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DEHEMS – Digital Environment Home Energy Management System

D7.7: Project Cycle Analysis Report for Cycle 3

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1. Executive Summary

The DEHEMS research programme has been organised in 3 cycles. Cycle 1 established methodologies for using Living Labs for this research and tested the DEHEMS system in 58 households in the UK. Having developed a robust methodology, Cycles 2 and 3 have been about gathering live data from about 250 participating households in 5 Living Labs in Manchester, Birmingham, Bristol, Plovdiv & Ivanovo. This process has been iterative and the DEHEMS system has been developed and improved from one cycle to the next based on user feedback and internal project review. Thus Cycle 3 has incorporated some additional components as well as improvements to the existing system. The key additional components have been gas monitoring (UK only), variation in community contexts including a team incentive scheme (Energy Team Challenge) and the creation of a DEHEMS Facebook page for energy data display.

This report combines both the quantitative and qualitative data elements which have been collected during Cycle 3 using the following sources:

- Participating household energy usage as monitored by the DEHEMS system
- Results of user surveys conducted by all Living Labs
- Transcripts of focus groups conducted by all Living Labs
- Other feedback from users recorded by individual Living Labs
- Records of User Groups and other meetings
- This report puts Cycle 3 within the context of the whole DEHEMS programme and identifies the lessons that have been learned. These are reported in detail in Appendix 1: Lessons Learnt from Cycle 3.
- D7.7 feeds into D2.15 Future Requirements Evaluation (documentation of future requirements for a DEHEMS type system).

The overall Work Package is led by Bristol with programme management assistance in the implementation of tasks across this WP supported by Clicks & Links, whilst data analysis has been undertaken by Salford University.

Deliverable 7.7 is concerned with the evaluation of the implementation of the project Cycle against its objectives, based on usage data, end of cycle user surveys and end of cycle user focus groups.

2. Project and Cycle Objectives

Work Package Overall

The purpose of this Work Package is to address *O3 Living Labs Validation* and *O4 Living Labs Analysis*. The Work Package objectives related to D7.6 include:

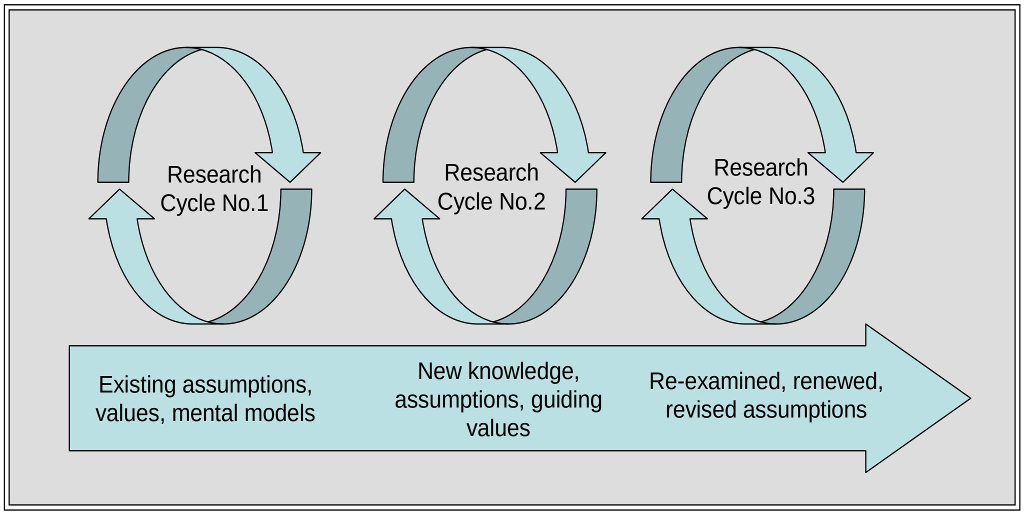
- Active participation of European residents from diverse settings in the Living Labs
- User generated evidence base to inform system development
- System usage data to inform system evaluation

In order to understand the deliverable outcomes, the objectives O3 and O4 must be encapsulated within them.

O3. Living Labs validation

The overall process of iterative learning throughout the DEHEMS programme is indicated by the schematic below. Cycles repeat to create a series of experience based learning episodes through which people can learn and create knowledge:

- on the basis of their concrete experience
- through observing and reflecting on that experience
- by forming abstract concepts and generalisations about what to do next
- by testing the implications of these concepts in new situations -- which will lead to new experiences and hence the beginning of a new phase series learned during the first cycle.



The Project Cycle Analysis Report for Cycles 1 and 2 (D7.5 and D7.6) included feedback from users and project partners and indicated where methodologies for working with Living Labs could be improved. The planning documents for Cycles 2 and 3 indicated how these cycles would develop from previous cycles in order to better meet users' requirements.

O4 Living Lab analysis

There is an established RTD base for evaluation of information management systems balancing requirements for system and user centric analysis. There has been specific activity on IT, user behaviour and decision-making which has established a framework for the overall achievement of O4. O4 uses cyclical RTD development effort via the Living Labs and impacts greatly on the project cycle analysis undertaken within D7.7.

Effort across multiple WPs informs this deliverable and can be summarised as follows:

- WP2 - identified user requirements and system architecture
- WP5 - development of energy measurement metrics
- WP6 - integrate the different sub-systems,
- WP7 - generate system usage to be analysed with survey data from WP2 to inform WP2 User Requirements for the subsequent Cycle.

Tasks undertaken in relation to O3 and O4 can be summarised as follows:

T7.3 Living Lab Operation
This task and its sub-tasks will be repeated throughout each of the Cycles

T7.3.1 DEHEMS household implementation
Completion of this task has included a number of sub-tasks:

- Retention of Cycle 2 participants
- Recruitment of new participants to replace any "drop-outs"
- Managing participants expectations & communications during the period between Cycles 2 and 3
- Preparation of guidance materials for the new gas monitoring equipment (for both households & installers)
- Survey of participants' households to identify suitability for gas monitoring
- Re-training of installation teams & testing of new equipment
- Equipment installation
- Maintaining of engagement of Living Lab users in interacting with the DEHEMS system via the web user interface;
- Recruitment of Living Lab users for social networking engagement
- Recruitment of Energy Team Challenge participants
- Providing user support – including re-flashing data collectors to increase battery life and other home visits as necessary to rectify any faults
- Undertaking online survey & focus groups
- Maintaining user engagement through promotion of energy usage/saving issues

Installations across the DEHEMS programme for all cycles are shown below:

Living Lab	Number of DEHEMS Cycle 1 installations	Number of DEHEMS Cycle 2 installations	Number of DEHEMS Cycle 3 installations
Manchester	20	59	56
Birmingham	19	46	43
Bristol	19	47	55
Plovdiv	none	50	50
Ivanovo	none	36	50
Others		4	2
Total	**58**	**242**	**256**

T7.3.2 DEHEMS Support
Living Labs have provided support for participating households through 3 levels:

- Level 1 – local support provided by telephone and household visits as appropriate. Lessons learned in Cycle 1 identified that this is best undertaken by the original installation team. In Bulgaria, household electrical supply configuration required that level 1 support needed specialist electrical as well as IT skills
- Level 2 – issues are escalated to local Living Lab project management and where appropriate discussed with other Living Labs through User Groups
- Level 3 – technical & system issues are reported to programme technical partners for resolution before circulating updates to Living Labs for onward communication to households

T7.4 Living Lab Analysis
T7.4.1 Living Lab system development feedback loop
This task runs throughout all Cycles and involves ongoing analysis of survey and system data. End of Cycle analysis reports feed back into WP2 User Requirements activity and will be incorporated as part of the final Evaluation Report in WP8.

T7.4.2 Knowledge base development
Data from Cycle 3 will be used to populate European Household Energy Use Knowledge Base (D7.4). In practice, this will be undertaken by making the quantitative & qualitative data & analysis (Appendix II to this deliverable) available on the DEHEMS web site, through publications and at EU presentations.

Cycle 2 Objectives
These consist of objectives, concerned with research questions the project proposes to answer in this particular cycle and the expected knowledge contribution from this cycle that have been effected through the DEHEMS system. The research questions are as follows:

a. To what extent can the DEHEMS cycle 3 system contribute to users' changing their behaviour resulting in reduced energy consumption and what are the key factors in the DEHEMS cycle 3 system that determine its effectiveness in encouraging the end users to change their attitudes and behaviours regarding energy use?
b. In what ways and to what extent can community dynamics influence motivations to move more towards more environmentally motivated behaviours?
c. What are the key factors that affect engagement over a longer period of time and allow it to be maintained? Are there barriers?
d. What are the key factors in the DEHEMS cycle 3 system that affect acceptability to the end users?

e. How important is it to measure gas consumptions besides electricity? In particular, how acceptable are estimated gas usage figures in influencing users' behaviours?
f. Online social networking - how effective is the use of online social networking in getting users engaged in DEHEMS and how does this compare with engagement of users who are not involved in online social networking.
g. To what extent has DEHEMS encouraged users to become more involved in their communities, both online and off-line?
h. Is CO2 trading the 'right way' forward in order to achieve the objectives of the DEHEMS project?
i. To what extent can the DEHEMS carbon trading model engage users, and how is this likely to support the creation of a CO2 trading market place or support trading activity that will encourage absolute CO2 reduction?
j. To what extent has the technical apparatus of the DEHEMS system become 'domesticated' in the homes and home life of the Living Labs participants, and how is such domestication affected by individual's attributes (including gender, age group, and household role)?

3. Activities to achieve the Deliverable

Meeting the research objectives identified above, the review of Cycle 3 has been undertaken through the following activities:

- Ongoing review of all Living Lab activities - focusing on resolving issues arising during equipment installation & user support – fortnightly telephone conferences involving all Living Labs and representatives from other work packages. A record of these meetings has been maintained and is stored in the project's document archive for reference by all project partners
- A major review at the end of Cycle 3 with all project partners. The lessons learned table included as Appendix 1 arose from this session.
- Regular monitoring of DEHEMS participants' household energy consumption through interrogation of the system database
- Analysis of household survey responses & focus group transcripts
- Other feedback from users recorded by individual Living Labs

Through close integration with other work packages, specifically WP2 User Requirements and System Architecture, WP5 Energy Measurement and WP6 System Integration, Cycle 3 has built upon the success of previous cycles where the basis of the DEHEMS service was established via the generation of information on requirements and technical delivery capabilities. Living Labs have continued to work with users to ensure cohesive responses to questionnaire and focus groups, keeping users on board in order that Cycle 3 can be undertaken successfully and identifying eco-warriors who are truly committed to working within their neighbourhoods in order to affect a change in behaviour.

Full analysis of Cycle 3 qualitative and quantitative data is included in Appendix II. This interpretive research has been used to enable triangulation using qualitative survey and focus group data and hard quantitative data gathered and supplied by the DEHEMS system itself.

4. Next Steps

Cycle 3 is the final operational phase of the project. Lessons learned are set out as Appendix I of D7.7. These will inform D2.15 Future Requirements Evaluation – documentation of future requirements of a DEHEMS type system.

Appendix I: Lessons Learned from Cycle 3

	Cycle 3 Lessons Learnt	Actions for D2.15 (Cycle 4)
1	**Recruitment**	
1.1	Manage users' unrealistic expectations of prototype kit	√
1.2	Use male/female installers for BME families; installation team needs mix of technical & communication skills	√
1.3	Recruit communities of interest - e.g. people that work in the same place (e.g. Ivanovo)	√
2	**Installation**	
2.1	Some users confused over cubic feet/metres - intervention by staff s required	√
3	**Equipment**	
3.1	Improved solution (hardware) required for gas	√
3.2	Wider roll-out not be possible due to limitations of current monitoring devices	√
3.5	Gas unit needed specialist installation team and also special user briefing	√
3.6	Some users felt unable to provide feedback because the system was too complex	√
3.7	C3 required a reliable product so users can develop "normal" consumer behaviours around it	√
3.8	Quality, long life batteries to prevent equipment failure	√
3.7	Need to create confidence in the system - robust equipment	√

3.8	Reliability of some system components	√
3.9	Need to keep users online all the time – some users turned off routers	√
3.10	System should be self-install / plug & play. Householder could be incentivised to install.	√
3.11	Learn from Google Power Meter (ceased operating July 2011)	√
3.12	Radio communication between sensor and data collector is unreliable in large flats & houses	√
3.13	The more experimental the technology is the less reliable are the data on behavioural change	√
3.14	Gas metering technology – the need for maturity to ensure robust reliability	√
3.15	Close down and equipment disposal strategy – ways to retrieve equipment	√
4	**Other Technical - Including Dashboard**	
4.1	Dashboard is too complicated	√
4.2	Simplify the dashboard	√
4.3	Minimise technological development, keep it simple, not too clever with artificial intelligence	√
4.4	Alerts must be well defined and meaningful	√
4.5	More energy saving tips in relation to gas consumption	√

5	**Maintaining Interest / Engagement**	
5.1	Need to strengthen team aspect of carbon saving aspects	√
5.2	Importance of personal contacts, playing in teams, awards	√
5.3	Alerts & features help to keep people interested	√
5.4	More direct incentives- e.g. dinner invitation, community events, cost reimbursement	√
5.5	Need to ensure commitment and ongoing engagement of end users	√
5.6	Competition drives change and helps engagement	√
5.7	Need a realistic baseline (other than 1st weeks usage)	√
5.8	Carbon trading needs more meaningful on larger scale (neighbourhood, city, region)	√
5.9	Participants' loyalty was with the local organisers rather than project partner or the project	√
6	**User Support**	
6.1	Helpdesk needs to be properly resourced	√
6.2	1st, 2nd & 3rd line support must carefully planned and managed	√
6.3	Consider out of hours to accommodate working people	√

7	**Data Capture**	
7.1	Focus group questions need to be meaningful and clear	√
7.2	Questions on ethnicity & income upset some users & refused to complete on questionnaire	√
7.3	Managing LL's locally resulted in users dealt with differently in each location and possible inconsistent results – need for common methodology and terms but allowing for divesity	√
7.4	More fuzzy rules to be introduced in association with thermo model	√
7.5	Data sets should be modelled as services to facilitate data fusion	√
7.6	Thermo model should include user comfort level	√
7.7	Risk availability of data management on servers – consider cloud for collected data	√
7.8	Different models of community engagement - existing communities / random recruitment	√
7.9	Unique aspect - introduced people into product development and used their feedback	
8	Communications	
8.1	Similar products/systems are now available on the market - need to create a unique identity	√

Appendix I: Lessons Learned from Cycle 3

9	**Project Design**	
9.1	Divide (a) product development, and (b) behaviour research	√
9.2	Methodology issues e.g. if we recruit people that are already interested, results are biased	√
9.3	Results are much richer through integrating into own life/household patterns	√
9.4	Use a stable group of participants engaged over 3 cycles to see them grow with the product	√
9.5	Recruit a new set of users each cycle - see each product version fresh	√
10	**Planning for Cycle 4**	
10.1	Widen community engagement - work with offices, businesses, schools (3 phase supply issues)	√
10.2	Include water monitoring – is the technology available?	√
10.3	Use orbs or other signalling system	√
10.4	Facebook app should enable other users to be identified	√
10.5	Increase family involvement by including more child friendly features	√
10.6	Recruit "super users" - part of a wider Living Lab e.g. "be a part of your city's future"	√
10.7	Convenience - e.g. mobile app, smart phone essential	√

Appendix II

DEHEMS Cycle 3 Quantitative and Qualitative Analysis

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1. Introduction

DEHEMS Cycle 3 was designed to continue the collection of live energy consumption data from participating households in the UK and Bulgaria and also to test some new aspects of the DEHEMS system. The key objectives of the cycle were:

- To introduce gas monitoring
- To explore the use of social networking technologies for engaging participants in energy saving
- To investigate how being involved in a community can impact on energy saving
- To attempt to collect energy consumption data on a continuous basis over a 3 month period
- To add to Cycle 2 results (June to August 2010) in order to have energy consumption data from different seasonal conditions

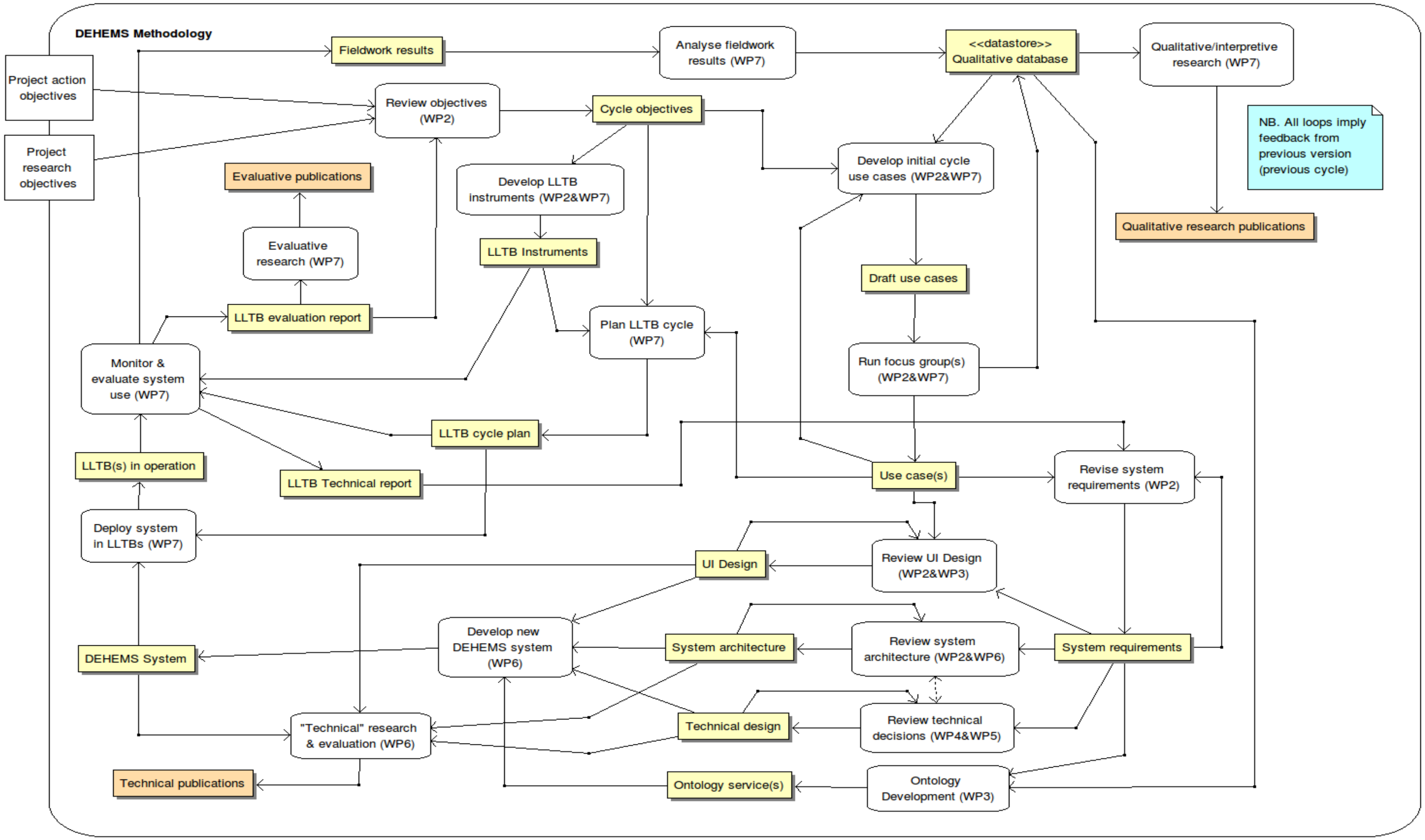
This report builds on the analysis of data from previous cycles – notably D7.5 (Cycle 1) and D7.6 (Cycle 2). This report is an early attempt to analyse the various angles of Cycle 3 data. Subsequent to this effort, the intention is to publish more scientific publications containing in-depth analysis of the results.

The report is organized as follows. Section 1 outlines the research questions that are addressed in this report, and explains the research methodology and the methods applied for the survey, focus group and energy data. Section 2 provides quantitative and qualitative analysis, combining the results of (1) the analysis of the Cycle 3 questionnaire responses received from 183 households, (2) the qualitative analysis of the Manchester, Bristol, Birmingham, Plovdiv and Ivanovo focus group transcripts, and (3) the quantitative analysis of the DEHEMS energy data collected for the months of February to April 2011. Section 3 reviews the results in the context of the Cycle 3 research questions and the conclusion (Section 4) highlights the key results.

1.1. Research Methodology

The overall methodology of the DEHEMS project is shown in Figure 1. At the beginning of each cycle of the project, the action and research objectives for the cycle are agreed, based on the overall project objectives as well as the outcomes of the previous cycle. These cycle objectives are then used as the basis for: the system development activities, which begin with the definition of system use cases, and the Living Lab activities, which begin with the development of appropriate research instruments, which are comprised of data gathered by the DEHEMS system as well as results obtained from questionnaires, from focus groups, and from direct observations made by the Living Labs participants in the project.

Figure 1 DEHEMS project methodolgoy



The research questions for Cycle have already been defined in Section 4.3 of D2.5 (User Requirements report for Cycle 3). They are:

1. To what extent can the DEHEMS Cycle 3 system contribute to users' changing their behaviour resulting in reduced energy consumption and what are the key factors in the DEHEMS Cycle 3 system that determine its effectiveness in encouraging the end users to change their attitudes and behaviours regarding energy use?
2. In what ways and to what extent can community dynamics influence motivations to move more towards more environmentally motivated behaviours?
3. What are the key factors that affect engagement over a longer period of time and allow it to be maintained? Are there barriers?
4. What are the key factors in the DEHEMS Cycle 3 system that affect acceptability to the end users?
5. How important is it to measure gas consumptions besides electricity? In particular, how acceptable are estimated gas usage figures in influencing users' behaviours?
6. Online social networking - how effective is the use of online social networking in getting users engaged in DEHEMS and how does this compare with engagement of users who are not involved in online social networking.
7. To what extent has DEHEMS encouraged users to become more involved in their communities, both online and off-line?
8. Is CO_2 trading the 'right way' forward in order to achieve the objectives of the DEHEMS project?
9. To what extent can the DEHEMS carbon trading model engage users, and how is this likely to support the creation of a CO_2 trading market place or support trading activity that will encourage absolute CO_2 reduction?
10. To what extent has the technical apparatus of the DEHEMS system become 'domesticated' in the homes and home life of the Living Labs participants, and how is such domestication affected by individual's attributes (including gender, age group, and household role)?

As stated in the Cycle 2 Data Analysis Report (D7.6) the research philosophy we have adopted is a combination of the two main traditions of philosophies; positivism and social constructionism / phenomenology [4,5]. While positivist approach assumes that that the world exists externally and its properties should be measured through objective methods, the social constructionist approach is based on the view that the reality being observed is not objective and exterior but is socially constructed and given meaning by people [5]. The latter approach is often the more suitable when studying social and behavioural phenomena, in which the context is extremely complex, the system is open rather than closed, and results are not necessarily expected to be repeatable. Table 1 outlines the contrasting implications of positivism and social constructionism.

Table 1 Contrasting implications of Positivism and Social Constructionism (adopted from Easterby-Smith et al.[5])

	Positivism	**Social Constructionism**
The observer	Must be independent	Is part of what is being observed

Human Interest	Should be irrelevant	Are the main drivers of the science
Explanations	Must demonstrate causality	Aim to increase general understanding of the situation
Research progress through	Hypotheses and deduction	Gathering rich data from which ideas are induced
Concepts	Need to be operationalized so that they can be measured	Should incorporate stake holder perspectives
Units of analysis	Should be reduced to the simplest terms	May include the complexity of whole situation
Generalisation through	Statistical probability (Quantitative analysis of questionnaires and energy sensor data)	Theoretical abstraction (Qualitative analysis of questionnaire and focus groups)
Sampling requires	Random selection of a larger number of participants	Small numbers of cases chosen for specific reasons
Methods used in DEHEMS	Survey, energy sensor data	Action research (focus group)

The research methods applied in this analysis are both quantitative (based on indirect observations taken from the DEHEMS database) and qualitative (based on direct observations taken from questionnaires and focus groups). The analysis also involves a degree of triangulation between these different sources of data in order to add weight to the findings reported.

Although the DEHEMS project addresses a fairly large number of households, it is still a relatively small sample in terms of statistical significance. Consequently, there is an emphasis on theoretical abstraction when drawing findings from the data. Care needs to be taken in any attempt to generalize the results, although the findings do provide a contribution to the general body of evidence produced across the range of home energy management research carried out across the world.

1.1.1 Survey Data Collection Methodology

As reported in D7.6, an online survey tool (www.smart-survey.co.uk) was used for the participant survey in Cycle 2. Full details of the rationale for using this tool are included in D7.6 Appendix II. It was decided to use the same methodology again for Cycle 3, but to benefit from the lessons learned during the previous cycle. In particular, we wanted to improve the response rate (which was 64% for Cycle 2). The key change introduced for Cycle 3 was to provide additional support (through telephone calls and personal visits from Living Lab team members) for people who were uncomfortable with the online survey tool. This decision can be judged to have been successful as the response rate achieved for Cycle 3 was 86.5%.

Cycle 3 participants were invited to complete the questionnaire from 13 April 2011. All Cycle 3 equipment installations were in place by the beginning of February 2011, so by the time users responded to the questionnaire, they had over two months experience of using the DEHEMS System. It closed on 9 May 2011 thus allowing a period of almost 4 weeks for the questionnaires to be completed.

Emails to participants inviting them to complete the questionnaire provided background information about the DEHEMS project. This was supported by newsletters circulated immediately by all Living Labs beforehand.

As in Cycle 2, two slightly different methodologies were adopted for (a) UK Living Labs, and (b) Bulgaria Living Labs. This was because although the survey itself was translated into the Bulgarian language, the survey tool did not offer this functionality for email communication with participants (invitations to complete the survey, reminders, etc). The two methodologies can be summarised as follows:

Table 2 Survey Methodologies in UK and Bulgarian Living Labs

UK Living Labs Survey Methodology	
1.	Smart Survey tool license renewed
2.	New questionnaire drafted using Cycle 2 questionnaire as template
3.	Draft questionnaire piloted with all members of the User Group
4.	Changes made and final pilot carried out
5.	Survey is distributed using the mailing list function on Smart Survey by uploading a CSV file
6.	Regular monitoring of numbers of questionnaires completed
7.	Reminders emailed to participants who had not completed via the Smart Survey tool and, in some cases, individual follow-up (including telephone calls & visits) by Living Lab teams to encourage questionnaire completion
8.	Questionnaire closed on 09/05/2011
Bulgaria Living Labs Survey Methodology	
1.	Smart Survey tool license renewed
2.	New questionnaire drafted using Cycle 2 questionnaire as template
3.	Draft questionnaire piloted with all members of the User Group
4.	Changes made and final pilot carried out
5.	Questionnaire translated into Bulgarian by Plovdiv Living Lab team
6.	Individualised links created to enable the completion of the questionnaire by Living Lab team member of behalf of respondent

7.	All participants invited to complete the questionnaire with a member of the Living Lab team through a telephone call / personal visit
8.	Questionnaire closed on 09/05/2011

The questionnaire response rates per Living Lab are shown below. Reasons for different response rates between UK and Bulgaria are discussed in Section 2.1.1.

Table 3 Response rates by Living Lab

Living Lab	Questionnaires distributed	Questionnaires completed	Response rate
Manchester	45	34	76%
Birmingham	34	24	71%
Bristol	44	36	82%
Plovdiv	46	44	96%
Ivanovo	45	45	100%
Total	**214**	**183**	**86%**

The control group did not receive the questionnaire as this is a scientific research which uses the control group to baseline the information from this group against those who have full use of the system and were restricted from using the DEHEMS dashboard to ensure the validity of the research.

A full copy of the questionnaire is included as Appendix III. The questionnaire used in Cycle 2 was used as a template but it was re-structured to investigate the research questions set out in Section 1.1 above. The questions were a mix of qualitative and quantitative. They are grouped into the following sections:

- Background information
- Participants & Roles
- The DEHEMS System
- Social aspects of DEHEMS
- Benefits of using the DEHEMS System

The questionnaire was piloted with members of the User Group as representatives of DEHEMS users. The results from the pilot led to changes in the order of the questions and changes to language and style. The questionnaire also followed principles of research ethics by enabling individuals to opt out at any stage and also to use the option: "Save and continue later". In addition, Living Labs did not harass people, beyond an initial reminder, nor force a participant to complete a questionnaire and hence gave the participant the right to withdraw from the research process.

A considerable benefit of the survey tool is that "mail lists" of potential participants can include both email address for distribution purposes and unique DEHEMS identification for analysis purposes. Thus each completed questionnaire can be linked to a set of data on energy consumption collected via the DEHEMS system. This enables the data to be triangulated with the statistics coming from participants' usage of appliances and individual energy consumption and also with statement made by the people who attended focus groups.

Respondents' anonymity was maintained because names, addresses and email addresses were not requested in the questionnaire. The questionnaire included a data protection statement to ensure the research was covered by Data Protection legislation and the European Union's (EU) statement on ICT Research Ethics which also covers the European Unions convention on Human Rights. In addition, assurance was given by using Secure Socket Layer Technology which ensures any data sent over the internet is encrypted and hence secure transmission of data.

1.1.2 Focus Group Data Collection Methodology

Participants were invited to Focus Groups through emails, newsletters, personal visits and telephone calls. Focus Groups were held in each of the 5 localities as shown below. A total of 41 participants took part. Table 4 gives a breakdown of participants by locality:

Table 4 Focus group dates and numbers of participants

Living Lab	Date	Number of participants
Bristol	11 May 2011	7
Manchester	16 May 2011	4
Birmingham	9 May 2011	5
Plovdiv	12 May 2011	10
Ivanovo	28 May 2011	15
Total		**41**

We used Internet enabled PCs, laptops and Power Point presentations to show the features of the DEHEMS system to the participants. Each session was recorded and transcribed to produce a written record. Refreshments were provided to ensure a relaxed atmosphere. Most sessions were for about 2 hours.

The five Living Labs ensured that participants included people with a high level of interest/motivation in environmental issues as well as those with less. Some of the participants were already known to the Living Labs through participation in focus groups in previous DEHEMS cycles, home visits for DEHEMS installations or through communication on other projects. Participants in focus groups are representative of a cross-section of the experimental groups including: electricity only monitoring, those with remote display devices (sometimes referred to as Current Cost or Efergy monitor), appliance level monitoring (sometimes referred to as Plugwise) and gas monitoring. Table 5 gives a breakdown of participants in each focus group:

Table 5 Details of Focus Group Participants

Living Lab	Name	M / F	Age	Eco Interest	DEHEMS Monitoring Equipment				
					Ctrl	Elec	App	Remote Display	Gas

Living Lab	Name	M / F	Age	Eco Interest	DEHEMS Monitoring Equipment				
					Ctrl	Elec	App	Remote Display	Gas
Ivan	Marieta	F	20 – 35	High		√			
Ivan	Petyr	M	U 20	Medium			√		
Ivan	Romeo	M	35 – 50	Medium			√		
Ivan	Dimcho	M	50+	Medium		√			
Ivan	Vladimir	M	20 – 35	Low		√			
Ivan	Liliana	F	50+	Low		√			
Ivan	Marin	M	35 – 50	Low		√			
Ivan	Vedat	M	35 – 50	Medium					
Ivan	Silvia	F	35 – 50	Medium		√			
Ivan	Mitko	M	50+	Medium		√			
Ivan	Galina	F	20 – 35	High			√		
Ivan	Tihomir	M	20 – 35	Low					
Ivan	Sejhan	M	35 – 50	Medium		√			
Ivan	Tihomir	M	35 – 50	High		√			
Ivan	Ivelin	M	20 – 35	Medium			√		
Bristol	Erica	F	20 - 35	Medium		√			
Bristol	Emily	F	35 - 50	High				√	√
Bristol	Russell	M	35 - 50	High		√	√		√
Bristol	Mike	M	50+	High		√			
Bristol	David	M	20 - 35	Medium		√			
Bristol	Allan	M	50+	Low		√			
Bristol	Heather	F	20 – 35	High			√		√
Manc	Luke	M	35 - 50	High		√			
Manc	Heather	F	50+	Medium			√		

Living Lab	Name	M / F	Age	Eco Interest	DEHEMS Monitoring Equipment				
					Ctrl	**Elec**	**App**	**Remote Display**	**Gas**
Manc	Mike	M	20 - 35	High		√			
Manc	Tas	F	20 - 35	Medium		√			
Birm	John	M	50+	Medium			√		
Birm	Jean	F	50+	Medium		√			
Birm	Chris	M	50+	High		√			
Birm	Hilary	F	50+	Medium		√			
Birm	Simon	M	35-50	Medium			√		
Plov	Venelin	M	20 – 35	High			√		
Plov	Zdravko	M	20 – 35	High			√		
Plov	Vladimir	M	50+	High					
Plov	Liyana	F	50+	High	√				
Plov	Milena	F	20 - 35	High		√			
Plov	Klimentina	F	35 – 50	High		√			
Plov	Nina	F	50+	High		√			
Plov	Viktoriq	F	35 – 50	Medium					
Plov	Dimka	F	35 – 50	Medium		√			
Plov	Iovka	F	35 – 50	Medium		√			
Total	41					26	11	1	3

1.1.3 Energy Data Collection Methodology

Energy data has been collected from the DEHEMS system, cleaned up to remove erroneous data points, and reduced for the purposes of analysis.

Electricity

Overall electricity consumption of each household is collected by the DEHEMS system at six second intervals in order to provide feedback in close to real time for the users. It is neither necessary nor useful to use such a fine resolution for the purpose of analysis, and for that reason, the data has been reduced to daily and weekly consumption figures for the analysis work.

An important issue that needs to be taken into account in the methodology for data reduction is the quality and completeness of the data. Due to a range of technical issues (which are discussed elsewhere), there are gaps in the data. These include periods when data is not available for a household, as well as missing data points that result in fewer than expected data points being available even though there is no identifiable gap in the data stream.

The complete set of SQL queries that were used to process the data for analysis is included in Appendix V.

The approach that has been used to derive daily consumption figures for a household is to take an average of the data points (in kWh) that are available for that household on that day, and multiply that by the number of hours in the day (24). This means that, where data points are missing, they are effectively replaced by the average value for that household on that day, which will usually be a reasonable approximation.

In addition to the daily consumptions for a household, the number of data that were used to derive the daily consumption figure is calculated, allowing the resulting data subsequently to be filtered to remove household daily consumptions that are based on too few data points. An analysis was performed of the data against different values of this cut-off point to determine its effect on the number of homes included in each day's overall average, and its effect on the daily averages obtained. On the basis of this analysis, household daily consumptions based on fewer than 1000 data points were excluded from subsequent analyses. This value results in all household daily consumption values being discarded for 19th March and 30th April, 59% of those for 25th March, and an average of 4% discarded across all other days in the Cycle 3 period.

Weekly energy consumption figures for households were derived from the raw data in a similar way to the daily consumption figures. In this case, a cut-off of 10000 data points was used to filter out unreliable weekly figures. This value results in an average of 8% of weekly individual household energy consumption values being discarded.

Gas

Gas figures have presented a much greater challenge. Analysis has shown that the gas data is very unreliable. This is due to a number of technical challenges that resulted in patchy coverage of households, and unreliable data from the commercial optical character reading devices that were used to take readings. In particular, many readings would be misinterpreted due to the display being part way through changing to the next value, and certain digits would often be confused even when they were displayed properly (for example, 0 and 6).

In order to clean up the gas data, analysis was carried out on individual raw data points in relation to adjacent ones in the time series in order to identify the majority of erroneous data points and either correct or discard them. The criteria that were used to identify these were based on the fact that readings should only ever increase (the readings are cumulative), and large differences between consecutive readings are likely to be incorrect. This automated filtering and correction left approximately 1200 remaining data point ranges that were suspect, and these were handled by manually inspecting each of the suspect ranges in the data stream and either discarding data points in the range or correcting them using ad-hoc SQL queries.

From the cleaned up gas data, daily figures were produced by taking the difference between the minimum values on consecutive days. Where there was a gap of more than one day between readings, the gas consumed was allocated equally across the days involved. The number of readings used to derive each day's consumption was also calculated; for periods that covered more than one day, the average number of readings per day across that period was assigned to each day. In the cleaned up gas data table, each record contains the dates, and the minimum and maximum readings for the two days and the beginning and end of a period (usually one day) in the time series and the number of days involved (usually 1), along with a consumption figure for the period and a daily average consumption figure for the period (normally the same). For analysis, an additional query was defined that derived a consumption figure for each household, for each day in the period over which the household was monitored for gas usage.

Weekly data for each household was then derived by calculating the average of the available daily consumption figures for each household in each week and multiplying that by 7. If data is not available for all days for a particular household, the effect of this approach is to replace empty days with an estimated value based on the average across the other days in that week. No attempt was made to filter out weeks with a small number of daily consumption figures in this case.

Additional challenges in relation to the analysis of gas measurements is that there is some uncertainty regarding the units that are being recorded for some of the households (cubic feet or cubic metres), and the relatively small sample of households having gas monitoring installed.

Given the quality of the data, it is considered that only quite general conclusions can be drawn from the quantitative gas data, and the majority of the research outcomes in relation to gas monitoring are derived from qualitative data gathered during the surveys and focus groups.

1.1.4 Quantitative and Qualitative Data Analysis Methods

Quantitative analysis is often associated with empirical, positivist research. It is designed to ensure objectivity, thus supporting the formation of some generalizations and to provide some reliability in the research output. However, it is important to recognize that the existence of quantitative data does not necessarily imply objectivity in the positivist, scientific sense. In the DEHEMS project, quantitative analysis is performed on two materials; open and closed questionnaire responses on the one hand, and the DEHEMS system sensor data on the other. Questionnaire results, including the numerical ones obtained from closed questions, represent the user's reported perceptions of reality rather than the reality itself. Whilst this is useful in its own right, it is important to carry out some degree of triangulation against other sources of information to improve the reliability of such results.

Sensor data is the most objective available from the DEHEMS project; however, it is important to recognize that even this data is necessarily subject to some limitations, given the incompleteness of the data due to practical, real-world issues, and the possibility for the data quality to be influenced by user behaviour. Examples of such influences include: the possibility that some users may switch off the DEHEMS system at times of particularly low energy usage (e.g. night time and during holiday absences), resulting in low consumption data being absent from the database. Another example is the possibility that users may deliberately disconnect the sensor in order to reduce their apparent energy usage, particularly if they are placed in a competitive context.

Qualitative research is designed to provide the researcher with the perspective of target audience members through direct interaction with the people under study. These methods help researchers to understand the meanings domestic energy consumers assign to ecological and environmental issues and to elucidate the mental processes underlying ecological behaviours. Hypotheses are generated during data collection and analysis, and measurement tends to be subjective. In the qualitative paradigm, the researcher becomes the instrument of data collection

(thus results may vary depending upon who conducts the research). Qualitative methods generate rich, detailed data that keeps participants' perspective intact and provide a context for ecological behaviour. In the DEHEMS project, qualitative analysis is performed on open questions in the questionnaires, and focus group transcripts.

The following summarizes the input materials for the analysis and the tools used:

Qualitative analysis using NVivo -Qualitative analysis is performed on focus group transcripts and the open text responses in the questionnaires. Each new interpreted theme that participants introduce into the focus group discussion or questionnaire is called a "Node" in NVivo, Each time a subject brings up a theme, we "code" the reference to the theme (dialogs, statements), and the number of times the same theme is brought up is called "the number of coding references". We categorize the themes into:

(1) motivations to save energy

(2) usability of the system infrastructure

(3) usability of the DEHEMS dashboard

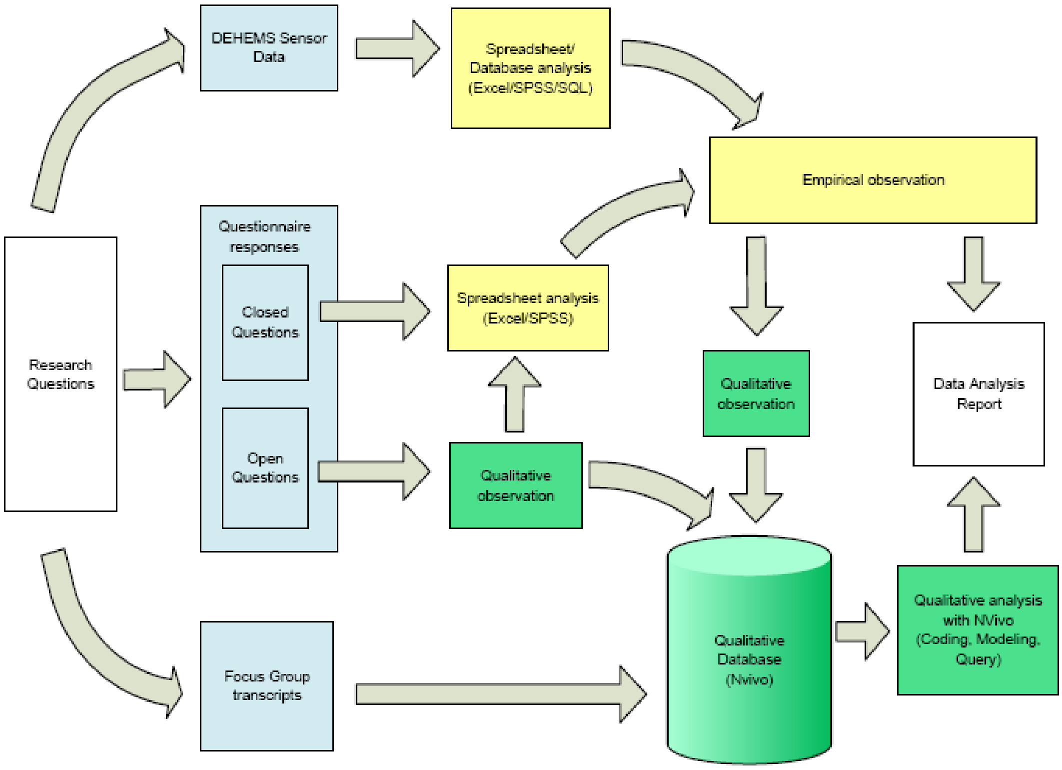
(4) Social aspects of DEHEMS

(5) Behaviour change resulting from DEHEMS

Quantitative analysis using SQL, SPSS, Excel and NVivo - Quantitative analysis is performed on energy data, questionnaire responses including the open-text questions. Statistical analysis on the energy data is performed using SQL queries and MS Excel, which are explained in more detail in Section 0. More straight forward statistical analysis on closed questionnaire responses are done mainly using the Smart Survey in-built tool and SPSS/Excel. Using the Smart Survey tool, we can also perform cross analysis between two different questions, such as income group or Living Lab cities vs the response to a certain question. For open text questions, we use NVivo to obtain the quantitative results by charting graphs where the y-axis is the number of coding references (the frequency of a theme, brought up by the subjects). Using NVivo, we could provide 3-dimensional graphs for analysis, where the axis are the attributes of a node or several nodes (x-axis), vs the number of coding references (y-axis) vs the income group or the Living Lab city (z-axis).

Finally, it has been possible to triangulate results by identifying themes, anomalies and unexpected findings, and investigating these by further analysis of the datasets. In some cases, further investigation of the qualitative/quantitative findings from the survey and focus groups has enabled us to identify factors which may account for unusual energy usage data and vice versa.

Figure 2 DEHEMS Data Analysis Methodology



2. Quantitative and Qualitative Results and Discussion

2.1. Demographic Analysis

2.1.1 Locality

The 186 questionnaire respondents were split between the Living Labs as shown below. The number of participants excludes the control group for each Living Lab.

Table 6 Survey Response Rates by Living Lab

Living Lab	Questionnaires distributed	Questionnaires completed	Response rate
Manchester	45	34	76%
Birmingham	34	24	71%
Bristol	44	36	82%
Plovdiv	46	44	96%
Ivanovo	45	45	100%

Total	**214**	**183**	**86%**

The higher response rate achieved by the 2 Bulgarian Living Labs is likely to be as a result of the different methodologies applied for engaging households in completing the survey (see Section 1.1.1). However, this finding (as well as others discussed elsewhere in this report), suggests that there was a greater engagement in the programme showed by users in Bulgaria. A possible explanation of this is that payment for electricity in Bulgaria is monthly and is based on actual meter readings taken by supply companies. The meters themselves are often in cabinets (external to the apartment/house) which are locked and which householders cannot access. As a result, people are mistrustful of suppliers, and participation in DEHEMS has provided an opportunity for users to check their supplier's energy consumption charges. This contrasts with the position in the UK where most people are on complicated tariffs and pay for their energy by standard monthly instalments which do not fluctuate as a result of short-term variations in energy consumption.

2.1.2 Income

In order to allow for differences in the cost of living between the UK and Bulgaria, the income categories were translated into Bulgarian Lev (BGN) and also adjusted to reflect lower prices in Bulgaria. Hence the lowest category in the UK (less than £10,000 pa) became less than 1,000 BGN per month in Bulgaria, and so on. This is shown in Table 7:

Table 7 Household income broken down by Living Labs

Q2. What is the income category of your household? (UK: annual / Bulgaria: monthly)	Birm	Bris	Ivan	Manc	Plov	Total
Less than £10,000 / Less than 1,000 BGN	6	8	22	1	14	51
£10,000 to £20,000 / 1,000 to 2,000 BGN	2	12	7	4	1	26
£20,000 to £40,000 / 2,000 to 4,000 BGN	4	8		14	3	29
£40,000 to £80,000 / 4,000 to 8,000 BGN	7	5		10	1	23
More than £80,000 / 8,000 BGN			1	2		3
Prefer not to say	2	5	15	3	26	51
Total	21	38	45	34	45	183

We can make some general observations from these figures. The income profile for UK participants is broadly consistent with the population as a whole, with households in most localities from all income categories. However, there are no households in Bristol & Birmingham with household incomes greater than £80,000. Most Bulgarian households are either in the lowest income category or preferred not to answer.

2.1.3 Ethnicity

Over 85% of respondents gave their ethnicity as white. The remainder were mixed (5%), Indian (2%), Pakistani (1%), Bangladeshi (1%), other Asian (1%), Caribbean (1%), African (1%), Chinese (1%) and other (2%). The numbers of participants from ethnic minorities were too few to allow for any analysis by ethnicity.

2.2. Participants and Roles

2.2.1 Household occupants

Numbers of household occupants are shown in Table 8.

Table 8 Number of household occupants

How many of the following people (age and gender) are included in your household?					
	0-12 yrs	13-18 yrs	19-30 yrs	31-50 yrs	Over 50 yrs
Male	24	20	37	96	59
Female	37	16	26	100	66

Table 9 shows the average sample sizes for occupancy groups of households returning weekly electrical energy consumption data during Cycle 3:

Table 9 Total occupancies of households completing the DEHEMS questionnaire.

Occupants	Number of Households
1	16
2	54
3	56
4 or more	56

Table 10 shows the average occupancies of households grouped according to whether they included under 19 year olds and over 50 year olds.

Table 10 Occupancies of homes for different age groups

Over50s	Under19s	Average Occupancy
Yes	Yes	4.1
Yes	No	2.5
No	Yes	3.9
No	No	2.1

(Note, this table includes only households that provided data during the data collection period and also filled in the Cycle 3 questionnaire.)

This data is relevant to the analysis carried out later in Section 2.7.6.

2.2.2 Responsibility for managing DEHEMS within the household

Across all Living Labs there was a slightly greater number of males (57%) than females (43%) as the main person involved with installation and maintenance of the DEHEMS system. However, there were variations in this finding for individual Living Labs – most notably

Ivanovo where the main person involved with DEHEMS was male in 92% of households. Nobody under 19 took on this role within participating households.

Table 11 Breakdown of responsibility for managing DEHEMS within the household by age and gender

	Q5. Which person in your household was the MAIN person involved with the installation and maintenance of the DEHEMS system (as opposed to using the data)?	Q6. Which people accessed the DEHEMS data for your household more than twice?	Q7. Which person in your household is completing this questionnaire
Female 0-18yrs	0	7	1
Female 19-30yrs	9	21	9
Female 31-50yrs	42	62	45
Females over 50	27	32	30
Male 0-18yrs	0	7	1
Male 19-30yrs	14	20	17
Male 31-50yrs	60	49	52
Males over 50	31	30	28
Total	183	228	183

A correlation between questions 5 and 7 shows that for 155 of the total of 183 households the age and gender attributes were the same – i.e. in 155 households, it is probable that only one person was engaged with DEHEMS. If the numbers of responses to questions 5 and 6 are compared for Male 31-50yrs and Males over 50, less respondents accessed the data more than twice than were responsible for installation. This is consistent with the finding that a significant number of users did not view data after the start of Cycle 3 (see Section 2.3.2).

The total for question 6 (number of people accessing the DEHEMS data more than twice) is greater than the total number of households indicating that in some households, the data was viewed by more than one person. However, in contrast to the hypothesis that children are likely to get involved in DEHEMS, only 14 of the people accessing data more than twice are under 19yrs despite there being a total of 97 under 19's in all households.

2.2.3 Energy consumption motivations before and after DEHEMS

Table 12 shows responses to the question: What is your strongest motivating factor when considering energy consumption before and after using the DEHEMS system. The broad finding is that the DEHEMS experience brings about a significant increase in motivation towards environmental impact and a significant reduction in motivation towards cost

Table 12 Energy consumption motivations before and after DEHEMS

Q8. What was/is your strongest motivating factor when considering energy consumption BOTH before and after using the DEHEMS	Before DEHEMS	After DEHEMS	Change as a percentage of total number of

system?			respondents
Only environmental impact matters	4	4	0%
Mostly environmental impact matters	27	33	+ 3%
Equally cost & environmental impact matter	53	103	+ 27%
Mostly cost matters	71	38	- 18%
Only cost matters	28	5	- 13%
Total	183	183	

If responses are broken by Living Labs, as shown in Table 13, it can be seen that the greatest shift in motivation is in Ivanovo where 39 out of 45 respondents were "mostly" or "only" cost matters before DEHEMS and only 12 out of 45 afterwards.

Table 13 Energy consumption motivations before and after DEHEMS broken down by Living Lab

Q8.1. Before ever using DEHEMS	birm	bris	ivan	manc	plov	Total
Only environmental impact matters	1	2			1	4
Mostly environmental impact matters	2	4	2	12	7	27
Equally cost & environmental impact matter	7	14	4	12	16	53
Mostly cost matters	9	14	24	8	16	71
Only cost matters	5	2	15	2	4	28
Total	24	36	45	34	44	183

Q8.2. After using DEHEMS	birm	bris	ivan	manc	plov	Total
Only environmental impact matters		1	1		2	4
Mostly environmental impact matters	1	5	7	10	10	33
Equally cost & environmental impact matter	13	20	25	19	26	103
Mostly cost matters	7	10	12	5	4	38
Only cost matters	3				2	5
Total	24	36	45	34	44	183

Q8. Percentage change	birm	bris	ivan	manc	plov
Only environmental impact matters	-4%	-3%	2%	0%	2%

Mostly environmental impact matters	-4%	3%	11%	-6%	7%
Equally cost & environmental impact matter	25%	17%	47%	21%	23%
Mostly cost matters	-8%	-11%	-27%	-9%	-27%
Only cost matters	-8%	-6%	-33%	-6%	-5%
Total	24	36	45	34	44

If this change in motivation is cross tabulated against respondents' household income (see Table 14 below) it shows that (a) for low income groups initial motivation is more likely to be cost rather than environmental, but that (b) the greatest shift in motivation is amongst low income groups. This supports the hypothesis that cost saving is a primary motivator for low income households, but also shows that this can be changed by increased awareness of energy consumption.

Table 14 Energy consumption motivation scores before and after DEHEMS broken down by income group

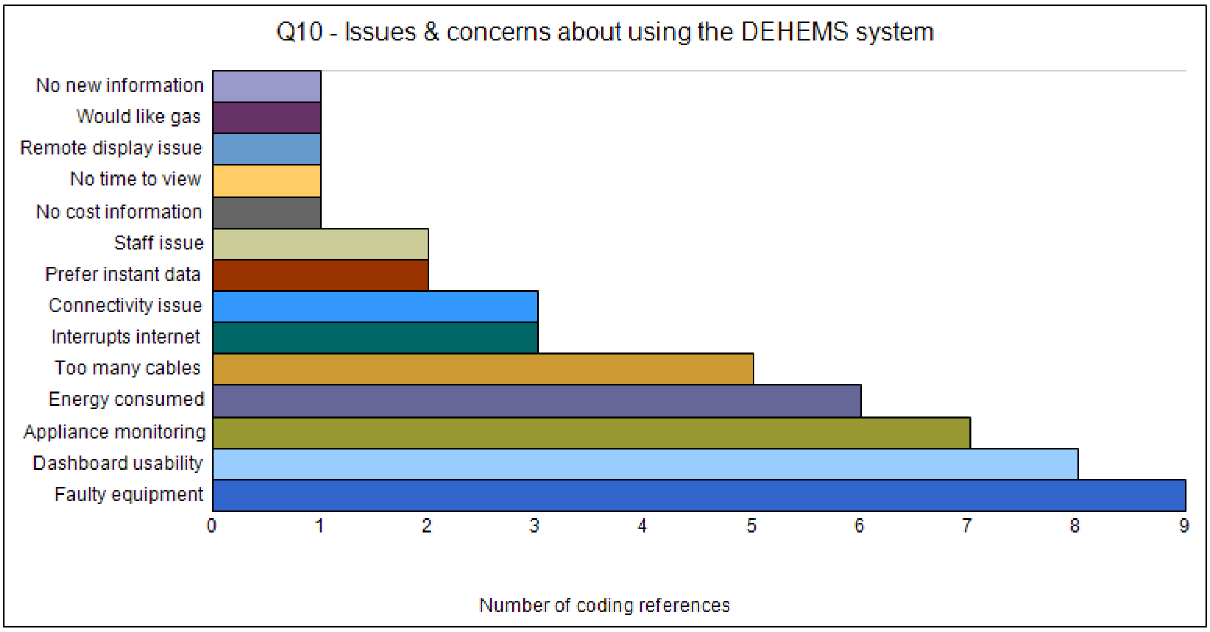
Q8. Percentage change	Below £10,000 / 10,000 BGN	£10-20k / 1000 – 2000 BGN	£20-40k / 2000 – 4000 BGN	£40-80k / 4000 - 8000 BGN	£80k + / 8000 BGN +	Prefer not to say
Only environmental impact matters	2%	4%	-6%	0%	0%	0%
Mostly environmental impact matters	8%	0%	0%	-4%	33%	4%
Equally cost & environmental impact matter	38%	28%	9%	24%	0%	30%
Mostly cost matters	-30%	-20%	3%	-12%	-33%	-20%
Only cost matters	-18%	-12%	-6%	-8%	0%	-14%
Total	51	26	29	23	3	51

2.3. DEHEMS Usability

2.3.1 DEHEMS System Infrastructure

Most users (80%) reported that they had no issues or concerns about using the DEHEMS equipment in their homes. This finding almost exactly replicated the response to the same question in the Cycle 2 questionnaire. However, 35 users added comments which are shown in the bar chart below. Issues are grouped into themes and the number of times the issue was raised is shown.

Figure 3 Issues & concerns about using DEHEMS equipment



Some of the above issues need further explanation:

- Prefer instant data: user would have liked to access data via a remote display unit rather than the dashboard
- Connectivity issue: user concerned about the periods when no DEHEMS data was transmitted due to faulty equipment (as evidenced by the data presented in Section 2.7.2)
- Interrupts internet: no evidence was found that linked the DEHEMS system to household broadband connectivity but 3 users perceived this to be the case
- Energy consumed: users concerned about the energy consumed by DEHEMS monitoring equipment
- Faulty equipment: usually related to battery failure in data collector

A further question asked users to respond to a number of statements describing what the DEHEMS system was like. This was in order to understand more about their experience of having the equipment in their own home.

Table 15 Respondents' views on the DEHEMS system

9. Now that you have used it, when thinking about the DEHEMS system overall, to what extent would you agree with each of the following statements?						
	Strongly agree	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Responses**
The DEHEMS system is experimental technology like a futuristic smart home	9% (15)	41% (75)	34% (63)	16% (29)	1% (1)	183
The DEHEMS system is familiar technology like a DVD or satellite TV box	8% (15)	51% (93)	23% (43)	15% (27)	3% (5)	183
The DEHEMS system is domestic technology like a washing machine or dishwasher	9% (16)	35% (64)	30% (54)	25% (45)	2% (4)	183
The DEHEMS system is household technology like a central heating system	10% (19)	39% (71)	29% (53)	20% (36)	2% (4)	183
The meters, plugs and cabling are simple and straightforward	19% (34)	52% (96)	17% (32)	10% (18)	2% (3)	183
The website (dashboard) is familiar and easy to use	19% (35)	56% (102)	17% (31)	7% (13)	1% (2)	183

An overall ranking of these statements can found by adding together the positive responses (strongly agree/agree) are subtracting the negative ones (strongly disagree/disagree).

Table 16 Ranking of respondents views on the DEHEMS system – with the most positive statement listed first

Statement	**Positive minus negative responses**
The website (dashboard) is familiar and easy to use	124
The meters, plugs and cabling are simple and straightforward	112
The DEHEMS system is familiar technology like a DVD or satellite TV box	76
The DEHEMS system is experimental technology like a futuristic smart home	61
The DEHEMS system is household technology like a central heating system	52
The DEHEMS system is domestic technology like a washing machine or dishwasher	31

We can investigate how age and gender impact on users' perceptions of the DEHEMS system by cross tabulating positive responses (strongly agree/agree) against the attributes of the person completing the questionnaire. This is shown in the Table 17 and Table 18:

Table 17 Positive responses to statements about the DEHEMS system broken down by gender

Statement	**% positive response (strongly agree / agree): Male**	**% positive response (strongly agree / agree): Female**
The website (dashboard) is familiar and easy to use	80%	68%
The meters, plugs and cabling are simple and straightforward	78%	64%
The DEHEMS system is familiar technology like a DVD or satellite TV box	56%	62%
The DEHEMS system is household technology like a central heating system	47%	52%
The DEHEMS system is experimental technology like a futuristic smart home	48%	51%
The DEHEMS system is domestic technology like a washing machine or dishwasher	46%	40%
Total responses for each gender	100	86

Table 18 Positive responses to statements about the DEHEMS system broken down by age group

Statement	**% positive responses by age group**			
	1 - 18	**19 - 30**	**31 - 50**	**50+**
The website (dashboard) is familiar and easy to use	100%	87%	73%	74%
The meters, plugs and cabling are simple and straightforward	50%	71%	73%	72%
The DEHEMS system is familiar technology like a DVD or satellite TV box	100%	62%	58%	59%
The DEHEMS system is household technology like a central heating system	100%	54%	48%	50%
The DEHEMS system is experimental technology like a futuristic smart home	50%	71%	41%	57%
The DEHEMS system is domestic technology like a washing machine or dishwasher	50%	67%	42%	38%
Total responses for each age group	2	24	100	58

Cross tabulating responses to statements describing what the DEHEMS system was like against DEHEMS role (responsible for installing/maintaining equipment, accessing DEHEMS data, completing the DEHEMS questionnaire) found little or no differences. This would suggest that in most cases, the same person within the household was undertaking all of these roles.

2.3.2 DEHEMS Dashboard

Analysis of the DEHEMS system data which recorded when users logged on to the dashboard to view their energy consumption data showed that a significant number of users chose not to do so (see below). However, feedback from Cycle 3 focus group participants provides evidence that users who have been part of the project since Cycle 2 no longer need to view their data on the dashboard because they have already done so on many previous occasions and already understood their patterns of energy consumption.

Table 19 Dashboard accesses after the start of Cycle 3 (excludes controls and households which did not send any data)

Living Lab	Accessed the dashboard to view household energy consumption data	Did not view data after start of Cycle 3
Plovdiv	28	14
Ivanovo	40	1
Manchester	20	26
Bristol	27	18
Birmingham	19	14
	134	73

As a result of user feedback received in Cycle 2, some additional features were incorporated in the DEHEMS dashboard for Cycle 3. Users views on these features were specifically sought through the questionnaire and their responses are shown below.

Table 20 DEHEMS dashboard feedback

11. What is your experience of the following functions of the DEHEMS dashboard						
	Strongly agree	**Agree**	**Neither agree or disagree**	**Disagree**	**Strongly Disagree**	**Total**
We found it useful to compare our energy usage against the Living Lab average (DEHEMS average)	26	107	33	14	3	183
We found it useful to see what types of homes had similar consumption to our own (Compare My Home)	23	103	44	9	4	183
We found it useful to compare our energy use against our past energy use (My Energy History)	60	101	15	4	3	183
We found the energy saving tips provided by the system relevant and useful (Various Screens)	30	85	45	15	8	183
We found it useful to be able to explore energy usage issues about our own home (My Experience)	38	88	43	10	4	183
We found it useful to receive warnings about the system operation (e.g. sensor off, broadband off etc.)	37	88	38	17	3	183

If the positive responses are added together, then the above dashboard features can be ranked as follows – with the most positive listed first:

Table 21 Ranking of respondents views on DEHEMS dashboard features

Dashboard feature	**Positive Responses**
My Energy History - comparing our energy use against our past energy use	88%
DEHEMS average - comparing our energy usage against Living Lab average	73%
Compare My Home - seeing what types of homes had similar consumption to our own	69%
My Experience - exploring energy usage issues about our own home	68%
Warnings - sensor off, broadband off etc.	68%
Energy Saving Tips	63%

We can make some observations from the above findings. Respondents were more interested in how their own energy consumption had changed over time than they were in comparing their energy consumption with other homes. Energy saving tips were judged less useful than other features, although this finding might not be replicated by another sample containing fewer environmentally aware people.

2.4. *Social Aspects of DEHEMS*

2.4.1 Sharing home energy monitoring information with other people

45% of respondents reported that they had actively compared their energy monitoring results with other people and of these, 87% found this a useful exercise. Another 37% of respondents only mentioned their DEHEMS results to other people, while 18% of respondents did not discuss the issue at all.

Figure 4 Sharing home energy monitoring information with other people

12. Have you discussed your own home energy monitoring results with other people?		**Response Total**
We have actively compared our results with others and found it useful		70
We have actively compared our results with others but did not find it useful		11
We have only mentioned it to others		68
Not at all		34

However, if the results are broken down by location (see Table 22), it is clear that sharing information with other people is significantly more common in Bulgaria than the UK. A possible explanation of this (already discussed in 2.1.1) is that payment for electricity in Bulgaria is monthly and is based on actual meter readings taken by supply companies. The meters themselves are often in cabinets (external to the apartment/house) which are locked and which householders cannot access. As a result, people are mistrustful of suppliers and participation in DEHEMS has provided an opportunity for users to check their supplier's energy consumption charges and to compare their usage with other people. This contrasts with the position in the UK where most people are on complicated tariffs and pay for their energy by standard monthly instalments which do not fluctuate as a result of short-term variations in energy consumption.

Table 22 Breakdown of information sharing across Living Labs

12. Have you discussed your own home energy monitoring results with other people?				
	We have actively compared our results with others and found it useful	We have actively compared our results with others but did not find it useful	We have only mentioned it to others	Not at all
Manchester	5	0	21	8
Birmingham	6	0	4	11
Bristol	4	1	21	12
Plovdiv	26	6	13	0
Ivanovo	29	4	9	3
Total	70	11	68	34

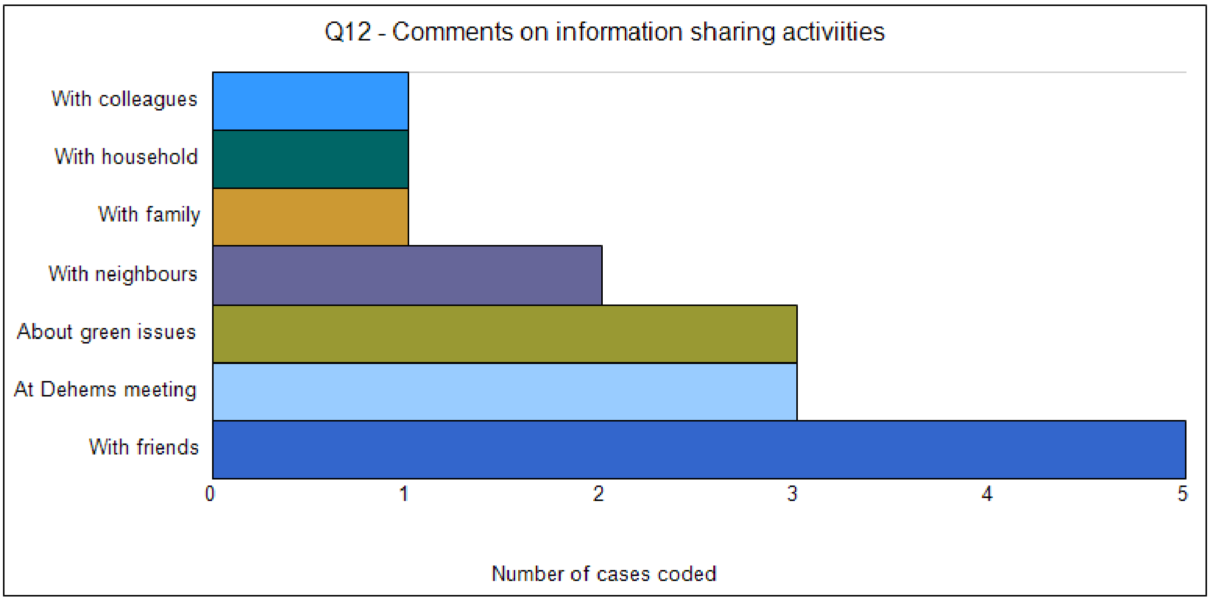
A breakdown of information sharing results by gender of respondents completing the survey does not show any significant differences.

Table 23 Breakdown of information sharing by gender

12. Have you discussed your own home energy monitoring results with other people?				
	We have actively compared our results with others and found it useful	We have actively compared our results with others but did not find it useful	We have only mentioned it to others	Not at all
Male	40	7	35	16
Female	30	4	33	18
Total	70	11	68	34

Respondents were asked to comment on their information sharing activity and an analysis of these comments is shown below – indicating the context in which information sharing took place. Interestingly, the comments about the DEHEMS meetings (which were usually focus groups) were very positive.

Figure 5 Comments on information sharing activities



2.4.2 DEHEMS on Facebook

An additional component of Cycle 3 was to investigate the use of online social networking in getting users engaged in DEHEMS. To this end, a Facebook page was created for participants to monitor their energy consumption. A total of 25 users registered on the DEHEMS Facebook page. Facebook asks users to indicate if they "like" Facebook pages and 13 reported that they did. The breakdown of Facebook users by Living Lab is shown below. A total of 15 out of 25 are from Manchester and Plovdiv. Living Lab staff in these locations are regular Facebook users and this may have impacted on the numbers of users accessing the page – indicating the importance of local champions in engaging people in energy saving.

Table 24 Facebook users (& questionnaire respondents) broken down by Living Lab

LL	DEHEMS Facebook page users
Birm	3
Bris	2
Ivan	5
Manc	6
Plov	9
Total	25

A breakdown of Facebook users by age and gender shows some difference between male and female users also shows a spread across age groups – including some over 50s. (The lack of 13-18 year old Facebook users simply reflects the lack of under 18s engaged in monitoring DEHEMS data – see Section 2.2.2). This is a significant finding because it might be assumed that Social Networking is a useful tool for engaging younger people only but the DEHEMS results demonstrates that this is not the case.

Table 25 Facebook users broken down by Age and Gender

DEHEMS Facebook users								
Female				Male				Total
Under 19	19-30yrs	31-50yrs	50+yrs	Under 19	19-30yrs	31-50yrs	50+yrs	
1	2	3	2	0	5	8	4	25

The questionnaire asked users of the DEHEMS Facebook page for feedback on their experience. Figure 6 shows their responses.

Figure 6 Feedback on the DEHEMS Facebook page

16. How useful did you find the summary at the top of the Facebook page?	**Response Total**
Very useful	6
Interesting	17
Of no interest	2
	25

17. Did you find the appliance summary in Facebook useful?	**Response Total**
A lot	11
A little	9
Not at all	3
Didn't have appliance meters	2
	25

18. To what extent do you feel the Facebook App increased your engagement with DEHEMS?	**Response Total**
A lot	9
A little	12
Not at all	4
	25

Facebook users were more engaged with DEHEMS than non-Facebook users (77% viewed their energy data on Facebook during Cycle 3 compared with 65% of all DEHEMS users).

In terms of sharing home energy monitoring information with other people, 18 out of 25 (72%) Facebook page users reported that they had shared energy data with other Facebook friends. We can contrast this finding with the 45% of respondents (out of the total 183) who reported that they had "actively compared our results with others" – eg. through conversation, etc (see 2.4.1 above). This suggests that Facebook users were more likely to engage with other people in discussions about energy consumption than other DEHEMS participants. It is not possible to conclude that this increased likelihood of sharing energy saving data was entirely due to Facebook itself, but the Facebook page certainly facilitated information sharing. This is supported by the following additional comments made by 2 out of the 7 people who made comments about the DEHEMS Facebook page:

- "This was extremely useful and quite motivating"
- "I use Facebook a lot, so didn't have to go to a separate web site to see DEHEMS data. Also, seeing the consumptions of people I know made the experience more real"

2.4.3 DEHEMS Energy Team Challenge (ETC)

Another new component of Cycle 3 was the creation of teams of 5 DEHEMS users within Living Labs and the monitoring/display of their energy consumption as a group. Incentives were awarded each month during Cycle 3 for the team which achieved the greatest energy reduction. However, it is clear that some users were not clear on whether or not they were involved in their Living Lab Team, as shown below. This may be because the terminology used in the questionnaire was slightly different from that used in the dashboard where the ETC results were displayed.

Table 26 Involvement in Energy Team Challenge

Living Lab	Challenge winners	ETC Team members	Were listed as team members but did not tick "yes" to Q.14	Ticked yes to Q.14 but were not listed as team members	Did not complete questionnaire
Birm	√	5	4		
Bris		5	2	2	
Manc		5	4		1
Plovdiv	√	10	2	4	
Ivanovo	√	5			
Total		30	12	6	1

Bearing in mind the issue identified in the table above, Figure 7 to Figure 9 show the responses to Energy Team Challenge given by the 23 respondents who recognized that their household were involved.

Figure 7 Frequency of viewing Energy Team Challenge pages

19. Roughly how often did your household look at the Energy Team Challenge pages?		**Response Total**
Daily		2
Weekly		9
Monthly		8
Never		3

Figure 8 Impact of Energy Team Challenge on energy saving

20. How much do you feel the Energy Team Challenge encouraged you to save energy?		**Response Total**
not at all		4
some		14
significantly		4

Figure 9 Impact of winning an incentive on energy saving

21. Would the chance of winning a prize have provided an incentive for your household to reduce its energy usage?		**Response Total**
Yes		11
No		10

The responses to Q.21 are interesting because the statement is phrased such that it applies whether or not respondents believed they were part of the challenge and whether or not they received an incentive. In other words, it is valid irrespective of the uncertainty shown by some users as to whether they were involved in their Living Lab team. In fact, there is little difference between the number of yes and no responses showing that a significant motivator was participating in and winning the challenge rather than receiving a reward.

Table 27 Link between responses on incentives and Living Lab

Q21. Would the chance of winning a prize have provided an incentive for your household to reduce its energy usage			Living Lab Locations which won incentives
Living Lab	No	Yes	
Birmingham	1		√
Bristol	2	1	
Ivanovo	1	3	√
Manchester	1		
Plovdiv	5	7	√
Total	10	11	

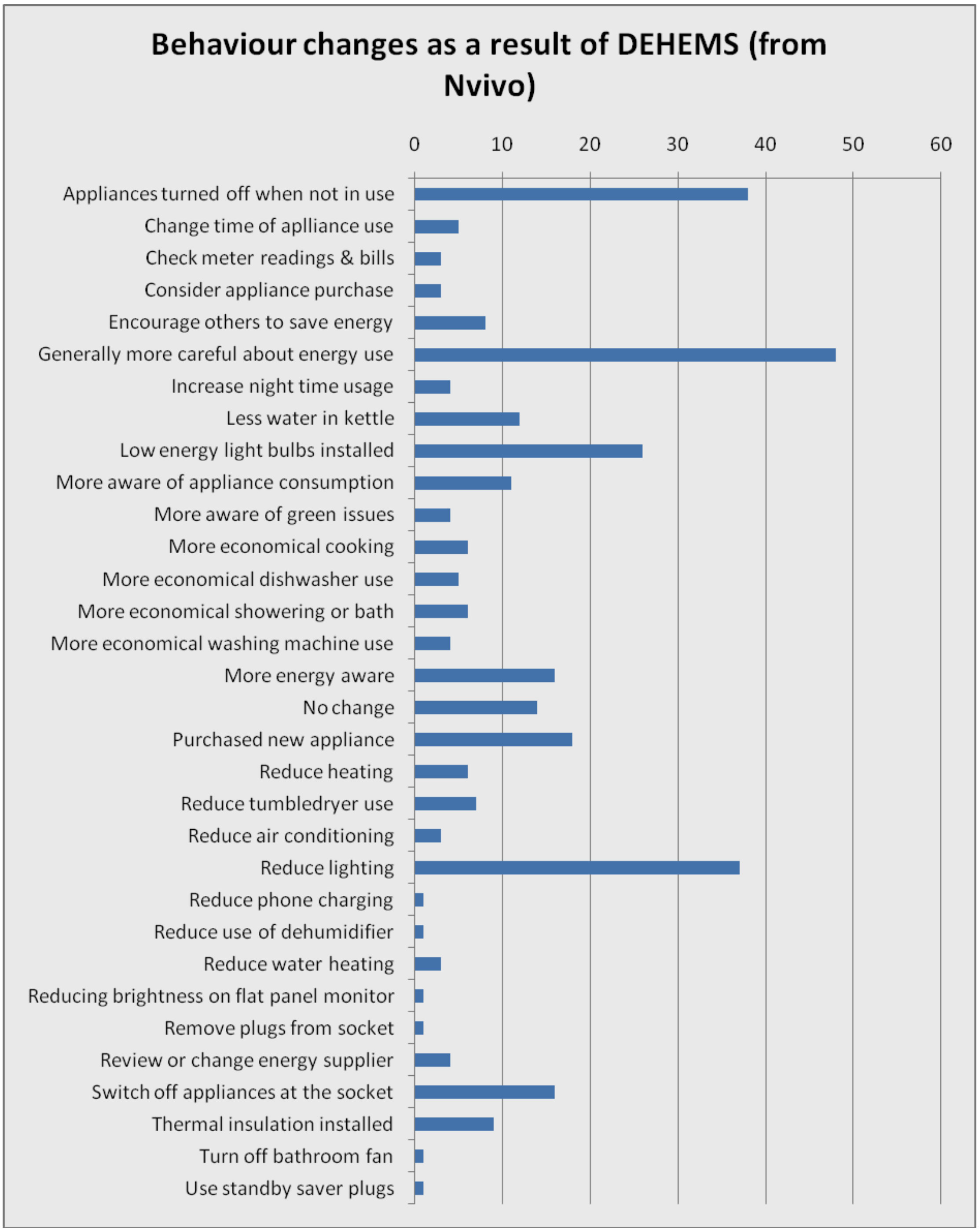
A comment made in response to Q.23 (which asks users why they have changed their energy consumption behaviour) is relevant to Energy Team Challenge: "Very interesting to see how much I differed from other users or lab average, I was always well below average, proud of myself, was good to see".

2.5. DEHEMS Impact on Energy Behaviours

2.5.1 Impact of DEHEMS generally

Questionnaire respondents were asked to list up to four changes that they had made to their use of energy as a result of being involved in DEHEMS.

Figure 10 Behaviour changes as a result of DEHEMS (in alphabetical order)



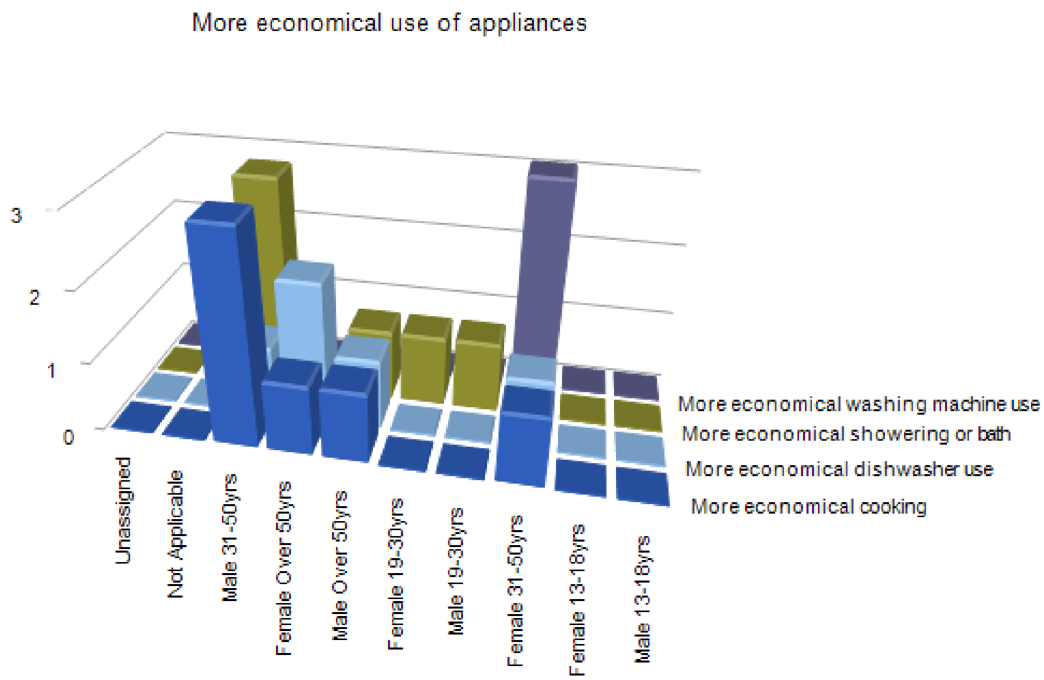
92% of respondents reported behaviour changes as a result of DEHEMS (14 people stated “no change”). The 169 users that did report a change provided details of a total of 366 new or changed behaviours. The survey provided respondents with an opportunity to enter up to 4 examples and almost 50% gave at least 2. This qualitative response provides a more powerful statement about the impact of DEHEMS than the energy consumption figures. It is, of course, difficult to judge whether these behaviour changes are permanent but some of the changes listed in Figure 10 will have a significant long term effect on household energy consumption.

Using NVivo, we can cross tabulate these behaviour change responses against user attributes. This analysis shows some interesting variations – a sample of which are shown below:

- Breakdown by Living Lab location shows that increased night time usage was only reported by users in Bulgaria (where there are different day and night tariffs (0.15 BGN/kWh by day and 0.10 BGN/kWh by night)
- Less than 1 in 4 of the users that installed low energy light bulbs were from the UK (where high energy light bulbs are no longer available)
- Breakdown of the users who reported purchasing new appliances by income group shows an equal spread across all categories

Analysis of users reporting more economical use of appliances by age and gender, shows that males are more likely to economise than females, with the exception of washing machines (which may be because males do not tend to use washing machines as frequently as females).

Figure 11 Breakdown of users reporting more economical use of appliances by age and gender



Respondents were also asked what they felt were the main reasons for the energy saving behaviours shown above. The responses show that there was little difference between "Just generally being involved in the project" and "Having access to our energy data". In other words, for many participants, being involved in the DEHEMS project and having energy monitoring equipment in operation in their home was about as effective in terms of promoting behaviour change as actually accessing the energy data itself. This is shown in Table 12.

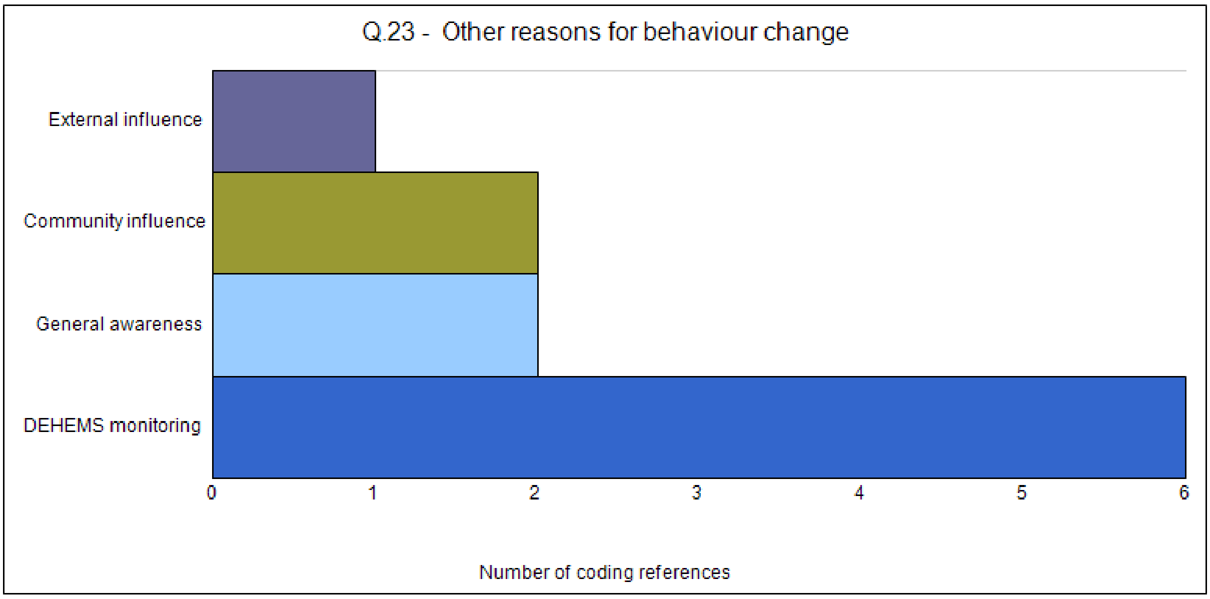
Figure 12 Reasons given for changing behaviour

23. What do you feel is the main reason for the changes you listed above?		**Response Total**
Just generally being involved in the project		33

Having access to our energy data		45
Both of these equally		91
Other (please specify in the comments box)		14

17 people made other comments and these have been summarised in Table 13:

Figure 13 Other reasons given by DEHEMS participants for changing behaviour



Although listed by respondents as "other" reasons, 6 of the responses in Figure 13 indicate that the behaviour change is as a result of DEHEMS energy monitoring. This would increase the number of respondents attributing their behaviour change to the DEHEMS system to a total of 51. Some of the words used in these responses are interesting as they give an indication about what it is about the system which is valued:

- "We have always been environmentally aware, but being able to see the usage makes us more conscious of what we are doing"
- "Being able to visualise the relative importance of these things is vital to my motivation for making a change"

2.5.2 Appliance Monitoring

69 of the questionnaire respondents stated that they had DEHEMS equipment installed which monitored the energy usage of specific appliances in their homes. Interestingly, this figure is slightly in excess of the 66 participants with Plugwise appliance-level monitoring equipment supplied by the project – suggesting that some users were using the more basic total electricity consumption monitoring equipment to investigate consumption by individual appliances. (This can be done relatively easily by switching off all other electrical appliances and using the DEHEMS dashboard or remote display device to measure the consumption of the single appliance still switched on – although these methods will give different results as the remote display only shows instantaneous usage whilst the DEHEMS system shows the much more reliable total energy consumption over a period).

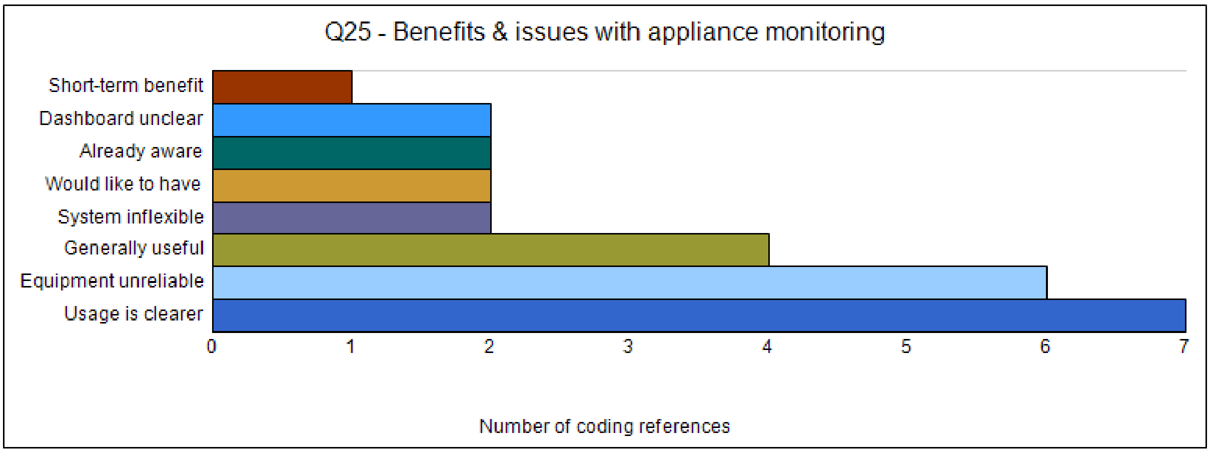
All respondents were asked if they understood the energy consumed by the different appliances in their home better as a result of the DEHEMS system and 78% indicated that this was indeed the case. This is shown in the Table 14. (It should be noted that the "DEHEMS system" includes not just the monitoring equipment but the dashboard display, including energy saving tips). These findings show that increased understanding of the electricity consumption of individual appliances can be achieved with relatively unsophisticated monitoring equipment – including devices that are not appliance specific.

Figure 14 Users' understanding of energy consumption by different appliances

25. Do you understand the energy consumed by the different appliances in your home better from using the DEHEMS system? (Please answer this question even if you do not have individual appliance monitoring installed.)		**Response Total**
Yes, we know when certain appliances are switched on, and understand now which appliances consume higher energy		143
No, we are not clear on the effects of the different appliances on my home energy consumption		40

Analysis of the additional comments made by 27 respondents, provides further insight into this aspect of the DEHEMS system. Figure 15 summarises these comments.

Figure 15 Further comments on appliance monitoring



For the most part, the comments reflect the quantitative findings – that users better understand energy consumed by different appliances. This is shown in the following comment: “I know my kettle and washing machine consume more than a PC and/or a laptop”.

The “system inflexible” comments refer to users who wanted to be able to move the appliance monitors from one appliance to another but were unable to do so as a result of the way that the DEHEMS system was set up.

The “short-term benefit” comment can be more easily understood once it is seen in full: “This was a short-lived benefit. Once the understanding of the relevant impact of appliance use had been gained, I rarely returned to the dashboard”. This is interesting because it suggests that for some users, increased understanding could be achieved through short-term interventions – e.g. through a home visit by a technician with mobile monitoring equipment.

2.5.3 Gas Monitoring

Gas monitoring was introduced for the first time in Cycle 3. It was only used in UK Living Labs because none of the participating homes in Bulgaria used natural (not bottled) gas. It was seen as an important development in the UK because for most homes, spending on gas is greater than on electricity and is usually the fuel source for heating, hot water and cooking. The gas monitoring equipment was not already available on the market as a usable system and had to be designed, commissioned, developed and tested. As a result, there were some technical issues, particularly the optical character recognition meter reading devices, which may have impacted on the feedback from DEHEMS users who had gas monitoring equipment installed in their homes. This is evidenced by looking at some of the comments from households with gas monitoring - 8 out of 22 comments refer to installation problems or difficulties with the equipment / dashboard display.

29 out of the 183 households that responded to the questionnaire had DEHEMS gas monitoring equipment. Of these 29 households, 11 stated that they found gas monitoring useful. Of the 18 that did not find it useful, 11 added comments indicating that they experienced equipment problems (7 users) or found it difficult to understand their gas consumption data from the dashboard display (4 users).

Figure 16 Usefulness of gas monitoring

26. If you are one of the households that have gas monitoring, did you find the gas monitoring useful in your DEHEMS installation?		**Response Total**
Yes		11
We had gas monitoring, but didn't find it useful		18
We didn't have gas monitoring		154

All respondents were asked how the DEHEMS experience had resulted in a change to their gas usage. Just over a third of the total number of respondents (36%) reported that they were more careful with gas consumption, which is far in excess of the number of users with gas monitoring installed (see Figure 17).

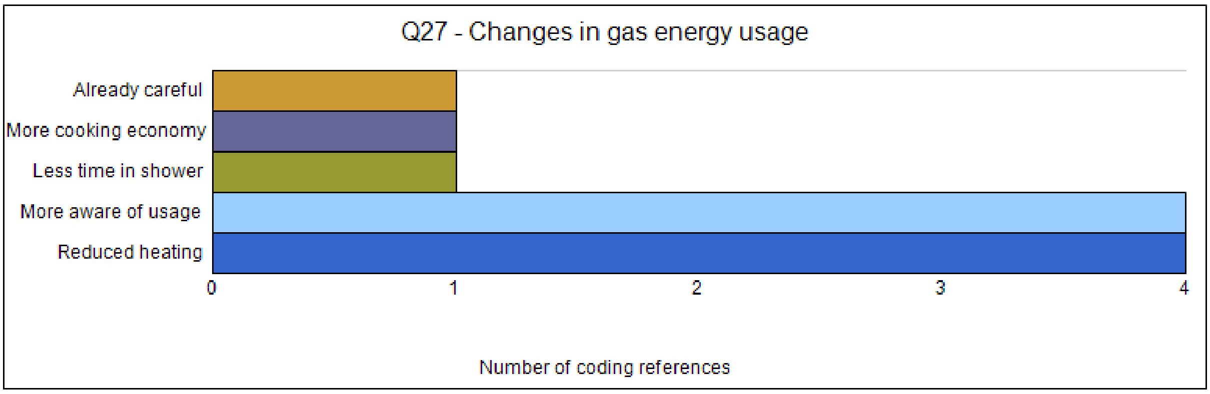
Figure 17 Gas energy usage change as a result of DEHEMS

27. In what ways has your gas energy usage changed as a result of DEHEMS? (Please answer this question even if you do not have gas monitoring installed.)		**Response Total**
We try to be more careful with gas consumption		67
We have not changed our gas consumption in any way		116

This supports findings reported elsewhere (see Section 2.5.1) in this document which suggest that there is a "DEHEMS effect" whereby there is a raised awareness of household energy consumption simply as a result of participating in the project, without necessarily using the DEHEMS system to access energy usage data.

Question 27 also asked respondents to comment on changes in their gas consumption. A summary of these responses is shown below.

Figure 18 Users comments on gas energy usage changes



Below are some examples of how users reduced gas consumption:

- "We try and use less heating and cover lids when boiling vegetable so they are made quicker. We also don't take as long in the shower"
- "Thinking energy consumption as a whole, so turning temperature down"

- "Turned down the radiators and thermostat and reduced hours of use for central heating. No change for cooking"

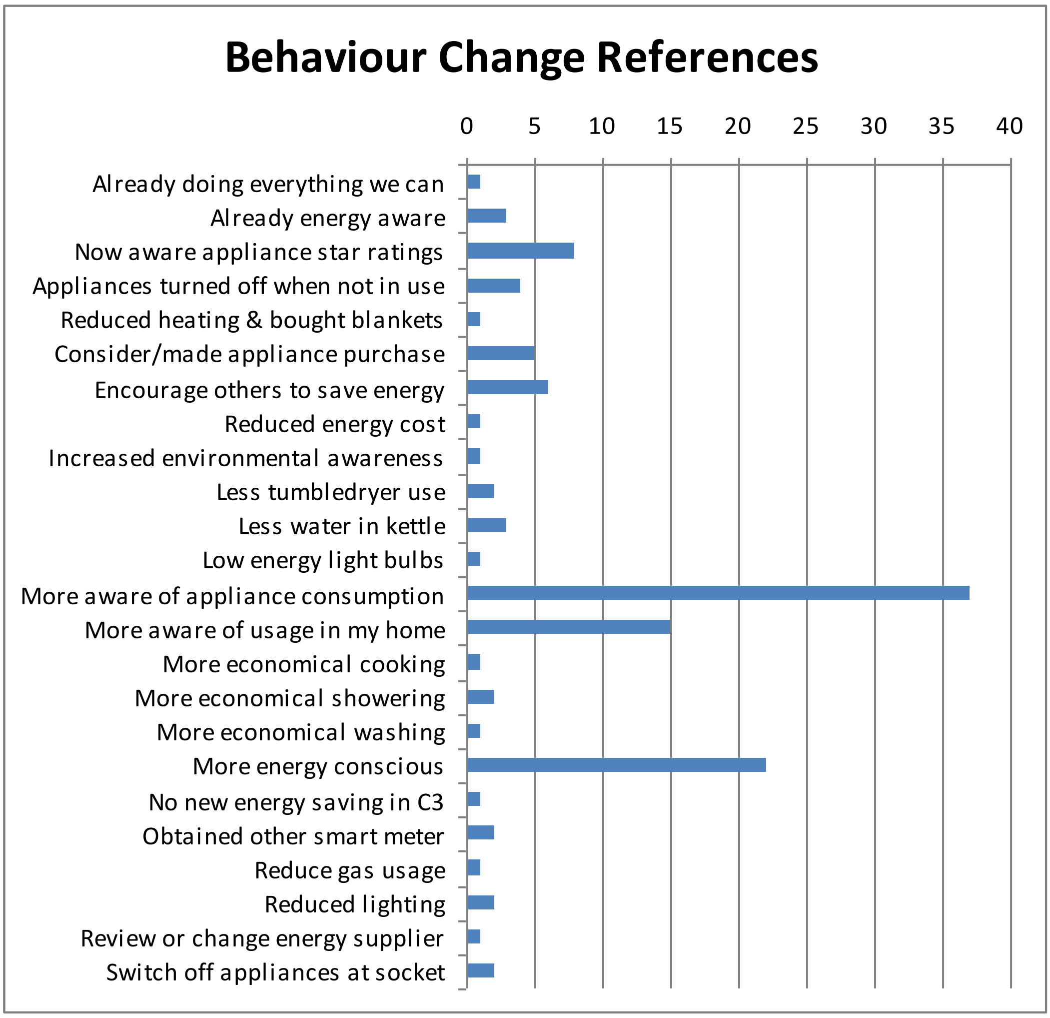
2.6. Focus Group Data analysis

The Cycle 3 Focus Groups had a common structure which reflected the research questions (see Appendix IV – DEHEMS Cycle 3 Focus Groups). This section is accordingly set out in sub-headings based on the Focus Group structure. Each section shows a graphical display of comments along with text highlighting the key issues raised. Whilst some comments appear to dominate, this is partly due to the greater number of participants at Plovdiv (10) and Ivanovo (15) and the method of documenting these 2 sessions - which summarised rather than transcribed in full. Therefore, comments which are only recorded a relatively few times are still important. Where possible, users' words are used. The analysis has been done using NVivo, which will enable more detailed analysis to be undertaken in the future linking comments with user attributes.

2.6.1 Behaviour change

The behaviour changes identified in focus groups shown in Figure 19, are broadly similar to those reported via the online survey (see Figure 10). However, focus group participants made greater reference to changes in energy awareness – including increased awareness to energy consumption by individual appliances and to the star rating of appliances.

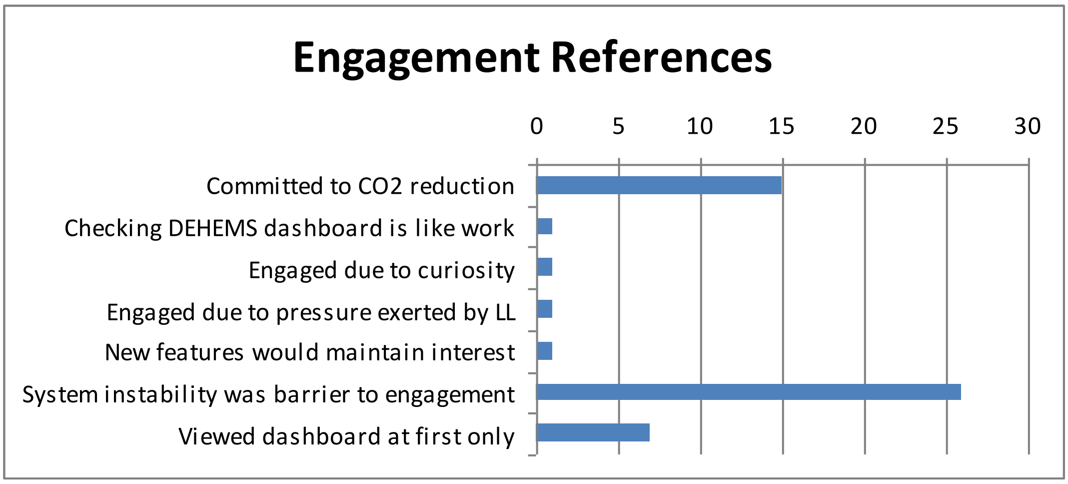
Figure 19 Focus Group analysis – behaviour change references (in alphabetical order)



2.6.2 Engagement

The most significant focus group finding was the extent to which system instability acted as a barrier to engagement with DEHEMS. The drop-off in users accessing the dashboard was due to increased understanding of household energy consumption resulting in a reduction in the need to see their monitoring data.

Figure 20 Focus Group analysis – engagement references (in alphabetical order)



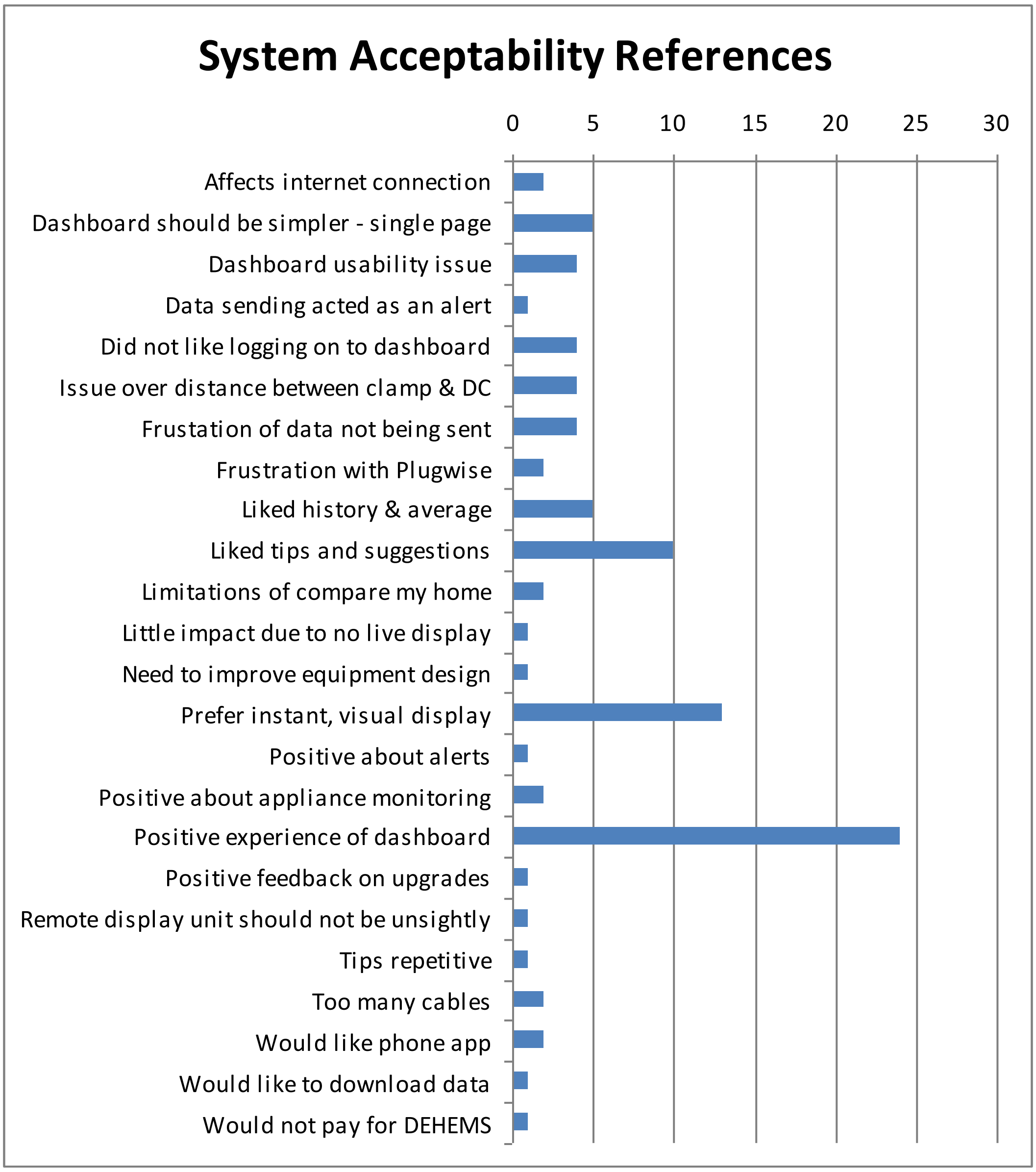
2.6.3 System Acceptability

In broad terms, focus group findings on system acceptability reflected feedback via the online survey (see Section 0). Focus group transcript analysis provides more detail on responses, including positive feedback on: the dashboard generally, energy history and compare my home functions, and energy saving tips and suggestions

One of the most interesting aspects to emerge from focus groups was the balance between viewing detailed energy consumption data via the dashboard and the instant, visual reading provided by remote display units (Current Cost and Efergy). Figure 21shows that there are a number of relevant factors for users:

- Is the display always on or does it require users to access a web site?
- Can the display unit itself be moved around the house?
- Is energy monitoring information available in a visual, easily digested format?
- Does the display enable users to differentiate between instant and long-term usage?
- Can users manipulate the data to suit their interest and motivation?
- Should simplified display options be available for users to select?
- How does the display format relate to continued interest and engagement?
- Should access via alternative technologies be available as standard?

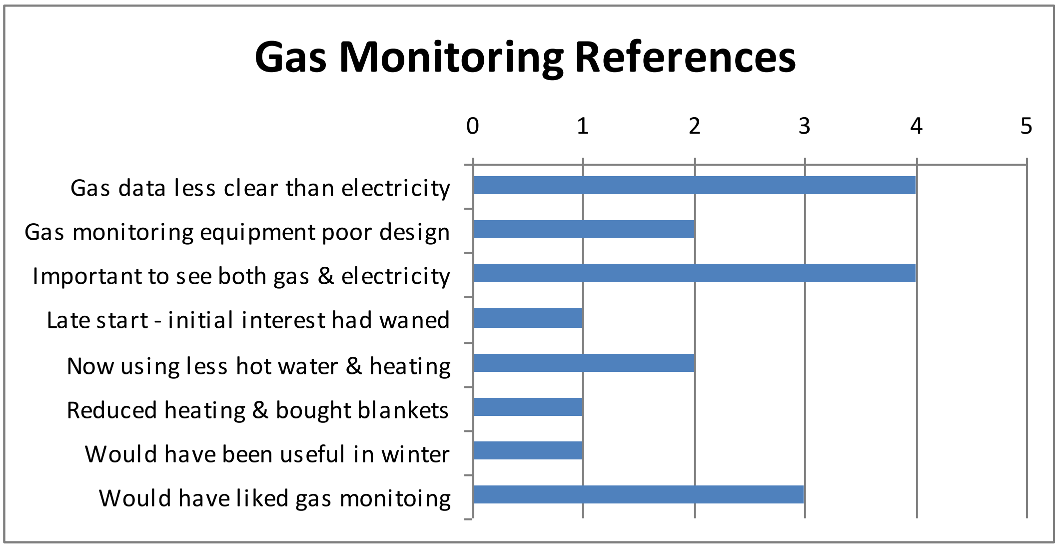
Figure 21 Focus Group analysis – system acceptability references (in alphabetical order)



2.6.4 Gas Monitoring

Again, focus groups findings supported the survey responses reported in Section 2.5.3. Feedback reflected the technical difficulties with the system and not all users understood the dashboard gas display, nevertheless it was valued by those that had it installed and the importance of measuring both gas and electricity was recognised.

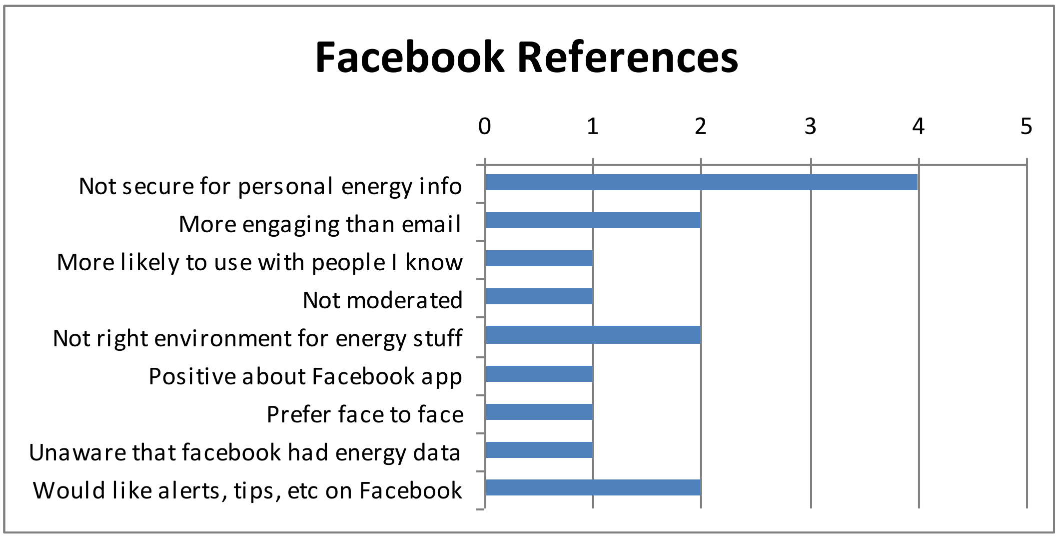
Figure 22 Focus Group analysis – gas monitoring references (in alphabetical order)



2.6.5 Social Networking (Facebook)

An interesting finding on social networking was that some users were concerned about their energy consumption data being available on a public forum – from a security perspective. A particular issue raised was publishing data which demonstrated that a house might be empty. However, the number of DEHEMS Facebook application users that attended focus groups was relatively small and issues identified via this route should perhaps be more fully investigated. It is likely that the users who raised this point are not actually familiar with the Facebook application and the privacy protections that are in place, such as not displaying live data, and publishing summary data only to designated Facebook "friends" who are also sharing DEHEMS data through Facebook.

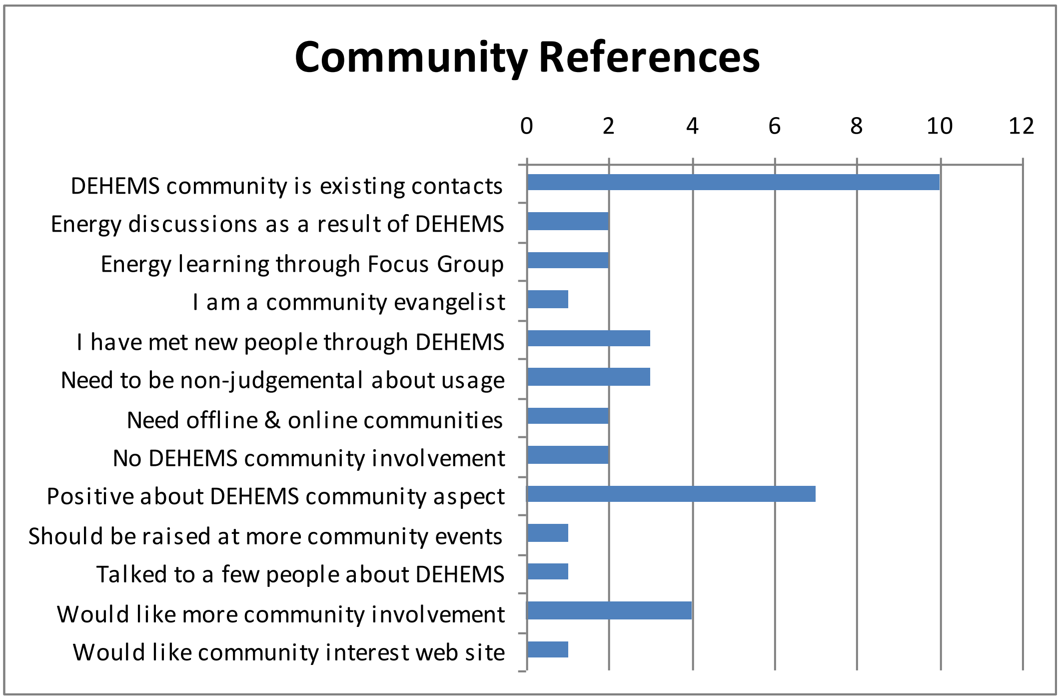
Figure 23 Focus Group analysis – Facebook references (in alphabetical order)



2.6.6 Community Involvement

Focus group participants were positive about the community aspects of DEHEMS and, if anything, would have preferred there to be more. Users clearly felt that energy saving (and environmental issues in general) are appropriate topics for generating community involvement. There was support for both offline and online communities.

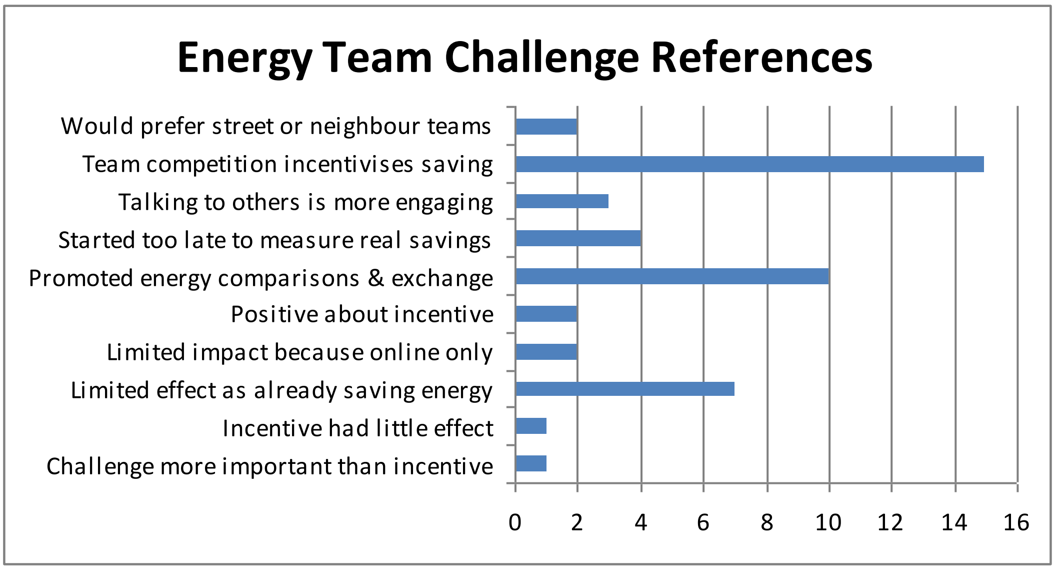
Figure 24   Focus Group analysis - Community references (in alphabetical order)



2.6.7 Energy Team Challenge

As already discussed in Section 2.4.3, findings on the incentive scheme were mixed -perhaps reflecting how people respond differently to incentives, competition and challenge. One of the responses which came over very strongly, but which was raised by fewer users, was the feeling that an incentive scheme is pointless if people are already doing all they can to save energy.

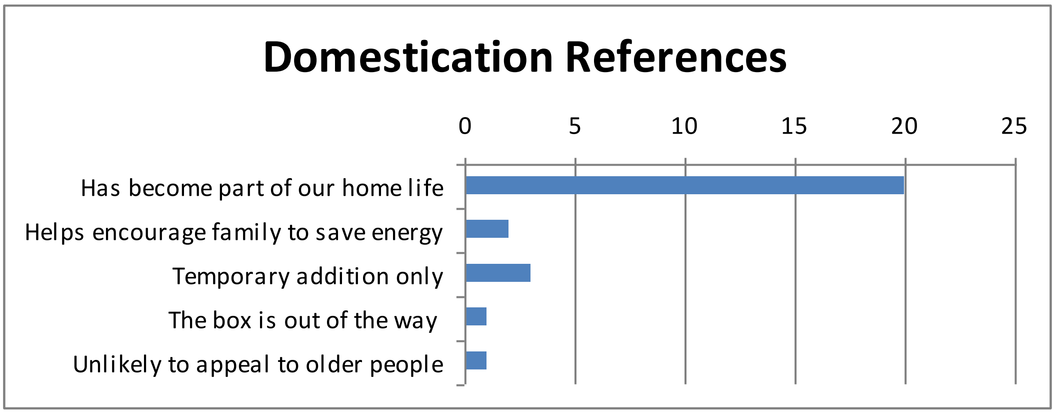
Figure 25   Focus Group analysis – Energy Team Challenge references (in alphabetical order)



2.6.8 Domestication

The focus group evidence is clear that DEHEMS became part of home/family life.

Figure 26 Focus Group analysis – Energy Team Challenge references (in alphabetical order)



2.7. DEHEMS Energy Data Analysis

2.7.1 Experimental groups

In Cycle 3 there were a total of 256 homes participating in DEHEMS across the 5 Living Labs. There were a number of experimental groups with different configurations of monitoring equipment as shown below. Some users had a combination of monitoring equipment and therefore occur in more than one group. No gas monitoring was installed in any homes in Bulgaria because none have piped gas.

Table 28 6 Experimental groups with different configurations of monitoring equipment

Living Lab	Control	Total Electricity only	Appliance	Remote Display	Gas
Plovdiv	5	23	14	10	0
Ivanovo	5	26	14	8	0
Manchester	10	27	17	1	10
Bristol	10	24	14	7	10
Birmingham	7	25	7	12	8
Total	37	125	66	38	28

Key:

Control = households with no access to the DEHEMS dashboard

Electricity = households with total electricity consumption monitoring

Appliance = households with appliance monitoring

Remote display = households with remote electricity consumption display unit

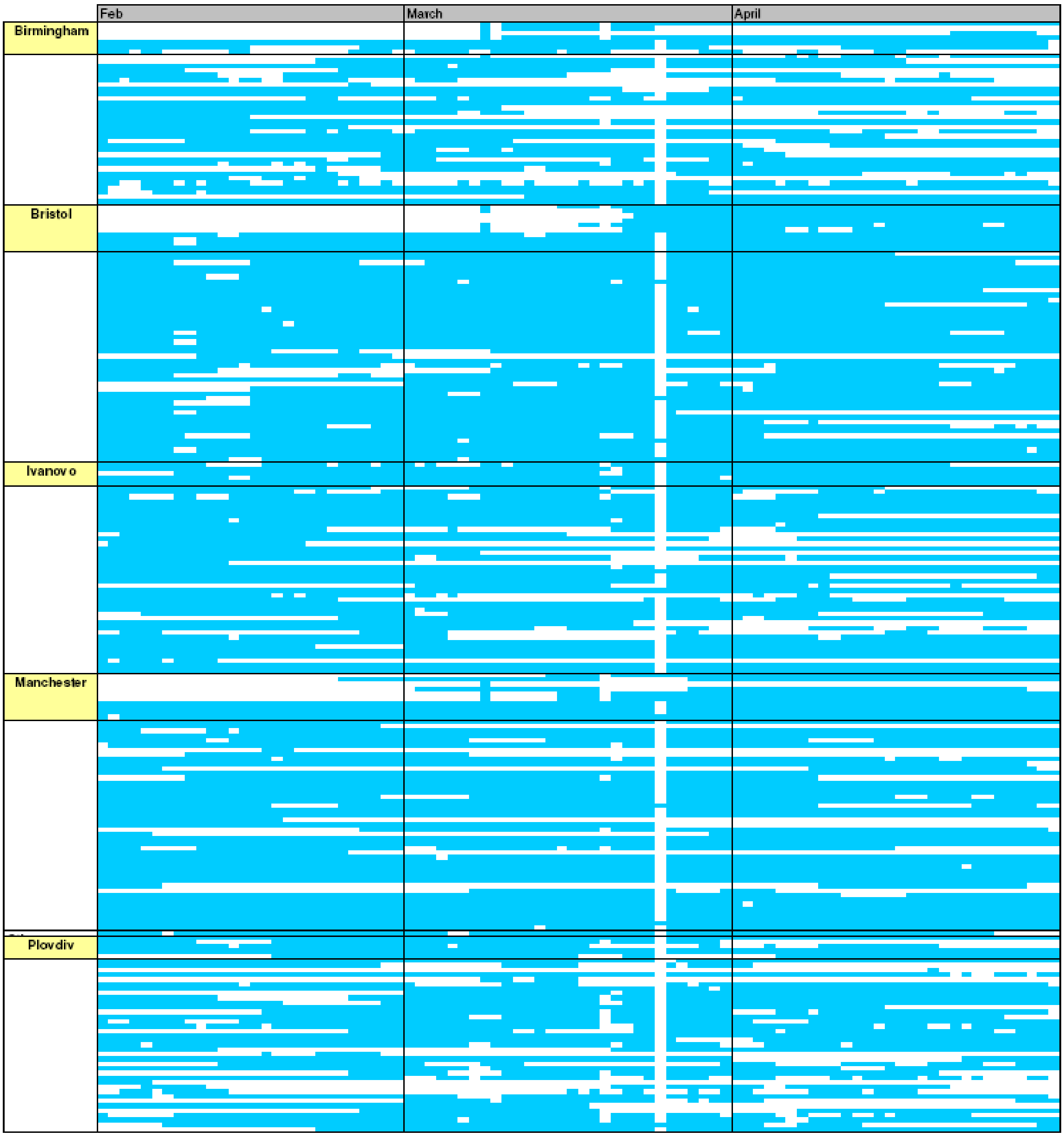
Gas = households with gas monitoring

2.7.2 Continuity of energy consumption data over Cycle 3

Figure 27 provides a summary of the days on which data was received from participating households over the 3 months of Cycle 3 (blue= data received). For each Living Lab, the first block of homes are control homes. A number of points can be made to explain the data:

- New control homes were introduced in early/mid March in Birmingham, Bristol and Manchester, ie. part way through the cycle, which accounts for the white block at the top of the section for each of these 3 Living Lab
- These was a power outage at the Institut e-Austria in Timisoara (where the relevant DEHEMS servers are located) in late March
- 7 Birmingham users requested that the monitoring equipment in their homes be removed half way through the Cycle due to changes in household circumstances. This can be seen by comparing the density of blue between February and April.

Figure 27 Days during Cycle 3 on which data (in blue) was received from each household (one household per row)

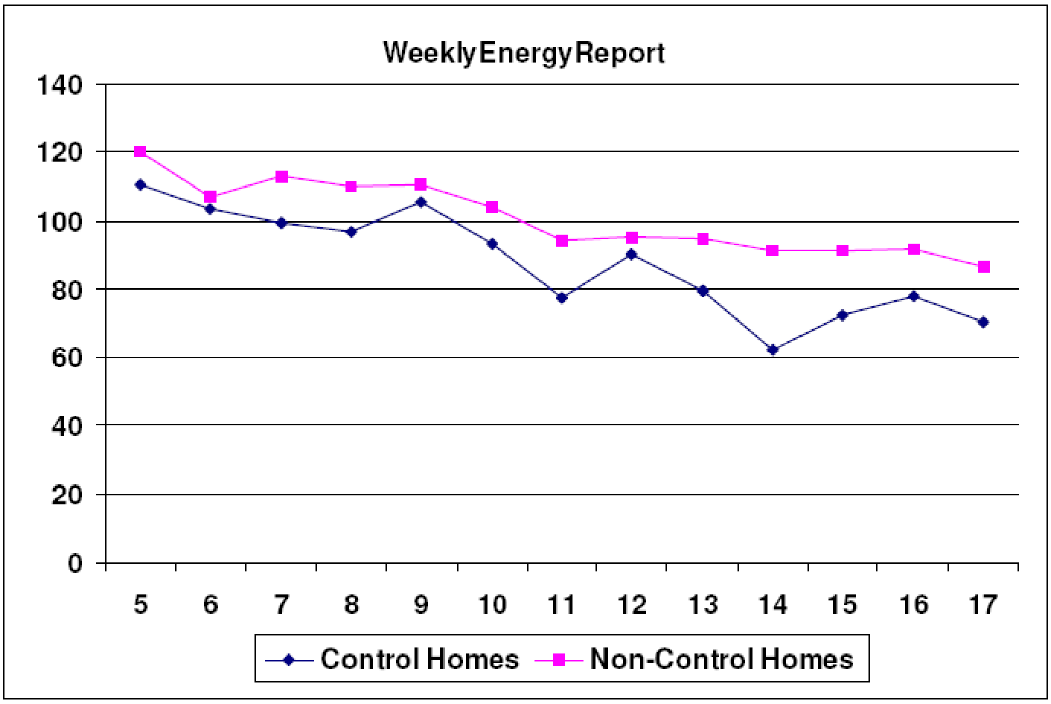


2.7.3 Overall energy consumption – all households

Most Cycle 3 households had already participated in previous cycles. New households were recruited to replace any that had dropped out of the programme between cycles 2 and 3 (usually as a result of changes in household circumstances). As a result, it was not anticipated that the drop in energy consumption shown in Cycle 2 would be repeated. As one user said "We are already doing everything that we can to save energy, other than sitting in the dark". Therefore, it was expected that the most informative results would be those relating to new interventions introduced in Cycle 3. These results are covered in Sections 2.7.5 to 2.7.9.

Nevertheless, analysis of the overall weekly energy consumption (electricity only) of all participating households from the first week in February (shown as week 5) to the last week in April (week 17) shows a downward trend (see Figure 28).

Figure 28 Weekly energy consumption (electricity only, in kWh) by all households broken down into control and non-control homes



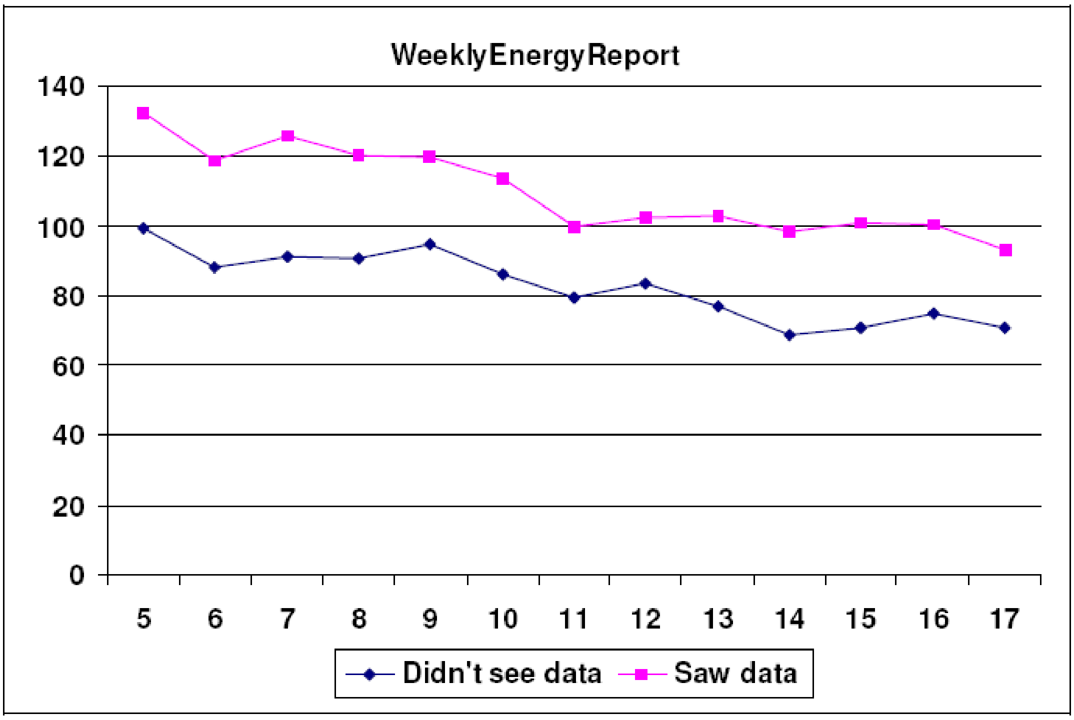
There could be a number of reasons for the downward trend in energy consumption between weeks 5 and 17:

- Households were still reducing energy consumption as a result of DEHEMS
- There was a drop in energy consumed on electric heating from February to April (especially in Bulgaria where many homes are heated electrically)
- All homes reduced their energy consumption on lighting as day length increased
- A combination of these factors
- Other

However, detailed analysis of the above graph suggests that the gradual reduction in energy consumption from weeks 5 to 17 is unlikely to be due to DEHEMS because the same trend is shown by both control and non-control homes. In addition, as already stated, a reduction in energy consumption as a result of DEHEMS was not anticipated because most households had been part of the project since early 2010.

The marked fluctuation in energy usage shown by the control homes is possibly due to the small sample size. However, if the weekly energy consumption (electricity only) of all participating households over the same 12 week period is broken down into those that viewed their energy consumption data and those that did not, then this has the effect of increasing the size of the control group because it includes (a) control households who could not access their data on the dashboard or on Facebook, and (b) non-control households who chose not access their data on the dashboard or Facebook. This increases the control group from 37 to 110 and provides a more stable baseline – as shown in Figure 29. For this reason, this approach is used for the more detailed analyses contained in the following sub-sections of Section 2.7. It is noted that this does not in any way explain why 73 participating households who could access their energy monitoring data chose not to (see also Section 2.7.1).

Figure 29 Weekly energy consumption (electricity only, in kWh) by all households broken down into households that viewed their data and those that did not



Weekly energy consumption can also be shown for individual Living Labs. This shows some interesting variations.

Figure 30 Weekly energy consumption (electricity only, in kWh) for all Living Labs – excluding control homes

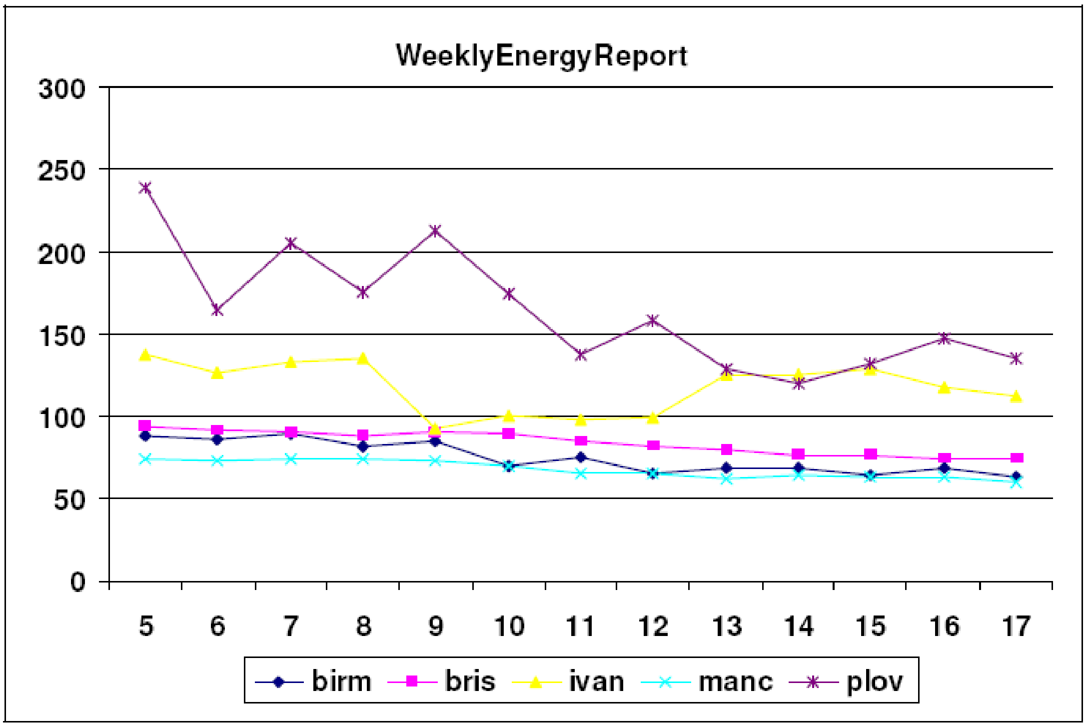
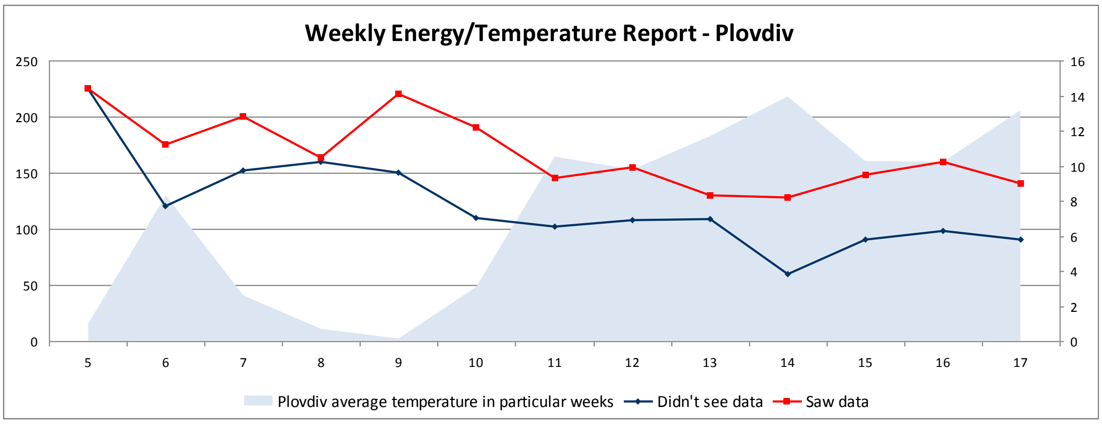


Figure 30shows stable energy consumption for UK Living Labs but fluctuating (and greater) energy consumption for Bulgaria Living Labs. This can be explained in terms of heating: no participating households in the UK use electricity as their primary heating source but in

Bulgaria, 8 households in Ivanovo and most in Plovdiv use electricity as their primary heating source. Figure 31 shows average weekly temperature in Plovdiv over the period of the project and it can be seen that weeks with significantly higher energy consumption coincide with lower temperatures and vice versa. 3 weeks in particular stand out: week 9 was abnormally cold and coincided with 4 days national holiday, week 11 showed a sharp rise in temperature and week 14 was abnormally warm including a day when the temperature was 23°C.

Figure 31 Weekly Average Temperature in Plovdiv plotted against weekly electrical energy consumption (in kWh) of Plovdiv homes

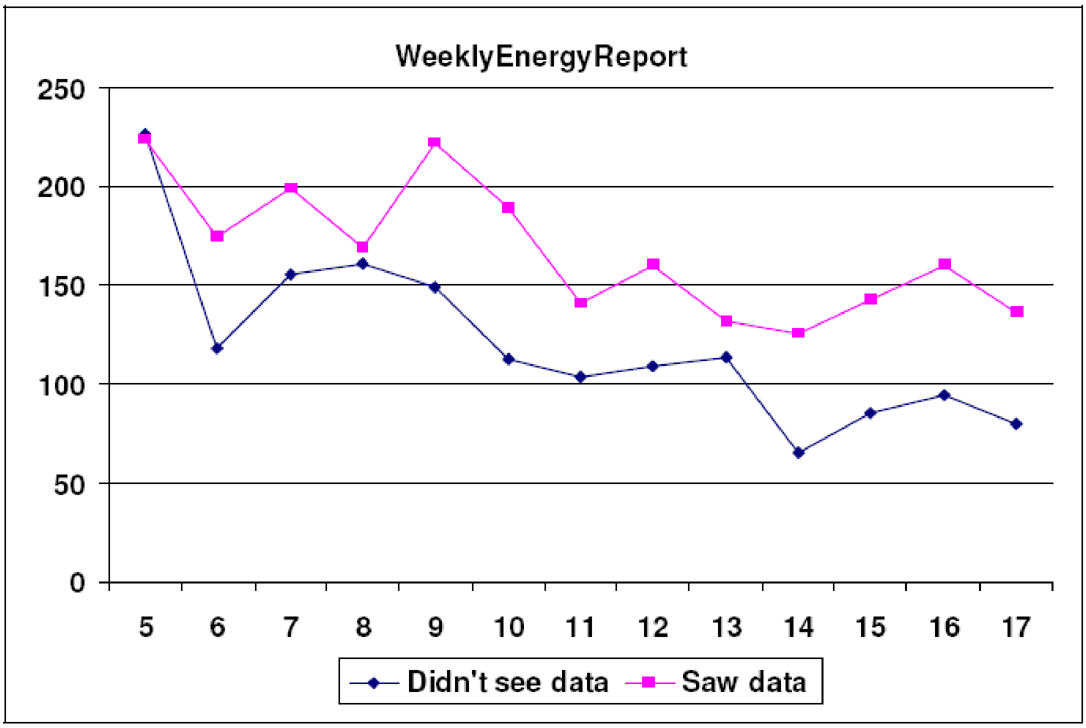


As a result of this observation, it was decided to look more closely at the relationship between cavity wall insulation and electrical energy consumption in Bulgaria, and this is reported in Section 2.7.5.

2.7.4 Energy consumption – Living Labs

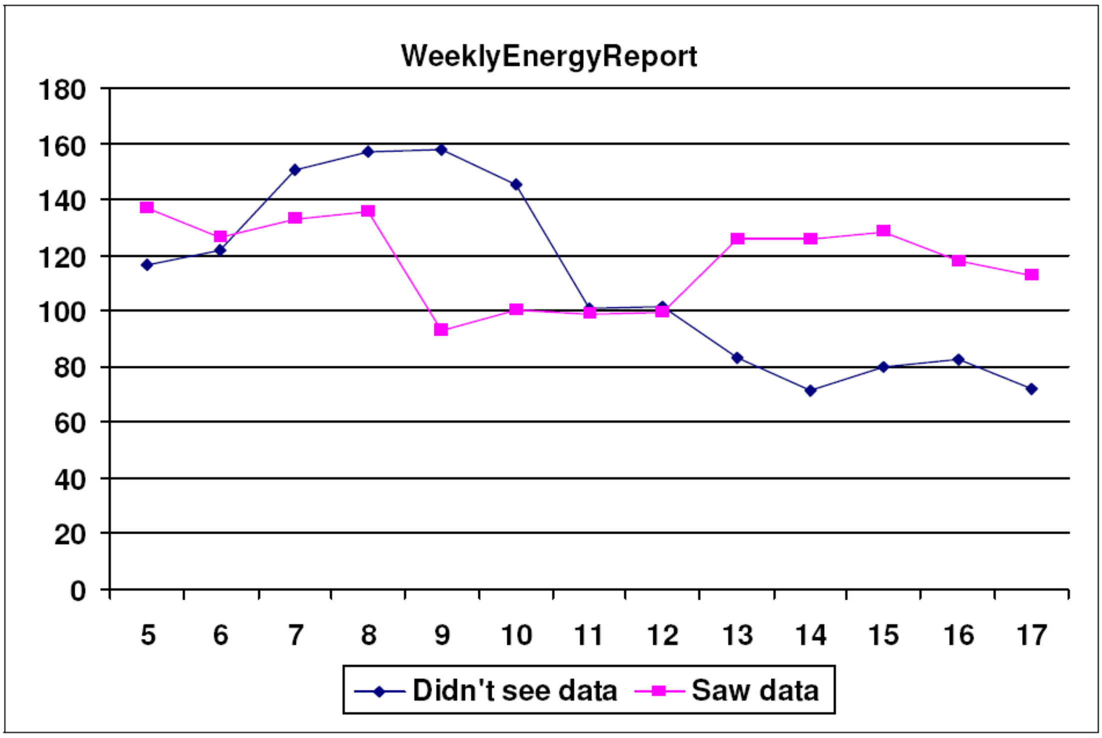
We can look in more detail at each Living Lab in order to try and understand the results.

Figure 32 Weekly energy consumption (electricity only, in kWh) for Plovdiv



The Plovdiv results have already been discussed in more detail in Section 2.7.3, where increases (and decreases) in energy consumption are closely linked to external temperature because most participating households have electric heating. The “didn’t see data” group consumed less energy over the period of the project than those that viewed data. This finding is not anticipated although it might be explained by the selection of control users who were predominantly staff (or family of staff) of Energy Agency Plovdiv - who might be expected to be good at energy saving.

Figure 33 Weekly energy consumption (electricity only, in kWh) for Ivanovo



In common with the results for all households, there was an overall reduction in energy consumed by Ivanovo users. This would be anticipated due to the 8 users with electric heating. The uplift in energy consumption for the “saw data” group between weeks 12 and 13 coincided with a period of extreme cold (-15° centigrade).

However, there are some questions about the Ivanovo results which need further investigation. Why was energy consumption higher for the “didn’t see data” group than the “saw data” group prior to week 11 and then lower subsequently? Why did the energy consumption of the “didn’t see data” group drop between weeks 12 and 14 when the external temperature dropped sharply and the energy consumption of the “saw data” group increased?

The weekly energy consumption for the 3 UK Living Labs are broadly similar – showing a slight gradual reduction in energy consumption over the cycle and little significant difference between users that viewed their energy monitoring information and those that did not.

Figure 34 Weekly energy consumption (electricity only, in kWh) for Manchester

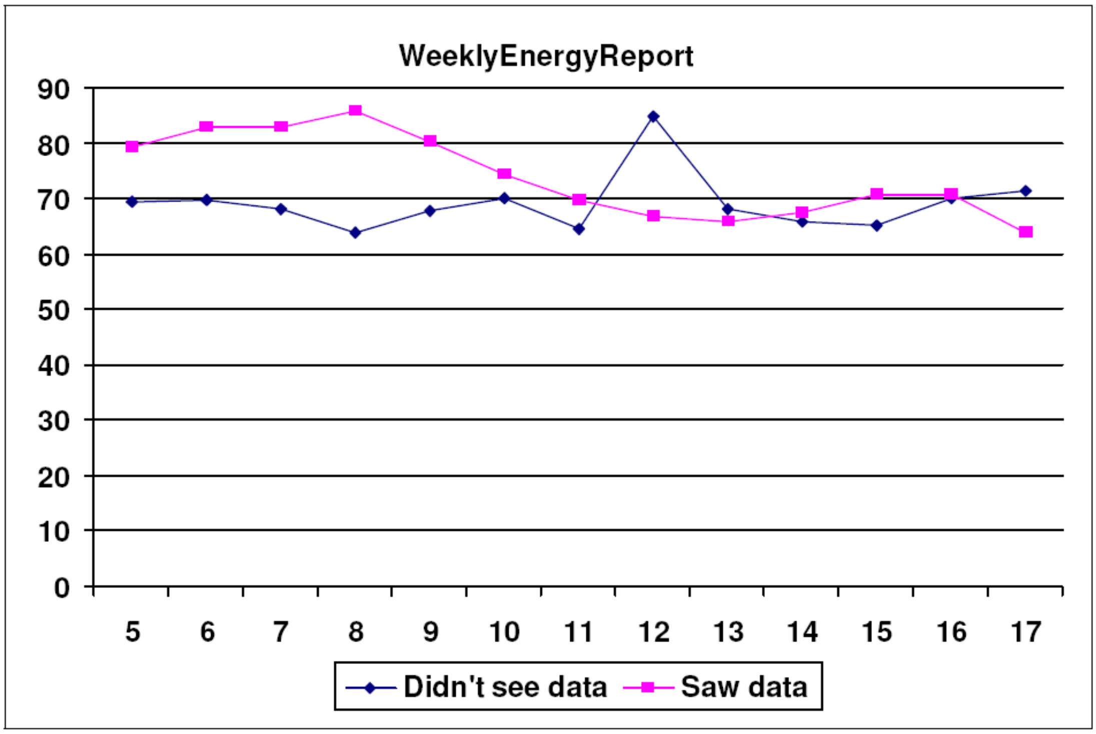


Figure 35 Weekly energy consumption (electricity only, in kWh) for Bristol

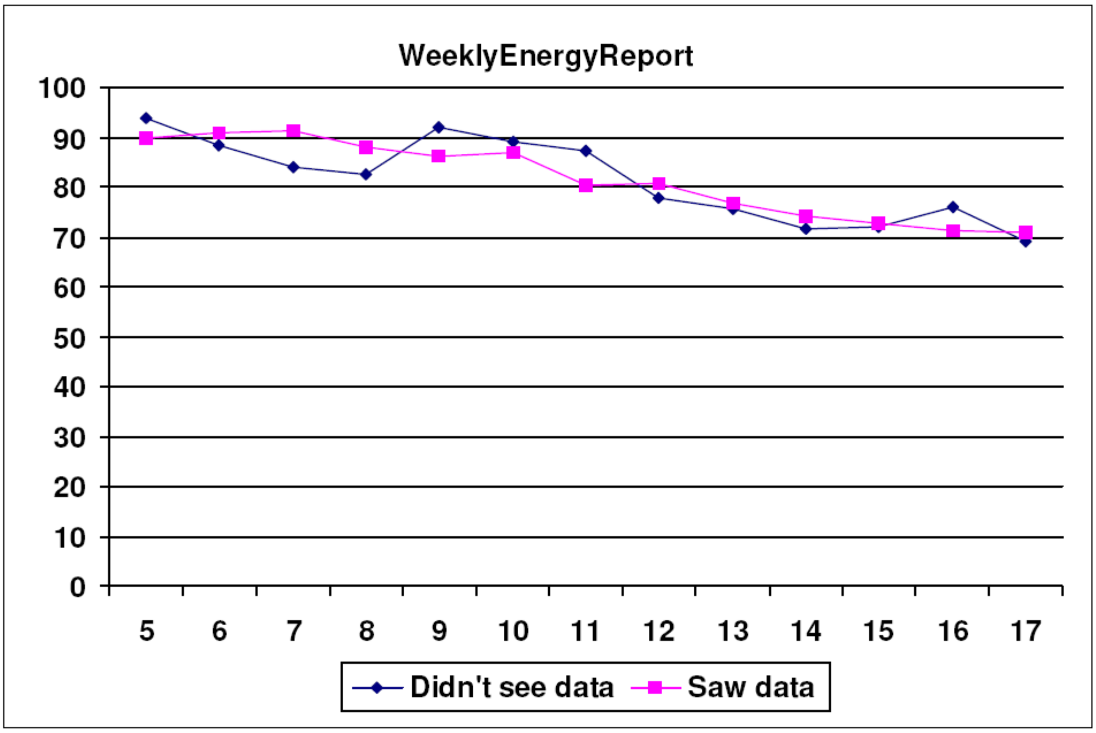
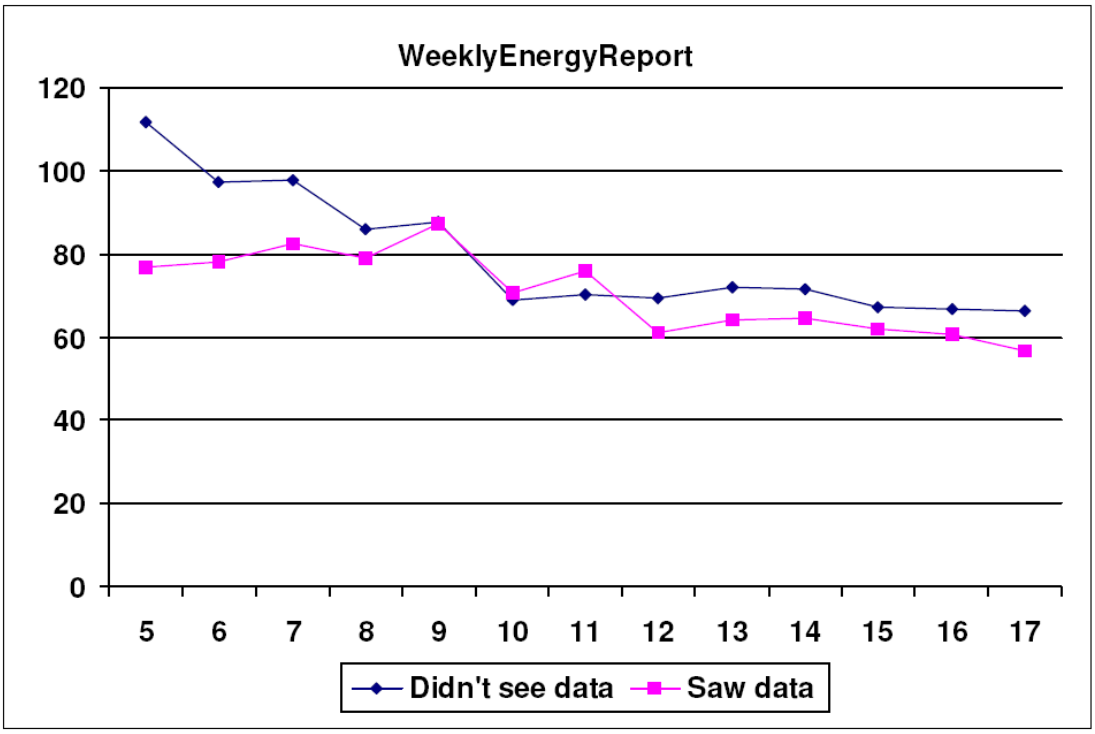


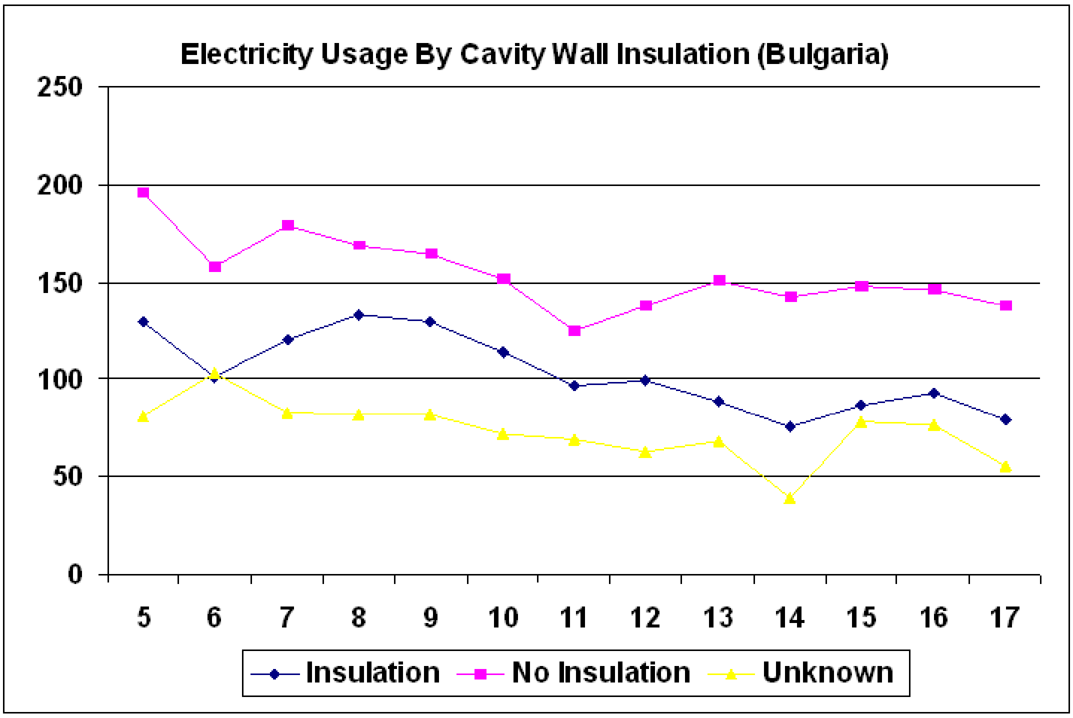
Figure 36 Weekly energy consumption (electricity only, in kWh) for Birmingham



2.7.5 Electrical energy consumption – impact of cavity wall insulation

Given the extensive use of electrical heating in Bulgaria, and the dramatic effect of outside temperature on electrical energy consumption, mentioned above, an analysis was performed on the effect of cavity wall insulation on those Bulgarian figures. These are shown in Figure 37.

Figure 37 Weekly electrical energy consumption figures (kWh) for Bulgarian homes with and without cavity wall insulation.



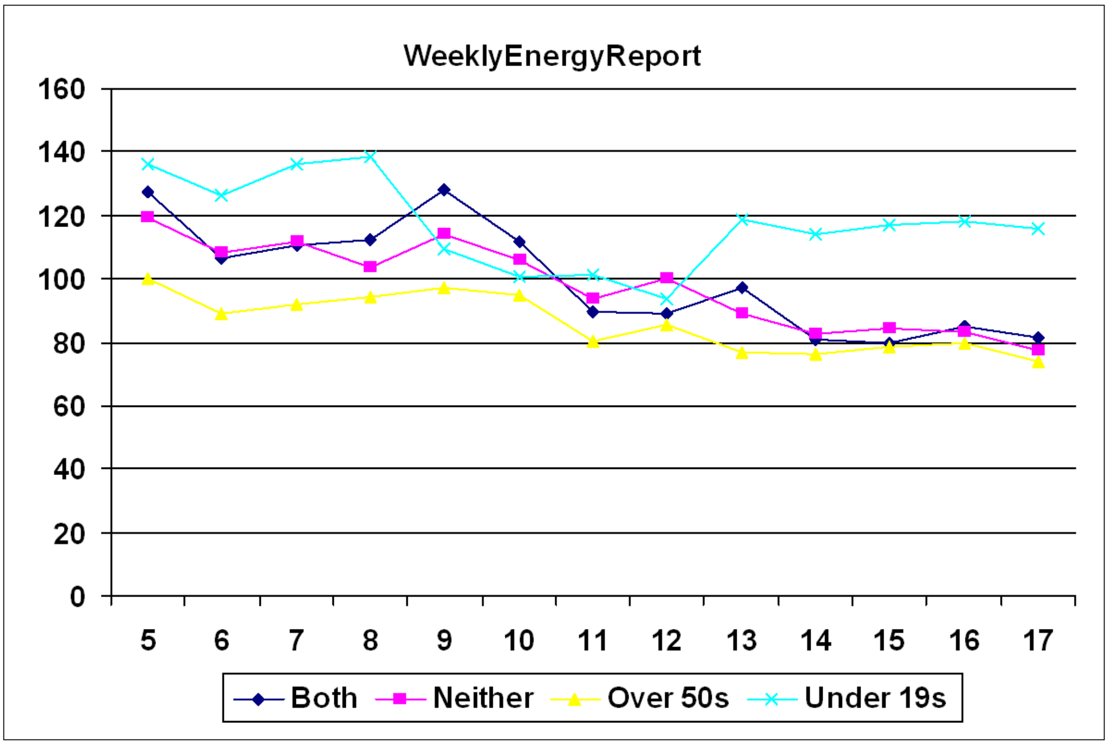
The graph shows consumptions for homes with and without cavity wall insulation, and suggests a significant reduction in energy use for those homes with insulation compared to those without. The "unknown" line consists of only 3 to 5 homes in each week, so cannot be used for comparison. In each week, data were available from around 20 homes with cavity wall insulation and around 40 homes without.

A similar analysis was attempted for loft insulation. However, of the 101 Bulgarian homes returning data, 74 were flats, making loft insulation irrelevant for most of the homes. Of the remaining homes, 19 had no loft insulation, 3 were unknown and only 5 had loft insulation. The results obtained were anomalous, but cannot be used for analysis due to the small numbers involved.

2.7.6 Electrical Energy Consumption – impact of occupancy

Figure 38 shows energy consumption by age group of household occupants.

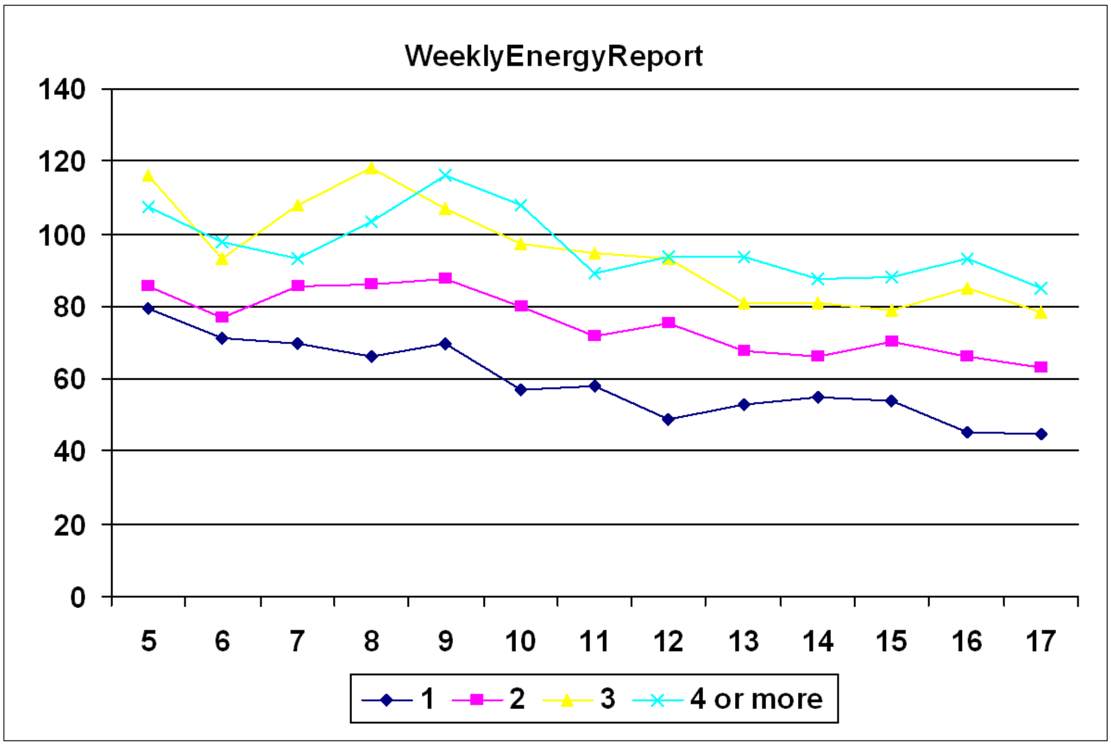
Figure 38 Household weekly energy consumption (in kWh) for households with under 19's and over 50's



On the face of it, this evidence suggests that the presence of under 19 year olds increases energy consumption and the presence of over 50s decreases it. However, it should be noted that the households with under 19s have, on average, more occupants than those with over 50s, as was shown in Table 10.

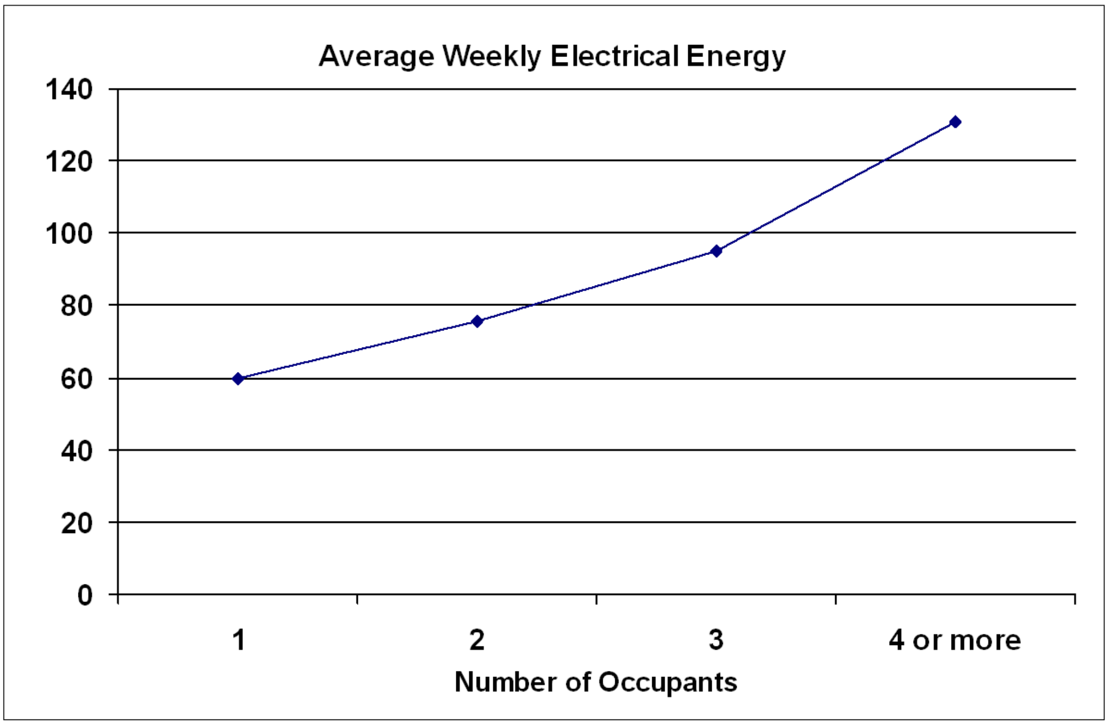
A similar graph showing weekly electrical energy consumption according to household occupancy is provided in Figure 39, which shows a clear trend of increasing energy consumption with increasing occupancy.

Figure 39 Household weekly energy consumption (in kWh) according to the number of occupants.



If we take the average weekly energy consumption across the period against household occupancy then, as expected, the electricity consumption increases with the number of occupants.

Figure 40 Average household weekly energy consumption (in kWh) according to the number of occupants.



Taking the figures quoted in the second and third rows of Table 29 and comparing against the graph above shows that the differences can be wholly attributed to the number of occupants in the household.

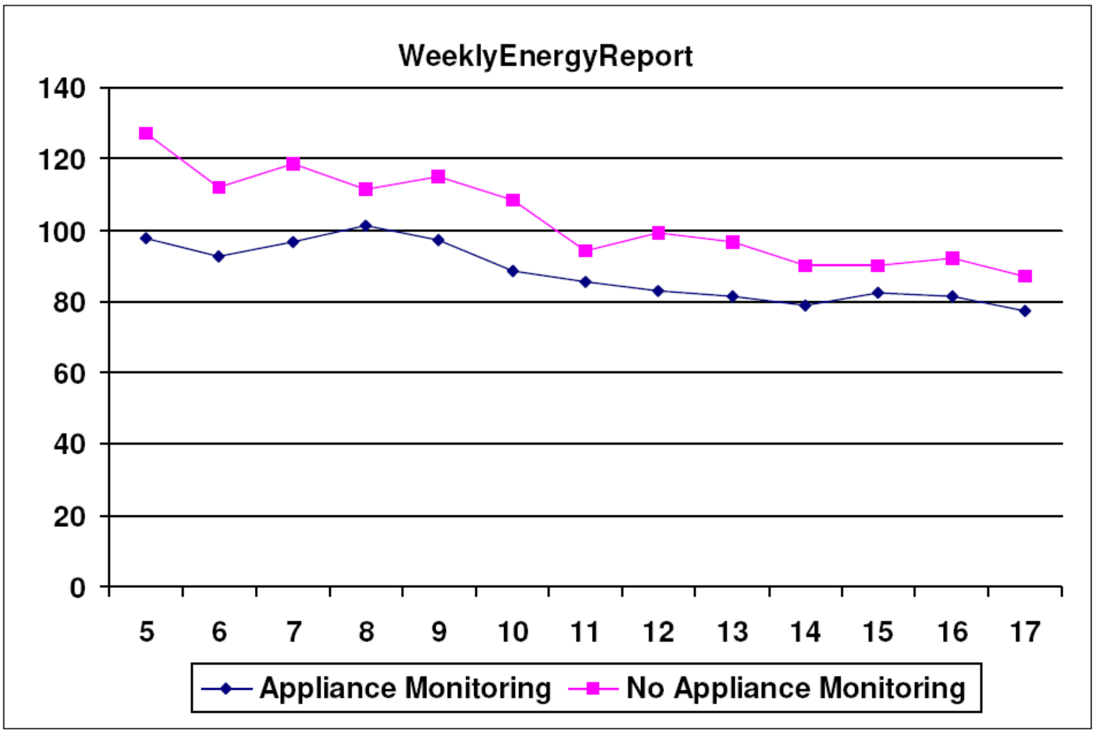
Table 29 Average weekly electrical energy use by occupant ages

Over50s	Under19s	Average Occupancy	Average Weekly Energy
Yes	Yes	4.1	101
Yes	No	2.5	86
No	Yes	3.9	117
No	No	2.1	85

A more detailed statistical analysis of this point is not feasible, however, due to the relatively small sample size.

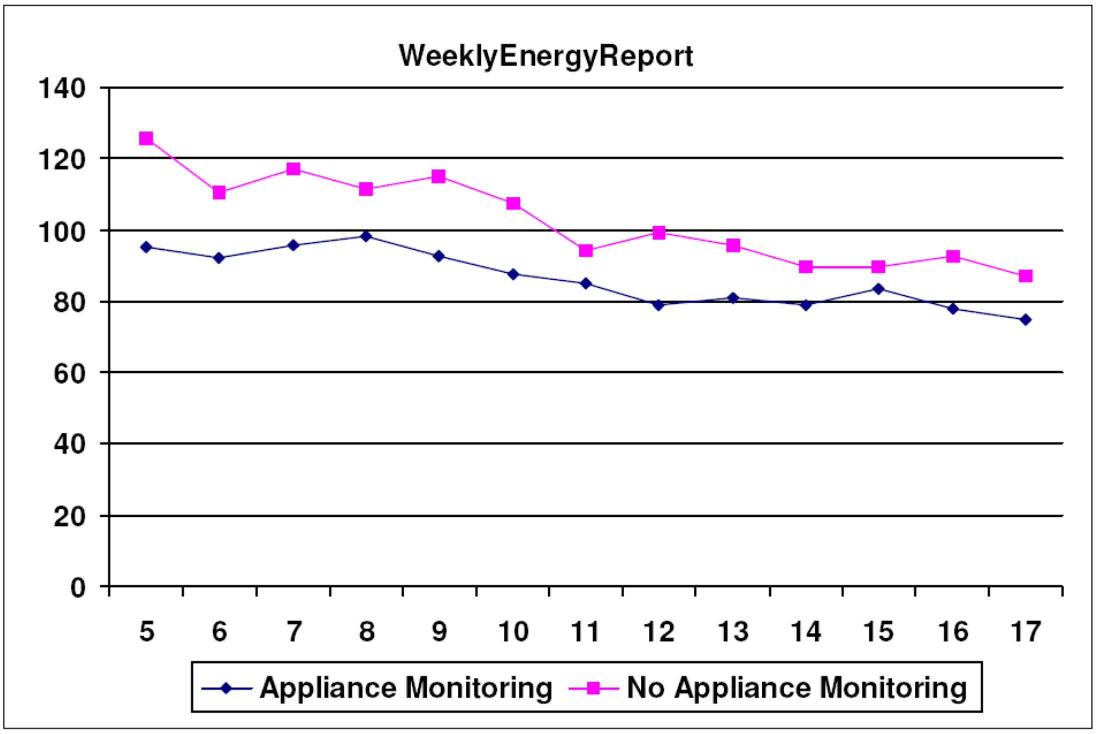
2.7.7 Electrical energy consumption – impact of appliance monitoring

Figure 41 Weekly energy consumption (in kWh) by all households showing impact of appliance monitoring



Overall energy consumption is lower for those households with appliance monitoring available. However, not all households that had appliance monitoring available actually looked at the data. If those that did not look at their data are excluded, there is a slightly greater difference between the energy consumption of the 2 groups as shown below. This indicates that appliance monitoring combined with dashboard display of monitoring information has a positive effect on energy saving.

Figure 42 Weekly energy consumption (in kWh) by all households showing comparison between (a) households with appliance monitoring available and looked at data, and (b) households with no appliance monitoring or who didn't look at the data.

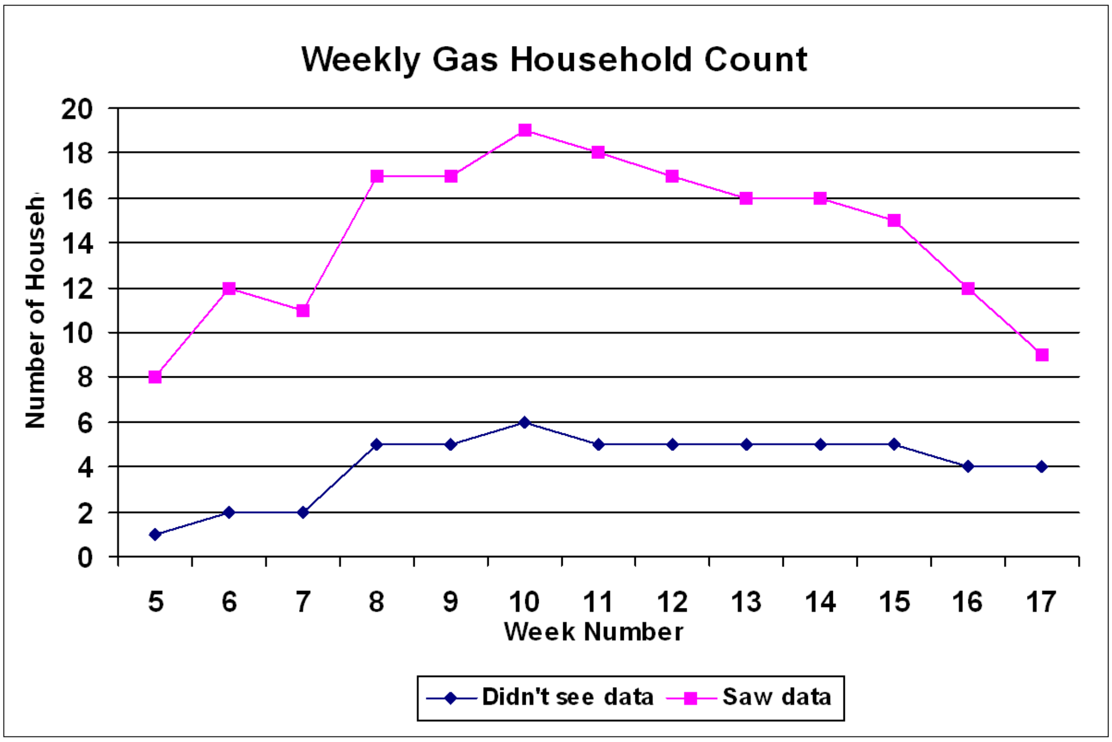


2.7.8 Energy consumption – impact of gas monitoring

Figures are presented here for measured gas consumption across those households with gas monitoring. Very few Bulgarian houses have access to mains gas, so gas measurement was installed only in UK households. As discussed in Section 0, the data obtained from gas measurement are of questionable quality, so the results presented in this section should be viewed as indicative rather than conclusive.

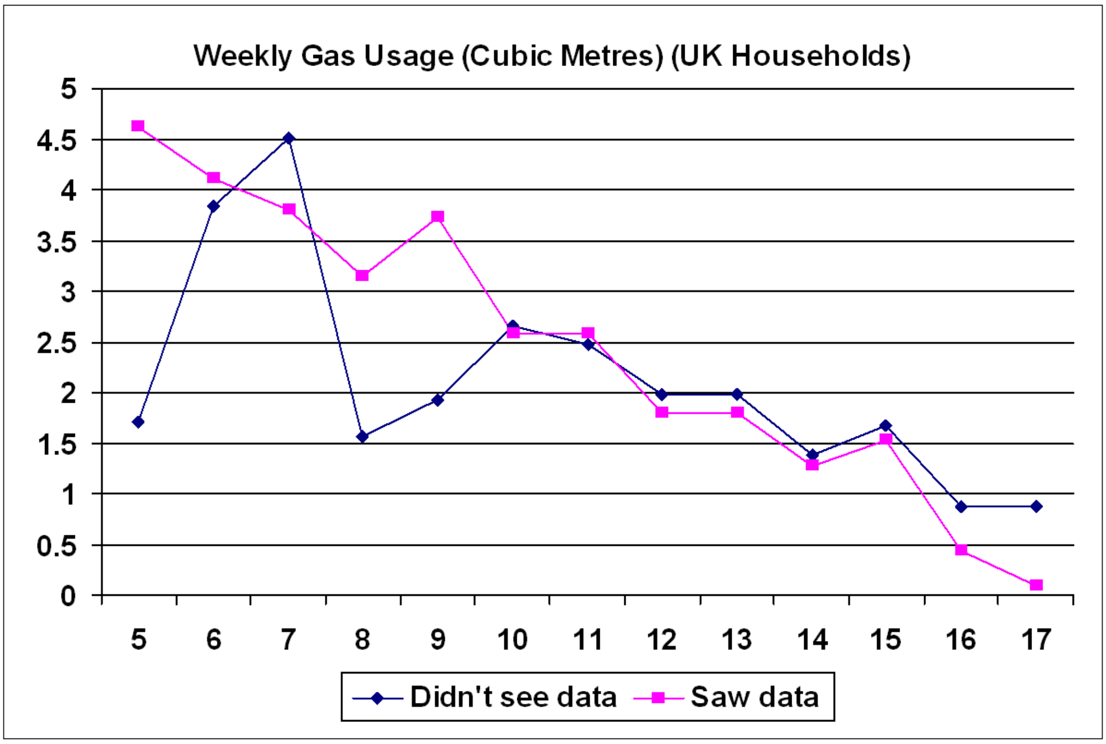
Figure 43 shows the numbers of households for which gas data was available in each week, broken down according to whether members of the households actually viewed their energy data during the Cycle 3 period. Given the numbers of households shown returning gas data each week, the analysis has focussed on calendar weeks 8 to 15 only (the 4th to the 11th weeks of monitoring), though data has been shown in the graphs for all weeks.

Figure 43 Numbers of homes returning gas data during each week of Cycle three



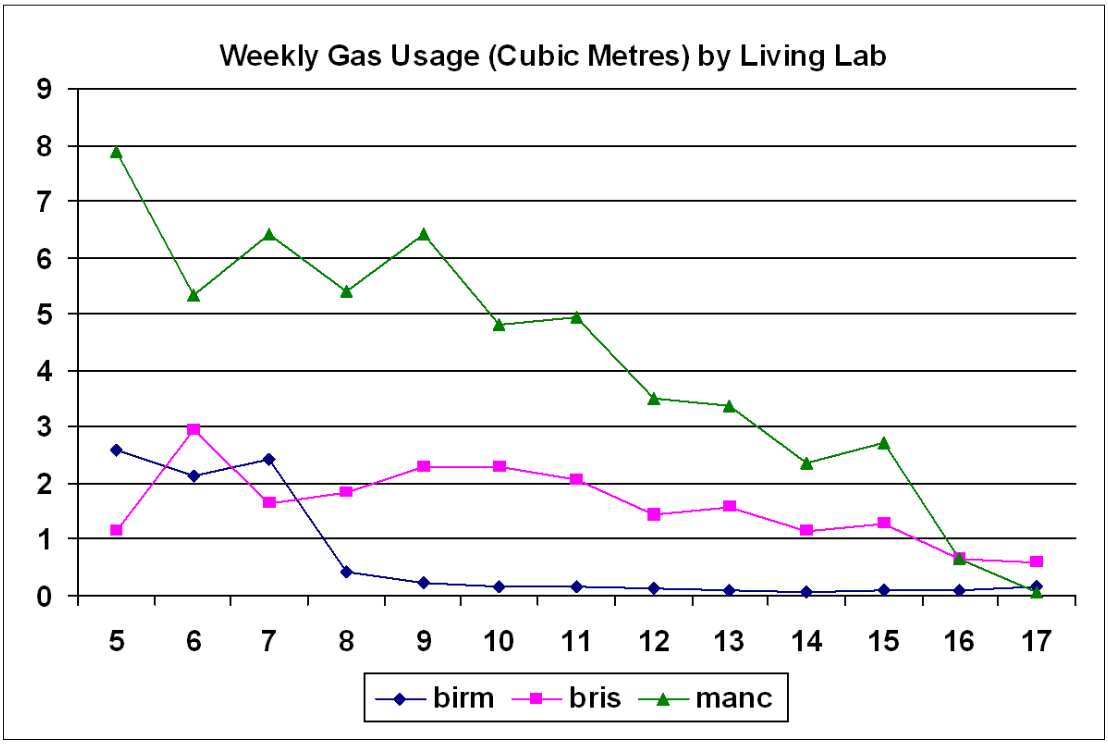
As may be seen from Figure 44, the overall trend for gas consumption between weeks 8 and 15 is downwards, which is not surprising, given that a high proportion of the gas consumption in the UK is for heating. Because of the low numbers of gas participants who did not see their data, it would not be sensible to draw conclusions from the comparison between the lines.

Figure 44 Weekly gas consumption of households according to whether they actually viewed the DEHEMS data.



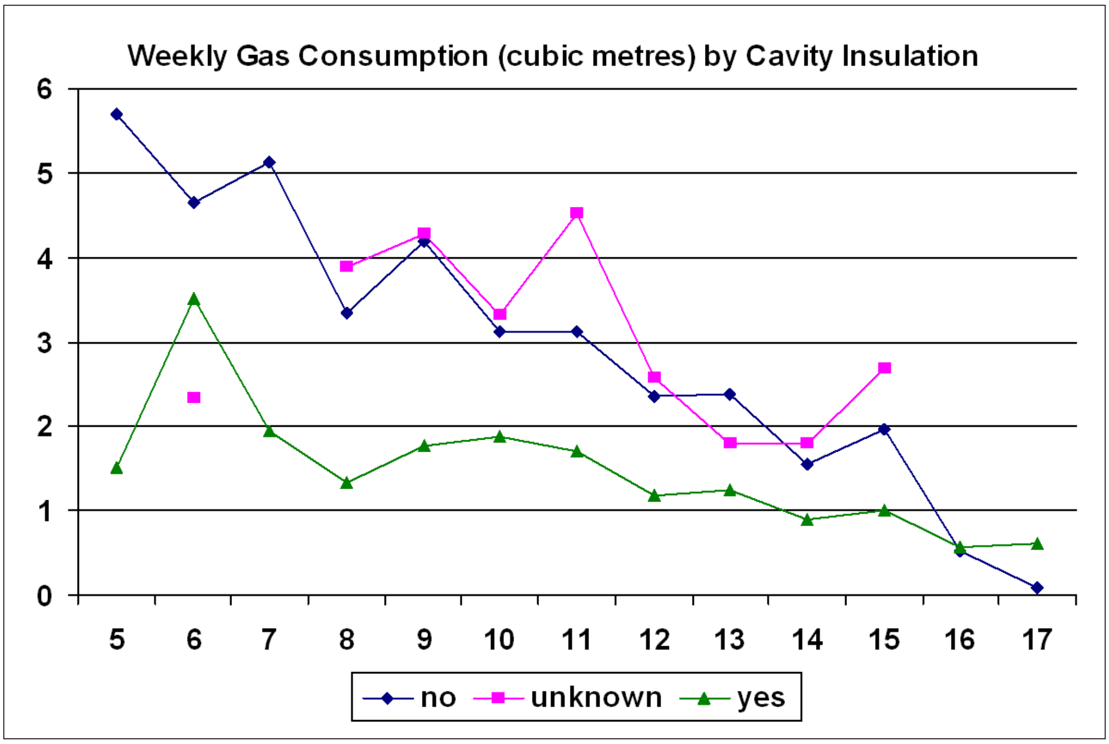
The same data is shown broken down by Living Lab in Figure 45. There is an interesting difference between the Living Labs in this figure. However, it would again be dangerous to draw any conclusions from this given the data quality and the low numbers of households involved.

Figure 45 Weekly gas consumption of households broken down my Living Lab.



A comparison of weekly gas consumption figures for homes with and without cavity wall insulation (see Figure 46), suggests that there may be a significant benefit to be gained from installing such insulation.

Figure 46 Weekly gas consumption according to whether the home had cavity wall insulation installed



Again, however, great care must be taken with this comparison as it appears that the majority of cavity wall insulated homes are found in the Bristol Living Lab, and all of the Manchester homes are without such insulation (See Table 30). As a result, there could be other factors that account for at least some of the differences, such as building type. Many of the homes in the Manchester Living Lab were constructed without cavity walls, making it impossible to install insulation of this type.

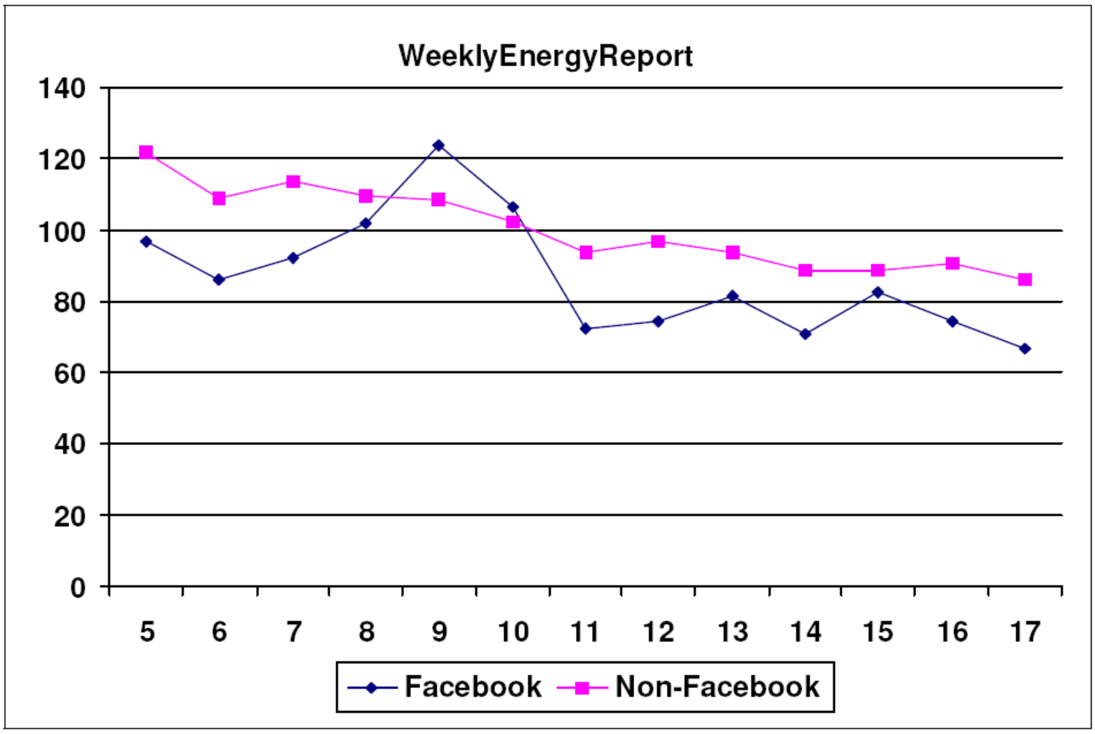
Table 30 Insulation status of gas-monitored homes in each Living Labs.

LivingLab	no	unknown	yes
birm	4	2	2
bris	1		9
manc	8	2	

2.7.9 Energy consumption – impact of Facebook application

The overall energy consumption is lower for those households that accessed their energy consumption data on Facebook. The exception to this is in weeks 9 and 10. However, this is very similar to the spike on the graph for energy consumption in Plovdiv shown in Section 2.7.4. This is to be expected because 9 out of the 25 Facebook users were in Plovdiv and therefore the spike can be explained in terms of the low temperatures experienced in Plovdiv during this period.

Figure 47 Average weekly electrical energy consumption (in kWh) by all households showing comparison between households accessing Facebook application and all other households



3. How do the results inform the Research Questions?

3.1 To what extent can the DEHEMS Cycle 3 system contribute to users' changing their behaviour resulting in reduced energy consumption and what are the key factors in the DEHEMS Cycle 3 system that determine its effectiveness in encouraging the end users to change their attitudes and behaviours regarding energy use?

Using the evidence of the energy consumption figures alone, it is not possible to conclude that DEHEMS Cycle 3 users have used less energy as a result of participation in the project. This is because Cycle 3 came after most users had already been involved in the project for over 6 months and had already demonstrated a significant reduction in energy consumption in Cycle 2 (see D7.6 Appendix II). Additionally, given that the same users were retained, it was not possible to start Cycle 3 with a period during which users could not view their energy monitoring data in order to establish a baseline against which subsequent energy usage could be compared, as in Cycle 2. However, the key point about the DEHEMS Cycle 3 system, was that it included some new interventions which can be reviewed because a number of experimental groups were established with different equipment configurations and different community contexts. Using the energy consumption data alone, we can see that users who accessed appliance monitoring data, or participated in energy monitoring or sharing on Facebook all consumed less electricity over the 3 month period than control users (i.e. users who didn't have access to or didn't access the data) (see Sections 2.7.6 and 2.7.9).

The picture for users with gas monitoring is less clear. Many users did not feel that the gas monitoring was particularly useful, and the results do not allow reliable conclusions to be inferred regarding the effect of gas energy monitoring on energy usage behaviour. The latter is largely due to the small sample involved, and the former may be attributed to the experimental nature of the gas monitoring solution that was implemented, resulting in some unreliability of the data itself. It did, however, provide a useful experiment from a technological point of view.

A clearer picture is shown if the qualitative evidence from users' responses to open-ended survey questions and from focus groups is included in the analysis of energy saving. It shows that a significant number of users reported behaviour changes which will yield considerable energy savings over time (see Figure 10 and Figure 19). These include:

- Reduced lighting
- Purchase of more energy efficient appliances
- More economical cooking, clothes washing/drying and showering/bathing
- Turning off appliances when not in use

There is also evidence of a "DEHEMS Effect" whereby participation in the project itself changes users' attitudes & behaviours. An example of this is shown by the total number of users reporting that they had made efforts to reduce their gas consumption (67) as against the number of users with gas monitoring (28) – see Figure 17.

3.2 In what ways and to what extent can community dynamics influence motivations to move more towards more environmentally motivated behaviours? And to what extent has DEHEMS encouraged users to become more involved in their communities, both online and off-line?

Over 40% of the DEHEMS questionnaire respondents shared monitoring information with other people, suggesting that participation is in itself a prompt to influence others towards more environmentally motivated behaviours (Figure 4). The extent to which community dynamics might play a part in this process can be investigated by considering how the 5 different Living Labs already existed as communities to different extents. Ivanovo, for example, included many people who worked at the University of Ruse, and Bristol's Living Lab was based on users of Knowle West Media Centre. Manchester, however, was largely composed of a range of different types of households. There is some evidence that the Living Labs which were drawn from stronger existing communities were more likely to share information about energy consumption and their participants more likely to move towards greater environmental motivations; this point was particularly evident in the data obtained from focus groups (see Section 2.6.6). This is particularly striking in Ivanovo which showed the greatest number of participants who actively compared results with others and found it useful (see Table 22.) and the greatest reported shift in motivation from cost to environmental as a result of DEHEMS (see Table 13.). Whilst it is not possible to conclude that motivation change occurs as a direct result of information sharing, it is likely that people will be more inclined to change their viewpoint if others around them are also doing so.

There were aspects of Cycle 3 which attempted directly to influence community dynamics. The results of these suggest that:

- Linking energy saving performance between different households by creating teams (Energy Team Challenge) may impact on individual behaviour but the DEHEMS results are not clear
- Providing opportunities for people to discuss energy monitoring through focus groups was valued by participants
- Creating online communities through social networking increases information sharing and DEHEMS Facebook users tended to consume less household energy than non-Facebook users

3.3 What are the key factors that affect engagement over a longer period of time and allow it to be maintained? Are there barriers?

Most DEHEMS Cycle 2 users remained engaged with the project until the completion of Cycle 3. For most users, this involved a period of 10 months continuous participation. Analysis of qualitative feedback provides evidence that most users valued the experience, despite some of the technical difficulties associated with the equipment (e.g. battery failure). There were some users that dropped out over this period and broadly speaking these fell into two categories: households where circumstances changed and key people were no longer available to be engaged with the project, and households where equipment consistently failed to perform or interfered with existing broadband connectivity. These issues were particularly evident in data obtained through the focus groups (see Figure 20). There is also evidence from the focus groups that support activities provided by individual Living Labs also had some impact on long-term engagement.

3.4 What are the key factors in the DEHEMS Cycle 3 system that affect acceptability to the end users?

Most users (80%) reported that they had no issues or concerns about using the DEHEMS equipment in their homes. Those that identified issues focused on the following concerns:

- Equipment faults - primarily data collector battery life and appliance monitor signal failure in larger homes
- The energy consumed by the monitoring equipment itself
- Broadband interference
- Dashboard complexity

(D2.15 Future Requirements Evaluation – Documentation of Future Requirements of a DEHEMS Type System, sets out the specification for DEHEMS Cycle 4, if there were to be one. All of the user concerns identified above have been addressed in this document).

Feedback on Cycle 3 dashboard features was positive (see Table 20 and Figure 21) and indicates that users primary interest is seeing how their own energy consumption changes over time rather than comparing their energy consumption with other homes.

3.5 How important is it to measure gas consumptions besides electricity? In particular, how acceptable are estimated gas usage figures in influencing users' behaviours?

The results from the questionnaire and focus groups were mixed regarding the usefulness of gas monitoring, but this appears to be due to the technical difficulties experienced (see Figure 16 and Figure 22), although there is evidence that this is at least in part dues to the experimental nature of the equipment. The focus groups particularly suggested that users would find gas monitoring useful, and did make some changes to their behaviour as a result of their having access to gas consumption data

At the present time, there is little data available to reach reliably conclusions regarding the second part of this question.

3.6 Online social networking - how effective is the use of online social networking in getting users engaged in DEHEMS and how does this compare with engagement of users who are not involved in online social networking?

As detailed in Sections 2.4.2 and 2.6.5, creating access to DEHEMS energy monitoring information through a Facebook application has provided useful feedback on how online social networking can impact on engagement. The results show a number of findings:

- Facebook users were more engaged with DEHEMS than non-Facebook users (77% viewed their energy data on Facebook during Cycle 3 compared with 65% of all DEHEMS users).
- DEHEMS Facebook users came from a wide spread of age groups – including over 50's
- Facebook users were more likely to engage with other people in discussions about energy consumption than other DEHEMS participants
- Facebook users consumed less household energy than non-Facebook users (Figure 47)

Concerns expressed in the focus groups regarding privacy suggest a lack of understanding of the nature and operation of the Facebook application and may be attributable to the fact that most focus group participants were not actually users of the Facebook application.

A particularly important observation in relation to the use of social networking relates to the "two-way" nature of the interaction between the social networking platform and the DEHEMS Application. The project made use of the Facebook platform and its existing social networks as a means of encouraging information sharing. It is clear that a much greater benefit could be achieved by supporting the creation and enhancement of social networks through the DEHEMS application itself; allowing DEHEMS users to find each other more easily through the functionality provided by the social networking platform, and thereby build social networks around the DEHEMS experience itself.

3.7 Is CO_2 trading the 'right way' forward in order to achieve the objectives of the DEHEMS project?

A Carbon Trading Working Group was set up early in Cycle 3 to consider how to implement this aspect of the project. It was concluded that carbon trading per se is impractical on such a small scale and where there is not a genuine trading situation. It was therefore decided to adopt an incentives based focus – hence Energy Team Challenge (see Sections 2.4.3 and 2.6.7).

In order to implement a true "trading" environment, it would be necessary to create a "scarce resource" than may be traded, such as the right to produce particular quantities of CO_2. It is likely that such a scheme would only work if it were coupled with either a regulatory framework with penalties for excessive consumption, or a scheme in which incentives are provided (and traded).

3.8 To what extent can the DEHEMS carbon trading model engage users, and how is this likely to support the creation of a CO_2 trading market place or support trading activity that will encourage absolute CO_2 reduction?

Given the decision taken to trial an incentive scheme rather than a carbon trading model, it is only possible to comment on how DEHEMS Energy Team Challenge might inform the creation of a CO_2 trading market place or support trading activity that will encourage absolute CO_2 reduction. Analysis of questionnaire responses about Energy Team Challenge (see Table 26, Figure 7 to Figure 9, and Figure 25) enables us to draw some conclusions:

- Users reported that participating in a community-based challenge is just as effective a means of promoting behaviour change as actually receiving an incentive
- Participation in a community-based challenge makes users much more likely to view their energy monitoring data (86% of Energy Team participants viewed their data on the DEHEMS dashboard compared with 35% of all DEHEMS users)

- Most Living Labs did not bring their teams together showing that the above positive engagement effects can be achieved with virtual communities

3.9 To what extent has the technical apparatus of the DEHEMS system become 'domesticated' in the homes and home life of the Living Labs participants, and how is such domestication affected by individual's attributes (including gender, age group, and household role)?

Just under 75% of respondents agreed or strongly agreed that (a) the DEHEMS dashboard was easy to use, and (b) the meters, plugs and cabling are simple and straightforward. This suggests that essential elements of the Cycle 3 system – i.e. energy monitoring equipment and visual online display - are largely acceptable, although comments suggest that there is room for design improvements (see Sections 0 and 2.6.8). There is some gender difference in the questionnaire data – with males showing a greater positive response to the above statements, although this may be simply as a result of more males being responsible for installing and maintaining the monitoring equipment and regularly accessing data.

In terms of how people conceptualise the DEHEMS system, there was a stronger tendency towards seeing the system as being like a DVD or satellite TV box than as being like domestic technologies (central heating system or washing machine). This suggests that the DEHEMS system is seen as something new and different rather than as something domestic or familiar. It would be interesting to investigate if greater energy saving is promoted through (a) externalising the monitoring function, or (b) integrating it within domestic appliances and systems.

4. Next steps

This appendix sets out the results of the data analysis that has been carried out in the short time from the end of DEHEMS Cycle 3 to the end of the project. In the process of carrying out this analysis, a great deal of effort has been expended on cleaning up, consolidating and structuring the raw data. The resulting corpus of data resides partly in a Microsoft Access database (quantitative data) and partly in an N-Vivo database (qualitative data). The academic partners are in the process of preparing a number of publications based on this report, and are intending to carry out further analysis in more depth to allow additional research publications to be generated from the project.

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Appendix III Cycle 3 Online Questionnaire

DEHEMS Cycle 3 (Final) Questionnaire

DEHEMS

An EU funded climate change initiative

Thank you for participating in the DEHEMS Project. In order to complete our research, we need to gather information about your use and perceptions of using the DEHEMS System.

This questionnaire/survey contains up to 28 questions designed to help us to do that. Please could you take the time to fill it in as completely as possible; this is a critical element of our project.

Please note that all replies will be treated in confidence, and any results that are produced will not be attributed to any particular household. We do need to know which DEHEMS account a questionnaire relates to, but the researchers who will be analysing your responses do not have access to any link between the account details (MAC Address) and the details of whose household that account belongs to.

Background Information

This information is to help us produce statistical breakdowns. All information in the questionnaire will remain private.

*** 1) Which Living Lab do you belong to?**

○ Manchester ○ Birmingham ○ Bristol ○ Plovdiv ○ Ivanovo

*** 2) What is the income category of your household?**

○ Less than £10,000
○ 10,000 to 20,000
○ 20,001 to 40,000
○ 40,001 to 80,000
○ More than 80,000
○ Prefer not to say

*** 3) To which of the following ethnic groups do you consider your household to belong?**

◯ White	◯ Mixed	◯ Indian	◯ Pakistani
◯ Bangladeshi	◯ Other Asian	◯ Caribbean	◯ African
◯ Other Black	◯ Chinese	◯ Other Ethnic Group	◯ I'd rather not answer

4) How many of the following people (age and gender) are included in your household?

	0-12 yrs	13-18 yrs	19-30 yrs	31-50 yrs	Over 50 yrs
Female					
Male					

***5) Which person in your household was the MAIN person involved with the installation and maintenance of the DEHEMS system (as opposed to using the data)?**

◯ Female 0-12yrs	◯ Female 13-18yrs	◯ Female 19-30yrs	◯ Female 31-50yrs	◯ Female Over 50yrs
◯ Male 0-12yrs	◯ Male 13-18yrs	◯ Male 19-30yrs	◯ Male 31-50yrs	◯ Male Over 50yrs

Comments (For example, did this change over time?):

6) Which people accessed the DEHEMS data for your household more than twice?

	0-12 yrs	13-18 yrs	19-30 yrs	31-50 yrs	Over 50 yrs
Female	☐	☐	☐	☐	☐
Male	☐	☐	☐	☐	☐

Comments (For example, did this change over time?):

* **7) Which person in your household is completing this survey/questionnaire?**

- ○ Female 0-12yrs
- ○ Female 13-18yrs
- ○ Female 19-30yrs
- ○ Female 31-50yrs
- ○ Female Over 50yrs
- ○ Male 0-12yrs
- ○ Male 13-18yrs
- ○ Male 19-30yrs
- ○ Male 31-50yrs
- ○ Male Over 50yrs

* **8) What was/is your strongest motivating factor when considering energy consumption BOTH before and after using the DEHEMS system?**

	Only environmental impact matters	Mostly environmental impact matters	Equally cost and environmental impact matter	Mostly cost matters	Only cost matters
Before ever using DEHEMS	○	○	○	○	○
After using DEHEMS	○	○	○	○	○

The DEHEMS System

This section focusses on your opinion of the DEHEMS system itself.

*** 9) Now that you have used it, when thinking about the DEHEMS system overall, to what extent would you agree with each of the following statements?**

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
The DEHEMS system is experimental technology like a futuristic smart home	○	○	○	○	○
The DEHEMS system is familiar technology like a DVD or satellite TV box	○	○	○	○	○
The DEHEMS system is domestic technology like a washing machine or dishwasher	○	○	○	○	○
The DEHEMS system is household technology like a central heating system	○	○	○	○	○
The meters, plugs and cabling are simple and straightforward	○	○	○	○	○
The website (Dashboard) is familiar and easy to use	○	○	○	○	○

***10) Do you have any issues or concerns about using the DEHEMS equipment in your home?**

○ No
○ Yes

If YES, please give your top three concerns

***11) What is your experience of the following functions of the DEHEMS Dashboard?**

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly Disagree
We found it useful to compare our energy usage against the living lab average (DEHEMS average)	○	○	○	○	○
We found it useful to see what types of homes had similar consumption to our own (Compare My Home)	○	○	○	○	○
We found it useful to compare our energy use against our past energy use (My Energy History)	○	○	○	○	○
We found the energy saving tips provided by the system relevant and useful (Various Screens)	○	○	○	○	○
We found it useful to be able to explore energy usage issues about our own home (My Experience)	○	○	○	○	○
We found it useful to receive warnings about the system operation (e.g. sensor off, broadband off etc.)	○	○	○	○	○

Social Aspects of DEHEMS

This section explores whether and how you have shared information with friends, family and others.

***12) Have you discussed your own home energy monitoring results with other people?**

- ◯ We have actively compared our results with others and found it useful
- ◯ We have actively compared our results with others but did not find it useful
- ◯ We have only mentioned it to others
- ◯ Not at all

Please comment on any information sharing activites you have been involved in where DEHEMS data was discussed:

***13) Has anyone in your household made use of the DEHEMS Facebook Application?**

- ◯ Yes.
- ◯ No, because we don't use Facebook
- ◯ No, because we were not aware of it
- ◯ No, because we use Facebook but did not want to share energy data in this way

***14) Has your household been involved in the Energy Team Challenge? (Carbon Trading page)**

- ◯ Yes
- ◯ No, we didn't have the opportunity
- ◯ No, we didn't want to

Social Aspects of DEHEMS (Facebook)

A few questions about your Facebook use.

***15) How many Facebook friends did you share data with?**

○ None ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 or more

Please comment on how useful this was for you.

***16) How useful did you find the summary at the top of the Facebook page?**

○ Very useful ○ Interesting ○ Of no interest

***17) Did you find the appliance summary in Facebook useful?**

○ A lot ○ A little ○ Not at all ○ Didn't have appliance meters

***18) To what extent do you feel the Facebook App increased your engagement with DEHEMS?**

○ A lot ○ A little ○ Not at all

Please comment about the Facebook App and its use:

Social Aspects of DEHEMS (Team Challenge)

A few questions about the Energy Team Challenge.

***19) Roughly how often did your household look at the Energy Team Challenge pages?**

◯ Daily ◯ Weekly ◯ Monthly ◯ Never

***20) How much do you feel the Energy Team Challenge encouraged you to save energy?**

◯ not at all ◯ some ◯ significantly

Please comment on how this encouraged you.

21) Would the chance of winning a prize have provided an incentive for your household to reduce its energy usage?

◯ Yes
◯ No

Benefits of Using the DEHEMS System.

Here we wish to explore the extent to which you may have benefited from using DEHEMS.

***22) Please list up to four changes that you have made to your use of energy as a result of your involvement in DEHEMS.**

*
*

***23) What do you feel is the main reason for the changes you listed above?**

- ◯ Just generally being involved in the project
- ◯ Having access to our energy data
- ◯ Both of these equally
- ◯ Other (please specify in the comments box)

Comments:

Benefits cont'd (Individual Appliances)

***24) Do you have equipment installed which monitors the energy usage of specific appliances in your home?**

- ◯ Yes
- ◯ No

***25) Do you understand the energy consumed by the different appliances in your home better from using the DEHEMS system? (Please answer this question even if you do not have individual appliance monitoring installed.)**

- ◯ Yes, we know when certain appliances are switched on, and understand now which appliances consume higher energy
- ◯ No, we are not clear on the effects of the different appliances on my home energy consumption

Please comment on your experience

Benefits cont'd (Gas)

***26) If you are one of the households that have gas monitoring, did you find the gas monitoring useful in your DEHEMS installation?**

- ◯ Yes
- ◯ We had gas monitoring, but didn't find it useful
- ◯ We didn't have gas monitoring

Please give reasons for your answer:

***27) In what ways has your gas energy usage changed as a result of DEHEMS? (Please answer this question even if you do not have gas monitoring installed.)**

- ◯ We try to be more careful with gas consumption
- ◯ We have not changed our gas consumption in any way

Please explain the reasons for your choice below:

Finally

***28) Thank you for answering the survey. Finally, is there anything about your DEHEMS experience you would like to share with us, that has not already been covered in this survey? (For example, were you surprised by any of the data you saw about your own energy consumption?)**

*

D7.7 Appendix IV - DEHEMS Cycle 3 Focus Groups

This section describes the methodology and the questions for the DEHEMS Cycle 3 focus group sessions. A general guideline for running a focus group is given in the next section.

Focus Group Participant Selection

We need people from every experiment group, except for the control group. Fresh focus group participants would be good, but if there is a small number from previous cycles, this is still fine. It would also be good if we have a combination of eco-warriors and non-eco-interested people. The total for each focus group should be around 10 people or a little more, including the moderator and one other LL person.

Focus Group Tools

Power point presentation or laptops to present Cycle 3 Dashboard
A couple of Current Cost display units
Refreshments, notepad and pens for the participants.
Suggestion: Gift/Restaurant Vouchers as incentives to recruit participants?

Focus Group Transcription

The session should be recorded and transcribed afterwards. Transcription should clearly state who is talking (Mary, Jane, Tom, etc instead of Man, Woman). Moderator and LL person should clearly be identified so that their responses can be differentiated from those of the participants.

Focus Group Questions

1. How has the DEHEMS cycle 3 system contributed to users' changing their behaviour resulting in reduced energy consumption? What are the key aspects of the DEHEMS cycle 3 system that have helped to achieve this? (Remember to include gas & appliance monitoring)

2. What are the key factors that have affected engagement over Cycle 3? Are there barriers?

3. What are the key factors in the DEHEMS cycle 3 system that affect acceptability to the end users? What dashboard features were useful and what were not – eg. tips & advice? (Please bear in mind that not all planned features were available)

4. For households with gas measurement: how important is it to measure gas consumption besides electricity? Did information on the dashboard about gas usage assist users to change behaviour & reduce gas consumption? (Again, please bear in mind that estimated gas usage figures were not available as planned)

5. How effective is the use of online social networking (Facebook app) in getting users engaged in DEHEMS and how does this compare with engagement of users who are not involved in online social networking.

6. To what extent has DEHEMS encouraged users to become more involved in their communities, both online and off-line?

7. Energy Team Challenge: how can community dynamics influence motivations to move more towards more environmentally motivated behaviours? Is this approach the 'right way' forward in order to achieve the objectives of the DEHEMS project?

8. To what extent has the technical apparatus of the DEHEMS system become 'domesticated' in the homes and homelife of the Living Labs participants, and how is such domestication affected by individual's attributes (including gender, age group, and household role)?

Guidelines on Conducting a Focus Group

This brief note distils some core ideas on how to run a focus group. One important factor is that the participants in a focus group need to be *notified in advance*, and the *venue should be comfortable*, accessible and suitable. Book the room ahead of time and allow enough time for the meeting and a possible over-run of the schedule, just in case.

The room should be well ventilated, well lit and of suitable size, and there should be sufficient chairs. If it is to be a long meeting, consider making refreshments available.

Most people respond best by *interacting around a table as relative equals*. Participants should feel that the discussions are private, ie they cannot be overheard by non-participants. A *confidential environment* promotes free-flowing discussion, which is one of the main points of a focus group.

Advice and proposed structure for a focus group session
1. Before the session: rehearse the ground rules □ Aim for equal participation □ Display respect for others (let them finish what they're saying, no put downs) □ Reflect on potential political or personal conflicts before starting the group □ Devise advance strategies for dealing with these; e.g. seating arrangements; pre-group requests □ Keep focused □ Maintain momentum (don't get bogged down in particular issues) □ Get closure on particular questions so far as possible □ Allow space for both the 'sacred' and the 'profane' It is a great help if, prior to the focus group, you have a chance to meet participants face-to-face. They will then be more at ease when the focus group is held. You can also explain to them the purpose of the focus group, and what will be done with any information which emerges from it. At this stage you may or may not want to tell them what questions will be asked. Giving them prior notice allows them to think about the issues ahead of time. It may also mean that they attend the focus group with their mind already made up; if so, you lose the benefits of cross-fertilisation between participants. I assume that you have chosen the venue to be comfortable, and to offer visual and aural privacy. If group members do not know each other, try to create an informal atmosphere where they are encouraged to talk to each other. It can help to have coffee or orange juice available. Greet them as they arrive, and provide some introductions to get them talking.
2. Introduction: starting off □ Record location, time, date □ Welcome participants □ Appreciate their time □ Review the goal of the focus group □ Introductions – around the table

When the actual session starts, begin by introducing yourself. Let them know briefly who you are, and what your role is in this. For example, are you collecting this information on behalf of someone else, or are you the person who needs the information...

Have a quick round of introductions so that participants have a chance to form a beginning relationship with other participants. Time permitting, it is also helpful to ask them to spend a little time talking to one or two other people -- some relationship with at least one other person will help them to feel less anxious.

3. Establish agenda: why are we here and what will we do?
- Review of agenda
- Review of purpose: why are we here?
- To elicit views on the topic
- There is no right answer to the questions
- Review of activity: what will we do?
- Questions will be introduced and responses encouraged
- Explain the means you will use to record the session (tape? scribe?)

After announcing that people will be given a few minutes to think about the issue, ask your contextual question. Encourage people to take brief notes as an aid to memory. This increases the likelihood that they will speak their own mind and not be unduly directed by the first speaker they hear.

Announce that everyone in turn will be given a chance to speak. Ask participants to take notes on the variety of opinions offered. Say that they will also be given a chance to ask questions for clarification before an open discussion proceeds.

Then invite each person in turn to offer two or three sentences.

After everyone who wishes to speak has said something, allow a few minutes for questions for clarification. No debate is allowed: this is merely to give people a better chance to understand each other before the discussion begins. Supportively and gently correct anyone who either speaks for too long, or tries to debate an issue. As this is the first information collection, what happens here will do much to set the style of the later phases. You have a better chance of collecting good information enjoyably if you can discourage bad habits at this point.

Ask people during the discussion which follows to try to note down the opinions and information which are important. Remind them that you are interested in the range of views, and that you don't expect them to reach agreement.

Then provide a brief overview of the session and its purpose...

- explain the purpose of the focus group, especially the intentions of you and the other people who will be given access to the information
- provide a brief overview of the process; a few sentences is enough, but allow some time for questions
- briefly explain what will be done with the information: how it will be analysed, and what it will be used for
- be clear about whether or not the participants will be identified when the information is passed on to someone else.

Then follow three phases which have a close resemblance. In each, nominal group technique is used to ensure that **all participants have a chance to think through the issues and voice their response**. A **discussion then follows**. Finally, participants are **asked to agree on the major opinions** and themes which emerged. In this way, the information is refined during the different phases, and the participants help in interpreting the information.

An open discussion is held. As facilitator, concentrate on keeping the discussion going while discouraging people from talking too much or debating issues.If this first discussion is slow starting, try asking people to talk briefly in pairs about their views, and then return to the large-group discussion.

CONCLUSION: Ask Question -> Allow thinking time -> Encourage all participants to give brief responses -> Open the discussion -> Get some agreements on issues/topic.

Appendix V

DEHEMS Cycle 3 Data Analysis – SQL Queries

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July 2011

```
/* *********************************************************
Table AVG_DAY_ENERGY: Average Daily Energy in Cycle 3
*********************************************************/

--1. Daily Energy
CREATE TABLE tEnergy_Avg_Day_cnt AS
(
  SELECT mac as MAC, DATE(sample_time) AS Date,
    AVG(ch1_watt)/1000*24 AS `Daily Energy`,
    COUNT(*) AS samples
  FROM cycle3_data
  WHERE ch1_watt > 0
  GROUP BY 1,2
  ORDER BY 1,2
);

--2. Day Map
create table tDate as (select distinct date from tEerngy_Avg_Day_cnt order by date);

--3. MAC Map
create table tMAC as select distinct MAC from tEerngy_Avg_Day_cnt;

--4. Day + MAC Map
create table tMAC_Date as select * from tMAC full join tDate;

--5. Average Daily Energy
create table AVG_DAY_ENERGY as
(
  select tMAC_Date.MAC, tMAC_Date.Date,
```

```
    t1.`Daily Energy`, t1.Samples
  from tEerngy_Avg_Day_cnt t1
  right join tMAC_Date
    on t1.MAC=tMAC_Date.MAC and t1.Date=tMAC_Date.Date
);

/* ************************************************************
Table AVG_WEEK_ENERGY: Average Weekly Energy in Cycle 3
*************************************************************/
--1. Weekly Energy
CREATE TABLE tEnergy_Avg_Week_cnt AS
(
  SELECT mac as MAC, WEEK(sample_time) AS Week,
    AVG(ch1_watt)/1000*24*7 AS `Weekly Energy`,
        count(*) as Samples
  FROM cycle3_data
  WHERE ch1_watt > 0
  GROUP BY 1,2
  ORDER BY 1,2
 );

--2. Week Map
create table tWeek as select week(date) as Week, date as Sunday from tDate group by 1;

--3. Week + MAC Map
create table tMAC_Week as select * from tMAC full join tWeek;

--4. Average Weekly Energy
create table AVG_WEEK_ENERGY as
```

```
(
select tMAC_Week.MAC, tMAC_Week.Week, tMAC_Week.Sunday,
  t1.`Weekly Energy`, t1.Samples
from tEnergy_Avg_Week_cnt t1
right join tMAC_Week
  on t1.MAC=tMAC_Week.MAC and t1.Week=tMAC_Week.Week
);

/* **********************************************************
Table profile: Full Household Information in Cycle 3
************************************************************/
--Dumped from DEHEMS Datawarehouse

/* **********************************************************
Table GROUPING: Experiment Group and Living Lab in Cycle 3
************************************************************/
--1. Create Table
create table GROUPS as (select * from tMAC);

--2. Add Columns
alter table GROUPS
  add column LL text,
  add column CTRL bool NOT NULL,
  add column ELEC bool NOT NULL,
  add column APP bool NOT NULL,
  add column CC bool NOT NULL,
  add column GAS bool NOT NULL;

--3. Update LL information
```

```
/*Note: there are still two households with no living labs allocated AND 1 in "OTHER".
+--------------+-------+------+------+------+------+------+
| MAC          | LL    | CTRL | ELEC | APP  | CC   | GAS  |
+--------------+-------+------+------+------+------+------+
| 001F1F3A4748 | NULL  |    0 |    0 |    0 |    0 |    0 |
| 001F1F3A4790 | NULL  |    0 |    0 |    0 |    0 |    0 |
| 001F1F3A8CDC | other |    0 |    0 |    0 |    0 |    0 |
+--------------+-------+------+------+------+------+------+
*/
update GROUPS t1, profile t2 set t1.ll=t2.lab where t1.MAC=t2.dcid;

--4. Update Control Group information
/*-------------------Birmingham: 7-----------------------
+--------------+------+------+------+------+------+------+
| MAC          | LL   | CTRL | ELEC | APP  | CC   | GAS  |
+--------------+------+------+------+------+------+------+
| 0004A32EAF93 | birm |    1 |    0 |    0 |    0 |    0 |
| 0004A32EB1E1 | birm |    1 |    0 |    0 |    0 |    0 |
| 0004A32EB740 | birm |    1 |    0 |    0 |    0 |    0 |
| 0004A32ED245 | birm |    1 |    0 |    0 |    0 |    0 |
| 001F1F3A5133 | birm |    1 |    0 |    0 |    0 |    0 |
| 001F1F3E262F | birm |    1 |    0 |    0 |    0 |    0 |
| 001F1F3E5C60 | birm |    1 |    0 |    0 |    0 |    0 |
+--------------+------+------+------+------+------+------+
*/
update GROUPS t1, tGroup_Ctrl_Birm t2 set t1.ll='birm', t1.CTRL=true where t1.MAC=t2.dcid;

/*-------------------Manchester: 10-----------------------
+--------------+------+------+------+------+------+------+
```

```
| MAC          | LL   | CTRL | ELEC | APP  | CC   | GAS  |
+--------------+------+------+------+------+------+------+
| 0004A32EAE14 | manc |    1 |    0 |    0 |    0 |    0 |
| 0004A32EAE83 | manc |    1 |    0 |    0 |    0 |    0 |
| 0004A32EB0A3 | manc |    1 |    0 |    0 |    0 |    0 |
| 0004A32EB73B | manc |    1 |    0 |    0 |    0 |    0 |
| 0004A32EB76B | manc |    1 |    0 |    0 |    0 |    0 |
| 0004A32EB7E0 | manc |    1 |    0 |    0 |    0 |    0 |
| 001F1F3A89BA | manc |    1 |    0 |    0 |    0 |    0 |
| 001F1F74397A | manc |    1 |    0 |    0 |    0 |    0 |
| 001F1F7439F8 | manc |    1 |    0 |    0 |    0 |    0 |
| 001F1F743A32 | manc |    1 |    0 |    0 |    0 |    0 |
+--------------+------+------+------+------+------+------+
*/
update GROUPS t1, tGroup_Ctrl_Manc t2 set t1.ll='manc', t1.CTRL=true where t1.MAC=t2.dcid;

/*------------------Bristol: 10----------------------
+--------------+------+------+------+------+------+------+
| MAC          | LL   | CTRL | ELEC | APP  | CC   | GAS  |
+--------------+------+------+------+------+------+------+
| 0004A32EAF23 | bris |    1 |    0 |    0 |    0 |    0 |
| 0004A32EB003 | bris |    1 |    0 |    0 |    0 |    0 |
| 0004A32EB630 | bris |    1 |    0 |    0 |    0 |    0 |
| 0004A32EB769 | bris |    1 |    0 |    0 |    0 |    0 |
| 0004A32EBB54 | bris |    1 |    0 |    0 |    0 |    0 |
| 0004A32ECAA5 | bris |    1 |    0 |    0 |    0 |    0 |
| 001F1F3A4764 | bris |    1 |    0 |    0 |    0 |    0 |
| 001F1F3A8A36 | bris |    1 |    0 |    0 |    0 |    0 |
| 001F1F3A8B6E | bris |    1 |    0 |    0 |    0 |    0 |
```

```
| 001F1F3A8BDC | bris |    1 |    0 |    0 |    0 |    0 |
+--------------+------+------+------+------+------+------+
*/
update GROUPS t1, tGroup_Ctrl_Bris t2 set t1.ll='bris', t1.CTRL=true where t1.MAC=t2.dcid;

/*-------------------Ivanovo: 5-----------------------
+--------------+------+------+------+------+------+------+
| MAC          | LL   | CTRL | ELEC | APP  | CC   | GAS  |
+--------------+------+------+------+------+------+------+
| 001F1F3A8A26 | ivan |    1 |    0 |    0 |    0 |    0 |
| 001F1F3A8A38 | ivan |    1 |    0 |    0 |    0 |    0 |
| 001F1F3A8B70 | ivan |    1 |    0 |    0 |    0 |    0 |
| 001F1F3A8BEA | ivan |    1 |    0 |    0 |    0 |    0 |
| 001F1F3A8BF2 | ivan |    1 |    0 |    0 |    0 |    0 |
+--------------+------+------+------+------+------+------+
*/
update GROUPS t1, tGroup_Ctrl_Ivan t2 set t1.ll='ivan', t1.CTRL=true where t1.MAC=t2.dcid;

/*-------------------Plovdiv: 5-----------------------
+--------------+------+------+------+------+------+------+
| MAC          | LL   | CTRL | ELEC | APP  | CC   | GAS  |
+--------------+------+------+------+------+------+------+
| 001F1F3A510B | plov |    1 |    0 |    0 |    0 |    0 |
| 001F1F3A87FE | plov |    1 |    0 |    0 |    0 |    0 |
| 001F1F3A89F8 | plov |    1 |    0 |    0 |    0 |    0 |
| 001F1F3A8BCC | plov |    1 |    0 |    0 |    0 |    0 |
| 001F1F3A8C18 | plov |    1 |    0 |    0 |    0 |    0 |
+--------------+------+------+------+------+------+------+
*/
```

```
update GROUPS t1, tGroup_Ctrl_Plov t2 set t1.ll='plov', t1.CTRL=true where t1.MAC=t2.dcid;

--5. Update Electricity Group Information
update GROUPS set ELEC=true
where mac in
(
  select * from tGroup_Elec_Manc
  union
  select * from tGroup_Elec_Birm
  union
  select * from tGroup_Elec_Bris
  union
  select * from tGroup_Elec_Ivan
  union
  select * from tGroup_Elec_Plov
);

--6. Update Appliance Group Information
update GROUPS set APP=true
where mac in
(
  select * from tGroup_App_Manc
  union
  select * from tGroup_App_Birm
  union
  select * from tGroup_App_Bris
  union
  select * from tGroup_App_Ivan
  union
```

```
  select * from tGroup_App_Plov
);

-- 7. Update Current Cost Group Information
update GROUPS set CC=true
where mac in
(
  select * from tGroup_Cc_Manc
  union
  select * from tGroup_Cc_Birm
  union
  select * from tGroup_Cc_Bris
);


--8. Update Gas Group Information
update GROUPS set GAS=true
where MAC in
(
  select dcid from profile where gas_id IS not NULL
);



--9. Clean up gas data
CREATE TABLE anomalies AS
(
SELECT t1.SeqID AS seq1,  t2.SeqID AS seq2, t3.SeqID AS seq3,  t4.SeqID AS seq4,
    t1.GasID,
 t1.Time AS Time1,
    t1.`Gas Readings` as Gas1, t2.`Gas Readings` as Gas2,
    t3.`Gas Readings` as Gas3, t4.`Gas Readings` as Gas4
    FROM GAS_READINGS AS t1, GAS_READINGS AS t2, GAS_READINGS AS t3, GAS_READINGS AS t4
```

```
    WHERE t1.SeqID+1 = t2.SeqID AND t2.GasID = t1.GasID AND
          t2.SeqID+1 = t3.SeqID AND t3.GasID = t1.GasID AND
          t3.SeqID+1 = t4.SeqID AND t4.GasID = t1.GasID AND
          t3.`Gas Readings` < t2.`Gas Readings`
    ORDER BY t1.SeqID
);
--Raised values:
delete from GAS_READINGS where SeqID in
(
SELECT seq2 from anomalies where Gas3 > Gas1
);
--Lowered values:
delete from GAS_READINGS where SeqID in
(
select seq3 FROM anomalies WHERE Gas2 < Gas4
);

--10. Get daily minimum and maximum gas readings
CREATE TABLE jGas_MinMax_Day_cnt AS
(
  SELECT GasID, DATE(Time) AS Date,
    MIN(`Gas Readings`) AS `DailyMin`,
    MAX(`Gas Readings`) AS `DailyMax`,
    COUNT(*) AS samples
  FROM GAS_READINGS
  GROUP BY 1,2
  ORDER BY 1,2
);
ALTER TABLE jGas_MinMax_Day_cnt
```

```
    ADD seq INT UNSIGNED NOT NULL AUTO_INCREMENT FIRST,
    ADD PRIMARY KEY (seq);

--11. Get daily gas usage figures
CREATE TABLE jGas_Tot_Day_cnt AS
( SELECT t1.seq AS seq1,  t2.seq AS seq2,
    t1.GasID,
    t1.date AS date1, t2.date AS date2,
    TO_DAYS(t2.Date)-TO_DAYS(t1.Date) AS Days,
    t1.DailyMin as Min1, t1.DailyMax as Max1, t2.DailyMin as Min2, t2.DailyMax as Max2,
    t2.DailyMin-t1.DailyMin AS GasUsage,
    (t2.DailyMin-t1.DailyMin)/(TO_DAYS(t2.Date)-TO_DAYS(t1.Date)) AS DailyUsage,
    t1.samples
    FROM jGas_MinMax_Day_cnt AS t1, jGas_MinMax_Day_cnt AS t2
    WHERE t1.seq+1 = t2.seq AND
          t1.GasID = t2.GasID
    ORDER BY t1.seq
);
```