INNOVATION REVIEW

ISSUE 14, FEBRUARY 2013

SUSTAINABLE BUILDING DESIGN AND REFURBISHMENT IN SCOTLAND

Smart DC: the Internet Revolution Comes to Buildings
Embedding Post Occupation Evaluation into Practice
Driving Measurable Change for Sustainability
Developing Robust Solutions for Roof Upgrades
Overcoming the Challenges and Barriers for Innovation in Construction
Welcome to the last issue of the Innovation Review that has been published quarterly by CIC Start Online project from December 2009 until February 2013. All the issues will remain available on [www.cicstart.org](http://www.cicstart.org). Each article can also be found by using key words in our Knowledge Base.

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Overcoming the Challenges and Barriers for Innovation in Construction
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What was CIC Start Online?

- It was a joint project of seven Scottish universities funded by European Regional Development Fund and Scottish Government’s SEEKIT programme, from 1st September 2009 until 28th February 2013

- AIM: To embed sustainable building design and refurbishment into practice

- OBJECTIVE: To support academic/industry collaboration in developing and testing innovations, and to disseminate the outcomes in order to facilitate the application of innovations in practice

- WHY?
  - To reduce CO₂ emissions and other negative environmental impacts from buildings
  - To reduce fuel poverty and improve indoor climate
  - To create jobs and support competitiveness of Scottish construction industry through innovation
  - To remove the barriers to the application of innovation in practice

- HOW?
  - Through competitions for academic/industry feasibility studies and for 10-days free academic consultancy on sustainable building design and refurbishment
  - By testing innovations at the testing facilities of the project partners’ institutions
  - By publishing guidelines for the application of innovations in practice
  - By developing and publishing database of design solutions for sustainable refurbishment
  - By providing assistance and advice on sustainable building design and refurbishment to Scottish small to medium sized enterprises
  - By disseminating the project outcomes through the project website, seminars, interactive webinars, webcasts and three whole-day online events that will include an exhibition, a conference and networking facilities
  - By publishing information on products and services for sustainable building design and refurbishment offered by Scottish small to medium sized businesses registered with CIC Start Online.

PROJECT LEGACY

All project outputs can be searched through the KNOWLEDGE BASE on the project website:

www.cicstart.org

PROJECT PARTNERS

Funded by

Scottish Funding Council
European Regional Development Fund
Investing in your Future
Welcome to the last issue of Innovation Review!

As the funding for the CIC Start Online project ends on 28th February 2013, this is the last issue of our quarterly online magazine Innovation Review. You will find out how to continue using the outputs of our project in the article Project Legacy: Knowledge Base on pp. 20-21. Information on downloadable free video recordings of three webinars delivered since the previous issue of Innovation Review is provided on pp. 6-8, and on the latest DVDs of four recent live conferences on pp. 10-17.

The future context for sustainable building design can be glimpsed in the article Smart DC: the Internet Revolution comes to Buildings by James Johnston of ARUP, one of the speakers at our conference on Security of Electricity Supply, Demand Side Management and Smart Grid Strategy on 13th December 2012, on pp. 24-33. The tools for designing ‘smart’ cities and buildings are being developed by IES, and presented in the article Driving Measurable Change for Sustainability by Ruth Kerrigan of IES, pp. 44-53.

However, the built environment can also perform significantly better if existing buildings are improved. Grigor Mitchell of GMA writes about the tests undertaken by Energy Systems Research Unit of the University of Strathclyde on different solutions for improving traditional roofs in his article Developing Robust Solutions for Roof Upgrades, pp. 54-65. As the performance of innovative building technologies has to be tested, the article on the feasibility study Embedding Post Occupancy Evaluation into Practice, undertaken in collaboration by Mackintosh Environmental Research Unit of the Glasgow School of Art for Kraft Architecture, proposes the way forward to mainstreaming post occupancy evaluation, pp. 34-42.

At the end of our project that assisted development of innovations for sustainable building design and refurbishment, David McBeth of Duncryne writes on Overcoming Challenges and Barriers for Innovation in Construction based on the experience of Duncryne and its engagement with academics through CIC Start Online, pp. 66–71. Annabel Cooper of Edinburgh Centre for Carbon Innovation (ECCI) provides an update on the low carbon adaptation of an existing listed building in Edinburgh for the ECCI offices, pp. 43.

We hope that the articles by academics and practitioners about sustainable building design and refurbishment published in Innovation Review have been a useful knowledge sharing experience. The outputs of the CIC Start Online project will remain accessible to all the members at www.cicstart.org. All articles can be searched by using key words in our Knowledge Base.

We look forward to engaging with you again in the future through our next project Mainstreaming Innovation which will start on 1st April 2014, following confirmation of the funding from Scottish Government. We will advise all CIC Start Online members about the launch events that will take place in April.

Kind regards,
There are discussions over how best to measure the performance of a building and in what ways it should be assessed. There are standards that will address quality related matters in the building design and build; for example Passive House, Code for Sustainable Homes, BREEAM, regional building regulations and others. These standards have a similar goal to lower the impact of buildings on a site and to lower the demand of energy by creating a more environmental design.

It is recommended through the study analysis and the review of other documents and references, that in order to verify if the building is performing and considering all aspects of an energy and ecological standard it should be assessed not only with energy predicted software and calculators but also by conducting post-construction assessments before occupation and during occupation and thereafter graded upon the results. This webinar presented the outcomes of this recent study.

Please click on the image to access the video recording.
Sustainability & energy efficiency of three new-build dwellings in Aberdour

Jon Stinson (Edinburgh Napier University) and Stuart Hannah and Drew Srawford (Finex Joinery)

Energy modelling for the three dwellings was undertaken to established heating and power demand. These figures were used to compare against Scottish Building Standards Section 7 and Passive house design requirements. Each dwelling was virtually constructed using the plans, elevations and elemental build-up of the dwelling’s envelope as provided by the architect.

The outcomes of this feasibility study are to be utilised to create a projection towards the design and implementation of micro-renewable technology in the dwellings. The results of this study will portray the feasibility of the technology in terms of its sizing and operation and its potential return on investment.

Please click on the image to access the video recording.
The use of cross laminated timber in high density affordable housing

Stuart Taylor (Artel Associates) and Peter Wilson (Edinburgh Napier University)

The evolution of cross laminated timber over the past 20 years has opened up new opportunities in the development of high density affordable housing, opportunities that are of particular relevance to Scotland’s ever-increasing housing needs and for the potential to manufacture a new, high added value product from the country’s forest resource. The feasibility study is in two parts –

An examination of current housing needs and technical requirements and the extent to which modern methods of construction (MMC) especially offsite construction in conjunction with parametric design can deliver successful responses to each.

The manufacturing technology and the extent to which of the local forest and sawmilling resource in the Dumfries and Galloway region of Scotland (the country’s largest area of production forestry) might support local industrial manufacture of CLT.

Please click on the image to access the video recording.
Thermal and humidity testing of a hard to treat Wall

Julio Bros-Williamson (Edinburgh Napier University) and Wilson Shaw (BCA Insulation)

The work conducted in this feasibility study sets to provide an analysis of a common refurbishment upgrade developed by BCA Insulation Ltd to decrease the thermal transmission. Currently, the insulation company conducts many of these building upgrades to improve buildings thermal response and to minimise owners over spend in heating bills. In some instances the alternative would be to insulate inside a cavity wall with minimal disruption, but in this case the building in question is a single red sand stone wall which requires special attention because of its original setting and functionality.

Single wall buildings are prone to conduct heat very easily and thermal upgrades which include the use of insulation of the walls have resulted in a reduction of heat escaping easily. In some instances, external insulation can be the solution, generally where buildings are not listed or are located in conservation areas this can be applied. More often, it is the case that building owners prefer to conserve the original exposed solid stone elevations and refer to internal insulation solutions.

Additional to the above, the field study included testing to identify possible interstitial condensation of the wall, verifying that any thermal upgrades would not create any moisture build up in any of the layers of the wall; particularly in the slightly ventilated cavity behind the internal wall finishing’s or mould appearing on the internal surfaces. These fears of moisture build up have been highlighted by the insulation company who are conscious that these occurrences can disturb the building owners and create health concerns.
This conference addressed several issues related to the electricity supply such as the threats to the security and resilience of energy supply in the UK, the impacts of the electricity demand reduction, the demand side response to the energy requirements of electric vehicles and heat pumps, and the solutions to prevent fuel poverty in an all electric UK.

The conference video is of interest to the electricity suppliers, energy regulators, services engineers, renewable energy professionals, construction industry professionals, property owners and organisation involved in the reduction of fuel poverty.
CONFERENCE DVDs

Prof Joe Clarke  James Johnston  Prof David Infield  Scott Restrick

Consistent with policies. but is it affordable for consumers?

Brian Galloway

Speakers answering questions from the audience
Electric vehicles are silently arriving to our streets. But, they will soon be more than the means of transportation. They will be storage units for electricity produced by photovoltaic panels on the house in whose garage they are parked and they will also heat that house. This symbiosis of electric cars with our homes signals new approaches to urban planning, building design, energy generation, storage and distribution, and transportation. Electric vehicles will be the mobile part of this new system.

The conference highlighted the prospects, challenges and opportunities in developing these new relationships between energy, buildings and vehicles. The DVD is of interest to urban planners, architects, building services engineers, electricity providers, house builders, transportation engineers, vehicle suppliers and buyers.
As the development of more sustainable built environment includes recycling of building materials and components, the conference highlighted the aims of Scottish policy on waste management and recycling in construction. It presented the outcomes of research on the use of recycled aggregate in concrete and other recycled materials for different uses in construction.

The talks about potential markets for and the industry experience in using recycled building materials informed on the current practice. Three architects talked about the challenges and achievements in applying recycled materials in building design.

The conference DVD is suitable for architects, construction engineers, building surveyors, contractors and suppliers of building materials.
CONFERENCE DVDS

Allan Sandilands  Chris Stewart  Prof Rod Jones  Bruce Newlands

Dr Mohammed Imbabi  Dr Charles Russell

John Watt  Dr Paul Baker  Prof. Dr. Vlastimir Radonjanin
The UK and Scottish Governments have set challenging targets for improving sustainability and limiting anthropogenic climate change, starting with the goal of achieving an 80% reduction in carbon dioxide emissions in the UK by 2050, with an intermediate goal of 26% by 2020 compared to 1990 levels. All new buildings and an increasing number of existing buildings are being designed to address these targets. An intelligent design and construction industry should be asking some questions; Are these targets being met? If not, why not? Are there other effects, for example on occupants' health? Can people live in these building? And how do we capture this knowledge and feed it back into design?

It seems the answer to the first question is frequently no. There is typically a significant discrepancy between the predicted energy performance of a building (and hence its CO2 emissions) and its performance in practice. The energy requirements of a building can easily be as great as four times that predicted.

These discrepancies arise from a variety of sources, including design intention, prediction and modelling tools, buildability, build process and quality, systems integration and commissioning, handover and operation, and crucially the understanding, comfort and motivation of occupants.

This afternoon seminar and discussion will bring together a community of interest in Building Performance Evaluation centred on projects building supported by the Technology Strategy Board Building Performance Evaluation Programme, but including other projects undertaking evaluation that are investigating these questions. It will be an opportunity to hear from those currently involved in a range of BPE projects, as clients, developers, designers and researchers talking about why they are doing it, what they hope to achieve, what issues may emerge. As well as sharing information the intention is also to capture information about how BPE can be achieved in the future for communication to industry and government stakeholders.
Final CIC Start Online event:
The Project Legacy and the Future

The Outputs of CIC Start Online:
Innovations for Sustainable Building Design and Refurbishment in Scotland
Friday, 22nd February 2013, 12:30 - 18:00
The Lighthouse, Mitchell Lane, Glasgow G1 3NU

As the funding for CIC Start Online project will end on 28th February 2013, we organised a final joint live event to thank everyone involved in its funding and delivery, celebrate the project achievements and outline the future plans. As the event provided a summary of innovations developed through 50 feasibility studies and 20 academic consultancies undertaken through the project, it was an exclusive preview of the book which will be co-authored by seven academics involved in the project and published by Springer in 2013. SMEs and researchers who collaborated in the studies, the members of the CIC Start Online project from the construction sector, and businesses and organisations that collaborate with the sector were attending. The end discussion provided the opportunity for suggestions regarding our forthcoming project.

An award was made at the end of the event to the academic who had participated in the most studies with CIC Start Online. The winner was Julio Bros-Williamson from Edinburgh Napier University.

The announcement was made about the forthcoming joint project of nine Scottish universities, led by Glasgow Caledonian University. The project Mainstreaming Innovation will focus on integration of sustainable infrastructure into the existing built environment. The project will start on 1st April 2013 and will be funded by Scottish Government. More information will be available at the launch events and on the new project website from 1st April.
### Programme

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<td>13:00</td>
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<td>Branka Dimitrijevic</td>
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<td>The project legacy, results</td>
<td>Glasgow Caledonian University</td>
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<td>Towards more sustainable</td>
<td>Richard Laing</td>
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<td>Context and policies</td>
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<td>Use of Buildings</td>
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<td>The Glasgow School of Art</td>
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<td>of the project steering group</td>
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If you were unable to attend and contribute to the discussion about potential future areas and formats of collaboration between construction sector and academia in Scotland, and dissemination of the outcomes, you are very welcome to send your comments and suggestions to [branka@cicstart.org](mailto:branka@cicstart.org).
The Project Legacy: Knowledge Base

Some of the CIC Start Online members have already asked what will happen with the project outputs such as video recordings of webinars, online conference videos, DVD packs of live conferences and articles published in our online magazine Innovation Review when the project closes on 28th February 2012. The answer is that our project website www.cicstart.org will remain accessible and that all the outputs will be there, except DVD packs which can be ordered by contacting admin@cicstart.org.

Quick search of the outputs is enabled through the following categories in

**Knowledge Base**

01. EU, UK and Scottish policies  
02. Spatial Issues  
03. Building Age  
04. Building Use  
05. Intervention Approach  
06. Resources Management  
07. Building Materials  
08. Building Components  
09. Building Services  
10. Decision Making Tools  
11. Energy Management  
12. Renewable Energy  
13. Construction  
14. Occupant Behaviour  
15. Performance

Each category contains key words (tags) to refine the search.
The DVDs from our live conferences available for order

The DVDs are professionally produced, printed and packaged, with digitally remastered presentation slides for clarity, and good quality audio. The DVDs are playable in any DVD player, or using the DVD drive in your computer. The prices shown below include UK postage and exclude VAT. For international orders there is an additional fee - please contact us by emailing admin@cicstart.org.

**Half Day packs**

**ECO & Energy Efficiency Improvements in Hard-to-treat Housing - £35**
(half day, 8 sessions)

**Integration of Sustainable Infrastructure into the Existing Built Environment - £35**
(half day, 10 sessions)

**BIM & Sustainability - £35**
(half day, 7 sessions)

**Sustainable Refurbishment of Healthcare Estates - £35**
(9 sessions)

**Security of Electricity Supply, Demand Side Management and Smart Grid Strategy - £35**
(5 sessions)

**Electric Vehicles and the Built Environment - £35**
(6 sessions)

**The Use of Recycled Materials in Construction - £35**
(9 sessions)

**Building Performance Evaluation - Why and How? - £35**
(7 sessions)

**Innovations for Sustainable Building Design and Refurbishment - £35**
Outputs of CIC Start Online – a preview of the joint publication
(7 sessions)

** OR BUY ANY TWO FOR £49 +VAT **

**Full Day packs**

**Build Tight Ventilate Right - Air Quality in Housing - £79**

**The Green Deal and Sustainable Refurbishment of Traditional Buildings - £79**

** OR BUY BOTH for £109 + VAT **
PROJECT OUTPUTS

WEBINAR ATTENDANCE

WEBINAR ATTENDANCE

MEMBERS FROM 53 COUNTRIES
Smart DC: the Internet Revolution comes to Buildings

James Johnston  
ARUP

21st Century, meet the 19th Century

Digital technology is now a fundamental part of our lives, especially with the ubiquitous expansion of mobile Information and Communications Telecommunication (ICT) devices: laptops, netbooks, tablets, e-readers and smartphones. To enable this mobile world, ICT infrastructure behind the scenes is also going through a silent revolution of virtualisation and cloud computing. Through mobile data capture and connectivity, cloud based databases and big data analysis, the internet is enabling services and lifestyles never imagined even at the turn of the 21st century.

As the distributed ICT devices are getting ever smaller and pervasive in our lives, the visuals and graphics are getting ever larger and more enveloping. 2013 may come to be known as the year that OLED (organic-light-emitting-diodes) broke onto the consumer market: 55 inch monitors that are 4 mm thick, transparent and highly efficient (Bhagat & Bajaj, 2013). The OLED revolution will extend further than just display technology, and is also expected to help revolutionise the plasma printing process for high efficiency organic solar PV windows (Galagan & Vries, 2008). Add in innovations such as 3D printing of load bearing non-homogenous shapes for the construction sector (Fosters and Partners, 2013); buildings will simply not look the same as they did in the previous century.

They will not operate the same either. Tech-savvy Generation-Y (defined as those born between 1980 and 2000) is beginning to enter leadership positions in society, and globally they are beginning to enact real change. Typical business concerns such as Intellectual Property are being won over by greater community participation (generally online) and a prevailing sense of the benefits of openness. Distributed information, distributed generation and distributed manufacturing are the three pillars in what futurists believe could lead the world towards a 3rd industrial revolution based upon distributed capitalism (Rifkin, 2011).

Buildings will be the battleground for this new and dynamic world: exciting because this is not just a solution for rich and affluent countries: Gen-Y is very much a global phenomenon. But in 10 years time, if we peel back these layers of digital innovation in our buildings, will we still find a 19th century analogue power distribution infrastructure? Will we still rely on a dumb and naturally live (and dangerous, hence the strict wiring regulations) distribution system? Will we still require mechanical devices to trip circuits during fault conditions, using the brute force of the fault itself, rather than any intelligence?
The Power Distribution “Hack”
The legacy infrastructure was first built and designed in the 19th century as a solution for centralised power generation stations to provide power for incandescent lighting and synchronous motors. Even the different voltage levels in Europe and US were decided before the turn of the century, as Germany, lagging behind the US in the adoption of electrical systems, optimised its voltage levels for metal rather than cardboard filament incandescent lighting (Hughes, 1983).

A commercial office built today will likely have no natively synchronous alternating current (AC) demands, especially now that all lighting is moving towards digital LED. Even large AC motors require speed control which means they are asynchronously controlled using digital electronics. Looking around the office space, it is easy to see the result of a 120 year old infrastructure being used for a purpose it was never designed for: the endless number of “power bricks” and “wall warts” required to convert the national grid AC into safe, low voltage direct current (DC) power. Generation-Y would call this a “hack”, a term used in the software community to describe a solution that is inefficient, inelegant, or even unfathomable, but which nevertheless (more or less) works. This “hack” is shown in its most extreme during national grid power failure: where locally produced DC power from a solar panel cannot be used by a local DC powered device, because the AC bridge between them is not functional due to a problem occurring on the other side of the country.

If we were to redesign building power distribution networks from scratch, they would undoubtedly be digitally controlled DC networks. But in the real world, what is the business case to change this 120 year old industry?

The Status Quo and the ICT Sector
Is the answer with the popular “Smart Grid” movement? Indeed many aspects of Smart Grid policy involve and are based in buildings, including: integration of distributed energy resources, demand response, energy-efficiency measures, electric-vehicle battery integration, thermal-storage HVAC systems and provision of time of use pricing signals (EISA, 2007). According to Bruce Nordman, however, this is the wrong approach for change in buildings. Smart Grid initiatives will involve the wrong institutes and people (with misaligned values, in particular with regards to energy efficiency) and thus will impede research on building centric networks that are optimised for occupants (Nordman, 2009).

Perhaps the answer lies with the ICT industry: a sector that has truly embraced and supports decentralisation and distributed control. Moreover, the ICT industry is not frightened of challenging the status quo. Just like it has done with the information and media industries in recent decades, it could swallow up the building sector; and with the combined power of the smartest minds on the planet could redefine power distribution on its own terms. Look below the surface and you will see that this process is already well underway: in particular with 60W Universal Power over Ethernet (UPoE), 100W Universal Serial Bus (USB) 3.0 and 380V DC power supplies for data centres.

Smart DC: State of the Industry
By 2014, Cisco expects that 33 million devices will be powered by their 3rd generation Universal PoE system (Parmar, 2011). At 60W, UPoE can provide all the power and data requirements for trading floor IP turrets, virtual desktop devices, and hospitality and retail terminals. To put 33 million into perspective, this is almost half the total number of 1st generation PoE devices used for Voice over IP telephony devices installed since 2003: suggesting that in only a few years, UPoE could become a ubiquitous solution in the commercial environment.
Similarly, the USB 3.0 Promoter Group (a consortium of companies including Intel, HP, Microsoft and ST-Ericsson) are working on extending the USB specification to include the ability to transfer up to 100W along the cable. Their aim is to provide a standardised approach for the charging of laptops and printers, to reduce the number and variety of device specific AC-DC power supplies.

Whilst the capacity of DC power networks is increasing, the power demand of devices continues to drop, according to Koomey’s law. As Koomey discovered in 2009, the electrical efficiency of computing (the number of computations that can be completed per kWh of electricity) since the start of personal computing has doubled every 18 months (Koomey et al, 2009). In other words, if a processor was rated at 100W in 2005, the equivalent processor in 2013 would be rated at 3W.

These Smart DC solutions are also beginning to move into different sectors within the built environment, most predominately LED lighting. Two companies have solutions based on the PoE and USB approach: Redwood Systems (based in the US) provides a constant current PoE solution for networked LED lighting and Moixa Technologies (based in the UK) provides a USB 3.0 solution for domestic LED lighting and consumer electronics.

The US is taking a lead in the development of standards for DC networks in buildings: the EMerge Alliance outlines a specification for meshed DC power networks over ceiling tiles and communication using the Zigbee protocol. Members of the EMerge Alliance have now grown to include key players in the lighting, power distribution and ICT sectors: including GE, Philips, Samsung, ABB, CISCO, Emerson, Osram and Intel.

**Active Intelligence**

A key attribute of Smart DC systems is in the intelligent manner in which power is delivered over a network. Unlike the always live dumb AC mains, Smart DC is an active system: where end-devices need to negotiate with the power source before any current is sent. This concept is extended to fault monitoring too, where instead of relying on the brute force of a fault to trip a circuit breaker or fuse, the power levels are digitally monitored for abnormal operating conditions (see Figure 1).

The benefit of circuit breakers is that once they are tripped, they provide 100% isolation between supply and load through physical separation. Smart DC gets around this problem using the concept of galvanic isolation, in which the high frequency transformer within the dc-dc converter does not allow any direct current flow when it is not being actively controlled.

Higher voltage systems can extend this active intelligence philosophy through including more safety features, such as insulation monitoring. If the resistance between the earth and active goes below a certain threshold (for example 50kΩ, used by IEC standards for medical applications), then a warning signal can be sent to the power source before the fault occurs.

A building power network could go circuit-breaker-free, but only if there was embedded intelligence throughout the network, so that each connection knew the total power it was expecting at each moment in time. For example, if a connection was expecting a steady state power level of 5kW, then it would accept anything within 15% of this value, but if it were to rise unexpectedly to 10kW, then a warning signal could be sent.
Intuitively, electrical designers feel uncomfortable with a circuit-breaker-free building, but in reality the risk is lower because of the higher accuracy and transparency of fault detection. Core benefits of a circuit-breaker-free building are the reduced costs and smaller electrical installation footprint enabled by removing heavy duty mechanical equipment. Note: mechanical fault protection would always be needed with direct connections to primary energy sources such as PV and battery systems.

Moving power flow coordination from a hardware to software solution will open up many opportunities for innovative new processes. One example is controlling the maximum level of power that can go through a cable, creating a Virtual Maximum Demand (VDM). Any surplus power above the VDM limit could be queued in an energy buffer on the upstream side. Any power shortage on the downstream side would be made up from a local energy buffer. This approach would be useful for a laptop device that had short-lived peaks above the maximum current capability of the cable (i.e. above 60W if it were an UPoE cable).

Figure 1 - Power over Ethernet fault monitoring map (source- IEEE802.3, 2009)
Blueprint for Future Smart DC
As Smart DC systems evolve into the future, it is important that there is a shared vision about what a Smart DC system should ultimately be capable of. Taking inspiration from the internet, the first lesson is that any architecting should be entirely focused on how to encourage interoperability between systems rather than developing highly specific functionality requirements. The Internet Protocol Suite, led by the Internet Engineering Task Force (IETF) deals entirely with the process of interoperable communications on a virtual level (see Figure 2).

Any physical technology can be employed as long as it adheres to minimal specification requirements. This enables complete interoperability between all types of networking device, regardless if they transmit data over Ethernet, Fibre or Satellite etc.

Clearly, there are different challenges and design requirements for sending data around a room, and across a city: thus hidden from the virtual layer above, the physical technologies are grouped together in different geographical sub-sectors: for example Local Area Network (LAN) technologies such as Ethernet and Wi-Fi, and Wide Area Network (WAN) technologies such as Optical Fibre and Satellite.

Figure 2 – IETF’s Internet Protocol Suite and Geographical Classification
In the same way, it may be useful to build a classification system for Smart DC, to encourage system designers to really think about the needs of devices and occupants in the different spaces of a building.

Having a single voltage level in the building is very much a utility-centric solution. It is proposed that networks that are “fit-for-purpose” add more value than generic solutions and in the long run would reduce costs. From Figure 3, it is proposed that there could be a three tier classification system for buildings:

- **Micro**: the first grouping concerns large centralised plant and sources of power such as roof based PV systems. Performance and efficiency are core requirements. Design for occupants and adaptability for change are not so important.
- **Nano**: the second grouping concerns distributed sources and demands in a room environment. These could be anything from desktop PCs and monitors, to luminaries, and PV coatings on the facade. There is a high level of interaction with occupants, so Safety Extra Low Voltage (<60Vdc) and flexibility are core requirements. As the power levels are much lower, efficiency is less important than added value features such as sending power and data over a single cable.
Pico: the third group concerns ultra-low power and dispersed sources and demands within the room, on the desktop and even inside devices. Examples could be energy harvesting devices, smartphones, or the battery system within a laptop. Pico systems are integrally connected with occupants: with a constant need for mobility and ultra-high data requirements. Touch voltage (<24Vdc) and inbuilt energy storage are desired. Other innovations such as wireless power would be appropriate too.

Finally, a key factor in the Smart DC blueprint is the topological layout of the system: whether it is radial, ring or a hybrid of both (see Figure 4). There are different advantages and disadvantages of both: the benefits of radial networks are the simplicity in design and higher data transmission, whilst the benefits of ring networks are the higher efficiency and decreased infrastructure redundancy. There should be no limitations in the Smart DC Blueprint for either approach (or a hybrid of both) to encourage the best designs for each particular instance to emerge.

Integrated Energy Management

It is expected that in the next few decades, the transformative effect of networking will integrate the virtual and real world in a much bigger way: by giving any real thing an IP address and connecting it to an “internet of things”. Nordman uses the term “Universal Interoperability” to describe the opportunity for seamless connectivity between different domains, things, people, activities and automated processes (Nordman, 2008). This will lead to the convergence of previously defined verticals in the building sector, particularly building management systems (BMS) and power distribution systems: under a new name of integrated energy management.

In the market today, there are a number of BMS providers (most popular is BACnet) and building system interoperability providers (most popular is KNX). Neither approaches were designed for IP networking, and instead built up large eco-systems using their own set of communication protocols and standards. The ubiquity of IP networks in buildings in recent years have pushed both systems to “hack” on a solution that allows for more interaction with the internet (BACnet/IP and KNX/IP).

![Smart DC Topologies](image.jpg)
However, true interoperability is never really achieved, as the use of IP gateways breaks the fundamental architectural principle of the internet: end-to-end connectivity (Saltzer, 1984).

It is expected that as the convergence between the ICT sector and the building sector continues, the transformed sector will not necessarily attach onto status quo BMS solutions but instead will prefer to use its own very capable systems. The IETF standard for management over IP networks is called the Simple Network Management Protocol (SNMP), and is widely used for managing routers, switches, servers, workstations and printers. SNMP design is distributed and extensible, which means it is very scalable and there are few barriers to the development of new capabilities, control policies and device types.

In 2010, an IETF working group was created called EMAN (Energy-Management), which uses SNMP to deliver a generic but powerful energy management protocol for ICT devices and all other building energy management systems. It is still in the early development phase, but the promise of EMAN could be its ability to seamlessly bridge the gap between environmental sensor monitoring, environmental systems management and its ability to control Smart DC networks (PoE power control is an integral feature of SNMP). EMAN will enable IETF to focus on what it does best: innovating in the middleware challenges of network connectivity, meta-data translation, policy implementation and scalability. This will allow BMS developers (such as BACnet) to focus their efforts on designing the best services through the use of an Application Programming Interface (API).

By giving every device an IP address and managing the system using SNMP, true Universal Interoperability can be achieved.

This means there are very few barriers for 3rd party App developers to add immense value by leveraging on the latest innovations in cloud computing and data analysis. For example using Hadoop distributed data toolkit to provide timely insight (and realtime policy implementation) to optimisation problems containing hundreds of thousands of variables.

Digital Energy Networks

The convergence of Smart DC and energy management systems in the next 10 years will open up many more opportunities for innovation: perhaps leading to the creation of a true Digital Energy Network.

In this vision, Smart DC could evolve from intelligent fault monitoring towards the complete decentralisation of power control, where distributed “power routers” forward packets of power to IP addressable end-devices.

Routing tables could be created using “Most Efficient Path First” algorithms, extending on from the algorithms used in the internet, to send packets in the most efficient way across a network. See Figure 5 for an example network, where the most efficient route between the Fuel Cell and Desktop C and is shown in red.

The end-to-end power coordination could be undertaken by distributed SNMP managers at asynchronous time intervals. Any mismatch between the supply and demand would be provided by integrated energy storage in power routers throughout the network.

The Digital Energy Network would allow each device to get a different priority policy set by the SNMP manager, and under national grid power failure, power could be automatically routed around the DC microgrid to maintain power to the highest priority devices. Bidirectional power capability would also enable power to be pushed back from laptop batteries to support the overall network.
Towards an Internet of Power

The concept of taking lessons from the Internet and applying them to the future power grid is of growing interest, see for example (Rajagopalan, 2002), (He, et al., 2008), and (Shibata, 2011). Bob Metcalfe, co-inventor of the Ethernet, in his Enernet (Energy-Internet) concept stated that the future power grid should have its own TCP/IP stack of protocols, as well as be highly distributed and asynchronous in nature (Metcalf, 2009).

To enable this vision, as a suggestion by Bruce Nordman, perhaps the building sector needs to form a sister group to the IETF: the Building Engineering Task Force. The BETF can drive for open standards, help focus university research agendas, attract greater political support and generally give Smart DC the same sense of importance as the smart grid concept.
Bibliography


IEEE. (2008). IEEE802.3at Standard. IEEE.


Embedding Post Occupation Evaluation into Practice

Bruce Newlands (Kraft Architecture), Donald Shearer and Tom McNeil (Glasgow School of Art)

Over the past six months, Bruce Newlands of Kraft, Donald Shearer and Tom McNeil from the Mackintosh Environmental Research Unit of the Glasgow School of Art have been investigating how post-occupancy evaluation (POE) might be mainstreamed into general practice and be part of an ‘evidence based’ adaptive building standards regulatory framework.

The interim findings of this study have been a report submitted to CIC Start Online in late 2012. This article is an abridged version of that study highlighting some of the key issues the report raises and gives an indication of the future direction of the on-going study. The full report is available on CIC Start Online website.

POE involves systematic evaluation of opinion and data about buildings in use from the perspective of the people who use them. Building Performance Evaluation (BPE) 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 building has met its design goals for resource consumption and occupant satisfaction. For the purposes of our report and this article, we are using the title POE to describe both.

Our aim was to assess how well our designed built environment matches users’ needs, creating a feedback process that can allow users to adapt their environment more readily and for clients, designers, manufacturers and constructors to improve building design and real world performance.

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 often limited to demonstrator projects as a way of testing new technologies, typologies and designs.

If we are to achieve true sustainability, many feel that there also needs to be a prioritisation of building performance towards long-term health goals rather than short term carbon emission targets. POE offers the tools and techniques to encompass this holistic approach to measuring and discerning actual performance.

“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 required to conduct POE could certainly be seen as impediments to wider uptake.

Our investigation therefore attempted 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 routine practice?

Practice
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. As the industry experience is that forecast design energy usage is usually less than the actual figure achieved, 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 process for using data gathered to inform Government policy and 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 centred 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 frequently repeated issues are prohibitive cost and inaccessibility to a process. This study aims to examine if this perception 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.

Logging Qualitative Experience

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 any decisions made on the basis of this data will be similarly questionable. If these outputs are 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. 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 dataset, the more robust the findings are, 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 by Bright HF / Kraft Architecture with The Blackwood Foundation presents a good example of a project where POE can be used to determine the success of features 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 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 those with a direct connection to the building owners are questioning them, 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, there is always a risk that participants may give the responses that they think they should provide 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 responses. 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. 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. 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 is 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 there may be an economic model for mainstreaming this component quickly through further education or higher education departments.

**Diagnostic Data Collection**

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 which should 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 that a suitable kit is specified from each POE project and it relates to a specific research focus. 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. 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.

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.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Cost (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RX250AL data logger</td>
<td>£1,080</td>
</tr>
<tr>
<td>3 x GD47 wireless temp, RH &amp; CO₂ transmitter</td>
<td>£1,575</td>
</tr>
<tr>
<td>3 x window/door state logger</td>
<td>£660</td>
</tr>
<tr>
<td>External temp &amp; RH transmitter</td>
<td>£430</td>
</tr>
<tr>
<td>Half day training</td>
<td>£250 approx.</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>£3,995</strong></td>
</tr>
</tbody>
</table>

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. Kit costing £4,000 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.

**Routes to Mainstreaming**

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:

- In-situ 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.
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 and 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 out of the professions to become accredited members following training, testing and subscription to on-going continuing professional development.

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 and further education institutions, professional bodies, accredited bodies and private training businesses.
Figure 6. A route to mandatory adoption of POE
Open Data

Looking ahead, we are interested in exploring models which widen the collection of data from a more diverse pool of typology, occupancy and usage.

This investigation will also examine how 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 on-going projects, leading to quick and decisive regulatory change.

In effect, this would assist in providing evidence based building regulations and procurement policy prioritised on people’s health, their ability to pay for fuel and meeting Scotland’s carbon emission reduction targets. Pooling of data will become increasingly important in mainstreaming POE with public sector clients like Housing Associations & Local Authorities.

We also wish to explore perception of POE and its fundamental aims. Are there more intuitive and smarter ways to resolve building performance issues, those occupants can easily monitor and control, for instance?

Can POE help make our buildings be designed in such a way as to deal robustly with changing environmental conditions, occupancy and uses?

Can POE help make our building services be more adaptive, user friendly and smart?

Whilst it is difficult to summarise the potential impact of this open source way of collecting data, it intrinsically tackles two key issues, cost and accessibility albeit ethical concerns about logging data remain.

Moving forward we hope to work with other partners to develop a variety of cost effective open source monitoring equipment and modular options for monitoring that can be built into homes to provide continuous feedback to occupants.

A simple system that can detect the build-up of potential problems at an early stage must be the goal of POE, a live POE that informs the occupants so that they can take action to mitigate potential problems.

New home at High School Yards for Edinburgh Centre for Carbon Innovation

Edinburgh’s historic Old High School will be transformed into a state of the art, energy efficient hub for knowledge, innovation and skills.

The refurbished building, which dates back to 1777, will reopen in June 2013, following a £15 million investment. It is expected to achieve a Building Research Establishment Environmental Assessment Method (BREEAM) rating of “outstanding”, reflecting its green credentials, and will be the first urban building in the UK to achieve this.

Malcom Fraser, director at Malcolm Fraser Architects, said: “Many buildings that have won the [BREEAM] ‘Outstanding’ designation are styled to look like green spaceships, adrift in some distant business park-galaxy. This radical green building looks exactly like a historic one - given the urgency of the fight against climate change we need to understand that the joyful and creative adaptation of our existing building stock is the outstanding issue facing us.”

The building itself embodies everything the ECCI wants to achieve: excellence, impact, and sustainability, and the new home for the ECCI will act as a hub to bring academics, business and government together, and be a place where research, business strategy and public policy on climate change is shaped and aligned.

Introduction

Overall cities are responsible for a major portion of pollution and waste in our society, but having a population condensed into close proximity also allows energy, water and other services to be provided more efficiently while minimising infrastructure. The design of “eco-cities” – cities with sustainable smart buildings that integrate with each other and the grid itself to conserve resources – is becoming even more important as the world population is projected to keep rising for at least the next century. By 2050, 70 percent of the world’s population will live in cities, which makes efficiency within those cities a necessity. Controlling our use of energy, water and other resources will no longer be an option, but a necessity.

Our sustainable future is in smart eco-cities, which utilise information and communication technology (ICT) to incorporate real-time dynamic control. Performance analysis and predictive interrogation of data will play a key part in this. An emerging vision is that each building would be designed or refurbished using state of the art 3D simulation to quantify, optimise and verify its performance. The building simulation model would then be used to commission and subsequently control the building. However, in order for it to be a true eco-city it would not be enough for each building to be independently efficient. There would need to be a master system that can optimise city wide energy and water consumption in coordination with the relevant utilities.

Unfortunately, today there is a major barrier: the discontinuity between actual utilities consumption and design/simulated data. Buildings rarely perform as predicted, and Building Energy Management Systems (BEMS) only monitor and report in a descriptive, ad-hoc way. Vast amounts of data are collected but not fully utilised to inform decisions. These conventional management methods are laborious and make it difficult to maintain optimal control. Post-design, BEMS monitor only the individual building and rely on facility managers to interpret the data and act accordingly. This creates a lot of “data” but not viable “smart buildings”. So what can be done before, during and after the design process to solve this problem?

It isn’t the fault of the building designers, owners or even the operators. Until now, the technology to simulate and test optimisation hypotheses based on real operational data simply didn’t exist. There was a greater reliance on design simulation technology that could point out flaws and optimise performance virtually before the building was constructed, and BEMS systems which monitor usage after the fact. However, with new software and computer modelling capabilities, creating smarter, more efficient buildings is easier than it has ever been. Performance analysis is quite possibly the technology that’s going to drive true eco-communities, -districts and -cities.

Building design using 3D models is already the norm and if used correctly, Building Information Modelling (BIM) can deliver a 3D model suitable for operational activities. Connecting the dots by incorporating real operational data into the model is the next step, and one which IES has already taken successfully through its Scottish Enterprise funded SCAN research project which is detailed below.
During the design process the goal should be to create a zero-carbon building. This emphasises the need to reduce energy through a climate responsive design, which can meet those demands efficiently and effectively. Once this is achieved, renewables can be utilised to deliver on reduced energy demands and community & district solutions can be considered where appropriate. The industry as whole is starting to embrace the sentiment that you can't change what you don't measure. Based on this ethos more and more built environment stakeholders are beginning to understand the value of performance analysis and are adopting strategies to incorporate it.

Post design, the goal is to undertake enhanced commissioning to ensure optimum set up, followed by continuous commissioning throughout operation, making the building responsive to occupancy and usage changes, enhancing fault detection, and also enabling optimisation programs which assess suitability and impact of energy conservation measures and new technologies, alongside capital versus operational cost implications.

The application of 3D building performance simulation on new-build, refurbishment and operation optimisation projects facilitates a greatly improved integrated and sustainable design process, a necessary component to tomorrow’s eco-cities. It paves the way for smart interaction between buildings in a community or city to optimise efficiency at the next level.

Through virtual testing and performance analysis the industry is able to cut through greenwash and deliver measurable results. These results are what will drive eco-cities.
The Human Element
The design process of an eco-city should include experts from all segments of the construction industry. It also needs to engage residents. The answer lies within communication and exchanges of information between different experts that will spark innovations and create solutions, which will ultimately benefit everyone.

Developing this integrated approach and incorporating performance analysis from the early stages of the design through to operation whereby everyone from the architect to the MEP engineer to the facilities manager, owner and authorities work together is the key to designing an energy efficient building and ultimately an energy efficient community. By integrating this with initiatives that raise consciousness of the impact of a collective approach by inhabitants it should be possible to instil people with pride in their building/community/city and inspire them to want to be involved.

This is by no means an easy feat but it should be recognised as being just as important as technology development.

IES Technology
Glasgow based IES was founded in 1994 and has become an established and recognised force within the global green building movement. In that time it has become a hub for resource efficient, low-energy, zero-carbon buildings.

Dr Don McLean, Founder and Managing Director, created the company to deliver accessible environmental analysis to the building design community through the development of commercially viable software and associated consulting services.

The application of building performance simulation on new-build and refurbishment projects facilitates a greatly improved integrated and sustainable design process. Before IES began to develop this technology such tools remained in the hands of academics and were too complex to use commercially.

Over the last 15 years, IES has successfully brought to the global market its software suite, otherwise known as the Virtual Environment (VE). The company has also attained a unique position. Its technological solutions, consulting expertise and investment in research have ensured that, as the need for energy efficient buildings, communities and cities continues to grow, IES is consistently at the cutting edge of those building science developments that deliver true measurable sustainability.

Today's social, economic and environmental drivers continue to move the industry on significantly and consequently the role of IES is evolving. We believe that the application of Virtual Building technology from design, through construction & commissioning on into operation and renovation/adaptation offers a 3D platform upon which Smart building and ultimately city principles can be built.

IES Eco-City Technology Vision
IES invests over ¼ of its turnover into research & development, and is actively involved in a number of Scottish, UK and European funded projects across all areas of what IES terms the Eco-City Lifecycle. We are also actively involved in key sustainable building/community test sites considered to be at the forefront of global research.
Through this well-established division we are continuously investigating how analysis plays a vital role in cutting through greenwash to deliver measurable sustainability, whether that is designing or analysing a product range, regulatory system, building or entire communities/Eco-Cities.

Working with a whole host of partners from Manufacturers and Energy Service Companies to governments and building product makers, we are developing new innovative tools and providing new consulting services at the cutting edge of analysis technology to lead the way in driving measurable change for sustainability.
Across these projects IES is both providing the underlying technology and acting as a Hub to connect many different organisations and stakeholders into the Eco-City Lifecycle. Our concept maps the entire process from masterplanning through to simulation-based control of eco-communities and links with smart grids.

It reflects that at the end of the design process a detailed VE model of the building will exist. This model can be used for effective commissioning of the building and then as a simulation-based controller to maximise operation and refurbishment. An Authority will then be able to take control of each building in its masterplan to optimise the energy usage of the community or city. Making the necessary connections to utilities will make the community as sustainable as possible – not just in terms of energy but also water.

Most of what is outlined above is achievable as the fundamental technology exists in the VE and IES is working to make this vision a commercial reality. One related project that has already proved particularly successful is VE-SCAN.

**VE-SCAN: Smart Control Analysis**

VE-SCAN is an ongoing R&D project funded by Scottish Enterprise. It is developing the world’s first truly predictive building energy management solution; a Smart solution – one which equips buildings with the brain to think. It is about taking 3D design/simulation models to the next level using detailed metered data to achieve incredibly accurate calibrations that guide decisions.

Though a refinement of the final prototype is required to create a tool which is suitable for widespread use, we are already providing the capabilities of the technology as a consulting service.

The project helps create truly energy smart buildings by delivering business enabling intelligence through predictive analytics. Specific advantages range from enhanced commissioning, to fault detection, optimisation and continuous commissioning throughout a building’s life. This will deliver the ability to plan and strategise against legislative requirements, as well as providing transparent and automated adaptive building control.

Very substantial savings in energy, and consequently in costs, can be achieved across property portfolios. Commercial buildings utilise more than 42% of all electricity produced, yet waste up to 50%. And the costs to operate and maintain building stock are set to rise as organisations look to meet higher fuel costs, CSR targets, comply with current and future environmental legislation and mitigate the impact of climate change, all whilst ensuring on-going reliability and investment value of building stock.

The four drivers which led to the development of VE-SCAN have been covered in the introduction above: eco-city necessity, widespread use of 3D Model technology in building design, under-utilisation of BMS data, and the disconnect between predicted performance at design and as-built performance.

IES recognised that existing 3D performance simulation models were not realising their full potential. Detailed 3D models developed during the design process as a result of Building Regulations and voluntary rating systems such as BREEAM or LEED, hold the potential to be utilised on through construction, commissioning and into operation.

Therefore IES set about to create VE-SCAN to overcome:
- Discontinuity between simulated performance at the design stage and in operation
- Problems maintaining efficient operational control through BEMS
- Incorporation of actual weather data into model calibration and Performance Contracting.
VE-SCAN utilises the IES Virtual Environment (VE) as the 3D building performance simulation technology. It can not only identify how to make the BMS perform better, but through advanced analytics help uncover hidden inefficiencies which when resolved can reduce operating costs substantially. Plus, energy efficient refurbishment measures can be tested out virtually to accurately evaluate return of investment.

The ultimate overarching ability is to define and implement a measureable carbon reduction strategy across a whole portfolio. Informed decisions can be made on which buildings to lease, renovate, sell, buy or build – consequently increasing portfolio value and improving pertinent building rating or label levels. It will allow progress towards all buildings in the portfolio operating within a comparable league table so continuous optimisation with regular investment values can be employed.
The following outlines how IES Consulting is utilising this technology:

VE-SCAN will revolutionise a number of real-life services relating to existing building operation including remote monitoring, selecting energy conservation measures and Performance Contracting. 80% of a building's total lifecycle energy use occurs during operation and buildings account for 40% of the world's carbon emissions.

Unlike traditional simulation tools, VE-SCAN is an advanced calibrated operational model of a building that uses operational energy data from meters and sensors in the building, such as temperature, relative humidity, CO₂ etc. Its development is at the cutting-edge of building performance analytics. No-one else has achieved this level of calibration between simulation models and real-life.

It significantly increases accuracy because it moves the user away from average daily data profiles to what we call freeform profiles that track usage at the sub-hourly level. It also uniquely incorporates this alongside accounting for changes linked to actual weather patterns.

Its technological capabilities include; the power to simulate the building sub-hourly; the ability to automatically import sub-hourly operational data into the calibrated model; the capacity to easily compare the calibrated model results with the operational building data using an integrated results dashboard; and the use of actual weather data.

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**THERM: Manufacturing as a Special Case**

Through another R&D project, this time TSB funded, IES has been expanding this concept out into manufacturing and other process driven environments such as data centres, by developing “performance components” which can be dropped into 3D models of buildings.

The now complete THERM (THrough-life Energy and Resource Modelling) project was concerned with sustainable manufacturing, which integrates modelling of factory processes within their environment, assesses the materials, energy and waste of the processes and uses data analysis tools to understand the opportunities that exist for reducing energy consumption and carbon emissions, integrated with the factory building.

The project team (IES, Toyota, Airbus, Cranfield and DeMontfort University) has been worked together to incorporate the following key elements within a 3D modelling platform:

- Toyota’s Kaizen and Airbus’s Stre3tch continuous improvement practices
- Library of typical improvement tactics
- Efficient data hierarchy for manufacturing processes.

THERM is capable of modelling the interaction between the production system and its physical environment – firstly the building itself, and then the locality and time. Through such integrated modelling, it can identify improvements via its database of tactics. Information and guidance were embedded into an interactive workflow system – the early Kaizen / Stre3tch steps were evolved with more detailed user experiences and research on tactics to increase resolution. The final solution automates methodology while also providing Quality Assurance. Again IES has just being offering this as a consulting service which will directly deliver both improved factory processes and design practices that result in increased efficiency, reductions in process time and costs, lower energy bills and carbon emissions, and improved waste and resource management.

![Screenshot of THERM tool](image)
IES Consulting Activity

IES Consulting utilises cutting edge technological developments like SCAN and THERM to significantly optimise operational energy efficiency and other performance issues. Examples of this at work include:

Walmart
- Helped develop & provide low energy store prototype for 15 climates working with “Sustainability 360”
- Aim Achieved: 15-30% more energy efficient

Daikin
- Created bespoke specification tool to model performance & efficiencies
- First ever solution of its type for heat pump/recovery VRV systems
- Incorporated data from real life tests with simulation
- Three times the market response than anticipated

Confidential International Manufacturer
- LEED Gold Measurement and Verification (M&V) of design energy expectations against actual operation
- 20% reduction in annual HVAC energy bill discovered (no capital spend required)

Heathrow T5
- Sole energy & environmental modelling consultant 2000 - 2008 and T1 2012/13
- Helped minimise operational cost and maximise performance

Conclusion

Today’s social, economic and environmental drivers continue to move the industry on significantly and consequently the role of IES is evolving. As demonstrated above the fundamental 3D analysis technology needed for Smart Building, Community, District and City environments exists in the VE and is already being developed into a future commercial reality through our R&D.

We forsee that IES technology could be at the foundation of a myriad of smart building and city solutions. Being able to understand and predict exactly how a building is operating will enable greater integration with other systems as the industry starts to fulfil its Smart Eco-City vision. The application of Virtual Building technology from design, through construction & commissioning on into operation and renovation/adaptation offers a 3D platform upon which such smart building and ultimately city principles can be built.
IES contributed to the recently successful 24mil Smart City grant won by Glasgow – seeing off competition from London, Peterborough, Bristol and 30 other UK cities. The company advised on the aspect of using the communications hub to inform buildings on how to improve energy efficiency.

IES is also currently involved in the other following Smart City related R&D projects:

- People Friendly Cities in A Data Rich World – EU COST Action
- Interactive Decision Support Platform for the Creation of the Eco-City through the Integration of Sustainable Urban Metrics and a Common City Index (CitySUMS) – SMART: Scotland
- Glasgow Cities Future Demonstrator – TSB
- Indicator-based Interactive Decision Support and Information Exchange
- Platform for Smart Cities (INDICATE) – EU FP7
- Intelligent Urban Energy Tool (iUrban) – EU FP7
- Friendly and Affordable Sustainable Urban Districts Retrofitting (FASUDIR) – EU FP7.

We truly believe that no other technology exists in the world today that is as capable of addressing the Eco-City Lifecycle like the VE.
Developing Robust Solutions for Roof Upgrades

Grigor Mitchell and Pauline Ritchie
Grigor Mitchell Architect Limited

A process for the development and implementation of robust, practical solutions for the thermal improvement and moisture control of existing roofs above habitable rooms.

A late Victorian Edinburgh tenement, showing the arrangement of pitched and flat roofs.
1. Aim
The aim of this feasibility study was to assist in the development of a process which produces robust, practical details and specifications for the thermal improvement to habitable roof spaces of traditional properties in respect to moisture control and the avoidance of interstitial condensation. At present in Scotland there has been limited research into this area.

2. Background
Currently there are many initiatives to increase the energy efficiency of Scottish homes including the ‘Home Insulation Scheme’ which is managed by the Energy Saving Trust and backed by the Scottish Government. One of the aims of this particular scheme is to improve the energy efficiency of homes by promoting and installing free or discounted loft insulation. However there is little precise guidance available on the best practice for insulating the pitched and flat roof structures of traditional properties especially in respect to the avoidance of interstitial condensation. The idea for this project was developed from experience of this issue. Grigor Mitchell Architect has built up a large body of experience of dealing with architectural projects where clients have requested that existing roofs of traditional properties be thermally upgraded.

In addition, over the last 3 years Grigor Mitchell Architect (GMA) has gained expertise in the Passivhaus building standard and in using advanced software tools such as THERM and WUFI. These experiences have highlighted the need for caution when specifying thermal upgrades in order to control moisture and avoid interstitial condensation. In addition, the experience of dealing with traditional properties has underlined the importance of conserving their key features where they are of high quality.

During this CIC Start Project, GMA worked in conjunction with the Energy Systems Research Unit (ESRU) of the University of Strathclyde. GMA produced details of 4 typical roof interfaces and modelled them using Revit BIM Software. The specification options aimed to ensure optimal thermal performance, decrement delay, air tightness and thermal bridge free construction. The need for building conservation was taken into consideration. These roof interface details were then passed on to the ESRU who created numerical models of them.
3. Relevance

3.1 Environmental
The main aim of this project is to look at the best way to reduce energy loss (and, hence, CO₂ emissions) through the roofs of ‘hard to treat’ traditional properties. The solutions will be cost effective and will best respect the existing building fabric. Natural insulation products will be considered for use in the project due to their excellent decrement delay properties.

3.2 Social
The upgraded roof structures will have improved thermal retention and comfort and will be cheaper to heat – very important in an age of rising fuel costs. As there is a particular emphasis on the avoidance of interstitial condensation (and hence mould) the internal environment of the refurbished space will be healthier for the occupants. There have, of course, been studies that have found a close correlation between asthma and allergies and the environments found in the home, office and school.

3.3 Economic
The thermal upgrading of properties is central to the Government strategy of substantially (and rapidly) reducing CO₂ emissions.

Best practice solutions must be investigated using the powerful tools (and expertise) that are now available to us. Developing this process could help us avoid the damage that condensation can cause with the building fabric of properties and to the health of residents.

This project will allow the SME (and other Scottish professionals) to develop specialist skills in a key area which is applicable to a large number of property types, including tenements, in Scotland and further afield. Another potential spin off of this project could be the development and manufacture of suitable insulation products and membranes.

4. Scope
4.1 Traditional Roofs
The thermal upgrading of traditional roofs encompasses a large range of property types and building ages, each with their own particular construction methods and extent of ventilation. There are also a wide range of potential solutions for their thermal upgrade. In order to limit the scope of the study, through consultation with ESRU, the authors decided to focus on the upgrades to traditional flat roofs. This choice was also based on their recent experience of spatial and thermal upgrades of this form of construction in properties in South Edinburgh.

In addition, it was felt that as these constructions are deemed as ‘hard to treat’, they are often overlooked and therefore most subject to thermal ‘discomfort’ and heat loss. The solutions derived from these particular instances are also highly relevant to properties of all ages with flat roofs. In the case of this project, ‘traditional’, defines late Victorian, when flat roof became more common, through to pre-Second World War, when modern methods of roof construction became more typical.
4.2 Property types with traditional flat roofs

A/ Habitable attics
The habitable accommodation in Victorian detached and semi-detached houses may have been formed at the time of building as servant accommodation or converted at a later date as additional bedroom space or as a self contained flat. In most cases ornate cornices and architraves are not evident. The floor plan may also be intersected by a large light well connected with the stair void.
B/ Tenements
Top floor flats in late Victorian Tenement blocks in Edinburgh, as shown right, are often roofed to their rear with large areas of flat roof. Of note is the connection between the flat and pitched roof voids and the connection of private and communal spaces via the roof void.

C/ Upper villas
The arrangement of pitched/ flat roof displayed right is also evident on upper villa flats built between the early years of the last century and the 1930’s. Similar issues exist with the interconnection of roof voids and ventilation, although no clash exists between private and communal areas.

5.0 Specifications
5.1 Building Context
Property type A/ Habitable Attic Accommodation was selected as the basis for the analysis of the flat roof by ESRU. The justification for this is that a single room could be modelled in isolation, as opposed as a whole flat or series of rooms with a larger set of variables. Recent projects undertaken by the SME also include this type of accommodation, therefore their detailed knowledge of the roof construction could be utilised. To provide a context to the flat roof, it was assumed that the pitched roof would be insulated to a similar level and that an enclosed storage area would be formed at eaves level.
5.2 Existing Case
Based on the GMA's experience of this construction, the build-up of the flat roof was defined as follows:

- Low pitch felt finish
- Structural ceiling void of varying height with low rates of background ventilation
- Lathe and plaster ceiling
- High quality internal finishes not evident
5.2 Specification Options

The four constructions proposed for analysis using the ESP-r simulation tool fall under the following main categories:

A/ External insulation or warm roof
   (Option 4)
B/ Internal insulation or cold roof.
   (Options 1– 3)

The warm roof upgrade (Option 4) would generally be considered as the optimal solution in most cases, however issues of cost, access, ventilation mean that this is not always a viable route.

Internal insulation works are generally more disruptive and may pose the greatest risk of interstitial condensation in the existing roof void, once internal finishes are applied. As a method of limiting disruption, Option 2 was developed as a route to retain the existing ceiling finish. Options 1 & 3 present two possible routes of vapour control using a vapour open material such as OSB or a well sealed an impervious membrane.

In all three options dealing with the application of internal insulation, wood-fibre board insulation is proposed due to its environmental credentials, vapour permeability and density. The nominal thickness of 100 mm is deemed suitable for a thermal upgrade which is not regulated by the Technical Standards. In addition a service void is used in each case to avoid the puncturing of the vapour control layer by services.
6.0 Dynamic Modelling Assessment
Introduction
ESRU has a history of partnering with design groups to improve working practices and enhance deliverables. In this case the support involved creating a numerical representation of a typical roof conversion which would support the comparison of different choices of roof construction. The layout of the spaces was specified by GMA as were the constructions. The constructions under consideration are as described in Section 5.

Options 1/2/3 are cold-roof implementations and option 4 is a warm-roof implementation. Only the original and option 4 preserve the original plasterwork.

The roof spaces were lightly populated (mostly evening and weekend occupancy) with one sequence of high humidity generation on Saturday morning. The storage spaces were assumed to have 0.2ac/h, rooms were assumed to be slightly leaky 0.4ac/h and the roof void 0.5ac/h infiltration.

Environmental controls were assumed to be a room radiator with a TRV. This type of heat delivery is 80% convective and TRVs are assumed to sense 35% air temperature and the balance radiant. Heating is to 20°C during occupied periods with 15°C otherwise.

A wireframe image of the model

On the left is the base case (room/storage/ceiling space). Moving to the right are the variants 1/2/3/4. This approach allows the full performance characteristics of all of the variants to be available simultaneously. Performance issues under consideration were:

- Comfort within the spaces
- Heating demands
- Frequency of surface condensation with and without cooking
- Storage space and roof void temperature patterns
- Movement of humidity between the spaces
- Patterns of temperatures within the roof constructions
Analysis Method

Numerical assessments were carried out via the ESP-r simulation tool making use of Glasgow airport weather data. ESP-r is a multi-domain simulation environment. It assesses not only the heat flows within the fabric of the building but the transport of moisture. In effect it is able to create a virtual experiment with hundreds of sensors. This allows design teams to explore a number of performance issues. The range of performance topics and reports available were discussed and the performance predictions were reviewed interactively prior to inclusion in this report.

Results

The energy impact of design decisions for these spaces follows a consistent pattern (Table 1). All of the options result in approximately the same level of demands for heating (approximately 50% reduction). The base case requires a small heating input for frost protection. The room air temperature tends to overshoot slightly at the start of an occupied period as the surfaces are warmed (see Figure 2). The cooking period on Saturday morning (day 11) is evident in Figure 3. This results in a high relative humidity in the store room which is ventilated to the room, but at a lower temperatures. The ceiling void humidity is more closely coupled to the external condition.

<table>
<thead>
<tr>
<th>Option</th>
<th>Heating energy, kWh</th>
<th>Number of heating hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case</td>
<td>57.39</td>
<td>100.5</td>
</tr>
<tr>
<td>Option 1</td>
<td>24.46</td>
<td>62.</td>
</tr>
<tr>
<td>Option 2</td>
<td>26.22</td>
<td>64.</td>
</tr>
<tr>
<td>Option 3</td>
<td>24.37</td>
<td>62.</td>
</tr>
<tr>
<td>Option 4</td>
<td>26.56</td>
<td>63.8</td>
</tr>
</tbody>
</table>

Initial assessments identified the storage spaces as being a likely point of failure in refurbishment work. For instance, the doors to storage spaces tend to be ill fitting and the significant exposure in such rooms to the roof and façade are greater than in the occupied spaces. This results in cold spaces which nevertheless also get a portion of the moisture generated within the occupied space in addition to the moisture which might accrue from wet clothing tossed into the spaces. Figure 4 shows the difference between the temperatures in the storage space and adjacent room. The temperature patterns for all options were very similar, being in all cases slightly higher than for the base case.
The ceiling voids fall into three broad patterns: the initial un-insulated roof structure, the cold roof condition in options 1/2/3 and the warm roof condition with option 4 which is essentially the same as the ambient outside temperature. These are shown in Figure 5.
Condensation patterns were also assessed. A pulse of 200W of latent gains was added for two hours on the Saturday morning gradually trailing off to normal humidity from occupants. This resulted in high Relative Humidity for a number of hours until the ventilation air dilutes the humidity. The storage spaces have essentially the same condensation risk for all options, with 10.5 hours of condensation during the week. The original room has 9 hours of instances whereas all the other options have about 5 hours of instances of condensation during the week. The roof space for the original roof space and the option 4 roof space have no reported condensation. The other options have some condensation on the end-walls within the very cold space (Figure 6).

**Figure 6: Ceiling void humidities for base case and all options**

**Conclusions**

- Non-upgraded roof structures are more sensitive to internal moisture sources than any of the alternative constructions. Condensation risk in the roof spaces is relatively low, being greater for the cold roof options.
- For a two hour moisture generation scenario e.g. cooking or showering, condensation was detected in all models, however it was considerably reduced with upgraded constructions.
- The area of greatest condensation risk appears to be in storage spaces adjacent to the occupied space which tend to be colder and which are poorly sealed from moisture laden air within the occupied spaces.
- The alternative constructions reduce energy consumption for the room by about 50%.

Grigor Mitchell Architects have been provided with the models, and received training that will allow them to carry out further analyses of the cases considered in this project for themselves, or to modify the thermal models to represent specific cases that they may work on in future.
7.0 Conclusions

7.1 Learning Outcomes
At the outset the formation of a warm flat roof construction was anticipated as the preferred route in terms of moisture control and avoidance of interstitial condensation. Due to access limitations and/or ventilation issues, this method is not always viable.

It was anticipated that the 3 ‘cold roof’ options presented for analysis using ESP-r would display a more marked difference in relation to condensation risk due to the differing vapour permeability and position of the vapour control layer. The three ‘cold roof’ options do indicate a greater level of condensation risk, albeit small, than the ‘warm roof’ thermal upgrade. The removal of the existing lathe and plaster and use of either OSB or a membrane however, does indicate a slightly reduced ceiling void humidity. It is however beyond the capacity of the ESP-r software to analyse whether this would lead to a seasonal fluctuation of moisture levels in the roof void, ultimately resulting in a progressive build-up of interstitial condensation over a number of years.

The most interesting and potentially influential outcome of the assessment, and initially out-with the anticipated scope, is the high risk posed to perimeter storage spaces adjacent to an occupied space. Although these spaces are within the thermal envelope the restricted air exchange with the occupied space can lead to lower surface temperatures, higher humidity and surface condensation. Potential improvements to the design of these spaces, could involve an increased level of insulation either improved ventilation between the storage and main spaces (louvred doors). Sealing these spaces from the main room does not seem practical.

7.2 Future Aims
At present there is limited research in Scotland investigating how best to detail and specify thermal upgrades to habitable flat roof spaces of traditional properties in respect to moisture control and avoidance of interstitial condensation.

As the SME is already involved with in the refurbishment and conversion of traditional properties, the acquired knowledge/process can be applied immediately as part of architectural services or as a consultancy service to other design professionals, marketed via the company website, professional networking meetings, student lectures and community group talks.

The ultimate aspiration of the SME is to create a sustainable building consultancy with a comprehensive knowledge base of best practice solutions to improve the thermal efficiency of traditional properties. This knowledge base would encompass design, installation and testing. To this end it is hoped that further training with the Academic Partner using ESP-r, so that the simulation tool can be imbedded in the SME’s process for developing and analysing project specific solutions. The SME also proposes to undertake further work with advanced software tools such as WUFI, to establish the impact of different types of vapour control layer on the control of moisture over a longer period.

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Overcoming the Challenges and Barriers for Innovation in Construction

David McBeth
Duncryne

“Innovation is the ability to see change as an opportunity not a threat” – Anonymous

“Innovation by definition will not be accepted at first. It takes repeated attempts, endless demonstrations and monotonous rehearsals before innovation can be accepted and internalised by an organisation. This requires ‘courageous patience’. “ – Warren Bennis

In the 3 years, since first hearing of MgO, we are now well versed in the challenges and barriers that innovation in construction currently faces – principally, powerful vested interests and a struggling economy. These were the challenges we faced when we were introduced to magnesium oxide (MgO) in 2010, a new material which promised to transform the construction sector and bring environmental, performance and economic benefits to contractors, developers, landlords and end users alike.

**Vested Interests**
The construction sector, particularly for the supply of building materials, is dominated by an oligopoly of major international conglomerates. The testing regimes required to be undertaken are extensive and policed by regulatory bodies deeply influenced by these oligopolies – it is not in their interests for new products to be introduced to the market which they themselves have not developed.

We have come up against all forms of existing alliances, explicit and covert who seek to thwart innovation throughout the various construction sectors and trade bodies with whom we have engaged over the last few years.

It’s part of business life and we are not on a crusade to change that, we accept the uneven playing field and have learned to adapt to it using our lean company structure to our advantage. We can more easily change tack and focus on areas that bring maximum benefit to our customers.

Our task is to persevere and provide a consistently good product and service levels for our clients who have embraced the real advantages Econic Performance Systems can give their businesses.

**The Economy**
When faced with the real prospect of potentially being made redundant, unless your primary role in an organisation is to promote innovation, are you really going to take a risk by adopting new materials or work practices? Nobody gets sacked for specifying what they have always specified or sticking to the specifications dictated by the large conglomerates regardless of costs.
We acknowledge that reality, but have been fortunate to find and work with some of the stand out exceptions to the above attitude across all professional disciplines who have, in turn, helped us to engage with the technical managers/directors and owners of businesses rather than the buyers or accountants in an organisation. We will continue to demonstrate the overall cost and performance benefits available from adopting *Econic Performance Systems* to this target audience who, over time, will influence the buying decisions.

Despite the advantages *Econic Performance Systems* offer, we are realistic enough to know that the poor economic climate is placing more immediate priorities on potential customers. We are sensitive to that and have focussed our marketing attentions accordingly by thoroughly researching target companies and understanding their particular business requirements and issues. Our goal is to build a solid base for our company, servicing a number of key clients whose businesses are proving to be resilient despite the recessionary economic situation and ensure we are well placed to take advantage of opportunities that will come when the wider economy improves.

**Background**

Duncryne was established by 3 co-directors, 2 property investment/development professionals based in the UK together with another Glasgow born product sourcing expert based in Shanghai with over 30 years experience in sourcing and quality assuring a varied range of products in Asia for the UK and Australian based clients.

We were introduced to MgO (Magnesium Oxide) boards in 2010 – which promised a low carbon, fire and weather resistant, structurally strong building board that was relatively cheap to produce. From our point of view it ticked the right boxes - sustainability, high performance and economic benefits. Nevertheless, we were healthily sceptical of the claims being made and as the target markets for promoting the product were the contractors, developers and architects and associated professionals with whom we had over 20 years experience working with, we chose to carry out our own detailed research and analysis before “putting our names” to this product.

**Sustainability Credentials**

A common claim found on the internet for MgO is that it is a carbon negative material and even that it “eats carbon”. The fusion of MgO with magnesium chloride within the mix does draw carbon dioxide into the finished product, how much is dependent on the quality of the raw materials and the manufacturing process. There are a wide range of manufacturers of MgO in China, who produce products for very different markets with only a limited number producing MgO to the standards and quality acceptable for western markets.

Exactly what raw materials are used and how it is produced makes a big difference to the end result, both in terms of performance characteristics and sustainability credentials.

We do not want to promote a “greenwashed” product dealing in general unsubstantiated environmental claims. So, with the assistance of CIC Start and a funding grant from Scottish Enterprise, we engaged the services of Dr Charles Russell of Glasgow Caledonian University’ s Centre for Energy and the Built Environment to conduct a full Life Cycle Analysis on *Econicboard*.

The study looked in detail at our manufacturers’ particular method of production, the quality, source and transport of all raw materials and the energy used in production together with shipment of the finished material to our warehouse in Renfrew (a cradle to gate analysis).
The resultant conclusion of this study is “that the product is a low carbon product and best in class against other main board types that this product competes with”. It is calculated that Econicboard has a carbon emission rating of 0.374 kgCO₂/kg which is a half that of MDF, a third of OSB/Plywood and a fifth of fibre cement board.*

As far as we are able to ascertain no other supplier of MgO based materials in the world has conducted such an exercise on their products, instead preferring to rely on general assertions about sustainability and environmental credentials, with little real evidence to back up these claims. We have been contacted by contractors as far a field as Australia, solely on the basis of our LCA work to date undertaken through CIC Start Online.

We have also taken a proactive stance in relation to in service and end of life waste material from our products and engaged with Zero Waste Scotland (ZWS) to investigate the longer term issues concerning MgO and future waste streams. In turn, ZWS have, in conjunction with WRAP, appointed URS to undertake a UK wide scoping study of MgO, Magnesium Silicate and Calcium Silicate boards which are starting to enter the market. We believe this is a responsible stance to take and are assisting URS in their research and analysis project.

Product Performance

Whilst we were keen to verify the low carbon credentials of our Econicboards our marketing experience to date suggests that outside of select public sector related projects it has a negligible influence on decision making of what materials to use. In today’s economic climate it all comes down to performance and cost. We are firmly of the belief that supplying only sustainable products is the responsible route to take and that in the long term this approach will stand us in good stead and differentiate us from the mass market. Unfortunately, for the foreseeable future this brings us no identifiable commercial benefit – it’s just the right thing to do.

We were not content to rely on manufacturers declared results and are constantly surprised how little detailed due diligence is carried out by specifiers in the UK when deciding which materials to use. There is a well rehearsed game being played by suppliers of materials and, 3 years in, we are now well versed in how to really analyse published test data and marketing literature produced by our competitors – how many times have we seen CE marked products being promoted for uses they are not actually CE marked in relation to?

We continually see competitors referring to the fact that they reuse the waste off-cuts by grinding down and reusing them in the production of their finished boards as evidence of their products being “green”. To us, that simply tells that the quality of board they are producing is inferior as the waste material at that point in the production cycle is just that - waste! It has already reacted chemically and cannot add to the performance of the board – it is simply used as a cheap filler to bulk out the boards without adding to performance. Such claims indicate to us that such competitors are either content to sell lower quality material or at best do not understand the manufacturing process of the product they are promoting.

Our manufacturer maintains their environmental credentials by selling their off-cuts to the local brick manufacturer who can best use the inert material as an aggregate.

* “University of Bath; Inventory of Carbon & Energy, Version 1.6a” by Prof. Geoff Hammond and Craig Jones
Or, instances where products widely promoted by the industry are in fact “tested to the principles of” particular testing regimes rather than carried out via UKAS accredited authorities to the rigid terms actually set out in the BS EN standards.

Nevertheless, we have learned the hard (and expensive) way but now have what we believe to be the most extensively and thoroughly UKAS tested MgO based boards available in the UK market.

We have taken the factory produced performance data as a guide to expected results but have independently verified every single result using the UK based UKAS accredited test houses to BS EN Standards. This we have done using principally CERAM, Exova Warrington Fire, amongst others.

Beyond the performance verification, we have to demonstrate value for money for end users regardless of application. By fully understanding how Econicboards are produced we can amend the mix of ingredients and adapt the manufacturing process to produce a variety of boards and composites which address a range of real immediate problems in today’s construction market. So far, our product range consists of the products listed in the Figure 1. Each product is formulated to provide enhanced performance benefits over competing materials and at a cost effective price. Across the product range, the USPs for Econic Performance Systems are presented in Table 1.

Table 1. USPs for Econic Performance Systems

<table>
<thead>
<tr>
<th>Verified Low Carbon Product</th>
<th>Euroclass A1 Non Combustible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensionally Stable in all weather conditions</td>
<td>Category 1 Racking Strength</td>
</tr>
<tr>
<td>Non hazardous Material, promoting clean indoor air quality – no formaldehyde, benzenes or solvents</td>
<td>Category A for Robustness and Durability</td>
</tr>
<tr>
<td>Low Vapour Resistivity</td>
<td>Severe Duty Rated for Impact</td>
</tr>
<tr>
<td>Good Pull Out Strength</td>
<td>Easy to cut and fix</td>
</tr>
<tr>
<td>Good Bonding Strength for range of laminates</td>
<td>High Fire Resistance</td>
</tr>
<tr>
<td>Good Wind Loadings</td>
<td>Resists Mould and Mildew Growth</td>
</tr>
<tr>
<td>High Density for Acoustic Applications</td>
<td>Can be installed before wind and watertight</td>
</tr>
</tbody>
</table>

Econic GPS Board
Non Combustible Timber Sheathing Substrate for Building Envelopes Sheathing for Closed Panels & SIPS High Security Panels

Econic Render Board
Cement Renders Acrylic Renders Natural Lime Renders External Wall Insulation

Econic High Impact Board
Healthcare & Institutional corridors Hotel Room Pods Modular Accommodation Rail and Transport Infrastructure Fire Proof Hoardings

Econic Backer Board
Tile Backer for Floors and Walls Non- Combustible Noggins/dwangs Retrofit Solutions for High Moisture Areas

Econic Fire Board
Passive Fire Steel Protection FR Rated Partitions FR Rated Ceilings

Econic Acoustic Solutions
Roof Substrates Flooring Substrates Internal Partition Walls Acoustic Panels Retrofit Options

Econic Composite Panels
Decorative Panels Soffit Lining Panels Door Cores

Figure 1. Econic Performance Systems
All of the above characteristics can be individually enhanced further to meet particular demands depending on the end use required.

**The Future**

“Business has only two functions – marketing and innovation” – Milan Kundara

With the diverse range of *Econic Performance Systems* available for use within the construction sector we are faced with a strategic dilemma – how do we properly market our solutions throughout the UK and abroad, both within construction and other sectors, e.g. offshore?

Our principal clients are involved in timber frame construction, general contracting and specialist applications:

- UKTFA fire tested Category C solution for Fire Separation Guidance – clients throughout the UK. (major housing companies, housing associations, off-site manufacturers and self-build)
- Low Carbon Substrate for SFS in lieu of cement particle board – Schools projects in Scotland and England (Figures 2 and 3)
- Non-combustible backer boards throughout the New Southern General Hospital, Glasgow (Figures 4, 5 and 6).

Fig. 2 and 3. Low Carbon Substrate for SFS in lieu of cement particle board – Schools projects in Scotland and England
We wish to retain our lean company structure and have decided to concentrate on our strengths in sourcing the products and ensuring they are fit for purpose in their target markets. We are actively engaging with market leaders and industry experts in each target field to create strategic alliances and partnerships to jointly market our products. If individuals or companies have an identifiable existing route to market in any particular sector of industry or specific geographic location then we want to speak to them.

We are also keen to work with different industry and academic bodies to advance our own understanding of the issues of concern to the construction industry and jointly promote the accredited and verifiable benefits Econic Performance Systems can bring.

Website for further information:  [www.econicperformancesystems.com](http://www.econicperformancesystems.com)
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Linkedin Profile:  [http://www.linkedin.com/in/mcbethdavid](http://www.linkedin.com/in/mcbethdavid)

Fig. 4, 5 and 6. Non-combustible backer boards throughout the New Southern General Hospital, Glasgow
Dear members of CIC Start Online

Thank you for engagement with CIC Start Online project!

Our forthcoming joint project of nine Scottish universities, led by Glasgow Caledonian University, is entitled *Mainstreaming Innovation*. It will focus on integration of sustainable infrastructure into the existing built environment. The project will start on 1\textsuperscript{st} April 2013 and will be funded by Scottish Government. More information will be available at the launch events and on the new project website from 1\textsuperscript{st} April.

We wish you success in designing more sustainable new buildings and improving the existing built environment!

With best wishes,
CIC Start Online consortium & team