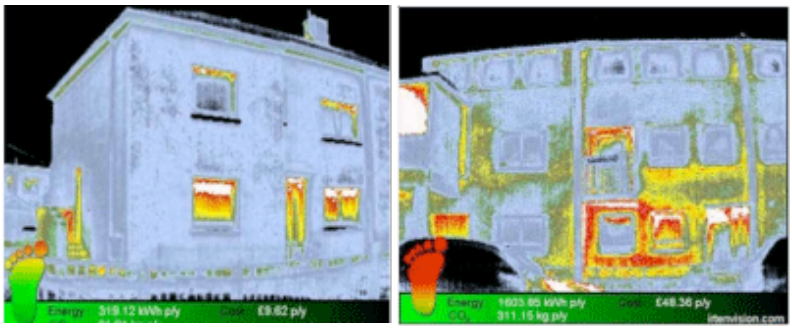

Embedding Post Occupation Evaluation into Practice

An investigation into how POE can be mainstreamed into general practice and be part of an ‘evidence based’ adaptive building standards regulatory framework

Principal Investigators

kraft

Bruce Newlands, Kraft Architecture

MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT THE GLASGOW SCHOOL OF ART

Donald Shearer, Glasgow School of Art
Tom McNeil, Glasgow School of Art

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1.0 Introduction

Post-occupancy evaluation (POE) involves systematic evaluation of opinion & data about buildings in use, from the perspective of the people who use them. (BPE) Building Performance Evaluation is a term also used to describe the process of post completion evaluation, often involving the inspection of buildings one to five years after their completion, and assessment of the extent to which a given building has met its design goals for resource consumption and occupant satisfaction.

For the purposes of this report, we are using the title POE to describe both.

The aim is to assess how well our designed built environment matches users' needs, creating a feedback process that can allow clients, designers, manufacturers and constructors to improve building design, performance and fitness for purpose.

Although the theoretical benefits of this process can be clearly expressed the uptake of the practice has, to date, been relatively limited with no legislative driver and use often limited to demonstrator projects as a way of testing new technologies, typologies and designs.

"The biggest challenge of all is how to ensure that housing occupancy feedback becomes embedded and routine rather than restricted to demonstration or research projects. Should the 'new professionalism' be voluntary or should occupancy feedback be an imposed legislative requirement? There is a legitimate concern that over-regulation will simply result in gratuitous 'tick-box' culture that prevents an intelligent understanding of feedback. On the other hand, it is clear that voluntary occupancy feedback in housing has been languishing for a long time and perhaps the greater challenge is to develop more responsive regulatory processes."

(Stevenson and Leaman, 2010)

Stevenson and Leaman's thinking on the risks of regulating to mainstream post occupancy evaluation are relevant and illustrate the perceived unease in practice and academia that the wider benefits of POE may be passing the mainstream construction industry by.

The additional costs and perceived specialism of POE are certainly perceived impediments to wider uptake.

This report therefore attempts to address these three issues:

1. How can POE be made more affordable.
2. How can POE be made more accessible.
3. How can POE be made a valued routine practice.

Whilst this study is was not conceived of as a 'how to' of POE, our ultimate hope is that is may serve as an opening dialogue with the industry on how to 'mainstream' POE practice and it's benefits.

Ultimately using POE feedback and using a broader scope of performance data that helps define more accurate design assumptions, we can better ensure that regulatory changes, legislative drivers and the solutions we employ will have a real and lasting success in tackling fuel poverty, ill health, build quality, social interaction, energy efficiency and related CO_2 emissions.

In attempting to better understand and illustrate the process, however, it has been necessary break-down and describe the considerations that should be made when planning and executing projects.

In this guise it can be considered as a guide to the process which all stakeholders within the construction industry are welcome to use as such or as a prompt to further discussions about the development, delivery and end use of POE.

2.0 The Existing Context

2.0 The Existing Context

2.1 What is Post-Occupancy Evaluation

POE has been defined as *"an appraisal of the degree to which a designed setting satisfies and supports explicit and implicit human needs and values of those whom a building is designed for"*.

(Friedman et al, 1978)

Put simply, it is the process by which buildings can be assessed to see if they meet the needs of their users and, by proxy, identify any related problems in its ability to meet these needs. The impact that buildings have on their users and on the local and wider environment and the ability to quantify this is becoming increasingly important.

In 2007 the Scottish Government's proposal document for the future of the construction industry, The Sullivan Report, identified the importance of the use of POE for all new energy efficient buildings.

While this recommendation is yet to take the form of any legislative requirement, the role of POE has been clearly stated. In this report, we widen this scope to include POE as a diagnostic tool for 'retrofit' as well as new build, with the potential for the process being used as a crucial tool for identifying issues which impact on the majority of people's lives.

One of the most widely used & respected POE resources is the freely available guidance available at the 'Soft Landings' online portal, supported by BSRIA and the Usable Buildings Trust. The website provides guidance to designers and constructors staying involved with buildings beyond practical completion. It aims to assist the client during the first months of operation and beyond, to help fine-tune and de-bug the systems, and ensure the occupiers understand how to control and best use their buildings. Soft Landings documentation extends the duties of the team during handover and the first three years of occupation, following:

Stage 1: Inception and briefing
More time for constructive dialogue between the designer, constructor and client.

Stage 2: Design development and review
Brings the entire project team together to review insights from comparable projects and detail how the building will work from the point of view of the manager and individual user.

Stage 3: Pre-handover
Enables operators to spend more time on understanding interfaces and systems before occupation.

Stage 4: Initial aftercare
Continuing involvement by the client, design and building team benefiting from lessons learned and occupant satisfaction surveys.

Stage 5: Years 1 - 3 extended after care and POE
Completing the virtuous circle for future projects, to close the loop between design expectation and reality

Examples of POE are available online for a variety of projects but there are very few comprehensive databases or attempts to gather the data, guidance and knowledge to date.

2.0 The Existing Context

2.2 What are the benefits of POE?

Many new and existing buildings do not perform as originally planned either in terms of use or performance characteristics. In some cases this can impact on running costs, end user satisfaction, health, safety and comfort.

For repeat construction clients, specifically registered social landlords with responsibility for large numbers of existing & new build housing stock, learning from and correcting past mistakes in design, retrofit and commissioning of housing can be extremely beneficial for tenants, designers, constructors and landlords alike, reducing call outs, defects and maintenance cycles.

POE can be used as the process of obtaining feedback on a building's performance in use and can;

1. Highlight any recurring problems that can then be addressed and solved.

2. Identify gaps in communication / understanding that impact on the building operation.

3. Provide lessons that can be used to improve design and procurement on future projects.

4. Act as a benchmarking aid to compare across projects and over time.

Through the use of such feedback, POE becomes the mechanism that can allow evidence based practice to develop within the construction industry. This process used in other sectors leads to clear improvement in design, procurement and ongoing upgrades.

POE is a process that should be at the heart of improving performance, quality & cost-effectiveness.

2.0 The Existing Context

2.3 Effective POE

Any process of effective POE has two key components which are required to ensure that the assessment process provides a complete picture of the performance of a building to include both empirical and sensory / perception factors.

These elements are;

1. Collation of end user perceptions of the performance

2. Collection of diagnostic data on actual physical performance

The first of these is critical to ensure that the views and experiences of the end users, those who the buildings are created for in the first place, are considered in the final evaluation outcomes.

The collection of data on the physical parameters can be used to quantify the performance of specific aspects of the building against set criteria or benchmarks which may relate to design performance or to statutory criteria - all of which will or should ultimately impact on the quality of environment which is created for the building users.

This simplification of data collection can be understood in the context of creating occupation models to study individual aspects, what appears to be lost however, is the collection of more holistic & real world data on how occupiers lifestyles may be characterised and limits formed upon those models.

This collection of data can be both narrowly prescribed in terms of measurable specifications and performance but other qualities measures can be used alongside this methodology to help inform how the internal environment is created and sustained by occupants lifestyles and habits.

This is particularly important when we consider those who stand to gain the most from adapting buildings; Groups that spend perhaps longer periods in their homes and includes people with mobility disabilities & illnesses, parents, carers, the elderly and the young.

In these cases we believe that there may also be an need for qualitative post occupancy research exploring design aspects such as space requirements, accessibility, security and wellbeing. Issues that affect strategic design decisions and could inform statutory universal space and accessibility standards by addressing specific user group's needs.

Current POE practice appears to be developed by gathering together a critical mass of small scale testing & research, that often uses (but is not limited) to a narrow methodological criteria measuring physical characteristics of performance. However this often uses simulated occupation inputs and often focused solely on specific issues in isolation such as air quality, energy use, humidity, emissions and user experience (although seldom delving into the physiological issues surrounding comfort).

2.0 The Existing Context

2.4 The Need for Study

Despite being clearly identified as a government priority the uptake of POE is currently limited. Anecdotally this is associated to cost and so this project is aimed at assessing if the process can be made more affordable.

Often POE is deployed on demonstration projects to test how building specifications intended for future adoption will perform, a guinea pig scenario. The industry experience is that forecast design energy usage is usually less than the actual figure achieved and so POE is used as a diagnostic tool to determine actual performance against a model.

Used in this way, post occupancy evaluation is an important method for designers and consultants to gain insight into the relationship between design and actual performance. However, there seems to be no direct input of data gatherers into Government Policy & Strategy and specifically Building Technical Standards.

Given the predominance of 'evidence based' policy making for other sectors including healthcare, it seems peculiar that such methodologies should not be imposed or prescribed for the building sector.

Our concerns therefore centre on exploring how to widen the data collection pool in a secure and anonymous way and how this data might be interpreted and then used by policy makers to improve statutory minimum design standards to tackle areas where evidence suggests housing stock is performing poorly in operation.

For Registered Social Landlords with an on-going duty of care for both their housing stock and increasingly the wellbeing of their tenants, the route to capturing, retaining and then learning from diagnostic and user feedback is difficult, specialist and ultimately often on the periphery of budget considerations.

The value of POE although being increasingly recognised, and becoming in some cases mandatory on many larger public projects only features on small and often special projects within the housing sector.

While the benefits of the POE are widely recognised the proportion of new build projects that go through this process remains very limited. The reasons for this relatively small uptake can be wide and varied but a frequently repeating issue is that it is a prohibitively costly and inaccessibility to a process.

This study aims to define if this perception is one which can be counteracted through focussed investigation of POE approach, monitoring equipment typology and analysis methodology.

The additional costs and perceived specialism of POE are clearly impediments to wider uptake.

This report therefore attempts to address these two issues:

1. How can POE be made more affordable.

2. How can POE be made more accessible.

2.0 The Existing Context

2.5 Aims of this Study

Given the prevailing context this feasibility study investigates whether affordable and practical data logging packages can be identified that allow various construction industry stakeholders to access and use collected data for the purposes of improving design, specification & build quality.

The analysis of this is presented as studies of the main elements of POE in three report sections;

3.0 **Project Planning**
The project duration, user group requirements, focus of evaluation,etc.

4.0 **Data Collection**
The analysis of equipment in terms of cost, ease of installation, use, maintenance etc.

5.0 **Data Analysis**
The investigation on what quality assurance measures would be required for mainstream POE.

The aim of the study is to investigate how improving the accessibility of POE, in terms of capital cost & usability, could help increase the number of clients that will use it as a key process in their business.

As the practice becomes more widespread, this will likely lead to a rapid acceleration in the improvement of technical understanding and design and build quality; a central tenet of the Sullivan Report and the Scottish Government's approach to meeting improved energy efficiency targets.

In addition to mainstreaming POE in terms of cost and usability, we also consider what legislative and/or quality assurance measures are required to ensure data is collected ethically and used appropriately.

This report represents the principal output for the project and identifies the challenges, risks, benefits and opportunities for POE uptake by varied stakeholders.

3.0 Project Planning

3.0 Project Planning

3.1 Duration

Parameters must be set to define the duration of any POE project. Generally this will be informed by a balance being struck between the minimum time required to achieve sufficient data for assessment of the desired outcomes and the funding available to undertake the study.

It is frequently the case that, particularly in these austere times, that funding levels are the principal consideration with other factors falling in line to suit - i.e. the project will run for as long as the budget will allow. There are however several other factors to be taken into account when defining the appropriate length of a POE study. A representation of these are provided by Figure 1, below.

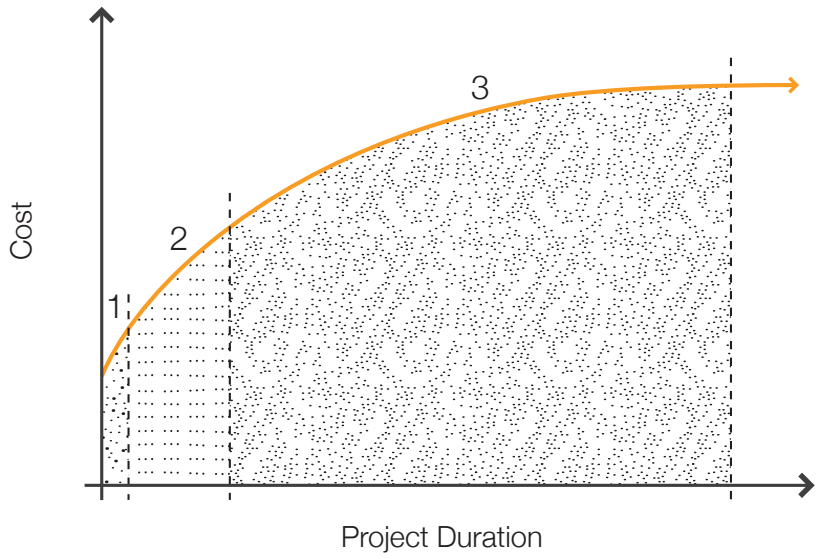


Figure 1. Indicative relationship between cost, duration and project type

POE studies can run for any length of time with the general presumption being that the greater the duration and larger volume of data collection, the more robust the results (Figure 1. option '3'). For example, projects which have recently been funded by the Technology Strategy Board (TSB) very much fall into this bracket as the standard timescale for each assessment is two years.

Projects of this scale are, obviously, expensive but for TSB the justification is there as they are endeavouring to gain as broad an understanding as possible of the performance of new build domestic and non-domestic buildings. To provide as full a picture as possible two full years of data are required to cover all seasonal variation and to mitigate the effects of any weather anomalies that could exist in one single year.

Projects of this duration are unlikely to be feasible to the user groups considered in this study so shorter term projects have a greater relevance.

It could be argued that the methods outlined by the TSB do not necessarily lend themselves to an easy transition towards embedding POE into non-academic bodies / mainstream industry, due to the level of rigour in retro-fitting all the required technology.

3.0 Project Planning

3.1 Duration cont'd

Recently MEARU have undertaken short term POE consultancy studies funded by individual groups, such as Glasgow Housing Association (GHA) and through specific research grants such as those made available by the CIC Start project (the funding body for this feasibility study).

Over limited monitoring periods, typically two to three weeks, these projects have shown the level and quality of data that can be gleaned and the relevance of finding that can be derived (Figure 1. option '2').

From these studies and the subsequent analysis and reporting a strong case has been made for the validity of short term POE. Short-term POE often doe not require 'hard-wiring' by specialists (electricians and plumbers) compared to longer term studies (TSB projects) which often do require it.

Notwithstanding the above, there are limitations on how short a project can be to allow classification as POE.

Studies which represent an instantaneous form of data collection should be dealt with very carefully (Figure 1. 'option' 1). Such 'snapshots' of performance if interpreted with too great a relevance have the potential to provide false or manipulable results. These studies should not be considered as presenting a true 'evaluation' of performance and, it is contended, should not be considered as POE. They can, however, be invaluable in gaining a sense of what the issues within a building are and can point the way towards the focus of a particular study (refer section 3.4).

In addition, consideration must be given to the disruption experienced by residents or occupants.

The shorter and more concise a study can be, in terms of monitoring period and time involvement for questionnaires, diaries, etc, the greater the likelihood of it being successful. This applies to both the initial uptake of residents at project inception and the proportion who will participate to the end of the study period. This last item also has a bearing on the validity of data which can be gleaned from participants where an enthusiastic respondent is more likely to give good (although not necessarily positive) answers and keep accurate records than one who is jaded by the whole experience.

As this study is aimed at investigating the potential for affordable POE the presumption will be that study durations are for short - medium term only (2 weeks to 1 month).

In general terms, and considering the wider scope of POE, it should be noted that the capacity to estimate the appropriate timescale required to undertake a performance evaluation could be very limited for parties with no prior experience of the process. In these instances, input from a more experienced partner could be of great benefit, although not essential, at the planning phase.

3.0 Project Planning

3.2 User Groups

When assessing the opportunity to provide POE packages, consideration was required of the different groups who might wish to train to undertake these studies.

The approach taken was to identify a range of potential users or commissioning bodies in an effort to understand the varied needs these groups may have. With respect to the Scottish construction industry context the following, non-exhaustive, list of relevant bodies was developed

Architectural Practices

Built Environment Professionals

Registered Social Landlords

Private Landlords / Factors

Contractors

Product Manufacturers

Private House Builders

Private Limited Companies

Local Authorities

Although the presented list appears to be relatively compact, it was quickly realised that within each category there would be a huge array of variations with respect to differing requirements.

If, for example, private or register social landlords are considered, this could present a range from small scale domestic landlords (with a portfolio of 5 dwellings, perhaps) at one end to housing associations with many thousands of existing houses at the other.

Given the complex nature of potential client bodies it would seem that a more viable approach would be to carefully consider the nuances and particular requirements of each at the project planning stage.

Project groupings could come close to meeting the needs of several evaluations but it is often the specialist needs that will provide the most significant outcomes and a failure to account for this will limit the success of any individual investigation.

A tailored approach is the most appropriate but, as with the assessment of project duration, is likely to require, or would significantly benefit from, the input of an experienced individual.

This in itself starts to suggest that training and possibly professional qualification is a necessity of POE and needs to be considered within this study if deployment is to be mainstreamed.

Approaches might involve a central register of qualified practitioners open to anyone involved in the built environment and covering approaches to discerning duration and scope of studies for their own particular areas. This might take the form of domestic and non-domestic POE Assessors in much the same way energy certification is currently delimited.

This would allow maintenance officers in larger Housing Associations for example to undergo training and offer the service within affiliated development groups in the RSL Sector or alternatively, allow for the creation of specialist consultants capable of offering quality assured and audited POE.

3.0 Project Planning

3.3 End User Requirements

Each type of client body may have a diverse range of building users or tenants which may have specific needs and requirements which can be even more challenging to effectively deal with than just those of the commissioning party. With any POE (noting the largely residential focus of this study) there will be requirement to understand the complexity of these needs which might ordinarily require consideration of;

Occupancy (Demographic, Employment, Age, Lifestyle, Patterns)

Social (Interactions, Hobbies, Visitors)

Habits (Cooking, Smoking, Washing, Drying, Sleeping)

Thermal Comfort (Physiology, Metabolism)

The above considerations alone present a complex scenario for project planning and analysis but if consideration is also given to any disabilities that users may have then the situation can become even more challenging to evaluate.

Recent work undertaken by Kraft Architecture with the Blackwood Foundation & Housing Association is useful to illustrate the varied conditions which could be experienced by any potential POE project. Many of the Blackwood Foundation's tenants have a variety of long term disabilities including mental illness, cerebral palsy, blindness, and mobility impairment. In such a circumstance the design of the evaluation project must be very carefully considered to ensure that representative and useful data can be collected.

If, for example, end users have dementia then the installation of unfamiliar and unusual looking monitoring equipment could prove confusing and may upset some residents. Similarly, some kit installations may act as obstacles to those with visual impairment and could be hazardous or result in the equipment or data being damaged. Beyond the issues of equipment placement the process of obtaining qualitative data, on end user's own experiences, may not be as straight forward as it could be in more 'mainstream' evaluation projects. With residents suffering from mental illness or learning difficulties it may even be more appropriate to record the perceptions of a carer rather than the tenant themselves. When this would or would not be appropriate is obviously an issue which could be sensitive and, as such, an ability to understand, work with and develop projects around individual's abilities can be central to the overall success of the process.

The work undertaken with The Blackwood Foundation presents a good example of a project where the value of where POE can be used to determine the success of aspects far beyond the more readily tangible (and measurable) aspects of energy use, thermal performance, etc.

It illustrates a situation where qualitative aspects regarding space standards, ergonomics, etc are of equal importance to performance criteria which are more readily associated with POE.

There are many areas that can be monitored, in many cases pre-evaluation, user complaints, anecdotal evidence from carers or indeed physical evidence such as condensation / mould should all be considered as key drivers when designing POE.

The planning and targeting of priorities is a key component of project planning.

3.0 Project Planning

Figure 2. overleaf suggests an example of how a pre-evaluation decision process of prioritisation might be conceived for housing, where excessive indoor humidity is identified as an issue, the occupants health is prioritised over other factors and a selection of evaluation methods.

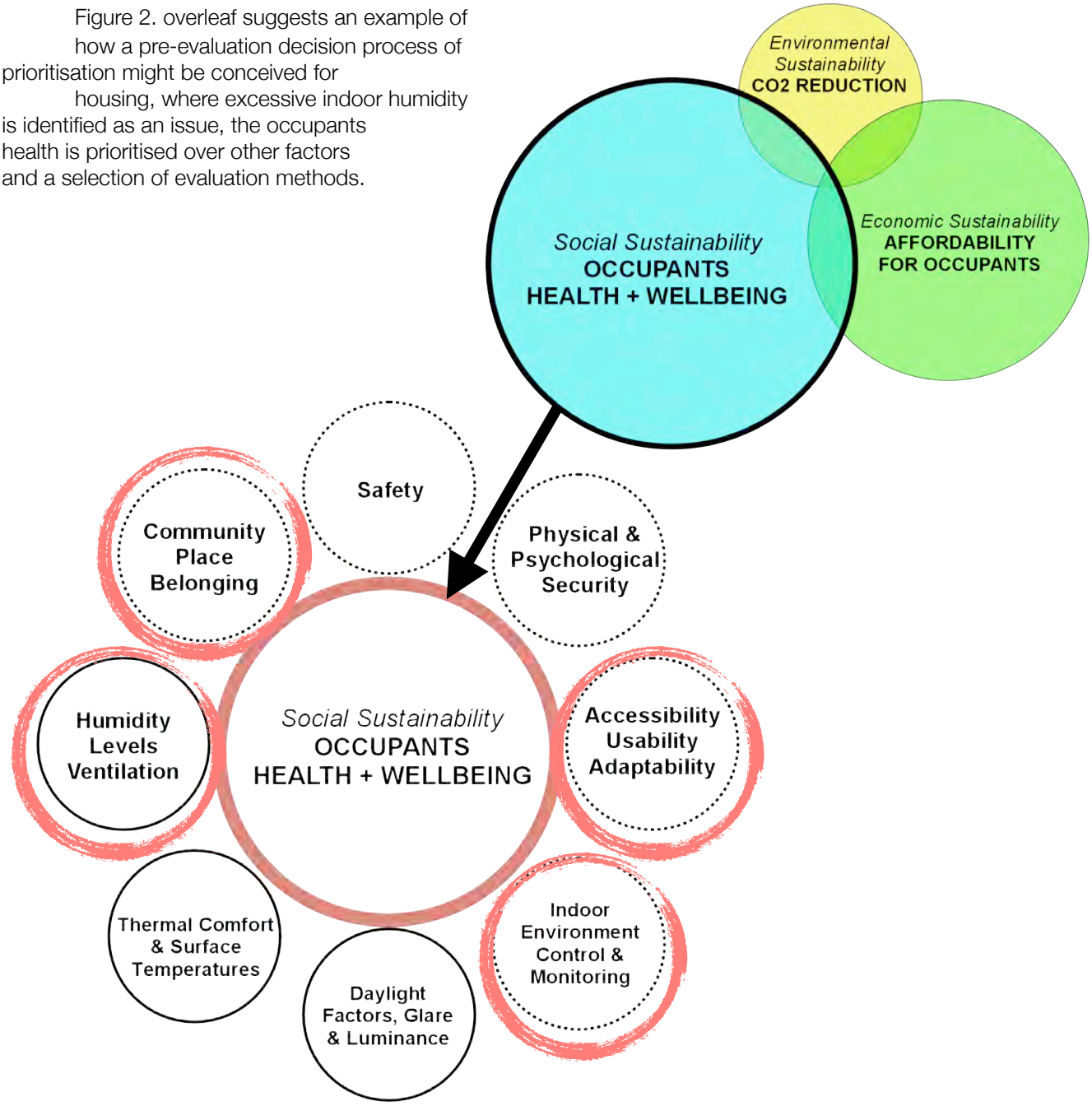


Fig 2. POE Prioritisation on Health & Wellbeing

Qualitative Evaluation by Survey, Interview and Observation

Diagnostic Evaluation by Short-term / Periodic Data Logging

Priorities selected for POE Package based on risk to health & available budgets

3.0 Project Planning

3.4 Focus of Evaluation

With each POE project a defined focus of evaluation will have an impact on the efficacy of the study. With shorter term projects it is essential that a focus is identified as it will allow the most effective use of both time and economic resources throughout the project.

As a guide, a selection of common project typologies is presented below along with a suggestion of the types of equipment which might be used to undertake the assessment.

Thermal Comfort

An analysis of thermal comfort can point the way towards fabric efficiency and effective operation of heating/ cooling systems. The presence or absence of thermal comfort is likely to be one of the key factors which defines a user's satisfaction with building performance. If comfort is easily achieved then users are likely to seek this out, frequently at the expense of increased energy use.

This parameter can be monitored by assessing;

- Air temperature with thermometers or thermistors
- Surface temperature infrared measurement, thermography or thermistors
- Air movement by anenometer

Internal Air Quality

The quality of the air within internal environs can have a significant bearing and impact on the health of those who experience it. Essentially, the quality of air is defined by how 'fresh' and free from pollutants it is. This, in turn, relates to the air change rate of the relevant internal volume.

Poor internal air quality has been identified as causing or stimulating numerous physical ailments and the requirement to understand and address it as an issue is central to good building performance.

It can be monitored by using air sampling equipment to assess levels of carbon dioxide, water vapour (relative humidity) and other potential building pollutants such as radon.

Acoustic Performance

In multiple occupancy domestic situations and other specific typologies the acoustic performance of the structure can be critical to the overall success of the building and the comfort of the occupants. Sound level meters can be used between dwellings and individual apartments to assess if appropriate levels of acoustic separation have been achieved.

3.0 Project Planning

3.4 Focus of Evaluation

Daylighting Levels

In certain work contexts suitable lighting levels have been defined to ensure the ocular health and safety of workers. In the context of healthcare facilities and respite homes, etc, the level of access to natural light can be central to the health and healing process. In all instances the values of this can be measured and recorded by lux meters, pyronometers and other light sensing devices.

The examples above present a sample of common evaluation subjects but obviously other elements may present a suitable focus for a study.

The realisation that this list cannot be comprehensively resolved suggests that a template for small scale POE projects may lack feasibility. It may also not be desirable due to its limitations in identifying the specifics; the nuances of a project that are most important in defining its success.

Energy Use

With the prevailing environmental conditions and publicised government attempts to reduce CO2 output, the significance of any energy use is well understood.

The ability to quantify and minimise this is, therefore, one of the key focuses of POE. Depending on the extent of the the study this can be undertaken at different levels using either main utility metering (simple/ short term studies) or more complex methods of smart metering and sub-metering.

Water Use

Section 7 of the Scottish Technical Standards gives increasing significance to water efficiency, with usage becoming a key metric in the evaluation of a buildings performance.

The ability to quantify and minimise this is, therefore, one of the key focuses of POE. Depending on the extent of the the study this can be undertaken at different levels using either main utility metering (simple/ short term studies) or more complex methods of smart metering and sub-metering.

3.0 Project Planning

3.5 Conclusions

All three of the main elements of POE are of importance and each relies on the other to ensue a successful outcome. Within any project, however, it is obvious that the better the planning phase the more likely a project is to succeed. What's more, the process of ascertaining an appropriate POE process is something that can be packaged as knowledge transfer from experienced bodies already involved with the POE process. This may take the form of continuing professional training modules or alternatively a set qualification administered by a central accredited register, much as energy certification and airtightness testing are currently modelled.

Training to undertake good practice pre-evaluation decision making is particularly relevant to short-term projects where the opportunity to latterly fix or modify the process will be limited by the project duration.

A defined decision making procedure as suggested in Figure 2 could be developed for a wide range of scenarios to assist clients in determining their targeted POE requirements.

Conclusion from this section include establishing the following:

1. Central Accredited Register of POE Practitioners / Assessors

2. Government accredited training programme to widen capacity to deliver POE.

The precise form of these proposals are outwith the scope of this study but there are already examples in industry that provide a sound basis for establishing the necessary vehicles to operate in a competitive market scenario that can work across domestic and non-domestic sectors.

Accreditation would normalise the provision of POE across Higher Education Institutions and in industry, opening up access to the process and ultimately we believe improving the processes currently used by pooling wider experience through an enlarged professional body of practitioners / assessors.

4.0 Data Collection

4.0 Data Collection

4.1 Introduction

The quality of data collected in any POE project is central to the success of the process; as the old adage goes; “rubbish in, rubbish out”. Without a degree of confidence that the data is both relevant and valid then any decisions made on the basis of this data will be similarly questionable.

If these outputs are then to directly impact on design decisions or the wellbeing of residents it is clear that they must be well founded and formed from good quality sources. The key considerations that must be made during the data gathering processes, and where applicable of the equipment that is required to undertake this, are noted in this section with a brief description of the relevance of each.

4.2 Occupant Surveys

As a device to ascertain the more qualitative aspects of the building’s performance, the use of occupant surveys is critical to the whole POE process. Based on the premise that a collation of subjective interpretations can create an objective outcome, the survey process can identify design issues that could otherwise be missed by the collection of physical performance characteristic data only.

In general the greater the number of responses or larger the dataset, the more robust the findings although, it should be noted that, specific individual responses can also be extremely useful in identifying problems in small scale projects. Central to the success of this process is the planning and design of each survey.

The work undertaken with The Blackwood Foundation presents a good example of a project where the value of where POE can be used to determine the success of aspects far beyond the more readily tangible (and measurable) aspects of energy use, thermal performance, etc.

This is something that must be considered relative to the focus of investigation and to the target respondent group as varying levels of complexity and understanding will impact on the quality of data that can be gleaned. It must also endeavour to cover topics which may not initially be obvious to the focus of study but which could ultimately provide critical information in assessing the true performance of a building. In trying to achieve both of these objectives it is also important that surveys do not become overly cumbersome as, in these instances, it is unlikely that occupants will be willing to participate or continue to provide good quality responses.

An unnecessarily onerous survey can also result in large quantities of data which may not be useful to the outcomes but which will certainly slow down the process of analysis and interpretation - data analysis is dealt with in more detail in later sections of this report.

If respondents feel that they are being questioned by those with a direct connection to the building owners, for example, they may have a sense that the anonymity of the process could be compromised and this could impact on the validity of the responses.

Unless anonymous responses can be assured then there is always a risk that participant may give the responses that they think they should rather than being completely honest.

This situation can be mitigated if the surveyors have no direct connection to the building owners, designers, etc. This level of detachment is likely to promote a more honest series of response. It should be noted that this is not simply a one sided situation. It is often the case that residents tend to vent frustrations during the survey process which can negatively skew results. Again this too is less likely to occur if surveyors can assure respondents of their ‘neutral’ position.

In each instance the survey must be carefully designed to ensure that an appropriate level of response can be derived for the focus subject. The design of a targeted survey is a key skill that can be learned.

4.0 Data Collection

4.2 Occupant Surveys cont'd

Fig 3. Example of Survey Considerations / Cause & Effect

4.0 Data Collection

4.2 Occupant Surveys cont'd

There is no one ideal method for identifying human related issues, it varies dramatically depending on user groups experiences and expectations.

Successful surveys benefit from co-ordinators that have research experience in this field and preferably across a range of public and private sector projects. This allows extensive insight and an understanding of typical human behaviours in the scenario of a survey.

Successful methods can include:

Literature reviews
Observational analysis
Persona development
Ethnographic techniques
Task analysis
Questionnaires and surveys
Focus groups
Interviews
Usability Testing
Expert reviews and audits.

Whatever type of assessment is conducted it is of paramount importance that the deliverables produced are tailored to tackling the principal needs of the user and any problems that have been identified in pre-evaluation.

In general, the core skills do often exist in the industry through tenant feedback questionnaires, building management and maintenance departments. However, it's clear that for successful POE, training is required in wider methodologies and how to identify relevant and pertinent methodologies for specific scenarios and end user groups needs.

Training to undertake good practice pre-evaluation decision making is particularly relevant to short-term projects where the opportunity to latterly fix or modify the process will be limited by the project duration.

Training of individuals to undertake what might be perceived as the key methodologies would clearly need to be a crucial component of any formal accreditation training / professional development offered as part of a registered POE Practitioner / Assessor scheme.

Training modules in these techniques could well be received very favourably across the sector from RSL maintenance departments to housing builder sales departments.

Identifying the market for this component would also suggest that their may be an economic model for mainstreaming this component quickly through further education or higher education departments.

4.0 Data Collection

4.3 Monitoring Equipment Considerations

Appropriateness to Focus of Study

During the course of any study it is easy to collate large volumes of data which may not be relevant to the key aspect being investigated. As such it is important to develop an appropriate focus for each study and for this to be supported by the correct equipment. If, for example, early indications point to dwellings having poor thermal efficiency and low internal temperatures then this cannot be monitored with light or sound level meters. This may seem an obvious point to make but it is key suitable kit is specified from each POE project and it relates to a specific research focus.

We would re-iterate the need for good practice a pre-evaluation in selecting the approach to POE.

Capital Cost

As noted previously, cost can be the main factor in determining the duration (and depth) of POE projects with the capital cost of the equipment being one of the most significant outlays. As demonstrated in the Equipment Options (section 3.3) cost effective monitoring equipment does exist but whether this is affordable or not will relate not just to the individual budget but also to the frequency of use.

Kit costing £2,000 may initially seem expensive but if this can then be used in 20, 30 or 40 individual dwellings then the cost per dwelling obviously becomes much more tenable. This is particularly true when considering the cost savings that can be made when POE is successfully undertaken and buildings are subsequently improved.

Ease / Cost of Calibration

Without calibration certainty there will always be a degree of question over the validity of the data that is output from a monitoring project. To mitigate this it is critical that equipment is properly calibrated at all times. While some equipment allows calibration by individuals much of it requires to be done by the original manufacturer and also comes with an associated cost. This process and associated cost should form part of the economic considerations when choosing equipment.

Additional Costs

For some types of equipment there can be associated set-up, software, or annual hosting costs (for digital platforms) which may not be immediately apparent when simply considering the cost of the equipment itself. As with calibration, these costs should be throughly investigated as they could make the difference between whether kit is affordable or not.

Ease of Purchase / Availability / Lead Time;

If more specialised applications are required then some equipment can require to be specifically developed for projects. Even if this is not the case then it can occur that items are not held in stock or readily available and extended lead times can, in some instances, impact on the ability to undertake projects with tight timescales.

4.0 Data Collection

4.3 Monitoring Equipment Considerations cont'd

Ease of Maintenance

Calibration constitutes one aspect of maintenance but over the life of the equipment there may also be requirements to perform other maintenance activities on varied items. These operations may just be as simple as replacing batteries but constitute another element of equipment ownership which should be considered prior to purchase.

Ease of set up

Frequently monitoring equipment is reliant on manufacturer developed software for its operation.

Due to the size of the market, particularly with some more specialist monitoring applications, this software is often far less intuitive or user-friendly than common applications.

While this situation continues to improve, as more development of software interfaces is made, it is likely that a reasonable level of computer competence would be required to set up and operate a significant proportion of monitoring equipment. The usability of these platforms, for some parties, may present an obstacle to the use of equipment generally.

Ease of Installation

The portability and flexibility of the equipment can be central to its success when used in the field.

For longer term projects this can be less of an issue as more permanent installations become more economically viable and suitably robust.

For shorter term studies, however, the capacity to easily transport the kit to site and quickly install it, with minimal disruption to the resident's life, can make a significant impact on the success or failure of the data gathering process.

Energy Source

The power requirements and energy source for any installed equipment can also have a significant bearing on the project success. This can relate to both the flexibility in equipment position and the willingness of participants to allow the installation. If monitoring kit requires a mains power supply then this can limit the scope of suitable positions.

In this instance the final placement can often be dependant on the position of a free plug space which may not necessarily coincide with the optimised monitoring location. It can often mean that monitors are placed within proximity of heat producing equipment or at altitudes that would otherwise be avoided.

In addition, when equipment is plugged in it has a visible connection to the mains electricity which can be concerning to some residents, particularly those on a low income, as they have an awareness that by allowing the installation they will be paying for the consumed electricity - a not unreasonable concern.

4.0 Data Collection

4.3 Monitoring Equipment Considerations cont'd

Wireless Capability

The majority of contemporary monitoring equipment has the capability to work wirelessly from sensor to logger. While this presents greater flexibility, as noted above, it can result in data being lost as wireless signals can drop out of range or be interrupted by the vast array of other wireless signals competing for the surrounding space.

This situation can be improved by testing prior to installation but it is difficult to completely overcome (unless using a more cumbersome wired system) due to the way in which residents use their dwellings.

Data Range, Sampling Rate and Accuracy;

For effective data outputs it is essential that consideration is given to the data range sampling rate and accuracy of the specified equipment. Many CO_2 sensors, for example, have a range up to 2000ppm.

In recent studies by MEARU of new build housing, CO_2 levels well in excess of this have been identified. Without the correct data range recording of any levels above this would essentially have been omitted and the usefulness of the returned data would have been greatly limited.

Similarly the sample rate (every second or every hour) and monitor accuracy are essential aspects to be considered relative to each project and the appropriate equipment choice.

Logging Capacity

Most logging devices have a finite memory allocation which will generally relate to the sample or logging rate frequency. This can invariably be manually adjusted but it is important that the logging capacity is always sufficient for the task in hand and also allows for some contingency. Without this insufficient data may be collected for the whole monitoring duration.

Data Security

In any POE project the recorded data is the most valuable element.

Equipment can be replaced or repaired but if the data is lost or invalidated then the only option is to run part or all of the project again. It is critical that data is downloaded as soon and frequently as is practical and that it is then securely stored ideally in more than one physical location.

When data is being stored it is also important to be aware of the requirements of the Data Protection Act (1997) and to ensure project participants are not identifiable and that sensitive data cannot be accessed by those without permission.

4.0 Data Collection

4.3 Monitoring Equipment Considerations cont'd

Vulnerability

During the course of a monitoring project any equipment interference from building users can have a significant impact on the recorded values or, depending on equipment type, can affect if it records anything at all.

Any kit which has operable buttons or is mains powered can fall victim to occupant action whether it is accidental (a plug being switched off) or just through the occupants being inquisitive (toddlers being attracted to a new 'toy').

There will also be instance where certain user groups (dementia sufferers for example) may find a new object confusing. In all cases the less obtrusive the equipment is the better and this should be considered at project design stage.

Data Accessibility

As a similar issue to the ease of set up, the way that data is downloaded can be reliant on the abilities of the user to work with various software platforms which may not be user friendly or representative of a fully automated process. In addition, once data has been extracted it then has to be put into a form (graphic or otherwise) that aids understanding and analysis.

The complexity of this process varies depending on the depth of investigation being undertaken and the type of equipment/ software being used. It can however represent a significant portion of the project time resource and is dealt with in further detail in section 5.1.

4.0 Data Collection

4.4 Equipment Options

One of the key questions of this report relates to the affordability or cost of equipment packages.

As an aid to equipment selection a cost matrix was developed (refer Appendix A)

If a simple POE is assumed for a single dwelling with project focus on the internal air quality then a suitable package of equipment would require;

- 1no. data logger
- 3no. temperature, relative humidity and carbon dioxide sensors
- 3no. window/ door state loggers
- 1no. external temperature and relative humidity sensor

In addition to this there would also be a requirement to purchase software to allow the download and analysis of the recorded data and, assuming this package is for a new POE user, costs associated with equipment training.

The cost of this package, relative to the values provided by Eltek Data Loggers, is noted below.

Equipment	Cost (£)
RX250AL data logger	£1,080
3 x GD47 wireless temp, RH & CO2 transmitter	£1,575
3 x window/ door state logger	£660
External temp & RH transmitter	£430
Half day training	£250 approx.
Total	£3,995

Table 1. Indicative costs for ‘simple’ POE equipment package

NOTE: The information presented above is not intended to provide a solution to individual monitoring projects but to raise awareness of the issues that are relevant to all POE installations. Through a consideration of these matters it was hoped that those investing in monitoring equipment will have sufficient awareness of the relevant issues and, therefore, be able to make informed and appropriate choices.

4.0 Data Collection

4.5 Conclusions

At almost £4,000, we feel that this represents a reasonably affordable POE package for larger registered social landlord maintenance department or private consultant offering a repeat POE service.

As well as undertaking research in environmental architecture, MEARU are frequently employed to undertake POE projects using the equipment of the type detailed in Appendix A.

When preparing tenders for these projects the cost of the use of existing equipment is assessed against the residual value of that equipment - a percentage of the original purchase cost. For the scenario detailed above the effective rental of the equipment by the commissioning party would represent a sum of around £750 (based on 20% of residual value and noting the omission of training costs).

If a daily rate of for example £300 is assumed for the consultancy then it is likely that the cost of the entire service for a single short-term POE would be less than the capital cost for the equipment alone, this value is ,however, diminished when repeated use is considered.

The repeated use of such equipment by an RSL on it's own housing stock for instance and with in-house trained and accredited staff could result in significant data collection at reduced costs when compared to using higher education or consultants.

The quality of data derived from any POE project is of critical importance; this is equally applicable to both monitored data and survey responses, the input of suitably trained and accredited individuals, whether in-house or external is a necessity.

The design and execution of occupant surveys is obviously something which can be undertaken by any party but questions remain over whether they should do this. If there is only one opportunity to survey building users then it is required that the survey is suitably focussed and concise yet simultaneously records all of the responses required for the project. Being able to achieve this in one 'hit' is can be more difficult than it might first appear and, therefore, as with project planning, the input of suitable trained and accredited individuals is a necessity.

With respect to monitoring equipment options it is clear from this investigation that a vast array of considerations must be made when selecting any form of device.

Generally the complexity of the data gathering process is such that it requires training and an accredited body to oversee and ensure quality assurance across the sector, this includes the higher education institutions and research bodies that currently undertake the majority of POE.

Our conclusions again, steer towards establishing this framework:

1. Central Accredited Register of POE Practitioners / Assessors

2. Government accredited training programme to widen capacity to deliver POE.

5.0 Data Analysis / Reporting

5.0 Data Analysis/ Reporting

5.1 Analysis Issues

The data analysis and reporting phase is the point at which all relevant project performance information is collated and assessed to extract key activities, events or findings which can identify both good and bad aspects of building performance. It is likely to be the key output from any project.

As it is the outcome of the analysis phase that will ultimately define any alterations that are made to a particular building, or future designs, the importance of this activity cannot be underestimated.

With such an important input into the whole performance evaluation, key questions arise which must be addressed in assessing how this process is undertaken. Each of these areas should be considered and resolved at planning stage for each individual project.

5.2 Timescale and Resource

Depending on the depth of investigation being undertaken the time required for data analysis can vary greatly. As a process it can be aided by having a specific focus of investigation or question to answer, software that can speed up the data visualisation and also by working with developed project methodologies (i.e. previous experiences and reporting templates).

For short term projects (circa 2 week monitoring) the process of data download, analysis and reporting may take the same amount of time again even when being undertaken by experienced evaluators.

Practical training & assessor testing would be necessary to avoid underestimating at planning stage.

5.3 Who Can Undertake Analysis

In practical terms there is a basic mechanical requirement to be able to operate relevant software platforms, to manage the recorded data and to produce suitable outputs for analysis. This requires a certain level of hardware & software competence, something that can be taught & tested on a regular basis with input from experienced practitioners and an accreditation body with minimum continuing professional development requirements.

Beyond this any potential evaluator requires an ability to read the outputs and interpret them into meaningful outcomes or to suggest reasons why certain phenomena may have occurred.

This part of the process is probably the key element requiring extended training in building physics, environmental science and professional judgement, possibly requiring professional indemnity insurance.

In terms of professional ethics / conflicts of interest, a code of conduct associated with a central audited register of qualified assessors would clearly be required. This currently exists in almost every other profession within the building industry but does not explicitly exist at the moment for practitioners of POE. We feel that this would be a welcome addition and would help mainstream the practice and give commissioners & most importantly end user groups an assurance of quality and independence. This is particularly important if the process is to be undertaken by parties who have a vested interest in reporting positive outcomes (or perhaps not identifying negative outcomes) of the POE. A commitment to acknowledge all findings would be required as part of the ethical process but this could also be supported by a greater uptake of POE and an acceptance from stakeholders that identifying problems in the short term is the only way to develop long term benefits. This, in turn, requires a dramatic shift change in the blame culture which can exist in the construction industry.

A clear route of complaint is an essential attribute of any regulated profession.

In addition to this, further consideration perhaps need to be given to the potential end use of POE, it is in effect evidence and could be used in litigation against designers to substantiate claims of negligence of incompetence when dealing with complex building and occupation patterns.

Tackling the are of indemnity for carrying POE is beyond the scope of this report but we highlight here as a critical issued that may determine uptake & engagement of POE processes.

5.0 Data Analysis / Reporting

5.4 Pooling Data

There may be merits in sharing anonymous data to help compare and identify patterns in a larger data set.

Anonymity may help alleviate any anxiety about a 'blame culture' arising from a greater uptake of diagnostic POE and the use of forensic building science in determining defective work.

There are current, albeit limited, examples of this shared & anonymous approach.

BRE, UCL, CIBSE and RIBA have launched Carbon Buzz, an online free platform that collects anonymous building energy consumption data to highlight the performance gap between design figures and actual readings. The site invites users to go beyond compliance and refine estimates to account for these when predicting energy use. Registered users can find out how a building performs against others, compare design estimates against operational energy use, study the end use composition of other projects and track the design and actual CO2 emissions of a portfolio of buildings.

The Technology Strategy Boards Retrofit for the Future database openly published the results from the programme, where details of the project, design team, approach and diagnostic data are readily available.

This approach was possible perhaps because of how the data gathering was implemented as part of a wider project that openly accepted risk and understood that construction can often be inherently innovative and novel where new materials, techniques, approaches are trialled.

Another initiative called the Carbon Portal & Home Insulation Pilot and assisted by Scottish Federation of Housing Associations (SFHA) gave housing associations across central Scotland access to free thermal imaging surveying of their existing housing and office stock to help identify defects, cold bridging and properties that may be affected by poor indoor environments.

Recently, Arup have introduced the 'BUS Methodology' (www.busmethodology.org) - an innovative approach to providing a way of logging multiple occupants perception of their environment through use of survey techniques.

Arup provide training, a range of costs / scales and the technical assistance to report on the data gathered.

This type of service provider approach could well be the future of large scale POE, with professional technical consultants providing support for organisations to conduct a variety of POE techniques across their building / housing stock.

Whilst there may be concerns over how this data is retained & verified in these collective initiatives, the model itself opens up an interesting dialogue about how anonymous POE data could be embedded in statutory policy making and influence decisions on future building regulations.

Such a platform could be easily integrated with a Central Accredited Register of POE Practitioners / Assessors and statutory requirements to sample POE all new build and refurbishment works.

An accessible database of POE feedback and analysis could help focus regulation of key issues affecting occupant health, material selection, thermal standards and improve build quality by identifying where design and construction mistakes are being regularly made.

Many of the initiatives noted above are in their infancy. A detailed review / critique of each is beyond the scope of this report, however the aspect of pooling of data is an important one that will, we suspect, become increasingly important in mainstreaming POE with public sector clients like Housing Associations & Local Authorities. Whilst it is difficult to summarise the potential impact of this open source way of collecting data, it intrinsically tackles two key issues, cost & accessibility.

5.0 Data Analysis / Reporting

5.5 Conclusions

Training, continual professional development and an audited quality assurance would appear to lie at the heart of how POE might be mainstreamed. The training would need to cover both the theory of building physics and the practicality of diagnostically assessing buildings. Individual bodies would have to assess whether this level of commitment is feasible when set against their own requirement for POE.

A regulated professional and accredited body would be required to undertake training, maintain standards and ensure that assessors act independently and within a clear code of conduct to ensure commissioner and end users are assured of the validity and extent of outcomes. In this context there should also be an acknowledgement of where conflicts of interest can exist. It is also likely that practitioners would require professional indemnity insurance where investigations reveal building defects and solutions are proposed.

There are models already in practice of how this might operate.

The collection of data from a wider pool could be positive in avoiding specific issues but identifying patterns of poor practice / technique or tradition in the construction sector.

Identification of poor practice could assist the formulation of specifically targeted Building Standards.

6.0 Project Conclusions

6.0 Project Conclusions

The importance of POE is unquestionable and the prospect that any other industry would attempt to operate without a feedback loop for quality improvement doesn't seem to be a viable future.

This study has attempted to identify actions to mainstream POE.

Qualified POE Practitioners / Assessors

The analysis and description of the POE process identifies the level of complexity involved and strongly suggests that training and accreditation are necessities. The training may need to be modular, post-qualification and cover a range of elements from qualitative surveying techniques through to diagnostic building performance surveying.

We feel that establishing such courses would bring wider benefits to all sectors of the Construction industry from site foreman to commissioning client as well as training a larger number of POE Practitioners / Assessors with comparable industry recognised qualifications.

Training providers could be higher education institutions, further education institutions, professional bodies, accredited bodies and private training businesses.

Regulation

"The biggest challenge of all is how to ensure that housing occupancy feedback becomes embedded and routine rather than restricted to demonstration or research projects. Should the 'new professionalism' be voluntary or should occupancy feedback be an imposed legislative requirement?"

(Stevenson and Leaman, 2010)

A regulated professional and accredited body would be required to regulate the content of the training, maintain standards and ensure that assessors act independently and within a clear code of conduct to ensure commissioner and end users are assured. Many of the elements of testing which can be applicable to POE already have well developed processes, thermal imaging for example, and member bodies, such as ATTMA, which provide a degree of quality assurance to customers. The remit of other bodies undertaking energy certification such as RIAS, NHER & BRE could be expanded.

These bodies have a pool of expertise in practice, codes of conduct and quality assurance in place.

They are open to those from out with the professions to become accredited members following training, testing and subscription to ongoing continuing professional development.

An expansion of these bodies, or development of a new body to specifically cover POE would provide the level of assurance required to counteract issues of objectivity and could support stakeholders by offering training and development to the recognised levels required to undertake the process.

With this in place the door could be opened for varied stakeholders to confidently and effectively perform POE.

Insurance

It is likely that practitioners would require professional indemnity insurance where investigations reveal building defects and solutions are proposed.

There are models already in practice of how this might operate.

6.0 Project Conclusions

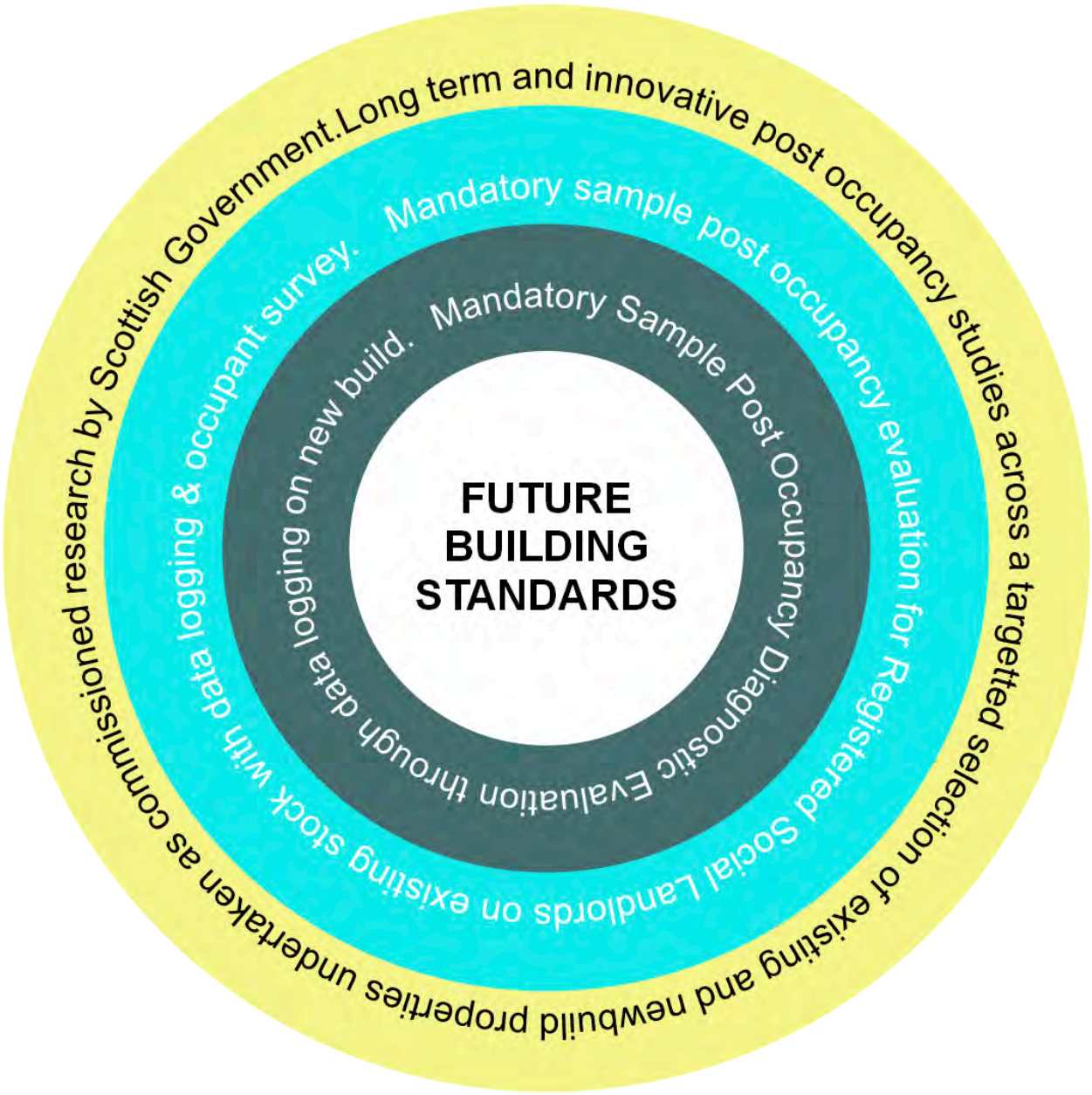


Fig 4. Example of evidence based adaptive Building Regulations

6.0 Project Conclusions

Statutory Requirements

The importance of POE must surely be acknowledged by the development of standards and processes that help to assure the quality of outputs.

Airtightness testing is currently undertaken as a sampling of new build.

Once no airtightness testing was undertaken.

Taking this analogy, the approach to achieving the mainstreaming of POE is as a stipulated part of legislation, written into the Scottish Technical Standards and undertaken as a sample of new build.

It would tangibly support the moves of the Government with regards to meeting their targets for improved energy efficiency of new buildings - something which many would argue is currently being met on paper but not necessarily in practice.

For the purposes of the regulations, POE may be a very limited diagnostic form, simply measuring as built performance against design specifications:

- Insitu U values
- Ventilation Rates
- Daylight Levels
- Humidity Levels
- Indoor Air Quality

Clearly, as a statutory requirement, the practice of POE would quickly become mainstream with a market created for accredited body and assessors and the growing capacity to undertake longer more in-depth studies which in turn inform building standards.

Data Pooling

The collection of data from a wider pool could be positive in avoiding specific issues but identifying patterns of poor practice / technique or tradition in the construction sector.

An accessible database of POE feedback and analysis could help focus regulation of key issues affecting occupant health, material selection, thermal standards and improve build quality by identifying where design and construction mistakes are being regularly made.

Identification of poor practice could assist the formulation of specifically targeted Building Standards.

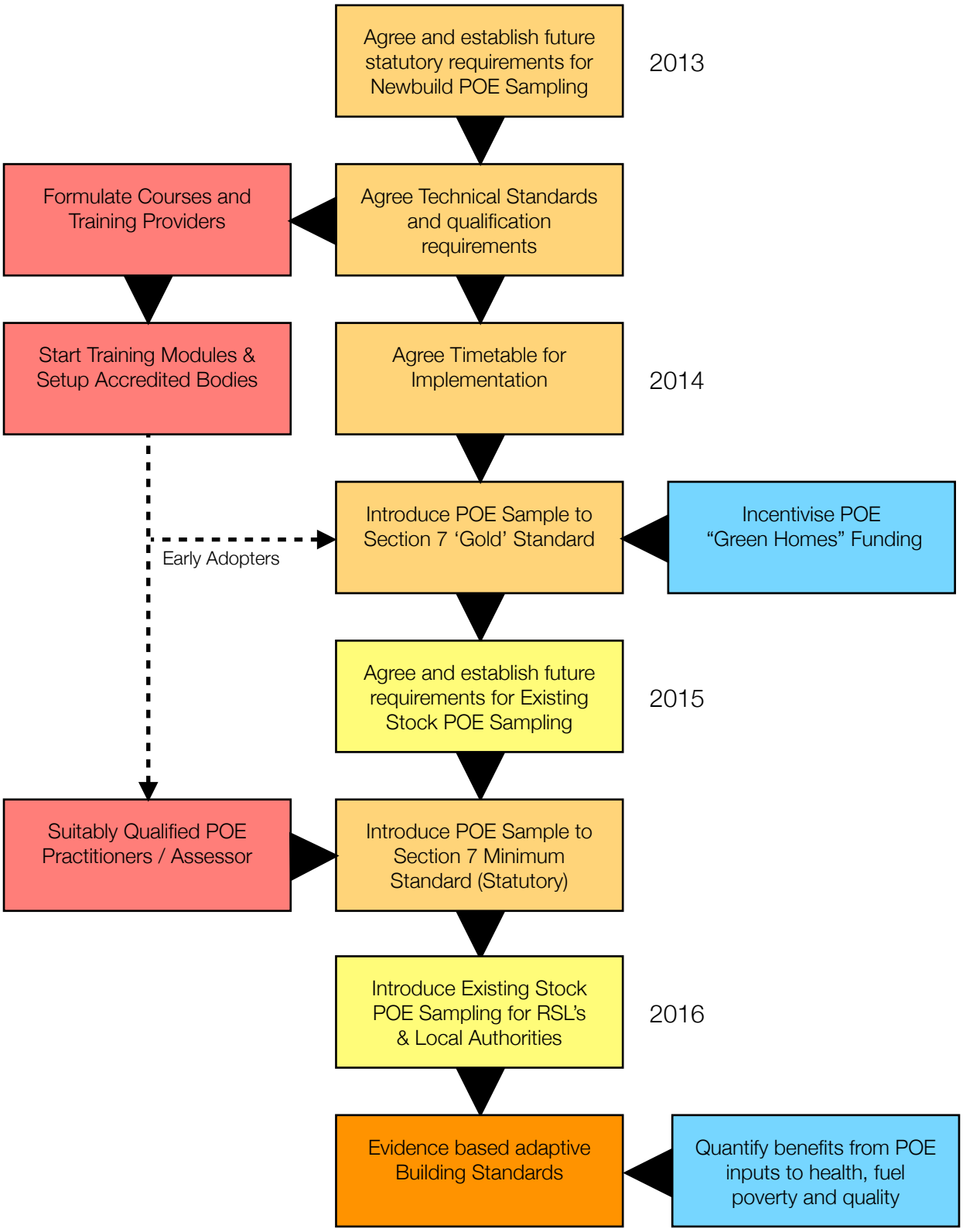
For example, data confirming that certain components are regularly failing in situ could be quickly collected from ongoing projects, leading to quick and decisive regulatory change.

In effect an evidence based building regulations & procurement policy prioritised on people's health, their ability to pay for fuel and meeting Scotland's carbon emission reduction targets.

Pooling of data is an important one that will, we suspect, become increasingly important in mainstreaming POE with public sector clients like Housing Associations & Local Authorities.

Whilst it is difficult to summarise the potential impact of this open source way of collecting data, it intrinsically tackles two key issues, cost & accessibility. To keep building with no common means of getting feedback on what's built, simply isn't a viable future.

7.0 Next Steps (Incorporating POE into Practice)



Appendices

Appendix A

Equipment type	Equipment manufacturer	Contact	Information		appropriateness to focus of study	capital cost (£)	ease/ cost of calibration	ease of purchase / availability/ lead time (weeks)	ease of physical installation	ease of maintenance	ease of set up	ease of use	shortest data sampling rate (minute intervals)	data range	data accuracy	logging capacity	wireless capacity	data security	data validity	tamper resistivity (equipment attraction)	energy source	data accessibility/ output form
			Overview	**Breakdown**																		
Multiple data recording systems	T-mac	Adam Humphreys email: adam.humphreys@t-mac.co.uk phone: 07584995909	Wireless data collection hub used with wireless transmitters. Capable of measuring: - Humidity - Temperature - CO2 - Occupancy (motion sensors) - Door and window openings - Light levels - No external RH sensors. Uses data from nearby weather station. - Requires a repeater to boost signal within the building	Data logger/reciever unit		1125		4							4hrs	✔				MP	
				Internal CO2 / RH / temperature transmitter (x3)		900							0-5000 ppm		50 ppm ± 1.5% RH ± 0.5 °C		✔				B + S	
				Window / door open / closed sensors (x3)		170											✔				B + S	
				Light transmitter		140								0-1530 lux		± 10 Lux		✔				B + S	
				External temperature transmitter												± 0.5 °C		✔				B + S	
				Electricity ESTI-meter transmitter with 3 CTs (up to 10m cable length)		250										± 1.5%						MP	
				Sim card for GPRS data transfer (6mb/month)		70/yr																	
				Data hosting on server - graphical data via web server for 3 yrs		220																	Web + CSV
	Eltek	**Robin Perry email: robin@eltekdataloggers.co.uk phone: 01223 872 111**	**Wireless Eltek data collection hub used with wireless transmitters. Capable of measuring: - Humidity - Temperature - CO2 - Door and window openings - Solar radiation - Light Levels - Requires GSM sim cards to be purchased seperately for wireless access - VOC sensors can be used in conjunction with Eltek transmitters**	RX250AL data logger + GSM modem with 24hrs battery backup		1080		4										✔			SMS alerts	MP + B	
				Internal RH / temperature / CO2 transmitter (x3)		1575								0-5000 ppm		50 ppm		✔				MP + B	
				Window / door open / closed sensors		660												✔				B	
				External temperature / RH transmitter		430										± 2% RH ± 0.4 °C		✔				B	
				Light transmitter		200												✔				B	
				Pyranometer		596												✔				B	
				Electricity transmitter with 4 CTs		530										1-2%		✔				B	
				Remote download software 'Darca Plus'		195																	GSM + CSV
	Omni Instruments Ltd	Steve Duncan email: sd@omni.uk.com phone: 0845 9000 601	Wireless data collection hub used with wireless transmitters. Capable of measuring: - Humidity - Temperature - CO2 - Door and window openings - Solar radiation	RC250-MOD receiver unit		500		4						1							MP	
				GRD GPRS data logger		615								1				✔			SMS alerts	MP	
				Internal RH / temperature / CO2 transmitter (x3)		1575												✔				MP	
				Voltage input transmitter		390																	
				Pulse input transmitter		190																	
				Access to remote download website 'M2MData web' (£20 setup fee)		40/yr																	Web + CSV
	Radio-Tech Ltd	Alan Gilbert email: alan.gilbert@bsria.co.uk phone: 01344 465563	Wireless Wi5 data collection hub used with wireless transmitters. Capable of measuring: - Humidity - Temperature - CO2 - Occupancy (motion sensors) - External humidity and temperature - Door and window openings - Solar radiation - No electrical data capture - requires a separate electrometer to be installed. - Data not presented graphically - only available as CSV files	Wi5 data hub GPRS and data SIM for 24 months.		850												✔				MP	
				Internal temperature / RH transmitter (x3)		460												✔				B	
				Internal CO2 transmitter (x3)		975								0-5000 ppm				✔				MP	
				External temperature / RH transmitter		235												✔				B	
				Window / door open / closed sensors (x3)		375												✔				B	
				PIR motion detection transmitter		435												✔				MP	
				Web portal setup - raw data via private web server		725																	Web + CSV
Handheld data loggers	Trust Science & Innovation (TSI) IAQ logger	Alan Gilbert email: alan.gilbert@bsria.co.uk phone: 01344 465563	Hand held device, stores up to 39 days of data. Measures: - CO2 - CO - VOC's - Temperature - Humidity			1595																	
	Casella sound level meter	Mark Winter email: Mark.Winter@bsria.co.uk	Environmental noise loggers			from 1306																	
	Irradian photometer		L203 Photometer measuring illuminance and luminance levels			1156																	

Key:

MP = Mains power, B = Battery, B + S = Battery with solar backup, MP + B = Mains power with battery backup