimum noise from other appliances. Since, for such training, either plug-level sensors or time-diaries are needed, these approaches might not be suitable for widespread deployment.

In (Liao et al., 2014) and (Elafoudi et al., 2014), we proposed an unsupervised method based on Dynamic Time Warping, which does not require a labelled dataset for training and has competitive performance to supervised approaches. However, the method of (Elafoudi et al., 2014) compares each newly extracted electrical signature with a database of signatures which is populated on-the-fly; this may result in high complexity if there are many appliances contributing to the aggregate load.

Finally, in (Zhao et al., 2016), we developed a ‘training-less’ approach based on Graph Signal Processing (GSP) that does not require any training and can start disaggregating measurements immediately. Due to the inherent properties of the underlying GSP design, this approach can capture signal patterns that occur rarely (as opposed to machine learning based methods), is robust to noisy data and outliers and has low computational complexity.

All above approaches have been tested on a range of datasets and demonstrated competitive accuracy with respect to state-of-the-art approaches.
3. Going beyond load disaggregation: Enhanced feedback on consumption habits

While NILM can identify when an appliance is used and how much electricity it consumes, this is hardly sufficient for motivating energy conservation. We conducted two types of detailed analysis based on disaggregated appliance-level data:

a) Appliance usage monitoring, i.e., analysis of appliance usage patterns, including seasonal effects, suitability for load shifting and suitability of variable tariffs;

b) Domestic activity recognition, i.e., analysing energy consumption through the lens of activities, potentially more meaningful to consumers as it is tied to their lived experience.

3.1 Appliance usage monitoring

By characterising appliance use in a household, it is possible to quantify energy savings through efficient appliance use and predict appliance-specific demand from load measurements. Specifically, we carried out: (i) time-of-use analysis to understand patterns of use of appliances and comparison of appliance usage and consumption patterns among households (Murray, Liao, Stankovic, & Stankovic, 2015b); (ii) analysis to quantify energy savings if appliances were used more efficiently and predict appliance-load demand (Murray, Liao, Stankovic, & Stankovic, 2016); (iii) analysis of suitability of variable tariffs stemming from households-specific consumption (Murray et al., 2015a).

The time-of-kettle-use analysis for 14 REFIT households in (Murray et al., 2015b) confirms that kettle usage patterns are regular at peak times (morning, evening around dinner) and mainly sporadic otherwise during the day. Additionally, we show quantitatively, in-line with previous other studies, that a significant percentage of households overfill their kettle. Additionally, households that appear not to overfill, based on household occupancy, waste energy on reheating or re-boiling soon after a boil. We demonstrate in (Murray et al., 2016) that due to well-defined patterns of use, it is possible to accurately predict kettle usage at a large scale using only disaggregated smart meter readings. An additional application of our proposed tools is the prediction of quantifiable energy savings if water filling patterns change through, for example, more efficient behaviour by filling to ideal levels.

Following the approaches discussed above, we provided one household with energy feedback (see (Murray et al., 2016, Appendix A) for more details and visual feedback examples) about changes in energy consumption incurred by replacing their standard kettle with an ‘eco’ vacuum kettle. A survey was completed prior to feedback to assess the residents’ thoughts. The survey revealed a number of traits about the household: they were committed to being eco-friendly and were positive about buying other products aimed at reducing energy, they believed that they had changed their habits significantly as they actively incorporated the vacuum kettle into their routine. The feedback was well received and a monthly breakdown of appliance usage deemed beneficial towards their energy saving goals. Our findings showed close to 50% energy savings caused by the switch to the vacuum kettle, a reduction in the number of re-heats and a continued economical usage style even when the vacuum kettle was replaced due a fault.

Energy feedback that incorporates time-of-use of appliances, is useful in determining suitability of different variable energy tariffs, such as the Economy 7 tariff, for those open to the flexibility of shifting white goods schedules. For example, while one energy-conscious household on the Economy 7 tariff used their washing machine mostly overnight (off-peak usage), it could have benefitted more by shifting the rest of its usage at off-peak times - see Figure 4 in (Murray et
al., 2015a) for details and an example of visual feedback. While assessing tariff suitability, we
found that only 40% of the households who were on the Economy 7 off-peak tariff were ben-
efiting from this. The other 60% were paying more than if they were on a standard tariff.

3.2 Activity-based feedback
Recent studies of energy-related feedback have found that electricity consumption data, aggre-
gated or disaggregated down to appliance level, is not often meaningful to households as it is
not tied to their lived experience (Hargreaves, Nye, & Burgess, 2013), (Wilson, Hargreaves, &
Hauxwell-Baldwin, 2015a). Activities such as cooking, washing, listening to music or playing
computer games are more consistent with households’ own experiences of life at home. Activi-
ties are a simple descriptive term for these common ways in which households spend their time
(Wilson et al., 2015b). Thus, in (Wilson et al., 2015b) and (Stankovic et al., 2015), through
analysis of qualitative and quantitative disaggregated appliance-level data, we relate electricity
consumption to domestic activities.

We first disaggregate a household’s total electricity load down to appliance level, generating the
start time, duration, and total electricity consumption for each appliance use. We then make in-
ferrances about activities occurring in the home by combining these disaggregated data with an
ontology that formally specifies the relationships between electricity-using appliances and ac-
tivities. Our method was tested on six households, making reliable inferences on four to nine
activities over the course of a month. Results presented in (Stankovic et al., 2015) show that the
time profile of domestic activities has routine characteristics but these tend to vary widely be-
tween households with different socio-demographic characteristics, with unique weekday and
weekend time profiles and also reveals certain households to be large energy users across a
range of activities - see (Stankovic et al., 2015, p. 9-11) for visual feedback examples.

Activity-centric feedback using smart meter disaggregated data has important implications for
providing meaningful energy feedback to households, comparing the energy efficiency of
households' daily activities, and exploring the potential to shift the timing of activities for de-
mand management.

4. Participants’ feedback
After the REFIT study period, when the smart meters and home automation devices were taken
out of the 20 REFIT homes, householders were asked to fill a questionnaire to gauge their expe-
rience and perceptions about the usefulness of smart meters, types of feedback, smart home au-
tomation and what motivated them towards energy conservation. We summarise some of the
responses below. Note that 80-85% of households responded that their energy bill and being
eco-friendly were the primary factors that motivated them towards energy conservation.

In-home display: While 60% of households rarely looked at the real-time in-home display
(IHD), which presented in real time total electricity usage in their home, as well as that of nine
selected appliances, 89% were open to having a smart meter installed in their home. Those who
looked at the IHD daily, responded a heightened awareness of how much electricity their appli-
cances were consuming and changed the way they used their appliances or carried out their daily
activities.
Temporal granularity of feedback: All households said they would like to see how their consumption compared with that of the previous month or year, and 65% stated that their monthly consumption was useful feedback, whereas only 25% stated that daily or weekly consumption feedback would be useful. 50% said it was useful to see how they compared with other similar households, whilst only 10% responded that they would like to breakdown appliance-specific energy use to the highest consuming appliances in their home.

Breaking the bill down to appliance level: 70% of households said that consumption broken down to appliance use would be useful.

Load shifting and variable tariffs: 65% of households said they would consider adjusting the timing of their activities to benefit from a better tariff. The activities or appliances they said they were willing to shift include dishwashing, laundering including washing machine and tumble dryer, hobbies, charging devices, bread-maker, computing, and charging their car.

5. Conclusion

This paper discusses how load disaggregation from smart meter data can be instrumental in designing enhanced energy feedback, beyond that possible from an IHD only. Besides presenting an appliance-itemised electricity bill, load disaggregation together with additional data analytics can support different appliance usage analysis feedback, including wasteful usage habits, suitability of different tariffs, and activity-centric energy usage for common domestic activities such as cooking or laundering. The feedback generated from load disaggregated data and analytical methods can be found in (Murray et al., 2015a), (Murray et al., 2015b), (Murray et al., 2016), (Wilson et al., 2015b), (Stankovic et al., 2015), (Zhao et al., 2016).

The initial feedback from a relatively small study of 20 REFIT households showed the potential of these types of energy feedback. However, the views were mixed and more detailed studies and visualization methods need to be investigated to evaluate the value of the proposed feedback mechanisms.

6. References


Acknowledgement
This work was carried out as part of the REFIT project (“Personalised Retrofit Decision Support Tools for UK Homes using Smart Home Technology”). The REFIT project ran from 2012-2015 as a consortium of three universities - Loughborough, Strathclyde and East Anglia - and ten industry stakeholders. The REFIT project was funded by the Engineering and Physical Sciences Research Council (EPSRC) through linked grants under the Transforming Energy Demand in Buildings through Digital Innovation (BuildTEDDI) funding programme. This study was conducted under Grant Reference EP/K002368/1 (Strathclyde). Other linked grants to consortium members includes EP/K002457/1 (Loughborough) and EP/K002430/1 (East Anglia). Further details on the REFIT project and related publications can be found at:
http://www.refitsmarthomes.org. The REFIT Electrical Load Measurements dataset can be accessed at http://dx.doi.org/10.15129/31da3ece-f902-4e95- a093-e0a9536983e4. The qualitative data, collected by University of East Anglia team, with the same house numbering is available at: https://discover.ukdataservice.ac.uk.
Visualising Scale-Invariant Comparative Energy Use

Gerard Briscoe, Glasgow School of Art

Abstract

While most energy monitoring efforts include some form of visualisation to provide feedback, they are often limited by either overly numeric representations or subjective interpretations of efficiency. Much of the challenge comes from understanding sustainability, or monitoring, only in terms of efficiency. So, we consider a framework for visualising energy monitoring, beyond understanding sustainability and monitoring in terms of efficiency alone. Especially given that increased energy efficiency often promotes increased, rather than reduced, energy use (Jevon’s Paradox). This allows us to propose a design to visualise scale-invariant comparative energy use. Including, how to manage integrating high granularity energy monitoring (e.g. a kettle) and low granularity energy monitoring (e.g. a building). We consider privacy issues of high granularity energy monitoring from the outset, rather than as an addendum. Including, approaches to manage privacy while still sharing some information. For example, sharing average daily energy use, rather per minute energy monitoring. Also, how to include energy provisioning information, so as to identify the proportion of energy being used from renewable sources. Critically, we identify approaches for normalisation that would be paramount for ‘comparing’ energy use. Including ‘filters’ for parameters such as floor space, number of desks, foot fall, building age, etc. Also, a facility for users to normalise over other parameters they deem appropriate, by integrating data sources to which they may have access. This is all visualised through a ‘zoomable user interface’, to enable interaction at all levels of granularity, ranging from comparing individual devices to comparing continents. We then explore the potential for our visualisation to be used in crowd-sourcing recognition of significant comparative observations. Also, the potential to provide a digital space for co-design to address them. We conclude by considering the potential of our approach for community-driven emergent sustainability.
Lessons on visual feedback from the eViz Project: The evidence for using thermal images as a visual intervention.

Matthew Fox, Julie Goodhew, Christine Boomsma, Steve Goodhew, Sabine Pahl. Plymouth University. Presentation by Matthew Fox (matthew.fox4@plymouth.ac.uk)

Abstract

Thermal images can play an important role in feeding back the consequence or outcome from energy use behaviour and through providing a platform to motivate energy efficient home improvements. This article describes four studies conducted through the eViz project, which used a variety of qualitative and quantitative methods, to investigate the impact that thermal images can have on household retrofit behaviour. Results from thermal image investigations were benchmarked against carbon footprint audit and control cases, and ranged from simple generic letters on energy efficiency to more tailored in-depth thermal image reporting. Findings have suggested that thermal images do provide motivation for households to undertake energy efficient improvements on their house. The extent to which thermal images promote a behavioural effect is likely to depend on the personal nature of the images’ subject, and the degree to which the viewer can elaborate on the images. Moving onto the next steps, this article reports on an on-going project to scale up this work to a citywide context in Canada.

1.1 Introduction

Energy-feedback has generally focussed on providing energy users with information about their energy use. This can be in the form of numbers, graphs and via apps or in- homedisplays, for example. Often this usage relates to appliance use and research in this area focuses on evaluating the impact of representing current energy use and analysing how to represent energy usage data (Fischer, 2008; Hargreaves, 2010). This type of feedback tends to dominate the literature and yet there are other ways to feed information about energy use back to householders. Indeed there have been calls to develop and test innovative feedback devices, especially those that have user engagement in mind (Buchanan, Russo & Anderson, 2015). Space heating is an important issue also for energy demand reduction. In the UK, heating a home can make up 66% of overall energy use (DECC, 2013).

The eViz Project (Energy Visualisation for Carbon Reduction) evaluated the use of thermal images in a series of studies as a behavioural intervention aimed at reducing the energy used to heat a building. Feedback is regarded as a consequence strategy, communicating the consequence or outcome that is contingent on a desired energy related behaviour. Using visual images such as thermal images can provide such feedback in that the technology acts as a medium to communicate firstly the areas of heat loss and secondly, by inference, the consequence of energy efficiency actions targeting that specific heat loss. Indeed, they can provide situation and behaviour specific information to a building user, prompt new goals and motives for energy efficiency (Goodhew, Pahl, Auburn & Goodhew, 2015).

We discuss the evidence for the use of thermal images as such an intervention, drawing on an
overview of the results of four studies using mixed qualitative and quantitative methods with householders in the field, ranging from in-depth, tailored approaches to simple letter communications showing thermal images of typical houses.

We present a collection of typical thermal images taken in and around domestic homes and discuss what they can communicate to building users, in terms of building defects. Next we summarise the evidence, which suggests that viewing such images can promote the take up of energy efficiency actions. We discuss the conditions that maximise or minimise such a behavioural effect across the four studies. Finally we report on a current collaboration with Canadian partners aiming to scale up thermal imaging approaches. In conclusion, thermal imaging is a powerful method to communicate heat and energy loss to householders that can lead to better understanding of heat loss and motivate retrofit actions.

1.2 The Affordances of thermal images, feedback on building defects, and heat loss.

Thermal imaging provides visual evidence of building defects (conduction, ventilation, draughts, missing insulation). A thermal camera is used to measure the thermal radiation emitted from a feature, which is then converted into a visual image, where differences in colour patterns signify differences in apparent surface temperature. Using this technology, areas of unexpected heat loss in building features and potential building defects can be inferred. Figures 1, 2, and 3 present example thermal images of typical building defects.

Many have seen the images as a potential behavioural intervention to encourage the uptake of energy efficiency measures amongst householders (Burchell, Rettie & Roberts, 2014, with Smart Communities and many UK Community group projects including The CHEESE Project in Bristol, Transition Bath, South West Oxfordshire). The underlying premise is that seeing (normally invisible) unexpected heat loss from a building will motivate the viewer to take action to stop that loss.

*Fig 1: An example of conduction heat loss and thermal bridging*
The behavioural context is that asking people to take voluntary actions to increase energy efficiency measures in their homes can be problematic due to the nature of heat/energy use. There is potential for individuals to be disconnected from the energy they use to heat their home. They may not be aware of the degree of heat, which is leaving the building (heat egress), through poorly insulated walls, lofts, fireplaces, curtain less windows, or how hard their heating system is working to achieve their desired comfort level. Thermal images can show the normally invisible heat as visible; thereby presenting visual evidence of unexpected areas of heat loss (Fox et al., 2015; Pearson, 2011). If the householder knows the building they might be able to connect their energy efficiency actions/inactions and behaviours to the heat loss. In this sense, thermal images can provide a visual medium (Midden, Kaiser & McCalley, 2007) through which heat loss issues are easily communicated and the consequence of energy efficiency actions can be imagined. It is a feature of visualisations that they can communicate messages quickly, powerfully and support the conceptualisation of complex messages (Sheppard, 2001; 2005; Nicholson-Cole, 2005).
The visual nature of thermal images may be important in motivating the householder. This is because making the invisible visible attracts attention (Gardner & Stern, 2002). Energy use and the potential of energy efficiency tends to be hidden, therefore the ability to attract attention to heat loss is important. A key step in changing behaviour is encouraging the active attention to energy issues (Page & Page, 2011).

Aside from attention and interest, visual images are strongly related to emotions; we respond quickly to visual images, compared to the same information in textual form (Holmes & Matthews, 2010). In particular vivid colours in images (red to blue spectrum) appear to promote an increased emotional response compared to black and white representations (Giacomin & Bertola, 2012). These images can become internalised as mental images, which are more readily remembered (Andrade et al., 2012; Smith & Shaffer, 2000) and in turn connect to motivation and the formation of goals (see Fig 4). To summarise, the psychology literature suggests that visuals can ‘attract attention, evoke emotions, facilitate memory and trigger goals’ (Pahl, Goodhew, Boomsma & Sheppard, 2016).

Fig 4: The suggested psychological process from energy visualisation to behaviour (Pahl et al., 2016).

1.4 The evidence that thermal imaging promotes energy efficiency actions

The eViz team at Plymouth University has investigated the behavioural impact of thermal images when used with householders. Four studies have investigated the connection between seeing thermal images and the uptake of energy efficiency behaviour in domestic homes. The first study provided evidence that seeing thermal images promoted the uptake of energy efficiency actions amongst householders. This small-scale study conducted in a small UK town (with participants’ homes within a 3 mile radius, therefore experiencing the same weather conditions) consisted of three experimental conditions. Householders either saw thermal images of their home and completed a carbon footprint audit of their home (thermal image group, n = 17) or completed the carbon footprint audit without seeing thermal images (audit only group, n = 17), or they were placed in a control group (n = 9). All households had a home visit from the researcher. One year after the intervention, the thermal image group had reduced their carbon emissions as calculated from their household energy bills (comparing the year before and after the intervention, see Fig 5). Additionally, as can be seen in Figure 6, the
behaviours they took were directly related to the type of energy efficiency issues visible in the thermal images (Goodhew, Pahl, Auburn & Goodhew, 2015).

![Graph showing change in mean annual carbon emission from domestic energy use before and after the thermal images were seen.]

*Fig. 5: Change in mean annual carbon emission from domestic energy use before and after the thermal images were seen.*

![Graph showing behaviours directly related to thermal images vs. not directly related.]

*Fig. 6: Behaviours directly related to thermal images vs. not directly related.*

A second study employed a larger sample of 87 householders who all, during a home visit from an energy auditor, completed an energy audit for their home. Of these, 54 houses were imaged, whilst 33 homes made up the control group and did not receive any images. After approximately 6 months, the households who had seen thermal images were almost 5 times
more likely to have installed draught proofing than the households who had not seen thermal images (Goodhew, Pahl, Auburn & Goodhew, 2015). These two studies provide evidence that seeing feedback in the form of thermal images of one’s own home can promote the take up of simple energy efficiency measures.

Fig. 7: Example of thermal image taken during Study 2, showing dark (cold) areas where there is cold air ingress around the surround of the doorway which leads outside (Goodhew, et al., 2015).

The two studies reported above used thermal images personalised to the householder (i.e. of their own home). A third study (Boomsma, Goodhew, Goodhew & Pahl, 2016) sought to explore this aspect and focussed on the importance of personalising the thermal images. The question was whether a less personalised thermal imaging approach could also trigger goals to conserve energy in the home. A homeowner may not easily connect their own behaviour with information in a generic thermal image (an image of another person’s home), and generic images are likely to be perceived less relevant to the householder. This study consisted of three conditions. One group of householders received an e-mail report containing the images taken during a visit from a thermographer. A second group received the same type of report but containing thermal images of ‘typical homes in your area’ whereas a third condition received a report with text only information (i.e. no images). Householders (N = 233) reported that they recalled thermal images better than text information, but the personalised group reported the images as more intrusive (the images ‘popped into their heads’ more often. Personalised thermal image reports were elaborated by the householders more than the generic images. Householders said they looked at the personalised images more often (Fig. 8) and shared them with others more than did the comparison groups. Furthermore the householders who saw the personalised thermal images reported a stronger belief that they would benefit from energy efficiency measures and were more likely to report that they had changed their plans for their homes.
Finally, Study 4 explored the efficacy of using thermal images in a mass communication (Goodhew et al., in preparation) in a collaboration with Plymouth City Council and the Behavioural Insights Team. It investigated whether inserting thermal images into a letter announcing a scheme to install solid wall insulation, would promote the uptake of the scheme. In this study 5483 eligible homes (those of solid wall construction) were randomly allocated to one of three letter types announcing the insulation scheme. One letter contained thermal images of two ‘homes like yours,’ one of which showed a house without solid wall insulation and one showed a house with solid wall insulation; the second letter type included one thermal image of a house without insulation and the control letter contained text only (no images). The behavioural measure was whether the householder made a telephone call to enquire about the scheme. Call rates were extremely low and preliminary analysis suggests that the no-image group rang up slightly more frequently than the two-image group. Further analysis is underway taking into account sociodemographic characteristics by geographical area. The initial analysis suggests that this more ‘shallow’ approach of a letter through the door addressed to ‘the householder’ does not work as well as the in-depth and personalised thermal imaging approach. Moreover, it is also known that solid wall insulation is a very difficult action to promote (Rosenow & Eyre, 2015).

### 1.5: The conditions that maximise the efficacy of thermal images as an intervention

In conclusion, the lessons from the eViz project suggest that thermal images can promote the uptake of energy efficiency measures in the type of information they feed back to householders.

Thermal images communicate energy waste and efficiency in a manner, which is difficult to achieve using other forms of communication. They can attract attention, encourage the viewer to connect their behaviour in the home to the images, they invoke emotion, trigger new goals and so promote action. Further, the four studies reported above together suggest that energy

---

"Feedback in energy demand reduction: Examining evidence and exploring opportunities" Edinburgh, July 2016Page 92
efficiency actions are promoted where there is increased elaboration by the householder. Thermal imaging feedback in the form of a letter (unannounced) containing images of other homes did not promote a behavioural effect. Yet, non-personal images were recalled better than textual information in a report on energy efficiency. This suggests that images attract attention anyhow; however, personalised images were recalled more and were more intrusive; they ‘popped into people’s heads’. Additionally, the personalised images were looked at more often and shared more. Ultimately, energy efficiency actions were promoted when images were personal to the householder. The behavioural effect is likely to be stronger the more personalised the images are to the householder viewing them and the greater the opportunity that the householder can elaborate and act on them.

1.6: Future work and scaling up thermal imaging as a feedback intervention

Recent work by Plymouth University in this field has scaled up the use of thermal imaging for visual intervention. This has been undertaken in collaboration with the University of British Columbia, where mass/large scale thermal imaging (drive-by thermography) is proposed as an intervention to motivate carbon reduction within entire neighbourhoods (several thousand homes) in a large Canadian city.

It is common in large-scale thermal imaging projects (e.g. drive-by and aerial thermography) for those who commission them to run out of time, money and enthusiasm before undertaking community engagement. The impact of such thermal imaging projects therefore often fails to deliver any meaningful or measureable energy reduction improvement at an individual homeowner level.

This work, which is due to be undertaken in winter 2016/17 will seek to bridge the gap between undertaking large scale thermal imaging projects and understanding the level of engagement, where thermal images are used to motivate homeowners to undertake energy upgrades.

1.7: Conclusion

This paper has presented an additional way of presenting energy information to householders, focussing on an area of energy use, space heating. It uses visuals to communicate heat loss so that the householder can infer the efficacy of taking action to mitigate that loss and thus save energy (and improve thermal comfort). We call for the debate around the efficacy of feedback, to include innovative and different ways of communicating energy use.

References


Fox, M., Coley, D., Goodhew, S. & Wilde, P. D. (2014) 'Thermography methodologies for detecting energy related building defects'. Renewable and Sustainable Energy Reviews, 40 pp 296 – 310


SESSION 3: Learning Lessons & Limits

Exploring energy feedback at community and household level through thermography, carbon mapping, online platform and home energy visits

Professor Rajat Gupta* and Laura Barnfield
Low Carbon Building Group, Oxford Brookes University, rgupta@brookes.ac.uk
*Presenting

Abstract
Alongside improved energy efficient technologies, reductions in demand through behaviour change are seen as key to reducing the household sector’s energy consumption. Feedback to households seeks to raise awareness and motivate behaviour change. This paper outlines the findings of a research study that used a variety of energy feedback approaches in order to stimulate behaviour change in communities and households that were involved in low carbon community activities. The approaches included carbon mapping workshops, thermal imaging, a web-based platform providing households with near-real-time energy and environmental data and personalised home energy reports combined with researcher visits.

Overall the majority of the feedback approaches used were able to some extent, to engage, raise awareness and motivate households into action. Furthermore, the findings drive home the point that it is difficult to prompt durable carbon reductions through technology alone; knowledge and practical know-how need to be transferred along with technology. Where feedback is concerned, some degree of personal contact was usually needed to make the most of what the feedback technology was able to provide in the way of information.

Introduction
The UK’s household sector accounts for 29% of the UK’s total energy consumption (DECC, 2014). As such the need for energy efficiency and conservation in this sector is critical in order to mitigate climate change, reduce national carbon emissions and enhance energy security (UKERC, 2009). Whilst improvements in the energy efficiency of household technologies (from washing machines to fabric measures such as wall insulation) are seen as key to reducing the household sector’s energy consumption, studies have indicated that even with more efficient technologies installed, households do not necessarily consume less (Gupta & Chandiwala, 2010). The reasons for this are varied and complex, with cultural and social norms, habitual behaviours, and the attitudes and values of the occupants all being seen to influence the occupant’s decisions to use energy (Gupta et al, 2014).

The invisibility of energy is seen as a reason why households, even if they do profess positive environmental attitudes do not always behave in ways that conserve energy use (Burgess & Nye, 2008; Hargreaves et al, 2010). As such, several studies (Steg, 2008; McKerracher & Torriti, 2012; Buchanan et al, 2014) indicate the provision of information and feedback on domestic energy consumption is critical to making energy visible, and subsequently prompting changes in energy behaviours and practices. Feedback can be provided to households in a number of ways, including via groups or directly to individuals (Abrahamse et al, 2007). Whilst feedback to individuals e.g. via home energy audits can provide tailored information on where further energy
reductions can be made, group feedback e.g. community-based programmes is suggested to be particularly effective as it engages with the social norms of individuals, and makes it clear that others are also actively engaged in energy demand reduction.

This paper describes the evaluation (using participant feedback) and key learning from providing different forms of energy and environmental feedback at different scales to householders in low carbon communities, at community and household levels, as part of a five-year research study looking at the effectiveness of low carbon community organisations.

Methodology

The study was conducted as part of an interdisciplinary and collaborative research project (entitled EVALOC and funded by Research Councils UK) that aimed to evaluate low carbon community (LCCs) projects in terms of their impacts on changing household and local energy behaviours, their effectiveness on achieving real-savings in energy use and CO2 emissions and their success in bringing about sustained and systemic change. The EVALOC project involved active participation from six low carbon communities (Table 1) that had projects funded through the Department of Energy and Climate Change’s (DECC) Low Carbon Communities Challenge (LCCC). The main work streams took place on two levels; community and household, using a variety of research methodologies including community events (14 events across the six communities), three rounds of focus groups, carbon mapping of 1,800 homes and case study household monitoring of 88 households over approximately two years.

Table 3. Description of six case study communities involved in EVALOC study.

<table>
<thead>
<tr>
<th>Community</th>
<th>LCC characteristic</th>
<th>Location</th>
<th>Geographical type</th>
<th>No. of households / residents</th>
<th>Socio-economic status</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Community-led</td>
<td>South Wales</td>
<td>Rural</td>
<td>13,500 residents in 12 villages</td>
<td>Disadvantaged</td>
</tr>
<tr>
<td>B</td>
<td>Community-led</td>
<td>North West England</td>
<td>Suburban</td>
<td>5,600 households</td>
<td>Disadvantaged</td>
</tr>
<tr>
<td>C</td>
<td>Partnership</td>
<td>North East England</td>
<td>Suburban</td>
<td>1,350 households</td>
<td>Disadvantaged</td>
</tr>
<tr>
<td>D</td>
<td>Community-led</td>
<td>South East England</td>
<td>Rural</td>
<td>1,100 households</td>
<td>Affluent</td>
</tr>
<tr>
<td>E</td>
<td>Multi-agency (local authority)</td>
<td>Yorkshire &amp; Humber</td>
<td>Urban</td>
<td>800 households</td>
<td>Disadvantaged</td>
</tr>
<tr>
<td>F</td>
<td>Community-led</td>
<td>South East England</td>
<td>Urban</td>
<td>1,560 households</td>
<td>Middle income</td>
</tr>
</tbody>
</table>

The use of a variety of energy feedback approaches was not initially part of the study. However, it was quickly apparent that the majority of EVALOC case study households also actively wanted feedback, from the research and from the LCC organisations themselves, not only in terms of advice on how to further reduce energy use but also in relation to monitoring progress during and after the project. More specifically, they wanted follow-up support and advice on the performance of the physical energy improvements. As an action research study, it was felt appropriate to trial a variety of different forms and scales of energy feedback at both household and community level, as outlined in Table 2.
Table 4. Feedback activities used in EVALOC project.

<table>
<thead>
<tr>
<th>Feedback type</th>
<th>Level</th>
<th>Frequency</th>
<th>Timescale</th>
<th>Sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon mapping</td>
<td>Community</td>
<td>Occasional</td>
<td>Indefinite</td>
<td>Five community workshops; 105 attendees</td>
</tr>
<tr>
<td>Thermal imaging</td>
<td>Community + household</td>
<td>Occasional</td>
<td>Indefinite</td>
<td>Five community workshops; 105 attendees. Images presented to, and discussed with 57 individual households</td>
</tr>
<tr>
<td>Home energy reports</td>
<td>Household</td>
<td>Illustrated history</td>
<td>Months - years</td>
<td>Posted to, and reviewed in person with 57 individual households</td>
</tr>
<tr>
<td>Web-based visualisation</td>
<td>Household</td>
<td>On demand</td>
<td>Day-late, historical</td>
<td>Details provided to 61 individual households.</td>
</tr>
</tbody>
</table>

Findings

This section outlines the findings from each feedback activity; carbon mapping workshops, thermal imaging, web-based energy environmental visualisation tool, and personalised home energy reports with researcher visits. The findings are based on feedback forms (at workshops) and direct feedback from households to the researchers during semi-structured interviews.

Carbon mapping workshops

Within this study, an urban energy modelling tool, DECoRuM, developed by the Low Carbon Building Group, Oxford Brookes University was used to visualise the carbon emissions of an area of the physical community in map format. At the workshops, powerpoint presentations with maps of baseline conditions, current conditions and predicted future impact of further energy and CO2 reducing measures (Figure 1) along with thermal images of local dwellings and an introduction to the web-based energy and environmental visualisation tool were presented to local residents by the researchers. In addition posters were displayed. The format of the workshop was a presentation followed by time for a Q&A session with discussion.

In total, approximately 105 people attended the five carbon mapping events, and a total of 36 evaluation forms were completed. Table 3 outlines key details of the workshops. The carbon mapping did not hold as much interest as the thermal images (see below), though the interest varied among the communities. It was felt that this was possibly due to the fact that carbon is
not a familiar concept to most people, and using costs or even kWh would perhaps have engaged people more. Furthermore, the need for technical detail varied within different case studies, and highlights the need to ensure the presented information is edited and formatted to suit different requirements and contextual needs. In general, the presentations were found to be informative but possibly too technical. The majority of respondents stated that they found the discussion more useful, and left the workshop feeling motivated to undertake either physical changes to their homes and/or change habitual behaviours such as turning heating down.

If the carbon map is to be developed as an engagement tool in communities with few resources to draw on, the EVALOC experience suggests a need to combine carbon mapping with the identification of what physical interventions would meet ‘golden-rule’-type requirements, and pointers to how householders might be able to meet the upfront costs.

A light touch web-based version of DECoRuM would be useful for communities and householders to self-conduct with minimum data, rapid energy assessment of their house, street or neighbourhood, and predict the potential of energy, CO2 and cost savings from appropriate energy saving measures.
Table 5. Key details and findings from the five carbon mapping workshops.

<table>
<thead>
<tr>
<th>Community</th>
<th>Attendees</th>
<th>Approach</th>
<th>Publicised</th>
<th>Findings</th>
</tr>
</thead>
</table>
| A         | 12        | Presentation, posters, Q&A, and group discussion | Invitations sent to all houses in mapped area | • Information presented too technical with not enough detail on individual households  
• 3/4 respondents stated that they felt more motivated following the event  
• 2/4 respondents more aware  
• 3/4 left with intentions to change (physical measures and behaviours) |
| C         | 25        | Presentation, posters, Q&A, and group discussion | Organised in collaboration with LCC; invitations to stakeholders and posted invitations to houses within mapped area. Posters and flyers displayed at Community Hub | • Presentation and group discussion valued equally by the respondents  
• 8/10 stated they felt more motivated following the event  
• 5/10 felt more aware  
• 7/10 left with intentions to change (physical measures and behaviours) |
| D         | 30        | Presentation, posters, Q&A, and group discussion | The workshop was organised in collaboration with LCC; invitations and questionnaires sent to houses within the mapped area. | • Most respondents stated that they learned most from the mapping of impacts of potential measures  
• All respondents (13) stated they felt more motivated following the workshop  
• 11/13 felt more aware  
• 9/13 left with intentions to change (physical measures and behaviours) |
| E         | 16        | Presentation, Q&A and group discussion | The presentation was placed into an agenda of an already arranged meeting between council members and local community representatives | • Most commonly cited things learned from the workshop were use of thermal imaging to identify heat losses and energy saving gained through LED lighting.  
• 7/9 stated they felt more motivated following the workshop  
• 4/9 more aware  
• 8/9 left with intentions to change (physical measures) |
| F         | 20        | Presentation, posters, Q&A, and group discussion | Organised in collaboration with LCC; flyers advertising the event were also posted to the 300 houses invited to complete the questionnaire. | • Presentation useful as it was found to help justify previous activities and guide future investments in the area |

**Thermal imaging**

Within the EVALOC project, thermal images were used both for diagnosis and awareness-raising. The images were presented at both community workshops (five communities) in powerpoint presentation and poster format and to individual households as part of personalised energy reports (Figure 2), alongside discussion with researchers (58 households). Thermal imaging proved a very successful and powerful engagement tool in terms of motivating individuals through increased awareness, particularly if combined with expertise in interpreting the images. It was able to provide clarity and peace-of-mind that fabric measures had been undertaken successfully, and provoked interesting discussion and active learning when using comparative images amongst a group of householders, not just when discussing with individuals. Discussion of thermal images with household occupants, particularly on site to enable physical inspection,
was able to provide the researchers with invaluable insight into any apparent anomalies within the thermal images. Several of the case study households reported on actions following the provision of the thermal images; “By the way, the unidentified cold spot on the corner of the front bedroom window was the result of dampness caused by crumbling pointing between the stones. Thanks to you I can have it restored – I would never have known about it otherwise.” And, “I took the pictures into the local housing trust because the flat below, it had a big light spot under the window...”

Figure 3. Example of a thermal image used during discussion of a home energy report.

**Web-based energy and environmental visualisation tool**

As part of the study, energy and environmental monitoring data for 61 households was uploaded onto a web-based visualisation platform (Figure 3), hosted by EnergyDeck (www.energydeck.com). The aim was to provide the householder with real-time (or near-real-time) energy and environmental data. The platform provided comparative benchmarks and allowed the user to search for specific dates and times. It also allowed users to select different variables (i.e. gas data and living room temperature) and display these on one graph together. Invitations were sent to 50 of the households by email and postal invitations along with a guidance brochure were sent to all 61.

Only 22 of the 61 signed up, with approximately 5 requiring significant help from the researchers. The project findings highlight the fact that a web-based feedback approach is not suitable for all individuals and that feedback methods should be carefully thought through in terms of accessibility and readability. The level of interaction appeared to be due to the type of individual and their familiarity and use of computers and the internet, rather than which community they belonged to. For example, very high and very low interactions were both observed in...
Communities B and D. The EVALOC experience suggests that web-based platforms should be designed to be pro-active in reaching individuals (for example, through the use of personalised reports delivered to the individual’s email address), rather than relying on the individuals to access and use them, as comments from one respondent suggests: “I think probably the access to the online data should have been the most useful if I got round to actually looking at it.”

Figure 4. Web-based visualisation of home energy use.

**Personalised home energy reports**

An alternative approach to the web-based tool used within the study in order to feedback energy and environmental information to the individual households was the personalised home energy report (Figure 4). The report was sent in draft form to 57 households by post approximately 1-2 weeks prior to a scheduled visit by a researcher. During the visit, the researchers discussed the report with the occupants.
The report was found to be a useful way of provoking discussion between the researcher and occupants on their energy use. It also prompted the occupants to discuss the reasons why their energy use and/or environmental conditions were the way they were. An example of this was the use of a graph showing annual energy use from 2008 to 2011. This generally acted as a trigger for the occupants to remember relevant contextual details that had otherwise been forgotten and not mentioned when they had been asked about any changes over the years. As such, it afforded the researchers greater contextual insight into the changes in dwelling and household characteristics.

Many of the occupants also stated that they found the report interesting, but often it was found too technical and simpler graphs were required; “Yes I’ve read it but I don’t understand everything in it.” Yet for some, the report did not go into enough detail; “I would have wanted to see that on a more regular basis so it’s not kind of crammed into one report so maybe a quarterly breakdown if not a monthly breakdown so that I could more easily relate consumption patterns to actions that I know I’ve taken. At the moment I think in that form the data is too aggregated to be useful.” Furthermore, it appears that many who did not understand the graphs tried to view them in terms of ‘good’ and ‘bad’ (i.e. better or worse than it ‘should’ be) but the graphs had no comparative data in them to give the occupants this information, and so the occupants were unable to understand what the graphs were supposed to be telling them.

A number of households had not looked at the report at all, stating that they had simply been too busy, or had forgotten about it. Yet even in these households, when the report was shown to them during the researcher’s visit, it prompted discussion and interest. This highlights the importance of a physical presence in terms of ensuring information is transferred and communicated fully.

**Conclusion**

Due to the qualitative nature of the evaluation process, and relatively small sample numbers, the findings are more illustrative than conclusive but do provide insights into the types of feedback that can be used as well as recommendations for future research studies and feedback activities undertaken at a community level.
Overall the majority of the feedback approaches used were able to some extent, to engage, raise awareness and motivate households into action. Carbon mapping was relatively successful, but was felt to be aimed more at community groups and organisations rather than individual households and as such did not engage the local residents as much as thermal imaging. Different feedback techniques appealed to different households, and this did not necessarily depend on the community in which they lived. However, even in households with high levels of engagement both with energy use and the research study, often the posted or emailed home energy reports were forgotten or ‘put in a drawer for later’. Yet, when combined with a researcher’s visit, they created the opportunity for discussion and ‘sense making’ conversation, using the feedback as a prompt which appeared to increase engagement through contextualising the feedback for the occupants, and also created an awareness of energy on a very personal level for the household.

A further outcome was to drive home the point that it is difficult to prompt durable carbon reductions through technology alone: knowledge and practical know-how need to be transferred along with technology. Where feedback is concerned, some degree of personal contact was usually needed to make the most of what the feedback technology was able to provide in the way of information. The usefulness of different modes of feedback at several levels, to contextualise as well as engage householders has been an important lesson from the EVALOC feedback programme.

References


The effect of real-time context-aware feedback on occupants' heating behaviour and thermal adaptation

Marika Vellei\textsuperscript{a}, Sukumar Natarajan\textsuperscript{b}, Benjamin Biri\textsuperscript{c}, Julian Padget\textsuperscript{c}, Ian Walker\textsuperscript{d}

\textsuperscript{*} Published in Energy and Buildings: doi:10.1016/j.enbuild.2016.03.045

\textsuperscript{a} Presenting author. Department of Architecture and Civil Engineering, University of Bath, Bath, UK. Email: M.Vellei@bath.ac.uk

\textsuperscript{b} Department of Architecture and Civil Engineering, University of Bath, Bath, UK

\textsuperscript{c} Department of Computer Science, University of Bath, Bath, UK

\textsuperscript{d} Department of Psychology, University of Bath, Bath, UK

Abstract

Studies have shown that building energy demand in identical dwellings could vary by a factor of three. Differences in occupant behaviour – i.e. purchase, operation and maintenance – have been implicated as a strong source of these differences. The literature suggests that feedback on energy use to building occupants – particularly real-time feedback – can be used to prompt lower operation-related energy behaviours. This is particularly true for thermal demand which, in cold countries, accounts for four times as much energy use as non-thermal demand. However, there is little evidence to support this claim. We report results from a winter field study that used in-depth energy, environmental and motion sensing to generate real-time context-aware feedback through a smartphone application. Subjective data and clothing levels were concurrently collected through questionnaires. Our results suggest that real-time feedback could lower radiator and room temperatures without significantly affecting occupant thermal comfort. The results also show that real time feedback could contribute to an increase in occupant perceived environmental control (a key variable in the theory of adaptive thermal comfort) while prompting lower heating energy behaviours.

Introduction

The domestic sector accounts for approximately 24% of the world’s energy consumption. In cold climates, 32% of this consumption, on average, is due to space and water heating. However, in highly industrialized countries, heating energy use represents a far higher proportion of the domestic energy demand, e.g. 57% in the UK (DECC, 2014).

Building space heating energy consumption depends on several physical factors (i.e. geographical factors, building characteristics, efficiency of the space heating system used). Non-physical factors such as economic and social factors also have a strong role to play but, since they are more difficult to quantify, little is known about the magnitude of their effects which are often neglected when estimates of building performances are made. The energy behaviour of building users represents the expression of these non-physical factors which act as underlying drivers and antecedents of occupant actions. Recent research has highlighted the potential impact on heating energy use arising from differences in occupant behaviour (Juodis \textit{et al.}, 2009; Andersen, 2012; Gram-Hanssen, 2010; Urban B, 2013).

In the emerging domain of domestic energy literacy research, several studies have examined the impact of increasing literacy on electricity-related behaviours (Kavousian \textit{et al.}, 2013; Delmas and Kaiser, 2014; Emeakaroha \textit{et al.}, 2014; Peschiera \textit{et al.}, 2010). However, few studies have
investigated its effect on the arguably more important topic of heating energy consumption (Huebner et al., 2013). Further, whilst some studies have begun to focus on the impact of information dissemination on occupants’ heating energy use (Schweiker and Shukuya, 2011; Bae, 2007; MCMakin et al., 2002), to our knowledge, no studies have investigated the effect of real-time context-aware feedback on occupant heating behaviour, specifically thermal adaptation and comfort. Understanding the links between feedback, behaviour and subjective comfort is important if we are to effectively influence energy-saving behaviour since perceived reductions in comfort are a major impediment to end-users accepting feedback and advice (Buchanan et al., 2015). This paper sets out to address this important gap by investigating the effect of real-time and context-aware feedback on occupants’ adaptive actions, thermal comfort and perceived environmental control in the context of their heating energy use.

**Methods**

**2.1 Participants**

The experiment monitored 15 volunteer subjects occupying near-identical single-occupancy rooms on the university of Bath campus. The participants signed a consent form at the beginning of the study in which they were assured that their data were treated confidentially. They were all first year undergraduates (8 males and 7 females) of various nationalities, but all were European. At the time of the experiment, all the students had lived in their rooms for about 6 months.

**2.2 Experimental procedure**

The field study had an overall duration of six weeks, divided into two phases of three weeks each. The first phase (control phase) consisted of monitoring the student rooms, with no feedback. In the second phase (experimental phase), students were provided with feedback via their smartphones, with a specially developed in-house application (Figure 7). The experiment started on the 16 February 2015 and ended on the 29 March 2015.

**2.3 Monitored rooms**

The 15 monitored rooms are part of three neighbouring residential blocks, on the University of Bath campus. The three buildings are naturally ventilated and are identical in terms of exposure and buildings characteristics. In each of the three buildings the source of heating is a natural gas boiler. The heating schedule was regulated by the estate manager but remained the same during the 6 weeks for the 3 buildings. Each room has a floor area of about 8m² and contains a waterborne radiator with a thermostatic valve. Students were therefore allowed to adjust their valve and also to set the valve to zero.

**2.4 Physical measurements**

Each room was equipped with environmental and motion sensors reporting every minute to a university-hosted database, allowing in-depth real-time monitoring of the rooms. The sensors consisted of an air dry bulb temperature sensor, a relative humidity sensor, a CO₂ sensor, a temperature sensor fitted on the radiator and a PIR infrared motion sensor to detect room activity (Figure 6).
2.5 Psychological measurements

Students were asked to fill two thermal comfort questionnaires per day after being in their room for at least 30 minutes. This enabled the collection of 624 valid questionnaires. Each participant provided between 14 and 66 questionnaires, for an average of 42 questionnaires per student.

At the end of the first and second experimental phases, students were asked to fill an additional questionnaire designed to measure overall satisfaction with the room and perceived environmental control. The aim was to detect changes to these responses as a result of the feedback.

![View of the residential blocks (left) and of a typical student room (right) showing the positioning of the sensors.](image)

2.6 The application

The smartphone application developed for this study is shown in Figure 7. The application uses real-time data and a set of heuristic rules to produce the following energy savings tips:

- **If Friday:**
  The weekend is coming! Remember to turn off the radiator (by adjusting the valve to zero) if you don’t plan to be in your room.

- **If between 8PM and 10PM:**
  Do you feel cold when you go to sleep? Rather than turning up the radiator have you tried wearing a heavy pyjama or using extra blankets? Drawing your curtains can also help to keep the heat in!
  - If CO₂ < 600 ppm:
    Oops! You might have opened both your window and door, which means that if the radiator is on, you are heating the outside air! If you opened these because your room was feeling stuffy, then remember to close them back quickly to save energy.
  - If CO₂ > 1800 ppm:
    Your room is getting stuffy! Open your window for a while and get some fresh air! Remember to close it back though as otherwise you are just heating the outside air!

- **If room temperature > 21 °C:**
  Your room temperature is more than 21°C at the moment. Most people find this quite warm. Turning down your radiator would help save energy. If you still feel cold, have you tried wearing warmer clothes instead?
2.7 Monetary rewards

In a domestic setting, the reduction of energy consumption directly impacts fuel bills and can be a powerful motivating factor for undertaking energy saving measures. However, in a university setting, students do not normally pay for their actual consumption directly since fuel bills are often bundled into the accommodation cost. To simulate as closely as possible the domestic setting in our study, students were rewarded for their energy saving with an amount of money proportional to the energy saved.

An artificial gas tariff (of 0.2 £/kWh instead of the 0.03 £/kWh typically paid by domestic consumers) was used for the monetary rewards to make the cost-feedback more salient due to the short duration of the feedback phase. This tariff is the same as the one used for calculating the daily energy costs shown in the application (Figure 7).
Figure 7 Screen of the application
Results and discussion

3.1 The effects of feedback on physical variables

For the analysis, students were sorted into two groups according to the number of questionnaire they filled in during the feedback period. During this period, the questionnaire was integrated in the application and, therefore, a low number of questionnaires can be associated with a low interaction with the app. Group 1 includes students that, during the feedback period, filled in more than 13 questionnaires (an average of 20 questionnaires each during the experimental phase). While students of Group 2, in the same period, filled fewer than 8 questionnaires each (an average of 7 questionnaires each). Finally, one student whose room was monitored for the 6 weeks did not receive any feedback since his smartphone was not compatible with the developed application.

The average outdoor temperature during the first three weeks was 5.8°C. During the last three weeks it slightly increased to 6.2°C. Since the heating schedule remained the same, room air temperatures were expected to increase. Room temperature slightly increased for student no. 15 of Group 3 who was monitored for the six weeks but did not receive any feedback; while, for all the students of Group 1 (with the exception of students no. 1 and 2) room air temperatures decreased. For students no. 1 and 2 (Group 1a) the temperature increase was due to the stricter control of window opening (their mean room CO$_2$ concentration increased respectively by 22% and 26%). This fact is confirmed by the decrease of radiator temperatures for both students during the last three weeks.

Therefore, unlike Group 2, all the students of Group 1 tried to save energy by lowering their radiator settings (Figure 8). However, they responded to the lower radiator temperatures through different adaptive responses (Figure 9):
- through a stricter control of window opening (Group 1a);
- by wearing more clothing (Group 1b).

For student of Group 1a there is an average increase of CO$_2$ concentration equal to 17% with no noticeable increase in clothing level. While, for students of Group 1a there is an increase of their clothing, on average, by 20%.

![Figure 8 Radiator temperatures before (prior) and after (post) the start of the feedback (Group 1)]
An in-depth analysis of CO₂ room concentrations for Group 1a shows that, while student no. 1 and 4 followed the feedback’s recommendations to keep CO₂ levels under 1800 ppm, students no. 2 and 3 exceeded the level of 1800 ppm for respectively 30 % and 20 % of the time. This unwanted effect was probably due to the fact that feedback tips were either not seen or ignored. This shows that there is a risk of air quality degradation when trying to save heating energy. This risk needs to be taken into account when designing feedback strategies.

From the analysis of the clothing levels (Figure 9) it can be noted that Group 2 tended to wear less clothing during the feedback phase. Therefore, they responded to the higher indoor temperatures through decreasing their clothing insulation. This fact confirms the previously hypothesized low interaction with the app.

![Figure 9 Percentage differences in CO₂ concentration (CO₂ %diff) and students’ levels of clothing (clo %diff) before and after the start of the feedback](image)
3.2 The effects of feedback on psychological variables

Two other important facts can be observed for students of Group 1: (i) overall perceived environmental control increases and (ii) thermal and air quality satisfaction levels increase. The Wilcoxon signed rank test is used in order to analyse differences between the samples before and after the start of the feedback. A non-parametric test is chosen due to the limited sample size and due to the fact that the sampling distribution is non-normal. The selected significance level is $p = 0.05$. For Group 1, perceived control levels for temperature and air quality are significantly higher (respectively, $W=8$, $p=0.046$ and $W=0$, $p=0.005$) after the start of the feedback (Median=3) than before (Median =2.5). Thermal satisfaction levels are significantly higher after the start of feedback (Median=4) than before (Median=3), $W=0$, $p=0.0049$. Satisfaction levels for air quality are also significantly higher after the feedback (Median =3.5) than before (Median =3), $W=7$, $p=0.036$.

Conclusions

This study aimed to detect and quantify changes in occupants’ adaptive responses, neutral temperatures and perceived environmental control as results of the feedback intervention. From the analysis of the monitored data, it emerges that feedback has the potential to prompt “good” adaptive behaviours such as wearing more clothes and better controlling the use of windows for ventilation, but it also reveals that a risk of high indoor CO$_2$ levels exists and that, therefore, this problem needs to be carefully addressed when designing feedback strategies. This study also confirms the importance of perceived control in defining thermal comfort and shows that the degree of occupant’s control over the environment depends not only on the characteristics of the building and of its systems (building contextual factors) but also on occupant’s awareness of them. Subjects felt they had greater control over their thermal environment and, consequently, this greater control was able to mitigate their thermal expectations and offset possible discomforts due to the lower temperatures. Given a sufficient motivation for interacting with the application, real time feedback can effectively and positively contribute to guiding occupants’ adaptive actions towards energy-aware behaviours without negatively affecting their satisfaction. The results of this study therefore demonstrate that saving energy does not always mean sacrificing occupant comfort.

Acknowledgments

This study was jointly supported by the EPSRC funded ENLITEN project (EP/K002724/1) and a University of Bath Research Scholarship.

References


Bae, N., Chun, C., Park, M., Changes of residents’ behavior as a result of education and information providing about indoor environments. In: RoomVent 2007.


Quantifying likely energy reduction opportunities in family homes

Paula Cosar-Jorda, Richard A. Buswell and Val A. Mitchell; Building Energy Research Group, Loughborough University, UK; Design School, Loughborough University, UK.

Abstract
Energy demand reduction towards domestic 2050 targets is part of the UK challenge to achieving intended CO2 emissions. Although energy use in the home depends on a high number of variables such as occupant behaviour, appliance ownership, space heating setting, hot water usage, number of people in the home, household characteristics and other parameters linked to householder choice, there is still much to understand about the potential reduction from specific ‘one off’ measures that have either an associated capital investment and/or a lifestyle implication. This study presents a systematic approach to modelling potential reductions from specific energy reduction measures for a set of seven family homes, feeding back this information to householders, and then evaluating the likely reduction potential based on their comments. The approach achieves this through a mix of whole house monitoring and semi-structured interviews. Insights are gained into the householders’ willingness to apply measures and their views on the potential use of smart home technology and ICT as enablers of change in the house. Results suggest that each case study has a unique priority list of reduction opportunities that can be applied to achieve 2050 targets; results are optimistic and suggest that householders do have a realistic opportunity to meet anticipated UK targets if a number of conditions are met.

Methodology
This work quantifies the impact of reduction measures on energy demand in specific homes together with a qualitative assessment of the extent to which householders are prepared to undertake the proposed reduction measures. This is achieved by utilising monitoring data and simple steady-state numerical modelling techniques to model the impact of individual and combinations of reduction measures.

In order to investigate the impact of family lifestyles and preferences on the likely uptake of reduction measures, the approach developed makes use of monitoring data from specific homes to target the analysis on evaluating each family’s specific building, systems and preferences. The tailored reduction analysis is conducted using data evenly distributed throughout a 12 month period from the sample of 7 homes, which was translated into a set of visual aids, and used in combination with semi-structured interviews to present the opportunities to householders, who established issues and barriers around implementing each measure. The interview results were used to adjust the parameters of each household’s model allowing the current whole house energy consumption to be compared with the ‘potential maximum’ reduction and that which is ‘more likely' to occur in practice. These results are then used as prompts to reflect on the implications for the current assumptions embedded in energy planning scenarios.
Sample characteristics

The sample is limited to family homes in order to enable comparable lifestyle considerations impacting on energy consumption. Seven households placed in Loughborough took part in the study; all houses are detached (D) except H05 and H46 which are semi-detached (SD). Houses were built between 1940 and 1990 and their insulation levels range from solid wall, to insulated cavity walls. The glazing characteristics vary from double windows with timber frame from the 50s with a percentage of single glazing; to PVC framed double windows with a proportion of triple glazing; the ground floor in all households but one is solid concrete slab; the different ground floor typology is suspended timber. House size varies from just above 100 m² to 170 m², ranging the number of rooms between 9 and 12.

<table>
<thead>
<tr>
<th>House</th>
<th>Built</th>
<th>Insulation</th>
<th>Glazing</th>
<th>Rooms</th>
<th>Showers</th>
<th>Hot water</th>
<th>Appliances</th>
<th>Adults</th>
<th>21-14 years</th>
<th>13-18 years</th>
<th>7-0 years</th>
<th>Weekdays occupied</th>
<th>Away weekends</th>
</tr>
</thead>
<tbody>
<tr>
<td>H05</td>
<td>1940</td>
<td>✓</td>
<td>✓</td>
<td>9</td>
<td>✓</td>
<td>C</td>
<td>31</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Regularly</td>
<td></td>
</tr>
<tr>
<td>H09</td>
<td>1960</td>
<td>✓</td>
<td>✓</td>
<td>12</td>
<td>✓</td>
<td>C</td>
<td>36</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>Barely</td>
<td></td>
</tr>
<tr>
<td>H10</td>
<td>1980</td>
<td>✓</td>
<td>✓</td>
<td>10</td>
<td>✓</td>
<td>C</td>
<td>39</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>Barely</td>
<td></td>
</tr>
<tr>
<td>H30</td>
<td>1950</td>
<td>-</td>
<td>✓</td>
<td>9</td>
<td>✓</td>
<td>C</td>
<td>33</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>Barely</td>
<td></td>
</tr>
<tr>
<td>H37</td>
<td>1970</td>
<td>✓</td>
<td>✓</td>
<td>11</td>
<td>✓</td>
<td>C</td>
<td>37</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>Barely</td>
<td></td>
</tr>
<tr>
<td>H39</td>
<td>1950</td>
<td>✓</td>
<td>✓</td>
<td>9</td>
<td>✓</td>
<td>C</td>
<td>42</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Barely</td>
<td></td>
</tr>
<tr>
<td>H46</td>
<td>1990</td>
<td>✓</td>
<td>✓</td>
<td>11</td>
<td>✓</td>
<td>C</td>
<td>49</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>Barely</td>
</tr>
</tbody>
</table>

Hot water is either supplied by a tank or a combination system; showers are provided with hot water from the main boiler and/or from electric showers; the number of showers varies from one to two and there are electric showers in 3 of 7 houses. The ownership of appliances varies from 34 devices to 49.

The sample included a single parental family home with one child; a multi-generation family home with four children, parents and grandmother; four houses with four family members and one house with three; the age of the adults ranges from one young couple in their thirties to one mature couple in their late fifties. All the families are high and middle income families with a variety of background levels from basic to post-graduate education. All households are generally occupied during the day at least one day a week, but most are occupied during the week, at least partially.

Monitoring data

Monitoring was undertook via three monitoring systems: an in-line turbine meter measuring hot water volume and temperature; an image capturing system on the gas meter; and a non-research grade system of sensors which monitored the electric circuits, end use appliances, air temperature, movement signal and windows position.

Modelling

An energy balance model is developed that combines detailed monitored data with assumptions about dwelling characteristics, producing a residual figure that is attributed to air change rate:
\[ 0 = Q_{sh} + Q_{use} + Q_e + Q_P + Q_s + Q_{loss} + Q_f + Q_v \]

**Equation 1 Energy Balance**

Where \( Q_v, Q_{sh}, Q_{use}, Q_e, Q_P, Q_s \) and \( Q_f \) are the daily sum of heat for ventilation, gas combustion for space heating and hot water production, electricity consumption, gains from people, hot water production and loss through the fabric. Monitored data is used in the calculations together with assumptions on not measured parameters such as wall conductivity or the glazing factor of windows.

The model is inverted predicting the impact of reduction measures through the application of a set of reduction models.

**Energy reduction analysis**

The energy model was applied to estimate how much energy can be reduced from current consumption, ranking for each case study, which are the most urgent measures to be implemented and developing an action framework: REB, 'The Reduction Effort Balance', which differentiates between the potential of home retrofit and replacement investment and that that could be achieved from occupant behaviour change. A selection of measures was modelled from those impacting on space heating and electric consumption; these are:

Lifestyle, these do not necessarily cost anything, but require the user to accept a lower level of service or comfort than they are used to:
- One fridge-freezer
- No standby loads
- No tumble drying
- Heating when home
- In use heating
- No heating over 15
- Heating to 17
- Ventilation

Replacement, items that require small to moderate investment, but are not particularly disruptive to carry out, such as replacing an old appliance:
- New cooking appliances
- New fridge-freezer
- New laundry appliances
- New media
- Insulated doors
- Replace bulbs

And, retrofit, major undertakings that usually affect the building fabric or heat production that are a significant cost and undertaking:
- Loft insulation
- Wall insulation
**Interviews**

The study was designed to perform face to face interviews in participant’s households, enabling a familiar context, where the discussion focussed on participants daily routines, often automatized and difficult to articulate.

Semi-structure interviews were intended to engage participants with their tailored energy consumption information and to explore their opinions and interest on applying reduction measures, using a set of tailored graphs and mixed questions that aimed at unravelling their thoughts and understanding of their home energy routines. A set of modelled reductions is then presented, evaluating householder’s willingness to apply those, and discussing their barriers to implement measures and the role of smart home technology, HEMS and ICT to enable change.

The interview was designed to answer the main research question: Are modelled measures likely to be implemented in real family homes? And it is outlined as follows:

**Contextualisation:**

The interview is contextualized by presenting to householders their tailored 2050 energy demand targets as presented in Illustration 2; participant awareness and interest on 2050 targets was discussed and their ideas on how to reduce energy in the home were recorded.

**Task:**

This section aims at answering the main research questions driving the qualitative analysis: Are modelled measures likely to be implemented? What are the barriers stopping householders to implement those? Illustration 3 is an example of the graphical information used to answer this question.

**Discussion:**

- Floor insulation
- Triple glazing
- Sealing
- Acquiring a new boiler
During the interview, questions were asked to raise key discussion points, these were: participants interest on energy reduction measures and 2050 targets; the role of the REB categorisation for householders, as presented in Illustration 4; barriers stopping householders applying measures in the home and the role of home innovation to enable change. The detail about these and their role within the interview are described.

**Qualitative data analysis:**

Participants’ willingness to apply measures and barriers for changing their current consumption were discussed. The willingness term was specified to householders as follows: Willingness

- **yes:** willing to apply a measure;
- **only if:** willing to apply change if a condition is met (for example a lifestyle change, or the acquisition of smart home technology);
- **no:** not willing to change their current consumption;
- **partially:** willing to change it to an extent, but not interested in fully applying the conditions specified;
- **partially applied:** currently applying the reduction to some extent and not willing to change their current routines; and,
- **applied.**

A thematic analysis was performed at a semantic level, and interpretative work led themes to emerge from the interviews, identifying the following barriers to adopting energy:

- **comfort:** reduction measures are against basic satisfaction needs perceived by householders. Temperature, humidity and air quality can affect people's physical and psychological feelings, making them feel uncomfortable at specific conditions and therefore leading them to take action against it. Some quoted examples used to show comfort/discomfort feelings are: ’It is stuffy’, ’don't want fresh air coming from a hole’, and ’I know what I like',
- **everyday life:** family lifestyle is limited by a number of constraints such as working patterns, practices in the home, community engagement, family time and specific needs tailored to each individual. Quoted examples are: ’need to open for the dog', 'boys in and out', 'the children need heating in their rooms', 'because of mum', 'bulk shopping', 'the way we cook' and 'there is always people at home';
- **technology:** current house equipment, existing or familiar technology in the market doesn't offer enough service to apply a specific measure; in this case, new technology is considered as a condition to achieve an aimed for reduction, for example people quoted: 'the right type of lights', 'finding the right fittings', 'better solutions', and 'curved windows' 
- **investment:** the cost of the intervention is not considered affordable or cost-effective and it is an issue to undertake an intervention; Quoted examples that elicit this fact are: 'costed up', 'if not too expensive', 'most efficient boiler affordable', 'economic sense', 'depending on cost', 'can't afford' and 'investment needed'
- **information:** either the lack of knowledge about an intervention, its impact on energy reduction and/or investment required to undertake it, or the knowledge on how small is the
impact of a specific measure, can impact on people's motivation for change: 'absolutely no idea', 'always difficult to know', 'need to know if it is worth doing', 'what is the cost involved?', and 'how much fresh air?';

- organisation: fitting in the diary the time for a retrofit, research about the best investment to reduce energy in the home and make an informed decision, or organising every day activities to be energy efficient can be non-viable for householders: 'need to be more organised', 'just haven't got round it', 'as part of something else', 'don't think of it', 'we don't always remember' and 'when we refurbish the kitchen'

- lifespan: replacing a device or applying a retrofit intervention needs from an investment of money that householders are interested only if goods need replacing/updating. People's quotes about the lifespan of appliances are: 'when they break', 'dies', 'when they blow', 'pack up', 'when replacing' and 'end of their life';

- functionality: acquiring and using equipment for a specific purpose makes it infeasible to change it or stop using it, for example, householders quoted the following: 'the gadget that we want', 'health environment, no asthma or hay fever' and 'avoid the damp and bad smell';

- aesthetics: the aesthetics of a retrofit or replacement is an important factor that impacts on householders decision: 'looks right' and 'looks cheap'; and,

- disruption: the process involved in retrofit measures is usually disrupting, and often perceived as a barrier for householders as the following quotes suggest: 'everything that needs to happen', 'quick and easy win', 'maintenance', 'big job' and 'practicalities'.

Table 2 Barriers to apply reduction measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Most common barrier</th>
<th>Mentioned times</th>
<th>Overall barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>One fridge-freezer</td>
<td>Everyday life</td>
<td>3</td>
<td>Everyday life and comfort</td>
</tr>
<tr>
<td>No standby loads</td>
<td>Information</td>
<td>3</td>
<td>Comfort, information, Everyday life, technology</td>
</tr>
<tr>
<td>No tumble drying</td>
<td>Everyday life</td>
<td>4</td>
<td>Everyday life, comfort and functionality</td>
</tr>
<tr>
<td>Heating when home</td>
<td>Everyday life, technology and organisation</td>
<td>1</td>
<td>Everyday life, technology and organisation</td>
</tr>
<tr>
<td>In use heating</td>
<td>Technology</td>
<td>5</td>
<td>Technology, investment, Everyday life, information and comfort</td>
</tr>
<tr>
<td>No heating over 15°C</td>
<td>Information</td>
<td>2</td>
<td>Technology, information, Everyday life, organisation, comfort</td>
</tr>
<tr>
<td>Heating to 17°C</td>
<td>Comfort</td>
<td>5</td>
<td>Technology, investment, comfort, Everyday life</td>
</tr>
<tr>
<td>Ventilation</td>
<td>Comfort</td>
<td>4</td>
<td>Everyday life, comfort, information, functionality and organisation</td>
</tr>
<tr>
<td>New cooking appliances</td>
<td>Lifespan</td>
<td>6</td>
<td>Lifespan, functionality, organisation and information</td>
</tr>
<tr>
<td>New fridge-freezer</td>
<td>Lifespan</td>
<td>5</td>
<td>Lifespan, investment, organisation</td>
</tr>
<tr>
<td>New laundry appliances</td>
<td>Lifespan</td>
<td>6</td>
<td>Lifespan and Everyday life</td>
</tr>
<tr>
<td>New media devices</td>
<td>Lifespan and functionality</td>
<td>7</td>
<td>Lifespan and functionality</td>
</tr>
<tr>
<td>Insulated doors</td>
<td>Lifespan</td>
<td>1</td>
<td>Lifespan, investment and functionality</td>
</tr>
<tr>
<td>Replace bulbies</td>
<td>Lifespan and technology</td>
<td>3</td>
<td>Technology, investment, lifespan and organisation</td>
</tr>
<tr>
<td>Loft insulation</td>
<td>Lifespan</td>
<td>4</td>
<td>Lifespan and organisation</td>
</tr>
<tr>
<td>Wall insulation</td>
<td>Investment</td>
<td>6</td>
<td>Technology, disruption, investment, aesthetics, Everyday life, information</td>
</tr>
<tr>
<td>Floor insulation</td>
<td>Information</td>
<td>5</td>
<td>Disruption, investment, information</td>
</tr>
<tr>
<td>Triple glazing</td>
<td>Investment</td>
<td>7</td>
<td>Technology, investment, organisation, information, lifespan</td>
</tr>
<tr>
<td>Sealing</td>
<td>Information and organisation</td>
<td>3</td>
<td>Investment, information, Everyday life, organisation</td>
</tr>
<tr>
<td>Acquiring a new boiler</td>
<td>Lifespan</td>
<td>7</td>
<td>Lifespan and investment</td>
</tr>
</tbody>
</table>

Quantification of insights:
Participants’ willingness to apply measures is considered by modelling only ‘negotiable
measures’, those measures that participants would apply in the future, either with or without a condition. The time frame considered to build the model assumptions is 2050, as the update of goods will have taken place in 30 years. The objective is to understand the impact of reductions which might not happen because of not negotiable family barriers, and quantify which is the 'best case' reduction that can be achieved in each specific home. For those measures that are partially applicable, participant’s conditions are applied to the model to recalculate the energy impact.

Results

Tailored reductions were applied considering participants willingness to implementing reduction measures; these suggest that while ensuring householders minimum comfort expectations and other personal considerations, the reduction required to achieve 2050 UK domestic targets can take place. Nevertheless, it should be noted that a number of conditions will have to be met for the reduction to be implemented. Conditions are linked to cost, family lifestyle, the spread of smart home technology and the end of life for existing goods as it can be seen in Table 2.

The difference between the first model’s achievable reduction and that from taking into account personal willingness and limitations, varies from 21% in H05 to 2% in H39, showing the range of limitations and participant willingness for change that can be found in even this small sample of family homes. The qualitative insights suggest that the barriers from those not negotiable measures are: comfort, everyday life, functionality and information. The lowest acceptable level of comfort and convenience varies; for example, H05 and H37 are less concerned about colder temperatures in the home, whereas current ventilation routines are not negotiable. Everyday life limitations are specific to each household, as most everyday life barriers are given by working schedules, the age of family members, and the use of rooms in the home; also, functionality is a barrier when changing a device, building element or system, as in some cases, the function and the output from a new device is different, keeping the old one or buying a similar one with a similar energy rate to maintain the current service. This is the case for retaining media devices, gas fired hobs, or for not considering a ventilation system. Lack of information was a barrier to undertake specific reduction measures in cases where there was no clear output and the cost of the process was unknown.

Limitations that need to be overcome to choose smart home technology are: cost, investment, organisation, functionality, lifespan, aesthetics and disruption. The impact of acquiring smart home and ICT technology was in most cases enough to reach 2050 targets, except in H30 and H39, solid wall households, which would need application of further measures to reach sufficient reductions. The reduction analysis suggests that smart home, HEMS and ICT could provide similar reductions to those likely to be achieved through expensive and disruptive retrofit measures and most importantly, it will impact energy consumption far more effectively than the replacement of appliances. The difference between investing in smart home technology and in retrofit measures is that participants do not need to change their lifestyle to achieve reduction through retrofit but they need to do if they will to reduce energy consumption through smart home technology. This fact needs to be taken into account when considering smart home technology as an enabler of energy reduction, as in itself it cannot guarantee it.
Table 3 Whole house energy reduction potential

<table>
<thead>
<tr>
<th>Reductions (%)</th>
<th>H05</th>
<th>H09</th>
<th>H10</th>
<th>H30</th>
<th>H37</th>
<th>H39</th>
<th>H46</th>
</tr>
</thead>
<tbody>
<tr>
<td>All measures applied</td>
<td>77</td>
<td>74</td>
<td>67</td>
<td>74</td>
<td>66</td>
<td>81</td>
<td>75</td>
</tr>
<tr>
<td>Only ICT measures</td>
<td>58</td>
<td>46</td>
<td>43</td>
<td>45</td>
<td>38</td>
<td>22</td>
<td>54</td>
</tr>
<tr>
<td>Participants agreed measures applied</td>
<td>61</td>
<td>69</td>
<td>63</td>
<td>70</td>
<td>59</td>
<td>80</td>
<td>64</td>
</tr>
<tr>
<td>Participants not negotiable reductions</td>
<td>16</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Reduction needed towards 2050</td>
<td>58</td>
<td>31</td>
<td>40</td>
<td>62</td>
<td>27</td>
<td>56</td>
<td>54</td>
</tr>
</tbody>
</table>

Conclusions

The main stated reason for the householders aiming to reduce their energy consumption was cost, which was unanimous across the participants. Therefore, to encourage householders to invest in building retrofit and new high efficient systems and appliances it is important to provide them with cost-effective options in the short term, with clear messages of the benefits they get from their investment. The development of policies to support investment in energy saving measures is therefore crucial if the modelled reductions are to be reached as well as provision of information from independent sources providing personalised feedback on possible savings, payback times and available financial assistance.

Householders’ background on energy consumption and the use of systems and devices in the home varied considerably; overall, householders understanding of energy consumption and the impact of their actions and the building characteristics and gadgets, was not enough to enable them to make the best decisions concerning energy demand reduction, either on a daily basis or when making retrofit decisions. This lack of information had influenced their decision making for example: choosing to invest in appliances that gave lower reductions on energy use than expected; opening windows and doors when the heating is on with no consciousness of the magnitude of the heat loss from it; using the central heating even if most rooms are not occupied or not being able to prioritize the best reduction measure because the benefit was not clear. Interestingly, the feedback of information on possible savings does not always lead people to wish to apply a change; in some cases, the value of comfort is higher than the possible financial benefit from applying a specific measure. Such reductions in comfort in the near future could be dissipated using ICT and smart home technologies, which can automatize user actions and avoid energy waste. Uptake of such smart technologies could be more strongly promoted in relation to energy demand reduction so that householders are more aware of the available technologies the potential benefits in terms of convenient energy demand reduction and how best to use them to make the most of their investment.

The impact from the modelled reduction measures is optimistic, suggesting that participants’ non-negotiable changes to their current energy consumption do not strongly impact on possible energy demand reductions. For all the houses in the study, households could apply their personal choices regarding the application of the considered measures and still achieve the reduction needed to meet the 2050 target. This will, however, require the design of decision support services that help households assess the potential energy demand reductions and cost savings achievable through investment in retrofit measures in relation to not only the performance of their individual house, but also in relation to their own lifestyle choices and the potential to enhance comfort and convenience through the targeted application of smart ICT based solutions.
Between empowerment and alienation. How feedback technologies can harm the prospects of successful energy transitions*

Susanne Jørgensen, Tomas Moe Skjølsvold, Marianne Ryghaug**, Department of Interdisciplinary Studies of Culture, Norwegian University of Science and Technology, N- 7491, Trondheim, Norway.11

Abstract

In this paper we explore the interaction between new “smart” energy feedback technologies and households. Based on in-depth qualitative video interviews with participants in two smart grid demonstration projects, the paper analyses how smart technology become integrated in the day-to-day activities of these households – how they interpreted and understood the technology, and in which way the technology became interwoven in processes of social learning. We have identified four kinds of relational re-arrangements that the feedback caters for: knowledge re-arrangements, material re-arrangements, social re-arrangements and routine re-arrangements. The re-arrangements illustrate how technological affordances opens for certain kinds of empowerment and action, while sealing off options for others, and through this we point to several design challenges.

Introduction

In this paper we focus on the role of one particular actor group, namely ordinary households. We study households that have been equipped with feedback technologies, with the goal of empowering and enabling more active energy consumption choices in this group. In this paper we explore how ordinary householders make sense of, and begin to live with new feedback technologies in an experimental demonstration setting.

Our analysis is based on nine in-depth qualitative video interviews with participants in two Norwegian smart grid demonstration projects. The households participated in Demo Steinkjer, and Demo Hvaler. At the time of the interviews, both these demonstration projects combined smart electricity meters with different solutions providing feedback to the users about their own consumption.

Domesticating smart energy technology: four relational re-arrangements

What roles were the feedback technologies ascribed as they entered the households? Our data indicates that they were given significance through four processes or re-arrangement, where the affordances of the technologies catered for new types of dynamics in the household. On the one hand, this is suggestive of the change potential associated with feedback technologies, but on the other hand the identified re-arrangements points towards substantial design challenges if the goal is to engage the household collective in more active energy system participation.

In the following analysis we discuss these four re-arrangements. While they appear below in a sequence, it should be highlighted that the four re-arrangements should not be read as a linear path.

* A full version of this paper will be published in the journal of Energy Research and Social Science.

** Presenter and corresponding author: marianne.ryghaug@ntnu.no
that must necessarily be followed, but rather as four potential dynamic states that the technologies allow for. In our data some of these re-arrangements are related, in the sense that the learning produced in one re-arrangement opens for new rearrangements, while closing off others.

**Knowledge re-arrangements**

As the technology came into the households, all respondents in our data reported an initial interest in trying it out. This interest was mainly individually driven by the men of the households, who began interacting with the feedback technology and tinkering with their electricity consumption. In this way, they described how they became increasingly familiarized with the way their building, household appliances and actions influenced their electricity consumption. Thus, the feedback technology served as an experimental device of knowledge re-arrangement, which allowed this particular group of users to understand how much electricity was consumed through various appliances and various practices. Hence, the feedback technology was considered a very useful information device, but it was only in combination with the creative user that it became practically applicable. Through this re-arrangement, electricity consumption changed from being invisible, intangible and mute, to become concrete, and in turn manageable.

Other examples from our data, however, indicates that the outcomes of such experimental procedures on behalf of the users should not be taken for granted, as sometimes the users were sensitized to the low electricity prices, leading them to conclude that changes were pointless.

Thus, the technology itself did not determine the outcomes for these three experimenters. Rather, the technology re-arranged elements of a pre-existing reality, where aspects such as the users’ beliefs about electricity prices, technology interest, and creative activities fed into the interpretation of the feedback as useful or not.

**Material re-arrangements**

Our data indicates that feedback technology might also lead to changing the physical infrastructure of the building through refurbishments, or replacing old household appliances. The feedback technology was interpreted as an information device that provided information about what they saw as problematic aspects of their consumption. Once the household infrastructure had been altered, and new settings implemented they did not interfere with the comfort or the day-to-day routines of others who lived together with him. They were examples of what others have dubbed “set-and-forget”-dynamics. This allows for the reduction of the overall electricity consumption of households by a few percent, but we are still far away from the actively engaged households operating as prosumers or providers of flexibility so often envisioned in the dominant discourse.

**Social re-arrangements**

So far, we have seen how the feedback technologies have catered for more or less individual projects on behalf of the men in the studied households. The results have been a set of knowledge re-arrangements and material re-arrangements, where outcomes have been differentiated. For instance, knowledge re-arrangements might not only lead to empowerment and energy action, but the rather the realization of how futile such action would be. Another outcome for some of the individuals by the knowledge-reconfiguration was the realization that much of the electricity consumption was out of the individuals’ control, and beyond the scope of what could be achieved through one-off material re-
arrangements. Thus, some of our respondents discussed the emergence of a need to re-configure some of the social relations in the household, often through new forms of internal control. The practical side of this consisted of attempting to establish new rules for how, when and why electricity could be used, collectively. This often led to conflicts in the household. A recurring theme in discussions on new rules was that while the men tended to focus on the kilowatt hours, the kroner (money) and the data generated, the remainder of the household inhabitants were more concerned about how they could make their everyday lives work under such a new regime.

**Routine re-arrangements**

A fourth kind of re-arrangement catered for by the feedback technology was the establishment of new modes of routinized interaction or co-existence with the feedback technologies. The character of these new routines differs across households, but tends to be characterized by some sort of “backgrounding” of the feedback technology and the information it provides. Some of the most eager users described this re-arrangement as de-intensification of the interaction with the feedback, because it was perceived as not providing new and relevant information over time.
Why Eco-Manager is Not Brilliant?

Mate Lorincz, University of Keele

Abstract
A frequent strategy to make energy ‘visible’ or ‘material’ is through electricity-display meters (Hargreaves et al. 2010). On the one hand, it is argued that ‘visible’ and ‘immediate’ energy monitoring help ‘individuals’ to reflect upon and change their level of energy consumption. On the other hand, recent literature suggests that individuals are more likely to ignore these energy monitoring devices - due to disinterest, lack of time or confusion as to what devices are actually displaying and materializing (Buchanan et al. 2014). One way to address this conundrum is to investigate how the Eco-Manager becomes integrated (or not) into newly established students households ‘everyday practices’. My research investigates the effect of the electricity-display meters in newly established student households and on their evolving everyday practices that consume electricity. Drawing on the insights of our preliminary analysis, I take this argument further by arguing that conceptualizing electricity as a resource for the performance of ‘everyday practices’ could help in understanding what electricity is and how it comes to matter (or not to matter) in the ‘everyday’ (Strengers 2013). Building on Strengers et al. (2012) approach on materialising energy systems as constituting practices of managing electricity, we will explore the know-how (or embodied habits), institutional knowledge, engagements and technologies (Gram Hanssen 2011) of ‘electricity-managing practices’, the electricity that they produce and the ways in which the electricity is integrated into ‘everyday practices’. In conclusion, I will argue that the ‘materialization’ through Eco-Manager is restricted to ‘individual’ physicality (or to the needs of the body) (Pink et al. 2012).

References
SESSION 4A: Beyond Domesticity: Feedback Outside of the Home

**e-Genie (Goal-setting and EEnergy Information Engagement) in the workplace**
Alexa Spence*, Nick Banks, Ben Bedwell, Enrico Costanza, Eamonn Ferguson, Murray Goulden, Mike Jewell, Caroline Leygue

*Presenting author; Corresponding author – alexa.spence@nottingham.ac.uk
1 University of Nottingham
2 Centre for Sustainable Energy
3 Southampton University
4 Southampton University (now Scenescope)

**Abstract**

Whilst a large proportion of carbon emissions stem from workplace buildings, research examining interventions to reduce energy use in this space is sparse. We developed a tool – e-Genie – to engage workplace occupants with energy data to encourage energy savings and trialled this in a small organisation in London. Engagement was only moderate and certain parts of the tool received little attention. Users particularly engaged with the tool in terms of existing space issues, in this case thermal comfort complaints whilst electricity data and tools for taking action were mostly ignored. Building users were motivated to save energy at work but felt that they didn’t have much control over their use of electricity. Our data points to the need to inform and support building users in recognising where they can make a difference, e.g. in cooperative actions, such as asking managers for change, or discussing energy saving with colleagues. We conclude that energy engagement tools will be most successful in relation to existing issues in the specific building context and in order to engage building users with energy more broadly, a clear use-case must be defined or further incentives (e.g. rewards, gamification) utilised.

**Introduction**

It is estimated that around 1/3 greenhouse gas emissions in the UK come from non-industrial workplace buildings (DECC, 2011). However studies intervening to reduce energy use in a workplace setting are few (Staddon et al., 2016). Notably the workplace setting is different from a residential setting, given that users do not pay for electricity used, are in a social environment, and are subject to organizational rules and policies (Bedwell et al., 2014). Encouragingly, it is observed that motivations to save energy in the workplace are generally high (Leygue et al., 2016).

The role of the Facilities Manager (FM) has a particularly pivotal role in the potential for achieving energy savings in a workplace but requires the support to do so (Goulden and Spence, 2015). Negotiations around energy use and management in the workplace are complex and there is a need to support communications between building users on this topic as requests made to the FM are often conflicting and disruptive to other areas. Given energy saving hasn’t traditionally been a focus in the workplace, leadership from senior management is particularly important in driving changes (Bedwell et al., 2016; Goulden and Spence, 2015) and empirical evidence supports this, with the most successful energy saving campaigns featuring strong management leadership (Staddon et al., 2016).
A systematic review of previous interventions to save energy in the workplace has identified enablers (providing autonomy and support to employees), and modelling (various forms of social influence) as key features of previously successful interventions to save energy in workplace buildings (Staddon et al., 2016). The use of environmental restructuring is also a key feature of a successful energy saving intervention but the ways in which this can be done are disparate ranging from the installation of automation technology, to the use of signs and posters, to the use of electronic energy feedback devices. It is difficult to demonstrate the impact of energy displays given that these are often combined with other intervention features, however there are indications that information alone is not enough, and other features, such as additional control or automation, are likely to make this kind of intervention more successful (Staddon et al., 2016).

Many energy displays installed are simple methods of communicating data that can be updated frequently however displays allowing user interaction may be more engaging. For example, displays in a domestic environment have demonstrated that those that allowed users to view, annotate and reflect on energy traces in the domestic environment particularly enabled users to relate energy consumption to their daily activities (Costanza et al. 2012).

Current Research

The current research aims to integrate interdisciplinary insights in the development and building of a new energy engagement tool, named e-Genie (Goal-setting and ENErgy Information Engagement). We integrated interactive features into this energy feedback tool in order to engage building users with their energy use rather than simply displaying energy consumption data. In addition, given individuals are already motivated to save energy, we focused behavioural engagement aspects on helping individuals plan how to transform their motivations into behaviour (using implementation intentions; Gollwitzer & Sheeran, 2006). Furthermore, taking into account the observation that the potential for individual behaviour change is often limited, we had a focus beyond individual behaviour to consider collaborative behaviours and organisational policy changes. The e-Genie tool provides energy information feedback (both electricity and gas) to building users, and encourages engagement with that information through labelling energy patterns observed, and acting on usage observed by contacting the FM, discussing issues with other building users and through planning behaviour changes.

Method

Study Design

An early version of the e-Genie platform was deployed at the Digital Catapult in London in April 2016 in order to test the functionality of the system, to engage building users with the building’s energy use and to encourage energy saving behaviour. The platform was launched with a lunchtime seminar, providing background about the tool to the building users, and using promotional materials (e.g. e-Genie branded chocolate) in order to incentivise engagement. The functionality of the platform was evaluated through technical monitoring of the data feeds and through ethnographic research. User engagement and impact evaluation were evaluated through ethnographic research, ad hoc user interviews, and via a survey conducted pre deployment of the e-Genie platform and approximately two weeks post deployment.

Deployment Site

The Digital Catapult is a not for profit organisation funded by Innovate UK in order to support breakthrough ideas and innovations in the digital economy. It is housed in a modern building next to Kings
Cross station in central London and houses around 60 occupants at any one time, many of whom are only based in the building for a temporary period of time (approximately a few months).

**e-Genie**

The e-Genie tool has two main sections: front screens which provide energy information feedback (both electricity and gas) and which scroll periodically, and further screens that users reach by ‘Taking Action’ to support discussing and changing behaviour and reporting energy related faults (see Figure 1).

![Figure 1: E-Genie screen shots of three front screens, which provide energy information (Temperature calendar, Annotation tool and the Always on tool) and the Pinboard, which supports discussion around energy issues.](image)

The energy data screens comprise a Temperature calendar (see Costanza et al., 2016), circuit monitoring of electricity with an Annotation tool so users can label usage observed (see Costanza et al., 2012), and an ‘Always on’ tool which provides information about overnight baseload usage. We also provided digital thermometers and thermal imaging camera add-ons for mobile phones that building users could borrow to explore their environment. Support for taking action comprises planning for individual behaviour change by encouraging people to think through and plan their actions more specifically (using implementation intentions) then pledging to make a change, a ‘Pinboard’ discussion space which supports interactions amongst building users, and a direct link to the building’s facilities manager for more straightforward actions.

The e-Genie system is a website accessible via [http://e-genie.co.uk/](http://e-genie.co.uk/). The website is responsive, adapting visually to desktop and mobile web browsers to support two use cases: 1) opportunistic use by
staff as a situated display on tablets mounted at strategic "public" locations within the workplace (e.g. by the watercooler), and 2) private use by individual members of staff on their own desktop or mobile devices. To alleviate possible concerns about privacy, the complete website was only accessible via devices connected to the workplace LAN (either in the building, or via VPN); external devices are only able to access e-Genie's front screens (and in this case only to view, not to annotate).

The implementation of the website was tightly coupled with the Digital Catapult workspace, visualising data generated by temperature sensors (developed by Wireless Things) placed in spaces around the workspace, and electricity monitors (produced in-house) deployed at the buildings electrical incomers and consumer boards (to capture both aggregate and circuit level electricity consumption). Data from these sensors was fed to data hubs (Raspberry Pis) on the LAN that periodically pushed the data to a remote data store, which was accessed and visualised by the e-Genie website.

Results and Discussion

The use of the e-Genie system overall was limited (N = 10; approximately 17% of building users). It was clear there was room for improvement in the design and support of the system in order to make it more focused, more engaging, and more robust.

Ethnographic evaluation

Whilst many occupants did try interacting with e-Genie, many of them did not go further than the front screens. The system requirement for users to log in to use certain aspects may have put people off exploring the tool. Observations and interviews suggest users found the system offered too much information and too little guidance. There was a general uncertainty about how the system was supposed to be used. This suggests the use case needs to be better defined. Where people did engage it tended to be through the prism of what is most tractable to them, in this case, thermal comfort complaints. It was notable that the Digital Catapult office, even though very new, suffers from the same issues seen in other office buildings in the C-tech project, with frequent dissatisfaction with thermal comfort. This dissatisfaction maps according to both personal preferences and location in the office relative to the position of HVAC vents - as one office member put it “If they're cold down the end, they’ll turn it up and then we’ll be boiling hot”.

Occupants of the Digital Catapult (like many other buildings) have little direct control over their use of electricity (e.g., laptop or monitor already automatically turn off) and heating at work, which means that e-Genie needs to do a better job of supporting the user to recognise where they can make a difference.

In regards to the supporting equipment which was made available (thermometers and thermal cameras), their usage supports the points above. The thermal cameras, whilst attracting interest, were largely unused as people were not clear on what the use case was. The thermometers however were adopted and used by several occupants, reflecting how thermal comfort is a highly tractable issue for workplace occupants. Where data from the thermometers was used it was in direct communications with the FM, rather than with e-Genie. This suggests there is more work to be done on linking the supporting tech to the software.

Survey results
Survey results (sample size, N = 7) show that participants feel some “instrumentality” in their energy use at work, see Figure 2. That is, they think that their energy use does have an impact on climate change, as well as their organisation’s energy use and financial situation. However, they didn’t feel they had much control over the energy that is used in their workplace. Generally participants appeared to have fairly high motivations to reduce their energy use at work, with a mean level of motivation of 4.08, just higher than the midpoint of the 7-point scale (a unipolar importance rating from not very important to very important).

Energy saving behaviours that were reported to be performed most often were to report energy waste, put on warm clothes when they feel cold (rather than change the thermostat), and take part in energy saving campaigns. The behaviours reported as least likely were to take into account energy consumption when making new purchases, and to discuss energy saving measures with colleagues; these are aspects that could be supported in future organisational initiatives. Note that pre- and post survey comparisons were not possible due to a low sample size at time 2.

Technical evaluation

This deployment also enabled the testing of the robustness of the data collection infrastructure, the ease with which the situated tablets could be kept operational over complete working weeks, and the extent to which we could monitor the deployment remotely. Key weaknesses in the infrastructure were highlighted: wifi network dropouts; ‘freezing’ of data hubs; and server issues. These technical problems are perhaps unavoidable but must be managed to minimise interference and to maintain trust in the system. In particular we observe that the identification and recruitment of someone on the deployment site responsible for monitoring the tool and dealing with the problem or alerting the research team is important.

General Discussion

Engagement in e-Genie was only moderate in this first trial of the system however valuable insights, into both the tool and energy use within the workplace, were gained. Primarily, we conclude that building users will need a clearer use-case, or incentives, for engaging with a system such as e-Genie. A clearer use-case might be achieved through by defining clear tasks for users, e.g. challenges for users to achieve around energy, which would require engaging with the system. This could be achieved...
through working with the FM to identify local issues that need to be addressed. Alternatively users could be supported to generate their own tasks, for example through workshop discussions. Incentives such as performance related targets or gamification related goals could also be introduced to encourage engagement.

We propose that the system overall needs to be more focused, and possibly simplified, again with the intention that the use case is clearer. One possibility in achieving this is to focus e-Genie more around thermal comfort issues, given that this is a problem that occurs across a large number of workplace buildings. We highlight it is important here to support communications around comfort issues, given the subjective nature of comfort with the aim of resolving issues to reduce the number of conflicting demands placed upon the FM. Simplifying the system, may reduce it’s utility however. Whilst electricity may be of less interesting to building users generally, the removal of such a feature means that at certain points when this might be interesting, e.g. installation of new equipment, the information is not available.

This trial has allowed us to test the technical robustness of the system also needs to be more technically robust. In future, we recommend monitoring in place to automatically identify failures in the web and local infrastructure. We also propose that responsibilities need to be defined within the project team and in the workplace for regularly checking that the infrastructure is operating as expected.

Conclusions

We developed e-Genie - a theoretically grounded system for visualising energy data in the workplace and engaging building users with understanding and reducing workplace energy use. Building users engaged with e-Genie primarily around existing issues of thermal comfort and ignored electricity screens and tools for supporting behaviour change. Users were motivated to save energy but felt little control over their energy use behaviour. If energy engagement is desired within the workplace then building users should be encouraged to recognise where they can make a difference in energy saving and enabled in doing so, particularly in relation to undertaking cooperative action and asking for organisational changes. Energy engagement tools are likely to be most successful in relation to resolving issues that already exist within a building. In order to engage building users with energy more broadly, a clear use-case and/or incentive mechanism is likely to be needed.
References


Energy Feedback in the Workplace: Effects of Display Units

Caroline Leygue and Alexa Spence, School of Psychology, University of Nottingham

Presenting author: Caroline Leygue, caroline.leygue@nottingham.ac.uk

Abstract

This research investigates energy visibility and the utility of energy displays in the workplace. In two studies using scenarios and mock-up displays, we examined the impact of framing energy use in terms of costs (£), carbon (CO₂) emissions or a combination of both. In study 1 (N = 93), we observe that the changes in display units, and potentially in numbers, affect the extent to which participants feel their savings can make a difference (i.e., instrumentality), which in turn affect energy saving intentions, indicating that CO₂ displays might be the best option. In study 2 (N = 142), we controlled for these differences in numbers to look at the differences in units only. Results reveal that units alone don’t affect instrumentality, but saving intentions and further sustainable choices, indicating that giving feedback in terms of costs, even if employees don’t pay for their energy use at work, might be beneficial. This contrasting pattern of results reveal that best type of unit will depend on the choice to give numerical feedback or not.

Introduction

Energy displays in the workplace

The British government, through energy companies, proposes to rollout smart meters across Britain by 2020. Research has indicated that these devices may help consumers to reduce between 5 and 15% of their energy usage, however most of the existing studies focus on energy at home and research in the workplace is scarce.

It has been suggested that around 33% of greenhouse gas emissions in the UK and 17% in the US are released from shared buildings within the business sector (non-industrial) (DECC, 2011; United States Department of State, 2010). Current advances on reducing energy use in workplaces has mostly focused on improving appliances, system efficiency, or appointing key personnel with energy responsibilities (e.g., facilities managers, eco-champions) (Aragón-Correa, Matías-Reche, & Senise-Barrio, 2004; Cordano & Frieze, 2000). There has been little investigation of how normal, individual workers (with no energy responsibilities) may change their own energy use behaviour to reduce emissions.

Carbon vs Costs Framing

Research has shown that considering units of displays, e.g., costs, carbon emissions is important for their usefulness in the home, but it remains a question on what will be their effect in the workplace. Indeed, it has been shown that costs will be the most popular display in the house, but in the workplace, typically employees don’t pay for their energy use, so their effects might be different. Furthermore, it has been shown that showing energy use and savings in these terms could trigger a backlash, as the low amounts of money saved made people think their savings were not worth their efforts engaged in trying to reduce their energy use (Spence, Leygue, Bedwell, & O’Malley, 2014).

So, framing energy use in terms of carbon emissions can reduce that feeling that “it’s not worth it”, and can also encourage other environmental behaviours (behaviour spillover) (Spence et al., 2014).
However, the question remains whether these results can be generalised to the workplace, where energy use is “free of charge” for most employees, and where many electrical appliances are shared.

**Present research**

With the current research we want to fill in the gap in the existing literature regarding energy saving in the workplace. Campaigns and interventions would benefit from the introduction of monitoring of savings progress and the question of displays rise naturally from this. Even more, the question of units is important, as their effects in the work context is bound to be different from their effect in the home, where motivations to save energy are different. Furthermore, the present research looks at the mechanism underlying these effects, and is the first to disentangle the differences between units and the confounded differences between numbers. In study 1, we will look at the effects of energy units on energy displays as they would appear “in real life”, that is, accompanied by large differences in the amounts reported. In study 2, we look at the mechanisms underlying these effects and investigate whether they are due mainly to the units or to the differences in amounts. To achieve this, in study 2 we kept the numbers appearing on the displays the same across all conditions, and talked about “X units of pounds/CO₂”

**Study 1**

**Method**

Participants. Participants were recruited in 3 companies, of which two were for-profit and one not for profit. In total, 93 people participated in the study, 66 men and 27 women, aged between 18 and 62 (M = 31.5, SD = 10.66).

**Scenarios and Displays**

Participants were asked to read a scenario where they had to imagine that they had started a new job and their company was introducing a campaign to encourage their employees to reduce their energy use by at least 10%. This was followed by two vignettes containing images of energy displays, where their initial energy use before the campaign and their use afterwards, reduced by 10%, was described. These vignettes and displays differed according to the condition participants were randomly assigned to. In the costs condition, energy use was reported in the scenarios and on displays in terms of pounds, e.g., “at the end of the month, you look at the display and it shows a cost of £21.50 for your energy use this month”. In the carbon condition, energy use was reported in terms of CO₂ emissions, e.g., “at the end of the month, you look at the display and it shows 65.38Kg of CO₂ emissions for your energy use this month”. In the combined condition, energy use was reported both in terms of costs and CO₂ emissions, e.g., “At the end of the month, you look at the display and it shows a cost of £21.50 and 65.38Kg of CO₂ emissions for your energy use this month”¹, see figure 1 for examples of displays.
Dependent variables

Instrumentality. Instrumentality was measured by 3 items, focusing on the effects of energy saving on climate change, the company’s finances, and the company’s total energy savings, e.g., “I believe that my energy use has an influence on my organisation's total energy use.” Participants had to reply using a Lickert scale from 1 “completely disagree” to 7 “completely agree”, Cronbach’s α = .74.

Behaviour intentions. Energy saving intentions were measured using 17 items (Cronbach’s α = .90). People had to state the extent to which they were likely to adopt these behaviours in the future on a scale ranging from 1 “very unlikely” to 6 “very likely”; a “not applicable” option was also available, see figure 2 for the list of items.

a. Suggest procedural changes to save energy  
b. Discuss energy saving measures with colleagues  
c. Turn off communal office equipment (e.g., printer, copy machine, lab equipment) after using them  
d. Put on layers of clothes rather than use additional heating  
e. Overtly disapprove (e.g. frowning, commenting) of other people wasting electricity  
f. Speak to key people in charge about energy issues  
g. Consider energy efficiency or environmental factors when requesting a new purchase  
h. Turn off your printer before leaving for the day
i. Turn off communal office equipment (e.g., printer, copy machine, lab equipment) before leaving for the day
j. Turn off your computer before leaving for the day
k. Turn off your computer/monitor when you are away from your desk for a period of time (e.g. lunch)
l. Turn off shared appliances when you leave at the end of your day
m. Take part in a campaign about an energy issue
n. Remind a colleague to switch something off to save energy
o. Turn off the lights before leaving for the day
p. Turn off your monitor before leaving for the day

Figure 2: List of behaviours used in the measure of energy saving intentions in Study 1 and Study 2.

Results and Discussion

Dummy coding was used to represent the different feedback conditions. We used the cost condition as a baseline (coded 0 in both dummy variables) as it will be the most common feedback unit in the general rollouts. Dummy coding enabled us to compare the cost condition relative to the CO\textsubscript{2} condition (represented by D\textsubscript{1}) and also compare the cost condition to the combined condition (represented by D\textsubscript{2}).

Instrumentality. The regression analysis using D\textsubscript{1} and D\textsubscript{2} as independent variables and the average score of instrumentality as dependent variable shows a significant effect of D\textsubscript{1} ($B = 0.83$, $p = .02$) and a non-significant effect of D\textsubscript{2} ($B = 0.14$, $p = .69$), adjusted $R^2 = .04$. Presenting energy use only with CO\textsubscript{2} emissions compared to only with costs increases instrumentality: people feel their energy use has a bigger impact.

Behaviour intentions. Regression analysis reveals an non significant effect of D\textsubscript{2}, ($B = 0.18$, $p = .50$), and a marginal effect of D\textsubscript{1} ($B = 0.46$, $p = .08$), adjusted $R^2 = .01$. We used a mediation analysis to examine whether instrumentality could explain potential effects of displays on energy saving intentions.

We took a general linear model approach to modelling a mediation effect to look at group differences of interest within the display conditions, and used PROCESS statistical software to model the data (see Hayes and Preacher, 2012). The same dummy coding was used to represent the different display conditions (D\textsubscript{1} and D\textsubscript{2}). Due to the strict assumption of normally distributed data within the product-of-coefficients approach to mediation, we used bootstrapping to resample the data 1,000 times in estimating the indirect effects. There were no missing data in the variables of interest. Analyses revealed that when comparing cost and combined conditions (D\textsubscript{2}) there is no significant difference in instrumentality ($B = 0.14$, $ns$), however when comparing cost and CO\textsubscript{2} conditions with one another, the CO\textsubscript{2} display significantly increased instrumentality ($B = .83$, $p < .05$), confirming results of the previous regression. A higher instrumentality in turn was associated with higher levels of energy behaviour intentions ($B = 0.42$, $p < .01$). We found that the relative indirect effect for D\textsubscript{1} comparing the cost and CO\textsubscript{2} conditions was significant ($B = 0.35$, $p < .05$) and that both remaining direct
effects of \( D_1 \) and \( D_2 \) were non significant, \((B = 0.12, \text{ ns } \text{ and } B = 0.14, \text{ ns}, \text{ respectively})\). So for those who interacted with the \( \text{CO}_2 \) version of the display, instrumentality increased more than in other versions and this translated into higher intentions to undertake energy saving behaviours, see figure 3 for the mediation.

![Diagram showing mediation model](image)

**Figure 3:** Mediation model representing the direct effects of display on energy saving intentions, as well as their indirect effects through instrumentality.

### Study 2

#### Method

Participants. Participants were taken from an opportunity sample using the snow-ball method. The inclusion criteria to participate was to be currently employed in a full-time or part-time job. One hundred and forty two people took part in the study, of which 90 were women and 52 men. They were aged between 16 and 62 \((M = 35.8, \text{ SD } = 14.18)\).

Scenarios and Displays. As in study 1, the scenario asked participants to imagine their company had introduced a new policy to encourage their employees to reduce their energy use by at least 10%. The two vignettes that followed also contained images of energy displays, with initial energy use and use afterwards, reduced by 10%. This time, these uses were described in all conditions in terms of “units of £/ \( \text{CO}_2 \)” and showed the same numbers of units. For example, initial energy use was reported in the scenarios as 12 units of £ (GBP) in the cost condition, 12 units of \( \text{CO}_2 \) in the carbon condition, and as 12 units of £ (GBP) and \( \text{CO}_2 \) in the combined condition. On the displays, next to the number of units, was placed a £ sign and/or a \( \text{CO}_2 \) sign, according to the condition\(^2\).

Instrumentality. Individual instrumentality was measured with the same 3 items as in study 1 (Cronbach’s \( \alpha = .89 \)). Group instrumentality (Cronbach’s \( \alpha = .90 \)) was assessed using 3 items focusing on the same aspects as individual instrumentality, with the difference that the instructions specified “I believe that the energy use of my colleagues and I has an influence on my organisation’s total energy use/on climate change/on my organisation’s financial situation”.

---

"Feedback in energy demand reduction: Examining evidence and exploring opportunities“ Edinburgh, July 2016Page 138
Energy saving intentions. The questionnaire included the same 17 items measuring intentions to save energy at work as in Study 1 (Cronbach’s $\alpha = .90$).

Budget allocation task. To look indirectly at actual sustainable choices, we used a budget allocation task, in which we asked participants to distribute a budget of £100,000 among 5 possible features for their workplace. To do this, they were given a choice of 20 features, of which 5 were sustainable (e.g., Ensure building operates at zero-carbon emissions by using Microgeneration).

Results and Discussion

The same dummy coding as in study 1 was used, to compare the cost condition relative to the CO$_2$ condition ($D_1$) and the cost condition relative to the combined condition ($D_2$). Both dummy variables were entered into linear regression analyses (OLS) to investigate their effects on each dependent variable.

Instrumentality. The unit of display had no effect on individual instrumentality or group instrumentality. For individual instrumentality, neither $D_1$ ($B = 0.35, p = .30$) nor $D_2$ ($B = -0.42, p = .20$) reached a significant effect (adjusted $R^2 = .02$). The results were the same for $D_1$ ($B = 0.30, p = .37$) and $D_2$ ($B = -0.47, p = .16$) for group instrumentality (adjusted $R^2 = .02$).

Energy saving intentions. Regression analysis using $D_1$ and $D_2$ as independent variables and the mean of energy saving behaviour intentions reveal that $D_1$ has no significant effect ($B = -0.31, p = .20$) however $D_2$ has a significant effect ($B = -0.49, p = .04$) on behavior intentions (adjusted $R^2 = .02$). Interestingly, it seems that compared to a costs display, presenting a combined display will decrease energy saving intentions.

Budget allocation task. The amount of money allocated to sustainable features was summed to compute a score of sustainable choices. This score was not further transformed as the distribution was not very skewed, $z_{\text{skewness}} = -.45, \text{ns}$, however kurtosis was significant, $z_{\text{kurtosis}} = -2.19, p < .05$, indicating a somewhat flat distribution. The OLS regression analysis indicates that $D_2$ has no significant effect ($B = -3051.84, p = .47$) however $D_1$ has a significant effect ($B = -11121.89, p = .01$) on budget allocations (adjusted $R^2 = .04$). This indicates that when the display gave feedback in terms of carbon emissions, people were likely to spend less money on sustainable features compared to when the display gave feedback in terms of costs, which is the opposite of the hypothesized spillover effect. This could be due to the fact that in the scenario, they succeed in reducing their energy use, so this could be a rebound effect.

General Discussion

Our research is the first, to our knowledge, looking at the effects of energy displays in the context of the workplace. Furthermore, it is the first time differences between displays are disentangled to explore the mechanisms underlying their effects. Two fundamental aspects in energy saving were observed as dependent variables: instrumentality, that is, the extent to which people will feel their contribution makes a difference, and behaviour intention.

Our results replicate results found in the context of home usage (Spence et al., 2014), in the context of workplace usage, and show that giving energy feedback in terms of carbon can alter the “not so worth it” effect of costs feedback, even when people don’t pay for their energy use (Study 1). However, they
show that these effects might not be due to the “environmental” aspect of the feedback, but to the high numbers. Indeed, when the confounded difference in numbers is removed, we observe that giving feedback in terms of costs might be the best option (Study 2). Interestingly, our results here are similar to the effects found in Evans et al. (2013), where presenting both costs and environmental arguments can be detrimental to environmental behaviour.

Our research contains a number of limitations that should be corrected in future studies looking at the effects of energy feedback in the workplace. Most importantly, the sample should bigger and allow for comparisons between job roles in the workplace. Also, direct measures of energy saving behaviours should be used, such as frequency of computer shut down, or electricity use monitoring.

Despite these limitations, this study brings important implications for policy on sustainability in the workplace. Our results show that taking into account energy units, on displays and potentially in campaigns more generally, is necessary in achieving the best possible results in energy saving at work. When spaces and behaviours are monitored to track energy use and energy savings, displays showing actual usage with exact numbers should preferably report usage in terms of carbon emission, to counter the potential backlash effect of the small numbers in displaying energy use in terms of costs. However, a solution can be found to this by showing the usage of several people (see Bedwell et al., 2014). Other types of feedback exist, that do not include digits, or at least do not focus on digits: e.g., traffic lights type of displays, or speedometer type of displays. In this case, using costs as a unit of feedback can be more useful than other types such as carbon units or a combined display.

Footnotes

1 In the combined condition, the order of presentation of costs and CO₂ emissions in the scenario and on the display was counterbalanced. Participants randomly assigned to that combined condition were in turn randomly assigned to one of the two orders of presentation. Participants in both order conditions were gathered for all analyses, as order of presentation was not part of our investigation here.

2 As in study 1, the order of presentation of costs and CO₂ emissions was counterbalanced in the combined condition.

References


Energy feedback in office workplaces: approach, design and implementation

Magdalena Boork (presenter), SP Technical Research Institute of Sweden, Sweden, email: magdalena.boork@sp.se
Cecilia Katzeff, KTH Royal Institute of Technology, Sweden

Abstract
This presentation includes the approach, progress and intermediate results from a Swedish research project on energy feedback in office workplaces carried out in 2011-2014, with a follow-up project running 2015-2017. The project aims at exploring how office workplaces can turn energy feedback into action by supplying energy visualization tools and implementing energy feedback in organizational processes. The approach includes participatory design workshops in the development of visualization prototypes, an intervention program comprising reflective workshops and assignments to initiate a process towards more energy efficient practices, as well as interviews to study the organizational change. The long-term goal is permanent behavioural changes and reduction of so-called absence electricity (electricity used when no one is present) in individual office rooms. The first project phase focused on developing and implementing a system of three visualization prototypes in one office workplace. In the second phase, a 1.5 year intervention program is applied at four different office workplaces to explore how organizations can incorporate and translate energy feedback into sustainable practices. The presentation describes both project phases.

1. Introduction
Office premises have undergone major energy efficiency improvements since the 1990s and the total energy supply is lower than 25 years ago (Statens Energiinmyndighet, 2007). The electricity use is more or less constant, despite the increased amount of electrical equipment. Still, there is a great potential for further efficiency inherent in the use of electrical equipment and employees’ routines. These workplace practices form the basis for how energy is handled within the organization (Palm, 2009; Palm & Thollander, 2010; Stephenson et al., 2010). Research has shown that although the introduction of electricity-feedback tools for households or workplaces generally may lead to an increased awareness of electricity use, they are not sufficient to achieve lasting energy efficiency (e.g. Pierce & Paulos, 2012; Katzeff, Broms, Jönsson, Westholm & Räsänen, 2013). The goal of reducing electricity consumption is for example often in conflict with deep-rooted workplace routines and productivity motives (Katzeff et al., 2013).

Although energy use at workplaces is often associated with productivity and necessary working tasks, there is also unnecessary energy use, such as computers and lighting turned on when no one is present. In the following we call this ‘absence electricity’. It does usually not serve any purpose and therefore constitutes a considerable energy saving potential. The responsibility for energy use at office workplaces is, however, not always obvious. Management seldom focuses on energy saving routines, while employees lack motivation and a sense of responsibility since energy savings are rarely rewarded (Jain, Agrawal, Ghai, Truong & Seetharam, 2013; Katzeff et al., 2013).

Research on people’s energy use has so far primarily focused on households (Schwartz, Betz, Ramirez & Stevens, 2010; Hargreaves, 2011; Katzeff et al., 2013). Even though employees are part of different types of households, the energy-related behaviour tends to be different at home and at work. Energy visualizations can increase the attention and discussion on energy issues, but it is not enough to achieve lasting and sustainable practices. Hargreaves, Nye and Burgess (2013) found that household users eventually lose interest in the visualization monitors and behavioural changes beyond the initial
were not achieved. Similar conclusions were drawn from experiments with visualizations in office workplaces in Katzeff et al. (2013). Therefore, the workplace routines need to be handled as well. Strong leadership is an important factor to motivate the organization in change initiatives (see for example Katzeff et al., 2013 and Hiatt & Creasey, 2003).

The research presented here aims at exploring the possibilities for office workplaces to turn energy feedback into action by supplying energy visualization tools, but also by implementing energy feedback in organizational processes. The main long-term goal is permanent behavioural changes, resulting in lasting reduction of so-called absence electricity in individual office rooms. The first project phase focused on the development and implementation of a system of electricity visualization prototypes addressing different types of feedback on both individual and joint electricity use. The second, ongoing, project phase focuses on how organizations can incorporate and translate energy feedback into action to achieve sustainable practices. This presentation includes both project phases and preliminary results until June 2016 and is built on Boork, Gustafsson, Dijkhuis and Katzeff (2015) and Boork, Katzeff and Balksjö (2016).

2. Methodology
In the first project phase, a participatory design approach was used to involve end-users in the design process and in the project. By involving users from the start of the design process, their ideas and needs are catered for in the creative early phases of the process. In the later phases their evaluation of the system certifies its usability and user quality.

In the second project phase, management and staff at four different workplaces were recruited to collaborate to reduce electricity use at their respective workplace. Besides electricity feedback via a visualization tool, workshops are arranged at each workplace as part of an intervention program (see section 4). The workshops aim to initialize the energy efficiency efforts, introduce methods and means to reduce energy use and develop and plan for the implementation.

The process of change at the workplaces is studied through both qualitative and quantitative data collection. Qualitative methods include focus group interviews (Wibeck, 2010), observations (Bryman, 2007) during workshops, and through log books kept by participants at each workplace. Electricity use data from each workplace is also monitored. It is used to establish the energy saving potential and is also analysed in relation to the qualitative data.

3. Designing energy visualization tools for office workplaces
The first project phase included one single workplace, where 30 office rooms were equipped with advanced measurement and control systems providing detailed data on heating, ventilation, lighting, electricity and presence for each room. Most employees work with energy technology and energy efficiency. A substantial part of the employees combine traditional office duties with laboratory work in the test facilities in the same building. The profession and competence of the employees were considered an advantage in the development of new energy visualization tools targeting office workplaces. For details on this project phase, see Boork et al. (2015).

A participatory design approach was used to involve end-users in the design process, see Figure 10. The initial work was focused on mapping the workplace culture and routines, including employees’ freedom of action. The mapping was primarily based on cultural probes methodology (Gaver, Dunne & Pacenti, 1999). Three office spaces were identified as particularly important:

- The individual office room for its privacy.
- The **lunch/coffee room** for informal discussions and to bring visitors to have coffee.
- **Meeting rooms** for formal discussions.

Figure 10. Employees were invited to participate in the design, development and implementation process. Left: Design workshop. Right: Installation event for the artistic energy visualization tool where each employee mounted an avatar representing themselves on to the metallic frame.

The mapping was followed by a design process including design and co-creation workshops as well as interviews for feedback and input to the process. Some recurring themes played particularly important roles in the design and development, namely:

- **Competition** triggers the employees.
- **Rewards**: Collective rewards are considered more desirable than individual. Attention from co-workers and management is sufficiently rewarding for individuals.
- **Technical presentation**: Most employees are engineers and asked for well-known presentations such as graphs and key figures.
- **Absence electricity** was selected for historical and peer comparison since it in many cases does not serve any purpose and therefore constitutes a considerable energy saving potential. It further provides a sense of fairness when comparing the electricity use of different employees, since it depends less on the various needs of equipment to carry out different types of duties.
- **Image-building**: Employees wanted to show customers and visitors that they ‘live as they learn’, i.e. being energy efficient.

A system of three electricity visualization prototypes was designed and implemented at the workplace. Feedback was given both on individual basis (through a PC application) and on collective basis (on a screen in the reception area and by an artistic representation in the lunch room), see Figure 11.

Figure 11. The system of the three electricity visualization prototypes: a) individual electricity use feedback on the PC (left), b) joint electricity feedback on a screen in the reception area (middle), c) joint electricity feedback via an artistic representation in the lunch room (right).

Throughout the first project phase, office workers pointed to lack of focus on and appreciation for energy efficiency from the management. The second project phase therefore comprises four different
types of office workplaces, where various methods and means for integrating electricity feedback into sustainable practices will be tested in collaboration with employees and management.

4. **Intervention program to promote reflection and change**

The second project phase is carried out as a field experiment with employees and management at four office workplaces. The competences and working duties vary between the different workplaces. The project engagement at each workplace is mainly driven by a specific person (usually an “enthusiast”) and the decision to participate was usually taken by the workplace management. This means that the workplaces participate voluntarily, while individual employees could not choose to sign up or not, but were engaged due to their group affiliation.

The 1.5 year intervention program aims to initiate a process towards more energy efficient practices and routines, built on collaboration between employees and management. The main types of activities include: a) *Workshops* aiming to initialize each stage in the program, b) *Electricity feedback* to support awareness regarding the correlation between practices and energy use, and c) *Assignments and activities* individually designed for each workplace to keep up a continuous process towards increased energy consciousness.

The intervention program can be divided into three stages:

1. **Mapping energy-related practices** and energy use at the workplaces, create interest in energy issues among the participants and begin to reflect on energy use and energy-related behaviours. This stage aims at initializing increased awareness of energy use in the daily life. Workshops were held in April and May 2016 (see Figure 12) and this stage has now been completed.

2. **Electricity feedback** aims to further strengthening the energy awareness among the participants and to turn the new knowledge into action. The participants get access to a PC application providing feedback on the electricity used in the individual office room or work station. Compared to stage 1, where activities were mapped, the participants are here provided by real consumption data, which gives them the possibility to link specific activities and electricity use. Stage 2 will be initiated in June to August 2016.

3. **Organizational change.** The aim is to implement energy feedback in the organizational processes at each workplace. This includes working out strategies and new sustainable...
routines in collaboration between employees and management to promote lasting energy efficient practices at the workplace.

Each stage includes one workshop, held at the individual workplace, as well as assignments correlated to the specific theme. A final joint workshop will be arranged to allow all participants to meet and exchange experiences and to formulate implications for future work.

4.1. Feedback on individual electricity use

The PC application for individual electricity feedback was further developed based on the experiences and user-tests from the first project phase. The feedback focuses more on absence electricity and provides automatic feedback as the user returns to the office after an absence period, see Figure 13. The electricity used during the last absence period and a comparison between the different days of the week are provided by default. Energy information, such as energy saving tips, will be provided occasionally. When interested, the user can open detailed graphs showing power usage over time and providing the possibility to compare the electricity use with that of colleagues.

![Figure 13. The PC application “Energikorten” (“Energy cards”) provides automatic feedback as the user returns to the office room after an absence period. Left: The lower card provides information on duration, power and electricity use during the absence, while the card above shows average absence electricity use for the last days. Right: The cards appear in the lower right corner of the screen.](image)

5. Findings and discussion

This presentation reports work in progress, which has so far led to the following findings:

- If competitions and challenges are used to encourage energy savings, comparable data are necessary. Absence electricity provides that kind of data and contributes to comparisons being fair.
- Measurements during the first project phase showed that absence electricity constitutes more than 50% of the total electricity use in individual offices, and the energy saving potential associated with behavioural changes during absence was measured 17% of the total electricity use.
- Simple, robust and cost-effective systems for electricity data collection must be available for electricity feedback systems to be used in conventional offices outside a test site.
- The second project phase shows that a majority of the employees at all workplaces experience lack of knowledge about how much energy ordinary desktop appliances consume. They express a willingness to learn more about how to become more energy efficient, and ask for tools that can help them in the change process.
- The interpretation of becoming more “energy efficient” varies depending on the professional backgrounds, roles and workplace culture. For instance, for a technology intense organization,
technical inventions might be the first solutions that come to mind rather than behaviour change. The type of organization, or culture, and its leaders play an important role in the process towards more energy efficient workplace practices. Therefore, the work carried out within this research project will be analysed in relation to research within organizational change and leadership (Hiatt & Creasey, 2003).

The intervention developed in the current study proposes a way to target organizational change rather than individual behaviour. The intervention program runs until spring 2017, and the first stage was completed in May 2016. Thus, the major part of the intervention program is still ahead: visualizing electricity use in a prototype for all participating workplaces; carrying out focus group interviews; running two more sets of workshops and analysing the outcome of the entire study. The findings will be related to other intervention programs targeting environmental practices in the workplace as well as to research on organizational change and leadership in general.

Acknowledgements
The research project is funded by partners and the Swedish Energy Agency. The authors would like to thank the workplaces engaged in the project, including the finance department at the University of Borås, the administration for management of premises as well as the environmental administration at the City of Borås and the department of Energy and Bioeconomy at SP Technical Research Institute of Sweden.

References


An Interactive and Diagnostic Energy Use Analysis Interface for Facilities Managers

Paul Shabajee¹, Daniel Schien¹, John Brenton², Chris Jones² and Chris Preist¹

¹Department of Computer Science, University of Bristol
²Sustainability, Estates Office, University of Bristol

Contact: paul.shabajee@bristol.ac.uk

Abstract

We describe an innovative, interactive diagnostic energy use analysis interface developed using open source software for a commercial BMS (Building Management System). This supports the needs of facilities managers to make practical use of high volumes of rich data from heating systems in order to monitor the use of energy and evaluate and develop energy saving initiatives. The interface can be used to easily detect a wide range of energy use issues, such as: under- and over-heating, sensor behaviour, fabric issues and behavioural anomalies. There is also the ability to ensure that local systems are adhering to scheduling and are not being overridden locally. This is particularly valuable for electric space and water heating, to check that it is not active during expensive tariff periods, when the grid is close to capacity, when costs are higher and when more carbon-intensive generation is brought on line. The approach allows interactive interrogation of the data and allows nuanced benchmarking to be undertaken. The result is effectively a toolbox for the exploration of anomalies that traditional BMS threshold alarms would miss. The interface has been developed under the InnovateUK IODiCUS project as an enabling work for a decision-making interface for heating systems.

Background & Needs

The University of Bristol has a large estate of buildings, ranging from offices and student halls to state-of-the-art research labs. It has a number of Building Management Systems (BMS) and, increasingly, local renewable and low carbon energy sources. It also has plans to introduce energy storage technologies. The various BMSs provide significant volumes of rich data from which fine-grained energy use and system behaviours can be estimated. However, analysis and making practical use of this data can be problematic.

As part of the IODiCUS¹² (Interoperable Open Digital Control Unit System) project (IODiCUS, 2016) we have identified, through consultation with the University of Bristol Estates and Sustainability departments, the need for facilities managers, to gain i) an overview of the performance and behaviours of buildings and ii) be able to drill down into data to find patterns, issues, ‘hot’ or ‘cold’ spots in energy use, and anomalies in the data. In addition, they need to be able to evaluate and improve the use of

¹² The IODiCUS project is funded by Innovate UK <http://www.iodicus.org/> – project partners are: the University of Bristol Department of Computer Science, University of Bristol Estates and Sustainability Department, Secure Controls Ltd, Critical Software Technologies, SH&BA, Telemetry Associates, Trusted Renewables

“Feedback in energy demand reduction: Examining evidence and exploring opportunities” Edinburgh, July 2016 Page 149
BMS control systems to help meet energy saving goals, such as reducing overall energy demand and reducing the use of electricity during expensive, peak demand periods.

A primary, currently unmet, need of the facilities managers was to be able to gain a diagnostic overview of the energy use behaviours of the extensive buildings and facilities. That is, while aggregated data, such as half hourly electricity meter data for building-units and/or high-level ‘dashboard’ views of the overall performance of a system are helpful, they lack the resolution to help locate specific issues. Some existing BMS systems provide data and visualisations at the device/room level, which is helpful but not ideal for a large estate; for example, a single student hall may have hundreds of BMS ‘nodes’ (rooms, corridors, kitchens, water heaters, etc.).

Though consultation sessions with the University of Bristol Estates Department, key needs were identified, these included:

1. obtaining an overview of energy use and energy using behaviours across various timescales and scales (e.g. site, building, floor, room, piece of equipment)
2. patterns and variations in behaviours of buildings and residents
3. evaluation of existing and pilot energy management initiatives
4. spotting anomalies such as areas of high or low energy use that might require further investigation

**Diagnostic Energy Use Analysis Interface**

The interface described here was developed using data from an existing BMS. Data includes, *sensor data*, e.g. node temperature, thermostat set-point and relay status (on/off) and *system meta and state data*; e.g. date-time of sampling, space/node identifier, whether the temperature has been manually adjusted, and what operational management program is currently in operation on each node (see below). The raw BMS data is combined with additional building metadata, e.g. location of nodes, whether floors, building or site, type of the particular nodes - water heater, room heater, kitchen heater, etc. - and other non-BMS data, e.g. external temperature.

The web-based interface provides an interactive multi-parameter visualisation, showing column or row charts and tables for a set of configurable dimensions (e.g. Node Name, Node Type, Temperature, Set-Point, Date, Day). In the interface, the length of a bar shows the sum of the energy use (kWh) of that particular item or variable value, e.g. Node Type = Room Heater, Corridor Heater, Kitchen Heater, etc., Day = Mon, Tues, etc. Dimensions can also derived, e.g. difference between current temperature and set-point.

The values of each ‘dimension’ can be interactively filtered by clicking on a bar or selecting a range of values. Filters are applied immediately and the visualisation then shows only results for the sub-set of data selected, e.g. clicking on ‘Tues’ on the day chart, will filter out data for all days but ‘Tues’. Multiple values from a dimension can be selected and multiple filters can be added and removed dynamically.

The unfiltered overview shown in Figure 1 itself is helpful: it provides aggregated (total) energy use for each of the dimensions over whole dataset. This shows, for example, patterns in energy use for
each dimension, e.g. node type, building-floor, hour-of-the-day, etc. providing a view of overall patterns. Interactive filtering (see sections below) enables detailed querying, e.g. “show me the energy use of room-heaters” – thus showing the distribution of energy use by individual nodes, buildings, days of the week, etc. for this sub-set.

Below we illustrate the use of the interface taking ‘evaluation of existing and pilot energy management initiatives’, a key need identified above, as an example. In the UK, during peak electricity demand periods, more power plants and network infrastructure must be available to supply peaks demand. ‘Dispatchable’ energy sources used to meet peaks are often less efficient open cycle gas plants and, increasingly, diesel generation with a higher carbon intensity than alternatives. Distribution and transmission networks may also be at capacity at these times. These factors increase the cost per kWh of generation, increase carbon emissions and increase difficulties in balancing supply and demand. Utility companies try to encourage reduced demand by customers at peak times using premium prices.
For example, DUoS (Distribution Use of System) charges are made by the regional electricity network operators towards their cost of operating the network, including dealing with variation in demand. DUoS charges are tiered into green, amber and red price bands, with red being the most expensive, illustrated for week-days (Monday to Friday) in. Red DUoS periods are not applied on Saturday and Sunday in the distribution region in which the University of Bristol’s properties are located.

Facilities and energy managers in customer organisations can respond by attempting to smooth out demand on external electricity supply through, for example short-term energy buffering/storing (boosting), reducing services at peak times, use (and storage) of local renewable energy.

At the University of Bristol the facilities managers use BMS scheduling functionality to attempt to reduce electricity demand during red DUoS periods. For example by, lowering room thermostat set-point temperatures by a few degrees centigrade during the red DUoS period (this can be over-ridden manually by the resident) and adding heat to water heaters (storage tanks) prior to red DUoS periods and reducing hot water set points during them, so that water is less likely to need heating during the expensive period.

Figure 3 illustrates how the interface provides interactive exploration of the BMS data to help facilities mangers assess the effectiveness of the BMS scheduling strategy. Users can click on the individual bars in the ‘Day’ chart to select all of the week days (Mon-Fri) – this filters the dataset to include only data points (instances) with those values for ‘Day’. In Figure 3, label 2 shows the comparison of energy use (kWh) by hour-of-the-day for weekdays and weekends.

This demonstrates clearly that the facilities managers’ BMS scheduling approach has the desired effect of reducing energy use during the red-DUoS period, giving a visual and quantitative sense of scale of the comparative effect.

Figure 3 also shows, in label 3, that further filters can then be applied, e.g. clicking on ‘Room Heater’ on the ‘Node Type’ chart would filter the dataset to include only ‘Room Heaters’, so that the specific effects on different kinds of node can be seen. Similarly – clicking on individual ‘Program Name’ or ‘Space Name’ bars would filter results to include only data point with those values.
Clicking on a selected bar will deselect that bar; there is also a ‘Reset All’ link so that analysis can be restarted with all data points. Individual charts have ‘Reset’ links (see ‘Day’ in Figure 3) so that selections based on particular parameters/‘dimensions’ can be easily and interactively set and reset.


One limitation of the existing implementation is that the tool can cope with of the order 700,000 to 1,400,000 data points/samples depending on the number of parameters/variables per sample and number of filterable dimensions presented in the interface. At present this means that we can explore data for a whole site (e.g. set of student halls) for period of the order of weeks or a sub-set for proportionally longer periods or whole sites for longer periods with fewer parameters. We are exploring various ways of mitigating these limitations: see future work below.

The use of the open source tools makes it relatively easy to re-configure the application – other prototypes have been developed that include other data or ‘dimensions’ derived from:

- the sensor data: for example ‘Temperature Adjusted’ - whether the thermostat temperature has been adjusted by a resident
- building metadata: for example ‘building storey’ or ‘building name’
- derived data: for example, ‘Temperature Difference’ - the difference between temperature and set-point temperature
In the cases of user tasks such as, for example, identifying energy use ‘hot spots’ or anomalies, other visualisations have also been developed at the level of individual ‘rooms’/nodes so that detailed behaviours can be investigated.

Beyond the kinds of analysis described above, early use of the interface by the University of Bristol’s facilities managers have found that, for example:

- Some rooms remain warm with no internal heat input overnight. This prompts investigation of whether heat in domestic hot water being circulated through pipes through the rooms is being lost to the room, which may point to a case for additional insulation,
- In some rooms there are obvious sensor problems,
- There is some unauthorised use of additional electrical heating, with attendant safety issues
- Fast heat losses have been detected suggesting that windows have been left open unintentionally, can be detected.

**Future Work**

Development is on-going. Planned enhancements include: addition of other core metrics such as financial cost and the addition of other metadata, such as room orientation (e.g. to help assess solar heat gain). We are also developing various approaches to enhancing the system to overcome the current limitations in number of data points, e.g. aggregating data-points, dynamic pre-filtering of data and exploring ways to support more data points.

While initially designed for Facilities Managers we plan to experiment with a simplified version for end-users.

**References**

Household energy-saving behavior and smart grid communication between utilities and customers:
Outcomes of the National Grid Smart Energy Solutions Program in Worcester, USA.

Josephine Munene¹, Gregory Trencher², Nicholas Corsetti³

¹Presenting author: Clark University, Department of International Development, Community and Environment, Worcester, MA, USA
²Corresponding author: Clark University, Department of International Development, Community and Environment, Worcester, MA, USA. gtrencher@clarku.edu
³National Grid, Waltham, MA, USA

Abstract
Smart metering and feedback technologies designed to foster changes in demand side behavior are a key part of the smart grid paradigm. Smart grids and their technologies are under pilot testing all over the world. They are shaped on assumptions that smart grid technologies can change consumer behavior and reduce demand side energy consumption. Yet, empirical evidence for this currently lacks. As a result, the question Do smart grids and smart technologies actually change behavior and promote more sustainable energy use? is yet to be answered—notably at the scale of a city. This study examines the way by which residential customers adopted and engaged with smart grid technologies, and the resulting changes in behavior from both these and pricing incentives from the utility. Data was obtained by analyzing a random sample of 240 respondents to three questionnaires (total n=1,303) implemented by a private sector consulting firm over summer in 2015. These questionnaires targeted participating households in Worcester (population 181,045), Massachusetts, USA where National Grid, the utility company, is piloting a two-year smart grid project involving 10,849 customers. This paper discusses the concept of socializing in-home feedback technology devices in both high-income and low-income households to influence energy saving behavior.

Our findings demonstrate that by creating a peak pricing scheme and diffusing household smart technologies, the program was able to foster an overall modest reduction in energy consumption through energy saving behaviors, as well as prompting a shift to off-peak energy consumption. We found that high-income customers saved the most energy, probably because they qualified for and had better access to smart grid technologies provided for free by the utility. More so, customers that saved the most energy were the active customers that were actively engaging with the digital picture frame and WorcesterSmart web portal as they utilized technology to monitor their energy usage. We explore the concept of socializing smart grid technology by interested and proactive customers. We conclude however that the effectiveness of smart grid programs in shifting demand times in households could be more successful if targeted customers actively interact with in-home technology whilst also adopting alternative behaviors to save energy. We also suggest that ‘socialization agents’ who are the key players in smart grid programs should work together to increase socialization of technologies by consumers.

Introduction: smart grid technology and influence on energy saving behavior
In December 2007, U.S. Congress passed and the President approved Title XIII of the Energy Independence and Security Act of 2007 (EISA). The primary aim of EISA was to increase the use of digital information and the control of technology so as to improve the reliability, security and efficiency
of the electric grid (U.S. Congress, 2007; Graab, 2010). As a result of this federal legislative and funding support such as the American Recovery and Reinvestment Act and EISA, the U.S. electric grid is undergoing significant transformation (Chopra, 2011).

Smart grids and associated technologies are also under testing in residential and commercial settings in various cities worldwide. Since they are currently enjoying massive government and private sector investment (Mah, 2015; Reinprecht, 2016), government and utility expectations are accordingly high. They are shaped on assumptions that smart grid technologies can change consumer behavior and reduce demand side energy consumption (Khan, 2016). Yet, empirical evidence for this currently lacks. As a result, the question Do smart grids and smart technologies actually change behavior and promote more sustainable energy use? is yet to be answered—notably at the scale of a city.

This study attempts to fill this gap by examining customer behavioral responses to a smart grid pilot program (Smart Energy Solutions [SES]) by National Grid (the utility), implemented in Worcester with a population of 181,045 (City of Worcester, 2016) in Massachusetts, USA. The overall objective was to determine the way by which residential customers adopted and engaged with smart grid technologies, and the resulting changes in behavior from both these and pricing incentives from the utility. A defining feature of the program was a triple strategy to influencing demand side energy consumption behavior: 1) free provision of smart in-home technologies such as smart plug control devices and smart thermostats 2) provision of energy consumption feedback via digital picture frames and Internet portals 3) real-time pricing plans. In particular, this study focuses on the influence of access to in-home smart technologies on participating high and low-income households. Data was obtained by analyzing a random sample of 240 responses to three surveys (total n=1,303) implemented by a private consulting firm on behalf of National Grid over summer in 2015. This data was used to answer the following research questions:

- To what extent did (some) people adopt and engage with energy feedback technologies in the home?
- How did customers from high-income and low-income households change their energy use activities in response to the pricing structure incentives and interaction with in-home technologies?
- Has the program been able to reduce energy consumption in participant households?

We find that customers adopted and engaged with energy feedback technologies such as WorcesterSmart web portal and digital picture frames. We also find that both high-income and low-income households used the information to change their behavior towards energy saving activities. They embraced activities such as avoiding usage of energy intensive household appliances, and discussing energy conservation issues with family. Findings also reveal that real time pricing influenced consumers to reduce demand of electricity. This was through the shifting of energy activities from peak event rate that was expensive to off peak rate when electricity price was affordable.

**Background**

“Socialization agents” are crucial factors in fostering the socialization of energy feedback technology and in-home smart devices, which can lead to increased awareness of energy consumption habits, and potentially, reductions in energy consumption. Socialization in standard sociology and psychology, is the process by which individuals identify their position and become entrenched parts of collectives such as, for instance, a family, class or society (Skjølsvold, 2015). We see socialization as the
possibility of humans interacting with in-home technology and incorporating feedback from these devices in their daily life. In particular, the human behavior with regards to energy consumption could be influenced by these technologies as people monitor their energy usage (Gottwalt, 2011). Adolescents have been seen to have socialization agents such as parents, peer groups, social media, TV commercials (Shim, 1996; Ryan, 2000) that influence the teens’ decision making and styles. In the same way, we imagine key influential players in the socialization of smart grids and we refer to them as “socialization agents”. We visualize these agents to be fundamental in smart grid programs: the smart user, the utility, marketing companies and the government (Gungor, 2012; Harter, 2010; Farhangi, 2010). Of these, the vital player is the “smart user” on the demand side, who takes part in actively using the smart technology (Chesi, 2013, Goulden, 2014). Smart grid technology such as digital picture frames, thermostats provide electricity monitoring that stimulates awareness and have the potential of initiating savings because of increased insight on energy consumption (Geelen, 2013). The extent to which in-home smart devices are socialized is influenced to a large degree by the level of curiosity and active engagement of the user towards the technology. Yet socialization can also be sensitive to electricity pricing. Consumers pay attention to when electricity rates are high and respond accordingly by elevating their living style, re-organizing their day-to-day energy usage routine with the aim of reducing their electric bills (Bouhafs, 2014). As other important socialization agents, utilities may play several crucial roles. These include designing real time pricing plans to influence the energy consumption patterns of the user, educating users about benefits of energy conservation and additionally, by diffusing smart in-home technologies and to connect these with the customer (Barbose, 2004; Gungor, 2012). Companies developing devices will perform the significant duty of designing technology devices that are comfortable and convenient for customers (Gungor, 2012, Siano, 2014). All these players depend on the government to create policies to encourage societal diffusion of smart technologies and in addition provide funds for R&D (Cavoukian, 2010; Faruqui, 2010). These ‘socialization agents’ should work in some level of collaboration to increase socialization of technology at the home. 

In addition to smart technologies, design of real time pricing plans from utilities can change behavior. Given that costs are incurred by the utility in generating, transmitting and distributing electricity, costs are recovered by charging customers a set tariff for each kilowatt-hour (kWh) of usage (Khan, 2016). Typically, the most common approach used for pricing electricity is a flat rate tariff. The introduction of distributed generation in the grid system has made it complex for old tariff methods to comply with smart grid requirements (Sioshansi, 2010). The pricing system should be designed to advance rates to meet developing challenges in form of environmental impact, management of bill, increase reliability and to recover cost (Chitkara, 2016).

**Methods and overview of case study**

**Smart energy solutions program (SES)**
Massachusetts, the study site for this paper, has an established history of energy efficiency programs in the electric utility sector (Hurley, 2008). The 2008 Green Communities Act enabled utilities to proceed even further, asserting: “Electric and natural gas resource needs shall first be met through all available energy efficiency and demand reduction resources that are cost effective or less expensive than supply” (Commonwealth of Massachusetts Acts of 2008). The Act mandated that each investor-owned electric utility conduct a smart grid pilot with the overall objective of reducing active
participants’ peak and average loads by at least 5%. Accordingly, National Grid\textsuperscript{13}, a utility company, launched a pilot smart grid project called Smart Energy Solutions Program (SES). The program cost $44 million. This was recovered through increased electricity charges to all National Grid customers throughout the entire northeastern USA grid network (Moulton, 2015).

The SES program pilot is ongoing from January 2015 to December 2016. National Grid installed 15,000\textsuperscript{14} smart meters on the homes and business of the customers who are residents in Worcester, Massachusetts. These customers were chosen when National Grid flagged their homes across 11 electric power supply feeders in the city. SES program customers were given the opportunity to choose from several home energy management devices and technologies at no additional cost (National Grid, 2016). These included WorcesterSmart portal that shows personalized electric information to the customer, digital picture frame, smart thermostat and plug control devices.

Customers were also enrolled in two different pricing plans. The default plan was the Smart Rewards Pricing that combines Time of Use and Critical Peak Pricing structures. This pricing plan offers daytime rates that are lower than the basic service rate (for a customer not in SES) for 335 days per year. This plan has Time of Use kind of smart pricing that offers a variety of prices at peak time (8:00 am to 8:00 pm) and off-peak time (8:00 pm to 8:00 am and weekend). On the remaining days each year, i.e. up to 30 days or 175 hours, called Conservation Days, rates would increase significantly during specifically designated hours known as peak events. The peak event rate is about five times the regular rate. These peak events typically happen during summer months, when electricity is in high demand and the supply is constrained. During these Conservation Days, customers are encouraged to take action to conserve energy and reduce their electricity costs during those designated hours. National Grid notifies customers through telephone messages and email the day before a peak event so they can plan accordingly.

Customers were however given the alternative choice of opting for the Conservation Day Rebate plan. This is modeled using the Peak Time Rebate structure. It offers customers the opportunity to stay at the basic service rate as non-participating customers in the SES program and earn a rebate when they reduce their energy usage below what they normally use during peak events. Customers receive a credit the following month for any energy they saved during the previous month’s peak events on the Conservation Days. This plan does not include the Time of Use rates for the 335 days of the year the Smart Rewards Pricing plan offers. For more information on the different pricing plans see Chitkara (2016) and National Grid (2016).

3.2 Data collection
A stratified sampling technique was used by the consulting firm to select the survey respondents. As shown in Table 1, the entire SES customer population (10,849 households as at September 2015) was stratified into different segments, then random samples were taken from each strata. This was done in accordance with the household’s enrollment in differing technology plans. The consulting firm surveyed a total sample of 1,301 sampled customers across a total of three surveys while retaining the

\textsuperscript{13} National Grid is an international electricity transmission, distribution and gas distribution Company based in the UK and northeastern US. As an energy distribution company, National Grid does not produce electricity or gas but connects consumers to energy sources through its networks. It is the largest distributor of natural gas and electricity in the northeastern US, serving more than 3 million customers in New York, Massachusetts and Rhode Island.

\textsuperscript{14} At the onset of SES program, 15,000 smart meters were deployed. But at the time this research was conducted, some customers had opted out; others shifted to different electricity suppliers or moved, reducing the number of participating customers to 10,849.
distribution of the population subscriptions. Questionnaire results were organized into high-income\(^{15}\) and low-income\(^{16}\) respondents.

<table>
<thead>
<tr>
<th>Level/Technology package</th>
<th>Types of technology</th>
<th>Requirements*</th>
<th>Share of population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Smart meter + Worcestershire smart web portal</td>
<td>None</td>
<td>92%</td>
</tr>
<tr>
<td>Level 2</td>
<td>Level 1 + digital picture frame + mobile app</td>
<td>High-speed broadband Internet connection</td>
<td>5%</td>
</tr>
<tr>
<td>Level 3</td>
<td>Level 1 + smart thermostat</td>
<td>Central air conditioning</td>
<td>1%</td>
</tr>
<tr>
<td>Level 4</td>
<td>Level 1 + Level 2 + Level 3 + load control devices</td>
<td>Central air conditioning and a broadband high-speed Internet connection</td>
<td>2%</td>
</tr>
</tbody>
</table>

\textit{Table 1: Source: Navigant Consulting, Inc. 2016}

Data analysis

The principle data used in this study consists of an analysis of questionnaire responses from a randomly selected sample of 240 respondents from the above-described population of 1,301 SES participants. As shown in \textit{Table 2}, this sample comprises of three smaller samples of 80 responses, each extracted equally from the three survey administration periods in the original survey (i.e. early, mid- and late-summer in 2015). The objective of our research is to study how in-home technology is influencing differing income household responses to calls to save energy. Accordingly, we selected our sample in each questionnaire administration period by ensuring an equal representation of high-income and low-income respondents. Random sampling was achieved by utilizing the random sampling tool in MS Excel.

<table>
<thead>
<tr>
<th></th>
<th>Survey 1: Early summer 2015</th>
<th>Survey 2: Mid-Summer 2015</th>
<th>Survey 3: Late summer 2015</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population (n)</td>
<td>525</td>
<td>270</td>
<td>506</td>
<td>1301</td>
</tr>
<tr>
<td>Low-income respondents sampled</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>120</td>
</tr>
<tr>
<td>High-income respondents sampled</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>120</td>
</tr>
<tr>
<td>Total sampled respondents</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>240</td>
</tr>
</tbody>
</table>

\textit{Table 2: Statistics of the sample we worked with in conducting data analysis}

\(^{15}\) High-income – Customers on R1 rate (basic residential rate), with income greater than $100,000 based on demographic data

\(^{16}\) Low-income - Customers on R2 rate (reduced rate) where they are given a 25% discount on their entire bill

\(^{17}\) There were eligibility requirements for certain technology packages. For example, in order to be eligible for the Level 2 package with a digital picture frame, customers had to have a high-speed broadband Internet connection. To be eligible for Level 3 with a smart thermostat, customers had to have central air conditioning. To be eligible for Level 4 with a smart thermostat and a smart plug and/or load control device, customers had to have central air conditioning and a broadband high-speed Internet connection.
Findings

Integration of different technologies
In analyzing the data, we first set out to determine the extent to which some people adopted and engaged with energy feedback technologies in the home. As shown in Figure 1, we found that across the three surveys the WorcesterSmart web portal was the most commonly integrated form of technology. This was incorporated by 78% of high-income and 57% low-income respondents. The WorcesterSmart web portal provides the customer access to electricity usage information via a desktop computer or mobile device. This portal offers personalized online graphical electric usage information, comparisons to friends and neighbors, and the opportunity to take part in a reward system to win prizes for conserving electricity. Smart plug controls (allowing customers to remotely adjust any appliance plugged into them such as a window unit air conditioner) experienced an extremely low adoption rate in both income groups. As an overall trend when comparing high-income to low-income households, we found that the latter lagged behind in integrating all the four sets of in-home technology provided by the utility. This most probably reflects financially related obstacles such as lack of access to high-speed internet (required for picture frames) or central air-conditioning (required for thermostats). This means that the majority of low-income households were not able to socialize with such technologies, and use them to guide their decisions and energy management.

![Figure 1: Types of in-home technology integrated by SES customers](image)

Actions taken by SES customers on Conservation Days
We also set out to determine the ways in which customers from high-income and low-income households were changing their energy use activities in response to the call to save energy during Conservation Days.

As shown in Figure 2, findings revealed that SES program through the real time pricing structures, was highly successful in triggering behavioral responses and energy saving actions during the Conservation Days. In fact, the proportion of respondents who did not take action was limited to 5% in high-income and 11% in low-income. The most common action across both high-income and low-income households was avoiding the use of certain appliances during peak event hours. This was practiced by 52% of high-income and 50% of low-income respondents. This could be due to the customers trying to reduce the high bills that could result from running appliances during the peak event hours. Changing the temperature setting on air conditioner was done by 22% of high-income compared to less than
half of this percentage (8%) for the low-income respondents. This could be attributed to the suspicion that maybe the low-income households did not afford to have the air conditioners in their homes.

Generally, examining the households by economic status, high-income customers who had better access to in-home technology, as seen in section 4.1, took more actions to conserve energy compared to low-income households, who had more limited access to in-home smart grid technologies.

Figure 2: Actions taken by SES customers to conserve energy during Conservation Days

Energy savings achieved
Lastly, we examined the energy savings for customers participating in the SES program. The consulting firm released an interim evaluation report (Navigant Consulting, Inc. 2016) in February 2016 to evaluate the first year (2015) results for all customers participating in the SES program. The most important findings are as follows.

Overall, it was found that by participating in SES program customers did conserve energy. The total of these energy savings equates to a 2,300 MWh reduction for calendar year 2015 for the 10,849 participating households. This translates to 17 kWh a month per customer on average reduction. In addition, not only did SES customers save energy, they also experienced dollar savings. However, it was found that the two differing pricing plans achieved different results. The most effective pricing structure was the Smart Rewards Pricing that combines Time of Use and Critical Peak Pricing. Respondents participating in this plan achieved an average bill saving of $109 for the first year period of SES. Customers in the Conservation Day Rebate plan, modeled using the Peak Time Rebate structure also achieved financial savings, although relatively less. Time of Use and Critical Peak Pricing structures appear to motivate energy consumption reductions (in both high and low-income households) more successfully.

Discussion
The analysis of our research showed smart grid customers willingly adopted and engaged with in-home technologies in the context of large-scale smart grid experiment. We found that across the three surveys, the WorcesterSmart web portal, followed by digital picture frame, were the most commonly integrated form of technology. The provision of real time feedback of energy consumption seems to have contributed to the socialization of the user, where they have realized their place in the broader...
context of the entire energy distribution system. This technology-enabled socialization seems to be influenced by the smart user’s curiosity regarding the novelty of the feedback data and devices, and a willingness to use them to guide decisions about electricity use to reduce monthly expenditures. It was also possibly influenced by some level of competition with his neighbors. Utilities, government and companies that design smart grid technology could collaborate as important ‘socialization agents’ and encourage customers to participate in energy saving behavior by providing access to smart grid in-home technology. Thus, smart grid programs implemented in the future should consider affordable access of smart grid in-home technology to all households when designing smart grid programs for increased socialization of technology. By socialization, we refer to the ability of different components to play a role in influencing interaction of smart grid technology. For instance, these ‘socialization agents’ could collaboratively facilitate arrangements with householders to obtain the requirements needed for the in-home technologies like digital picture frames. This could be achieved by partnering with internet providers to provide a discount on high-speed internet access based on participation in the smart grid in-home technology program. Additionally, we suggest that utilities could focus on early adopters, learn from, and involve them as advocates for technology adoption and socialization to other customers.

Related to obtaining in-home smart grid technology, we also found that high-income customers took more actions to conserve energy during conservation days compared to low-income households. This can be mostly explained by the lack of any obstacles in acquiring the freely provided technologies to customers with high-speed Internet (for digital picture frames) or central air-conditioning (for smart thermostats). These actions included avoiding usage of energy intensive household appliances, discussing energy conservation issues with family, pre-cooling homes in off-peak hours, adjusting air-conditioning temperatures, and vacating households and/or avoiding activities inside the home. This willingness to make behavioral changes could be attributed to the postulation that these high-income households readily utilized the technology to make informed decisions about saving energy. The higher participation in energy saving activities is also mostly likely the natural result of a higher exposure to additional reminders that the high-income received from their in-home technology devices such as the digital picture frame and the WorcesterSmart web portal. Such reminders were messages from utility that provided electricity usage information, real time pricing, which are vital in guiding more informed decisions about energy usage. As demonstrated in this case, utilities, as socialization agents, have an important role to influence demand side energy consumption behavior through three key strategies. First is through provision of smart in-home technologies such as smart plug control devices and smart thermostats. Second is through provision of energy consumption feedback via digital picture frames and Internet portal, with the third being real-time pricing plans.

Another finding was that there was reduction in energy demand in the SES program. In particular, the total of these energy savings was approximately 2,300 MWh reduction for calendar year 2015. This could appear as an insignificant achievement but this amount of energy could be sufficient to power a local library in Worcester for a year. Also, the reduction was achieved by residential customers and does not factor in commercial clienteles. National Grid was satisfied with this reduction. The utility was not expecting massive energy efficiency savings as the initial goal was for a 5% reduction in energy and demand savings. This was achieved and continues to be exceeded, with the program still in progress. Customers in the Smart Rewards Pricing also saved more energy and money compared to those in Conservation Day Rebate Plan. This suggests that the real time pricing has succeeded in influencing behavior through attractive off peak rates and, conversely, expensive peak event rates. Hence the program has demonstrated an ability to successfully guide customers to shift their energy demanding activities to off-peak periods when pricing was low.
Although participants in the program experienced energy savings, we foresee a possibility of future rebound effects, also known as the Jevons paradox. This states that energy efficiency gains result in increasing use of resources rather than reducing energy consumption (Sorrell, 2009). For instance, 11% of high-income and 6% of low-income respondents chose to seek activities outside home during peak event hours. Though these customers avoided staying in the house in an effort to save energy, the alternative actions taken might also have resulted in the consumption of other forms of energy such as gas while driving to seek for alternative ways to spend their day and also other energy expenditures. Projecting this situation on a large scale, we might end up saving energy in the indoor household setting but increasing use of energy and other expenditures outside the household unit. It could be worth considering the influence of environmentally meaningful behaviors that would accompany the technological influences to enable the successful achievement of the goal of saving energy holistically. For instance, utilities could organize low-energy use community events during peak event hours that customers participating in the program could consider doing on that day. At the very least, utilities could seek to educate customers on the importance of ensuring that environmental benefits accrued from electricity usage reductions were not offset by energy consumption elsewhere.

Conclusions

The main objective of our research was to examine customer behavioral responses to a smart grid pilot program (Smart Energy Solutions [SES]) by National Grid (the utility), implemented in Worcester, Massachusetts, USA. We set out to determine how customers adopted and engaged with smart grid technologies, and the resulting changes in behavior from both these and pricing incentives from the utility. We looked at customers across high-income and low-income households and their interaction with the freely provided technology.

Our findings reveal that smart grid in-home technology can be socialized. We call on the collaboration of all the socialization agents: utility, government and marketing companies; to provide affordable in-home devices to the customer for the successful intensification of socialization. The majority of low-income households were not able to socialize with technologies, and use them to guide their decisions and energy management. Utilities ought to ensure that there are no major limitations inhibiting some customers from acquisition of smart grid technologies. We were also interested in the difference in energy consumption with the introduction of SES across participating households. We found that the real time pricing encourages the consumers to take action towards saving energy where customers are able to shift demand to when the rate is cheap.

Thus, influenced by the motivation to save money, and guided by technology, consumers in other smart grid utility experiments could be brought to align their activities appropriately in response to calls for energy conservation from power utilities. In effect, smart grid in-home technology provides information of energy use in the house and influences the user to take actions to reduce energy consumption and for that reason save money in their electric bills.

References

Lawrence Berkeley National Laboratory.
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, 38(10), 6222-6231.
Goulden, M., Bedwell, B., Rennick-Egglestone, S., Rodden, T., & Spence, A. (2014). Smart grids, smart users? The role of the user in demand side management. Energy Research & Social
Science, 2, 21-29. doi: 10.1016/j.erss.2014.04.008
Lima, C. A. F. and G. D. M. Jannuzzi "Smart Grid implementation in developing countries: analysis focusing consumer behaviour, markets and regulation."


Challenges of feedback in organisations - can we foster partnerships not projects?

Richard J. Bull
Institute of Energy and Sustainable Development
De Montfort University
The Gateway
Leicester LE1 9BH
e-mail: rbull@dmu.ac.uk

Kathryn B. Janda
Environmental Change Institute
Oxford University
South Parks Road
Oxford OX1 3QY
email: Katy.Janda@ouce.ox.ac.uk

Abstract

Using a lens of feedback and engagement this paper discusses the relationships between people, organisations, and energy use in workplaces. It reflects on two projects that explored participatory energy practices in public and private organisations. The first, “Working with Infrastructure, Creation of Knowledge, and Energy strategy Development (WICKED)”, explored energy management practices in a range of different retail companies. The second, ‘Gooddeeds’ aimed to collaboratively create an ICT based tool and related social processes with a city municipality. The paper concludes, firstly, that energy management sits against the backdrop of competing organisational, institutional and political priorities and the core strategy of an organisation matters. Second, we need to move beyond the ‘them and us’ culture and ‘information-deficit’ approach intrinsic in the notion of dashboards and feedback to appreciate the positive contribution all can make to energy efficiency. Finally, there are still large discrepancies across organisations with regards to energy management capabilities and metering technologies. In conclusion we note that relationships and partnerships are central in moving forward.

1. Introduction

This paper sheds light on the challenge of energy use in organisations. Latest estimates show that organisations (including commercial, public and industrial) worldwide account for between 50% and 60% of energy use worldwide with buildings constituting 18% of emissions from buildings in the UK and 20% globally (Andrews and Johnson 2016; Stern et al 2016). A successful transition towards energy efficiency in organisations, as in society more widely, requires a shift in mind-set for policymakers and building users as we move from a ‘them and us’ approach to feedback to a participatory approach that appreciates context, culture and complexity. A recent review of over twenty energy and behaviour change interventions from around the world using the ‘behaviour change wheel’ as an analytic framework (Staddon et al 2016). The authors note that the most successful initiatives had a combination of technological automation and ‘enablement’ – that is opportunities for building users to move beyond education and training. The authors observe enablement appears to be linked to a change in the relationships of the relevant actors and a shift in levels of employee control and responsibility. ‘Enablement’ exhibits key traits of engagement, three benefits of which are noted by Sovocool (2014). First, democracy is increased as all citizens have a right to participate and be represented in environmental decision making, second, non-experts are often more attune to the ethical
issues of a situation, and third, greater acceptance can often be achieved by involving all those affected by the particular situation. One frequently cited model of engagement is Arnstein’s (1969) ‘ladder of participation’ (see Figure 1). Originally used within the context of planning, it has been applied to a range of contexts and sets out steps to increased participation, and ultimately, empowerment.

**Figure 17: Eight rungs on the ladder of citizen participation (Arnstein, 1969)**

[Diagram of the ladder of participation]

Engagement then, in the right circumstances, can lead to a greater sense of connection as people become involved, in a greater or lesser degree, to the decision making processes surrounding them. Yet, applying these principles to complex and varied organisational contexts poses a challenge as the role of the individual employee is subject to a whole range of complex factors and influences (Andrews and Johnson 2016; Stern et al 2016).

It is through the lens of engagement that this paper explores the relationships between people, organisations, and energy. Two projects are investigated that between them, cover aspects of both the public and private sector. The first project, “Working with Infrastructure, Creation of Knowledge, and Energy strategy Development (WICKED)”, explored energy management practices in a range of different retail companies across the UK. The second, “GoodDeeds – a research in the wild project, aimed to collaboratively create an ICT based tool and related social processes with a English municipality.

2. The Two Case Studies

WICKED (The Working with Infrastructure Creation of Knowledge and Energy strategy Development) investigated clusters of technical, legal, and organisational challenges faced by retail organisations, including those with smart meters and energy managers (the “data rich”) and those without (the “data poor”). Findings are drawn from interviews with 33 representatives of 23 different organisations, including property owners, retailers, letting and property management companies, energy management companies, law firms and legal experts, and industry intermediaries and associations). This evidence shows that the “data rich” and “data poor” need different energy management solutions to maximize their energy efficiency and behavioral opportunities.
In the public sector, Gooddeeds saw a team of academics working with the Energy Services team in an East Midlands local authority to explore a collaborative approach to energy management via user-groups and digital tools such as smartphones and social media. A user-group was formed with the intention of ensuring representation of the full range of people involved in energy management – from ordinary building users, the energy services team, the help desk, engineering and facilities management and inclusive of the range of the municipality’s building stock that was also typical of UK non-domestic buildings. This included a 1920’s office block, a 1970’s office block, a modern leisure centre and a Victorian library. The purpose was to facilitate interactions and knowledge sharing and co-develop an App to foster interaction between building users.

The user group was formed with help from the team leader of the Energy Services team who acted as ‘gatekeeper’ to the city council. An email was sent to 16 employees from various locations with a range of roles and responsibilities. After a couple of attempts to recruit a suitable group a core of eight was formed. It is worth noting here the difficulties encountered from the start with getting with key actors within the organisation, for example, representatives of the help desk, facilities management/contractors and the engineers being restricted. In part we believe this to be that as this project began, staff in property services (the directorate in which all of these roles sit) were identified as ‘at risk’ and began a process of re-organisation and possible staff redundancy.

The tool attempted to go beyond the provision of energy ‘feedback’ to building users and allows them (expert and non-expert) to feedback into the system rather than simply receive feedback from it (further details of the tool are available in Bull et al 2015). Findings from the analysis of a focus group and semi-structured interviews revealed encouraging signs with regards to increased user-engagement and digital tools, but challenges with regards to the ‘real world’ implementation of innovative, and technologically grounded, approaches.

3. Key Findings

Findings across the two separate projects are presented separately below, and then jointly reflected on in the conclusions. For the WICKED project three areas of variation were observed across the different organisations in terms of concern, capacity and conditions. For Gooddeeds a key challenge centred on competing organisational priorities and this is explored under variation in priorities. These are now considered in turn.

3.1. Variation in concern

The idea of energy management was not new to any of our interviewees or case studies in WICKED. However, each of the 6 organizations in our cases engaged in this topic in a different ways. Energy management can mean many things, and each of our partners participated in a unique subset of the possible topics that “energy management” denotes. All partners were interested in reducing “out of hours” energy consumption, looking to minimize energy use in the hours their stores are not in service. Beyond this, organizations were (un)concerned about a variety of other energy aspects. For example, only one of our four retailers we talked to was interested in engaging their landlords through the mechanism of green leases. None of the cases were seriously considering rolling out demand response strategies, although one interviewee mentioned an early stage pilot project. Across the cases, we found a number of instances where organizational infrastructures did not necessarily match the high level concerns. For example, several energy managers expressed frustration with the ways in which internal accounting mechanisms and pre-set thresholds for capital projects did not allow for
upgrades that would otherwise seem reasonable.

3.2 Variation in capacity

In all cases, energy management is understaffed relative to the scale of the problem. All of the organizations we interviewed, as well as our case studies, showed varying levels of effort devoted to the task of improving energy management. Most, but not all, of our cases had an energy manager. This energy manager is typically responsible for overseeing the entire portfolio of stores, which represents hundreds of stores. In case 6, for instance, the staff member responsible for energy is also responsible for water and waste in over 1000 premises. In all cases, the “energy manager” operated in a “1-to-many” context, rather than a “1-to-1” relationship, like a store manager. While this slightly distant relationship provides the ability to learn from multiple cases, it does not enhance the ability to understand what is happening “on the ground”. The energy manager can usually only see what the data tell him or her. For most cases, however, the energy information stayed with the energy manager. The premises in case 6, for instance, have “smart” meters but the meters send their data to a central location and are not pushed back out to the stores.

Even where energy managers are present in an organization, they rely strongly on external expertise and hire third parties to provide data management, analytics, and display services. These capabilities are not provided “in house” but instead are provided by consultants who may work entirely off-site or, in some cases, be embedded within the organization. However, store managers have considerable power to make independent decisions regarding sales displays and promotions, which includes adding feature lighting. Although these decisions may impact energy use, the store managers are not required to notify the energy managers or their team of making such changes. Their goal is to maximize sales, not minimize energy use. This theme of conflicting priorities re-emerges shortly.

3.3 Variation in conditions

This relates to the physical and technical conditions present in each portfolio, which extends to the presence and absence of meters and data. A perfect portfolio would have the database envisioned by the consultant in case 2 above: an accurate and complete accounting of every energy-consuming item in every store, updated in real time and without flaws, matched perfectly with energy data at sufficient spatial and temporal resolution to be able to problem-solve deviations. Further, these deviations would be automatically detected and flagged by smart algorithms, which could learn over time what is and is not a genuine problem. The ideal database is far from the reality. The norm is energy managers operating mainly with energy data, set at arm’s length from 100s of stores, often without a complete list of the building-level data, let alone equipment or appliance-level data. In our investigations we found common problems which include: heterogeneous building stocks; evolving data practices; and some difficulties in relating the stocks and data to each other, let alone to problem-solving.

3.4 Variation in priorities

These variations across the retail sector provide an insight into the challenges for managers and employees with regards to energy in the workplace. Organisations are heterogeneous with energy management competing against a host of organisational priorities and capabilities. As the manager of the retail companies is role is to maximum sales, not minimise energy use, so in Gooddeeds a similar picture emerges within the municipality as employees and the energy management team face a challenging set of issues and competing priorities (see Table 1).
Table 1: Example of the workplace issues facing employees

| Supporting Vulnerable Users | The problem I think we’ve got across the board is the operational staff, so staff that have got other priorities rather than the building . . . which is understandable because they’ve got an operational team which probably is usually quite a large operation team that could be supporting vulnerable service users, etc. or across the city. But they think, no, I’m employed as social worker or I’m employed as whatever it is, that’s my responsibility. It’s somebody else’s responsibility to manage the heating and the cooling and the ventilation of this particular building. |
| Function of the Local Authority | We do attempt to meet and get to high standards with energy and energy management. But . . . at the end of the day we’re an authority and our main port is to look after the community and our constituents and the services that we have to provide. |
| ‘More with less’ | The biggest challenge, apart from members of the public and our customers wanting more and wanting it 24/7, is the fact we are going to have to do an awful lot more with a lot less resource. So that’s the number one priority really the city council has got, to still actually deliver our services robustly and resiliently with a far smaller resource given to us. |
| Job losses | The difficult thing is everyone has now got quite a lot of work to do. A lot of people are being made redundant. People are doing two or three jobs, and will people have time to look at this, or will they just carry on with their jobs. And so it is something that most people have an awareness of but they might feel less minded to, you know, if they feel under the threat of losing their job then it possibly isn’t the highest priority on their mind. However it is a high priority on someone else’s mind who might be their current manager or whatever. So it is still something that we try to drive through. It doesn’t get discarded just because the public sector’s going through a hard time and there are cuts. |

These ‘workplace priorities’ are pressing in people’s minds with employees feeling disconnected from energy consumption in their workplaces. Energy is as ‘invisible’ in the workplace as it is at home [8]. But for many it seems the pressure of simply doing their job well means that energy is the last thing on their mind. As the Admin and Business Support leader observed, staff have conflicting responsibilities and priorities, “they’re more thinking about their day job and what we’re doing and it’s just tunnel, the vision’s tunnelled into and the energy impacts are outside of that tunnel for me.” This lack of engagement with energy may be due to ignorance and general busyness, for some though, members felt that a lack of engagement with energy, and wasting energy may be a result of tensions and ‘animosity toward management’ whereby leaving your computer on overnight is a way of asserting control by ‘screwing the system’. He went on to explain, “It’s a very stressful environment and it’s very pressurised, I think some people just sort of see it as, well, screw the system, really. Again it’s not really like, hey, you shoot them by leaving your computer on overnight, but I think it’s that sort of childish mentality that affects some people.”
4. Conclusions

Relationships can be difficult in any context and not least, in the workplace where myriad priorities and cultures collide. Four different sets of variations sit across these two organizational sectors yet these two studies coalesce as they illustrate the challenge of energy efficiency within organisations. Three broad lessons can be observed from these two projects that can serve as recommendations both for operational improvements and for the future research agenda in this field. Firstly, the core strategy of an organisation matters. Thus engagement around energy efficiency needs to happen within, and be aligned to, existing relationships, roles and teams. Further research is needed into how different internal organisational cultures frame employee duties, behaviours, and expectations, particularly with regard to data, analytics, and feedback. This also applies to how budgets are managed and financial targets are set for organisations. If energy efficiency targets are going to compete with core business activities and profitability then there will be only one winner. Second, we need to move beyond the ‘them and us’ culture and ‘information-deficit’ approach intrinsic in the narrow interpretation of energy efficiency as dashboards and feedback. Employee engagement should be framed in a way that acknowledges the positive contribution they can make to energy efficiency, rather than treating them as a ‘problem to be solved’ or another management project. Finally, the challenge of organizing and achieving greater participation in the workplace is ever-present and the technical challenges that exist for smaller organisations, around both accessing the energy data via metering and making sense of the data once its received, should not be dismissed. Relationships take time, trust and technical competency.

References


The role of non-numeric feedback in reducing domestic energy consumption: Lessons from Freiburg and Besançon

Arian Mahzouni School of Architecture and the Built Environment, Royal Institute of Technology (KTH), Stockholm (arian.mahzouni@abe.kth.se)

Abstract

This paper combines insights from neo-institutional theory and practice theory to better understand the elements and dynamics underlying households’ energy-consuming practices in everyday life (e.g., cooking, washing, lightning, space heating and cooling, and water heating). By undertaking a comparative case study between the cities of Freiburg (Germany) and Besançon (France), it will provide new insights into the role of non-numeric energy feedback in reducing energy use at home. The purpose of this paper is twofold: to contribute to future research in the field of non-numeric energy feedback; and then recommending policies to turn the energy-consuming practices in a more energy-reducing direction. The primary results show that non-numeric feedback, mostly in the form of home energy audits and comparative feedback, provides households with tailored advice on energy-saving options. However, non-numeric feedback can be more effective once different energy-consuming practices are categorised in a way to better understand the complexity of the phenomenon of household energy consumption.

1. Introduction

European countries have designed and implemented a wide range of pathways and incentives to reduce households’ energy consumption. However, along any pathway, it is important to investigate how far the individual efforts are converted into collective action. Many studies show the importance of interventions to change the technical and physical factors such as introducing retrofit practices to improve the energy performance of building envolves or assisting households in acquiring more energy-efficient appliances. However, soft factors such as occupant behaviour related to energy-consuming practices have not been adequately examined despite their potential role in influencing the energy use at home (cf. Abrahamse et al., 2005, p. 282; Steemers & Yun, 2009, p. 633; Allcott & Mullainathan, 2010, p. 1204; Burger et al., 2015, p. 12).

Energy feedback has recently draw large attention for its potential in providing relevant information on energy consumption to end users (cf. Darby, 2008; Gupta & Chandiwala, 2010; van Dam et al., 2010), which includes two major types: numeric (e.g., utility bills, smart metering, in-home-displays) and non-numeric (e.g., advice from friends, relatives and home audits). The latter has not been systematically examined in the literature and remains relatively unknown to the policymakers. Therefore, this paper will develop an analytical framework based on the four elements of energy-consuming practices (embodied habits, engagements, technologies, and institutionalised knowledge) discussed by
Gram-hanssen (2014) to better understand the role of non-numeric energy feedback in reducing household energy consumption. It will draw on the experiences from the cities of Freiburg and Besançon. These cities have implemented a wide range of policy instruments to reduce the households’ energy use, as a key strategy to realize their ambitious climate and energy targets. The following questions have been addressed throughout this on-going study:

- If and how non-numeric feedback mechanisms can increase awareness and knowledge of household’s energy consumption, and encourage people to make a commitment to saving energy at home;
- What would be the contribution of the neo-institutional theory and practice theory in understanding and supporting non-numeric energy-feedback mechanisms to change energy consumption behaviour at home;
- How far non-numeric feedback, usually shaped by cultural-cognitive element of institutions, could be extended to and applied in a variety of different contexts.

2. Rationale

Energy feedback can provide valuable information for policy interventions aimed at changing energy-consuming practices at home. However, as highlighted by Martiskainen (2007:23), any measure to change the household’s energy consumption behaviour should preferably consider both internal factors (individual with their attitudes, values and lifestyles) and external factors (planning policy framework, fiscal and regulatory incentives, and social constraints). Weber (1997, p. 835) emphasizes the social factors by claiming that “Energy consumption belongs to the realm of technology, energy conservation to the realm of society”. It is therefore necessary to study the patterns of energy-consuming practices beyond the household level and in a larger social and institutional context. Here, I discuss the neo-institutional theory to define ‘institutions’ and then practice theory to define ‘practices’.

According to Scott (2008, p. 48) ‘institutions’ are “comprised of regulative, normative and cultural-cognitive elements that, together with associated activities and resources, provide stability and meaning to social life.” The three analytical elements of institutions shape and are shaped by the existing social order “in interdependent and mutually reinforcing ways” (Scott, 2008, p. 50). However, the normative and cultural-cognitive institutions (values, habits), in contrast to regulative institutions (policies, laws and regulations), are deeply embedded in our culture and therefore involve a measure of ‘self-evaluation’ and ‘self-enforcing’.

In this paper, the energy-consuming practices, which are profoundly anchored in our culture, are identified as cultural-cognitive institutions; the energy efficiency standards and policies introduced by government, as regulative institutions; and the energy efficiency standards exercised by housing industry to build their own energy efficiency norms, as normative institutions. Depending on territorially-bounded factors (e.g., planning policy framework and actor constellation), these elements interact with each other in a particular way to maintain or change the existing energy-consuming practices. For instance, in the UK, as suggested by Adams (2004, p. 605) “politicians have placed too much reliance on market mechanisms and information campaigns to change prevalent attitudes and behaviour and not enough on direct and effective regulation. For example, although the Building Regulations were apparently tightened in 1990 to promote greater energy efficiency, builders were allowed to offset im
provements in one area against another, so making it possible for the thermal efficiency of walls to be decreased if double glazing were introduced". In this case, the building industry attempts to create its own energy efficiency standards and norms relatively different from the one introduced by government. The reason for using this type of ‘business as usual ‘practices’ in the building industry as highlighted by Mahzouni (2015, p. 288) might be that "long periods of increasing returns in existing technological systems and the institutions that have supported them have created different types of ‘lock-ins’” and pace dependency.

The recently developed practice theory (cf. Shove & Walker, 2010; Karvonen, 2013; Gram-hanssen, 2014) provides a comprehensive insight into the elements of households’ energy-consuming practices. Lounsbury & Crumley (2007, p.995) define ‘practices’ as “activity patterns across actors that are infused with broader meaning and provide tools for ordering social life and activity”. So, in contrast to behavioural approach, which claims that practices are determined by individuals’ norms, perceptions and attitudes, the focus of the practice theory is on ‘collective structures of practices’. Furthermore, the core message of the practice theory is that households do not consume energy by itself, they rather carry out indoor practices related to different daily activities (such as food conversation, cooking, washing, socializing and relaxing) that require energy consumption (see also Lorek & Vergragt, 2015, p. 26). Gram-hanssen (2014, p. 94) argues that households’ energy consumption is largely guided by four interrelated elements that hold practices together: embodied habits; engagements; technologies; and institutionalised knowledge, each discussed in detail in the following.

**Embodied habits** are routinized, taken-for-granted and unconscious practices, which are part of everyday habits of the households. As part of cultural-cognitive elements of institutions, they usually date back to childhood and are shaped by family upbringing, which could explain the huge variations in energy consumption among households. We often perform these practices unconsciously, for example, all the small activities we do every morning when we wake up such as turning the light on, putting the coffee on, etc. These practices impose huge variations among households, depending on a wide range of socio-economic and demographic factors. For instance, high electricity consumption in a certain household may relate to very different practices such as extensive washing, cooking, and computer & entertainment activities or might depends on the type and amount of cold appliances and food practices of the households. In order to better understand these variations, we need to get more insight into the energy-consuming practices the households perform in their everyday life.

**Engagements**, which explain the reason for performing a certain practice, are mostly not related to energy, as mentioned earlier. When we are turning on TV our intention is not to consume energy but to watch a TV program. Our intention to perform energy-consuming practices (e.g., cooking, washing and keeping a nice indoor climate) at home could be influenced by cultural-cognitive institutions (lifestyle, attitudes, expectations and preferences). Practices could be collectively shaped, where people try to create a social identity and distinct themselves from other groups.

**Technologies**, which are designed to improve the energy performance of building envelops, can support sustainable occupant practices e.g., by constructing low-energy buildings and retrofitting existing houses, or by acquiring new energy-efficient appliances (such as microwave ovens and electric cookers) that influence the way of conserving and preparing food relative to previous times.
**Institutionalised knowledge:** The energy-consuming practices could be influenced by various interventions to increase the households’ knowledge on energy-saving options, e.g.,:

- **Mass media campaigns,** in which households usually receive overload of general information that may not properly apply to their situation;
- **Home audits,** where households receive only relevant information and are offered energy-saving options based on their real energy consumption (Abrahamse et al., 2005, p. 277);
- **Comparative feedback,** the recent studies (cf. Dixon et al., 2014, p. 1; Allcott, 2011, p. 1084; Cabinet Office, 2011, p. 18; Abrahamse et al., 2005, p. 279) show that providing households with feedback about their energy consumption levels, in comparison with the performance of other households in similar settings, can be a successful intervention to reducing household energy consumption. In comparative feedback, a feeling of competition, social comparison, and group pressure can be stimulated, where households feel socially and morally obliged to contribute to public goods such as reduced greenhouse gas emissions.

To sum up, the policy interventions are identified as *regulative* elements of institutions that can provide households with necessary knowledge and feedback to reduce their energy use at home e.g., by introducing energy efficiency rating systems for appliances and buildings, and by the advice from energy advisors and craftsmen on how to alter practices and use technologies to achieve energy-saving. As a result, new practice can gradually become routinized and taken-for-granted, replacing the old one. The neo-institutionalism could help to better understand the institutionalization and diffusion process of new practices. Lounsbury & Crumley (2007, p.993) claims that “new practices become established via legitimacy and diffusion”.

### 3. Methodology

This paper applies a comparative case study (cf. Yin, 2009, 2003; Merriam, 2009), which involves the analysis and synthesis of key patterns of households’ energy consuming practices across two cities of Freiburg and Besançon. It addresses the intervention policies that have been introduced to alter the households’ energy consuming practices. It will, in particular, discuss if and how these cities have applied energy feedback in their interventions by looking at the program “200 Familien aktiv fürs Klima” in Freiburg and “Familles actives pour le climat” in Besançon. These programs (regulative institutions) have been designed and implemented to address and change the energy-consuming practices (cultural-cognitive institutions) at home.

The empirical work is conducted in two stages. An extensive desk study will be carried out to map various activities and programmes that have been implemented in both cities aimed at raising awareness and knowledge of households on energy use. It will, in particular, discuss the outcome (the possibilities and obstacles) of using the ‘comparative feedback’, as a way to facilitate social learning for reducing energy use. In the second stage, the results from the desk study will be cross-checked by conducting semi-structured interviews with involved households and with key actors at neighbourhood and city levels. The aim is to obtain detailed data on practices behind households’ energy consumption, and thus proposing ways for turning these practices in a more sustainable direction. In so doing, interviews will be designed to obtain information about routines, engagements, technologies, and knowledge related to each practice. This can be quite comprehensive, as energy is used in relation to many different practices to provide energy services at home (e.g., lightning, washing, cooking, space
heating and cooling and water heating). Therefore, this study will focus only on space heating practices.

4. Primary findings

Both cities of Freiburg and Besançon have carried out a wide range of information campaigns to influence the energy-consuming practices at home. In 2009, the City of Besançon launched the “climate-active families” initiative aimed at actions and tools to reduce the energy consumption at home by 15%. Through home audits, workshops, knowledge sharing, and meeting with other families, the families (Initially 170) have tried to exchange practical experience on energy-efficient choices and reduce their energy bills without giving up the home comfort (Ville de Besançon, 2016)\textsuperscript{18}. The initiative by the City of Besançon has been a success story, from which the City of Freiburg in 2011 started to draw many lessons in the framework of its partnership with the City of Besançon. The involved households in the project “200 climate-active families” have been able to overview their lifestyles and consumption habits in everyday life. The aim has been to create a feedback mechanism for sharing knowledge and experiences with the partners cities of Besançon and Padua on more efficient use of resources (City of Freiburg, 2014, p. 8)\textsuperscript{19}. As part of this initiative, the City of Freiburg initiated the program ‘Zuhause A+++,’ in which all households can receive free energy-saving home audits and advice on how to make their home and lifestyle more energy efficient. The program, which will be run until October 2016, provides households with personalized and tailored information combined with rewards (such as a free LED lamp). Two weeks after home audit, a home energy report is sent to the investigated household, which includes key results and recommendations to reduce their energy use.

5. Conclusions

The aim of this paper is to investigate the often under-emphasised non-numeric energy feedback that may contribute to energy efficiency at home and help policymakers in designing and implementing effective household energy reduction policies. It examines the possibility to combine neo-institutional theory and practice theory in searching for ideas that have large effects on reducing energy use at home.

The initial results from this study prove the potential importance of regulative institutions (in form of policy interventions) for energy efficiency. It is suggested that cultural-cognitive institutions, which shape energy-consuming practices, should be targeted more systematically. However, energy-consuming practices are highly influenced by both personal and social values, and therefore the potential role of non-numeric feedback to better address and alter these practices remains a challenge. Nevertheless, to better understand the complex phenomenon of household energy consumption each intervention should focus on a certain practice or a group of interrelated practices. For instance, practices behind space heating could be very different from practices behind using electrical appliances for washing, cooking, lightning, and entertaining. The energy-consuming practices should be categorised

\textsuperscript{18} In addition, the program encouraged a reduction of travel-related energy use, water use and waste production, which is beyond the scope of this study.

\textsuperscript{19} For the scope of this study, Padua is excluded from this analysis.
in a way to increase our understanding about the complexity of the phenomenon, and thus gaining synergies in designing and implementing interventions.

References


City of Freiburg. (2014). *Freiburg Green City: Approaches to sustainability*. International Affairs Division, Green City Office, City of Freiburg im Breisgau.


Constructing policy feedback on energy feedback: when is feedback ‘working’?

Rosalyn A.V. Robison1 *, Chris Foulds1
1 Global Sustainability Institute, Anglia Ruskin University, UK
*presenting author: rosie.robison@anglia.ac.uk

Abstract
In light of the finite nature of fossil fuel resources, and environmental impacts including climate change, energy feedback tools are now commonly used to promote energy saving. We argue that there are significant similarities between the assumptions underlying the widespread provision of explicit forms of energy feedback and the increasing invocation of the importance of ‘Evidence-Based Policy’ (EBP). These similarities raise questions about what exactly constitutes ‘strong(er)’ evidence, and how users, researchers and policymakers go about determining what ‘works’. Building on an extensive, mixed-methods dataset relating to the iMeasure online energy feedback case study (including user feedback profiles, survey responses, interview, netnography) together with an in-depth review of policy literature, our aims in this work are to illustrate and explore the (multiple) measures by which we might assess one energy feedback tool as ‘successful’; and the implications the use of these different measures may carry for the future direction of the policy programmes they are part of.

1. Introduction

Energy feedback tools exist in a variety of shapes, sizes and forms, and the number of different variations continue to increase as companies and researchers develop their understanding of the field. Energy feedback initiatives could encompass energy labels, energy bills and personal notetaking, as well as digital tools including In Home Displays (IHDs) and web-based applications. In the current paper we are developing (the subject of this extended abstract and talk), we argue that there are significant similarities between the assumptions underlying the widespread provision of explicit forms of energy feedback and those of ‘Evidence-Based Policy’ (EBP), namely relating to the ways in which data or ‘evidence’ are expected to influence future actions. These shared assumptions also raise interesting questions about what constitutes evidence in the first place, how an initiative may be assessed as ‘working’ or not, and how something could be deemed to be a ‘success’. These ideas are recurrent themes throughout this extended abstract and, as such, are revisited in more depth in the following paragraphs.

There has been much research on whether, and how much, different forms of feedback reduce usage (for a brief overview, see for example Buchanan et al, 2015). However, some users actively use feedback for other purposes, such as energy ‘monitoring’ (understanding usage patterns better), in order to e.g. better negotiate with suppliers, or simply due to an enjoyment of ‘data’. These wider aims therefore may not have an explicit energy reduction aim at all, as discussed further in Foulds et al (in review). This thereby challenges the dominant discourse that feedback is solely a means to one end (reducing consumption); in fact a range of measures exist against which feedback provision may be assessed as ‘successful’. Furthermore, evaluation criteria of current smart meter rollouts20 will play a critical role in shaping what they achieve since the assessment of success “actively constructs the

20 For example: “the EU aims to replace at least 80% of electricity meters with smart meters by 2020 wherever it is cost-effective to do so” https://ec.europa.eu/energy/en/topics/markets-and-consumers/smart-grids-and-meters
contexts in which it operates” (Power, 1994; p7). That is, what gets measured and indeed the process of that measurement, then focuses one’s subsequent actions in particular ways.

‘Evidence-Based Policy’ has been increasingly emphasised by politicians, and policy workers since at least the late 1990s. David Blunkett, in a speech to the ESRC on 2 Feb 2002 declared: “This Government has given a clear commitment that we will be guided not by dogma but by an open-minded approach to understanding what works and why” (emphasis added). Indeed, “using evidence as the basis for formulating public policy appears so uncontroversial as to be almost impossible to oppose” (Pearce et al, 2014; p161), and it is thereby unsurprising that the UK government is also currently investing heavily in ‘What Works Centres’21. Although there is recognition of the possibility that evidence may be moulded or selected to fit policy preferences (“Policy-Based Evidence”, EBP’s ‘evil twin’ according to Pearce et al., 2014), often this is interpreted as a shortcoming of the individuals involved, rather than (perhaps inevitably) bound up with the fundamental assumptions regarding the nature of ‘objective’ evidence. In addition, EBP prefers quantitative ‘evidence’ since: “the managerial side of policy making emphasizes that “only what can be measured, can be managed.” (Nowotny, 2007; p479). However in reality a wide range of qualitative measures may also be significant, and neglecting these is likely to preference certain outcomes of feedback provision over others.

In fact, EBP is itself a form of feedback. Both EBP and energy feedback aimed at energy reduction assume that feeding back (usually quantitative) information on past performance will shape future actions. Indeed the same rhetoric can be used for both: if only it were possible to find the ‘right’ type of information to provide to policymakers/feedback users, they could make the ‘right’ decisions. Or, put another way, data can be converted into ‘evidence’ which leads to a more informed user/policymaker, which leads to a better decision.

Thus, the respective energy feedback and EBP ‘projects’ both depend on very similar assumptions, and indeed each feeds into the other. An illustration of this is how, during the smart meter rollout, policy feedback on energy feedback will be used to inform the future direction of that same policy. As proposed by the UK’s Department of Energy and Climate Change (DECC, 2012; p4) “monitoring and evaluation of the smart meter roll-out will provide an essential feedback loop to inform decisions by Government … on smart metering implementation”. In reflecting upon this, we argue that it is thus increasingly important to unpack what exactly constitutes ‘strong(er)’ evidence, which would include considering how users, researchers and policymakers go about determining what ‘works’.

As far as we are aware, no research has been undertaken that has brought these two different research agendas together. We see significant value in this bridging in order to further ‘open up’ the policy agenda around energy feedback. Acknowledging that ‘objective’ policy evaluation of energy feedback programme is impossible, questions that might be asked about the current explicit energy feedback programmes in the context of evidence-based policy literature include: what trade-offs may be hidden through the use of particular ‘success’ criteria? How can transparency in one area mask effects in another? Exploring these questions may help us both better understand how political contexts shape interpretations of evidence (Muller, 2016) – specifically relating to future energy feedback ‘evidence’ produced by the research community – and indeed how feedback used to inform policy (such as evaluation metrics) can shape that political context itself (Pierson, 1993).

---

21 https://www.gov.uk/guidance/what-works-network
Finally, we note as an aside that there are numerous important implicit forms of feedback, including sensory feedback e.g. lights being on, thermal comfort (Strengers, 2013; Foulds et al, 2014). In this work however, our interest is in the parallels and interplays between energy feedback and policy development, and we focus therefore on the explicit forms of energy feedback commonly advocated by policymakers, such as those accompanying smart meter rollout across Europe (Giordano et al, 2011).

2. Research aims

Given these pertinent issues, the aims of this paper-in-progress, are:

(1) to investigate the measures by which we might assess one energy feedback tool as ‘working’ or ‘successful’; and

(2) to explore the implications that the use of these different measures carry for the future direction(s) that such tools might take, especially with regard to the policy programmes they are (or may be) part of.

In furthering these aims we will explore current constructions of evaluative evidence on energy feedback initiatives more widely, and also how the traditions of the energy feedback community itself (e.g. what counts as ‘good’ knowledge and metrics) can funnel researchers and designers in particular directions.

3. Data

Our paper will build on two distinct datasets and streams of analysis. These are (1) a review of the policy literature (particular to do with policy evaluations) regarding energy feedback programmes; and (2) experimentation with a novel (energy feedback) empirical dataset to demonstrate the multiple meanings of what exactly constitutes success.

Our work to date has been concentrated in (2), and we do not believe a similar interpretation has been undertaken before. This work builds on data relating to an established online energy feedback tool - iMeasure.org22. One of the founding objectives of iMeasure was to progress feedback research, and its setup was accompanied by a review of existing online carbon feedback tools (Bottrill, 2007) thus providing an explicit point at which the positioning of the tool was considered.

Our wider research project concerning this case study has produced a significant amount of different data. These include: an extensive longitudinal dataset (several years’ worth of data from 2007 onwards for several hundred users); a survey of 571 users; 10 iMeasure user interviews plus 1 founder interview; and extensive netnography of forums, social media and general online presences of the tool. Each of these datasets construct different sorts of ‘realities’ that essentially tell different stories of what the energy feedback tool and how it is experienced in various ways – which thereby provides us with a good foundation for contrast and comparisons in the context of what could be seen to be ‘working’.

Through these data (and case study), we will we illustrate our previous arguments, looking at the multiplicity of:

22 Now part of Pilio: http://www.piliogroup.com/
bullet aims (implicit/explicit; of different actors);
bullet impacts (savings achieved; user numbers/diversity; user/developer satisfaction; data quality);
bullet temporalities (energy reduction timescales; rebound/trickle effects; frequency of use; tool longevity);
bullet and implications for feedback policy, design and research.
(This is of course an indicative, rather than exhaustive, list.)

4. Final thoughts

In the conclusions of this future paper, we intend to draw out policy implications, for example in relation to the evaluation of the success(es) of the (In-Home Display element of the) current smart meter roll-out, as well as for the design and delivery of energy feedback initiatives themselves. We also hope to raise useful reflections on how the energy feedback research communities themselves construct our evidence, which may be of use as researchers design and interpret their own studies. There are also implications, in terms of potential messages which may be drawn, for how the vast amount of smart meter data that is now beginning to be collected, stored (in the UK, via Data & Communications Companies, and the government’s National Energy Efficiency Data-Framework respectively) is ultimately evaluated. Many different constructions of the same data will be enabled. And perhaps we should embrace this, rather than strive for one identifiable and agreed conclusion.

References


Foulds, C., Robison, R.A.V. & Macrorie, R. (in review) *Energy monitoring as a practice: Investigating use of the iMeasure online energy feedback tool*


Energy feedback: Place, Policy and Mobility

Authors: Dr Heather Lovell, School of Social Sciences, University of Tasmania, Australia/School of GeoSciences, University of Edinburgh, UK, heather.lovell@utas.edu.au; Dr Gareth Powells, School of Geography, Politics and Sociology, Newcastle University, UK, gareth.powells@newcastle.ac.uk.

Abstract

In this paper we examine the providers of energy feedback and those involved in its governance. We draw on theories of policy and knowledge mobility to conceptualise our findings, and explore the ways in which energy feedback has been framed, drawing on empirical material from the UK and Australia. A key finding from our initial empirical research in both countries is that energy feedback is seen as being able to do a great deal of (often new) work. In other words, energy feedback provides a policy solution to a host of policy problems, including climate change, fuel poverty, poor energy market function and limited customer engagement. Second, we analyse the mobility of knowledge generated from three large energy feedback trials, namely Smart Grid Smart City (Australia), the Customer Led Network Revolution, and the Energy Demand Reduction Project (both UK). We explore the careful positioning of these trials as having domestic and international applicability, and begin to consider the extent to which they have met these ambitions.

Introduction

The main aims of this paper are twofold: first, to explore the ways in which energy feedback has been framed by those organisations involved in its governance; and, second, to examine the international mobility of energy feedback information, knowledge and learning from three energy feedback trials in the UK and Australia. We are interested in establishing the work that energy feedback is conceptualised as doing, i.e. how it is being positioned as the means of solving a host of (often intractable, longstanding) policy problems, from fuel poverty to electricity sector modernisation. Further, the paper provides a preliminary investigation of how three large energy feedback trials have been positioned as having a global audience and reach, i.e. producing generalised learning or placeless knowledge, and the degree to which they have been successful in achieving this objective. This draft paper reflects work in progress, and feedback and comments are welcomed.

In our analysis we draw on the concepts of knowledge and policy mobility to better understand the framing and mobility/immobility of energy feedback research. Policy mobility is a relatively new area of scholarship with interdisciplinary origins in political science (policy transfer, lesson drawing), economic geography, and science and technology studies. It is defined as "... a conceptualisation of policy making as a global-relational, social and spatial process which interconnects and constitutes actors, institutions and territories." (McCann and Ward, 2012: 328). Connected to this through the wider ‘mobilities turn’ in social science (Sheller and Urry, 2006) is the notion of knowledge mobility, which theorizes knowledge as flowing between urban nodes unencumbered by national borders, and as an integral part of both urban governance and urban economy.
The focus of this paper is on the governance of energy feedback, and is thus distinctive to the majority of domestic energy feedback studies that have tended to concentrate on householders (albeit with some important exceptions, see for example Bulkeley et al., 2016). In contemporary highly liberalised and privatised energy infrastructure systems a number of organisations are central to governing energy feedback. It is a collaborative governance policy area, with private sector utilities, government, regulators, advocacy organisations and community groups all involved.

The paper is based on primary empirical research underway by the authors in Australia and the UK, funded by the Australian Research Council (Lovell) and the UK’s energy retailer, Ofgem, through its Low Carbon Networks Fund (Powells). The Australian case study is Smart Grid Smart City, a large-scale Australian federal government-funded program of smart grid and household energy efficiency trials, partnered with industry, which ran from 2010 to 2014 in the state of New South Wales, Australia. The UK cases are the Customer Led Network Revolution (CLNR) project and the Energy Demand Research Project (EDRP): large multi-faceted projects which included studies of energy feedback in a number of empirical settings across the UK.

The paper is organized into three parts. We begin by briefly introducing the literature on policy and knowledge mobilities. Second, we review energy feedback research and summarise findings of preliminary analysis on the policy framing of energy feedback in the UK and Australia. We then consider the ways in which new knowledge about energy feedback is being positioned geographically, drawing on our three case studies.

**Conceptualising energy feedback through the lens of policy and knowledge mobility**

In recent years scholarship on both policy and knowledge mobility has flourished. These emerging fields of research are part of the relatively recent ‘mobilities turn’ in social sciences that theorizes contemporary life as generative of movement in all manner of ways (Hannam et al., 2006; Sheller and Urry, 2006; Urry, 2004). A key feature of the world theorized as mobile are relays of knowledge, ideas, practices and norms between nodes in a topological rather than territorial world. The significance of this is that it suggests that knowledge generated in such a world is ‘born mobile’; if it is recognized and valued it will move, or rather it will be distributed, to other nodes – other places. What we are interested to explore here is the geography of these mobilities of energy feedback knowledge and policies. In particular, we are attentive to urban-global mobilities as well as the effects of territorial and economic geographies of boundaries and borders.

The concept of policy mobility has been developed over the last decade in an effort to capture empirical observations about the contemporary international movement of policy (Ward 2006; Peck 2011; McCann 2011). A number of ideas have been proposed by policy mobility scholars, building on existing scholarship in political science (on policy transfer and diffusion, see for example Dolowitz and Marsh, 1996; Walker, 1969), economic geography (on globalisation and neoliberalism, see for example Jessop, 2003; Peck, 2002), and science and technology studies (see for example Jacobs, 2012). First, that policy ideas and programs appear to be circulating with greater ease and increasing in scope and scale – a phenomenon linked to wider processes of globalisation - and termed ‘fast policy’. The notion of ‘fast policy’ conveys the increasing time pressure under which policy decisions are having to be made (Peck 2011). Second, policy mobility scholarship is attentive to the materiality of policy, that is the objects and things that constitute policies, exploring how they are an integral part of...
the policy making process (Peck and Theodore 2015). The heterogeneous networks comprising people and technologies that comprise policy are termed assemblages, defined by policy mobility scholars as “… a purposive gathering of people, institutional capacities, expertise, models, techniques and technologies, political sustenance, etc. from local sources and, crucially, from elsewhere.” (McCann 2011b, p. 144). Third, policy mobility scholars have documented the ways in which policy is increasingly being made beyond the formal, official government venues concentrated on in studies of policy transfer and diffusion within political science scholarship - with non-state actors such as multi-national companies and consultants identified as crucial (McCann 2011a; McCann and Ward 2012; Prince 2012), particularly in highly technical areas of new policy development (Larner and Laurie 2010).

With regard to the related but distinct subset of scholarship on knowledge mobilities, it is worth noting that economic geographers have long studied flows of knowledge in a largely sub-disciplinary examination of innovation, including topics such as intellectual property as a feature of local economic development (see Döring and Schnellenbach, 2006; Feldman, 1999). More recently however, “a sustained body of critically engaged research has emerged, focusing on the circulation of urban policy models and knowledge” (Temenos and McCann, 2013, p825). This is new interest in knowledge mobility is notable for three reasons; first for its emphasis on global circuits of knowledge mobility rather than local knowledge transfer and spillover, secondly for its explicitly urban emphasis, and thirdly because of the way it theorizes policy and knowledge mobilities as being co-constitutive.

**Energy feedback**

Having outlined the concepts of knowledge and policy mobility, we now turn to consider how energy feedback is defined and its current knowledge base and policy development, concentrating on the UK and Australia. The term ‘feedback’ describes changes in a system or process because of information:

> “The modification, adjustment, or control of a process or system (as a social situation or a biological mechanism) by a result or effect of the process, especially by a difference between a desired and an actual result; information about the result of a process, experiment, etc.; a response” (OED, 2016).

Energy feedback is a term used more specifically to refer to the provision of information on energy use to relevant parties. In this paper we focus on energy feedback to householders, i.e. domestic consumers of energy, with respect to electricity. In this context energy feedback is about the provision of more frequent, understandable, and more granular energy information to householders. Energy feedback can be categorised as either direct “…immediate, from the meter or an associated display monitor” or indirect “…feedback that has been processed in some way before reaching the energy user” (Darby, 2006: 3).

Over the last decade the technical capabilities for providing energy feedback have expanded, with the emergence of digital communications-enabled meters connected to in-home displays (IHDs), energy monitors on individual appliances, household temperature sensors, and so on. Domestic energy feedback was traditionally about improved billing and energy labels, but it now mostly encompasses digitally-enabled forms of information provision and engagement with householders.
In what has become an obligatory reference document for researchers interested in the effectiveness of various forms of energy feedback, Darby (2010) made clear the diversity of recent energy feedback studies both in terms of the range of interventions being trialled in the early 21st century but also the range of conceptual apparatus being deployed. There was then, and remains, great uncertainty about exactly which interventions, in which combinations targeted at which households will generate the greatest changes in energy use. Analysis of the UK EDRP data shows that direct energy use feedback to households generates total energy savings of between 0 and 11%, with an average of 3%, while feedback in combination with a time of use pricing regime reduced early evening (peak) consumption by ‘up to 10%’ but did not reduce total energy use (AECOM, 2011). What this range of uncertainty in household response indicates is that a ‘one-size-fits-all approach’ is not appropriate. Complex interactions between several factors make energy feedback a nuanced and context-sensitive endeavour.

In their summary for the Californian government (which draws on Darby’s mainly Northern European research), Mahone and Haley (2011) identify three modes of feedback-based energy efficiency initiatives: those with an individual household focus which often invoke financial/efficiency benefits as the motivating factor; those with a peer or comparative element which invoke competition as a motivating factor; and those with a community focus which rely on a sense of common purpose and collective action to bring about energy use changes. These forms of feedback have been thoroughly tested by scholars in a wide range of disciplines over the last decade, and most studies are in agreement on the importance of contextually attuning a package of interventions rather than ‘fitting and forgetting’ feedback devices (see for example Faruqui et al., 2010). The breadth of this research also reveals many wrinkles in the often smoothed out imaginary of future smart energy systems, such as users’ disengagement (Burchell et al., 2016; Westskog et al., 2015), the long term ‘backgrounding’ of IHDs which erodes the effectiveness of interventions (Hargreaves et al., 2013), and unintended consequences of IHD installations such as induced fears and anxiety (Raimi and Carriço, 2016).

Exploring the ways in which energy feedback has been framed in the UK and Australian policy
The term ‘energy feedback’ has been used much more extensively in UK policy compared with Australia. For instance, an Advanced Google search looking for the specific terms “energy feedback” in the title of the page in Australia yielded just 25 matches, and the UK 190 matches. But the conceptualization of the role of energy feedback by those organisations involved in its governance appears to be broadly similar across the two countries. In particular, policy attention has centred on new technologies enabling energy feedback, namely the smart meter and IHDs.

Smart meters as enablers of energy feedback
Energy feedback has become a key feature of UK energy policy since the Department for Energy and Climate Change took on the responsibility for a national “roll-out” of smart meters to all homes in the UK by 2020. In its public facing website, Smart Energy GB - an arm’s length agency acting on behalf of government - makes it explicit that all homes in the UK will be offered a smart meter and that this includes an in-home display (IHD):

“An in-home display – a handheld digital device that sits in your home and allows you to see how much energy you are using as well as how much it's costing you in pounds and pence, in near real time. This may be called lots of things - like an IHD or smart meter display.” (Smart Energy GB, 2016)
Similarly in Australia there has been a focus on smart meters as an ‘enabling technology’ for energy feedback (and more broadly demand side participation (‘DSP’)):

"... enabling metering technology is important for consumers to have the ability to take up some DSP options and be able to capture the value of their decisions. Currently, where a consumer makes an informed decision to switch to a flexible retail offer or take up of different DSP products (ie install smart appliances); the market is generally unable to support that choice due to a lack of installed advanced metering capability.” (AEMC, 2012: 77).

The UK smart metering roll-out is already using some of the most unequivocal research findings to present smart metering and IHDs as positive additions to UK homes and to overcome common objections found across prior qualitative research. Utilities are, for example, promising a coaching session at the time of installation to overcome issues of disengagement and perceived concerns about how smart meters may be domesticated by households (Aune, 2007; Jensen et al., 2009; Sundramoorthy et al., 2011):

“During your smart meter installation, the installer will show you exactly how your in-home display works and set it up for you. The display communicates with your smart meter to show you information about your energy usage. Position it somewhere useful, such as your kitchen or living room, and you can see exactly how much you’re using and what it’s costing at a glance.” (Smart Energy GB, 2016)

and reassuring customers about privacy (McKenna et al., 2012);

“Who can access my smart meter data and how is it used? Only your supplier, and they won’t share any of it without your permission... The meter will keep your data secure.” (Smart Energy GB, 2016).

Central to this paper, however, are the ways in which Smart Energy GB along with energy market regulators in Australia are making direct links between smart meters, framed as a bundle of connected technologies including IHDs, and a range of wider policy problems. This is operating through two different discourses: first, is that smart meters through the effects of the IHD are able to resolve energy market failures; second, is that when combined with IHDs smart meters can play a pivotal role in a much wider range of energy policy problems.

Smart meters as market correction devices

In the UK context, Ofgem’s smarter markets program positions smart meters as able to act as market correction devices:

“smart meters open the door to far greater customer involvement in the energy market. Through this, we will have a more dynamic and competitive market.” (Ofgem, 2015a)

Thus the work that is being done by energy feedback here - facilitated by the smart meter - is to allow the individual householder to effectively participate as an informed consumer within energy markets. The 2015 Australian Energy White Paper similarly encapsulates this objective, as follows:
“Effective and timely consumer access to their own data from these [smart] meters (either directly or through an authorised agent) is critical to enable a more sophisticated response to cost-reflective tariffs and help consumers select the best services for their needs.” (Department of Industry and Science, 2015: 12).

A dimension of this policy framing is that customers’ engagement with the market is deemed to be important to improving market functioning, with IHD-delivered feedback positioned as one of the central mechanisms for customer engagement. The logic being employed here in the UK in particular is that more engaged customers will have greater expectations of suppliers and will thus incentivise innovation:

“Consumers find the market more engaging ... Increased consumer engagement encourages providers to innovate.” (Ofgem, 2015b)

IHD-equipped smart meters as a silver bullet

Successfully responding to climate change and energy insecurity crises via a smart grid is framed as contingent upon effective successful smart metering, with feedback from IHDs positioned as an essential part of that process. In these energy policy narratives - which are circulating most noticeably in the UK - smart meters therefore unlock solutions to a host of diverse energy policy problems including CO2 emissions reductions, fuel poverty, active matching of supply and demand for power, energy security, network reliability, long term planning and market efficiency gains:

“Smart meters help enable the smart grid, which is a whole new way of running our energy networks. ... The energy network we have now was designed for a time when our gas and electricity needs were much simpler. Now, we’re using more energy and have to find ways to reduce our carbon emissions. We need to integrate new technologies, like electric cars and solar and wind energy.

The smart grid has the potential to help us solve lots of Britain’s energy problems.” (Smart Energy GB, 2016; emphasis added)

The smart meter itself is framed as necessary but, on its own, insufficient for the realisation of these potential solutions and remains contingent upon being bundled with effective energy feedback through IHDs. Attention to IHDs in Australia has been more limited, but there is a similar broader recognition of both the opportunities but also the challenges of achieving effective energy feedback:

“Influencing energy consumption by changing consumer behaviour presents a significant energy efficiency opportunity, but it requires responsive feedback and continuous engagement.” (NSW Government 2013 Energy Efficiency Action Plan, p12).

Large energy feedback trials and their mobility

In this section we turn to explore how three UK and Australian energy feedback trials have been positioned as having a global reach, i.e. able to produce generalised learning or placeless knowledge. We report on preliminary analysis of how successful they have been in achieving this objective.
Australia: Smart Grid Smart City (SGSC)

There has been careful positioning of the location of SGSC trials as able to generate highly transferable knowledge, relevant to other places within Australia and internationally. For example, one of the seven original objectives for SGSC - as listed in the government’s SGSC pre-deployment report - was to:

“Develop an innovative solution that can serve as a global reference case.” (Department of the Environment, 2009: 16).

In the Executive Summary to the Final Report on SGSC this global ambition is somewhat toned down – with more emphasis on the value of SGSC findings domestically, to Australia - but it is nevertheless claimed that:

"The Smart Grid, Smart City Program was arguably one of the widest-ranging technology assessments of smart grid products in the world." (AEFI, 2014: 5).

Further, the geography of the SGSC trials is carefully explained with regard to how and why the trial locations were selected in order to maximize the applicability (or mobility) of the SGSC findings:

"The trial was largely focussed on the greater Newcastle and Sydney CBD areas... The selection of appropriate geographic locations for the trial was considered critical to producing reliable data that could be accurately extrapolated to assess the viability of a large scale smart grid roll-out in Australia. The greater Newcastle area was selected as one of the focal points for the trial due to its mix of regional and suburban characteristics that result in representative geography, climate, socioeconomic and demographic factors. The customer demographic and socioeconomic indicators in Newcastle closely reflect the demographic attributes of a typical Australian city." (AEFI, 2014: 10).

Forthcoming empirical research will investigate how successful SGSC has been in achieving its aspirations to be a global reference case: a survey of all registered users (c1500) of the SGSC Information Clearing House - an online database comprising the full data sets and reports from SGSC - is planned for the second half of 2016. Meanwhile, some indication of the international mobility of SGSC can be gleaned from exploratory internet searches: a Google Scholar search for citations of key SGSC documents (final main report (AEFI, 2014) and final customer report (Langham et al., 2014)) identified several citations, but from Australia only; and a Google Advanced Search for “smart grid smart city” (exact phrase, in title of page) had the following number of hits, by country: Australia - 40; UK - 6; US – 44. These findings tentatively indicate some international mobility of SGSC.

UK: CLNR and EDRP

In the UK a great deal of the recent research into smart grids and meters and the role of feedback in interacting with each has been paid for either directly or indirectly by national government bodies or their key operational partners, such as the UK energy markets regulator Ofgem. This research has been explicitly tied to national policy challenges, and a common criteria for the ‘evidence’ being produced through Low Carbon Network funding and the smart metering program is that, similar to Australia and the case of SGSC, it must be “nationally applicable” if the projects are to report successful
delivery of the research projects. The geography and rationale here is that locally specific cases are not seen as valid uses of nationally collected tax-payer or energy bill payers’ money, and that the UK as a whole must solve what is framed as the collective, national challenge of sustainable energy provision. This is explicitly written into the terms of the funding and as a result the claims made by research teams reporting on the findings of research undertaken on this basis.

“An important feature of the CLNR project is that trials are taking place on real networks and with real customers to produce real-world, usable data. ... We purposefully selected a range of rural and urban locations for our network technology trials to ensure our findings can be applied more across the UK. These locations combined offer a representative sample of 80% of Great Britain’s total electricity distribution network, which means that the learning we gain from these trials will be applicable to 80% of GB networks.” (CLNR, 2014).

CLNR included several sub-projects (‘trials’ in the project vernacular) of households using in-home displays to optimise their energy use. The research activity included analysis of energy usage data as well as survey and semi-structured interview data. The quantitative data sets have been made publicly available, and the findings published in a number of channels (Bulkeley et al., 2016; Powells et al., 2014, 2015). The EDRP was an earlier (2007-10) smart meter research project comprised of a portfolio of large scale trials aiming to understand how consumers react to improved information about their energy consumption over the long term. (ref 23). These large scale studies hoped to create general, transferable knowledge of the impact of smart meters and displays as an evidence base ahead of a UK-wide implementation of smart meters. The project was administered entirely by third parties on the UK regulator’s behalf (Ofgem) with four of the UK’s ‘big six’ energy suppliers delivering the trials and an independent consultant analysing the data. In total over 50,000 households were included in the trials which ran from 2007 until 2010. The data from these trials has also now been made available to the research community via the UK Data Service 24.

Our analysis of these data points to multi-scalar flows of policy-knowledge emanating from the trials we have studied. There are clearly claims and actual flows of knowledge that are global in nature – such as California’s governmental review using Darby’s European review of trials, and SGSC’s stated aim to be a global pioneer through the generation of globally important policy innovation. However, we observe that the national remains an important boundary in energy feedback research mobility because of the ethical and political mandate that nationally publically funded research must generate knowledge that is applicable across the same tax-paying territory. In identifying this multi-scalar geography we do not make a comparative analysis of Australia vs UK, but rather we draw on cases from both countries to argue that the concepts of policy and knowledge mobilities that emphasize the importance of local context and materiality in knowledge production are useful in understanding the circulation of knowledge both within territories and national energy systems and between them.

23 https://www.ofgem.gov.uk/gas/retail-market/metering/transition-smart-meters/energy-demand-research-project
24 https://www.ukdataservice.ac.uk/
Summary and Conclusions

In this draft paper we have begun to explore the governance of energy feedback policy and the mobility of energy feedback trials, drawing on empirical research underway in the UK and Australia. We propose scholarship on policy and knowledge mobility as a suitable conceptual framework for evaluating energy feedback in this way, because of its focus on the geographies of knowledge claims, and its attentiveness to context. In particular, this literature enables our analysis to go beyond ideas of local knowledge spillovers found in innovation theories, in which *knowledge* circulates or spills into local innovation networks, to think about global circuits and connections. By connecting these insights with the *policy* mobilities literature which emphasizes the social, economic and political geographies that animate and shape policy mobilities we are able in this draft paper to start to develop an analysis which can attend to both the mobility but also the factors which constrain, block and route knowledge differently. Our preliminary analysis reveals a mixture of global and some national flows. In conclusion, the following tentative observations can be made:

1. Energy feedback has in recent years become an area of governance reinvigorated by, and increasingly framed by, technical innovations in smart metering and IHDs. This is the case in the UK as well as Australia;
2. Energy feedback is seen in policy circles as being able to do a great deal of work, potentially providing a policy solution to a host of policy problems, including climate change, fuel poverty, energy market function problems, and customer engagement;
3. Those organisations involved in the three energy feedback trials discussed here - SGSC (Australia) and CLNR and EDRP (UK) - have made substantial efforts to position the trials and findings from them as globally and nationally relevant;
4. Further research is required to establish the extent to which these ambitions for policy and knowledge mobility of trial findings have been realized. Early indications suggest domestic/national mobilities have been most significant.

Acknowledgements

Dr Heather Lovell would like to thank the Australian Research Council for funding the project ‘Smart Grids Messy Society’. Dr Gareth Powells would like to thank the collaborators on the Customer-Led Network Revolution Project: Northern Powergrid, British Gas, Durham University, National Energy Action and EA Technology.

Bibliography


Bulkeley H, Powells G, Bell S, 2016, "Smart grids and the constitution of solar electricity conduct" Environment and Planning A 48 7-23


Department of the Environment W, Heritage and the Arts, , 2009, "Smart Grid, Smart City: a new direction for a new energy era", (Commonwealth of Australia, Canberra, Australia)

Dolowitz D, Marsh D, 1996, "Who learns what from whom: a review of the policy transfer literature" Political Studies 44 343-357


Advances in understanding energy consumption behavior and the governance of its change – outline of an integrated framework

Annika Sohre, University of Basel, Switzerland

This extended abstract is based on the published paper:

Abstract
Feedback instruments that aim to substantially reduce the total energy consumption at the individual level have partially been found to be effective in changing people’s behavior in single domains. However, the so far weak success story on reducing overall energy consumption indicates that our understanding of the determining factors of individual energy consumption as well as of its change is far from being conclusive. Among others, the scientific state of the art is dominated by analyzing single domains of consumption and by neglecting embodied energy. It also displays strong disciplinary splits and the literature often fails to distinguish between explaining behavior and explaining change of behavior. Moreover, there are knowledge gaps regarding the legitimacy and effectiveness of the governance of individual consumption behavior and its change. Against this backdrop, the aim of this paper is to establish an integrated interdisciplinary framework that offers a systematic basis for linking the different aspects in research on energy related consumption behavior, thus paving the way for establishing a better evidence base to inform societal actions. The framework connects the three relevant analytical aspects of the topic in question: (1) it systematically and conceptually frames the objects, i.e., the energy consumption behavior and its change (explananda); (2) it structures the factors that potentially explain the energy consumption behavior and its change (explanantia); (3) it provides a differentiated understanding of change inducing interventions in terms of governance. Based on the existing states of the art approaches from different disciplines within the social sciences, the proposed framework is supposed to guide interdisciplinary empirical research.

1. Introduction - Problem Statement, Aims, and Relevance
Transforming today’s energy systems in industrialized countries requires a substantial reduction of the total energy consumption at the individual level. Selected instruments as feedback instruments have been found to be effective in changing people’s behavior in single domains. However, societies are not yet really on track with the ambitious goals they aspire to. In Switzerland – comparable to other industrialized countries – the total final energy consumption of private households in 2012 exceeded the consumption in 2000 by 4.5%, instead of the intended decrease (BFE, 2013: 5). The so far weak success story on reducing overall energy consumption indicates that our understanding of the determining factors of individual energy consumption as well as of its change is far from being conclusive. Among others, the scientific state of the art is dominated by analyzing single domains of consumption and by neglecting embodied energy. It also displays strong disciplinary splits and the literature often fails to distinguish between explaining behavior and explaining change of behavior. Moreover, there are knowledge gaps regarding the legitimacy and effectiveness of the governance of individual consumption behavior and its change.

Against this backdrop, the aim of this paper is to establish an integrated interdisciplinary framework that offers a systematic basis for linking the different aspects in research on energy related
consumption behaviour (ECB), thus paving the way for establishing a better evidence base to inform societal actions. The framework connects the three relevant analytical aspects of the topic in question:

(a). it systematically and conceptually frames the objects, i.e., the energy consumption behavior and its change (explananda);
(b) it structures the factors that potentially explain the energy consumption behavior and its change (explanantia);
(c) it provides a differentiated understanding of change inducing interventions in terms of governance.

It seems that both our understanding of the determining factors of energy-related consumption and our understanding of the drivers and barriers of change need to be improved for making progress toward reduced energy consumption in households. The distinction between understanding behavior and understanding change of behavior has been introduced on purpose. (cf. also Darnton, 2008). The first explains energy consumption behavior (ECB) as it is today, and the second explains its change. This distinction is decisive and allows us to unfold the different scientific tasks stated above: The first goal of “explaining ECB” implies answering the following two questions:

1. What is ECB?
2. Which factors determine ECB?

Question (1) is by no means trivial, as an explanation is basically dependent upon what is to be explained and different disciplines subsume different meanings under the term ECB. Thus, answering question (1) is a first indispensable step toward clarifying the research object (explanandum, a). Question (2) then addresses the explaining factors of the behavior in question (explanantia, b), e.g., milieu related aspects, decision heuristics, spontaneous developments, norms etc.

However, explaining “ECB” includes neither the temporal dimension of change nor the reduction goals. Hence, there is a second explanatory goal, namely explaining “change of energy consumption behavior toward reduction”. Accordingly and following the above made distinction between explanandum and explanantia, two further questions can be formulated:

3. What is “change of ECB”?
4. Which factors explain changes of ECB?

Again, answers to question (3) are not as straightforward as it first may seem. Among others, a clear definition of the scope of “change” is mandatory. Are we simply talking in terms of reduced kJ on the individual level or do we broaden “change” to capture a changed perception of what makes up quality of life (cf. Mourik and Rotmann, 2013)? Hence, analyzing behavior and analyzing its change force us first to clarify the object of interest (explanandum, a).

Question (4) also asks for clarification, as the term “factors explaining changes” (explanantia, b) could be interpreted in two ways. First, it can refer to those factors that explain behavior according to question (2). As changing behaviors ask for different determinants, we need to identify the variation of the factors within the types. Second, “factors” can also refer to interventions, political instruments etc., i.e., to elements directed to steer behavior toward a change. However, we do not use the term “factor” in that second sense. Instead, we propose to add a fifth question:

5. What are the constituents to be taken into account to successfully govern change of ECB?
Question 5 deals with the realm of governance. Given the complex scientific debate on “governance of societal change,” it is worth considering this topic and refraining from an exclusive focus on political instruments.

An abundance of literature already contributes to many aspects within the sketched explanatory fields. Whether the current state of the art copes with the indicated distinctions and their inherent complexity is at least doubtful. Despite the large number of scientific studies, science still struggles with understanding ECB and the triggers for changing it. There is only partial knowledge on what forms of governance induce which changes in what kind of energy-related behavior of which individuals. Most importantly, the scientific state of the art displays strong disciplinary splits (Keirstead, 2006) to the effect that there is only little understanding of the interrelations among different aspects of ECB across the different fields. To cope with this requirement, we base our framework on the existing state of the art in the disciplines we represent, i.e., psychology, economics, consumer behavior, business science, sociology, and political science.25

Some integrated models have already been set up in (more or less) interdisciplinary approaches (e.g. Hitchcock, 1993; Dholakia et al., 1983; Wilk, 2002; Keirstead, 2006; Stephenson et al., 2010; Wilson and Dowlatabadi, 2007). While recognizing the instruction value of these models, there are obviously some important caveats. First, there is a gap between economics and the other types. Second, all rely on some disciplinary, partly contested theory. Third, governance of change is often only represented by the very general category “intervention,” leaving it as a black box. Hence, we follow Wilson and Dowlatabadi’s (2007) statement that there is still an academic gap regarding integrated, interdisciplinary models or frameworks that systematically capture the different explanatory tasks regarding ECB and its (governed) change. Our paper contributes to closing this gap.

Moreover, there is a practical add-on. The authors of the original paper are all members of the work package on change of behavior within the Swiss Competence Center for Research in Energy, Society, and Transition (SCCER-CREST).26 In this context the proposed framework in this paper already guides research providing empirical evidence for business, political, and civil society actors on the change of ECB. For example it proved to be successful as the basic concept for the newly established SCCER-CREST long-term Swiss Household Energy Demand Survey (SHEDS).

2. **An integrated framework**

Following the overall definition that a conceptual framework provides a rather general descriptive foundation for explanatory inquiries, our framework does not give explanations by itself, but frames the space for searching for explanations. Moreover and in contrast to the frameworks mentioned above, we refrain from building the framework onto a specific theoretical fundament. Searching for such a common theoretical basis is an unrealistic endeavor given the manifold of theoretical behavior approaches, e.g., rational choice, bounded rationality, theory of planned behavior, norm-activation-model, value-belief-norm characteristics, social practice theory etc. (cf. Keirstead, 2006; Wilson and Dowlatabadi, 2007; Darnton, 2008; Stephenson et al., 2010; Karatasou et al., 2014). Accordingly, the framework is problem oriented, not theory oriented.

25 The thus composed framework is based on the results of the disciplinary reviews (cf. in the original paper, Burger et al., 2015). However, it also goes beyond them by relating and integrating them within an interdisciplinary framework.

We will proceed as follows to present our integrated framework: we will frame the explananda (a) in a first step, hence approaching question (1) regarding ECB and question (3) regarding its change. The second step concerns the explanantia (b), taking up questions (2) and (4) on the factors that explain the behavior and its change respectively, by introducing the categories “Opportunity Space” and “Decision-Making”. The third step would then deal with the governance aspects, related to question (5).

2.1. Explananda: Types of ECB and their Change

We talk about ECB not in terms of consumed energy, expressed in some kJ/individual, but in terms of “energy services.” The latter takes into account (1) that individuals generally consume goods and services, i.e., do not use energy directly, but are demanding services like a heating system that (2) serve specific benefits expressing subjective well-being like having it nice and warm. Turning the heating on is connected to coziness and health, using the car is often associated with comfort and convenience etc. (Shove, 2003). The last example adumbrates, however, that the associated underlying expectations regarding well-being could differ remarkably across the individuals.

Furthermore, we follow Bergius distinguishing between action-specific and material-specific ECB (Bergius, 1984). Lighting, cooking, driving by car, and watching TV are examples for action-specific ECB accompanied by some direct energy consumption. In contrast, material-specific ECB are normally purchasing activities that do not include any direct energy consumption. However, there is already a notable amount of energy consumed for production and transportation of the products when looking at the whole life cycle of a product: embodied energy. By further distinguishing the main consumption domains “heating,” “electricity,” “mobility,” and “consumption of products,” we get to the table in Figure 1. The categories within the frame, illustrated by exemplifications, display our answer to the first question.

<table>
<thead>
<tr>
<th>Action-specific / Direct</th>
<th>E.g., heating, using warm water</th>
<th>E.g., cooking, washing, watching TV, listening to music, turning lights on, using air conditioning</th>
<th>E.g., driving, using plane</th>
<th>E.g., skiing, going out for a meal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material-specific / Embodied</td>
<td>E.g., purchase specific heating units, boiler, heat pump</td>
<td>E.g., purchase specific washing machine, TV, pc, mobile, light bulbs, air conditioner</td>
<td>E.g., purchase specific car</td>
<td>E.g., purchase leisure equipment, soft goods (food, apparel), hard goods (furniture)</td>
</tr>
</tbody>
</table>

**Demand of Energy Services**

<table>
<thead>
<tr>
<th>Heating</th>
<th>Electricity</th>
<th>Mobility</th>
<th>Consumption of Products</th>
</tr>
</thead>
</table>

*Figure 1* Explananda – examples for types of ECB.
There seems to be a straightforward answer for question (3) on “what is change of ECB”: the amount of reduced energy like some ΔkJ/individual or some ΔTJ on an aggregated level. Following our line of reasoning, however, this can hardly be the explanandum because individuals do not consume energy but energy services. “Change of ECB” means changed demand for energy services. The explanandum could therefore encompass any feature within Figure 1 including changed expectations toward “demands” and thus quality of life. Accordingly, our second explanandum (a) consists in the same categories as in Figure 1, but also including (b) a time factor, and (c) variations in demand of energy services that are expected to contribute to achieving the reduction goal (figure 2).

<table>
<thead>
<tr>
<th>Action-specific, Direct</th>
<th>Material-specific, Embodied</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.g., reduced temperature in dwelling, changed heating and ventilation habits, showering instead of bathing, reducing shower time</td>
<td>E.g., increased building-related efficiency (isolation), purchase more efficient heating, own generation of heat (solar heat, heat pump), energy service contracting</td>
</tr>
<tr>
<td>E.g., renouncement of air-con, using appliances (e.g. laundry rack instead of dryer), turning off stand-by, changed cooking behavior</td>
<td>E.g., purchase of more efficient appliances, energy-saving light bulbs, own generation of electricity (PV), energy service contracting</td>
</tr>
<tr>
<td>E.g., renouncement of using a car, using bike or public transport, driving behavior (eco-drive), reducing traveling by plane, choice of dwelling location</td>
<td>E.g., car sharing, purchasing more fuel-efficient cars</td>
</tr>
<tr>
<td>E.g., change of diet (e.g. eating less meat, less energy-intensive cooking), wearing second-hand clothes, reducing food waste, etc.</td>
<td>E.g., buying seasonal/local/organically produced food, purchasing eco-labeled cloths or furniture, own production of food</td>
</tr>
</tbody>
</table>

**Figure 2**  
Explananda – examples for types of changed ECB.

To sum up, we propose to frame the explananda – the individual consumption behavior and its change, respectively, as illustrated in Figure 3.
2.2. Explanantia: Explaining Energy Consumption Behavior and its Change

The disciplines offer a variety of determinants for explaining the behavior in question: psychology points to values, attitudes, emotions, while economics refer to socio-economic determinants such as income and prices, consumer behavior and economics to decision heuristics, and sociology to determinants like milieu, status, and inequalities. All disciplines contributing to explaining ECB stress the interplay between the different factors. The challenge for answering question (2) is not so much related to the factors themselves, as it is related to organizing them by taking account of explicitly not basing it on a specific theory (cf. above).

Against this backdrop, we suggest framing the realm of explanantia as follows: to capture the interplay between “the social” and the “individual” factors, we use the term “situated individual” to highlight that we are looking at individuals living embedded in complex social environments. The explicit choices or the routines leading to ECB of such a situated individual are then thought to be based on two major categories: the existing opportunity space and the individual’s decision making.
Opportunity Space

There are two types of factors that make up an individual’s opportunity space: factors on the macro-level expressing the social environment, and factors on the individual level. A distinguishing feature between them is that the former are normally not directly influenced by the individual, whereas the latter could be (with few exceptions). An individual cannot change, e.g., the technological options, but can try to change her own educational or economic performance.

We label the structural elements framing the action fields for individuals on the macro level as belonging to the social opportunity space (SOS), cf. figure 4. For example, if certain (energy-efficient) technologies are not commercially available, the options for changing the material-specific consumption behavior are restricted accordingly. Contrarily, we name the many factors on the micro-level discussed by the disciplines above as belonging to the “individual opportunity space” (IOS).

The relation between SOS and IOS is thought to be twofold. On the one hand, the components of the SOS are to some extent translated by the individuals into their IOS to form their behavior. For example, selected from the commercially available technologies there is a certain stock of available appliances in the households. On the other hand, there are feedback-loops from IOS to SOS. Changed demand on the individual level through change of expectations can induce changes on the SOS level, e.g., new products and services or change of market conditions.
The SOS and IOS encompass together the realm of potential determinants of ECB as well as its change. It is not the factor *per se* that will change, but how it is instantiated today. Prices will always be determinants, but their variation leads to different behaviors. The task consists in looking at those variations that will lead to the expected change of behavior. Moreover and as expressed by the notion “opportunity,” it is neither the case that every single contextual factor is a necessary prerequisite in explaining the observable ECB nor is the listing of the factors in the graph meant as being exhaustive.

**Decision-Making**

Given their social and IOS, individuals make specific decisions “translating” the elements within the OS into a specific observable material- or action-specific ECB. Hence, besides the factors within the OS, there are additionally those factors that are determinants for “decision-making”, as belief structures, value systems, attitudes, emotions, motivations, heuristics, and biases. For example, demands for comfort, motivations like financial benefits, or environmentally friendly values and emotions could translate the OS-factors into behavior X, whereas other determinants for decision-making could lead to behavior Y. Thereby, we let “decision-making” encompass both – conscious choices as well as routines, as long as the latter implicitly includes the option for choices.

That scheme of explanantia (cf. figure 4) is meant to function as a heuristic that helps to sort the complexity of potential explaining factors. It is not to be confused with a sequenced model or theory, as we already pointed out above. No causal claims have been linked to the factors within SOS and IOS and the factors for decision-making. Causal claims have to be empirically established. We expect that the according evidence on how the different factors in and between the three different dimensions (SOS, IOS, and DM) “play” together will lead to a better understanding of what determines ECB and its change. For example, constraints in the SOS might be so severe as to make it extremely costly for an individual to act on his/her values or to react to price incentives. Similarly, the individuals’ value system might determine how they react to common behavioral economic incentives. For example, individuals react differently to the very same economic incentive to invest in home improvements (Stern, 1986, 2014). Thus, by starting to look into how these different dimensions interact, we expect to get a more comprehensive explanation of ECB and its changes.

2.3 Governance of Individual Behavior Patterns

The third component of our framework deals with the governance of individual behavior, following question (5). “Governance” is not just another word for “policy” but refers to constellations of instruments, institutions, and actors that collectively shape individual action toward common goals. “Governance of ECB” potentially includes all three dimensions politics, polity, and policy. Drawing on this and in light of the differentiated picture of ECB as well as the multiple factors that explain the various types of behavior and their changes, governance of ECB turns out to be a complex issue itself. It is not merely about the proper design of single policy instruments addressing particular factors. Rather, governance is about the design of complex instrumental arrangements that address different factors in a coordinated way. These instrumental arrangements are themselves created and enacted by institutionally embedded collective actors (i.e., not only the state but also business and civil society) affecting the design and implementation of instruments as well as their legitimacy and effectiveness. Questions to be answered then include: who (what constellation of actors) is governing, under which conditions (institutional setting) with what means (set of policy instruments) to address which determining factors of which type of individual energy-related behavior? These basic questions can orient both the empirical analysis of existing governance arrangements and the design of practical governance
arrangements. In Figure 5 accordingly, the three domains policy, politics, and polity frame the triangle, taking account of policies, procedural factors such as networks, hierarchies, resources, and structural factors like institutional settings. The arrows above the triangle link the governance scheme to the scheme of determinants (SOS, IOS, and decision making).

![Figure 5](image)

**Figure 5  Governance of changing ECB.**

The general three-dimensional conception of governance can be further specified by including the characteristics (a) group-specific, (b) multi-factorial, (c) integrated and (d) adaptive:

(a) **Group-specificity**: governance of ECB can address diverse groups of individuals: different individuals with different behavior patterns, not acting constantly rational or consistent. Moreover, there are different types of ECB. By analyzing or designing governance of ECB, the potential relevance of group-specific factors or the characteristics of different ECB-types need to be considered.

(b) **Multi-factorial**: governance interventions can be directed to different components of the opportunity space or decision-making (access points). For example, one could try modifying market conditions or legal norms (arrow to the SOS) or to directly influence the ECB by a change of price structures (arrow to the IOS). Likewise, factors such as heuristics behind decisions or routines could be addressed, say by interventions like nudges, or information campaigns. Thus, interventions can trigger a number of factors. However, not all factors that explain ECB and its change are potential access points for governance, e.g., demography, geography, age, or gender.

(c) **Integrated**: additionally and related to (b), there are multi-instrumental settings (policy mixes), accompanied by interactions between the different instruments. The according analysis (or design) of policy instruments on change of behavior then should not only address sets but also combinations of instruments and their coordination by taking their aggregated effects into account.
(d) Adaptive: current patterns of ECB are the result of a certain incumbent governance regime and changing ECB requires its transformation. As individual behavior can only be changed step by step and as attempts of governing energy-related behavior are embedded in complex societal situations that include many options for unexpected development and side effects, governance of change is an ongoing task. Analytically, it requires including uncertainty and the capacities for on-going adaptive forms of governance.

Put in a nutshell, “governance” offers a differentiated set of categories for analyzing the steering side of change of ECB. It directs the researcher to taking account of the different dimensions of governance, of different groups and types of behavior as well as the variety of explaining factors, and requirements of integration and adaptability. It provides a conceptual basis, which allows looking at which type of governance arrangements has the potential to influence which type of determinants to get which type of change of behavior. Which factors are really relevant in what fields of change of ECB has to be established empirically.

Besides, the question of desirability or legitimacy arises. The “bossy state” telling citizens how to behave or how to change behavior and leaving the individual with only restricted choices is rarely compatible with a liberal stand. Likewise, scientists can certainly not prescribe how individuals should live their lives. Is there something like a liberal paternalism expressed for example in nudging efforts? In any case, research on governance of change of behavior needs to be accompanied by scrutinizing the legitimacy of such governance.

3. Synthesis and Outlook

Putting the three pieces together then, we come to the overall framework as illustrated in Figure 6.
Figure 6  Integrated framework – understanding ECB and the governance of its change.

The framework displays our answers to the five initially stated questions and links the three analytical aspects (explananda, explanantia, and governance). It systematically distinguishes the two explanatory perspectives and offers an integrated approach to understand and explain ECB and its (governed) change. Based on the best available disciplinary and interdisciplinary knowledge and aggregated over the subsectors of consumption, our framework provides an interdisciplinary basis for linking different aspects in empirical settings. The framework – not model or theory – does not offer explanations or evidence about sequenced relations. Moreover, we certainly do not claim that an empirical research design has to pay attention to all elements addressed by the framework. The framework is a heuristic tool that already guides present and may guide further theoretical work and empirical analyses by especially addressing possible interfaces between the manifold of factors.

Literature (Full list of References, cf. Burger et al., 2015)


Beyond calorie counting: What can energy feedback learn from weight loss programs?

Michelle Shipworth, UCL Energy Institute, University College London, m.shipworth@ucl.ac.uk

Abstract
Losing weight used to be seen as an exercise in counting calories and limiting their intake. This required knowing the calorie content of each food ingested, with dieters referring to reference materials on the calorie content of foods. One problem with the calorie counting approach is the difficulty of measuring the effect of different foods on the body, since the body does not absorb all the calories present in some foods. Another problem is the different "value for calories" in different foods; some calories come in foods that are nutrient rich, while others are "empty" of goodness. Moreover, governments are increasingly abandoning a calorie-counting approach to weight loss, using instead culturally relevant food based dietary guidelines, such as images of healthy meals on plates. These communicate graphically what a healthy meal looks like. Finally, anti-obesity policies are now exploring how "obesogenic environments" may be creating conditions that make it extremely difficult for individuals to lose weight. This paper explores the possibilities and difficulties of energy demand reduction programs learning from weight loss programs.

Extended abstract
In the 1980s, weight loss programs focused on counting calories, different ways of explaining the calorie content of food and targeted individuals with clear weight problems (Wing et al 2012). This approach required knowing the calorie content of each food ingested, with dieters referring to reference materials on the calorie content of foods. The difficulty of measuring the effect of different foods on the body is one problem with the calorie counting approach. The system used for determining the energy value of foods, founded over a century ago by Atwater at the US Department of Agriculture, has been found to significantly mis-estimate the available calorie content of some foods and over-estimate the available calorie content of almonds by 32% (Novotny et al 2012). One reason for this is the amount of energy it takes to digest food. Barr & Wright (2010) have shown that digesting a whole-food meal consumes 20% of energy available in the meal whereas digesting processed food consumes only 11% of meal energy. It takes twice as much energy to digest protein as carbohydrate and protein also reduces hunger more effectively (Acheson et al 2011). In energy demand reduction, we are a long way short of providing the equivalent of a reasonably accurate calorie counter reference. Even though households may know whether their overall "calorie intake" is increasing or decreasing, they don't know what actions by which members of the household are making a difference. Even if it were possible to provide a reference akin to a calorie counter, there are reasons beyond the difficulty of measuring calorie intake for calorie counting falling out of favour as a weight loss tool.

The different "value for calories" in different foods is another reason for calorie counting falling out of favour; some calories come in foods that are nutrient rich, while others are "empty" of goodness. Even Weight Watchers has decided that calorie counting is unhelpful given that not all calories are created equal (Sachs 2011). For instance, whereas "trans fatty acids from partially hydrogenated vegetable oils have clear adverse effects and should be eliminated… polyunsaturated fatty acids are essential and...
reduce risk of heart disease…(so) increasing intakes of nuts, fish, soy products and nonhydrogenated vegetable oils will improve the mix of fatty acids and have a markedly beneficial effect on rates of CHD (coronary heart disease) (Willett 2012 p.13). Analogous to different foods are the different specific services provided by a kWh. A kWh consumed by using a mobile phone to surf the web may provide more value than a kWh consumed by leaving the hall light on overnight, suggesting the possibility of energy saving programs targeting low value kWh savings. Unfortunately, unlike "value for calorie", "value per kWh" varies enormously depending on the specific technology providing the service, the person receiving the service and when and where the service is provided.

It is also difficult to consistently count calories. It requires a lot of individual motivation, is complicated and time consuming and not easily accommodated in everyday shopping, cooking and eating habits. These problems reflect those found in studies of the use of energy feedback devices, which frequently fail to live up to the energy reduction expectations of policy makers.

In the 1990s, weight loss programs shifted from a focus on counting calories to one on culturally relevant food-based dietary guidelines. Nutrient requirements were transformed into something individuals could understand and act on to achieve healthy weight and good health (Dwyer 2012, Weisell & Albert 2012). Food pyramids and healthy eating plates abounded; these communicate graphically what a healthy meal or diet looks like. Calorie counting was increasingly seen as a tool appropriate for use by health experts and the small minority of individuals particularly motivated to control their weight. Examples of food-based dietary guidelines include the NHS "eatwell plate" and the Harvard School of Public Health "healthy eating plate". Physical plates with imagery have also been developed to help with portion control and food selection at mealtimes. These images and physical support tools are easy to use when engaged in the everyday routine of eating meals. The content of these communications shifted to culturally relevant social routines (e.g. meals), but the target of the campaigns remained individual behaviour change, although more recently there are arguments to further target the approach and visuals to particular groups in societies (Hawkes 2015, Montagnese et al 2015). Is there a role for a "healthy eating plate" of energy demand services? What would this look like?

Pullinger et al 2014 outline the EPSRC TEDDINET funded IDEAL project (Intelligent Domestic Energy Advice Loop (March 2013-March 2017), which aims to use disaggregated smart meter data to provide tailored feedback informed by social practice theory. Citing Spurling et al, Shove et al and Hand et al, they outline social practice theory as investigating a specific 'entity' that can be conceptualised as constituting three classes of elements: materials ("physical spaces and artefacts"), competencies ("skills and know-how of the performer") and meanings. The specific elements vary over time, according to the availability of materials and variation in "cultural and social norms". The project uses social practice theory in two ways. Firstly, they use it to inform the understanding of different energy consuming routines, such as space heating and washing. Secondly, they view the feedback device as the material component of a new practice of reflecting on energy consumption. However, project outputs have not yet outlined what that feedback might constitute.

Shove & Royston (2014) express scepticism with such an approach, arguing that energy use is so deeply embedded in everyday life that "it is impossible to treat energy as something that can be stripped out from the detail of daily life. Helping people understand their energy consumption, as if this were a topic in its own right, is therefore of limited value. Knowing just how much energy is used in making tea, or in doing the laundry will not transform established habits and practices that are embedded in the fabric of social life as we know it today…If we are to understand how people engage
with energy systems, it is not the meter that needs to get smarter, but our understanding of what energy is for and how it is used."

In the 2010s, although individual behaviour is still considered important in weight loss programs, obesity programs increasingly include investigation of "obesogenic environments"; the physical and social environment creating conditions that make it extremely difficult for individuals to lose weight (Roberto et al 2015; Government Office for Science 2007).

"Calorie-focused thinking may have already exacerbated the epidemics of obesity and related diseases….Yes, calories count, and calorie balance sheets matter, but net intake or expenditure probably results more from qualitative distinctions in the foods we eat than conscious attempts at quantitative control. New public health initiatives and messages focused on encouraging consumption of whole/minimally processed foods would be ideal, especially to counteract industry's near-exclusive marketing of foods that are highly processed/refined and concentrated sources of the most rapidly absorbable starches and sugars. Promoting the consumption of whole foods will require careful attention to food systems, cultural traditions, peer influences, food environments, assistance programmes and a host of other issues beyond the scope of the present commentary." (Lucan & DiNicolantonio 2015 p.577, emphasis added)

Likewise, energy demand research informed by theories from science and technology studies finds that the built and technical environments can create conditions that push energy consumption up. Anthropological studies have found similar social drivers for energy consumption. Shove (2015, p.40) argues that consumers are not necessarily "both willing and able to modify the timing of what they do [given] the extent to which daily rhythms are socially, and not individually, orchestrat-ed…Understanding the potential for rescheduling the timing of energy demand arguably depends on much better understanding of the social ordering and orchestration of daily life...[including] standardised working hours - a patterning that generates spikes and peaks of demand when people return home, an in the morning before they set off for work." She argues that the focus needs to shift to the range of public policies that impact on this temporal ordering, (e.g. education, employment) but also cautions that this shift in focus is a poor fit with current policy making.

References


Malhotra, A., DiNicolantonio, J. J. and Capewell, S. (2015) It is time to stop counting calories, and time instead to promote dietary changes that substantially and rapidly reduce cardiovascular morbidity and mortality, *Open Heart*, 2(1). Available from: http://openheart.bmj.com/content/2/1/e000273.short.


SESSION 5A: Communities & Collectives

Householder engagement with energy consumption feedback: The role of community action and communications

Kevin Burchell*, Ruth Rettie and Thomas C Roberts
* Policy Studies Institute, University of Westminster
k.burchell@westminster.ac.uk

This abstract is based on the published paper:

Abstract

The provision of energy consumption feedback on in-home displays (IHDs) has a prominent role in government strategies for domestic energy demand reduction. Research suggests that IHDs can support energy consumption reduction, but also that engagement with IHDs is: not appealing to many householders (because it data-oriented and insufficiently relevant to everyday life), is often short-term, can be limited to one household member (leading to conflict), often seems to reinforce existing practices and can be difficult to convert into demand reduction. In this paper, we draw on research carried out in a project called Smart Communities. This study was distinctive because the energy consumption feedback was: accompanied by a weekly email communications programme that emphasised consumption monitoring and engagement with the feedback, provided within the context of a programme of local community action (such as workshops and other events) and implemented over two years. Thus, while many feedback projects focus on content, this study emphasises the importance of context. Project findings suggest that, although by no means panaceas, approaches such as these can support long-term engagement with energy consumption feedback and can support behaviour change. The community action was important because it promoted a valuable sense of ‘being part of something’ among participants. The email programme was important because it prompted action and engagement, and because it led to a sense of ‘working together, but apart’ among the participants who were not involved in the community action activities. The importance of the local, informal, friendly and supportive tone of the emails cannot be over-emphasised. In our discussion, we suggest that what our work did was render feedback relevant to everyday life, we discuss ways in which the insights from this work might support large-scale energy consumption feedback programmes, and we encourage policy-makers to start planning future app-based feedback platforms.
Transforming Feedback into Collective Knowledge

Lara Schibelsky Godoy Piccolo*, Harith Alani
Knowledge Media Institute, The Open University
Milton Keynes, UK
{lara.piccolo, h.alani}@open.ac.uk

Abstract
Energy feedback can assume a strategic role in energy policies to promote energy conservation in large scale. But it is well known from the literature that feedback alone does not always lead to energy savings in domestic environment. People usually need more specific guidance on how to change their behaviour in an effective and sustainable way, reflecting their own values and circumstances. Based on this assumption, this research considers energy consumption feedback as a learning element part of a 3-steps process: i) **self-perception** - people first need to understand their values and motivations to save energy; ii) **understand consumption** - become aware of how they are using electricity, opportunities to change habits and behaviour, and impact of their consumption; iii) **collective knowledge** - promoting dialogue and collaboration to define best practices and engage people with energy conservation as a social issue. In this abstract, we describe the tools we have applied to develop this process and summarise the feedback received from a group of community leaders in the UK working on promoting energy savings. Results point out that familiarity with technology may be a strong barrier for people to adopt and make sense of energy feedback. And suggests that tools to mediate discussions around energy savings can help overcoming this barrier that prevents people’s engagement. By bridging the gap between strongly motivated people and the more technically skilled ones, we are able to transform feedback information into collective knowledge.

1. Introduction

As one of the humanity development foundations, electricity keeps challenge science both in technical and social aspects. Many technical innovations still rely on individuals’ adoption and behaviour change to be successful. Finding the right strategies to engage people with the energy issue, though, has proven to be a complex task. Some people might be indifferent to the issue, but many recognise the need to rethink the way energy has been consumed or generated. Even so, a number of barriers, many already identified in literature, may prevent changes in behaviour towards energy conservation.

Although ubiquitous, energy is also invisible. A diversity of feedback technology has been made available to bring energy to a more “tangible” and measurable dimension. But several experiences, both in literature and also in our research have proven that just providing feedback is not enough for engaging people with energy conservation as a social issue. Cultural aspects, social norms, energy regulation, design of appliances, the relationship with energy suppliers, are examples of the multitude of forces that influence the way people perceive energy and make sense of the feedback, when it is provided.

To cope with these “social” variables, in the context of the project DecarboNet\(^{27}\), we rely on dialogue and collaboration as social dynamics to engage people with energy conservation as a social issue. As

\(^{27}\) DecarboNet ([www.decarbonet.eu](http://www.decarbonet.eu)) funded by the European Commission focused on raising awareness of climate change.
part of our Energy Trial, we have developed tangible artefacts and an online platform to mediate discussions around energy consumption within social groups, as explained as follows.

After describing our tools, in this abstract we summarise results of the feedback provided by community leaders in the UK on how the tools and strategies could be applied to support their existing energy saving campaigns. We then conclude the abstract with some main findings, and pointing out on going and future works.

2. Towards building collective knowledge

As reported in 0, we propose a 3-steps strategy mediated by a set of tools to trigger discussions and collaboration around energy saving:

1) Developing self-perception is the first step, supported by the paper tool Value Tree. It aims to leverage personal and group values, identifying then the forces that lead or prevent people in this group from saving energy.

2) The second step involves the House Mapping tool, another paper-based artefact to help people understand their own consumption at the appliances level, and to identify opportunities for savings. Energy consumption feedback is also provided in this step for people to evaluate the impact of current energy-related habits.

3) Once this individual knowledge is developed, we introduce the EnergyUse, an online space to share energy saving experiences and to build knowledge collectively.

This process was built taking into account a set of guidelines that summarises lessons learned from the literature and from our previous studies 0:

- **Apply energy monitors as learning tools**: we are relying on smart plugs for people to learn how to configure appliances efficiently, quantifying benefits of shutting-down or unplugging devices, quantifying costs of daily actions, etc. 0.

- **Create mechanisms and strategies for sharing personal experiences**: instead of focusing on providing general recommendations for reducing energy consumption, we expect people to build knowledge collectively by sharing stories and experiences.

- **Promote emotional (not only rational) involvement**: people must feel comfortable to evaluate and discuss the trade-off between environmentally friendly choices and individual values, such as comfort, security, and so on. Discussions and negotiation among people in a social group have been encouraged to come up with concrete possibilities to save energy.

The tangible and online artefacts that mediate this process are described in the next subsections.

2.1 Tangible artefacts

Components of the DecarboNet Utility Toolkit 0, the tangible artefacts Value Tree and House Mapping were designed to mediate activities in the domestic context towards energy conservation 0. Value Tree aims at linking personal values with environmental commitment and energy usage, thus creating a shared understanding within a group of users, usually a family. Group members list 5 personal values regarding the environment and energy, such as protection, comfort, etc. Then they negotiate and agree on a final list of the 5 main values to be represented in their collective tree.

For the House Mapping, participants are invited to draw the layout of their house, considering all the energy points and appliances. They start from the room each person feels most comfortable in. Once the mapping is complete, participants apply the Mood Tokens on the top of the map. The tokens represent the feelings related to how energy is consumed there ranging from very good (happy) to
very bad (unhappy), or a a question mark for when they cannot reach consensus. Figure 1 illustrate both artefacts in use by a community leaders group in the UK.

![Figure 1 - Value Tree (a) and House Mapping with Mood Tokens (b)](image)

Families in the Netherlands, Switzerland have also applied the Utility Toolkit 0 in social activities to discuss their values and possibilities to change their current energy consumption patterns.

### 2.2 EnergyUse

EnergyUse is an online social and collaborative platform for people to discover, share, and discuss tips for conserving energy. The main components of EnergyUse are:

- **Discussions**: The homepage (Figure 2a) shows all discussions going on with the respective number of votes, replies and views each discussion has. Discussions can be explored by any website visitor, but the user has to sign up to contribute to current discussions or to create a new one.

- **Tags (topics and appliances)**: Users can navigate discussions by tags associated to appliances or contexts of energy usage (e.g., working in the office, breakfast). Every appliance and topic has a dedicated page of discussions. If available, average energy consumption data within the community for a given appliance will be displayed. For privacy reasons, users are only able to view aggregated energy consumptions from all other community members, for any given appliance. Finally, users can subscribe to the topic or appliance feed to receive updates of new posts.

- **Profile and consumption feedback**: Users’ profiles contain their picture, username, reputation score, and recent contributions. Users of energy-monitoring devices from Green Energy Options (GEO - Figure 2b) can also interact with the consumption feedback of specific devices connected to smart plugs, or of their entire households, and compare with the community’s average. Energy consumption data is collected from GEO database every 15 minutes.

Currently, the platform users are mainly participants of DecarboNet energy trial in the UK. Around 150 households across the country volunteered to install energy monitors and smart plugs, and have now been invited to share the knowledge acquired with other people through the online platform 0. So far, 57 participants are registered, and 38 of them linked their GEO devices with the EnergyUse platform. According to Google Analytics, up to now EnergyUse received more than 520 unique visitors, generating more than 1,000 sessions with an average duration of almost 5 minutes each, with 54% returning visitors.
3. Feedback from community leaders

As fully reported in 0, we counted on 8 community leaders in Liverpool, UK, to establish how these tools would be perceived in local communities. The participants are already involved with energy saving campaigns engaging a diversity of groups, including families from deprived areas, immigrants, and elderly people. For this reason, the feedback the participants provided potentially represent also how people in their community would deal with a tool or situation. Along 3 workshops of 2 hours each, participants discussed values, motivations and barriers related to energy savings, mapped energy-hungry spots in the community centre and in their own houses, discussed energy usage in their daily routines, and tips for energy saving. They also evaluated how our strategies and tools can support their current mission to spread energy conservation messages across their neighbourhoods.

The main findings and suggestions for future works obtained from this experience are summarised as follows:

- **Self-perception**: “It's not about time or energy, is what we need to keep our lifestyle”. This participant’s statement illustrates the need to consider energy actions that respect personal values. The discussion also brought to light concerns that may prevent people to change behaviour towards reducing consumption. To mention a few, reducing heating, which may impact health, and turning lights off, related to the sense of security. Mainly for the tangible and interactive nature of the Value Tree and the House Mapping activity, they were found to be effective in engaging groups in discussions and negotiations around their self-perception. As a community leader recognised: “it’s better to ask people instead of assuming what they need to know.”, referring that disseminating on-size-fits-all tips for energy conservation is not the most effective strategy for community campaigns.

- **Understanding consumption**: We are constantly making choices on how we use energy. For example, participants discussed the eventual impact of cooking with microwave or slow cook; efficient settings for appliances, like the eventual advantages of “eco-mode” of washing machines, etc. This discussion made evident the need to measure appliances and devices consumption to compare choices and to explore typical myths. Even though, the participants did not feel the energy monitors were suitable for them. They also argued that if they cannot make sense themselves of the feedback provided, they do not perceive the value in supplying people in...
the community with these monitors. Electricity consumption in kilowatt/hour rarely emerged as a topic. “There’s an assumption that people know about kWh. Everything that comes out information-wise is in that level! This is too technical!” mentioned a participant. They preferred to check an estimate cost online instead of measuring consumption. Money is still the main target for making energy tangible and measurable, even though the little money associated with individual appliance consumption was too low to raise interest. External factors, such as tariff options, deals with energy suppliers, characteristics of buildings, appliances settings, etc. frequently dominated the conversation.

- Collective knowledge: Sharing experiences with other people is a common approach in all aspects of our lives. For instance, participants mentioned asking neighbours’ advise on operating typical devices, such as boilers or thermostat in efficient way, since they are likely to have similar equipment. EnergyUse has the purpose of empowering technically skilled people keen to learn from feedback devices and disseminating this experience across the community. Even though, the community leaders considered the platform too technical in terms of content and interaction design. As a participant clarified “open-ended question is more confusing in the end of the day. People need options or choices.”, referring to the suggestion of creating menus related to everyday activities such as cooking, then the options of appliances related to that, rather than a forum-based format. Also, to expand the target user group to those who are not that familiar or keen on technology, the platform should evolve to support the navigation by people interested only in consuming tips, and should target also money and tariffs. A community leader also strongly suggested offering incentives to bring people to discuss energy conservation online. According to their experience “some people have a natural desire to learn more, but [for some people] vouchers might help”.

4. Conclusion and Future works

Some preliminary results of evaluating the Energy Trial pointed out the energy monitors as valuable learning tools, but not suitable to everyone. Installing them, making sense of the feedback, and transforming it into alternatives to save energy require some degree of familiarity with technology, which is not a reality for many people in the society, including the community leaders involved in our research. But some people are actually skilled and keen to explore the potential of the devices. This group of users should be identified, empowered, and invited to disseminate their knowledge with others. This study also suggested that people in general usually do not spontaneously talk about energy either online or in conversations. They actually need an external motivation, a trigger to do so. The tangible artefacts applied in this study, the Value Tree and Value Map, were found to be effective in triggering discussions within social groups. DecarboNet is now expanding the energy trial inviting new users and investigating what interventions/technology is more suitable to specific group of people, considering different degrees of familiarity with technology, and levels of concern related to saving energy that goes from saving money to protect the natural environment.

5. References


Social Media and Smart Phones: A way of influencing behavioral change using feedback.


Abstract
Low income households face daily decisions in how they use energy. Traditionally, helping these households to meet energy needs has been done through fabric improvements to a building alongside advice provision. Whilst advice provision is designed to help the household manage their energy effectively, in practice the way people live in their homes or use their energy systems is sometimes ignored. Truly understanding the social causes, pressures and lifestyles which can contribute to fuel poverty can not only help devise ways of tackling the problem but can also provide households with real information and support which can be community based. This in turn can create a more effective management of energy and a reduction of energy consumption. This paper highlights a project that sort to address these issues by looking at behavioural change research and then using social media as a method of creating interaction with a competition and developing an understanding of people’s lifestyles. It shows the importance of interaction between households, a community, and those agencies looking to deliver measures to reduce fuel poverty and the benefits that this approach can deliver.

Background
There are many people in the UK who are in Fuel Poverty. This is where a person cannot afford to effectively keep warm in the coldest weather and often have to make a decision between heating a house to keep warm or feeding themselves. Fuel Poverty is caused by a complex series of factors which vary from household to household, but essentially there are three key factors that cause fuel poverty (NEA 2016).

These being:
- Increasing fuel bills
- Low income
- Low energy efficient housing

There are official definitions by which levels of fuel poverty are measured, in England this is by something known as the Low Income High Cost method and in the devolved administration it is measured by the 10% definition. At the time of writing this paper, levels of fuel poverty in England in 2013 (DECC 2015) stood at 2.73 Million households or 12% of the population and across the UK as a whole at 4.5 Million or 17% of the population.

It should be noted though that these figures only reflect the households that fall under the definition and that have been identified.

Energy prices are also key to levels – in 2004 the average energy bill for both gas and electricity was £617.00 and by 2015 this had risen to £1254.00 doubling people’s bills. Saving energy is therefore a key part in helping people save money.

---

28 Figures based upon a usage of 15,000 kWh per year of gas and 3800kWh per year of electricity.
This paper is written on the findings of a project designed to help people help themselves. It focused on how people’s behavior towards energy could be improved over the longer term and to help them take actions which alongside improvements which could help reduce the potential of fuel poverty and help keep households warm in winter. The main tool for this project was Facebook and was used not solely to inform actions but to also to put emphasis on the ability of friends and neighbours to make improvements.

The scheme was carried out in an area known as The Meadowell in North Tyneside. This area was selected for several reasons. Firstly a project called Meadow Well Connected (MWC) had been looking at ways over several years to help people manage resident’s fuel bills. Secondly, Meadowell is one of the more deprived areas of the country. Ranked at 338 (DCLG 2015) on the IMD score across England out of 6791, it falls within the 5% most deprived wards of the country. Thirdly and most importantly, funding for the project was provided via North Tyneside Council and so had to be carried out in their area.

Methodology

Given the title “Game of Homes”\(^{29}\) The project was designed to create a friendly competition between households around saving energy and promoting activities. The 10 participating households were provided with energy efficiency advice from a qualified advice\(^{30}\) provider tailored to suit their needs. A game card with 10 top tips\(^{31}\) was distributed which participants were encouraged to implement on a daily basis and then discuss what they had done on the MWC Facebook page. Points were awarded for each post and the number of times that an activity had been carried out. Additional points were also awarded for carrying out measures that were not included within the tips along with savings made to energy bills and consumption comparing previous years and initial data. The project was carried out between the 28\(^{th}\) November 2015 and the 28\(^{th}\) February 2016. In order to ensure that households did not just switch their heating off to reduce bills to gain extra points putting health at risk, data loggers were installed to measure the temperatures within the properties over that period of time.

The aim of the project was to try and develop behavior change by using accessible technology. It was designed to both show people how easy it is for them to reduce energy consumption and manage it, and also to implement these actions themselves so they could appreciate the simplicity of it. At the same time the scheme also developed a peer to peer support mechanism by which the methods used to make savings were also be given to family, friends and neighbours who were not part of the scheme. By posting on Facebook on a daily basis, the intention was that the methods they used to save energy and the actions that they carried out became an everyday activity, embedding energy savings within their sub-conscious and helping them to embed behavior change over the long term.

Trying to understand behaviours across a range of disciplines has been the subject of much research and a range of differing approaches. E.g. Heiskanen, Johnson & Robinson. (2010); The European Environment Agency (EEA 2012); Shove, (2003) and Davis, Campbell, Hilden, Hobbs and Mitchie (2015).

---

\(^{29}\) The title and project concept belongs to Giacene 2015 who developed the game.

\(^{30}\) The advice provider was qualified to City and Guilds level 3 Energy Awareness.

\(^{31}\) See Box 3
The project though focused on the findings of report carried out by the Behavioural Insights team in the Cabinet Office on behalf of DECC. This report identified three main areas that need to be considered in any scheme for people to change behaviours. These being:

1. The tendency to ‘discount the future’;
2. The power of social norms; and
3. The use of defaults

1. Discounting the future. One of the barriers to making energy efficiency improvements relates to the fact that the benefits are accrued over a long period of time, whereas the costs associated with them are immediate and sometimes large. People often may prefer a smaller reward today over a larger reward in the future.

   Box 3 – The 10 top tips that participating households were given

   1. Keep the Curtains drawn from Dusk. Do not let them fall over radiators as this will just direct the heat out of the window
   2. Don’t heat rooms which are not used – either turn the heating off in the room, or down it down low
   3. If you have a room thermostat, do not use the boiler stat. Leave the Boiler stat on high and operate the temperature from the room stat. 20 degrees is the maximum it should be set at. This keeps the house at a temperature that is comfortable and prevents cold related illnesses.
   4. Turn off equipment when not in use including lights, chargers, TV’s Play stations etc. This includes turning appliance OFF standby
   5. Where possible use a pressure cooker or slow cooker to cook food. The Slow Cooker uses less energy than any other cooking equipment.
   6. Only fill the kettle with the amount of water needed, do not overfill.
   7. Use low energy light bulbs wherever possible. LED lamps use a fraction of the energy of standard bulbs and last up to 10 times longer. They are more expensive than other lamps, but will save money from longer life and lower energy use.
   8. Check bills against meter readings. Lend an energy display if possible and understand how much energy is used in different situations. This will help you lower your energy consumption
   9. Dry washing wherever possible outside, if bad weather means they need to be dried inside, don’t hang them direct on the radiators. Use a radiator hanger which will still let heat into the room but dries clothes at the same time.
   10. Wash at a lower temperature. If your washing machine can be turned down to wash at 40 or even 30 degrees, use the function, it takes less time and uses less electricity in heating the water.

To address this, the project did not focus on high cost measures but instead focused on simple tips and low cost items to help people make immediate savings and also show them how these savings could accrue over a period of time giving them more certainty when managing finances.

2. Social norms. People are heavily influenced by what others around them are doing. This project used social norms through Facebook posting to encourage the adoption of green behaviours.

3. Defaults. Individuals tend to go with the flow of pre-set options, or defaults, often regardless of whether the pre-set options maximise their wellbeing. There is also a tendency for people to revert
back to a “default” setting if learned practices are not reinforced. Working with the households and giving them an understanding of how they interacted with their energy systems provided them with options as to the best times to use systems and generate savings from the adoption of simple behaviours.

All the households that participated in the project were rented allowing the project to purely focus on measures that the households could implement. While the focus was on the top 10 tips (see box 3), the initial bespoke survey identified measures that people could carry out themselves for minimum cost including help on how to use heating controls effectively.

Findings
Upon completion, the results showed a significant impact on the participating households in both a reduction in energy consumption and a reduction in the amounts people were paying for fuel bills. The majority of participating households were on pre-payment meters some of which were Smart meters allowing households to see how much they were using.

Charts 1 & 2 below show the savings made by 6 out of the 10 properties participating
Evidence from player posts suggest that their energy-saving activities fell into two broad categories: those associated with behavioural change and those associated with the use new technologies, or engaging with existing technologies in new ways.

The most frequent behavioural activities about which players posted related to:

- Turning off the lights
- Closing doors
- Turning plugs off at the wall

Because their posting-patterns followed the form of day diaries, this meant that lighting, doors and plugs were mentioned within the context players’ ongoing routines. To get washed on a morning it was necessary to open and close a certain number of doors, and turn off a certain number of lights. Hence such activities would be heavily documented when recounting the minutiae of everyday life on Facebook. Moving around the house required that such behaviours be repeated often. The fact that, over the life of the game, players turned out over 7,000 lights, closed over 8,000 doors and switched-off over 5,000 plugs demonstrates that such behaviours became embedded in their everyday lives, turning into habitual and routine activities.

Players also demonstrated daily engagement with other behavioural means of saving energy. Though published on Facebook less frequently than those discussed above, these included:

- Wearing warm clothes, nightwear and indoor footwear in order to stay warmer for longer
- Closing thermal curtains over doors
- Boiling the exact amount of water required e.g. when making drinks, sterilising baby bottles
- Opening all curtains on a morning for natural light, but closing all curtains at night and tucking them in behind a radiator
- Using draught excluders

Players included such activities within their diary posts on a daily basis. They formed part of their daily routine, and so represented some of the most frequent activities players could do to save energy. Whilst they appear at lower rates than turning off lights and closing doors, this difference in
frequencies can in a sense be attributed to the varying repetitive potential of energy saving activities. While the postings showed an enormous differences in terms of the frequencies with which players are posting about activities, they had all become equally as routine. Activities became embedded in the day-diary routines of players, and represented significant behavioural change in terms of the kinds of activities that became common place for members of a household.

Similarly, players demonstrated regular and consistent energy-saving habits which developed during the game. E.g. some had identified that they had chosen not to watch television in order to save energy. This could also encourage other, more unintended results. Not watching television meant that children would play with toys and board games together, or play together outside. Hence, not watching television in order to save energy could in fact enable more social interaction for members of a household. In addition, adult players often mentioned that they had chosen to read a book rather than watch the television, even though this would not have been their first choice of activity had they not been thinking about saving energy. Thinking about energy usage and turning off the television, then, could also have implications for developing the literacy habits of individual players. Thus turning off the TV had wider implications in terms of its potential for achieving social and personal development.

Other activities which players generally conducted on a daily basis included:
- Washing dishes by half-filling a plastic tub with water which was at a lower temperature
- Sweeping floors rather than using a hoover
- Mopping floors with one bucket of water, with the water at a lower temperature
- Going to bed with a hot water bottle
- Taking showers instead of baths
- Having a shower on economy setting
- Letting hair dry naturally
- Using an extra blanket when sitting in the living room
- Drying clothes using a clothes horse, radiator or air drier

Hence, the range of activities that players carried out in order to save energy encompassed a broad spectrum of behaviours – from washing habits to cleaning techniques and means of preparing food.

**Technological adaptations:**
At various points in the game players demonstrated engagement with technological means of saving energy at home. At the start of the game one of the most frequently posted-about activities by the energy champions related to purchasing sealant and tape in order to close gaps in doors and window frames, as well as in walls and floors. At the later stages of the game this also included putting cling-film over the windows. Throughout the game, players would periodically post about other technological interventions such as using energy-saving lamps around the house.

The most frequent and popular use of technologies was the purchasing and fashioning of ‘bespoke’ draught excluders by players. One player fashioned a draught excluder that could be stapled to the door, thus overcoming the problem of being unable to place excluders in front of the door when leaving the house. Not only was this tip shared with other players, but they visited others at home in order to help them make an excluder, and gifting others with their own attachable excluders. This method of preventing draughts was expanded in the final quarter of the game to include sticking curtains to the wall using Velcro. Hence, the game opened up a space in which players could creatively develop technologies to save energy, according to their own needs and imagination.
Players would also use technology as a means of informing their behaviour within the house. As the game continued, players demonstrated an ever-increasing engagement with indoor-room thermometers, heating timers and their gas and electricity meters. Hence the game can to incorporate an interplay between players’ increasing ability to assess their own energy usage and needs, and not only adapt their behaviours accordingly but to plan ahead for the most efficient use of energy at different times of the day. Hence, one form of behaviour changed induced by the game became that of increased engagement with monitoring technologies, and their practical application within the home.

**Observations**

All the participants managed to make savings and found the experience to be beneficial in helping them think about energy efficiency on a more frequent basis. The amount and kind of energy saving behaviours, and the frequency with which individual players were able to post, were inherently linked with their personal lives and the context of their daily routines. This therefore means that our understanding of the kinds of behaviour changes achieved during the game needs to encompass an individually tailored perspective which takes the different lives that people lead (even when living on the same street) into account.

The use of Facebook by a means of measuring the activity of the players proved to be a successful way to monitoring activities, although a change had to be made in the rules to allow a maximum number of posts in a single day to avoid sheer overload. Players then found innovative ways of evidencing their energy-saving activities on Facebook. At the start of the game, players would post large numbers of single photos in order to illustrate particular activities and earn points. After the imposition of a five-post limit, however, players began to look for more creative ways of evidencing a large number of activities within one post. This involved the use of photo-editing software on smartphones in order to combine a number of pictures into one, and even adding text to describe them, and one person went so far as to put all of their photos into a video incorporating both text and a soundtrack.

What these pictures, videos etc. show is that the game became a medium through which players could not only save energy, build points and win prizes: it also became a medium for the expression of player creativity and shows a true engagement with, and enjoyment of, the game itself.

The variety of player lifestyles showed us that households have different energy needs and different daily routines (which influenced the amount of time they spent at home), as well as widely differing abilities for employing technologies to access social media sites. The use of social media was shown in this project to be a useful tool for people to adopt energy saving behaviours and could work again in other areas. Lifestyles and occupancy have an influence on practice and opportunities exist regardless of the length of time people spend in their homes. It cannot be expected that each household within that community will have the same energy needs and same daily routine. However, the fact that one player who was outside of the home for most of the day was eventually able to overtake a player who stayed at home for much longer periods of time shows that such differences can in some ways be overcome by players themselves, and their own extensive capacity for creativity, innovation and determination.

**References**

NEA (2016) www.NEA.org.uk


Working in out. How the prepayment meter took on a new role for social housing tenants with solar PV

Nicolette Fox, Research Fellow, Sussex Energy Group, Science Policy Research Unit, University of Sussex. n.fox@sussex.ac.uk

Take 7 YouTube film: cied.ac.uk/engagement/newsandeveNnts/index/ikkifox

Abstract

Take 7 - 7 families, 7 prepayment meters, 7 solar roofs – 1 estate.
The Take 7 study examined over ten months what happens when you give seven families, living in social housing, the opportunity to be able to use their own generated free electricity. Using a social practice approach it looked at how households adapted their domestic routines to be able to use the solar power they were generating and the impact this has on their lives. The study found that monitoring became important to the households in working out how to undertake prosuming – producing and consuming – solar energy. It also discovered that there were different types of monitoring used by the households and, far from being just information tools, they were instrumental in helping to embed prosuming knowledge in day to day routines. What stood out from the findings was that, to varying degrees, all seven households turned to their prepayment meters to help them monitor and develop embodied knowledge around their solar energy use.

1. Introduction

Whatever electricity system evolves within the UK over the next few decades, it will be significantly different from the one today given the challenges it needs to address, as Newberry and Green highlight:

“Ambitious environmental targets, rising electricity prices, rapid technical progress, combined with cheaper and better information and communication technologies will have a dramatic impact on the electricity sector of the twenty-first century...Decarbonising the economy means increasing the share of electricity, which will power cars and heat pumps, reducing the importance of oil and gas but creating new and more concentrated demand patterns.” (Newbery, Green 2011 p xxv)

In 2010 the Department of Energy and Climate Change (Decc) introduced the microgeneration Feed-In Tariff scheme to “enable broad participation of individuals and communities, as well as energy professionals, in the ‘big energy shift’ to a low carbon economy” (Decc 2009 cited in Decc 2015). However, the Government also hoped that the uptake of microgeneration technologies - “small scale renewable electricity production at point of use” – could offer a number of other benefits to householders and the energy network” (Bahaj, James 2007 p2124).

“The Microgeneration Strategy will, alongside RHI and FITs, support the growth of Microgeneration and thus help to deliver the wider benefits of: greater consumer engagement (including greater energy awareness, potentially leading to lower energy demand and load - shifting); public acceptance of alternative ways of delivering energy needs; diversifying the
For households, a key attraction of being a producer and consumer - prosumer - is the opportunity to save money on electricity bills that have risen rapidly in recent years. And yet a major study (Bulkeley et al 2014) of solar photovoltaic (PV) homeowners in the UK found that while they had increased energy awareness, they were generally not active prosumers. Instead their focus was generally much more on the income stream from the Government’s feed-in-tariffs, rather than saving money through using their own electricity (Bulkeley et al 2014).

Even if such households are not currently making the most of their solar energy, they are, arguably, well placed to cope with potential future increases to electricity prices (Newbery, Green 2011 p xxv). As energy supply becomes increasingly decarbonised, there will inevitably be “winners and losers” (Walker 2013 p183). Some households will be more able to afford low carbon technologies to address fuel costs, while others will potentially be left out in the cold. Households who are currently vulnerable to fuel poverty are at the front line of those who could well be the “losers” in a transition to a decarbonised world.

But what happens when those vulnerable to fuel poverty are given the means to create their own energy without access to feed-in-tariffs? How do they adapt their routines to capture solar power given that its generation is influenced by weather, seasons and changing daylight hours? What knowledge and skills are required to make the best use of solar energy including the role of monitoring and what impact does this have on the household?

Take 7 is believed to be the first UK longitudinal study to explore what producing and consuming - prosuming - renewable energy looks like in households who rely on prepayment electricity meters. It undertakes an in-depth investigation into whether social housing tenants with meters, can become active producers and consumers of renewable energy following the installation of solar panels, and how this evolves.

2. Methodology & Theory

The research consisted of a series of in-depth interviews with seven families over ten months. All the households lived in social housing with their children and relied on prepayment electricity meters. Over four seasons the study tracked their solar journeys, both prior to and following the installation of solar PV panels by their social landlord. The households were also given the opportunity to make video diaries of the experience.

The study drew on a social practice lens to offer insights into how prosuming develops in a domestic setting. Such an approach also helped shine light on the different types of monitoring that individual - ‘practitioners’ - took up as their relationship to prosuming evolved. As Shove et al write, “Monitoring, whether instant or delayed, provides practitioners with feedback on the outcomes and qualities of past performances” and how this might shape future activity (2012 p99). The authors also highlight how it is often difficult “separating monitoring from doing” (2012, p99). This small, but in-depth, study revealed just this, that the ‘doing’ and the monitoring, invariably became intertwined as highlighted below in some of the initial findings:
3. Finding & Discussion

3.1 Turning to the prepayment meter as a solar PV tool

“You’re conscious of it at the beginning, because I think you’re ... a bit sceptical, as you’re thinking, ‘How is this working and why is it working and what’s happening?’ And then after a while you’re thinking, ‘Well it does work because I did my little test’. Then it just becomes the normal thing that’s working in your house and it’s saving you money”.

The families in the study had a ‘love-hate’ relationship with their prepayment meters. They thought it was wrong that they were paying over the odds for their energy, but for most it was a device that they could not imagine living without. For these families the prepayment meter was essential for keeping on top of tight budgets and their interaction with it was an embodied experience - both mentally and physically. Constantly ‘feeding’ a hungry meter demanded a mental agility in working out how much electricity was needed for certain tasks before the money ran out. It also demanded a physical presence - checking the meter, going to the shops, ‘topping-up’ and returning home - that bears no resemblance to paying a quarterly bill by direct debit. As Sian highlights below, the prepayment meters meant that she could both ‘see’ and ‘feel’ her energy use because of the physicality involved:

“On a key[prepayment] meter, you know, you've got to physically take the key out to go and physically top up, or you don't have electric in your house. It is totally cut off. For us, we do see it, we do feel it, because we physically have to do something about it, whereas if you are on a quarterly bill you don't, [the electrics are] just there.... I always had to check ... ‘Are we alright? Yep’, ‘Can we go another couple of days before I have to top up?’ ‘Right I'll put this money by for that.’”

Given the close relationship between the prepayment meter and domestic routines, it is perhaps not so surprising that the families turned to this ‘tried and tested’ piece of technology to help them navigate their way to becoming prosumers. From the outset of getting the solar panels, they started to improvise with their prepayment meters. Some carried out specific tests, others just kept a close eye on the credit - but either way they started to develop a knowledge of what it means to be a prosumer of solar energy. As Harry explained: “I've got the TV on, I’ve got the Sky box on, and I have been using electric all day, so you just want to keep pushing...One day we used 20 to 30 pence... ‘We had the washing machine on all day.’”

The prepayment meter offered the householders a way of knowing energy that was embodied both physically and mentally, and this experience started to be applied to prosuming. Thus individuals started to develop practical, embodied knowledge - “know-how” - based on their experiences rather than just factual information - “know-what” - that was given to them by the solar installation company (Royston 2014 p150). This was a key piece of the prosuming jigsaw that helped, where work and family life allowed, households to utilise solar power through their daily routines.

3.2 Learning to ‘read’ the weather

“Yeah like in the mornings... I’ll get them up for school and I’ll be like sitting on my bed like doing my hair ...and I’ll put the weather on, so I know whether it's going to be sunny...”

Many of the households realised through checking their prepayment meters, that utilising solar power was not simply about turning on the washing machine, but working out when best to do this - whether
it should be synchronised with the sun or form part of a sequence of domestic routines. In addition to using prepayment meters, households also started to develop new skills around ‘reading’ the weather - not only by looking out the window but also monitoring weather forecasts. For example, Moria, who is quoted above, would watch the forecast in the morning on the television and then set the delay button on her washing machine to coincide with the sunniest part of the day in order to maximise her use of the solar power while at work.

3.3 Using the prepayment meter to deepen the practice

By the winter Rose started to experiment with being more systematic in how she used her prepayment meter to support her use of solar electricity. Over a couple of months she fairly regularly record the figures of how much money she had spent on electricity and recorded this against what had been happening during the day: “The fact I’ve got to go check the electricity anyway to see how much is on there and then... I write it down instantly what's left on. And then I'll work out how much has been used.” She adds, “Because I write it down...every day...the oven’s been on, ...or what the weather’s been like, or sometimes the lights on early...I can see the saving and I can show them to other people, ‘Look at this, we’ve saved this much!’ ”

Out of the seven households, Rose became the most proficient in prosuming and made the biggest financial savings – reducing her electricity by around 50 percent – not only in the summer but also significantly over the winter. The savings impacted not only on her family finances but also on her confidence. In the past it was her husband who was the energy ‘expert’ but the monitoring gave her an expertise as well. As she says, “I mean Tony knows all his stuff anyway....[but] it’s me doing it. I... check the electricity and I write down all what we do in a day....cos it’s me doing most of the day to day chores...It’s me that’s been doing it all...I’ve learnt a lot and I’ve realised that yeah, just because it’s a bit overcast...[the solar panels] still work”.

The monitoring not only increased Rose’s confidence and knowledge around the household’s energy use, but also her well-being. The checking of the prepayment meter was no longer tied to simply worrying about how little credit was left on it, but was also a reminder of how much money she had saved on her electricity costs:

“In the stress levels ... it works wonders because if ...there’s only a couple of pounds on [the prepayment meter], I know it’s going to be fine until tomorrow...I haven’t got to panic about putting the emergency on...Any savings that have been made or the less the money I haven’t had to put on it, just goes into the shopping, into the other bills in the house so [it] makes... that little less of a burden to keep worrying about the electricity every five minutes. Because I used to be awful for checking it, checking it, make sure it’s not going to run out...And now I don’t have as much of a worry to keep checking it...because I know it is.”

3.4 How a solar energy monitor spoke out

“The [solar energy] monitor has made a hell of a difference because I mean... it just tells you. It’s like it speaks to you... ‘Go on, go and put a load of washing on! And go on, go and do this, go and do that, you’re saving you’re generating, you’re not generating!’ So it does, it does tell you.”

While Rose started to use her prepayment meter more systematically over the winter, for most families it became less useful. With daylight hours dwindling and the sun no longer a reliable visual cue,
the prepayment meter proved not such a sensitive tool for picking up small amounts of energy savings. However for three of the families this did not matter, they found that by keeping up their prosuming routines they were still saving some energy and money, albeit at a reduced rate compared with the summer. However for the other three households they struggled to keep up their practice of prosuming during the winter.

Part way through the winter, all the households received solar energy monitors from their social landlord. For many of the families the monitors offered a helpful visual cue, in addition to the sun. For example, when it glowed green they knew that they were generating solar power even if outside there was no sun. For Moira it was a revelation. She had loved her solar panels, but stopped being an active prosumer at the start of winter because she believed that without sun she was not generating any energy. However, the solar energy monitor immediately revealed that this was not always the case and gave her the knowledge she needed to come back into the prosuming fold, as her quote at the top of this section highlights.

Yet not all the families found the solar energy monitors helpful. One never used it and another put it away after a short time. In one household there was mixed feelings: while Harry found it beneficial to knowing when solar energy was being generated, his wife Freya found it intrusive. As she says, “I’m just set in my ways. I don’t like something saying, ‘Oh I’m green’ or whatever, ‘Quick go and put the tumble drier on, do the washing!’ No, I’ll do it when I’m ready to do it, when I feel like it.”

4 Conclusion

The study showed that prosuming can help to reduce vulnerability to fuel poverty, at least for part of the year. All the families used monitoring to help them save on their electricity costs – but it was much more than just an information tool. In many cases monitoring became part of the practice of prosuming – the “doing” (Shoe et al 2012, p99): improvising with the prepayment meter, ‘reading’ the weather, synchronising routines with the sun and combining the visual cue of a solar energy monitor with embodied knowledge. Different families drew on different ways of monitoring – but overall it helped all of them to get more out of their solar power and, for at least part of the year, they no longer had to constantly ‘feed’ a ‘hungry’ meter.

All the names used in this paper have been changed to protect identities and ensure confidentiality.

References:


*Energy Research & Social Science* 2 p 148-158.


Walker, G. (2012) Inequality, sustainability and capability: locating justice in social practice in 
Reflections on designing an engaging in-home energy dashboard using participatory design and gamification

Georgina Wood\textsuperscript{a} Dan van der Horst\textsuperscript{b}, Rosie Day\textsuperscript{a}, Shuli Liu\textsuperscript{c}, Mark Gaterell\textsuperscript{d}, Panos Petridis\textsuperscript{e}, Atif Hussain\textsuperscript{c} and Ashish Shukla\textsuperscript{c}. Presenting author contact email address: G.V.Wood@bham.ac.uk

\textsuperscript{a}School of Geography, Earth and Environmental Sciences, University of Birmingham
\textsuperscript{b}School of GeoSciences, University of Edinburgh
\textsuperscript{c}School of Energy, Construction and Environment, Coventry University
\textsuperscript{d}Faculty of Technology, University of Portsmouth
\textsuperscript{e}Aston Business School, Aston University

Abstract

Trials of smart energy in-home displays (IHDs), or ‘dashboard’-style applications for use on tablet or smartphone, have been reported in numerous papers in recent years. Varying levels of success have been described in terms of user engagement, particularly with members of the household beside the bill payer. EPSRC Smarter Households looks to explore two possible ways of increasing engagement with a new energy dashboard: participatory design and game mechanics. Participatory or co-design approaches to research have been praised but difficulties in applying the principles in practice have been noted. Gamification has seen success in the fitness sector and in pro-environmental efforts, where a clear motive to change behaviour in a particular direction has been applied (e.g. to help a user to lose weight or save energy). However its relevance to engagement rather than direct behaviour change is currently unclear. This paper reflects upon the process of designing a dashboard application displaying real-time information on electricity and gas use (along with indoor environmental indicators), specifically two co-design and feedback workshops which were held with housing association staff in 2015 and 2016. We offer some reflections on the challenges associated with implementing a participatory approach, and with integrating gamification in a meaningful way in situations where behaviour change (in particular towards saving energy) is not always desirable or appropriate.

Introduction

Trials of smart energy in-home displays (IHDs), or ‘dashboard’-style applications for use on tablet or smartphone, have been reported in numerous papers in recent years (e.g. Alahmad et al. 2012, Buchanan et al. 2015). Varying levels of success have been described in terms of user engagement, particularly with other members of the household beside the bill payer (Hargreaves et al. 2010).

There have been few attempts, to our knowledge, to actively engage users in the design of an energy in-home display. Anderson and White (2009) used focus groups with a strong design element to pin down the types of displays people preferred. After one focus group, participants were given an IHD available on the market to test, which had some influence over the eventual designs they produced. Another study found little agreement within households as to their preferred IHD design, leading to the suggestion that multiple options should be available to choose from (Froehlich et al. 2012).
Smarter Households, an Engineering and Physical Sciences Research Council (EPSRC) project funded under the BuildTEDDI programme, looks to help households to manage their energy use according to their own priorities, whether they are looking to save money, help the environment, or feel more comfortable at home. A core component of the project is the design and trial of an ‘Energy Dashboard’ application displaying real-time information on electricity and gas use, as well as temperature, relative humidity and carbon dioxide, from a system of sensors. This is being developed for trial by 20 social housing properties in the Midlands of England.

In this paper, we outline an important step of the dashboard design process, namely participatory workshops with housing association staff. We reflect upon the benefits and drawbacks of this approach and the ways in which it has helped us to make sense of the role of gamification for meaningful householder engagement with energy use.

Background

Participatory design is a set of methodologies and practices that centre on working in collaboration with users to try to reach a more successful end product. Muller and Druin (2010) describe a “third space” of “hybrid experiences” that participatory design can invoke: “…practices that take place neither in the users’ domain, nor in the technology developers’ domain, but in an ‘in-between’ region that shares attributes of both spaces.” (p2). Participatory or co-design approaches to game design research have been praised (Vanden Abeele and Van Rompaey 2006) but several authors have noted the difficulties in applying the principles in practice (e.g. Scaife et al. 1997; Danielsson and Wiberg 2006).

There is a key decision to be made in terms of framing: to what extent existing ideas for the game should be communicated to participants in order to provide context and help to ensure emerging ideas are usable and ‘relevant’, but at the same time not constraining creativity or channelling ideas too far in the designers’ (possibly preferred) direction. Equally, a potential weakness of participatory design methods is losing the creative ‘spark’ that professional designers might bring to the table. Academics/designers are in disagreement over the most appropriate role for the user: Danielsson and Wiberg (2006) engaged participants as “informants” (c.f. Druin 2002), framing their design for a game around gender issues before engaging teenagers from the target audience. They also overrode some of the suggestions from the participants later on that did not fit with their remit for the game. Conversely, Vanden Abeele and Van Rompaey (2006) engaged senior citizens early in the game-design research process. The resulting game ideas were mostly multiplayer with a distinct social element.

However, early engagement elsewhere has led to issues. All et al. (2012) reflect on the extent to which framing the scenario task around a map influenced ideas and limited creativity, but also provided guidance and more useful outcomes, potentially. Complete freedom might have limited the usefulness of the resulting ideas. This suggests that there is a need for a careful balance between framing the workshop to make outcomes useful to the designers, and overly influencing ideas to suit designers’ previous plans.

Beyond engaging users in the design process, there is also a need to engage participants when they are using the product, and try to keep them interested over a significant period of time. Gamification (the application of game mechanics to non-game environments) is one way of motivating users to take part, remain involved and keep interest levels high. Aspects of gamification include- at the simplest level- points, badges and leaderboards, but can stretch to making pledges and competing with oneself or others. Gamification has seen success in the fitness sector and in pro-environmental efforts, where a
clear motive to change behaviour in a particular direction has been applied (e.g. to help a user to lose weight or save energy). A key reason for gamification is keeping people engaged in or motivated to complete something that is relatively boring, over a period of time. While there is acknowledgement of a potential novelty effect, it is anticipated that participants will be averse to loss of accrued points and benefits (Hamari et al. 2014).

Previous studies have reflected upon the difficulty in engaging IHD users over the longer term (e.g. Snow et al. 2013; Alahmad et al. 2012), so there is potential for the application of gamification in the domestic energy sector. Existing examples include the smartphone app JouleBug and the US company OPower. However, it is notable that successes have tended to be in situations where there is a clear motive and direction for behaviour change, (typically) to save energy. Where there is potential for households to be in fuel poverty, for example, or not heating their homes sufficiently to stay warm and healthy, saving energy is not an appropriate message to be communicated. The application of gamification to situations of engagement needs to be further explored, i.e. what can gamification add to factual feedback in making/keeping users more interested, better informed and more competent and confident in making the right decisions for themselves and their families, whether those result in behaviour change or not.

Method

The application design process followed the process indicated in Figure 1.

![Diagram of application design process](image.png)

**Figure 1** Process for design of Energy Dashboard application
At all points up until household installation, the application and its early prototypes functioned with ‘dummy’ data. It only displays real time personal sensor data when used by a participating household with sensors installed in their home.

**Workshop and Prototype 1 (2015) - The ‘Energy Garden’**

The first workshop was held in Spring 2015 with staff from a UK housing association taking part in the research project. 4 men and 5 women volunteered from a range of departments across the organisation including Media and Data Protection. The workshop was approximately 90 minutes long, and followed the structure detailed in Table 1. This structure takes inspiration from the process used by All et al. (2012).

While we recognise that the users engaged in the workshops were not the very end users, they gave us a more balanced view of social housing customer needs, as well as the perspective of the housing association as a user and supplier of the developed system. In addition to their professional role in the social housing organisation, workshop participants were domestic energy users themselves.

Annotating or adding content to hand or computer-drawn sketches, and organising paper cut-outs and backgrounds, has been noted to work well in other studies (Druin 2002; Danielsson and Wiberg 2006), hence we used this method to structure participant feedback.

<table>
<thead>
<tr>
<th>0-10 mins</th>
<th>10-15 mins</th>
<th>15-45 mins</th>
<th>45-50 mins</th>
<th>50-85 mins</th>
<th>85-90 mins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to project and aims of workshop</td>
<td>Ice breakers (brainstorms around energy-using activities)</td>
<td>Evaluation of current gamified dashboard concept</td>
<td>Short break</td>
<td>Designing a new level/element</td>
<td>Exit questionnaire and thanks</td>
</tr>
<tr>
<td>Participants to read and sign consent forms</td>
<td></td>
<td>-Demo of prototype so far</td>
<td></td>
<td>-Group creative activity followed by guided discussion</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Annotation of screen shot images in pairs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Guided group discussion</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The first prototype created by the project team (and presented to the participants of Workshop 1 as an initial idea) was highly gamified, with a virtual world (in the form of a garden) that the user navigated around in order to learn about their real time and historic electricity and gas consumption and their indoor environment. The incorporation of fantasy elements and travelling to other worlds was also suggested by the project team. Due to the early stage of development, it was shown to participants via computer and still images.

The absence of monetary units in the first prototype was criticised by participants, as was the level of gamification and 3D graphics. Overwhelmingly the message was that outputs needed to be “tangible”
with “things that translate to their everyday lives”, rather than any fantasy elements, and a “flatter” design was desirable and would be easier to use.

When asked to develop a new level or element for the application during the workshop, participants story-boarded a different concept: a smartphone app for setting and tracking personal goals. Whilst similar to apps already available on the market, this helped us to see priorities and preferences of our target audience and shape a second prototype around these. Time was spent following the workshop changing the prototype according to feedback, and integrating design elements suggested in the workshop.

**Workshop and Prototype 2 (2016)- the 2D and 3D dashboard**

The second workshop was held in Spring 2016. 2 men and 3 women attended. One participant took part in both workshops. Following feedback from Workshop 1, the introduction to the workshop and the purpose of the project was also adjusted to be clearer (Table 2).

<table>
<thead>
<tr>
<th>Table 2 Structure of Workshop 2 (2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10 mins</td>
</tr>
<tr>
<td>Introduction to project and aims of workshop</td>
</tr>
<tr>
<td>Participants to read and sign consent forms</td>
</tr>
</tbody>
</table>

The second prototype dashboard was flatter (rather than requiring navigation around a virtual world). Reflecting on outcomes of Workshop 1, and following the results of Froehlich et al’s (2012) study, we designed a 2D (graph) and 3D (house) view of the dashboard, to allow for different preferences of information display. We also incorporated different gamification elements to support this: points awarded for exploring hints and tips (and returning to these if a particular indoor environment issue e.g. high CO₂ needs addressing); and the ability to set yourself a personalised goal and follow progress. This was presented to the participants of Workshop 2. Due to the later stage of development, participants were able to try out the application on tablets.

The annotation activity was repeated but the workshop was focused far more around feedback and critique rather than co-design. This was for several reasons: the later stage of development; having already integrated design ideas from Workshop 1; and the challenges met in Workshop 1 around encouraging co-design to take place. Participants also answered a list of tasks- questions to test the usability of the application, such as “What was the temperature in the lounge at 2am today?”. Participants in Workshop 2 were positive about the prototype, trying out the different features and reflecting on different uses of the application, such as pinpointing issues with the property, or helping people learn about increasing their level of comfort and wellbeing in the winter through not just heating one room:
“Actually it is educating the older generation….do you understand that your gas fire and your electric fire, although you’re nice and toasty warm in your one room, it’s actually costing you twice as much as if you had it at a steady temperature, you could have the rest of the house and the humidity at a decent standard, but it’s not going to cost you any more…” (Workshop 2 participant)

Summary of findings

Challenges arose in Workshop 1 over integrating gamification in a meaningful way to make the dashboard more helpful and engaging, rather than distracting from its overall purpose. While game-like visualisation elements were not overly popular in Workshop 1, and a virtual world was seen as distracting from the purpose of the dashboard, participants were keen on goals or targets. This inspired us to use gamification to support useful features such as learning what issues exist in your own home (real-time colour highlighting supported by data) and how best to tackle these (tailored hints and tips). Integration of gamified elements was also key to helping users engage with budgeting, and learning about how practical actions link to bills:

“I’d love to have this, to get to the end of the week and wow…my actions have actually saved myself five quid…that a week, times fifty two, is a potential saving of the year…” (Workshop 2 participant)

It is, of course, necessary to pay attention to the heating season and not oversimplify aggregate savings across a year. However the quote above does suggest that gamification can be applied in meaningful ways for engagement rather than behaviour change (with the user setting goals or targets themselves, or simply becoming more informed about how actions link to bills, and to health and comfort, which may not result in a net energy saving).

Reflections and next steps

This paper has put forward and tested participatory design methods with adults as a means of gaining input into the design of an energy dashboard application, and the best ways in which to use gamification for user engagement. There is a clear place for these methods in developing applications which are suited to the target audience- and in redefining suitable audiences to target with a product- but as with authors previously publishing in this area, we faced challenges doing truly participatory design. Framing helped to guide ideas to be relevant and useful to the designers, and there was a need to take a prototype to a stage in which participants had something to critique, even if this meant a significant shift from the prototype later on. A tendency towards critiquing content, which dominated the first workshop, has been noted previously (Danielsson and Wiberg 2006).

Participatory design helped us to reflect upon ways in which gamification can be useful to the user, and how to make use of it to help people make their own decisions about comfort and energy use. It also helped us to define customer and housing association priorities.

A more extended analysis of the workshop results, combined with results of (soon to be held) large scale technical evaluations will be written up for publication in due course.
Acknowledgements

This research was funded under EPSRC BuildTEDDI grant EP/K002716/1 ‘An Intelligent Digital Household Network to Transform Low Carbon Lifestyles’. It is a collaboration between 5 UK universities led by Coventry University, in conjunction with a UK housing association and energy supplier.

References


Exploring the Challenges and Opportunities of Eco-Feedback Technology for Shifting Electricity Use at Home

Nervo Verdezoto, Department of Computer Science, University of Leicester, University Road, Leicester, LE1 7RH, UK. nervo.verdezoto@leicester.ac.uk

Abstract

Encouraging people to reduce or shift resource consumption is one of the main areas where there is a huge spread of feedback technology (so called eco-feedback) such as smart electricity meters to make people aware of their energy use. Although these technologies have managed to raise awareness regarding people’s energy consumption, they have not been widely accepted/adopted as most of these technologies have focused on the individual behavior change and have often ignored the complexities of people’s everyday practices. Traditionally, the design of FTs has relied on persuasion and highly attentive interfaces aiming to change people’s behaviors often resulting in information overload, annoyance or just being ignored. As a result, people still find it difficult to make sense of the energy feedback received and have problems embracing these technologies into their everyday practices. Different game-based approaches have been used to increase the user engagement with feedback technology but mostly focusing on encouraging people to reduce the amount of electricity they consume.

During this talk, I present the challenges and opportunities for encouraging people to shift the timing of consumption activities based on different case studies coming from my participation on the EcoSense project – a multidisciplinary energy project in Denmark.

Introduction

There is a growing desire to address societal challenges in sustainability through the use of energy feedback technology (FT) – so called eco-feedback technology. Indeed, more and more eco-feedback FT is being implemented to support people's self-awareness of resource consumption (e.g., water, heating, energy) through the use of lighting mechanisms, attentive feedback (e.g., energy displays and meters) and visualizations (Froehlich, Findlater, & Landay, 2010). Although FTs have managed to raise awareness about resource consumption, many challenges still remain, as many people have problems adopting them (Barreto, Karapanos, & Nunes, 2013; Snow, Buys, Roe, & Brereton, 2013), as these technologies have often failed to consider how people actually use and integrate these devices into their everyday lives and routines. To increase the user engagement with feedback technologies, game-based approaches (Bang, Torstensson, & Katzeff, 2006; Gustafsson, Katzeff, & Bang, 2010) have been applied, however, most of these efforts only focus on encouraging people to reduce the amount of energy they consume. However, addressing sustainability challenges is not only a matter of reducing consumption but also a matter of consuming electricity at the right time.

* This work is based on my earlier work as part of the EcoSense project and the references are included and highlighted (#) at the bottom of this abstract.
Exploring Challenges And Opportunities For Shifting

In this section, I will describe some of the challenges and opportunities for eco-feedback technology as a result of my participation in the EcoSense project that I consider important for the Energy Feedback Symposium.

Getting People to Shift their Resource Consumption

Getting people to shift their resource consumption is not an easy task. Based on our experience understanding and developing interventions to encourage people to shift electricity usage, we have highlighted three main challenges (Brewer, Verdezoto, Rasmussen, et al., 2015). First, the concept of shifting is more complex for people to understand than electricity curtailment. To enable people to shift, they should be able to understand the reasons and motivations for shifting such as the dynamics of power generation of the modern grid (Brewer, Verdezoto, Rasmussen, et al., 2015). Second, people should be informed about the good and bad times to use electricity – off-peak times or when there is more or less renewable power generation. Understanding when to shift is difficult as there are several data sources to take into account as we reported in (Brewer, Verdezoto, Rasmussen, et al., 2015). The basic idea is to provide people with information regarding the forecast of electricity use desirability as well as with a historical view of electricity usage (Brewer, Verdezoto, Rasmussen, et al., 2015) so that people can check and combine these information to identify possible activities and times for shifting.

However, understanding the concept of shifting and providing historic and desirable usage feedback are not a gateway for shifting as we experienced while conducting two pilot studies of the ShareBuddy game (Brewer, Verdezoto, Holst, & Rasmussen, 2015). Levering prior work on game-based approaches in the sustainability domain, we made the first attempt to address shifting through the design of a casual mobile game to encourage players to reduce and shift their electricity usage patterns. ShareBuddy integrates real resource data into the game play to enable players to share their resources with their buddy – the character in the game. All the real savings of electricity by reducing or shifting are translated into resource points that enable users to play. ShareBuddy provides both feedback on player’s electricity usage as well as a CO₂ intensity forecast of electricity use desirability for the next 24 hours – “green” hours to use electricity. While our first pilot study on a student dormitory reported that no player had attempted to shift as they had difficulties understanding the concept of shifting, our second pilot study reported that most players understood the concept of shifting and were aware of the CO₂ forecast, however, very few players attempted to actually shift due to the complexity of their everyday practices. For instance, an individual might frequently be outside the home (e.g., at school, restaurant or any other social setting) when it is the right time to use electricity. In particular, our participants found electricity curtailment easier as there is no need to make sense of different kind of data (Brewer, Verdezoto, Holst, et al., 2015). Third, the dynamic nature of shifting e.g., weather conditions (how much the wind blows), imports, or failures in the generation affect the feedback provided on daily basis (Brewer, Verdezoto, Rasmussen, et al., 2015). This variability poses challenges on people’s activities as the feedback is not static and it is continuously changing making more difficult for people to understand and adapt their everyday practices and routines to shift electricity use.
Exploring the Flexibility Potential of Everyday Life

Our second case explores the challenges experienced by different types of households (3 single-person, a couple, and a family) regarding the use of eco-feedback technology to support shifting the timing of consumption activities in a one-week trial per household (Rasmussen, Nielsen, & Verdezoto, 2016). Rather than using a game, we took a more simplistic strategy combining an ambient awareness system (AAS) – an augmented clock – with a mobile app and proactive and positive suggestions to make people aware about the good and bad times to use electricity. Traditionally, demand shifting seeks a reduction of peak demand through shifting to off-peak times but this can have a negative connotation as people might fear additional charges if the utility can figure out their energy usage times. However, viewing energy by the CO2 emitted by electricity consumption and not in kWh used, can offer more opportunities for shifting if people are willing to use electricity at the right time. While our participants increased their energy awareness, only certain types of household activities were recognized as “shiftable” and participants expressed the need to plan ahead as long as these activities would not affect other everyday practices. An interesting finding was that some of our participants felt guilty using electricity when they were not able to consider the forecast information while performing everyday practices (Rasmussen, Nielsen, & Verdezoto, 2016).

Understanding the Complexities of Everyday Practices

As people do not see themselves as consumers of energy (Strengers, 2011), we found practice theory to be a helpful tool to understand the complexities of everyday practices and to uncover the challenges of shifting electricity use. Taking a practice-oriented research approach and based on our experience, we have proposed the Contextual Wheel of Practice (COWOP) as a research framework for Sustainable HCI (Entwistle, Rasmussen, Verdezoto, Brewer, & Andersen, 2015). COWOP aims to support designers and researchers with a practical tool to further understand the complexities of everyday practices (suitable to shift vs. non-negotiable) towards the design of technological interventions that better fit people’s everyday practices. In addition, COWOP serves as a boundary object supporting a shared understanding among people with different backgrounds and understandings regarding electricity usage. COWOP is composed by four different, equally important and interrelated quadrants to account for: 1) the individual (e.g., values, skills), 2) societal structure (e.g., social norms), 3) infrastructure (e.g., physical environment), and 4) near materiality (e.g., technology). Rather than focusing only on the individual behavior, COWOP highlights aspects that shape and change everyday practices that are important to consider when designing interventions. In particular, especial attention should be given to how to support the articulation of work in everyday practices that refers to all the planning and coordination of who, what, when, where, and how to perform specific practices (Verdezoto, 2015).

Discussion And Conclusion

First, the examples highlight the importance of understanding the complexities of people’s everyday practices when designing eco-feedback technology. Based on our experience, we have suggested taking a more practice-based research approach to facilitate the identification of activities that could be potentially “shiftable” in people’s everyday practices.
Second, as most FTs rely on screen, keyword, or tactile interaction focusing on the centre of user’s attention, these methods might not be sufficient to interact with the physical world as many everyday interactions take place in the periphery of user’s attention. As a result, FTs are often ignored; cause information overload or drag attention away from the user’s primary activity. In our projects, we have started looking at how FTs could be embedded into everyday settings through the use of physical and peripheral features of ambient awareness systems. Early feedback highlights how giving simple information through an ambient clock could make people aware and trigger actions towards more sustainable behaviors. Furthermore, we also saw how the combination of the web forecast and the physical clock could offer more opportunities to support shifting and their integration into everyday practices.

Future work should further investigate the ways on how people appropriate FTs in relation to their everyday practices, uncovering the participation of all the involved actors. In particular, the notion of appropriation in Sustainable HCI has been overlooked as most research has taken a narrow focus on individual behavior change.

Acknowledgments
I thank all my colleagues, students and participants from all the projects I have reported in this abstract paper. This work has been supported by The Danish Council for Strategic Research as part of the EcoSense project (11-115331) and by the Danish Energy Agency project: Virtual Power Plant for Smartgrid Ready Buildings (12019).

References


Triggering Electricity-Saving Through Smart Meters: Play, Learn And Interact Using Gamification And Social Comparison

Roberta Castri*1, Devon Wemyss2, Francesca Cellina1, Vanessa De Luca1, Vivian Frick2, Evelyn Lobsiger-Kägi2, Pamela Galbani Bianchi1 and Vicente Carabias2

1: SUPSI University of Applied Sciences and Arts of Southern Switzerland
CH – 6952 Canobbio, Switzerland
*e-mail: roberta.castri@supsi.ch, web: http://www.supsi.ch

2: ZHAW Zurich University of Applied Sciences
CH – 8401 Winterthur, Switzerland
e-mail: wemy@zhaw.ch, web: http://www.zhaw.ch

Abstract

The present study tests and compares the efficacy of two different social game modes, collaborative and competitive, as interventions to motivate electricity-saving behaviour at the household level by means of a gamified mobile App, called Social Power. The collaborative game has a common savings goal that the team aims to reach collectively. The competitive game compares weekly savings and thus sets two cities against each other to save the most. The App integrates electricity saving challenges, tips, quizzes in order to motivate participants to earn points and reach set consumption reduction goals. Smart meter data complements the user experience by showing hourly and weekly electricity consumption which is directly compared to their own historical consumption and their team’s savings performance. While completing challenges on the App, participants learn how to positively improve electricity use in their household. Participants are encouraged to interact with each other over Blog and Facebook pages which provide additional information about the weekly challenge and overall intervention. Overall, there were significant electricity savings in both game modes compared to historical values and the control group, however the feeling of community building and social interaction was minimal. Thus the game approach was successful, but future studies can better integrate interaction elements.

1 Introduction

Due to its enhanced energy feedback capacity, the advent of smart metering has been growingly praised as a potential solution to assist society’s collective goal of reducing energy demand and adopting energy-efficient lifestyles. However, for a socio-technical innovation such as smart metering to be effective, the information feedback needs to be embedded into a wider system of communication and awareness-building to create a relation with the end-user, as it is not automation and fine control that hold the promise of improving customer’s knowledge and motivation for change spontaneously (Darby, 2010). Like other eco-innovations, smart meters ultimately require the acceptance and action of people and communities to ensure success (Sabadie, 2013).

Hence much research is under way, particularly in the household domain, to test different feedback modes aiming to positively impact energy-related behaviour and enhance the efficacy of smart meter information to engage consumers.
Considering the many limitations of individual decision-making (Heiskanen et al., 2012) and the fact that human behaviour is socially embedded also when it comes to energy-related choices (Welsch & Kuling, 2009), current energy feedback research orients around the social aspects of energy consumption. In general, literature suggests that the inclusion of socially-based, engaging, competitive and comparative feedback is more effective in reducing individual energy consumption (Abrahamse et al., 2005; Carrico & Riemer, 2011; Fischer, 2007; Schultz et al., 2007; Darby, 2006; Degen et al., 2013; Vine et al. 2013) compared to more generalized and non-targeted information (Costanzo et al., 1986; Breukers et al., 2013).

However, as behavioural change also implies educating and guiding consumers towards appropriate actions, motivating engagement in energy-saving practices is very much about finding innovative ways of learning.

In this context, gamification - the use of game design techniques and game mechanics in a real-world context – provides an engaging, self-reinforcing and playful setting in which to raise energy policy and management issues and features the virtue of increasing intrinsic motivation, engagement and learning (Malone and Lepper, 1987; McGonigal, 2011). Considering that learning itself is fundamentally a social process that is “situated within the practices of the community of practice, rather than something which exists ‘out there’ in books” (Lave & Wenger, 1991), gamification techniques turn out to be more effective in motivating behaviour change when the acquired knowledge is coupled with hands-on, everyday life experiences.

In synergy with gamification, social comparison can also effectively trigger motivation (Grevet et al., 2010). Depending on the context in which it is employed, social comparison may enhance collectivism when individuals understand that they are part of a larger picture (Haluza-DeLay, 2007). Or it can lead, for example, to competitive feelings and striving for better performance (Siero et al., 1996). In both cases, social group feedback can lead to a strong personal identification with one’s own group, resulting in a more cooperative behaviour within the group (Wit & Wilke, 1988). Thus, both a collaborative and competitive perspective may co-exist and work together with social group feedback contributing to the attainment of a collective goal. Considering that most environmental concerns today are affected by collective behaviour, social group feedback emerges as an opportunity to encourage people to increase individual action in order to attain a more significant collective impact for change.

2 Methodology

A local neighbourhood energy contest acted as the frame for the recruitment of 108 volunteering households, ready to take part in a field experiment on collective electricity-saving in the respective cities of Winterthur (n = 55), Canton Zurich, and Massagno (n = 53), Canton Ticino, Switzerland. The energy contest took place over a period of 13 weeks, between February and May 2016. Out of the 108 recruited households, 46 actively played until the end of the contest period.

The participating households were provided with Social Power, a gamified mobile App for smartphones, designed to maximise the efficacy of electricity feedback derived from smart meters by means of a playful, interactive, and social learning narrative.

The pilot project seeks to determine whether a difference in game setting might impact social group performance and better motivate people to manage their electricity consumption at home more sustainably. Thus two Social Power game forms are implemented in the mobile App as behavior-change
interventions: one is a “collaborative” goal-setting, engaging fellow participants in the same city to reach a fixed, collective 10% electricity-saving goal. The second is a “competitive” goal-setting, where participants are involved in a dynamic energy competition between the two cities in pursuit of the lowest electricity consumption result.

Households were randomly assigned to the different treatment groups. An equivalent control group, anonymously drawn, serves as a benchmark. To examine the differential effects of the two forms of social feedback, electricity consumption in the three experimental conditions (control, collaborative, competitive) is tracked before, during and after the game period (with a planned long term monitoring into 2017).

Shortly before, and immediately after the intervention period, participating households were asked to complete an online survey about their energy awareness, literacy and practices in order to assess changes in reported behaviour. A second post-intervention survey will be run one year later to collect long-term observations.

An evaluation of the motivational and social aspects, and the contextual learning process triggered by the Social Power feedback design, is not yet possible, as this qualitative analysis will be carried out in semi-structured interviews and focus groups planned in September 2016.

2.1 Application design

Social Power employs an action-oriented model of social learning to stimulate consumer engagement. A series of 50 electricity-saving related challenges and energy tips are proposed by the game, covering 12 weekly energy-related topics. The challenges contextualise learning by asking the participant to take actions in their real-world environment. Depending on the game to which the player has been assigned (collaboration or competition), the App displays an overview of individual household and team performance in terms of electricity-saving goals and points earned from completing challenges.

Self-comparison feedback

The App displays hourly, daily and weekly electricity consumption in a user-friendly, meaningful way and compares weekly consumption with a historical reference period (Oct. – Dec. 2015). This information facilitates self-evaluation and learning: the player can view trends in personal consumption, as well as question the cause of a given electricity usage and the context in which it took place.

Social group feedback

Social Power stimulates collective action by visualizing the completion of challenges by other team members. A completion barometer shows what percentage of the team has completed a specific challenge and additional ‘social bonus’ points are rewarded to those players who have completed the challenge when 1/3, 2/3 or the entire team have completed a challenge. Thus, playing strategically with your team through completing challenges together pays off. Both the collaborative and competitive games are driven by the ‘team saving bonus’, where a significant points bonus is awarded to teams in response to the attainment of set weekly savings goals, thus rewarding collective saving efforts.
Team community

Outside of the app, there is a Social Power blog and Facebook page as a place for participants to interact, share experiences and cooperate to build a creative understanding of how to save electricity at home.

3 PRELIMINARY FINDINGS
3.1 Technical limitations

An unexpected data transmission problem during the experiment caused irregular delays in the electricity consumption data reported in the App for some households. This resulted in incorrect savings calculations at the team level. A game reset with correct data was made in week 10. Further analysis is needed to assess the presence of additional undetected errors after correction, as well as the repercussions of the known errors. The impact of this aspect on participants’ understanding and motivation to play the game will be discussed during the interviews planned in September 2016.

3.2 Electricity savings

Compared to the historical consumption, as well as to the control group, there is a significant reduction in electricity consumption in both the collaborative and competitive game modes (Table 1). However, no significant savings difference between the game modes is detected. The control group registers an increase in electricity usage during the same interval. Further analysis is needed to assess the overall statistical significance of the results gathered.

Figure 1 and Figure 2 report the changes in electricity savings on a weekly basis for each game mode. The peak savings occurring in week 9 corresponds to Easter holidays for both cities. Note that a data point below zero means higher consumption, and no savings.

Table 1: Team household consumption savings (active players only)

<table>
<thead>
<tr>
<th></th>
<th>Historical consumption (kWh)</th>
<th>Intervention consumption (kWh)</th>
<th>Consumption change (kWh)</th>
<th>Consumption change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Teams</td>
<td>n</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Massagno</td>
<td>13</td>
<td>623.9 (440.8)</td>
<td>586.2 (428.3)</td>
</tr>
<tr>
<td></td>
<td>Winterthur</td>
<td>11</td>
<td>867.1 (788.8)</td>
<td>850.5 (866.2)</td>
</tr>
<tr>
<td></td>
<td>Massagno</td>
<td>10</td>
<td>671.4 (329.3)</td>
<td>615.1 (279.2)</td>
</tr>
<tr>
<td></td>
<td>Winterthur</td>
<td>12</td>
<td>913.0 (694.0)</td>
<td>882.6 (719.5)</td>
</tr>
<tr>
<td></td>
<td>Massagno</td>
<td>23</td>
<td>881.2 (521.6)</td>
<td>1053.7 (835.6)</td>
</tr>
<tr>
<td></td>
<td>Winterthur</td>
<td>23</td>
<td>705.4 (529.7)</td>
<td>793.1 (607.0)</td>
</tr>
</tbody>
</table>

Note: Negative consumption means a savings. Comparison made between weekly electricity use during intervention as compared to historical weekly average.
3.3 Challenge engagement

There is no difference between the game modes in terms of the engagement level for completing challenges. A general drop in commitment after the first month of game occurs for both groups (Fig. 3). Engagement levels rise again slightly starting in week 10, likely as a result of increased communication between the project team and the participants concerning the reset of the electricity data.
3.4 Behaviour and social processes

Qualitative changes in behaviour are analysed based on the pre- and post-test surveys (see Table 2). Both game modes significantly changed the intention to save energy and the reported behaviour compared to before the intervention, yet there is no difference between the two game modes. However, there is a slight tendency for the competitive game to result in more intention to save energy in the future. Even though the game mechanisms are designed with a focus on community engagement, the sense of community within the Social Power team is relatively low.

Table 2: Reported behaviour and social process between collaborative and competitive teams (all participants)

<table>
<thead>
<tr>
<th>Category</th>
<th>Collaborative (n = 31)</th>
<th>Competitive (n = 37)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td><strong>Impact and reported behaviour</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reported impact of the intervention</td>
<td>4.23</td>
<td>1.77</td>
<td>4.65</td>
</tr>
<tr>
<td>Reported electricity use after intervention</td>
<td>5.54</td>
<td>0.76</td>
<td>5.74</td>
</tr>
<tr>
<td>Reported electricity use behaviour change</td>
<td>0.49</td>
<td>0.6</td>
<td>0.46</td>
</tr>
<tr>
<td>(energy saving after – energy saving before)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Savings Intentions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intention to save energy in the future</td>
<td>4.92</td>
<td>0.9</td>
<td>5.25</td>
</tr>
<tr>
<td><strong>Social processes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sense of community in the Social Power team</td>
<td>3.25</td>
<td>1.72</td>
<td>3.45</td>
</tr>
</tbody>
</table>

Note: Values range from 1 ‘does not apply’ to 7 ‘fully applies’, p < .01 = significant difference.
4 Conclusions

This preliminary analysis finds that the deployment of both a competitive and collaborative social game mode is effective in reducing electricity consumption. Neither approach outperformed the other, but long term efficacy of these feedback mechanisms will be examined in 2017.

The sense of community in the Social Power teams has been reported as rather low. Hence, it appears that the reported results are not specifically impacted by the wider social setting of the game, but possibly the self-comparison feedback instead. With the current results and experimental design, it is not possible to differentiate the effect between the individual feedback and social game mechanics, but planned follow-up interviews will help gain deeper insights into the motivational and social processes triggered (or inhibited).

Critical points in the present design might be (1) team formation and (2) anonymity, both of which were modelled as to accommodate a rather large team size (n = 30): players were randomly assigned to teams and did not create their own teams and natural social groups. Also, to preserve single users’ privacy, performances were displayed to others only in aggregate form. Since the online world is absent of many basic cues of identity, personality, and social roles, this setting can make it harder for players to collaborate on a common goal.

Here, relying on out-of-game social media sources (Blog, Facebook) to motivate group engagement seems not to be effective. In the future, the communication aspect between team members should be revisited. An interesting field of research might be the integration of game design that facilitates existing real-life relationships over merely network-based virtual communities to maximize intra-group communication and support.

Acknowledgements
The research has been supported by the Gebert Rüf Stiftung under the BREF program Social Innovation, as well as carried out thanks to the Swiss utilities AEM Massagno and Stadtwerk Winterthur.

References


Energy Efficiency Advice: A Toolkit for Engaging Consumers at Smart Meter Installation Visits

Andrew Charlesworth and Mairi Budge, Smart Metering Programme, Department of Energy and Climate Change, andrew.charlesworth@decc.gsi.gov.uk

Abstract

This study developed and tested an energy efficiency advice intervention to be delivered, by installers, at Smart Meter installation visits. The final advice approach included a range of print materials focusing on different energy saving behaviours (including routine and purchasing behaviours), designed to support installers in delivering tailored. We used an action research approach to develop the materials, with input from consumer focus groups, depth interviews and a stakeholder workshop. They were tested through a pilot of over 400 actual Smart Meter installations, following which depth interviews were conducted with consumers and focus groups held with participating installers. The research identified a range of factors that can support advice provision, including the use of engaging evidence-based hooks; myth-busting information; and guidance in energy know-how to ensure customers know not just what to do, but how to do it. The pilot also had practical implications for the delivery of advice, including ensuring expectations are set in advance of installation visits, enabling installers to deliver advice through training and linking advice provision to use of the IHD to exploit synergies between feedback and advice. DECC will publish this research in full later in 2016.

Overview

Energy suppliers are required to roll out electricity and gas smart meters to homes and smaller businesses in Great Britain by 2020. At present, the Smart Meters Implementation Programme is in its ‘Foundation’ stage in which technical specifications and the communications infrastructure are being put in place, and suppliers are developing their roll-out strategies and customer journeys. To support the delivery of consumer benefits from the roll-out, the UK Government established a consumer engagement strategy, which includes specific aims to support consumers (including those who are vulnerable, have low incomes, or have pre-payment meters) in using smart metering to manage their energy consumption. The Strategy envisages that these aims will be achieved, in part, through energy saving behaviour change, facilitated by advice and guidance, on energy and energy reduction (by paper, web, mobile, face-to-face or phone).

The Strategy also sets out how consumer engagement will be delivered, including requiring suppliers to provide consumers with clear and accurate advice and guidance about the smart meter, In-Home-Displays (devices providing real time feedback on consumption also provided at installation) and energy efficiency at the installation visit. Research with consumers who had received Smart Meters early
in the roll-out, carried out as part of DECC’s Smart Meters Early Learning Project [1], identified the potential for this advice to be optimised, through:

- Tailoring to customers, so that it is salient
- Providing consumers with specific actionable strategies, including ones that make use of feedback available from smart meter data, via the In-Home-Display (embedding use of feedback with consumers)
- Making links for consumers to wider energy efficiency advice and support
- Considering the needs of vulnerable and priority consumers
- Exploring the role of specific motivational devices (prompts/ free practical aids)

This study tested an approach to delivering advice designed to meet these objectives using an ‘action research’ methodology with the advice delivery approach developed iteratively across four phases. The first of these explored best practice for the content and delivery of advice via a small-scale evidence review of key literature and a stakeholder workshop. Phase Two developed draft pilot advice, informed by general public discussion groups and depth interviews with vulnerable customers. In Phase Three, following installer training, the advice was piloted with over 400 customers across four locations in installation visits. The final stage evaluated the piloted approach in follow-up research with a wide range of customers (through follow-up interviews conducted between six and ten weeks after installation) and installers, as well as a stakeholder workshop, and finalised the approach in light of the findings. The project was innovative, using actual installation visits to pilot advice delivered by installers, at an early stage of the GB Smart Meter roll-out.

The final advice approach included a range of print materials focusing on different energy saving behaviours, designed to support installers in delivering tailored advice. Behaviours covered by the materials ranged from low or zero-cost tips, to buyers guides for more efficient appliances and information on energy efficiency measures. Installers were trained to use observations, along with some initial prioritisation questions to identify the most relevant factsheets for householders at the beginning of the visit. Following the installation and demonstration of the IHD, the installer would then return to the advice and answer any questions from the householder.

Our approach to the materials was informed by the concept of energy ‘know how’[2] and materials were developed that included actionable strategies for consumers to reduce their energy consumption with. A range of motivational messages were tested, including comfort, financial savings, environmental messages, and framing messages around social norms. We drew on previous work using visualisations of heat loss to communicate energy consumption from heat and the impact of insulation to consumers [3]. As advice will be delivered through smart meter installation visits, we also explored the potential for synergies between advice and real time feedback (provided by the IHD), with behaviourial strategies that made use of feedback from the IHD included on the materials.
Evidence from the pilot supported this, identifying the following key elements: an engaging evidence-based hook (ideally, estimated financial savings from an independent source); myth-busting information; and guidance in energy know-how to ensure customers know not just what to do, but how to do it. Although a range of fact sheets were provided to consumers, the research also signalled the importance of ensuring these were relevant. The most popular areas of advice for consumers were messages providing free and simple ways to save energy (through routine behaviours) and information that could be provided in response to specific, unprompted, questions.

The pilot also had practical implications for the delivery of advice. Communicating to consumers in advance that energy efficiency advice will form part of the installation visit can increase consumer engagement. Training can provide installers with the skills and confidence to provide advice on a range of measures and property types. Lastly, linking the demonstration of the IHD with energy efficiency advice provides an opportunity for householders to gain motivation and skills for identifying appropriate changes in their home.

Reflecting the current stage of the GB Smart Meter roll-out this study did not include a fully representative group of consumers. Study participants were more likely to be ‘early adopters’ of Smart Meters, a group who are potentially more engaged in their energy consumption. Energy suppliers are not currently rolling out Smart Meters to all their customers, and those with pre-payment meters, specific medical equipment needs, or where English is not their first language are not included in this study.

Lastly, follow-up interviews were carried out over Winter heating months, we anticipate that both advice in general, and specific recommendations may be more or less salient to consumers at different points in the year. As the roll-out progresses there will be opportunities to assess the effectiveness of different consumer engagement strategies with a wider range of customers, and over a greater period of time following installation.

References


Improving participation in the energy market

Alexander Belsham Harris, Citizens Advice

Abstract

Consumer engagement in a well-functioning energy market is intended to work via consumers being given the freedom to contract with any supplier, having easy access to information in order to compare providers and marrying the two by acting in their self interest to periodically switch tariffs and secure a better deal. In theory this arrangement should drive better outcomes, by ensuring that energy suppliers compete against each other on price and non-price factors in order to win a greater share of the market. The outcomes of this activity are intended to be positive for all: consumers because they get more choice and a better service than a monolithic nationalised utility could ever provide, and companies as they profit through innovation, and thus drive each other on to do better.

Yet, 18 years after the privatisation of the domestic market, the energy supply industry is struggling to live up to these ideals. An ongoing Competition and Markets Authority (CMA) investigation found that 56% of consumers said they had never switched energy supplier, almost a third reported that they had never considered switching their gas or electricity provider and 5% were unaware that they could change their gas or electricity supplier. Although switching rates have increased slightly in recent years this market context indicates that more work is needed to encourage consumers to actively engage with the energy market.

Counter to conventional economics, those who have exercised their market power and switched have reaped benefits seemingly at a cost to inactive consumers, as price differentials between open-ended and fixed term tariffs have risen sharply in recent years. Unlike other markets, the nature of energy means that price cuts are not easily perceived, and require positive action by individuals to realise, adding a further layer of complexity to attempts at opening up the benefits of competition to all.

There has been no shortage of schemes to tackle this lack of engagement, including public information campaigns and regulatory changes aimed at making switching easier. Despite this, clearly more work is needed to encourage consumers to actively engage with the energy market.

Citizens Advice proposes that this is because the current approach of optimising information, process and awareness-raising mechanisms are important and necessary, but may not be sufficient to reach the non-engaged. Other factors, such as the nature of energy as a product and time constraints on people must be better understood in order to develop appropriate remedies and increase engagement. The process of switching supplier loses much of its allure in a market like energy which provides a homogenous ‘necessity good’ and where, apart from cost and possibly customer service, there is no discernible difference in product performance between suppliers.

The use of behavioural insights to understand the reality of the consumer experience and to inform the design of appropriate remedies has grown in use by public bodies and regulators over the last 10 years. Remedies have tended to focus on particular ‘nudges’ such as altering wording, requiring greater consistency on the type of information to be provided in key communications, new channels of communication, incentives etc.
In the short and medium term, Citizens Advice considers it necessary that a switching-led model for the energy market should evolve in a way that at least recognises the behavioural reality outlined above and adapts to it, to succeed in a way that has eluded policymakers until now. This research comprised testing with over 1,000 consumers of four different behavioural insights-based switching messages, and presents results on the comparative effect of those messages on consumers’ perception of and willingness to engage in the energy market.

References

1) CMA Energy Market Investigation, July 2015

2) http://www.energy-uk.org.uk/publication.html?task=file.download&id=5659

3) Citizens Advice analysis from July revealed that the average difference between suppliers’ cheapest fixed deal and their standard tariffs now stands at £176, and that the gap between the two has risen by a staggering 47% in just the last three years
The surge of energy data: What does it mean for EDF Energy employees and householders?

Christopher Weeks, EDF Energy and University of Bristol

Abstract

Over the last four years at EDF Energy, we have seen an interesting change that is going to revolutionise the way we provide feedback about energy, namely, the rapid increase in the amount of data we are now collecting. It is strange to say that four years ago the energy industry was data-starved, but for most householders we only had two meter readings per year that were 6 to 12 months apart if we were lucky. Now we have 10 second resolution electricity consumption data and gas readings every 30 minutes thanks to smart meters and CADs (consumer access devices) being installed, and 10 min heating setpoint, indoor temperature, outdoor temperature, heating schedule and boiler usage data thanks to smart thermostats. This gives us a total of 10,272 data points per customer per day. The change has been rapid and long awaited, but what impact does it have on the way we provide feedback to EDF Energy employees and householders? In this extended abstract we first start by looking at the core drivers for the rapid increase in data, we then move onto highlight what EDF Energy R&D UK Centre has been developing to help maintain the best feedback for both employees and householders and we highlight a number of the key learnings that we have achieved over the last 4 years as we move to using real-time large scale datasets for the energy sector.

1. The data surge - What is driving the rapid data increase?

In just the past four years we have seen a huge increase in the overall data that the energy sector is collecting from householders. Firstly, it is no secret that in the UK we are moving to a world of smart meters with the mass rollout looking to be completed by 2020 and over 53 million gas and electricity meters installed in domestic homes and small businesses (Ofgem 2013). However, one vital point of the smart meter rollout that is sometime underestimated is the huge surge of data that will be generated from the smart meters rollout. This will be amplified by the deployment of CADs (customer access devices) that enable the collection of 10-second electric meter readings and 30-minute gas meter readings. This means that we are collecting 8,640 electric readings per day per customer, and 48 gas meter readings per day per customer. At this resolution we can now start to look at disaggregation of total energy consumption into separate appliances within the home. In conjunction, the datasets that we are collecting can now be accessed in near real-time rather than looking at historical static datasets, enabling us to develop real-time visualisations and algorithms, rather than doing retrospective data analysis. In pushing to increase the level of detail achieved by disaggregation, with the aim of providing energy use information at the level of the individual appliance, we require sub-second data; this will soon become the standard level of data granularity.
In building on top of the smart meter rollout, we have also seen an increase in the take up of smart thermostats. Smart thermostats add a number of vital data streams including: heating setpoint temperature, indoor temperature, householder’s heating schedule and boiler usage. Heating, ventilation and cooling (HVAC) is the largest source of energy consumption in the residential sector (Lu et al. 2010), therefore we must understand these data streams if we are going to move towards a more sustainable domestic energy sector. In a similar manner to smart meters, the smart thermostat data resolution is sub-hour at 10 - 30 minutes and can be accessed in near real-time. The smart thermostat provides a vital dataset to enable house modelling, but it also enables us to understand the way in which householders heat their homes, and therefore allows us to start to model the householder’s heating behaviours.

The next dataset to add is external weather. This data can come from a householder’s own outdoor weather modules or from the large number of public or open industrial weather stations that provide reliable localised weather conditions. Together, these provide a clear overview of the external temperature and weather conditions at the householder’s property. Connecting the external temperature with the internal heating settings provided by the smart thermostats allows for advanced house thermal modelling, and it also helps us to better understand the relationship between external temperature and householders’ expected comfort. This final point is especially important given the rise in the level of comfort householders expect. In 1970 the average UK household temperature was 12°C, and it has risen to 17.6°C in 2011 (Palmer et al. 2013). These levels of comfort are replicated across Europe, with Nordic countries having the highest average indoor temperatures in the EU (22°C in Swedish houses), while Southern Europe has an average indoor temperature of 20°C (Kemna 2014).

Finally, as householders drive to make their households smarter we see an increase in sensors in the home. These may be related to energy - for example thermostatic radiator valves - or linked to other aspects of domestic life such as cameras, locks or safety devices. These help build up a much richer picture of how householders are using their homes, but also adds to the ever increasing amount of data points collected. In focusing on space heating, there is large energy savings to be had by knowing when individuals are in their homes or which room they are currently occupying, especially as space heating makes up 66% of total domestic energy consumption (Department of Energy and Climate Change 2014). However, we must understand the security and privacy implications as we move forward into building a smart home that understands when your are at home and your behaviours in the home (Komninos et al. 2014).

The surge in data has a large impact on the types and methods of providing feedback to both employees and householders. It must be noted that in this abstract we start with employees as this is the core area that the authors have recently been working on, and it is also a research area that is often under researched compared to feedback that is given to householders.
2. The impact on employees

In the business environment data is changing the way that we are making decisions and we are seeing a large number of companies using business intelligence to make better decisions about products, services and their customers. Therefore, as we have a surge in data in the energy sector, especially in the connected home market, it is critical that the feedback that we provide to employees helps them to make better actionable decisions. In looking to achieve this we have built a platform called the virtual data lab. The virtual data lab is a cloud based platform that draws together all the data streams highlighted in section 2, we transform and restructure the data, then perform different methods of analysis before finally, converting the data into visualisations that are accessible to employees from across the business. In the analysis there are four core areas of investigation: house modelling, householder modelling, energy advice, and country wide data analysis and clustering. In providing feedback to employees there is a wide number of different stakeholders from researchers, marketers, engineers, senior stakeholders and strategist. In developing a platform that provides feedback to a wide audience of stakeholders we have learnt a lot from the challenges we have faced.

The first area of challenge was how to present data that would enable actionable decision making. To solve this challenge there are two approaches, firstly you can take an inductive grounded research approach and build your knowledge up from the data, or alternatively you can take a more deductive theory building approach where you develop the questions you wish to answer from the data. In both these approaches we found that you end up with a chicken and egg situation, as you’re not sure if what you find from the grounded approach is useful, or if you can answer your questions from the data in the deductive approach. This challenge is also heightened in an environment where not everyone using your visualisations has a high level of data literacy. Thus, we have found it important to involve employees in the analysis of the data and the development of the data visualisations. This method of development is usually facilitated through workshops, user testing and hackathons. In taking this approach the feedback is the end result of a learning journey that helps build data literacy and helps build data democracy, as individuals feel empowered with the tools and knowledge to convert the data into their own feedback visualisations. Finally, as the employees build their own visualisations to suit the problem they wish to solve or decisions they want to make, they can use either an inductive or deductive approach to suit their needs.

3. The Impact on householders

There is already a large body of research on the best methods for giving energy consumption information to householders (Darby 2006), therefore in this abstract we aren’t looking to define any new methods of feedback. However, we would like to highlight the way we see feedback changing with the increasing amount of data collected. The first area that is already moving forward is appliance disaggregation (the ability to break down overall energy consumption into individual appliances). Appliance disaggregation helps to provide a level of transparency around electric energy consumption, but it has limited impact on space heating as disaggregation of gas consumption is mainly split between heating, heating water and gas cooking. It also only provides more details to householders, which has
shown to increase engagement (Chakravarty & Gupta 2013) but it can still be complex for householders to understand. Therefore, in looking to engage householders further we have to look at what is the next step for feedback.

We believe there is a need to build feedback methods that allow householders to naturally engage with their energy consumption in a language and framework that they understand. With this in mind we have been implementing a platform that can take natural language and convert it into answers for householders, for example “what is my gas consumption last week?”, results in “your gas consumption last week was 1,522.75 kWh”. In building these methods of feedback householders can start to explore the data by posing their own questions and having natural responses to their questions. This approach allows the householder to control the level of detail they wish to be presented in the feedback rather than the level of detail being specified for them.

The next step towards helping householders reduce their overall energy consumption is to understand how we can use appliance disaggregation and natural engagement to develop householders’ energy literacy. Without a good level of energy literacy householders cannot understand how to reduce their overall energy consumption. It has also been highlighted that limited expert knowledge can be a barrier stopping householders installing energy efficiency measures (Weeks et al. 2015). We therefore need to demonstrate that energy is not super-complex, we just need to find the right method of teaching it. In other industries there are a number of examples of complex topics being taught to consumers to help them understand what they are buying: data plans in telecoms, calories in the health sector and drink-driving limits for the public health sector. In empowering householders with the right level of energy literacy we need to make sure we highlight the factors that cause the biggest impact on their overall energy consumption. For example, encouraging householders to install energy efficiency measures has a much larger impact than small behavioural changes like turning lights off (Weeks et al. 2014). Finally, in providing feedback to householders we need to understand how we can engage the least engaged householders, as a number of householders don’t read their bills or letters that are sent to them from their energy company. How do you provide feedback to householders in a way that starts to engage them in their energy consumption? This is a highly challenging research area that needs to be developed further.

4. Conclusions
In this extended abstract we have shown a number of the drivers that are causing an acceleration in data collected from householders’ homes, we have shown how EDF Energy R&D UK Centre is implementing a platform that allows employees to build their own feedback visualisations to understand the data, and finally highlighted how we are investigating a method to develop householders energy literacy through appliance disaggregation and natural engagement.

5. References


How is feedback on energy consumption currently being delivered to customers?

Scott Bryant (Analyst) & Steven Ashurst (Senior Analyst), Delta Energy & Environment (Edinburgh). Contact: scott.bryant@delta-ee.com

Abstract

Most customers remain apathetic when it comes to the subject of energy, despite a sizeable proportion of the population indicating that saving energy is a priority. From our research into the decentralised energy sector Delta-ee is able to provide a clear overview of why and how feedback on energy consumption is currently being delivered to customers. More specifically, with reference to its application in existing commercial business activities, and how this might evolve over the coming years. Our ongoing direct customer research has highlighted what forms and formats of feedback the market is looking for; accurate predictions on running cost savings, which are delivered via either written advice or from real-time prompts through internet-enabled devices. Two innovative business models currently incorporating feedback as a key component of the offering are tiko and OhmConnect. Each has seen moderate success to date, based on different value drivers; the former is focusing on the provision of timely graphical feedback while the latter uses a gamified approach to reward customer participation in demand response. Key challenges to increasing the use of feedback as a way to reduce energy consumption include the presentation of feedback in a convincing way to demonstrate tangible savings can be made, and determining the most appropriate types of incentives to get customers to take action.

Overview

The energy system is undergoing a process of rapid and unprecedented change. As a consequence of this so are energy markets – and particularly how energy related services and products are offered to, used by, and paid for by end-users. Arguably, the opportunity has never been stronger to increase revenues from energy related businesses and at the same time engage people with their energy usage. However, the challenge ahead remains considerable, as most customers remain apathetic when it comes to the subject of energy.

Delta-ee provides our clients with commercial insight and strategic recommendations across our wide range core knowledge areas – all of which share a focus on distributed energy and low-carbon heat. With this presentation we look to add to the debate of how energy demand is/will/can be reduced through feedback, by sharing some of the key highlights from our recent research covering the domestic sector, and from both the supply- and demand-side perspective.

The goal is to provide a clear overview, with reference to existing commercial business activities, of why and how feedback on energy consumption is currently being delivered to customers, and how this might evolve over the coming years. Specifically, we address three key related questions:

1. What are the current drivers for feedback?
2. How is feedback being deployed to engage the contemporary energy customer?
3. How is this approach to feedback deployment likely to evolve in the coming years?

We have addressed these questions through a combination of our Heat Insight Service (HIS), Connected Home Service (CHS), and Energy Services Innovation (ESI) research services. Based on our ongoing direct customer research, we have been able to establish the current key drivers for customers to engage with the provision of consumption feedback. Subsequently, by looking at examples we have
analysed as part of our ESI research, we explore in detail two innovative business models currently incorporating feedback as a key component of the offering: tiko and OhmConnect. More specifically, we analyse the value drivers for these offerings. Finally, we examine the ongoing challenges to-date experienced in the rollout of these business models, and how they are likely to develop in the future.

Current Drivers

So far, we find that in the majority of cases the principal supply-side drivers for feedback on energy usage are to upsell related energy products and services (e.g. insulation), and to reduce end-user consumption. The latter driver being a stepping stone to releasing additional value to the supplier through mechanisms like demand response. As for customer drivers for feedback, we have used ongoing research via an online panel of homeowners in Great Britain has allowed us to gain valuable insight into what feedback would best be received by customers to encourage behavioural change.

During the 2015/16 financial year, out of the 901 private householders that Delta-ee surveyed and asked the question: “how much of a priority will it be to you to reduce your energy costs in the coming 12 months?”, over 60% stated it is either “quite a high priority” or a “very high priority”. Of course there are a wide range of drivers for why customers would look to receive feedback on energy their consumption, but for now it seems it is the simple economic argument which outweighs all other options (emotional, societal, environmental, etc.). Over the last five years of researching why customers take energy-related decisions, we have routinely found this to be the case – e.g. “to reduce ongoing running costs” is consistently the strongest motivation behind people installing microgeneration technology in their homes.

We have similarly found that over 60% of householders would be interested in receiving feedback on their energy consumption, e.g. “to highlight how you could save on your energy bills”. There is far less homogeneity in customer thinking regarding the form that feedback should take in order to encourage people to action the advice. We see that, at least for the ‘private homeowner’ segment of the market (and we caution that this will not necessarily be representative of the entire domestic sector), feedback in the form of “incentives – e.g. rewards for taking action” will be necessary to encourage behavioural change among the majority of users (and we explain the case of one US company currently active in the market with this strategy). The provision of feedback in the form of written advice (e.g. on a fuel bill), and through real-time alerts/nudges/triggers (through an in home display or a mobile phone app) also have strong appeal – to over 20% of the customers who are open to feedback – further emphasising how varied the approach to feedback must be in order to maximise its efficacy.

Finally, regarding the nature of the data, the preference is again more obvious – almost two-thirds of customers state that potential savings should be shown in pounds and pence so it “grabs their attention”. Around half this much of customers are looking for statistical feedback; how much energy and the percentage of running costs could be saved by the measures suggested.

Current Deployment of Feedback

Tastes in the energy sector are evolving, with lots of talk about the dash for the provision of services in the utility market (although in some markets it’s more like a slow, Sunday morning stroll). With this shift away from the commoditisation of energy, towards a provision of services to customers, comes an influx of new business model offerings from new and incumbent players. These business models, typically driven by new start-ups, have attempted to engage with a traditionally disinterested and unengaged end-consumers. Two firms who have recently been gaining traction in the energy
services space, entrants from outside the energy sector, have adopted, customer-centric, demand response feedback propositions:

- tiko (Switzerland)
- OhmConnect (US)

Tiko is a spin-out of the telecommunications giant Swisscom, providing a means for low cost demand response (DR) from in-home electrical heating systems with advanced analytics and a free remote heating control app and control interface for customers. Tiko provides direct, upfront feedback to prospective customers about their energy consumption, and the potential energy savings and DR value generated. This is achieved through the installation of a tiko smart-plug-control and monitoring system (combined with a cloud-based app) which provides users with ongoing graphical feedback as to the energy consumption of their electric heating system, and the ongoing efficiency and savings created for them by the tiko system.

From the customer-side, they have the opportunity to override any tiko request for demand response (i.e. a temporary shut-down of their system). However, the key point of value creation for tiko, is that customers rarely do this, as the overall proposition from tiko is that they will never impact user comfort, all the while providing energy savings and DR revenue. Interestingly, the feedback mechanism from tiko is a customer-pull setup, with customers having the option to never look at the feedback, safe in the knowledge that tiko is ensuring their comfort and maximising their efficiency. This use of a non-force-fed style of feedback to customers, and the subsequent relationship building that it facilitates, presents the potential for tiko to interpose itself between energy suppliers and customers, from where it can upsell other smart services.

On the other side of the Atlantic, OhmConnect, an energy data analytics software start-up, has also looked to capture value from the demand response market through the ongoing engagement of their customers with feedback. More specifically, OhmConnect looks to bridge the valley of energy customer disengagement, providing an entertaining and accessible platform for users to engage with their energy consumption, all for free. Demand response is turned into a “game” for residential consumers, with both manual and automated requests for participation in DR events, ‘OhmHours’, allowing users to score points which can be used in OhmConnect community competitions (or eventually taken as cash).

OhmConnect generates value from system operators by helping to shift or reduce residential load to avoid the need for expensive peaker plants, passing on 80% of this revenue to its customers. Customer participation allows the customer relationship to be effectively owned by OhmConnect, as they require customers to provide them with their utility customer accounts in order to access and analyse smart meter data to formulate suitable demand response events. Not only has OhmConnect developed a unique approach to access and aggregate residential DR capacity i.e. by engaging customers with their energy consumption, but by effectively owning the customer relationship they have positioned themselves to extend into other energy retail offerings in the future (at the expense of utilities).

Tiko and OhmConnect highlight both the commercial opportunities for engaging customers with feedback, and the need for existing stakeholders in the energy sector to engage with feedback, else risk being left behind by competitors and new entrants from both within and outside the energy market.
The Evolution of Feedback in the Energy Market

Retail energy companies have traditionally dealt with customers at an account level, with relationship management reserved for larger commercial and industrial clients. Customer data has inevitably been poorer than in industries such as financial services, so client needs have often not been properly understood. It is therefore perhaps not surprising that attempts at upselling services have often had mixed results. Smart meters are starting to improve matters by replacing demand usage profiles with records of actual behaviour, and the research Delta-ee conducted with customers shows a latent level of interest in options like real-time alerts. However, this is just the start, with the rise of IoT, cloud services, advanced data analytics and the connected home all bringing opportunities for insight. The age of the passive energy consumer is coming to an end, replaced by users who have learned they have power in the energy services market and would now like to start using it.

Research from our Connected Homes Services shows how the accelerating deployment of connected home devices such as smart thermostats will be a route to expand the provision of feedback within the UK domestic heating market (already yearly installations number over two hundred thousand), but that industry also faces a key challenge related to this. To date, ‘feedback’ is at best a secondary proposition in most customer offerings. British Gas, for example, promotes the ‘Hive’ smart thermostat (the UK market leading connected home product) based on the increased degree of control and flexibility it affords customers – not on how much it can save them on their energy bills.

There are questions over how compelling telling people they can save ‘X percent’ on their annual fuel bills is as a sales pitch, and if customers actually believe these claims. Industry typically cites a savings range of between 10%-30%, which is too wide to allow providers to confidently put a figure on how much their products will save an ‘average’ customer. ‘Comfort’ is easier to guarantee and so has emerged as they primary engagement model. For ‘energy saving’ to become a higher priority, providers will have to be able to give a more accurate estimation of the savings for energy customers – and come up with the right ways of engaging users, through incentivisation in particular, to engage the wider market on the concept of feedback.
Energy-feedback services provided by utilities: Lessons learnt from the Empowering project

*Stoyan Danov*, Jordi Cipriano, Xavier Cipriano, Gerard Mor

* Centre Internacional de Mètodes Numèrics en Enginyeria (CIMNE), Building Energy and Environment Group, C/ Rambla Sant Nebridi 22, 08222 Terrassa, Spain

* Corresponding and presenting author: sdanov@cimne.upc.edu

Abstract

The Empowering project involved 6 utility companies and a team of university researchers, social scientists, and energy experts for developing and providing consumption feedback services to utility customers. The objective was to enable the utilities for delivering cost-effectively personalised information to the end-users, empowering them for energy savings, and thus improving their satisfaction with the utility. A range of services were developed within a centralised analytics system coupled to local user visualisation tools at the utilities. The services were applied and tested over a population of more than 344,000 household customers at four pilots in Austria, France, Italy and Spain. Empowering demonstrated noticeable beneficial impact of the services on the users, improving both the energy saving and customer satisfaction. Customer engagement showed to be a key issue for programme success. The easy service access, the perceived usefulness of the information, intelligibility, and personal motivation are the principal factors for engagement, but the legislative and regulatory frameworks have also considerable impact. Metering data access, customer consent and regulated energy bill content are limiting factors for effective service provision. Some regulatory changes, simplification and unification across European countries might be considered for wider adoption of the services in the future.

Introduction

The Empowering project was led by the motivation to deliver effective and cost-efficient energy services to residential consumers and targeted their offering through utility companies in order to take advantage of the existing data from fiscal meters and the possibility to offer the services at large scale. In a situation of extensive rolling-out of smart meters the relevance of this approach is currently increasing. The project developed a range of informative services implemented as a personalised energy reports, delivered either with the energy bill, or through online software tools offered by the utilities to their customers in order to provide them with more insight and detail about their actual energy consumption. The principal target was the improvement of the end-user energy efficiency and awareness on basis of improved information, benefitting at the same time the utility with increased customer satisfaction.

The action involved 6 utility companies from 4 European member states – Austria, France, Italy and Spain, and the services were deployed over a population of 344,000 customers. Services were provided mainly to electricity consumers, but were offered also to gas consumers in France and to district heating customers in Italy.

Empowering started over the current state-of-the-art and further developed a comprehensive modular set of services implemented in a central cloud-based analytics engine supporting the local utility service systems. The approach permits each utility to customise its own solution by configuring the desired service modules from the analytics engine. The specific utility and customer requirements were
envisaged and taken into consideration in the design of each pilot implementation, a process that enabled considerable knowledge acquisition and sharing among partners.

The project succeeded to overcome the main technical barriers by developing a flexible analytics engine seamlessly coupled to the utility systems and delivering through their back office of highly configurable services, avoiding the necessity of especially skilled staff at the utilities. The developed free open software solution is important result of the project and is currently maintained, promoted and further-developed by CIMNE, the lead technology partner of the project (see BEE Data, www.beegroup-cimne.com).

The present work reviews the results from more than 1 year of service operation and analyses the different factors influencing the success of the programmes. Special emphasis is placed on the importance of customer engagement, pointing out some regulatory and policy measures that might help for the widespread application of these services in the future.

#### Technological solution and services

The technological solution developed in Empowering is an open source data analytics engine exchanging data with the local utility energy-feedback tools through standard Application Programming Interface (API) under high security and privacy standard. The services are implemented as software modules in the cloud-based analytics engine which allows each utility to configure its own service solution and use its own user interfaces for providing the feedback services.

The final collection of services resulted in a set of 42 service modules pertaining to following conceptual service groups:

- Comparison with similar households
- Comparisons with own previous consumption
- Detailed consumption displaying
- Personalised energy saving tips
- Consumption-weather dependence
- Consumption prediction
- Alerts

The solution is inherently suited for the European market due to its flexible and adaptable concept capable to address different legislative and utility-specific requirements without major implementation effort. The major customer’s privacy requirements are resolved by adopting largely the “privacy-by-design” principle. This was achieved by accepting only strictly anonymised data and adopting treatment procedures that do not permit individual customer to be recognised outside the utility, or customers to be able to recognise those to which are compared to. In any case, only the necessary information for the services is exchanged and is kept in the system only for the necessary time.
The provision of energy-feedback services from the utility companies can have impact on both the energy savings and the customer satisfaction, but the measure of this impact depends on multiple factors inside and outside the utility. The Empowering project had the objective to, first, assess the effect of the services in large pilot applications and, secondly, to find out how different technical, organisational and regulatory aspects influence on the service effectiveness.

The effect on the energy saving and customer satisfaction has been addressed with quantitative evaluation methods, as explained below, while the different influencing factors have been revealed through in-depth interviews of the utility pilot managers.

The evaluation of the energy-feedback services was focused on the achieved energy savings and the improvement of the customer satisfaction due to improved billing information.

The evaluation of the energy savings was based on the difference-in-difference method comparing the changes in the energy consumption of control and experimental group of customers over a baseline and treatment period and implemented over the formulation in [1]. The experimental design in each pilot site was based on a previous randomised selection of control and experimental group of customers, including finally only the service users in the experimental group.

The consumption data were collected by the utilities and sent to CIMNE for the elaboration and processing. The preliminary data cleaning procedure was based on the following:

- including in the experimental group only of the real users of the services
- removal of consumers that show high differences (2,35 times) in energy consumption for the same month in different years
- elimination of outliers such as atypical consumers with extremely low or high consumption not representative for the data set (consumption higher than 50 kWh/day)

The evaluation of the customer satisfaction was focused on investigating the satisfaction with the billing information provided by the utilities which is directly influenced by the services developed in the

**Methodological approach**

Figure 1. Conceptual scheme of the Empowering system
The evaluation didn’t have as objective to assess the global satisfaction of the customers with their utility company, as it is affected by a number of external factors such as energy prices, governmental policies, taxes, etc., which are out of the project scope.

The evaluation, similarly to the SERVQUAL methodology [2], surveyed the perceptions and expectations of users regarding the services, establishing as an indicator of satisfaction the gap score between them (Gap score=Perception-Expectation). The methodology allowed for evaluating quantitatively the quality of the Empowering services and the changes of satisfaction by analysing the user perceptions and the gap score before and after receiving the services.

The customer preferences about additional information and motivation for the service use were investigated through surveys, focus groups and customer interviews.

The influencing factors affecting the widespread service application were investigated by collecting and analysing qualitatively the practical experiences of the utilities in implementing feedback services together with the legal and regulatory context in the participating pilots. The information was collected during the project and through in-depth interviews with the pilot managers by the end of the action. The interviews focussed on the experiences from the service implementation and operation and discussed, among other things, the following issues:

- reasons for offering the services
- technical, organisational, and legislative challenges
- technical challenges
- utility internal organisation structure challenges
- legal and regulatory challenges
- ways to increase customer participation

The main findings from the interviews were summarised and conclusions for further replications were drawn.

**Results**

**Energy savings**

The energy savings have been evaluated over comparable experimental and control groups of customers. Where possible from the availability of additional user characteristics, the analysis has been done separately for groups of customers with similarities in their energy use or service treatment. This was done to minimise the possible selection bias that might arise from analysis of heterogeneous groups of customers in overall evaluation, and provided also more insight into the results.

The evaluation demonstrated the achievement of energy savings in all of the pilot sites.

- Electricity savings ranged between 3 and 21% among the different pilots and user groups
- Gas consumption savings of about 4 % was achieved at the French pilot.
- District heating energy savings ranged between 5 and 6% at the two sites of the Italian pilot.

The only user group among which the services couldn’t demonstrate positive impact was a sub-group of electricity customers in the Italian pilot which was characterised with higher contract power with reference to the standard usual contract for retailers (families) use in Italy. A slight increase of the energy consumption of about 1,8% during the service period was observed for that group.

The obtained results should be interpreted in the context of the differences in content and offering mode across the pilots. In Austria and France the services were offered in opt-in mode requiring user
registration. In Italy and Spain the services were offered in opt-out mode by sending energy reports to the predefined experimental group. In Spain, additionally, an opt-in strategy was used for more interested users by offering online service access upon registering; this allowed for a comparison between the effectiveness of both modes. The opt-out service consisting in energy report delivered to the whole experimental group achieved 6% saving versus the 11% saving obtained by the customers who received in addition also online treatment (opt-in). The more detailed analysis of the savings by the consumption level of the users showed predominantly higher savings for the upper consumption segments of customers in all pilots.

Customer satisfaction

The quantitative evaluation the impact over the customer satisfaction demonstrated the positive effect of the treatment, with 67% of the whole amount of users involved in the program satisfied with the services.

The particular aspects of improvement from the services with respect to the previous state which were quantified in the evaluation on the average are:

- 20% improvement in the presence of additional information on energy consumption
- 29% improvement of suggestions and help on how to save energy
- 25% improvement in tools for understanding the energy consumption
- 17% improvement of availability of information at any time

The global increase of the satisfaction with the received information from the utilities increased on the average about 20%.

Customer preferences for information

During the initial developing phase of the project an analysis of the customer preferences about the type of information to be included in the services was performed. It consisted in local surveys based on precursor services asking the customers to rank their preferences about the information they would like to receive in addition to the bills. The options included different type of comparatives, tips and predictions. A compilation of 964 utility customer surveys in Austria, France, Italy, Spain, and Denmark showed a ranking for the most valuable information for them:

- Personalised energy saving tips (74% of the customers)
- Comparisons with previous periods (69% of the customers)
- Similar household comparisons (50% of the customers)

Motivation for service use

A sociological study performed at the French pilot in Grenoble [3] about the motivation for using the Empowering services discovered the following types of motivations related to different user energy profiles:

- Economic (44%) – motivated only by economic reasons
- Economic and ecologic (30%) – motivated by economic reasons but also happy to contribute to emissions’ reduction
- Energyphile (15%) – interested in technology, efficiency and control
- Ecologic (11%) – motivated exclusively by ecological reasons
Discussion of findings

The Empowering project demonstrated that energy-feedback services delivered by the utilities can save energy among the users in all of the participating countries, and that the additional information, in general, contributes to increasing the satisfaction with the utility. The amount of savings varied considerably from one pilot to another, with savings between 3% and 21%, with the only exception of a subgroup of users in Italy that increased their consumption with 1.8%.

The customer engagement with the services was identified as a key challenge for the overall success of the programmes. The active service usage depends on factors, such as personal motivation of the consumers for energy savings, perceived usefulness of the service, appearance and ease of use of the service interfaces.

Motivation

The sociological study [3] revealed different motivations for usage of the Empowering services among a representative sample of utility customers. It classified the users into 4 energy profiles (see above), suggesting that each of them responds to different type of messages and keywords. For example, users with economic rationale respond positively to simple messages and economic saving stimulus, while users with energyophile rationale require more detailed explanations about how the results in the services were obtained. Effective feedback services have to take into account the user’s energy profile in order to provide effective and motivating communication.

Usefulness

The perceived usefulness of the services depends on how the feedback received helps to the user in achieving his objectives. The extensive user surveys performed in the project provided some insight into the question. Surveys indicate that 74% of the users need specific actionable advices personalised to their particular situation. Comparisons with previous periods permitting the user to make causal connection between his actions and the energy consumption are considered useful by 69% of the users. Sufficient consumption data resolution (daily, hourly) and timely feedback can increase the effect of these comparatives for energy saving. Another type of comparatives is that with similar households, perceived as useful by 50% of the users. Similar household comparatives work on social norm principles and might be stimulating for higher than average consumers, but can also lead to a “rebound effect” in lower than average consumers. Feedback from the users during the service operation showed that comparatives with similar households might be irritating for some users, especially if they have already applied some energy saving measures. The last suggests cautious application of these comparatives and special attention to the selection of the customers’ similarity criteria.

User interfaces

The user interfaces for effective feedback services are important to assure the easy access to the services and to maintain the user’s interest, thus making persisting the effect of the services. The project tested both web-based tools and periodic energy reports in order to provide the services. The selection of the service modality was influenced by the utility preferences, as well as by the national regulatory restrictions.

The offering of web tools alone demonstrated not very effective, with overall usage between 2-5%. For accessing the services, the customers had to subscribe in the web portal (opt-in), attracting only very motivated customers. On the other hand, the energy reports delivered periodically to every customer reached everybody (opt-out), but offered less possibilities for detailed information, showing relatively lower effect on savings. The most effective way of service offering was the combination of
periodic energy report with basic information combined with web-based tool providing more detailed information for interested users. The Spanish pilot site offering both modalities of services permitted clear comparison: users receiving only energy reports saved 6% of energy and those who in addition accessed the web tool saved 11%.

External factors - regulation
The regulation in the different European member states regarding metering data access, customer consent and regulated energy bill content had a strong implication in the service design and affected indirectly the customer engagement. The impediments to collect and store frequent consumption data, the tedious procedures for customer consent and the regulation obliging for excessive amount of sometimes “useless” for the user information within the energy bills led to a number of restrictions which reduced the energy-saving potential of the services.

Conclusions and recommendations
The effective providing of energy-feedback services by the utilities depends on a complex combination of factors, some of which can be controlled by the service provider, and other which are external. The national legislation and regulation regarding energy consumption data and customer data treatment strongly influences the possibilities for service offering, the service content, and finally affects the user engagement and the overall results of the energy-feedback programmes.

Some regulatory changes for facilitating the consumption data access, the management of the customer consent for receiving the services and the adoption of measures permitting the offering of the services by default (opt-out) to all utility customers will help for the wider and more effective adoption of these services in the future.

References
“Waiting for Data: Market Adaptations to Poor Smart Meter Policies in America”

Michael E. Murray, Mission: data Coalition

Abstract

The worldwide installation of smart meters was supposed to bring a cornucopia of ubiquitous energy feedback technologies that would significantly reduce building energy use in the U.S.. Unfortunately, smart meters have, in practice, provided very little direct value to consumers. In America, over 60 million smart meters are installed but only a few thousand have connected devices providing real-time energy information. Based on the author’s experience as CEO of an energy feedback company in Silicon Valley, the following reasons have emerged for the dismal utilization rates of smart meters in the U.S. First, the development of a technical standard for in-home device communication (ZigBee) was not established before millions of smart meters were installed. Competing companies jockeyed for position, causing numerous delays in the development and adoption of a Home Area Network communications standard. Second, regulators shied away from technical matters, leaving industry to self-organize in a vacuum of leadership, increasing market uncertainty. Third, legal and privacy matters were an afterthought to the infrastructure upgrade, giving utilities the excuse to indefinitely postpone the sharing of smart meter data for the sake of customer privacy. As a result, the potential for mass energy savings via energy feedback technologies in America has not been realized, providing valuable lessons for other governments considering advanced meters.

Overview

The installation of smart meters in America was supposed to bring forth a cornucopia of energy management and feedback technologies. Electric utilities proudly announced to regulators and the public that smart meters would “empower consumers” with detailed information about their usage patterns, allow consumers to cut their bills with time-of-use (TOU) pricing, and provide the Home Area Network (HAN) for real-time communication between the smart meter and home appliances. Public utility commissions (PUCs) require utilities to publish detailed cost-benefit analyses of any proposed investment, and “customer empowerment” benefits figured heavily into utilities’ proposals for advanced metering infrastructure (AMI; e.g., California PUC, 2012, p. 5). In order to pass cost-benefit tests required by PUCs, utilities needed a strong showing of benefits from feedback. One industry report found that energy savings resulting from feedback could account for 33% to 66% of the operational benefit of smart meters (Faruqui et al., 2011, p. 27). Unsurprisingly, utilities described feedback mechanisms in optimistic terms in their AMI proposals.

In retrospect, however, very few of these feedback benefits to consumers actually materialized. Despite over 60 million smart meters installed across the U.S., tangible benefits to consumers have remained elusive. Three main reasons are responsible for the underwhelming performance of smart meters as feedback enablers: the fact that legal and privacy matters were not settled until years after AMI deployment; a battle of competing communications standards for the HAN led to costly delays in exchanging AMI data with new technologies; and utility regulators’ aversion to complex but critical
technical matters prolonged inaction. All three problems proved to be major barriers to lowering energy use, and they could have been avoided. Furthermore, feedback technologies were forced to adapt to a challenging environment, dramatically limiting their features. The author hopes this analysis of the U.S.’s poor record of fostering feedback technologies will provide valuable lessons to other governments considering smart meters.

The first reason for the prolonged delay of feedback technologies in America has to do with privacy. Meter data was supposed to be accessible to consumers in two ways: real-time data sent to devices via the HAN and so-called “backhauled” data in 15-minute or 60-minute intervals sent back to the utility and made available on a web portal. In order to package data for effective feedback (such as with social norms), either the utility must conduct an analysis, or else third party companies must have access in order to develop smartphone apps, home automation systems or other offerings incorporating energy data. The process by which third parties access AMI data is not resolved and is the subject of ongoing regulatory proceedings in numerous states (e.g., Murray and Hawley, 2016).

That third party access was not addressed before AMI approval meant that feedback offerings from companies other than utilities languished for years, according to first-hand accounts from dozens of U.S. companies. Many companies, having heard AMI’s promises of rich data, knocked repeatedly on the door of utilities inquiring about electronic access only to be told that signed, wet-ink signatures from customers were required before releasing energy data to third parties (e.g., PG&E, 2007), a process that can take four weeks. Eventually a CD-ROM would be mailed to the authorized party. The clumsiness of the process, uncertain timing of receipt by the third party and wide variations in possible formats (PDF, CSV, Excel) meant that most business models for non-HAN energy feedback technologies were quickly thrown into the dustbin.

Privacy became a primary barrier to innovation in energy feedback when utilities and consumer advocates expressed legitimate concerns about AMI data getting in the hands of “bad actors.” The easiest way to eliminate privacy risks is not to share data with anyone – the default position of utilities. Entrepreneurs countered that, if a customer assents to have his or her data shared with someone, the utility should offer a streamlined process for doing so. Legal debates are ongoing, even in cases when the customer has clearly provided consent (see, e.g., Murray and Hawley, 2016). A key obstacle cited by utilities is their legal liability in case of a third party breach of privacy laws. Time-consuming litigation in this area would test the resolve of even the most committed entrepreneurs: In California, it took six years after AMI approval for the PUC to affirm customer rights to access personal usage data (CPUC, 2011, p. 164). It would be another two years before the CPUC required the utilities to offer an electronic system for data-sharing known as Green Button Connect My Data (CPUC, 2013), and it would be another three years after that when the system would be operational. Today, entrepreneurs still complain that the customer consent process is anything but frictionless, hindering uptake (CPUC, 2016). Even Texas, despite being the only state to delare that customers have ownership rights over data generated by the meter (see Texas Public Utility Regulatory Act §39.107(b)), is plagued by customer-consent friction, resulting in extremely low rates of data-sharing (SPEER, 2015). All of these challenges could have been avoided by addressing key legal questions and mandating a streamlined consent process for consumers prior to AMI installation.
Table 1

<table>
<thead>
<tr>
<th>Electric Reliability Council of Texas (ERCOT)</th>
<th>% of smart electric meters in service territory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of meters with a HAN-connected device</td>
<td>9,520</td>
</tr>
<tr>
<td></td>
<td>0.135%</td>
</tr>
<tr>
<td>Number of customers sharing back-hauled data</td>
<td>1,952</td>
</tr>
<tr>
<td>with a third party</td>
<td>0.028%</td>
</tr>
</tbody>
</table>

*Source: Smart Meter Texas, 2016 and ERCOT, 2016.*

The second blow to energy feedback’s prospects came from competing communications standards of the HAN. The HAN promised to provide real-time feedback to consumers, but the communications protocol was not finalized until after America’s largest utilities had already begun AMI deployment. Regulators in California, a state with over 17 million electric meters and eager to adopt new technology, found out the hard way that installing AMI first and picking a communications protocol second proved detrimental to the intended purpose of smart meters. In 2005-2007, when California’s $5 billion AMI investment was approved by the PUC, there were at least a dozen competing communication standards in existence: wireless protocols included ZigBee, Wifi, Z-Wave and Bluetooth, and wired protocols included Universal Powerline Bus, HomePlug 1.0, HomePlug AV and numerous proprietary protocols. Choosing a standard for a 20+ year AMI investment was a difficult task for regulators, and it was not made easier by industry heavyweights Cisco Systems, Intel, AT&T and others entering the fray to advocate their preferred standard. A “VHS versus Betamax” battle emerged with powerful economic interests jockeying for position. But unlike VCRs in the 1980s, AMI saw over a dozen competing standards instead of merely two. There was also a prolonged period in which no clear winner emerged. The uncertainty faced by energy feedback entrepreneurs dimmed investment prospects in the sector as losses piled up from products built for standards that failed to take hold.

Amidst a dizzying array of alternatives, California made an effort to unify the industry when it decided to support ZigBee in 2005-2006. ZigBee was selected in part because of its “meshing” feature in which signals hop from device to device. ZigBee was among the first open protocols for home automation and HAN purposes, ratified by IEEE as 802.15.4 in 2004. California regulators insisted on an open standard rather than a proprietary one, and ZigBee appeared to fit the bill.

But challenges soon arose. ZigBee is a high-level interface with many details purposefully left unspecified. An “application profile” was needed to make ZigBee devices “talk” with one another. The ZigBee Alliance formed technical groups to agree on an application profile known as Smart Energy 1.x. (Today, Smart Energy 1.1b is the current standard.) In the late 2000s, however, the industry was divided over concerns about security and the fact that Smart Energy 1.x was not based on the Internet Protocol (IP). A schism developed between IP supporters such as Cisco Systems and Silver Spring Networks (SSN), who advocated for Smart Energy 2.0 (an IP-native profile), and Itron and device manufacturers whose products already supported 1.x. Itron sold meters with 16-bit processors – not
enough processing power for 2.0 – while 2.0 supporters such as SSN sold meters with 32-bit processors.

Given technical complexities and disagreements among large industry players, it was no surprise that California regulators were hesitant to decisively rule on the issue. And yet years ticked by as the ZigBee battle continued and Californians failed to reap tangible AMI benefits. Eventually, the California PUC ruled in 2009 that utilities must enable the HAN and provide customers with access to real-time data no later than 2011 (CPUC, 2009), but the deadline was not achieved. The PUC did not specify which application profile should be used, evidently thinking that it was the utilities’ job, and not regulators’, to decide technical matters. In 2011, the CPUC again ordered HAN enablement without specifying the application profile (CPUC, 2011). Even more time passed with negligible HAN adoption. Finally, the CPUC took decisive action in 2012, requiring utilities to permit unlimited HAN device connections by 2015 (CPUC, 2012). Ultimately, Smart Energy 1.x became the de facto standard not because the PUC explicitly required it but because 1.x was the least common denominator across the state’s mixture of 16-bit and 32-bit meters.

A full decade after AMI approval, the saga of which HAN standard to use had come to a close, and this delay exacted a significant toll on the nascent energy feedback industry. Investors lost patience and most companies left the space entirely, either going out of business or entering adjacent sectors. Of the 32 companies listed under Greentech Media’s “HAN/Building Area Network” industry category in 2010 (http://www.greentechmedia.com/articles/read/who-are-the-players-in-the-smart-grid-and-how-much-is-the-market-worth), only two are left with HAN products. It is not surprising that very low HAN usage persists today (see Table 1).

Table 2.

<table>
<thead>
<tr>
<th>Utility</th>
<th>Number (percent) of electric meters with connected HAN device</th>
<th>Total number of smart electric meters in service territory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Gas &amp; Electric (PG&amp;E)</td>
<td>3,066 (0.060%)</td>
<td>5,070,987</td>
</tr>
<tr>
<td>Southern California Edison (SCE)</td>
<td>865 (0.017%)</td>
<td>5,024,164</td>
</tr>
<tr>
<td>San Diego Gas &amp; Electric (SDG&amp;E)</td>
<td>7,859 (0.558%)</td>
<td>1,408,733</td>
</tr>
</tbody>
</table>

While technically complex, the standards battle itself would not have slowed progress to the extent it did were it not for PUCs shying away from technical issues. Utilities could claim their AMI systems had the capacity to share data and enable the HAN, but implementation of that capacity was not closely tracked nor required by the PUC until it reached a breaking point. By refusing to consider and resolve information technology matters, perhaps because of lack of expertise, the PUC created an environment in which industry was left to organize itself. A well-functioning HAN became the first casualty of an anarchic process. The end result was also unworkable for consumers in apartment buildings, where meters on the ground floor can’t communicate with in-home devices more than 100 feet away. One utility, Consolidated Edison, recently received regulatory approval to install 3.5 million smart meters with ZigBee capability at a cost of over $1 billion, but the utility has no plans to ever let customers use ZigBee because its customers live in high-rise buildings in New York City where low-power radio communication is unfeasible (Consolidated Edison, 2016, p. 24). In these cases, a wired standard using the powerline would work well, but meter manufacturers have chosen ZigBee exclusively. Clearly, competing interests left to self-organize failed to produce a universally good outcome for consumers. Wasting ratepayer funds on HAN features never to be used in urban environments is likely to continue so long as PUCs are averse to understanding technical issues and fail to provide consistent and detailed oversight. Regulators should employ technologically sophisticated staff to embrace, rather than sidestep, technical matters.

These problems necessitated adaptive measures on the part of feedback companies. First, an unfortunate consequence of HAN failures is that detailed energy disaggregation is not possible. A HAN device can read the meter every 5-10 seconds, resulting in rich datasets for machine-learning algorithms to identify the patterns of individual appliances. However, with poor HAN support and adoption, customers don’t reap the full benefit of this technology. An itemized utility bill, for example, offers highly actionable feedback likely to result in savings. Armel et al. established that shorter time intervals of whole-home measurement provide greater specificity of feedback (2010). As the HAN’s promise faded in the period 2010-2015, feedback companies shifted their focus to the data that were accessible: much coarser 15-minute or 60-minute data backhauled to the utility. The analytical implications of this shift are significant: loads are identifiable only in a category (i.e., heating, cooling, plug loads), not by specific appliance. Analysis of hourly data can thus suggest general areas of focus for the resident but not provide the level of detail that some believe is needed to effectively reduce consumption.

Aside from whether readings are measured every five seconds or hourly, it also matters when the data are made available to the feedback technology. If transmitted instantly, a smartphone app user can be prompted with a question like “What turned on right now?” and the load is immediately identified. But backhauled data in California, Illinois, New York, Texas and Washington, D.C. are only available...
24-48 hours in arrears. As a result, feedback companies must plan for interaction models in which the user is not assumed to have real-time access.

Feedback companies were also forced to adapt to the friction a customer faces when granting third party access. When companies can’t cost-effectively access meter data via customer authorization, they seek to avoid needing permission in the first place by becoming a contractor to the utility. Scale is achieved with opt-out feedback via the utility. But in exchange for access to a large customer base, the entrepreneur must serve the needs of the utility. Some utilities can increase earnings and please regulators by achieving energy savings as calculated by complex evaluation, measurement and verification protocols; significant revenues await companies that successfully deliver energy savings in the manner utilities require. Complying with these rigid rules, rather focusing on engagement or customer delight, narrows the breadth and creativity of services across the marketplace. Opower is a leading example of a company that succeeded by serving utilities rather than consumers, essentially becoming an IT contractor to utilities. Many companies in the period 2010-2015 began selling energy management services to consumers or businesses only to run out of money and turn to the utility as a reliable source of income. Of the 32 companies shown in Figure 1, 10 made such a transition.

Building energy use accounts for 40% of U.S. greenhouse gas emissions. The policy obstacles discussed must be addressed for a rich array of feedback technologies to reach consumers. Privacy concerns over sharing AMI data, even with customer consent, continue to stifle the market. Allowing a streamlined consent process and immediate data transmission is critical. Regulators must also take a strong role in establishing standards and must not leave technical matters to the discretion of utilities. In conclusion, other jurisdictions can learn from these mistakes to realize the benefits of AMI and encourage, rather than restrict, development of energy feedback technologies.

References


California PUC. (Dec 7, 2009). Decision D.09-12-046. Retrieved from http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/111856.PDF


California PUC. (Sep 27, 2012). Resolution E-4527. Retrieved from http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M028/K949/28949960.PDF

California PUC. (Sep 19, 2013). Decision D.13-09-025. Retrieved from http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M077/K191/77191980.PDF

California PUC. (Jun 9, 2016). Decision D.16-06-008. Retrieved from http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M163/K294/163294060.PDF


