Glasgow School of Art
POE Methodology Study
Summary (Draft)

MACKINTOSH SCHOOL OF ARCHITECTURE
THE GLASGOW SCHOOL OF ART

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ARCHITECTS

CICSTART
ONLINE

How can Post Occupancy Evaluation help you?
Post Occupancy Evaluation (POE) is the systematic evaluation of buildings in use, from the perspective of the people who use them. It assesses how well the building performs against the design criteria and how well it matchs users' needs. The outcome is a series of actions to improve building design, performance and fitness for purpose.

- POE gives you real data on the building performance to measure against the design criteria

- POE can assist in identifying areas where future stock can be improved

- POE can identify areas for improvement in your Design Guide

- In older properties it will allow you to prioritise areas for rehabilitation and renewal

- It helps educate residents in the efficient use of their house, reducing their energy bills and carbon footprint

- Identifies areas for further information in tenant handbooks and training

- Supports the implementation of your sustainability and quality assurance policies

Outcomes from a POE study

- A measure of actual performance against design performance

- Information for tenants on efficient use of the house

- Priorities for refurbishment (in older properties)

- Actions to reduce tenants bills and improve future housing

Methodology and Testing

Over the summer of 2010 MEARU at Glasgow School of Art and John Gilbert Architects undertook a research project to test a Post Occupancy Evaluation methodology on recently completed houses across Scotland. This involved:

- 8 houses
- 19 residents
- 4 housing associations
- 4 architects
- 9 months

The process considered 3 questions:

- How much energy is a specific dwelling actually using? Compared to Standard Assessment Procedure (SAP) predictions.
- How much energy would we expect to be used in a specific dwelling, in a particular location, occupied by a defined type of household?
- If the actual energy used is significantly different from that expected (either more or less), what is causing the difference?
- What internal comfort conditions are being achieved?

This process is now being offered to housing associations by John Gilbert Architects and MEARU at Glasgow School of Art.

A synopsis of the results are outlined on the following pages.

|	Action	Timescale
1	Coordination and discussion with Housing Association and residents. HA provides original design SAP calculations if available	Week 1
2	Obtain drawings from the architects (if available)	Week 1
3	Install survey equipment and sensors, together with undertaking resident survey.	Week 2
4	Two weeks survey period, data collected remotely from sensors in house.	
5	Resident returns sensors by post	Week 4
6	Survey data collated, follow up phone call to resident to confirm any anomalies. Initial results available to view online.	Week 4 - 6
7	Reports issued: • POE certificate • Residents information sheet • Housing Association information sheet	Week 7

POE typical timescale for a study.

Results

Examples of key points identified by this study include:

- There are wide variations in the actual energy use compared to the predicted emissions, up to 200% in some properties.

- In well insulated houses there is a trend of people keeping the heating on for long periods of time whilst also keeping windows open. This contributes significantly to energy demand.

- Spikes in CO2 were found in houses when the windows were shut in the early evening.This was found for a range of types and is unlikely to be wholly justified by cooking activities.

- The use of trickle ventilation was poorly understood by many residents. Further education on this issue was recommended in a number of cases.

- 24 hour occupation of the houses did not necessarily lead to higher energy costs.

- Average living room temperatures varied between 19.5° and 23°C. Higher temperatures only influenced energy use significantly where there is an indication that windows were open whilst the heating was turned on.

- Houses which kept their bedrooms at a cooler temperature than their living rooms tended to have a lower energy use.

- Taking an average of all results, the actual energy requirements are 5% more than the SAP predictions

The graphs on the right show energy use and indoor air quality, they are benchmarked as a percentage, against the SAP prediction and average internal CO2 levels.


Legend:
- Energy Use (compared to SAP)
- Internal Air Quality (CO2) (compared to rec avg.)
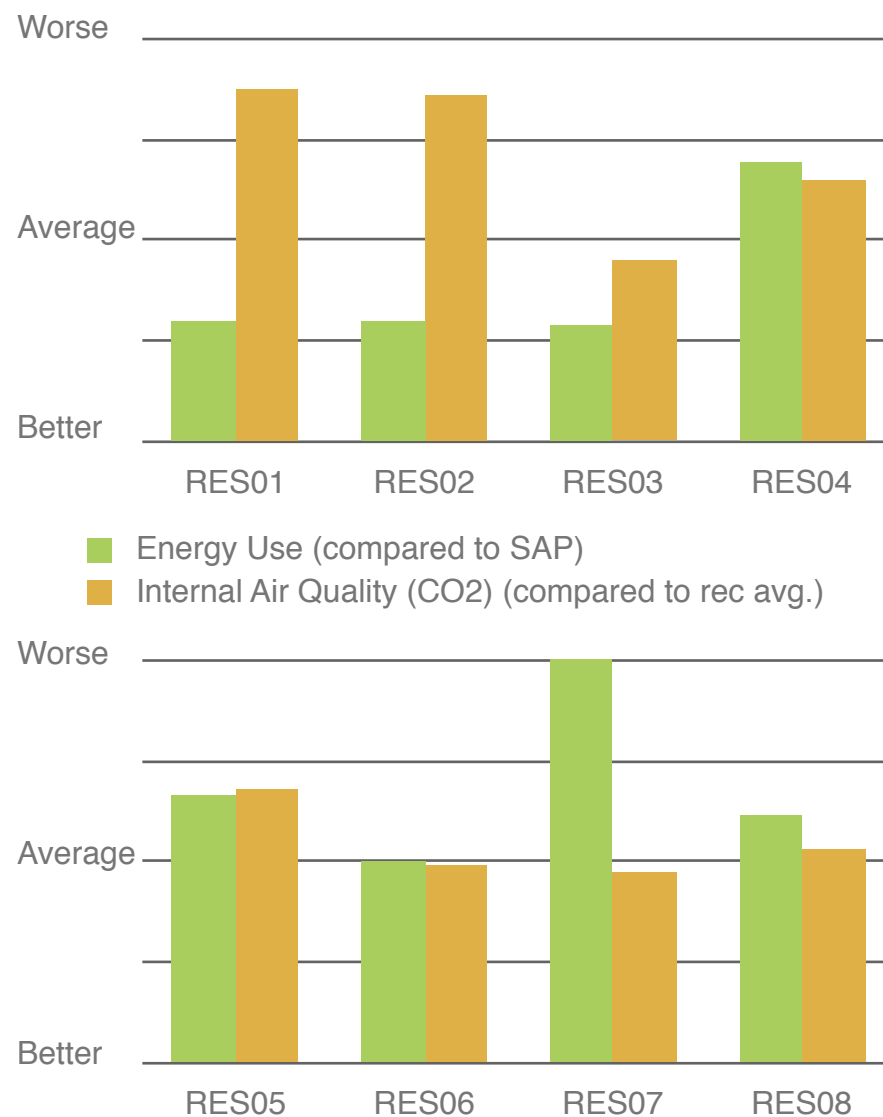
Results from initial projects

Albyn Housing Society
The measurement of these houses revealed lower energy use than predicted by SAP and that the heating system is operating efficiently. Internal air quality was not as good as expected and information on location of clothes drying together with use of trickle vents should be passed to the resident.
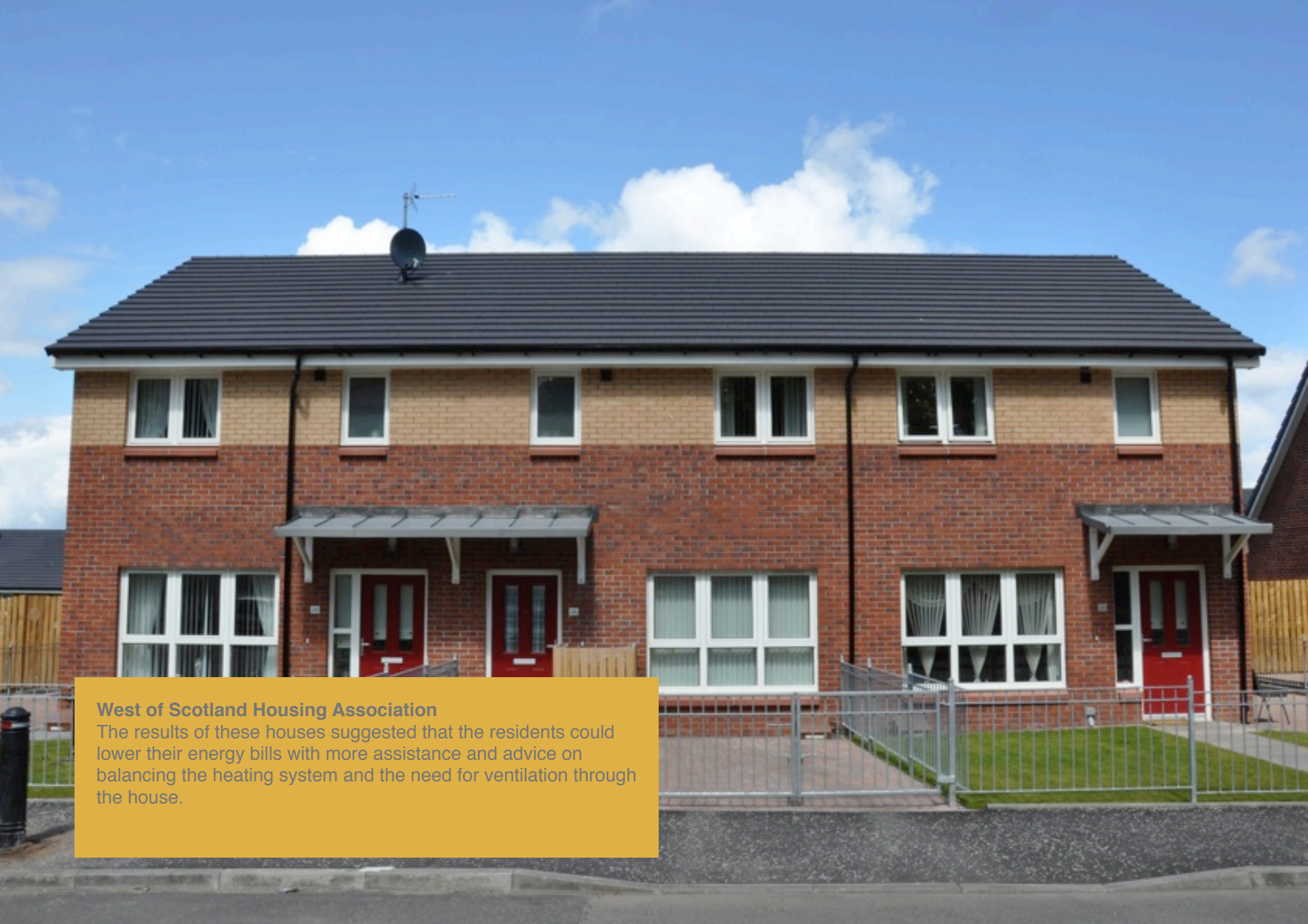
West of Scotland Housing Association
The results of these houses suggested that the residents could lower their energy bills with more assistance and advice on balancing the heating system and the need for ventilation through the house.

Ayrshire Housing Association
Energy consumption was lower in these houses than predicted which could be attributed to solar gain from the large living room windows. Air quality varied due to a resident smoker, this led to windows being opened for ventilation and subsequent high setting on the thermostat leading to overheating.

Ayrshire Housing Association

The lifestyle of the the residents in these houses led to higher energy use than predicted. A young family undertaking significant internal clothes drying and setting thermostats higher than SAP expectations were both identified during the study. CO_2 levels were average due to use of trickle vents and ventilation system.

Hanover Housing Association
The solar water panels in these properties were making a significant difference to residents energy use. Further assistance with optimising the use of the heating system and ensuring the house is not overheated would be useful to minimise residents costs.

Want a post occupancy evaluation undertaken or need more information? Please contact:

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POE Methodology Study

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Contents

1.0 Introduction

This project has been led by MEARU (Mackintosh Environmental Architecture Research Unit) with key assistance from the partner SME, John Gilbert Architects Ltd (JGA). The aim of this feasibility study has been to explore the potential for the development of a cost effective Post Occupancy Evaluation (POE) methodology (with a sustainability focus) that can be used to gather both quantitative and qualitative information regarding housing performance. JGA have assisted in the selection of house types for the pilot monitoring study and have liaised with participating housing providers. MEARU's role has been to gather the data via resident survey questionnaires and durational monitoring of selected housetypes. JGA and MEARU have reviewed the process undertaken during a pilot study of 8 houses to identify key areas for inclusion and most cost effective outcomes for a POE methodology which could be widely used. MEARU has also developed a POE tool and sample template certificate which could be applied to future POE exercises carried out by Housing Associations on their new build housing stock.

2.0 Background to the project

Social housing in Scotland is currently undergoing significant changes in legislation and energy targets. Much of this is being led by the Government through changes in the Building Regulations, and some via changes to procurement practice. However, a significant amount is also being driven by organisations that wish to see high quality thermally efficient housing for the benefit of their tenants.

Innovative housing projects appear frequently claim to achieve considerable energy savings. These are often based on theoretical predictions based on assumptions about their use, rather than on measured data. Certain approaches to building and energy provision may be driven more by contemporary trends rather than by evidence of performance.

There is clearly a need to gain a better understanding of how such buildings are performing in real world conditions. This requires the capture of data on both performance but also human factors in terms of occupancy and behaviour.
There are a number of published post occupancy studies but these are focussed on larger commercial and public buildings. This study undertakes a holistic approach to POE and intends to use the outcomes to widen the understanding of a buildings performance among housing providers.

3.0 Aims + objectives

This study aims to identify a relatively simple POE methodology which is not intrusive on the resident, is cost effective to the housing association and which can provide clear and concise results that can enable landlords and users to improve efficiency, comfort and performance and can provide guidance to housing providers on effective ways to improve both their existing and future housing stock.

This research aims to identify a proposed methodology that can be used to determine energy use in modern highly insulated houses. This methodology addresses three specific questions:

- How much energy is a specific dwelling actually using? (compared to SAP predictions)

- How much energy would we expect to be used in a specific dwelling, in a particular location, occupied by a defined type of household?

- If the actual energy used is significantly different from that expected (either more or less), what is causing the difference?

- What internal comfort conditions are being achieved?

During the pilot study, 8 homes were monitoring and the following data was gathered over a 2 week period:

- Collection of the fuel usage data from meter readings- as these are new build properties, energy from date of occupancy requires to be established.

- Use of a simplified questionnaire to complete face to face with resident to establish occupancy patterns and heating and appliance use. (sample questionnaire attached- Appendix 3).

- Installation of sensors to record temperature and humidity at regular intervals (every 10 mins) in the main living spaces within the house (including living room and bedroom)

- Installation of CO_2 detectors in the living room and one bedroom to give an estimate of the amount of ventilation in the property with data being used in conjunction with occupancy information;

- Obtain hourly weather data to provide comparison between internal and external conditions,

- Obtain copies of original SAP worksheet from architect. Review of the SAP worksheet to obtain the essential heat loss parameters of the house.

- Comparison of actual usage with expected performance, as given in SAP worksheet, plus estimate of energy use for appliances based on the questionnaire.

4.0 Methodology

The following steps were taken to obtain the above pilot study data and to propose a future methodology:

- Review of the methodologies for Post Occupancy Evaluation of new housing by MEARU and JGA

- JGA liaison with Housing Associations across to Scotland to seek their participation in the POE study. This has involved the Housing Association identifying willing residents (from their new build housing stock). Participating HA's- Hanover HA, West of Scotland HA, Albyn HA and Ayrshire HA.

- Formation of a questionnaire to determine occupancy regimes, patterns of use and consumption, users understanding of systems and controls.

- Conduct face to face surveys with questionnaire with 8 residents in their homes to determine occupancy regimes, patterns of use etc.

- Installation of monitoring equipment in each of the 8 residents homes over a 2 week period of time measuring performance in terms of temperature, humidity and air quality.

- Transfer of data to electronic format and analysis of data through graphical representation.

- Gather predicted energy performance data from architecture design team of each housetype (SAP worksheets + Energy Performance Certificates- EPC's).

- Analysis of data to determine performance, identify problems and issues arising, to link aspects of performance, knowledge and behaviour, and to identify possible actions and improvements

- Discussion of evaluation methodology to be used to gather both quantitative and qualitative information regarding housing performance which could be conveyed in a simple format to Housing Associations as a template for future POE studies.

- Identification of areas for further study to refine POE methodology

- Format findings of study and feedback of the results to the participating Housing Associations and present POE methodology tool and certificate template.

4.1 Identification of case studies for monitored projects

The series of 8 case studies were identified based on variables including housetype, geographical location and occupancy pattern. 2 dwellings from each participating Housing Association were selected each which had been designed to have a SAP rating of above 74 (some with renewable devices) and all having been recently completed and occupied for 1 year.

The following case studies were used:

RES01
Housetype- semi detached (3 bedroom)
Rural Location- Glenmore, Aviemore
Construction type- timber frame with timber cladding
Main type of heating and fuel- Electric boiler with slimline storage heaters + biomass stove
Occupancy- 2 adults + 2 children
SAP rating- 74

RES02
Housetype- semi detached (3 bedroom)
Rural Location- Glenmore, Aviemore
Construction type- timber frame with timber cladding
Main type of heating and fuel- Electric boiler with slimline storage heaters + biomass stove
Occupancy- 1 adult + 2 teenage children
SAP rating- 74

RES03
Housetype- Top floor flat (2 bedroom)
Coastal location- Ayr
Construction type- Steel frame with cement render exterior
Main type of heating and fuel- Gas boiler with radiators
Occupancy- 1 adult
Original SAP calc- 74

RES04
Housetype- detached (3 bedroom)
Coastal/Urban sheltered location- Ayr
Construction type- timber frame with brick facing
Main type of heating and fuel- Gas boiler with radiators, Assisted ventilation- positive air supply
Occupancy- 2 adults, 2 children
Original SAP calc- 82

RES05
Housetype- Sheltered housing -Ground floor flat (2 bedroom)
Sheltered urban location- Paisley
Construction type- timber frame with facing brick
Main type of heating and fuel- Gas boiler with radiators and flat plate solar water heating panels
Occupancy- 2 adults
Original SAP calc- 86

RES06
Housetype- Sheltered housing -Ground floor flat (2 bedroom)
Sheltered urban location- Paisley
Construction type- timber frame with facing brick
Main type of heating and fuel- Gas boiler with radiators with flat plate solar water heating panels
Occupancy- 2 adults
Original SAP calc- 86

RES 07
Housetype- End terrace house (2 bedroom)
Sheltered urban location- Rutherglen
Construction type- timber frame with facing brick
Main type of heating and fuel- Gas boiler with radiators
Occupancy- 2 adults
Original SAP calc- 84

RES08
Housetype- Cottage flat (2 bedroom)
Sheltered urban location- Rutherglen
Construction type- timber frame with facing brick
Main type of heating and fuel- Gas boiler with radiators
Occupancy- 1 adult
Original SAP calc- 84

Monitoring period

A two week period was used during the pilot study however a one month monitoring period may be needed to account for seasonal variations and residents holiday. Ideally the monitoring should be undertaken within the heating season of October to May to ensure the results reflect the patterns of heating ventilation and energy use within their home.

Timing

It is proposed that future POE studies are undertaken 1 year after the occupant has moved into the property. This allows time for them to familiarise themselves with heating systems and controls. This also allows the contractor time to complete any snagging issues within the defects liability period and ensures that the resident's experience of their home is not clouded by unresolved snagging issues. Within a year residents can experience a complete heating season and identify patterns of behaviour between summer and winter.

Meter readings taken over the course of one year will give a more accurate annual consumption reading as opposed to taking monthly meter readings and using seasonal adjustment factors.

4.2 Durational monitoring of C02, Temperature and RH levels

Equipment
The following monitoring devices were used within the 8 monitored homes-

- ELTRX250AL Receiver Logger with Alarm
- DARCA+ Darca Plus With Modem Function
- 1000 Series Squirrel Set Up & Download Application For
- Windows 98, Win2000
- GSM-MDM-EXT GSM Modem Kit
- ELTGD-47 Transmitter With Display 3 x Channel transmitter for Temperature/RH/CO2

The sensors were place in 4 key spaces within the property and these varied depending on the dwelling size and occupancy pattern of the resident. The living room and bedrooms are key spaces. Bathrooms and kitchens (except open plan kitchen dining rooms) are omitted due to the nature of activities undertaken in these spaces. Data was logged at 10 minute intervals over a 24hours for a 2 week period.

The CO_2 sensors require a higher degree of power than temperature and humidity and the Eltek sensors therefore require to be plugged in to a power supply therefore the surveyor must ensure that a suitable socket can be identified which allows the sensor to capture the required data accurately (away from direct sunlight and potential heat sources which could affect data). Ideally the sensors should be situated 1m above floor level- this may involve attaching it to the wall with a small panel pin or placing on a table dependant on residents furniture layout. Consideration must also be given to the residents power socket usage and if likely to be inconvenient then a multiplug adapter should be installed.

The advantage of using a radio controlled system is that it allows the surveyor to remotely check that the system is still recording data and that there are no faults or that the resident hasn't mistakenly unplugged any of the sensors or the data logger. Using a GSM data card the monitoring equipment can be called from anywhere in the UK and a simple call to the resident should be able to rectify this. Gaps in data will invalidate the survey results.

As the pilot study showed, this can often happen. RES01 based in Glenmore mistakenly disconnected the logging device and a significant amount of data was lost.

It was also noted during the study that each set of monitoring equipment was both bulky and heavy therefore only 2 installations (or retrievals) could be undertaken in one day. The system required the surveyor to return to the property on a mutually convenient time with the resident to retrieve the devices. Given the geographical location of several of the properties in this study, this had significant travel cost and time implication.

An alternative to the Eltek system would be 'Tiny Tag' loggers which are more discrete and lightweight. It is proposed that if these were used, the resident could actually return them to the surveyor using a self addressed and stamped padded envelope. Sensors which can be returned in post by resident save the surveyor an extra journey. Also smaller battery operated sensors are less likely to be turned off. However this would mean that critical information about air quality could not be collected and even without this, the battery life is limited and the monitoring period could not be extended beyond 2 weeks.

4.3 Survey Questionnaire

The appended survey questionnaire (Appendix 3) was used in this trial. The aim was to develop a series of key questions which specifically targeted energy consumption, air quality, occupancy patterns, appliance use and effectiveness of heating to generate a short series of clear and concise answers from the resident. Previous experience has indicated that residents begin to tire of lengthy questionnaires and responses may become less accurate as the survey progresses.
Whilst the 2 pages used in this questionnaire kept the residents responses clear and concise, there were several key areas which require to be added in. Those include more detailed information regarding occupancy and appliance use to allow a more in depth comparison with SAP predicated energy use and actual energy use.
A revised questionnaire is also therefore appended (Appendix3).

The questionnaire was carried out by the surveyor using a traditional paper format and transferring the data electronically at a later date. However, it is proposed that a more time effective method would be to record survey responses electronically via a laptop or data tablet (ipad) during the face to face interview.

In both this study and earlier survey work undertaken by MEARU it has been observed that residents are much more receptive to participation in the survey and monitoring process if there is an incentive for their input (such as a token shopping voucher). Their willingness to be flexible regarding appointment dates and times and prior sourcing of utility bills is significantly increased!

Care and respect for the monitoring equipment would also be increased- during this study one resident actually unplugged the equipment and left it on the doorstep in a polythene bag as they had to go out unexpectedly on the agreed date of retrieval!

MEARU has previously given £10 TESCO voucher incentives and within this study Ayrshire Housing gave a similar incentive to their participating residents. This would require to be taken into consideration of the overall POE study costs.

Alternatively Housing Associations could give a £10 reduction in rent and write it into the rental agreement that participation in the POE study after 1 year is mandatory.

4.4 Additional Data

Actual energy use - Energy monitoring

During the face to face resident interview the surveyor takes a meter reading from both gas and electricity meters. Assuming the meter was set at zero when the resident moved in and that a confirmation of move in date is noted then an accurate reading of energy consumption over a set period of time can be recorded.

However there are some situations where total energy consumption is difficult to ascertain. Taking readings by this method provides only a total energy consumption and does not give a breakdown of water heating energy demands or appliance energy consumption. Whilst individual appliances could be metered at the power socket an overall appliance consumption reading is more problematic. This then makes future energy comparisons with predicted SAP ratings more problematic.

Total energy consumption of homes heated using fuel including coal, wood or biomass stove (RES01+02) cannot be ascertained unless the resident keeps an accurate diary of fuel purchases but even then the efficiency of the heating appliance requires to be calculated to gain any form of usable data.

There are also some situations where individual energy consumption cannot be ascertained e.g. properties heated via communal heating or energy generation systems, unless alternative metering systems were used, such as heat meters. Properties with integrated renewable forms of energy including solar and wind devices (example-solar thermal plates in RES05 and 06) are not always metered separately.

Predicted energy use-SAP calculations and Energy Performance Certificates

During the study, the architects for each development provided copies of SAP calculations and Energy Performance Certificates.
Whilst the SAP rating on a scale of 1-100 is industry standard it is perhaps not recognised by residents. Neither however, is familiarity with the energy consumption unit of kWh/m^2.

However this study aims to use the kWh consumption value which a resident can relate directly to their fuel bill.

Problems with comparing SAP predicted energy consumption and actual energy consumption.

Appliance Energy Consumption

SAP omits any assumption for energy consumption from electrical appliances. This proposed methodology therefore aims to create a system whereby the surveyor can make an estimation of energy use for appliances based on questionnaire data. This can be used to give a more realistic comparison with actual metered energy consumption data. 1,000- 2,000kWh annually may be considered average consumption but will vary considerably depending on resident demography. For example, the pilot study indicated that RES 01 with 2 teenage children had a

significantly greater number of in energy consuming electrical appliances compared with the elderly couple in RES05.

This proposed methodology highlights the need for questions to be included in the questionnaire regarding key energy consuming appliances (plasma TV's and tumble driers) and these annual consumption rates can be sourced from web site- www.sust-it.net

Occupancy Patterns

SAP 2005 defines standard occupancy patterns as 9 hours a day during typical weekday and 16 hours a day on typical weekend day (During heating season- October- May). SAP standard occupancy regimes can vary significantly from actual patterns dependant on demography. For example, in monitored data RES 05 and 06 are elderly and therefore occupy the home on a 10-24 hour basis.

Weather Data

It is beneficial to have average daily temperatures, rainfall and sunshine hours to reference when undertaking data analysis. Making reference to weather data can assist in the explanation of certain monitored data results such us temperature spikes and changes in RH values (vapour pressure levels).

However weather data has been omitted as part of this simplified methodology. Accurate weather data can be difficult to obtain as weather stations are not necessarily in close proximity to the monitored properties. Whilst it is possible to install external sensors for temperature and humidity, in practice there are problems with this in terms of security for the devices, or inaccurate readings due to proximity to the dwelling.

4.5 Data analysis

During the POE study data is gathered from 3 sources

1. Survey questionnaire (transferred to Excel file)
2. Monitored data- Darca software
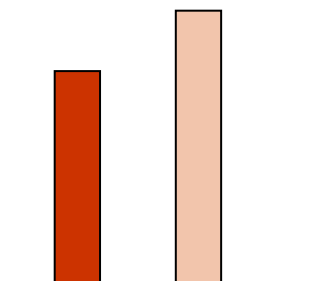3. SAP cals and EPC's from architect (hard copy)

The case studies and pilot study were undertaken to develop methodology not to evaluate particular dwellings, however the attached files in Appendix 2 gives a graphical representation of data in each room and gives a brief analysis of energy consumption and air quality for each case study.

In order to compare monitored data with recommended temperature and C02 levels a simple diagram can compare these results by taking average readings from the 2 week monitored data. For a more detailed breakdown- refer to Appendix 2
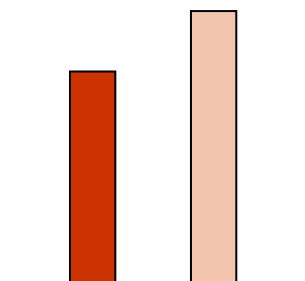
Flat 1/2, 7Sandbank drive

Legend: Kitchen (°C) — Kitchen (% RH) — Kitchen (ppm)
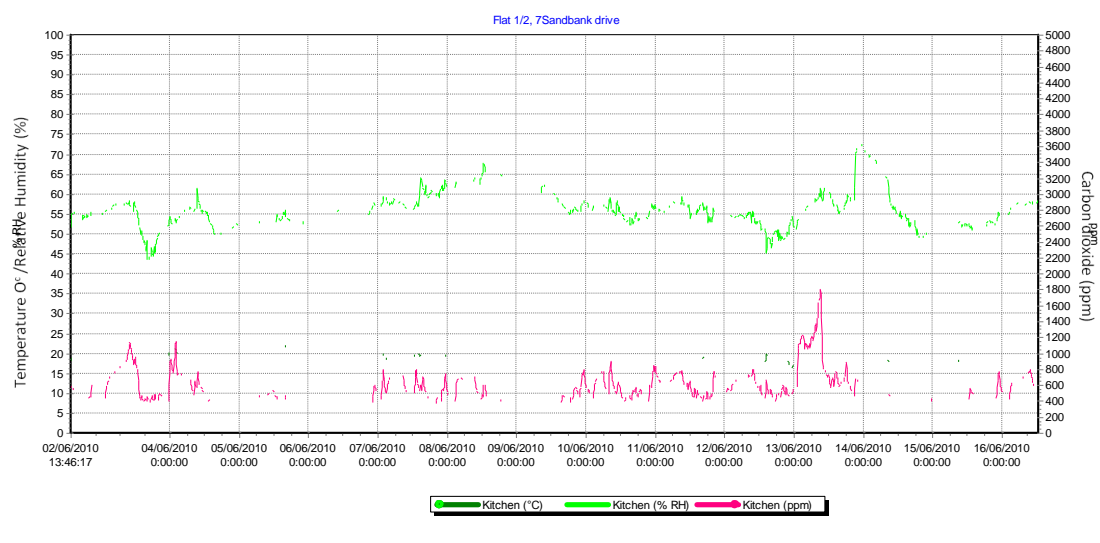
Living Room- C02 (ppm)
Living Room- RH (%)
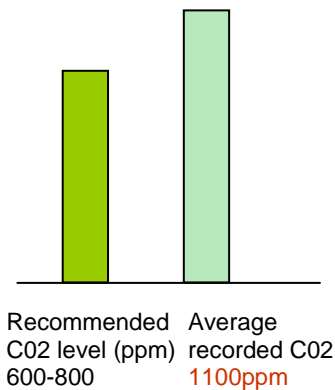Living Room- Temp (oC)

Livingroom Temperature

Recommended temp- 21degrees
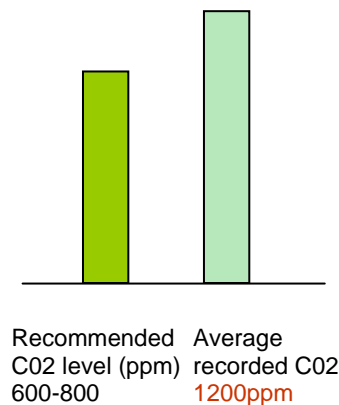
Average recorded temp- 23 degrees

Bedroom Temperature

Recommended temp- 18degrees

Average recorded temp- 20 degrees

Livingroom C02 profile

Bedroom C02 profile

Recommended
C02 level (ppm)
600-800

Average
recorded C02
1100ppm

Recommended
C02 level (ppm)
600-800

Average
recorded C02
1200ppm

Questionnaire is used to build up a picture of how resident uses their home. This then helps to explain (and build up patterns of events and user habits) identified via the monitored data.

5.0 Outcomes

The pilot study:

- Reviewed the POE process to ensure the most cost effective POE methodology could be generated
- Assisted in the development of a detailed questionnaire and a time effective method of capturing data from a face to face survey
- Generated a dataset from 8 house case studies which was used to identify key areas of analysis
- Developed a template which could be used to communicate POE outcomes to housing providers in a clear and concise format.

5.1 POE survey tool and certificate template

In order to translate the data analysis to a usable format for Housing Providers MEARU together with the GSA Visual Communication Department to develop a template to highlight key findings from each of the case study surveys.

The key areas which the certificate would aim to highlight are:

- How much energy is a specific dwelling actually using?

- How much energy would we expect to be used in a specific dwelling, in a particular location, occupied by a defined type of household?

- If the actual energy used is significantly different from that expected (either more or less), what is causing the difference?

- Are there particular problems with environmental conditions or air quality that can be identified?

This would then aim to make a series of recommendations to

1. Housing providers to:

- Address currently in that particular housetype through advice or modifications
- Address in future housing developments

2. Residents- including small measures they could take in their home regarding the use of their heating system, or some of their habits regarding ventilation regime as to increase energy efficiency.

See appendix 4 for a sample of the certificate template and POE animated tool.

This aims to summarise the survey data including designers intentions, occupant comfort and satisfaction and building management. It also helps to identify ways to improve building design, performance and fitness for purpose.

A sample of the type of comments are below:

Advice to HA
Current homes

- Install C02 + temp display units within livingrooms
- Supply air systems
- Ensure all homes fitted with TRV's in each room
- Distribute energy advice sheet to residents
- Installation of communal drying room

Future homes
- Ensure livingrooms benefit from good solar access to max energy heat gains from sun
- Consider district heating system

Advice to resident

- Use trickle vents to ventilate
- Use heavy curtains to keep heat in during winter

Whilst some of this advice is already available to residents via the EPC, the EPC can be difficult for the resident to understand. Many householders are not familiar with rates of energy consumption based on kWh/m2. An overall kWh consumption rate would at least be able to allow them to make a direct comparison with their energy bill.

5.2 Enhanced option of POE study

This study aims to identify an affordable option for POE analysis for Housing providers however MEARU acknowledge that a more sophisticated survey with more

extensive programme of monitoring with specialist equipment could help to identify problem areas in buildings.
These systems could include:
- Thermal imaging survey
- Air permeability – fan pressurisation / tracer gas
- Measurement of in-situ U-values
- Specialist meters to measure consumption of specific appliances

However, it would be easier to target houses that required this type of in-depth analysis if they had participated in a baseline POE which identified that problems might be occurring.

5.3 Areas of Further study

From this pilot study MEARU has identified 3 potential areas which require further research:

POE data tool
We propose that a further study to develop a tool which would integrate survey data gathered on site electronically (ie responses recorded with an ipad) which could integrate with the data logging devices to allow a POE certificate and series of recommendations to be generated. This would therefore negate the time needed for data entry and data analysis phases of each case study property.

MEARU has been working closely with the Visual Communications department within Glasgow School of Art to develop visual information that can explain issues of performance and consumption in a more understandable way, and for a certificate which Housing providers can use the data to quickly identify any energy issues in a quick and easy manner. This form would display the results of the data in a very easy to read user friendly manner and may even be distributed to residents.

Device to calculate overall appliance energy consumption
Another key area of further research identified from this study is a potential method of calculating appliance consumption. Whilst it is possible to meter individual appliances this is not practical at this stage. Comparing SAP predicted energy consumption with actual energy consumption via gas and electricity meters does not give a true comparison due to SAP's exclusion of appliance usage and the current standard energy meters installed in the UK which only recorded total consumption. However there are emerging technologies which purport to use signal processing to identify power consumption of individual appliances.

C02 and temp electronic displays
A final area of research would be to investigate the potential uptake for electronic displays of C02 and temp in each room (perhaps integrated into light switch or power socket). This would allow the resident to get a series of prompts to turn down heating or open trickle vents and windows.

6.0 Project Cost

The proposed methodology aims to be as cost effective as possible whilst producing a valuable dataset.

- 0.5 hour- co-ordination of willing residents with HA, co-ordination of suitable dates with resident.
- 1 hour survey and installation of monitoring equipment
- 1.5 hour travel time (assuming local HA)
- 2 hours- equipment retrieval
- 2 hours -Data entry- and data analysis
- 1 hour- Sourcing of SAP calculations and energy certificates from architects
- 1 hour-Generation of POE evaluation certificate and recommendations

- 9 hours of surveyors time per household.
- £12 per hour- £108 per survey.

Plus
- **Travel cost- £10**
- **Resident incentive- £10**

Ways to reduce costs identifies during pilot study

- Housing Association (HA) to brief resident and co-ordinate survey date and ensures that resident has utility bill ready for inspection.
- HA retains copies of SAP calcs and energy certificates at construction stage and makes these available to surveyor prior to survey date.
- Resident returns sensors in the post negating the need for a 2nd visit by surveyor.
- Surveyor gathers survey data electronically and uses a custom made software tool which analysis data and produces POE certificate and tailor made series of recommendations.

Improved costs

- 1 hour survey and installation of monitoring equipment
- 1.5 hour travel time (assuming local HA)
- 1 hour -data analysis
- 1 hour-Generation of POE evaluation certificate and recommendations

- 4.5 hours of surveyors time per household.
- £12 per hour- £54 per survey.

Plus
- **Travel cost- £5**
- **Resident incentive- £10**

Future Costs
Development of a software tool
Tiny tag sensors
Data recording equipment- Electronic tablet eg ipad

7.0 Appendices

7.1 Appendix1- 8 case studies- monitored data translated into graphical format Including analysis of each housetype with SAP predictions and energy consumption data

7.2 Appendix2- 8 case studies- questionnaire responses

7.3 Appendix3- Sample questionnaire used in pilot study + revised questionnaire – (Excel format)

7.4 Appendix4- POE survey template

8.0 Acknowledgements