Energy • Life Sciences • Techmedia

MARKET INTELLIGENCE REPORT

ENERGY MANAGEMENT IN THE BUILT ENVIRONMENT

An initial study for energy management, defined as:
“Products and systems that manage energy use within buildings”

June 2009

CONTENT

EXECUTIVE SUMMARY

This document provides market intelligence on the concept of Energy Management in the Built Environment (EMBE) by the Intermediary Technology Institutes (ITI) in Energy and Techmedia.

For the purposes of the report the definition of EMBE is:

"Products and systems that manage energy use within buildings".

There is now an acknowledgement among stakeholders that information and communications technologies must be added to the energy infrastructure in buildings. Significant changes are now occurring in the power industry as new, interactive and dynamic communications technologies make it possible to have "smart" energy networks that, like the Internet, can be used to control operations more efficiently and to enable customers to monitor and provision their own services.

This Report provides an overview of the EMBE market, sets out key trends, drivers and inhibitors, reviews the outlook for market development and describes a number of market opportunities, one or more of which may form the basis for further ITI activities in this area.

In-building applications are a huge driver of energy consumption

Energy use in buildings comprises about half of all European energy consumption and occupies a similar position in most other global economies. It offers huge potential for improvements and research suggests that the economics of investing in energy productivity—the level of output we achieve from the energy we consume—are very attractive. Possible improvement measures related to EMBE include:

- Improvements in efficiency and effectiveness (some studies show savings of up to 40% are possible, by for example, not heating buildings when empty)
- Reducing peak demands on energy networks
- Enhancing the quality of life of occupants

The EMBE market is very broad and can be segmented in many different ways. The segmentation used in this report is as follows:

- Industrial applications
- Domestic applications
- Commercial applications

Within these segments ITI believes that the commercial sector represents an attractive future market opportunity (it is underserved at present and the market is large) and any EMBE technology entering it has the potential to address opportunities in the domestic market, which is also very large and underserved.

EMBE applications exhibit significant innovation potential

EMBE technologies, systems and products have developed to the point where a number of market applications are already being exploited. Market growth is occurring mainly in industrial and large commercial applications, where the significant installation expenditure and operational complexity can be justified.

Falling costs coupled with market drivers such as rising energy prices and environmental concerns are creating opportunities for wider application of EMBE devices in the commercial and domestic markets.

As novel, economically-viable, technologies allow market opportunities to be addressed, the EMBE market for commercial applications should witness significant growth in the medium to long term. Indeed, by 2030, this potential EMBE market opportunity could be worth over GBP20 billion, from a base of around GBP15 billion currently in the EU/US (this estimate is based on an assumed 10% saving on total energy spend in this market segment in the EU/US).

Given that market growth in these sectors will be driven by a very different set of (primarily low cost easy to use) solutions, this provides opportunities for the creation of novel business models and technology solutions.

Opportunities exist in a number of areas

As with any opportunity that offers significant new commercial opportunity, the emergence of aggressive small companies and start-ups can be expected. As such, the EMBE market could represent a significant new and addressable opportunity for technology businesses in Scotland.

Through the creation of underlying technology platforms, ITI could play a role in enabling the development of such businesses. ITI has identified opportunities that could lead to the creation of technically novel and commercially enabling technology platforms as follows:

- Using less fuel to do the same job
- Using less power to do the same job
- Smart-metering and building energy management systems
- Information provision to influence behaviour and diagnostics
- Managing energy use in the building to achieve wider performance goals, such as efficient use of power generation facilities, across the entire power grid.

ITI Scotland will use these trends and opportunities to identify appropriate R&D programmes

Further to this opportunity identification, subsequent analysis has indicated that the following opportunities could form the basis for further ITI activity in this area:

- Building sealing
- Energy budget management
- Identifying health risks from energy use
- Influencing and improving energy use behaviour

Prior to progressing activities in this area, ITI will seek to engage further with stakeholders to validate and confirm those opportunities that should form the basis for its subsequent activities. In addition, ITI welcomes R&D programme proposals and expressions of interest in related areas to assist in providing an understanding of the capabilities and commercial interest within Scotland.

1 INTRODUCTION

1.1 Document Purpose

The purpose of this document is to provide a 'snapshot' view of the Energy Management in the Built Environment (EMBE) industry in order that stakeholders can:

- gain access to market information relevant to the sector;
- have visibility of the market analysis activities undertaken in this sector by ITI;
- gain insight into opportunities that ITI may explore further in order to establish whether they could form the basis of a research and development programme.

This report aims to provide an understanding of EMBE, and give those who wish to act as players in this space an appreciation of the industry and potential scale of this market.

This document should not be considered as providing a comprehensive analysis of the competitive environment within the EMBE industry. Such an analysis is beyond the scope of this document.

1.2 Document Structure and Content

This document provides market intelligence on the sector defined by ITI as EMBE (see Section 2.1 for the definition of EMBE). The information captured within the document has been obtained following the principles of market intelligence gathering (otherwise known as foresighting) established by ITI.

During the process of developing this market intelligence report, both primary and secondary market data were acquired and collated. Primary data was collected by interviewing and surveying experts and practitioners from academia and commerce, and a Scottish experts workshop attended by both industry and academia. The primary data gathering process was augmented by desk-based research which was used to obtain secondary data from internationally recognised analysts and other sources. Where possible, the source of any data used in this report has been identified.

The document contains the following sections:

- **Section 1: Introduction**. This Section covers the background, aims and scope of ITI Scotland. It also provides a high-level description of the EMBE areas of focus. Further background information can be obtained on the ITI website.
- **Section 2: Market Overview**. This Section provides a working definition of EMBE, highlights the main characteristics of the sector and the segmentation of the market. The main trends, drivers and inhibitors are identified
- **Section 3: Market Opportunity Assessment**. This Section provides an analysis of the top market opportunities identified during the foresighting process. For each opportunity, it includes a description, a market overview, unmet market needs, market drivers and barriers and a timeline
- **Section 4: Conclusions and Next Steps**. This Section provides the key conclusions of the report together with a summary of the next steps that ITI intends to take in the area of EMBE.

1.3 Background: ITI Scotland

1.3.1 Economic Context

A global driver for economic growth is the development and exploitation of technology both for present needs and future requirements. Successful economies are underpinned by a vibrant research base which extends from basic science through to pre-competitive research and development, with a clear focus driven by global market opportunities. Scotland has a reputation for world class research in many fields and already undertakes significant research activity in several areas which have the potential to be strong future market opportunities. In addition to the research base, most developed economies have institutes or organisations that promote knowledge generation and increase commercial exploitation capacity. The establishment of such organisations has had significant economic impact over the long term.

1.3.2 ITI Scotland

ITI Scotland is a commercial organisation focussed on driving sustainable economic growth in Scotland, through ownership of commercially targeted R&D programmes that deliver world-class intellectual assets. The activities of ITI will assist bringing Scotland's economy to the cutting edge of new emerging markets by allowing local companies to access and build upon pre-competitive technology platforms developed by ITI.

Specialists from ITI Scotland's three divisions - ITI Techmedia, ITI Energy and ITI Life Sciences - identify technologies required to address future global market opportunities, then fund and manage R&D programmes and the subsequent commercial exploitation of new intellectual property (IP). This publicly funded company has an active Membership of interested parties from the business, research, academic and public sectors. Members enjoy exclusive access to market foresighting (such as that contained within this Report), the opportunity to participate in leading-edge technology R&D programmes and networking opportunities brought about by regular meetings of a growing network of like-minded organisations.

The ITIs also interact with each other to identify potential overlap or "white space" market opportunities between ITI Techmedia, ITI Life Sciences and ITI Energy. This report is a result of such an interaction between the Techmedia and Energy ITIs.

The ITIs are a centre or "hub" for:

- identifying, commissioning and diffusing pre-competitive research that is driven by an analysis of emerging markets
- managing intellectual assets to maximise commercial and economic value.

The key to identifying opportunities for research and development lies in a process called Market Foresighting which involves detailed market and technology analysis to identify trends, evolving requirements and potential demand for new technology. ITI compiles the output of this activity in Market Intelligence Reports which are published to stakeholders. This market foresighting informs the ITI R&D programme identification process.

1.4 ITI Techmedia

ITI Techmedia is focussed on the development and creation of commercial opportunities encompassing the communications technologies and digital media sectors.

The term 'ITI Techmedia' arose out of the need to reflect the market evolution of communications technologies and digital media. The overall trend in the marketplace is one governed by a value chain ranging from content/application generation through delivery to consumption. Content, service provision, delivery channels and enabling and managing technologies can no longer be treated in isolation and ITI seeks to operate across this value chain.

The Techmedia sector is potentially very broad. Hence a phased approach to market foresighting has been adopted. Previous foresighting has concentrated upon a number of major market areas:

- Health (including a further report on technology opportunities in Remote Health)
- Commerce and Finance
- Learning and Education
- Communication Services
- Entertainment and Leisure

- Digital Cinema
- Nanotechnology
- Homeland Security
- Ubiquitous Computing
- Next-Generation Computing
- Advanced Robotics.

To date, these foresighting activities have helped ITI to identify a number of R&D programmes:

- **Games-Based Learning** - to develop a differentiated creation and authoring platform to simplify the creation of games-based learning content. Completed January 2007
- **Machine-Readable Security Tagging** - to develop an end-to-end system solution, featuring a range of component technologies required to protect brands and combat the growing global threat to products from illegal counterfeit activity. Completed March 2007
- **Ultra-wideband Wireless Communications** - to develop the components, system and network management elements for ultra-wideband wireless technology in consumer markets
- **Condition-based Monitoring** – to apply sensors and networks technology to condition-based monitoring for predictive intervention in animal health
- **Biosensors** - to create a technology platform that will facilitate both diagnosis and treatment of infectious diseases
- **Online Game Development** - to make the games development process more productive through provision of novel technologies that can be integrated into the existing tools and middleware chain
- **Backlighting Using Polymer Optics** - to develop a novel backlight platform for liquid-crystal flat-panel displays to improve viewing quality, reduce weight and improve power efficiency at lower cost
- **Software Integrity Engineering** - to develop novel, user-friendly, code design and development tools that assist in the identification and elimination of critical, high impact, software errors for mainstream applications
- **Chronic Wound Care –** to develop a point-of-care infection detection diagnostic for chronic wounds, particularly diabetic foot ulcers
- **Explosives Detection –** to develop technology for use in homeland security situations to enable the stand-off detection of explosive devices.

1.5 ITI Energy

ITI Energy focuses on the development and creation of commercial opportunities in the energy sector (which covers a range of industries from the conventional oil & gas and electricity industries to renewables and sustainable transport). Energy is essential in almost every aspect of our lives and for the success of our economy. Change in it is being driven by Government (both national and local) policies seeking to address air quality, climate change and energy security issues as well as by measures to underpin economic growth and competitiveness.

Previous foresighting has concentrated upon a number of major market areas:

- Mature Oil and Gas assets
- Conventional Power Generation
- Condition Monitoring of Wind Turbines
- Offshore Wind Turbine Blades
- Future Power Networks
- Low Cost Renewables

- Torrefied Biomass
- Energy Storage
- Microgeneration
- Emerging Fuels
- Electric Vehicles.

To date, these foresighting activities have helped ITI Energy to identify a number of R&D programmes:

- **Composite Pipeline Structure** - a low-cost, lightweight, high strength, steel composite pipeline, capable of being manufactured onsite, in a continuous process
- **Wind Turbine Access System** - a lifting device, which will dramatically improve the efficiency of maintenance of wind turbines
- **Resonance Enhanced Drilling** – a novel drilling technology, which can significantly reduce the weight on bit and dramatically speeds up the drilling process
- **Rechargeable Battery** - a new low-cost, high-energy rechargeable battery material based on using Lithium-ion (Li-on) technologies
- **Battery Management System** - applied in Electric Vehicles this device improves the information available on battery systems
- **Hydrogen handling materials** – Hydrogen is seen by some as the clean fuel of the future. This programme sought to develop a family of innovative low-cost materials that can store and release hydrogen under mild thermodynamic conditions (room to moderate temperature and pressure)
- **Very large scale flow batteries** – Large batteries are seen as a means of storing energy from renewable sources such as wind or solar for discharge during periods of peak demand; for peak shaving, where spikes of demand can be met by the battery; or for uninterruptible power supply when mains power fails.

In addition, ITI Energy has four programmes which are likely to be submitted for approval shortly.

- **Seaweed Anaerobic Digestion** – an alternative energy resource to land based biofuel crops with an excellent Scottish fit
- **Energy Recovery Systems for Electric Vehicles** – a mechanism for improving the capture of energy from braking events, extending vehicle operating range and cutting costs.
- **Intelligent Energy Interface** - an intelligent node within a home or business that controls electricity demand and supply technologies at the point of consumption.
- **Offshore Blade Technologies** – novel technologies to improve the performance and reliability of offshore wind turbine blades.

2 MARKET OVERVIEW

This section presents an overview of the EMBE market, its development and the various drivers of that development. As such this section:

- defines the EMBE market (Section 2.1)
- identifies the major market segments (Section 2.2)
- describes the market and industry structure (Section 2.3)
- describes major trends, drivers and inhibitors affecting the development of the EMBE market (Section 2.4)
- provides high-level forecasts for the evolution of the EMBE market (Section 2.5).

This Section provides a framework for the identification of the specific opportunities described further in Section 3.

2.1 Market Definition

For the purposes of the report the definition of EMBE is:

"Products and systems that manage energy use within buildings"

Within the next 5-20 years EMBE is expected to impact increasingly on everyone, both at home and in the workplace. This is a technologically complex emerging market with significant opportunities for the right applications.

The built environment incorporates a vast range of buildings, from one-bed residential flats through to public buildings, industrial buildings and commercial buildings. Industrial and agricultural buildings may need fuel or electricity for very specific process needs, but generally speaking most other buildings need energy to achieve the following:

- comfortable internal environment (warm enough, cool enough, adequate light)
- operation of an ever-increasing range of appliances (mostly those using electricity)

The catch-all phrase Energy Management in the Built Environment refers to products and systems that manage energy use in buildings. All devices that burn fuel or consume electricity are therefore part of the EMBE space, as is the building envelope – the physical components of the built environment that influence flows of energy within and through buildings.

The goal of EMBE practitioners, from professional energy managers through to domestic householders, is to achieve a desired level of energy services at the lowest energy costs, with a secondary benefit of reducing the associated environmental impact. Core technology requirements include reliability, cost effectiveness, safety and ease of use.

2.2 Market Segmentation

The scope of this study incorporates a large number of energy demands, including various unique, industrial processes and requirements. Although such applications fall within the scope of the EMBE opportunity, this report focuses on the energy requirements that need to be met in most buildings; i.e. those relating to a comfortable environment (heat, cooling, ventilation and lighting) and those served via common electrical appliances (e.g. computing, entertainment, refrigeration).

For the purpose of this report, buildings are segmented as follows:

- Industrial
- Commercial
- Domestic.

Figure 1 below provides a high level comparison of EMBE characteristics in these segments. In the remainder of this Section these characteristics are explored in more detail as follows:

- Overall in-building energy market (Section 2.2.1)
- Industrial energy use[1] (Section 2.2.2)
- Commercial energy use (Section 2.2.3)
- Domestic energy use (Section 2.2.4).

	Industrial	*Commercial*	*Domestic*
Product Opportunities	Well served	High	High
Price	High	Medium to Low	Low
Product Volume	Low	Medium	High
Users	Highly trained	Trained	Untrained
Requirements and Standards	Highly specialised	Industry specific. Contractually driven	Consumer protection and safety legislation
Approximate EMBE market opportunity (EU/US)[2]	GBP20 billion	GBP15 billion	GBP35 billion

Figure 1: User characteristics of EMBE [Source: ITI Scotland]

2.2.1 Overall Market

According to the International Energy Agency, global energy consumption is projected to expand by 50 percent from 2005 to 2030[3]. Underlying growth rates diverge markedly between developing and developed countries:

- in the developed world, demand for electricity has risen at around 2-3% pa and has generally risen with GDP, although the link between the two is weakening and annual energy demand growth is currently below 1% pa
- in the developing world energy demand is still rising in line with annual economic growth.

Figure 2 below shows examples of historic electricity demand growth.

	TWh pa	2001-2005 averaged demand growth (%)	Population** (millions)
UK*	343	1%	61
EU-27	2,739	1%	499
US	3,815	1%	306
China	2,197	13%	1,328
World	15,747	4%	6,741

Figure 2: Examples of electricity consumption [Source: DOE[4], Wikipedia[5]]

[1] Due to the diverse nature of energy consumption for industrial applications, this Section provides only a very high level overview of the segment

[2] Based on a 10% saving on energy spend in these segments in 2007

[3] IEA 2008 http://www.iea.org/Textbase/stats/electricitydata.asp

Outside the transportation sector (which at present is dominated by liquid fuels and other petroleum products) the mix of energy use in the residential, commercial and industrial sectors varies widely by country and region. Such variation is dependent upon a combination of regional factors, such as the availability of energy resources, the level of economic development, and political, social and demographic factors.

As seen in Figure 3 below, overall energy consumption across all sectors of the UK economy has remained flat or declined slightly in the last 5+ years as a result of efficiency gains, a stable population and relatively subdued economic growth. The broad split between sectors has also remained stable, with transport accounting for 39%, the domestic sector 28%, industry 20% and the service sector 12% of total consumption of 155 million tonnes of oil equivalent (MTOE) of energy used in 2007. (1 TOE = 42Giga Joules)

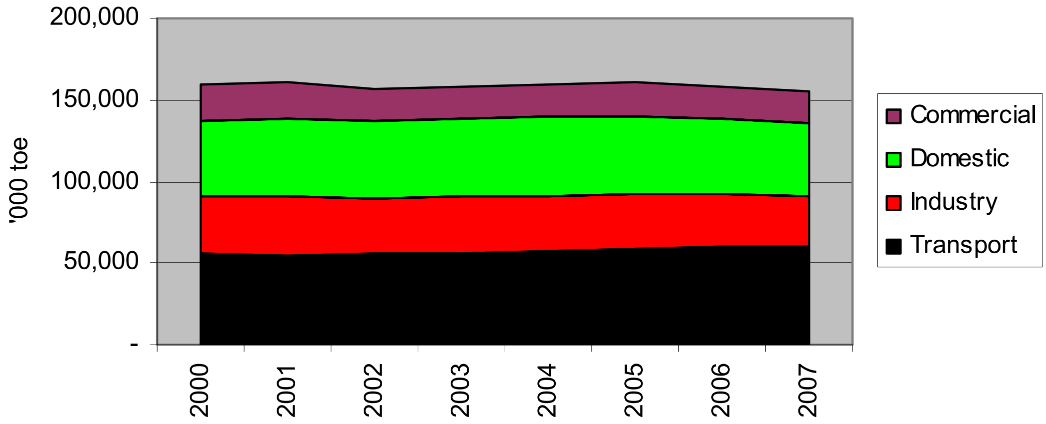


Figure 3: Energy consumption trends by end use in the UK [Source: BERR, ITI Scotland]

Figure 4 below, illustrates UK energy consumption & spend by sector, excludes energy consumed for transport purposes. The term 'Other' fuels primarily covers fuel oil use. Broadly speaking, the domestic sector is the largest consumer of energy and spent around GBP33 billion in 2007 on energy, while the industrial and commercial sectors spent GBP21 billion and GBP15 billion respectively.

	Thousand tonnes of oil equivalent				Millions pounds pa spend			
	Electricity	Gas	Other	Total	Electricity	Gas	Other	Total
Domestic	10,013	31,371	3,885	45,269	14,458	12,770	5,873	33,101
Commercial	8,392	8,695	1,239	18,326	10,248	3,034	1,585	14,867
Industry	10,172	12,366	10,228	32,766	8,872	2,876	9,516	21,265
Total	28,577	52,432	15,352	96,361	33,579	18,680	16,975	69,233

Figure 4: UK energy consumption and spend by end use, excluding transportation, 2007 [Source: BERR, ITI Scotland]

2.2.2 Industrial Energy Use

Energy is consumed in the industrial sector globally by a diverse group of industries including manufacturing, agriculture, mining and construction and for a wide range of activities, such as process and assembly uses, space conditioning and lighting.

In the UK there are some 44,000 heavy industry plants and several tens of thousand more light industry plants and their total energy consumption amounts to some 33 Mtoe. This is around 12% of all UK energy use (which totals 238 Mtoe, including transport energy use). This ratio has remained broadly stable for the last 5 years. Across developed and developing countries this

[4] http://www.eia.doe.gov/emeu/international. DOE TWh figures are all net electrical consumption data from 2005, except for UK which is DTI [5] 2007 data. Wikipedia population data is 2007 numbers

[5] http://en.wikipedia.org/wiki/List_of_countries_by_population

percentage will vary from country to country, but in most cases is unlikely to vary by more than plus or minus 10%.

2.2.3 Commercial Energy Use

Commercial buildings vary enormously, and include various owners and occupiers including a large number of publicly owned buildings. Figure 5 below illustrates energy consumption patterns within different commercial sectors in the UK. Such patterns are broadly typical of most of Europe and temperate North America.

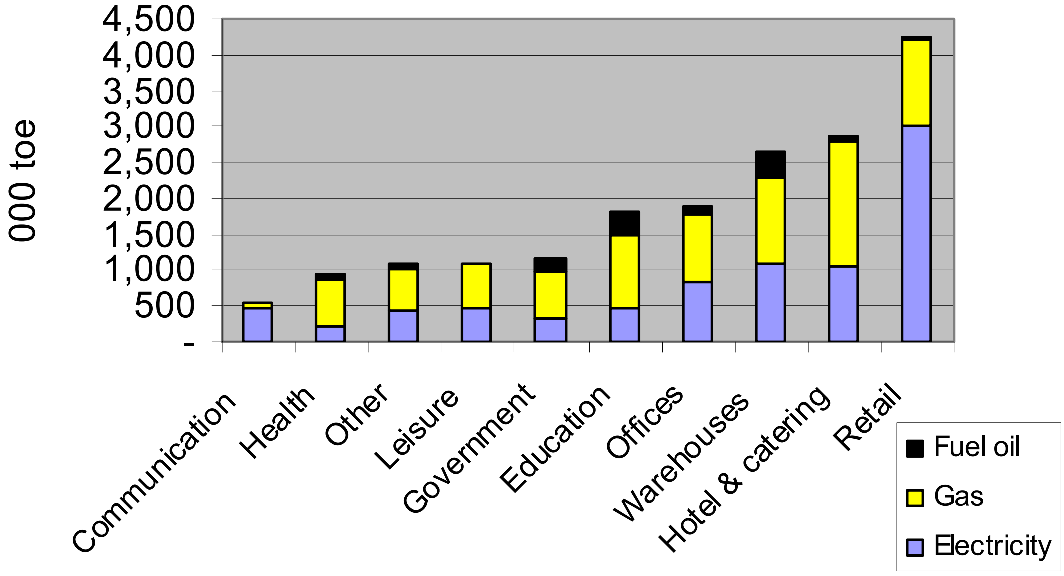


Figure 5: UK energy consumption by commercial building type [Source: BERR]

The commercial sector – often referred to as the services sector or the services and institutional sector – consists of businesses, institutions and organizations that provide services. The sector encompasses many different types of buildings and a wide range of activities and energy-related services. Examples of commercial sector facilities include schools, shops, warehouses, prisons, restaurants, hotels, hospitals, museums, office buildings, banks, and stadiums that hold sporting events. Most commercial energy use occurs in buildings or structures, supplying services such as space heating, water heating, lighting, cooking and cooling.

Higher levels of economic activity and disposable income lead to increased demand for hotels and restaurants to meet business and leisure requirements; for office and retail space to house and service new and expanding businesses; and for cultural and leisure space such as theatres, galleries, and arenas. In the commercial sector, as in the residential sector, energy use per capita in the non-OECD countries is much lower than in the OECD. Non-OECD commercial energy consumption per capita averaged only 3 MTOE in 2005, compared with the OECD average of 41 MTOE[6].

Slow population growth in most of the OECD nations contributes to slower anticipated rates of increase in the commercial energy demand. In addition, continued efficiency improvements are projected to moderate the growth of energy demand over time, as energy-using equipment is replaced with newer, more efficient stock. Conversely, strong economic growth is expected to include continued growth in business activity, with its associated energy use, in areas such as retail and wholesale trade and business, financial, and leisure services.

The United States is the largest consumer of commercial delivered energy in the OECD and is expected to remain in that position throughout the projection period. US commercial energy use accounts for about 45 percent of the OECD total through to 2030.

---

[6] http://www.eia.doe.gov/oiaf/ieo/world.html

In the non-OECD nations, economic growth and commerce are expected to increase rapidly, fuelling additional demand for energy in the service sectors. Faster population growth is also expected, relative to that in the OECD countries. Such growth is expected to result in increases in the need for education, health care, and social services and the energy required to provide them. The energy needed to fuel growth in commercial buildings will be substantial, with total delivered commercial energy use among the non-OECD nations expected to rise by 3.3 percent per year, faster than any other end-use sector.

Meeting the fast-paced growth in demand for energy in the commercial sectors of non-OECD nations is likely to present a challenge. In China, for instance, a large number of existing commercial buildings are classified as "high energy-consuming," with energy use per square foot at levels that are two or three times as high as those in the western world.

Even more so than the domestic sector , there is a diversity of segments in the commercial market and within each of these demand varies significantly. The detail of consumption within these segments in the UK is shown in Figure 6 below and this has been converted into approximate market sizes using representative energy costs [refs] for electricity, gas and fuel oil of 11p/kWh, 3.5p/kWh and 12p/kWh. In total, spend in this market amounted to around GBP1.5 billion annually in 2007.

	Thousand tonnes of oil equivalent				Millions pounds pa spend			
Commercial & public sector	Electricity	Natural Gas	Other	Total	Electricity	Natural Gas	Other	Total
Communications	468	88	5	561	571	31	6	608
Health	228	640	76	945	279	223	97	600
Other	422	594	59	1,076	516	207	76	799
Leisure	482	606	6	1,094	589	211	8	808
Government	341	635	177	1,153	417	221	226	864
Education	480	1,006	330	1,815	586	351	422	1,359
Offices	851	939	110	1,900	1,039	328	140	1,507
Warehouses	1,072	1,229	350	2,652	1,310	429	448	2,186
Hotels & catering	1,051	1,761	65	2,877	1,284	614	83	1,981
Retail	2,996	1,197	61	4,255	3,659	418	78	4,155
Total	8,392	8,695	1,239	18,326	10,248	3,034	1,585	14,867

Figure 6: Energy use and spend by type of commercial consumer [Source: BERR, ITI Scotland]

Figure 7 below shows what this energy is used for based on an average of all the energy consumed across this sector.

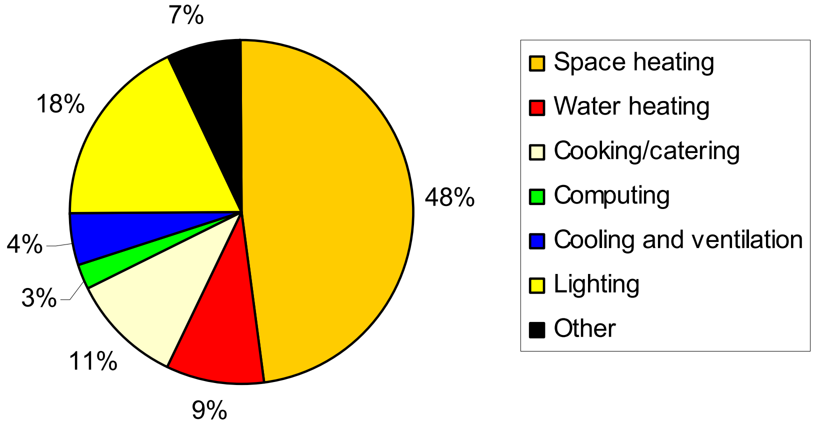


Figure 7: Commercial energy use by application [Source: BERR, ITI Scotland]

Annual energy spend in the EU-27 region is more than 6 times greater than in the UK (based on population numbers) and in the US this sector spends USD92 billion per annum on energy– or roughly 4 times as much as is spent in the UK. In total then the market potential of this sector, based on energy spend in the EU/US is around GBP150 billion pa at present.

Figure 8 below illustrates typical spend at an individual commercial building level in the US. Lightly occupied churches exhibit the lowest levels of building energy spend whilst health care buildings exhibit the highest levels of spend.

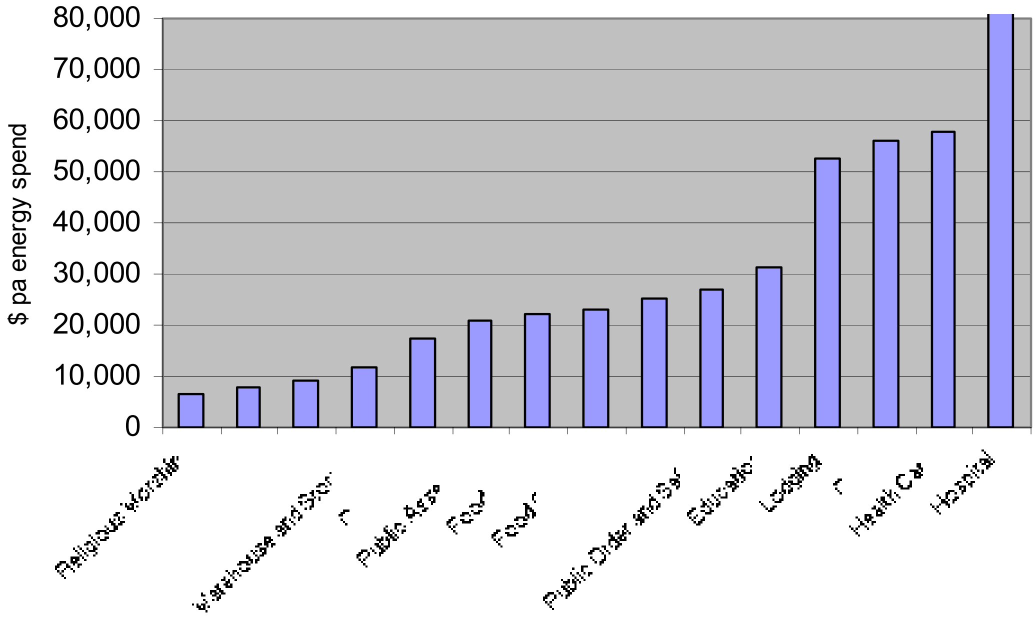


Figure 8: US energy spend by type of commercial building [Source: DOE, ITI Scotland]

Figure 9 below illustrates the subdivision of US commercial buildings by floor space, - probably the most significant factor affecting energy spend - with the vast majority being under 5000 square feet in area.

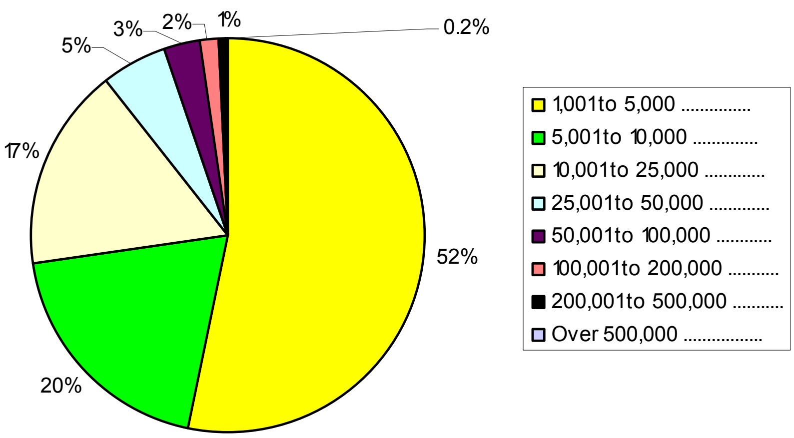


Figure 9: US commercial buildings split by floorspace [Source: DOE, ITI Scotland]

Looking at the distribution of spend on energy expenditure by floor space in the US, the vast majority of commercial buildings spend less than USD5000 per year (see Figure 10 below). With such levels of energy expenditure, relatively large energy consumers would currently constitute a typical user of a Building Energy Management System (BEMS).

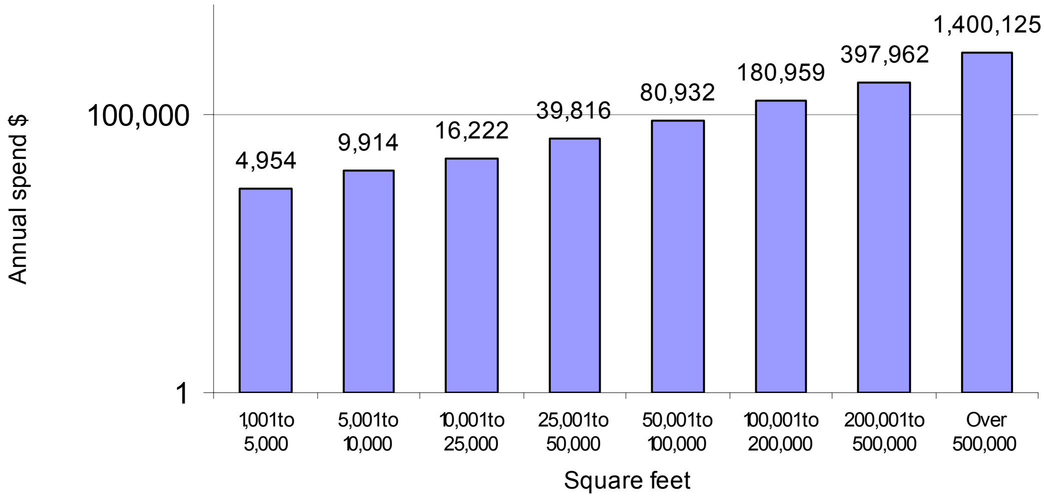


Figure 10: US commercial building energy spend by floorspace size [Source: DOE, ITI Scotland]

For EMBE purposes, commercial buildings types can be split into two broad categories:

- those that have a dedicated energy professional
- those that have an individual identified as being responsible for energy management, but this comprises only a part of their job function.

Commonly, larger buildings and those with significant energy consumption will employ an energy manager who will concentrate for at least part of his/her time on optimising energy use within their building or building portfolio. For example, a hospital, airport, retail chain, or local authority are most likely to have a dedicated energy manager.

Energy managers are likely to already utilise EMBE technologies that exhibit attractive periods to payback, and they are likely to ensure that deployed EMBE technology is used properly and is working as specified. However many energy managers report significant difficulties in accessing funds for EMBE.

Commercial buildings without energy managers are likely to have lower energy bills than those buildings with a dedicated energy manager. Small and medium sized enterprises (SMEs) and other small organisations occupying buildings have traditionally paid utility bills as and when they arrive, without investing much in optimising energy use. Commentators agree that there is considerable potential in improving energy management in buildings without energy managers.

2.2.4 Domestic Energy Use

The type and amount of energy used by households vary from country to country, depending on income levels, natural resources, climate and available energy infrastructure. In general, typical households in the OECD use more energy than those in non-OECD nations, in part because higher income levels allow OECD households to purchase more energy-using equipment. In the United States, for example, GDP per capita in 2005 was about USD37,000 and residential energy use per capita was estimated at 95 MTOE. In contrast, China's per-capita income in 2005, at USD5,900, was only about one-sixth the US level and residential energy use per capita was 8 MTOE[7].

[7] http://www.eia.doe.gov/oiaf/ieo/world.html

There are 25 million homes in the UK with total domestic energy consumption amounting to some 45 MTOE. In the UK annual energy spend per household is in the order of GBP1000, roughly equally split between electricity and gas expenditure.

For new buildings, building regulations governing energy performance vary dramatically around the world. For example Scandinavia has stringent building regulations whilst regions such as British Columbia have no regulations addressing the energy performance of new buildings. As a general trend, building regulations can be expected to tighten further in most markets - the UK and California, for example, have targets to achieve "zero carbon homes" over the next decade.

Despite the focus on the energy performance of new buildings, the slow turnover rate of residential building stock means that existing buildings will continue to account for the vast majority of domestic energy expenditure and carbon emissions.

Detached and semi-detached homes account for over half of the UK housing stock (see Figure 11 below).

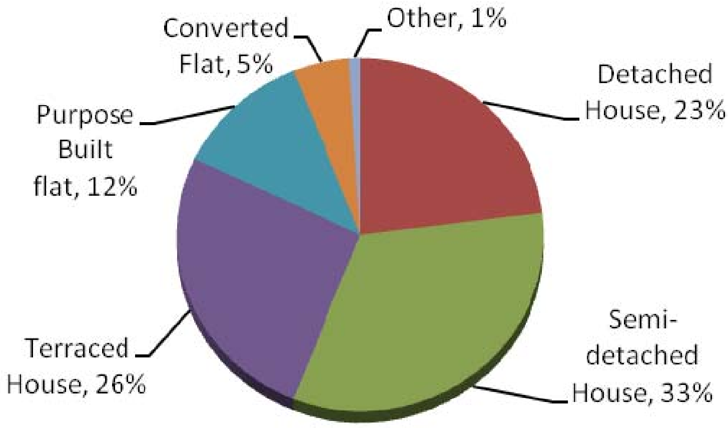


Figure 11: Distribution of residential accommodation in the UK [Source: BBC, DCLG]

The 'energy manager' in residential buildings is the homeowner. A number of other players are also involved in the provision of energy services in residential buildings: the building designers and builders; landlords; utilities; plumbers and electricians; and appliance vendors.

There is huge scope for improving the management of energy in domestic buildings. According to the UK's Association for the Conservation of Energy, efficiency could be increased by 40%, with about half of this from low cost or zero cost measures such as turning appliances off when not in use. Higher cost improvements range from increased insulation, through more efficient appliances; to intelligent control systems for heating or cooling that regulate individual room temperatures at different times of day and sense whether a room is occupied.

Despite the huge scope for potential improvements, there is a general recognition that the sector is a difficult one to improve. Total energy expenditure in a home is relatively small, meaning that householders do not prioritise the use of energy saving measures even when the payback time is short. Few observers realise the extent to which space and water heating dominate domestic energy consumption in cold countries. As illustrated in Figure 12 below, space heating accounts for well over 50% of an average homes carbon emissions and energy expenditure in the UK.

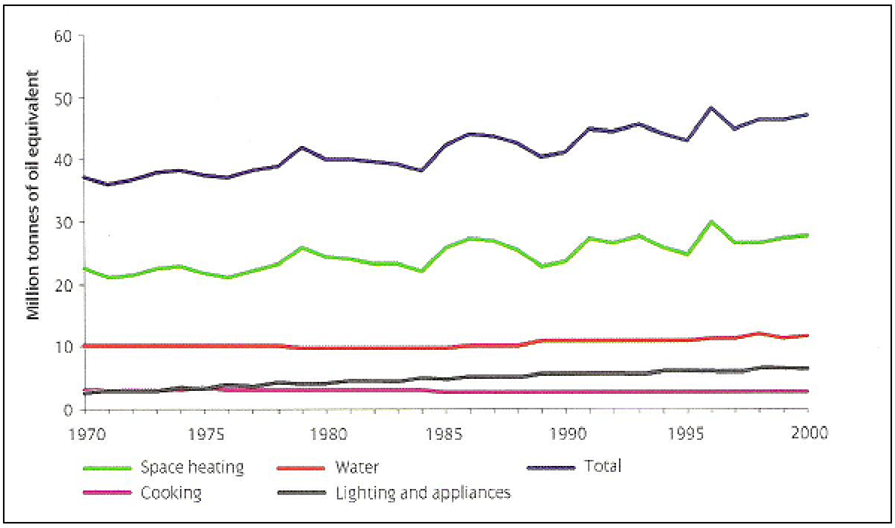


Figure 12: UK domestic final energy consumption by end use 1970-2000 [Source: TBC]

In hotter climates, cooling becomes significant. For example, in the US, cooling accounts for some 13% of residential energy consumption. This proportion will be significantly higher in southern States. For example, in Florida, cooling accounts for around one third of residential energy consumption.

2.3 EMBE Market and Industry Structure

The market for EMBE equipment and services is energy users – householders, utility-bill payers in organisations without an energy manager, and energy managers in bigger organisations. Architects, builders and various energy services professionals may also purchase and install EMBE equipment on the energy user's behalf.

To penetrate any mass market in the long run, products will need to demonstrate clear benefits. For EMBE, this is often in the form of significant cost savings, although some niche markets will pay for expensive products with a long payback of several years. Regulation can also make some EMBE products attractive in markets where cost savings alone are not enough to create sales. Safety, comfort or convenience could be other benefits.

Although differences exist between the major market segments, it is possible to apply a general model to the development and manufacture of existing EMBE systems (see Figure 13 Below).

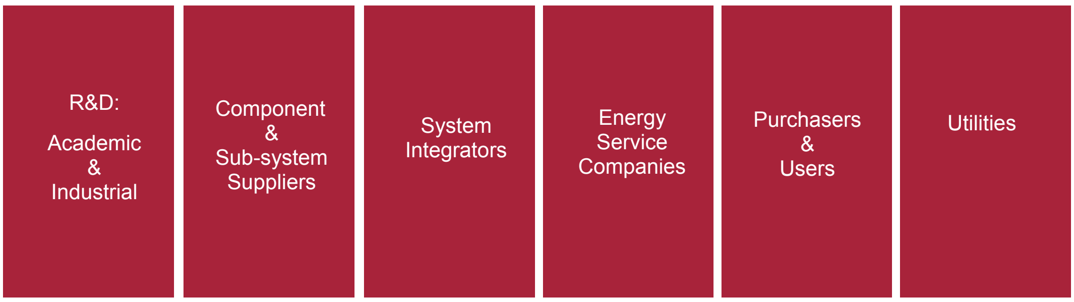


Figure 13: Generic EMBE market structure [Source: ITI Scotland]

Each of the elements of the value chain includes both small companies/organisations and major industry players operating either alone or together with trade associations and partners. Competition appears to be intense and the market is very dynamic with rapidly changing technologies, evolving industry standards and new product introductions. Many participants are trying to use closed or proprietary systems, technology, software or network protocols and by forming alliances to try to protect their markets but countervailing pressures from purchasers of systems and new market entrants offering open source solutions appear to mean that competition will become more intense.

The purchase and use of EMBE involves different parties in different segments. Homeowners will make purchase decisions based on relatively complex criteria which are not always driven by reductions in energy expenditure. Double glazing is an example of a technology where the economic pay-back period is unattractively long where equipment installation provides valuable benefits to users (e.g. noise reduction). The converse is also true – homeowners often fail to install simple 'win-win' energy saving technologies. Loft insulation is an example, where the payback is relatively fast but the perceived benefit is low, thereby hindering adoption.

In commercial environments, EMBE investment is most likely to be driven by a consideration of the associated economics (e.g. payback period, return on investment etc). These organisations typically require short paybacks (3-6 years is typical) if energy cost savings are the only driver. However, if other drivers are present, (e.g. potential for disruption to activity or desire to promote green values) EMBE projects with longer payback periods may be considered economic.

Building developers, architects, engineers, consultants and builders are all key actors in the in the specification and provision of EMBE systems. However, across this group, knowledge of EMBE options varies significantly, with the choice of final EMBE equipment often heavily influenced by building fabric design, customer specifications and prevailing building regulations.

The technology subsets of an EMBE system can be thought of at three levels, i.e.:

- Sub-systems
- Components
- Enabling technologies.

It is the EMBE subsystems where the unique attributes of an advanced technology are most visible. At the top level the grouping of the most significant sub-systems are:

- Controls
- Interfaces
- Local area networks
- Wide area networks.

In terms of delivering an EMBE device to the power industry 'mass market', the value chain is expected to be made up of many companies that are involved in productising smart meters (which have a very similar supply chain to this device) and to comprise four major tiers, as follows:

- **Utilities and Energy Service Companies:** These are the power utilities and and energy service companies that could incorporate an EMBE system into products or services they are offering to their target markets. Despite the favourable economics of energy productivity investments, and even if government and business leaders focus on the right ones, some opportunities will probably remain on the table as a result of information gaps, high discount rates for energy investments, and uncertainty about future savings, as well as the disinclination of landlords to make investments that benefit their tenants and vice versa. A range of intermediaries, such as utilities and energy service companies (ESCOs), will therefore have opportunities to finance, enable, and profit from energy efficiency investments.
- **System integrators:** Companies such as Echelon and GridPoint are currently industry leaders in developing software and hardware into control system and network products for power industry equipment manufacturers, based on components supplied to them. Bayard, GE, IBM and Siemens are other well established and very large product integrators for the power industry.

- **Equipment manufacturers:** Equipment manufacturers 'design in', or embed other products into their own products and systems in order to give them local intelligence and networking capability. They are then able to provide utilities (and others) complete system offerings. Examples of companies offering such systems to the power industry include Mitsubishi, Siemens, ABB, Johnson Controls, Honeywell. Gorlitz, Elster, Actaris and Onzo are examples of companies currently supplying smart meters.
- **Component & sub-system suppliers:** Suppliers like Altera provide digital integrated circuits, while companies like Wolfson, Tyco, WKK and Flextronics provide other electronic components to product integrators.

Utilities deliver energy to buildings, mostly via electricity and gas networks. Ten years ago their involvement would have stopped there, but today gas and electric utilities play a larger and increasing role in delivering EMBE. Progressive utilities aspire to deliver energy services rather than units of energy and are making steps in this direction, but we are at least several years away from utilities providing a comprehensive suite of energy services to buildings.

Some utilities, particularly in the UK, Netherlands, Germany and parts of North America, now install heating and air conditioning systems in commercial and domestic properties.As a consequence the utilities are gaining market share in some heating / cooling markets from independent installers. Utilities are usually keen to offer a full service potential to customers, including various energy efficiency options, and may be better placed to deliver integrated solutions to large and small buildings. Utility interest in building-based demand response solutions to their grid problems is slowly increasing. Utility interest in more conventional energy efficiency, including in their residential customers' homes, is also increasing, driven by policy and regulatory requirements.

Utilities will play an increasingly critical role in the EMBE market as long as their incentives are aligned with higher energy productivity. Traditionally, the revenues of utilities have been tied to the volume of electricity delivered, encouraging growth in electricity consumption rather than energy efficiency. Instead, regulators can reward utilities for promoting energy efficiency and reducing energy consumption among their customers. For instance, the state of California has an incentive program that rewards and penalizes the state's privately owned utilities by up to about USD450 million, depending on their energy efficiency performance.

With the right incentives, utilities' demand-side-management (DSM) programs could have a large impact on household energy consumption. For example, advanced metering, which allows utilities to communicate more effectively with customers about the precise cost of their current usage patterns, would help them keep down peak-period energy consumption. Once utility bills can disaggregate time-of-use patterns, attractive financing options become practical. Some utilities are already experimenting with market-based programs that allow energy service companies to aggregate and bid on opportunities to reduce demand as an alternative to building new power generation capacity.

It should also be noted that governments are heavily involved in a variety of aspects of the EMBE market:

- Advice to energy users (the Carbon Trust and Energy Saving Trust in the UK work respectively with businesses and householders, and there are equivalents in many other countries)
- Financial support for desirable technologies (for example, VAT reduction to 5% for much EMBE equipment in the UK and federal tax credits in the USA)
- Support for R&D of innovative EMBE technology and concepts through universities and publicly-funded industrial research
- Regulation of the building industry via Building Regulations and Planning Control, and their equivalents elsewhere. Also setting of targets for zero carbon homes or sectoral energy efficiency improvements, and obligations on building owners to perform energy assessments and display the results.

- Regulation of the energy industry. The UK Government, for example, is providing impetus for a lot of EMBE innovation via Carbon Emission Reduction Targets imposed on utilities – these are targets imposed on utilities to reduce the greenhouse gas emissions of their customers. In North America local regulators work with municipal and private utilities to achieve various energy policy goals, including improved efficiency.
- Regulation of the appliances industry, through minimum energy efficiency standards and energy labelling obligations.

For some market segments, single organisations will cover several parts of this supply chain. Figure 14 below lists examples of players for each stage of the chain.

	Example players in existing EMBE market
Research & Development	Academia, BRE, UK Energy Research Centre, California Energy Commission Utilities' VCs (e.g. SSE Ventures Team), Microsoft, Google, Industry – existing manufacturers
Component & sub-system suppliers	Trend Controls, Honeywell, Elutions, Siemens
System Integrators	Trend Controls, Honeywell, Energy ICT, Adam, TAC, Schneider
Energy service companies	Adam, L-Tec, TAC
Purchasers & Users	Architects, building owners, building managers – local government, commercial, industrial
Utilities	SSE, Scottish Power, npower, Enmax

Figure 14: Characteristic players in the supply chain [Source: ITI Scotland]

As with any opportunity that offers significant new commercial opportunity, the emergence of aggressive small companies and start-ups can be expected. As such, the EMBE market could represent a significant new and addressable opportunity for technology businesses in Scotland. Through the creation of underlying technology platforms, ITI could play a role in enabling the development of such businesses.

Climate change mitigation as a serious policy focus is largely, though certainly not entirely, confined to the developed world (Europe, North America and parts of South East Asia). As we have seen, regulatory drivers for EMBE are much stronger in these countries than in the developing world.

There is very considerable difference in the way buildings are designed, built and used throughout the world, with influences ranging from local climate through material availability and cultural preferences. Availability and cost of primary energy (either direct costs or internalised costs via government action or societal pressure) also varies significantly around the world.

As a result there are massive differences in the level of EMBE effort between (and within) countries, but also on the specific EMBE techniques that are applied.

Climate does of course make a difference to the types of EMBE equipment installed in buildings – the UK heating season, for example, may be as long as 33 weeks a year (days when outside temperature is below 16°C, or sometimes 18°C, for most of the day)[8], while in Southern California room heating technology will be rarely used. Heating degree days are a useful measure of the duration and severity of cold weather (the Carbon Trust has published a good explanation[9]): degree days in different parts of North America (both with long heating seasons) range from around 5,000 in New York City to over 20,000 in Barrow, Alaska.

2.3.1 European Union

With energy-efficiency standards in Europe set higher than in many other regions, European companies are in a strong position to make large energy-cost savings and innovate lucrative new markets in energy-efficient technologies and services, attracting worldwide demand. If policy makers and business engage fully in boosting energy efficiency, Europe could hold energy demand at today's level instead of seeing it grow 1.2 percent annually.

Countries in Europe *tend* to lead in the development and application of most EMBE technologies, though Japan (which has no indigenous fossil energy supplies) has historically concentrated hard on energy efficiency and renewable electricity, and specific states in the U.S have very significant regulatory drivers.

Next, we provide selected highlights of leading EMBE countries and regions

- Scandinavian countries undoubtedly lead the world on thermally efficient building techniques. Their building standards are some 10 years ahead of most European standards (perhaps 5 ahead of Germany) with regard to insulation and building air-tightness. Techniques which are considered cutting edge in the UK and North America, such as triple glazing and Modern Methods of Construction, are often used as standard in Sweden, Denmark and Norway.
- The Netherlands leads on boiler efficiency. The condensing boiler was developed in the Netherlands, following considerable public R&D spending, and the Dutch have the highest penetration of condensing boilers in the world. German and UK heating services companies are developing integrated heating products and BEMS, although the application of these products (for example integrated gas heating with solar thermal water heating) tends to depend on local drivers.

2.3.2 USA

Several States in the north-east of the US have significantly better building energy efficiency than the US average (Vermont has the lowest primary energy consumption of any State), primarily because of a historic focus on energy efficiency and relatively stringent building regulations. Several of these States – Massachusetts is an example – have imposed very ambitious energy efficiency mandates on utilities.

- California leads on efficiency standards in North America - it has for many years been at the forefront of energy efficiency and renewable energy application in the US, and has electricity prices 20-30% higher than the US average[10]. In 2008 the California Public Utilities Commission adopted a long term strategic energy efficiency plan with the following goals for 2009 – 2020:
    - All new residential construction in California will be zero net energy by 2020:
    - All new commercial construction in California will be zero net energy by 2030
    - The Heating, Ventilation, and Air Conditioning (HVAC) industry will be reshaped to ensure optimal equipment performance; and
    - All eligible low-income homes will be energy-efficient by 2020

[8] http://www.encyclo.co.uk/define/heating%20season

[9] http://www.carbontrust.co.uk/publications/publicationdetail?productid=CTG004

[10] http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=CA

- Incentivisation for demand response is very location specific, with most interest in north-eastern U.S and California. Demand response is common to some degree in many electricity markets, with large users accepting lower prices in return for reducing demand during times of peak electricity demand. Extending this to a larger range of customers has only taken place on significant scales in California and north-eastern U.S, although interest in replicating these efforts in emerging in Europe and beyond.
- In the U.S, aggregating all non-residential buildings, cooling accounts for 10% of energy consumption along the Pacific coast, and 15% in the south-east.

2.3.3 Developing World

Buildings in the developing world tend to use significantly (several times) less energy per occupant or unit of floor space than equivalent buildings in poor countries. This is partly climatic – most poor countries do not require heating, and AC is always optional – and partly because a significantly lower level of energy services is considered acceptable (less indoor climate control, fewer appliances).

Energy efficiency is rarely a top priority, therefore, in developing countries – the enforcement of building codes tends to concentrate on safety rather than energy performance – and the opportunity for saving money or carbon from EMBE equipment correspondingly lower.

Nevertheless, economic signals to increase energy efficiency in the developing world are arguably stronger in poor countries than rich ones. This is primarily because modern energy supplies are proportionally more expensive (in many developing countries electricity prices are kept artificially low by government mandate and subsidy, but the price of energy compared to other costs is as high if not higher than in the developed world). These signals apply to local individuals and companies, but sometimes not to rich companies with bases in poor countries – Asian offices of trans-national corporations in South East Asia, for example, have been accused of being energy profligate. Governments in the developing world, including China and India, have begun to pass legislation to improve the energy efficiency of the bigger companies and buildings.

Some poorer countries are facing very specific electricity system problems as demand for electricity increases rapidly. As a result continuity concerns are becoming very significant for individuals and companies in some countries, notably South Africa at present. Reducing demand is the cheapest and easiest way of overcoming these system problems, so governments and national utilities are in some places using carrots and sticks to incentivise energy efficiency measures and load-shifting.

2.4 Market Trends, Drivers and Inhibitors

Key trends, drivers and inhibitors impacting on the EMBE sector are identified below. The assessment of drivers and inhibitors is based on a PEST analysis (Political, Economic, Sociological and Technological factors)

2.4.1 Technological Trends

The field of EMBE equipment includes many sorts of both straightforward and innovative technology. There are two broad directions of progress in the EMBE field:

- **Equipment that enables more and better use of existing technology.** This includes a host of diagnostic technologies that can inform building users of their energy consumption, as well as advances that make existing technologies like insulating materials cheaper and more attractive. There is scope for going further with existing technology in all building-types, but particularly in domestic homes.
- **Innovations that directly improve the way energy is delivered and converted into energy services.** These include simple improvements in appliance efficiency, which tend to be driven by minimum standards and energy labelling commitments imposed by government, as well as complex ‘intelligent’ systems for controlling numerous energy loads in a building. Innovative techniques that today can only be justified in large

buildings with significant energy bills may tomorrow be simplified and cost-engineered to make them suitable for smaller buildings and homes. Similarly the new build sector, for buildings of all sizes, is often the proving ground for innovative technologies that after a few years become attractive for retrofit in existing buildings.

2.4.2 Key Drivers

In this Section a range of political, economic, socioeconomic and technological drivers affecting the EMBE market are described.

Political drivers

Environmental policy

Concern about Climate Change, as reflected in the Kyoto Protocol commitments and recent EU targets to reduce CO_2 emissions by 20%, by 2020, is leading to long-term, concrete and ambitious international Climate Change policies. The Intergovernmental Panel on Climate Change has recommended a global reduction of at least 60% on 1990 global emissions will be needed to stabilize concentrations at sustainable levels. Tighter emission targets are not just likely to push up the cost of energy but are also forcing a fundamental reassessment of how energy is provided. This is leading to the concept of Energy Service Companies (ESCOs) which sell not commodities but services (such as, for example, cutting a customer’s energy bill).

Improving the energy efficiency of buildings has always been recognised as one of the cheapest way of reducing greenhouse gas emissions, so as mitigating climate change becomes more of a priority EMBE is gaining more and more attention, both from individual building owners and from governments. All signs indicate that this will continue from 2009 onwards, although the economic downturn and a lower than expected oil price may reduce the attractiveness of some EMBE measures in the short term.

Specific Regulatory Drivers for EMBE

With few exceptions, developed countries have specific regulatory drivers for improving the energy performance of their buildings.

Energy efficiency is seen as a key pillar of energy policy throughout the world, including in poorer countries (although many energy efficiency advocates argue it rarely secures the policy focus it deserves).

In the developing world regulatory drivers do exist but are generally less strict and rarely enforced, except for some prestige buildings. Many poor hot countries are struggling to maintain electricity supply as air conditioning becomes more and more common, as a result some have introduced quite significant energy efficiency drives. India, for example, introduced an Energy Conservation Building Code in June 2007 which applies to buildings with electrical load of 500 kW or more. However, energy-specific building standards in the developing world remain rare.

Next, we provide examples of regulatory initiatives in the European Union and the US.

European Energy Performance of Buildings Directive

The EPBD (2002/91/EC) is intended ‘to promote the improvement of the energy performance of buildings within the Community, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness’.[11] The Directive requires governments to apply minimum energy efficiency standards for all new buildings, and for large existing buildings being refurbished. It also establishes a general methodology for calculating the integrated energy performance of buildings, which includes the thermal performance of the shell as well as the heating, cooling, lighting and ventilation systems installed.

[11] EPBD 2003. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002L0091:EN:HTML

The EPBD also requires national governments to introduce energy certification and regular testing of heating and AC systems. Energy Performance Certificates (EPCs) are country-specific, although based on the same overall methodology, and will have been introduced throughout Europe within the next ten years. Large public buildings in the UK now need to display an EPC that details their designed energy performance and buildings being bought and sold, including homes, will also be required to display EPCs. Energy certification is expected to increase interest in bolt-on EMBE solutions, as well as consolidating perceived increases in building-value that are currently associated – with limited evidence – with good quality EMBE additions.

Energy Star

The Energy Star is an energy efficiency performance standard that was developed in the nineties in the USA and has been adopted in many countries including Canada, Australia, Japan, Taiwan and New Zealand. It was initially applied to appliances, but has since been applied to homes and building lighting, heating and cooling systems. The Energy Star certification for homes in the US implies an energy saving of 15% compared to the 2004 International Residential Code (20-30% compared to an average US home), as well as the installation of Energy Star qualified appliances[12].

The Energy Star standard is still voluntary for most products, but it is a significant advertising tool, and many regional energy efficiency mandates and utility grant schemes are linked to it.

Zero Carbon Homes

Both the UK and California have announced legislation for all new houses to be 'zero carbon homes' within the next decade, although neither jurisdiction has yet clarified exactly what this means. The UK target date is 2016, with California aiming for 2020.

Carbon emissions caps

Energy businesses are being forced to look at providing services or products rather than selling ever larger quantities of commodities like electricity as a result of Climate Change policy in order to provide shareholder value growth. The sale of EMBE systems (and other energy efficiency products) presents an alternative and also enables utilities to deliver carbon emission cuts.

Smart meters

The EU and US is now considering legislation for the mandatory roll-out of smart meters (electronic meters providing more wide-ranging information than traditional electromechanical ones). This will enable the introduction of EMBE devices into the smaller commercial and domestic markets by providing both consumers and utilities with real-time information about energy use.

Economic drivers

Rising Energy Costs

The cost to building managers of meeting energy services expectations has increased significantly over the past years across most developed economies, as fuel (and in many cases electricity) prices have increased.

Between 2006 and 2008 the price of gas and electricity has risen significantly, driven by a number of well known factors including plateauing oil production and rapidly rising demand in the

[12] http://www.energystar.gov/index.cfm?c=new_homes.hm_index

IEA 2008 http://www.iea.org/Textbase/stats/electricitydata.asp

DOE http://www.eia.doe.gov/emeu/international/ table62

http://www.eia.doe.gov/oiaf/ieo/world.html developing world. Despite recent price falls, the long term outlook is for energy costs to continue to rise. Rising power prices mean rising energy bills, which in turn generates demand for devices that cut bills. Increases in utility costs not only decrease the payback time on EMBE investments, they also serve to focus the minds of decision makers on potential cost savings. There is thus an economic and psychological increase in EMBE interest as energy costs increase. However, energy is still not a really significant priority and there are often non-cost barriers.

Increasing intermittent generation of electricity (e.g. wind turbines) and increasing insecurity of natural gas supply put an additional focus on efficient energy management at the point of demand. This additional focus may manifest itself in alterations to electricity tariffs to make load shifting and demand response attractive to consumers, or in policy incentives from government for increased efficiency of heating or cooling systems.

Falling EMBE costs

To date, it has only been some industrial and large commercial customers that have been able to carry out energy management activities. Management of demand in smaller customers (notably domestic users, who make up 35% of overall energy use) has not occurred yet. However, reductions in the cost of control and communication technology and its increased ubiquitity have provided the opportunity to develop innovative ways to introduce EMBE systems in a cost effective manner to these smaller customers.

Sociological drivers

Changing energy consumption patterns

In the UK (and in other developed countries) increases in building related energy use (driven by the increase in the number of households, increasing numbers of domestic electrical appliances, an increase in the number of light fittings, reduction in the average number of occupants per building, plus other factors, had led to an increase in total national energy consumption in buildings as a proportion of the UK's total The UK Select Committee on Environmental Audit noted that emissions from housing alone could constitute over 55% of the UK's carbon emissions in 2050, up from over 30% now. As a result it has become an energy saving major policy target.

Energy continuity concerns

While energy cost savings and environmental concerns are certainly the two obvious drivers for EMBE, there are some more prosaic reasons why householders and decision makers install EMBE equipment. One of the most important is a concern for the continuation of energy service provision.

Decision makers may not prioritise simple energy savings enough to even consider the investment case under normal conditions, but in situations where the normal operation of their building is threatened – if an inefficient A-C system is failing to maintain comfortable temperatures in an office for example – energy efficiency improvements can often be included as part of the solution. Energy efficiency can often be improved as a positive side-effect of work to improve continuity.

Technological drivers

Control and communications technology

Reductions in the cost of control and communication technology and its increased ubiquity have provided the opportunity to develop innovative ways to introduce energy management in a cost effective manner to smaller customers. As awareness of the benefits of home network services grows, an increasing proportion of homes will be networked. The total number of residential households using broadband alone surpassed 250million in 2008 [OECD]. The development of new network technologies such as Zigbee, Bluetooth, Wi-Fi and Ultra Wideband and new devices such as next generation game consoles will affect the home automation landscape by altering the method of information sharing and thus will change consumer lifestyles.

The emergence and adoption of common protocols and standards in the near future will help to drive growth in the home automation market. At present, most home device and appliance manufacturers use their own proprietary protocols and standards. Progress towards greater interoperability has been made through the introduction of standards such as Universal Plug and Play (UPnP). Increasing use of open-source operating systems, such as TinyOS designed for wireless embedded sensor networks, now provides a common platform for the application of such standards and protocols.

Smart meters

A key enabler for energy management will be 'smart metering', or the availability of real time information about consumption in homes, to both home owners and power suppliers. At present about half the market has real time metering (industrial and larger commercial customers). However, across the EU, and the US, a number of initiatives are now underway to roll-out smart metering to domestic and other smaller customers.

2.4.3 Key Inhibitors

In this Section a range of political, economic, socioeconomic and technological inhibitors affecting the EMBE market are described.

Political inhibitors

Energy efficiency focus

Environmental policy will be a key driver for the EMBE market, but policies currently focus on promoting energy efficiency rather than energy management. Energy efficiency will cut emissions and fuel use, whereas better energy management could simply shift energy use away from peak price periods or deliver a better indoor living environment.

Economic inhibitors

Cost competitiveness

A number of other low-tech measures are likely to offer significantly more value for money than EMBE as methods of improving energy efficiency in the home. These include boiler lagging and roof or even wall insulation and the housing stock in the United Kingdom (seen as a key microgen market) is amongst the least energy efficient in Europe.

Market structures hinder mass uptake of the device.

There is currently a lack of market structures and rules to enable appropriate rewards for demand side management by smaller customers. However, such tariffs are well established for larger customers and the advantages of enabling this technology to enter the market are a significant incentive to utilities to introduce them to home owners (or small commercial enterprises), particularly in a competitive, deregulated, environment.

Energy subsidies

In many countries energy is subsidised below its true cost, undermining incentives to reduce consumption.

Misalignment of incentives

Property builders, owners and tenants can all have drivers which conflict with investing in energy efficiency. Builders seek to minimise the cost of developing new properties, and both landlords and tenants are unwilling to invest in energy management because they feel the benefits will not accrue to them.

Sociological inhibitors

Consumer indifference and installation incovenience

The benefits of EMBE devices compared with their costs may be poor, or so small, that they fail to lead to interest in buyers. An example of a major factor offsetting likely gains is installation costs (these can be financial but could include other factors like cost of time). However, in assessing this programme one of the routes to entry that minimises this cost would be when homes or other buildings will be accessed anyway and then the add-on cost of this device would be marginal.

Complicated technology may deter end-users

Systems, even if they get more technically mature over time, can be complicated to program, control and maintain. A mass market can only be won by simple, easy-to-handle technology.

Unwillingness to have intervention into energy supply use

Energy demand can be highly inelastic in terms of its responsiveness to price or other market signals (primarily because users tend to want their power when they want it and it is not easy to substitute). Smaller customers may thus be unwilling to have behavioural changes to their energy consumption. However, this could be offset by enabling some degree of customer choice in the energy management and by ensuring tangible fiscal benefits are passed on to them. Also, by cutting the need for human interventions through automation (which would also increase reliability) and ensuring wherever possible any discernable impact on home living (or office use) was reduced, the perceived impact of energy management can be minimised.

Technological inhibitors

Lack of standardisation

There is a lack of application level protocol standards (may not be a problem for commercial buildings) and a predominance of proprietary application level protocols which lock customers to one supplier (or supplier group).

2.5 EMBE Market Size

The number of actors involved in the EMBE space and the diverse nature of the EMBE market (as defined in this report) make market sizing of specific segments of the EMBE opportuinty a complex and involved exercise that is beyond the scope of this report.

Instead, this Section provides:

- a number of market comparators to provide some feel for the scale of the opportunity (Section 2.5.1)
- an overall sizing of the commercial building EMBE market opportunity as ITI believes this to be the single most promising EMBE market sector in the short to medium term (Section 2.5.2).

2.5.1 Market Comparators

In order to understand the broad scale of the EMBE market opportunity, the following comparator information is provided:

- Residential electricity and fuel sales in the U.S are estimated by the US Department of Energy at just over USD200 billion in 2005[13]

[13] http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/c&e/pdf/tableus5.pdf

- Frost & Sullivan report the annual market for Energy Management Services in Europe at EUR14.43 billion in 2008. This is assumed to focus on services that control how energy is used, rather than appliances and supply of electricity and gas[14]
- The same company predicts that the US residential heating, ventilation and cooling market would be worth some USD13 billion in 2009[15]
- The 2007 global market for air-conditioning is estimated by research company BSRIA at USD62 billion. Asia Pacific contributes USUSD28 billion, with China alone comprising USD12 billion. The combined North and South American market is valued at USD15 billion[16].

2.5.2 Commercial Building EMBE Opportunity

In the EU and North America, there are approximately 360,000,000 buildings according to official statistics. By extrapolating figures that certain governments (USA, UK, Finland, Norway) have produced on the breakdown of building stock, it can by estimated that approximately 4% of buildings are offices, retail premises and public buildings such as schools and health centres. The vast majority (>95%) of these buildings would have an energy spend less than GBP1 million and less than 500 employees and fit in the segment. This suggests 14 million buildings is the Total Available Market (TAM) in our target segment.

As discussed earlier, new technology will normally be adopted if it provides a payback over 3-6 years and, for the purpose of this analysis, a conservative assumption of 3 years is assumed. It can further assumed that a 20% energy saving is required to motivate users to adopt new technology. By combing these assumptions using the source data from Figure 9 and Figure 10, the potential market size of the commercial building EMBE market can be estimated. Note that it is assumed that that major updates of EMBE technology will only be made every 10 years in a building.

Based upon these assumptions, ITI Scotland estimates that the average annual addressable market opportunity in the US and EU is in the region of USD19 billion per annum as illustrated in Figure 15 below.

Building Size (sq.ft)	% of stock	Buldings EU+US	Spend USD	20% Saving	3 year payback	Segment Payback
1000-5000	51.8%	7252000	$4,954	$991	$2,972	$21,555,844,800
5001-10000	20.0%	2800000	$9,914	$1,983	$5,948	$16,655,520,000
10001-25000	17.0%	2380000	$16,222	$3,244	$9,733	$23,165,016,000
25001-50000	5.0%	700000	$39,816	$7,963	$23,890	$16,722,720,000
50001-100000	3.0%	420000	$80,932	$16,186	$48,559	$20,394,864,000
100001-200000	2.0%	280000	$180,959	$36,192	$108,575	$30,401,112,000
20000-500000	1.0%	140000	$397,962	$79,592	$238,777	$33,428,808,000
500000+	0.2%	28000	$1,400,125	$280,025	$840,075	$23,522,100,000
TOTAL	**100%**	**14,000,000**				**$185,845,984,800**
Average annual spend assuming 10 year EMBE update cycle						**$18,584,598,480**

Figure 15: EU and US commercial building EMBE addressable market opportunity [Source: ITI Scotland]

The actual market will represent a sub-set of this overall market be somewhat smaller than this because even if it is economically rational to invest in EMBE technology, many building owners

[14] http://www.frost.com/prod/servlet/market-insight-top.pag?Src=RSS&docid=153909136

[15] https://www.frost.com/prod/servlet/press-release.pag?mode=open&docid=8545202

[16] http://www.bsria.co.uk/news/1997/

will not do so, either because they are unaware of the benfits, are too busy to plan it or are simply struggling to fund the investment.

On the other hand, the proportion of building owners who do invest in EMBE technology can be expected to grow steadily over the next 10 years as regulatory drivers come into play, energy costs rise and general awareness of environmental issues increase. Based upon these drivers ITI Scotland estimates that the commercial building EMBE opportunity will reach USD9 billion by 2019 as shown in Figure 16 below.

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Adoption rate	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
Spend ($M)	$929	$1,858	$2,788	$3,717	$4,646	$5,575	$6,505	$7,434	$8,363	$9,292

Figure 16: EU and US commercial building EMBE martket forecast, 2011-2019 [Source: ITI Scotland]

These revenues will be accrued from a wide variety of different technologies for EMBE. As such, and given that the buildings stock is very varied, a variety of technology solutions that address a range of needs are likely to emerge.

3 MARKET OPPORTUNITY ASSESSMENT

The objective of the foresighting process is to identify areas of opportunity for the development of technology platforms which address unmet market needs that:

- are unlikely to be satisfactorily addressed by current solutions or approaches in the short term
- have the potential to be addressed in the medium term by new, technology-based developments
- are likely to provide a significant revenue opportunity for market participants in the medium term.

This section describes the scope of the Energy Management in the Built Environment study undertaken, the process used to identify market opportunities within the EMBE space and summaries the Opportunity findings.

3.1 Study Scope

An initial mapping of the Energy Management in the Built Environment (EMBE) space was carried out to define the scope of the study. Areas which could benefit from the combined expertise of ITI Energy and ITI Techmedia were prioritised. This lead to an initial definition of scope that included ***the use and conservation of all energy types within all building types***. Excluded from the scope was energy generation, energy distribution to and between buildings, energy use outside buildings and transport.

This initial scoping highlighted a numbers of variables which were considered to have a large impact on existing EMBE practises and future needs. These were:

- Building type
  - Residential, Industrial, Commercial/Public
  - Existing or New-build
- Building design
  - Building age, fabric and insulation
  - Interior layout open-plan or closed-plan
- Tenure
  - Owned or leased
- Energy usage
  - Heating (space, water, cooking, industrial), cooling (space, refrigeration, industrial), appliances (lighting, IT, industrial, etc)
- External climate / geography
  - Hot, cold, temperate, extreme
  - Developed or developing

These variables were used to help frame the following parts of the study.

3.2 Opportunities Identification Methodology

This study was undertaken using an outcome driven methodology to identify unmet customer needs, independent of technology. The process involved a number of steps, as illustrated in Figure 17 below.

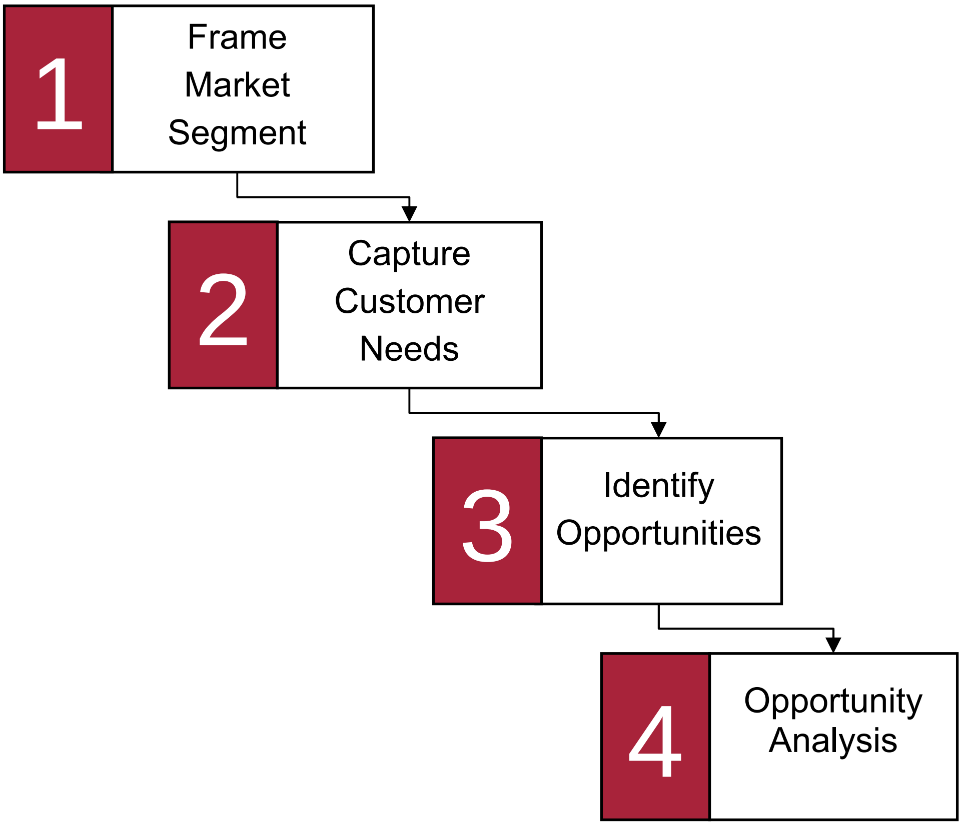


Figure 17: Opportunities identification methodology [Source: ITI Scotland]

3.2.1 Step 1: Framing the Market Segment

A mixture of expert interviews with leading UK and US regulatory and research associations, and secondary research data from market analyst reports, industry comment and published government information, was used to identify a target sector for the outcome-based study within the EMBE scope defined above.

There is clearly a need and potential to reduce energy consumption in all buildings. The domestic sector has the largest potential volume but it is considered by experts to be a particularly difficult market to penetrate due to low energy costs and usage resulting in long payback times and a lack of prioritisation. There are also privacy concerns within the domestic sector relating to devices which have the potential to feed back information on energy usage to the utilities companies, or even enable remote device control.

Larger commercial buildings, particularly those that are new and purpose-built, will typically have a complex BEMS installed and employ a dedicated building energy manager. These systems are complex to operate and difficult to optimise with the result that they often perform below optimum.

Smaller companies and organisations generally do not have a dedicated building or energy manager. These duties are often taken on in parallel with other roles within the organisation, such as MD/CEO, Office manager, HSE Officer, etc. As such, energy management is not an area of expertise for these individuals and it is often not seen as a high-priority part of their day-to-day role. Neither budgets nor personnel are available to install and operate an expensive BEMS system and often buildings or parts of a building are leased, not owned, severely limiting the extent of any possible modifications or installations.

As a result of these preliminary findings, the sector of small-to-medium sized organisations (SMEs) with no dedicated energy manager was considered to have the largest potential for unmet customer needs. In addition, it was thought likely that solutions could be scaled down for domestic EMBE, and possibly scaled up for larger organisations. In 2004, the DTI estimated that of the 4.3 million business enterprises in the UK, 99.9% were small to medium sized (i.e. < 250 employees).

To define this SME target segment the following criteria were used:

- Energy spend less than or ~ GBP1M
- Employees 20 – 500
- Public or private sector
- Office/Retail/Education/Health/Leisure/Light Industrial/Public Sector

3.2.2 Step 2: Capturing Customer Needs

Capturing the unmet customer needs was achieved by interviewing a representative sample of target customers to find out directly from them all of the energy management jobs that they are currently doing or would wish to get done, independent of existing technologies and solutions.

In order to capture these jobs, it was important that the interviews were carried out with individuals within the SME-sector organisations who are trying to do the job of energy management. These individuals were defined as:

- Non-dedicated energy managers; e.g. job titles could include: Building Manager, Facilities Manager, Site Manager, Operations Manager, Office Manager, etc.
- Involved with the energy management of a building, buildings or parts of a building
- Responsible for either:
    - making energy efficiency improvements in a building, buildings or parts of a building, or
    - controlling energy expenditures in a building, buildings or parts of a building
- Directly employed by the organisation that occupies the building, buildings or parts of a building for which you are responsible for energy management.

In addition, to ensure a global perspective covering a diverse range of climates, interviews were conducted within the UK, California and NE USA/Canada.

A total of 18 face-to-face and telephone interviews were carried with non-dedicated building energy managers. Organisations represented included both Public and Private sector covering Health, Leisure, Education, Office, Retail, Manufacturing and Utilities.

The interviews yielded a list of a total of 69 job statements covering themes such as:

- Understanding types and patterns of energy uses within a building
- Reducing costs on energy
- Seeking alternative energy sources
- Managing energy budgets
- Educating building occupants in energy efficient practices
- Executing energy management plans
- Monitoring energy use for improved efficiency

These job statements were deliberately captured without reference to the availability or otherwise of existing solutions. The full list of jobs can be found in .

The individuals interviewed within the utility companies were specifically selected segment managers for SME customers.

3.2.3 Step 3: Identifying Opportunities

In order to validate which of the 69 jobs are important to the target customer base and which offer opportunities of un-met need, a quantitative analysis of the jobs was undertaken.

A web-based survey was completed by 164 non-dedicated energy managers within the SME sector. They were asked to rate each of the 69 job statements independently for Importance (Not Important, Somewhat Important, Important, Very Important, Extremely Important) and Satisfaction (Not Satisfied, Somewhat Satisfied, Satisfied, Very Satisfied, Extremely Satisfied). With this information it was possible to complete a statistical analysis that identified which of the job statements were most likely to be a commercial opportunity; i.e. which jobs were most important but least satisfied. It should be noted that, as the identified jobs are technology independent, that fact that a particular job is unsatisfied may indicate technology and/or business model issues.

The same definition of responsibility was used for identifying survey respondents as was used for the qualitative interviews described above. In addition, the following criteria were considered to be key variables/drivers that were likely to influence the job statement Importance and Satisfaction ratings:

- Climate – Hot / Cold / Temperate / Extreme
- Regulatory Environment – Strong / Weak
- Energy Cost – Relatively Expensive (no subsidies, higher taxes) / Inexpensive (subsidised)
- Reliability of Supply – Reliable / Unreliable

To ensure representative coverage of each of these criteria the survey respondents were carefully selected across 4 climatic/geographic regions; i.e. UK, NE US/Central-Eastern Canada, Southern California and India.

Further to this, a minimum number of respondents was set within the different categories as shown in Figure 18 below.

Criterion	Min. Nos.
Private / Public Sector	40 / 40
Annual Energy Spend of < GBP500K / ≥ GBP500K	40 / 40
Use of Fuel (e.g., natural gas, oil, etc.) in Building	40
Heating / Air Conditioning	40 / 40

Figure 18: Respondents by category [Source: ITI Scotland]

As part of the web-based survey, all participants were asked to respond to a number of profiling questions to enable correlation with the opportunity ratings. These profiling questions included:

- Number of buildings managed – part, single, multiple buildings
- Number of building users per day, including visitors
- Total floor space of building(s) managed
- Building age
- Building type – converted, part-converted, purpose-built
- Building renovation
- Building interior layout – primarily open/closed plan
- Primary building use: Office, retail, light industrial, education, health, leisure

- Public/private sector
- Energy type(s) used – electricity, gas, oil
- On-site electricity generation from fossil fuel or renewables
- Plans to install on-site electricity generation from renewables in next 3-5yrs
- Months per year usage of room heating and room cooling
- Approx % of annual energy spend on water heating, lighting, refrigeration, room cooling, machinery & equipment
- Importance of improving efficiencies in & satisfaction with ability to manage use of: Heating, water heating, lighting, refrigeration, room cooling, machinery & equipment (incl. IT)
- Desire to monitor energy consumption change with time; by hour, day, week, month, season, year

A summary of the respondents' profiles can be found in Appendix 2.

3.2.4 Step 4: Opportunity Analysis

The Importance and Satisfaction ratings returned by the survey respondents were collated and rated to provide an overall 'Opportunity Score' where the highest scores were given to those jobs that were considered to be most important but least satisfied. The jobs were then ranked according to these opportunity scores.

The 15 top-ranked job statements are as shown in Figure 19 below.

Job statements	Rank
Detect a failure in energy supply, e.g., heating stops working, lighting goes out, etc.	1
Determine the impact of a change in energy prices on the total energy costs of a building	2
Prevent a failure in energy supply, e.g., heating stops working, lighting goes out, etc.	3
Identify potential health risks to the occupants of a building caused by energy consuming devices, e.g., CO2, carbon monoxide, etc.	4
Identify unwanted loss of cool air from a building	5
Determine if a building is going to exceed its energy budget	6
Identify which energy inefficient behaviours of building occupants can be changed, e.g., leaving lights on, leaving doors open, leaving equipment on, etc.	7
Implement machinery energy efficiencies in a building, e.g., replacing worn components, lubricating points of friction, etc.	8
Prolong the lifespan of energy consuming devices within a building	9
Educate building occupants to be energy-efficient when using a building	10
Determine the total energy cost of individual energy uses in a building, e.g., total cost of energy used for heating, total cost of energy used for lighting, etc.	11
Determine how to optimise the cooling of rooms in a building, e.g., save energy, distribute cool air, etc.	12
Determine how the need for cooling rooms in a building changes over time, e.g., by hour, by day, by season / time of year, etc.	13
Determine the current energy uses of a building, e.g., heating, lighting, room cooling, etc.	14
Predict future energy needs in a building, e.g., a need for more heating, a need for more hot water, etc.	15

Figure 19: Top-ranked job statements [Source: ITI Scotland]

These 15 jobs were then grouped into 10 themes - incorporating additional high-scoring related jobs – as shown in Figure 20 below.

OPPORTUNITY THEME
Detect supply failure
Energy budget management
Prevent supply failure
Identify health risks from EMBE devices
Building sealing
People and behaviour
Implement machinery efficiency improvements
Prolong the lifetime of energy consuming devices
Room cooling
Energy planning

Figure 20: Major opportunity themes [Source: ITI Scotland]

A preliminary review of these 10 opportunity themes was completed to identify existing & potential technology options and the current market climate. It was decided to select five of these themes for more detailed investigation of the current and future market and potential. These selected themes are discussed in more detail in Section 3.3 below.

In deciding which of these themes to target they were examined for their market potential based on the following criteria:

- Potential for current technology and product disruption (based on solid innovation theory)
- Potential for adoption by non-consuming target customers
- Potential future technology developments
- Potential ITI Scotland intellectual property protection
- Potential for market development and sustaining growth.

3.3 Description of Top Opportunity Themes

Each of the top five opportunity themes selected is described further in this section. For each opportunity the following is provided:

- What is it?
- What are the unmet customer needs?
- What application does it enable?
- Market barriers and enablers
- Key players
- Conclusion.

3.3.1 Energy Budget and Planning Management Platform

What is it?

This platform covers two of the top five themes identified above; i.e. Energy budget management & Energy planning. BEMS technology exists for large commercial buildings and on a domestic level, increasingly sophisticated power meters are beginning to emerge onto the market. However, this study has revealed a number of significant unmet customer need within the SME sector that could be addressed by such a technology platform.

What are the unmet customer needs?

A number of jobs within this theme were found to be important but unsatisfied by current technologies or solutions.

Energy Budgeting

The jobs that were found to be particularly important were related to understanding energy cost changes and not just simply keeping costs down.

- ‘Determine the impact of a change in energy prices on the total energy costs of a building’
- ‘Determine if a building is going to exceed its energy budget’
- ‘Determine the impact of a change of building use’
- ‘Determine the total energy cost of a specific part of a building’
- ‘Determine the total energy cost of a building by type of energy used’ – by ‘service, e.g. heating, lighting etc’ and by primary energy
- Avoid supplier charges for energy not delivered (very low satisfaction.)

These jobs reflect the fact that managing energy budgets within planned limits is a key part of an energy management role – probably the only thing more important than ensuring continuity of supply.

Energy Planning

A number of high-scoring jobs were identified which reflected a desire to understand and monitor existing energy use and to be able to predict future changes.

- ‘Determine the current energy uses of a building, e.g, heating, lighting, room cooling, etc.’ and ‘Identify all electronic equipment within a building, e.g., servers, computers, peripherals’
- ‘Predict future energy needs in a building, e.g., a need for more heating, a need for more hot water, etc.’ (very low satisfaction – lowest of all top 30 opportunities)
- ‘Identify peak periods of energy consumption in a building’
- ‘Determine how the use of operating machinery in a building changes over time, e.g., by hour, by day, by season / time of year, etc.’ (very low satisfaction).

These two themes have been combined into a single potential platform since it is a relatively small step from understanding energy use and to understanding energy costs.

What application does it enable?

The energy budgeting & management jobs identified require a combination of sensors to understand real-time energy use, an ability to analyse the information in relation to other input data (including energy prices) and a simple-to-use display to enable useful interpretation of the data and optimisation of controls. BEMS in large buildings tend to incorporate many of these features, although displays and controls are often not user friendly. In smaller, non-domestic buildings BEMS are very rare. In small buildings, including homes, the key related technology is the advanced meter, variants of which will be required in tens of millions.

Building Energy Management Systems (often just Building Management Systems – BMS) are computer-based systems that control and monitor the building's mechanical and electrical equipment such as ventilation, lighting, power systems, etc. BEMS often also control other building systems such as smoke and security alarms. BEMS have a number of 'points' distributed around the building – both sensors and control switches –connected to a computer which analyses input data and controls switches, often automatically. Simple BEMS will probably have tens of points, while complex ones will have several hundred.

BEMS are expensive and are common only in large buildings (though by no means all large buildings have them). Each 'point' is likely to cost around GBP500 in the UK, meaning that the cheapest system will probably cost at least GBP15,000. Costs are currently high primarily because these systems are custom designed for specific buildings and because labour costs dominate for installation and connection of the sensor and control points. For the same reason, retrofitting such a system can be very disruptive and they are far more commonly installed in new buildings than in existing buildings.

Small commercial or public buildings currently tend to have no energy budgeting or management technology. However, within a 5-10 year horizon most buildings, including homes, are likely to have an 'advanced meter' of some sort installed. The key characteristic of advanced meters is the capability to transmit metering information to the utility (Automatic Meter Reading AMR), making onsite meter reading redundant. Most advanced meters can also transmit information from the utility to the meter, and within the building, potentially enabling system-level management interventions by the utility.

Advanced meter costs depend on the level of functionality, but a guideline cost for domestic smart meters once they are mass produced is around USD100. Who owns the meter – utility or building owner – in a deregulated market is an issue that would certainly impact on the value of additional functionality. For example, displays that show building owners their consumption might have considerable value to the owner but have no direct value to the utility.

Initial roll out of advanced electricity metering is likely to be in Europe. The global market for standard electricity meters is something around 100 million units each year, with this number growing slightly year on year. Advanced gas metering is also on the agenda, although the system-level drivers are less strong and there are some inherent technical problems with connecting sensors and transmitters to gas pipelines. Nevertheless there is good scope for including information from advanced gas meters in an energy management and budgeting platform along with electricity information. At least 20 million gas meters are installed worldwide each year with an expected annual growth of 4%[17].

The development of enabling technologies likely to be relevant for an energy budgeting and / or management platform includes:

- Sensors (including energy harvesting for self-powered capability)
- NALM (Non-intrusive Appliance Load Monitoring)
- Wireless data transmission
- Microgrids
- General IT-enabled buildings.

Market barriers and enablers

Drivers

- Energy costs – increasing and fluctuating energy prices

[17] http://www.energybusinessreports.com/shop/item.asp?itemid=335

- National and international policies and regulation – building efficiency regulations, building energy performance certificates, carbon emission limits
- Environmental awareness – customer perception and employee perception
- Company finances – validation of billing, meeting accounting requirements/deadlines

Barriers

- Cost – smaller energy spend sector therefore lower investment expectation
- Ease of installation – able to be retrofitted within existing buildings at minimal cost and with minimal disruption to building fabric or operation
- Ease of use – non-specialist users will require easy to understand and optimise controls / interfaces
- Lack of national or international protocols or standards

Key players

BEMS-like products are available from a large number of companies. The fact that so many respondents to the ODI questionnaires were non-consumers suggests, though, that these systems are not well suited for many SMOs, or simply too expensive. Utilities are beginning to take interest in the BEMS and energy management market; for example, Centrica acquired Building Management System Integrators (BMSi) in 2008. Another interesting example is Adam, a BEMS provider which has recently developed a wireless BEMS system.

There are perhaps twenty international companies that lead on the development and manufacture of advanced meters (many also manufacture other electronic devices such as controls, as well as water or heat meters). Most of these are members of the European Smart Metering Industry Group (ESMIG).

Companies involved with manufacturing sensors and other related EMBE equipment include big players such as Siemens. Siemens is also involved in wireless communications for energy applications through its spin off Cinterion Wireless Modules. Many of the big advanced metering companies are also involved with BEMS components, which are likely to be combined by specifiers such as ARUP. Software companies including both Microsoft and Google are involved in various related technologies such as NALM and computer-screen displays.

Conclusion

We have identified considerable potential for development of a technology platform with energy management and energy budgeting capabilities. Such a platform could be considered as a mass market BEMS or an advanced meter with advanced functionality. The platform could incorporate existing technologies in novel combinations and there is also scope for development of new hardware and software.

Features immediately relevant might include:

- Information inputs – both internal (sensors, meters) and external (real-time energy prices) – for electricity and, potentially, fuel.
- Analytics
- Diagnostics
- Information outputs – both internal (displays, warnings, Demand Side Management signals etc.) and external (transmission to utilities)
- Controls.

Those features with potential tie-ins, but less immediately relevant include:

- Technology to take advantage of tariff differentials (demand side participation)
- Linkage (verification) to utility and other carbon reduction targets

- Bill payment technology
- Utility billing information and analysis software
- Linkage with Opportunity in People and Behaviour (see Section 3.3.3), e.g. dashboarding, displays, warnings, etc.

The highest scoring job from the ODI analysis could also potentially be incorporated into a platform: simple alarm functionality to inform building occupants and energy managers of an energy supply failure (electricity and / or fuel).

3.3.2 Health Risk Assessment

What is it?

Recognising and understanding health risks in buildings (often associated with building energy infrastructure such as heating or ventilation systems) is recognised by experts as a key frontier in EMBE technology development over the next 3-10 years.

What are the unmet customer needs?

- 'identify potential health risks to the occupants of a building caused by energy consuming devices, e.g., CO2, carbon monoxide, etc'.

This job statement was rated particularly highly by those who participated in the quantitative survey.

What application does it enable?

'Healthiness' of the built environment is increasingly seen as one component of 'comfort' in a building (along with energy services like heat and light), meaning there will be opportunities in sensing hazards and in software to understand the health impacts of building design.

Potential risks to occupant health are associated with many aspects of a building design and use, including:

- specific elements of a building's fabric (asbestos is a good example)
- the interior environment (fumes, particulate pollution, damp, temperature, illumination levels, etc.)
- the way a building is used (noise, RSI)
- emissions from energy-consuming devices (potentially including volatile organic compounds, electro magnetic radiation, noise and other vibrations)

Sensors might be required for a long list of (perceived) hazards, many of which are related to a building's energy supply or use:

- Carbon monoxide and other gases
- Electromagnetic and other radiation
- Temperature and drafts
- Microbial or mould issues
- Adequacy of light / sound
- Vibration

Integration of hazard sensors with bespoke BEMS is increasing according to ARUP UK, but is far from common even in big buildings. However major UK organisations involved in BEMS technology developments see hazard assessment becoming much more common over the next ten years.

Various aspects of Building Health issues potentially overlap with building energy systems and controls, or with more general 'IT enabled buildings'. There may be opportunities amongst the following:

- Incorporation of additional hazard monitoring into existing building monitoring systems (potentially including BEMS, smoke alarm systems, or security alarm systems): Stand alone interior environment monitoring equipment is currently expensive and may be over-specified. There is scope for incorporating some specific health hazard sensors into a simple BEMS or energy display systems.
- Diagnostics: Because health hazards in buildings (particularly indoor air quality), are often the result of faulty heating, cooling or ventilation equipment, increasing concerns about the interior environment should lead to increased demand for diagnostics, particularly to understand minor faults that leave the equipment functioning apparently normally.

Market barriers and enablers

Drivers

- Improvement of indoor air quality – perceived to reduce as building air tightness (for increased energy efficiency) is increased and more electrical devices are used
- Staff perception of a good employer – prevention of 'sick building syndrome'
- Reduced employee absenteeism due to illness
- Regulation – it is expected that health issues will be incorporated into building regulations

Barriers

- Cost benefit – proving benefit will not be straight forward.
- Validation/correlation of reduced absenteeism difficult to prove.
- Regulation – no consensus yet on which hazards are likely to be regulated or to what level.

Key players

Global companies like DuPont are involved in various aspects of health and environment monitoring. First Alert and Kidde, among many others, make carbon monoxide and smoke detectors as well as other health/safety technology. Arup is just one of many firms that thinks there is scope for technology development towards a healthy built environment.

Integrated products are available, with sensors for various hazards linked to display units and audible warnings. Florida based **SmartAir Solutions** is a good example; they also respond on the ground to any hazards flagged in a warning state.

Conclusion

Identification and analysis of health hazards associated with buildings is a theme with significant market potential for EMBE technology in the 3-10 year period. Market growth is likely to be a result of natural concerns about new appliances and building techniques, with particular markets boosted by regulation.

Specifically there appears to be an opportunity in cheap and simple monitoring of particular hazards associated with energy consuming devices and with heating, cooling and ventilation equipment. There may also be scope for including health sensors and information in displays or platforms that are being installed in buildings with a different primary purpose (e.g. for energy budget planning or management).

It is expected that building regulations in the UK and elsewhere may come to incorporate indoor air quality standards, which would create a significant demand for CO_2 sensors and analysis and may also extend to cover other potentially harmful pollutants..

3.3.3 People and Behaviour

What is it?

Technology used to inform and influence the energy use behaviour of building occupants is an area of technology development which both experts and customers identified as a frontier of EMBE R&D. It holds very significant potential for large improvements in energy efficiency with minimal capital equipment cost – a fact of which governments with Kyoto and other related targets are well aware.

What are the unmet customer needs?

Two particularly highly scoring jobs (with high importance and very low satisfaction) emerged from the top opportunities:

- 'Identify which energy inefficient behaviours of building occupants could be changed. e.g leaving lights on, leaving doors open, leaving equipment on'
- 'Educate building occupants to be energy efficient when using a building'

What application does it enable?

It is widely accepted that there are both energy savings and money to be made by influencing energy use behaviour of individuals in buildings.

At present there are some clear related gaps:

- *Understanding existing energy use behaviour:* Technology might be linked to standard BEMS points or advance metering, but there are certainly opportunities to use technical developments in non-intrusive monitoring such as Non-intrusive Appliance Load Monitoring (NALM) and clip-on sensors. Making sensors cheap enough to allow positioning throughout a building will enable the understanding required.
- *Analysing existing and possible energy use behaviour:* There appears to be a lack of clarity on the options with regard to various possible behavioural changes: E.g. Does switching off a light make more difference than closing a window? Analysis and display of existing energy-use data needs to be related directly to up-to-date behavioural science.
- *Demonstrating carbon savings from behavioural change:* Building energy managers show a clear desire to understand the impact of any changes they make. At present, it is very difficult to credit energy savings to behavioural change. A technical solution to certifying energy savings could be immensely valuable, particularly where government or utility drivers require measurements of all savings.

Displays designed to present energy use information to building occupants – not just the energy managers – are already incorporated into some high-end BEMS. This is known as 'dashboarding'. Dashboard information is commonly displayed on purpose-built displays in building lobbies and sometimes on employee computer screens. Smaller buildings and SMOs, which are unlikely to have BEMSs installed, very rarely have any form of energy display.

Advanced meters, which are expected to become standard in most buildings in most markets over the next ten years, are likely to incorporate a display function of some sort. Displays on advanced meters will probably display both instantaneous energy-use data, but also graphics and statistics produced by utilities using transmitted meter information. Various companies are developing systems to enable utilities to manage and analyze massively increased information flows and to display the information to building managers in useful ways. Just as there is not yet firm agreement on the communications platform for advanced meters, there is no firm agreement on what information displays should include, or even exactly what information needs to be analysed.

Domestic 'energy monitors' display instantaneous building electricity consumption information to homeowners, allowing a householder to better understand how their device use can impact on electricity bills. These have basic displays that can convert electricity use figures into real time cost and carbon measures, and their usefulness in inspiring behavioural change is well documented[18]. These devices use clip-on magnetic sensors to estimate power flows, then transmit the information wirelessly to a display unit. Popular models such as the Centameter (known as Electrisave in the UK) currently have no logging capability but next generation devices, like that being developed by Onzo, will incorporate this, enabling users to monitor their history of energy usage.

Companies like Google.org (see Figure 21 below) are working on simple, software-based displays, for use by the domestic market but as yet, these are just demonstrators.

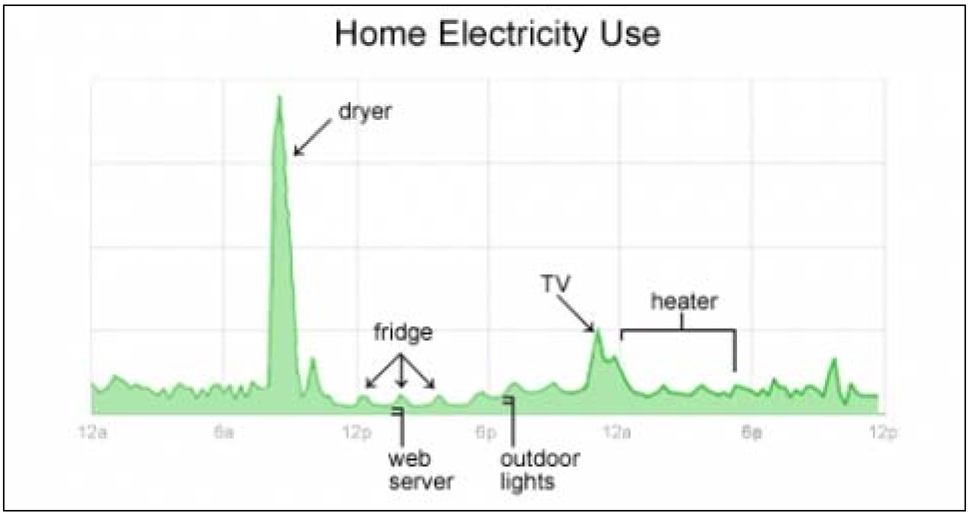


Figure 21: Mock-up of google.org's domestic energy use display [Source: Google.org]

Market barriers and enablers

Drivers

- Energy performance certificates (EPC) for buildings – data required for these could be used for promoting behavioural change
- Carbon emission reductions – increasingly, utilities have obligations to reduce emissions amongst their customers
- Regulatory – personal carbon trading may be introduced in the longer-term (> 10 yrs)

Barriers

- Difficulty of validating correlation between cost/energy/emission savings and behavioural change
- Investment in technologies to influence behavioural change is likely to be expected to be low, unless an integral part of an energy planning/management platform

[18] http://www.electrisave.co.uk/cms/thesite/public/uploads/uploadsbank/1112705999_390.pdf

Key players

Many BEMS suppliers can provide systems with display capability. Companies involved in software and component development, include Microsoft and Google.org. Domestic energy monitors under the Centimeter / Electrisave brands are manufactured by Wireless Monitors of Australia Pty. Advanced metering companies vary in their focus on display capability as an important function of their products. Onzo (part owned by SSE) is a good example.

Conclusion

While it is not yet a focus of attention amongst EMBE companies, there is recognised potential for massive energy savings from behavioural change and there is increasing demand for products that can enable that change. This theme has considerable potential on the 3-10 year time horizon.

There is agreement from experts that technology related to influencing building occupant behaviour is likely to become a key component of EMBE equipment over the next five years. Technology advances (cheap wireless sensing and communications, NALM) are making multi-point energy-use information systems more feasible, which in turn could lead to displays with the degree of detail needed to really influence individuals' behaviour.

This is also a market gap in which a simple and cheap product developed for the SME sector would have very good cross-over potential to the domestic market, or where cheap products being developed for the domestic market could have some added functionality and be targeted at the SME segment.

3.3.4 Building Sealing

What is it?

Efficient and satisfactory thermal regulation of building spaces was found to be one of the least satisfied jobs among the SME segment. There is a desire to eliminate heat (and cold) wastage from existing buildings, and also a need to understand exactly where and how cool or hot air is escaping. There are opportunities, then, in technology to identify egress of hot or cold air and in physically sealing the identified gaps.

What are the unmet customer needs?

Three jobs emerged from the customer research with a clearly perceived lack of servicing, particularly regarding loss of cool air. Each of these three jobs scored particularly low satisfaction ratings – indicating a distinct lack of market offering in the SME segment.

- 'Identify unwanted loss of cold air from a building' (very low satisfaction)
- 'Identify unwanted loss of heat from a building' (low satisfaction)
- 'Prevent undesired heat from entering a building'

What application does it enable?

There is clearly a demand for simple, off-the-shelf kit to enable building energy managers to understand how warm and cool air is lost from their buildings. Within ten years, thermal imaging core technology is likely to come down in cost, perhaps making simple cameras cheaply available. This could create opportunities for the core technology but also for tools to analyse and present the basic thermographic data. Fixed thermal imaging cameras are rare at present but if they became very cheap they might be used for leak detection in conjunction with some other EMBE function.

Experts recognise that existing techniques for identifying areas of heat or coolth loss have significant drawbacks, particularly with regard to pinpointing actual problem areas and with displaying information in an understandable form. There may be opportunities to develop software for analysing and presenting information around sealing.

Building sealing seems certain to get more and more recognition as a vital component of energy efficient building (as insulation already has) as primary energy savings become more and more important. There are many companies developing new techniques and technologies to make the building fabric of new constructions more air-tight. Current demand from the SMO segment would suggest opportunities in developing retro-fit building sealing technology, or in adapting technologies initially designed for new-build.

Buildings leak (or take in) air due to pressure differentials caused by wind, mechanical systems (heating, cooling and ventilation) and stack effects (hot air rising). Air leakage will always occur to some extent, both through the building fabric itself and through breakdowns in the fabric (holes, cracks, unsealed windows and doors).

Air-tightness of buildings has become an increasingly important issue in the construction and testing of new buildings. It is now widely accepted that increasing the insulation of a building (the U-value) is of limited value unless leakage is significantly reduced. Regulations in most countries now include maximum permissible leakage rates for new build. Part L (Conservation of Fuel and Power) of the English Building Regulations, for example, states that air permeability should not exceed $10m^3/hr/m^2$ at an applied pressure difference of 50 Pa.

Good quality construction is the key to well-sealed buildings; one of the reasons why Modern Methods of Construction (where building sections are manufactured offsite) are becoming more common. There are products available for improving building sealing, many of which will also increase insulation. Most are low-tech alterations to the building fabric such as draft excluders and insulating foams. There is some research into active (‘intelligent’) building sealing products, which adapt to building conditions.

There are two main methods for identifying sealing problems: **pressure testing** and **thermal imaging**. Pressure testing identifies when overall building sealing is poor, but is not good at identifying exact sites of air egress. Thermal imaging (infrared thermography) can identify exactly where heat (or cold) is being lost from a building, but it is sometimes difficult to relate images to building energy costs and budgets. Smoke testing is a low-tech methodology, which is sometimes used in conjunction with pressure-testing.

Market barriers and enablers

Drivers

- Very high energy savings in well-sealed vs poorly-sealed buildings
- Increasingly stringent building regulations – move towards zero-carbon buildings

Barriers

- Equipment costs for pressure testing and IR imaging are currently high and significant expertise is required to operate it
- Supply chain means that the purchaser of this type of equipment is typically not the building owner or energy manager but rather a service company
- Testing requirements are typically one-off or occasional, not regular

Key players

SPI Corp and FLIR are two of the major companies that develop and sell thermal imaging technology. Relatively low volumes of production (compared to standard cameras) mean prices are still several thousand dollars. Many service companies offer to survey buildings using thermal imaging cameras. IRT Surveys claim to be unique in being able to quantify the energy loss as opposed to simply locating it. This enables prioritised remedial action to be taken.

Numerous companies offer pressure-testing for new buildings, including BSRIA, Global Pressure Testing and Building Sciences. (Many of these also offer thermal imaging).

Conclusion

There is clearly a market for new products which could identify and quantify the egress of temperature-controlled air from a building, particularly for existing buildings; though it's not clear what form this product might take.

There is also scope for improving existing technologies, making them cheaper and making their output data more useful to untrained energy managers.

4 CONCLUSIONS AND NEXT STEPS

This section includes a short conclusion to the report together with the next steps that ITI will take to investigate opportunities arising from the EMBE foresighting activity.

4.1 Conclusions

This Report has reviewed the EMBE market using an outcome driven innovation focussed approach. Within the next 10-20 years EMBE is expected to impact increasingly on everyone, both at home and in the workplace. This is a technologically complex, emerging market with significant opportunities for the right application.

EMBE technologies, systems and products have developed to the point where a number of market applications for large energy users are already being exploited. However, a number of issues, primarily cost based, make wider application in the home and commercial environment challenging. As and when these issues are resolved, the opportunities for EMBE systems will flourish.

As market opportunities become addressed through technologically novel, economically-viable products, the EMBE market will witness significant growth in the medium to long term.

As with any opportunity that offers significant new commercial opportunity, the emergence of aggressive small companies and start-ups can be expected. As such, the EMBE market could represent a significant new and addressable opportunity for technology businesses in Scotland.

Through the creation of underlying technology platforms, ITI could play a role in enabling the development of such businesses. As such, ITI has identified a number of opportunities that could lead to the creation of technically novel and commercially exciting enabling technology platforms.

4.2 Next Steps

Prior to progressing activities in this area, ITI will seek to engage with stakeholders to validate and confirm those opportunities that should form the basis for its subsequent activities. In addition, ITI welcomes R&D programme proposals and expressions of interest in related areas to assist in providing an understanding of the capabilities and commercial interest within Scotland.

If you are interested in future engagement in the area of EMBE, how to make a proposal or provide an expression of interest relevant to this area, please contact:

Janet Milne
ITI Techmedia
Glasgow
0141 225 4459
janet.milne@ititechmedia.com

or

David Butler
ITI Energy
Aberdeen
01224 282652
david.butler@itienergy.com

APPENDIX 1: JOB STATEMENTS

DETERMINE HOW A BUILDING USES ENERGY

1. Determine the current energy uses of a building, e.g., heating, lighting, room cooling, etc.

2. Determine the unmet energy needs of a building, e.g., a need for more heating, a need for more hot water, a need for cooler rooms, etc.

3. Determine how the design of a building impacts the amount of energy it consumes, e.g., amount of sunlight entering the building, high ceilings, position of windows, etc.

4. Determine how the materials used in a building's construction impact the amount of energy consumed, e.g., type of glass, interior wall construction, etc.

5. Determine how the number of people using a building affects the amount of energy consumed

6. Ensure a building's occupants are comfortable, e.g., not too hot, not to cold, sufficient lighting, etc.

7. Determine how the need for space heating in a building changes over time, e.g., by hour, by day, by season / time of year, etc.

8. Determine how the need for water heating in a building changes over time, e.g., by hour, by day, by season / time of year, etc.

9. Determine how the need for lighting in a building changes over time, e.g., by hour, by day, by season / time of year, etc.

10. Determine how the need for refrigeration in a building changes over time, e.g., by hour, by day, by season / time of year, etc.

11. Determine how the need for cooling rooms in a building changes over time, e.g., by hour, by day, by season / time of year, etc.

12. Determine how the use of a building's electronic equipment changes over time, e.g., by hour, by day, by season / time of year, etc.

13. Determine how the use of operating machinery in a building changes over time, e.g., by hour, by day, by season / time of year, etc.

14. Determine the total carbon emissions of a building

IDENTIFY ALL THE ENERGY CONSUMING DEVICES/SYSTEMS IN A BUILDING

15. Identify all heating devices/systems within a building

16. Identify all water heating devices/systems within a building

17. Identify all lighting devices/systems within a building

18. Identify all room cooling devices/systems within a building, e.g., air conditioning units, ventilation devices, etc.

19. Identify all refrigeration devices/systems within a building

20. Identify all electronic equipment within a building, e.g., servers, computers, peripherals, etc.
21. Identify all machinery within a building, e.g., elevators, industrial machines, etc.

DETERMINE THE ENERGY COSTS OF A BUILDING

22. Determine the total energy cost of a building by type of energy used, e.g., cost of electricity, cost of gas, etc.
23. Determine the total energy cost of a specific part of a building, e.g., cost by floor, cost by room, etc.
24. Determine the total energy cost of individual energy uses in a building, e.g., total cost of energy used for heating, total cost of energy used for lighting, etc.
25. Determine the total energy cost of an individual device / system within a building, e.g., energy cost of a boiler, energy cost of a fridge, energy cost of a water heater, etc.
26. Determine the impact of a change in energy prices on the total energy costs of a building
27. Determine the impact of a change in the use of a building on total energy costs, e.g., a change in opening hours, a change in function, a change in the number of people using the building, etc.
28. Identify peak periods of energy consumption in a building
29. Prevent being charged by an energy supplier for unused energy, e.g., charged for energy never provided, not credited for energy returned to the supplier, etc.
30. Predict future energy needs in a building, e.g., a need for more heating, a need for more hot water, etc.
31. Determine if a building is going to exceed its energy budget

IDENTIFY INEFFICIENT USES OF ENERGY IN A BUILDING

32. Identify space heating inefficiencies in a building, e.g., which spaces are too warm, which spaces are too cold, etc.
33. Identify water heating inefficiencies in a building, e.g., water too hot, water too cold, hot taps left running, etc.
34. Identify room cooling inefficiencies in a building, e.g., rooms too cold, rooms too humid, etc.
35. Identify which parts of a building are energy inefficient, e.g., which floor, which room, etc.
36. Identify which individual devices/systems in a building are energy inefficient, e.g., which heating units, which water heaters, which types of IT equipment, etc.
37. Identify unwanted loss of heat from a building
38. Identify unwanted loss of cool air from a building
39. Identify where unwanted cold air is entering a building

40. Identify where unwanted hot air is entering a building

41. Detect a failure in energy supply, e.g., heating stops working, lighting goes out, etc.

42. Identify which energy inefficient behaviours of building occupants can be changed, e.g., leaving lights on, leaving doors open, leaving equipment on, etc.

43. Identify potential health risks to the occupants of a building caused by energy consuming devices, e.g., CO_2, carbon monoxide, etc.

DETERMINE HOW TO MANAGE ENERGY IN A BUILDING

44. Determine how to optimise the heating of rooms in a building, e.g., save energy, distribute heat, etc.

45. Determine how to optimise the cooling of rooms in a building, e.g., save energy, distribute cool air, etc.

46. Determine how to optimise the heating of water in a building, e.g., save energy, reduce temperature, etc.

47. Determine how to optimise hot water usage by occupants of a building

48. Determine how to optimise the use of lighting in a building, e.g., save energy, switch off lights in empty rooms, etc.

49. Determine how to optimise the energy use of an individual device/system within a building

50. Reduce the total carbon emissions from a building

51. Identify the potential return on investment of an energy management initiative

52. Determine when a return on investment on an energy management initiative is achieved

53. Comply with compulsory building energy-use-regulations, e.g., consumption targets, carbon emissions, etc.

54. Comply with non-mandatory energy-use guidelines for a building, e.g., consumption targets, carbon emissions, etc.

IMPLEMENT ENERGY MANAGEMENT INITIATIVES IN A BUILDING

55. Implement heating efficiencies in a building, e.g., changing air filters, calibrating thermostats, etc.

56. Implement water heating efficiencies in a building, e.g., using electric ignition, sealing ducts, etc.

57. Implement lighting efficiencies in a building, e.g., replacing bulbs, installing timers, etc.

58. Implement refrigeration efficiencies in a building, e.g., checking sealing, replacing compressors, etc.

59. Implement room cooling efficiencies in a building, e.g., sealing ducts, cleaning coils, etc.

60. Implement electronic equipment energy efficiencies in a building, e.g., sharing devices, implementing power-save functions, etc.

61. Implement machinery energy efficiencies in a building, e.g., replacing worn components, lubricating points of friction, etc.

62. Prevent unnecessary waste of hot water in a building

63. Prevent the unwanted escape of heat from a building

64. Prevent the unwanted escape of cooled air from a building

65. Prevent undesired heat from entering a building

66. Prevent unwanted cold air from entering a building

67. Prevent a failure in energy supply, e.g., heating stops working, lighting goes out, etc.

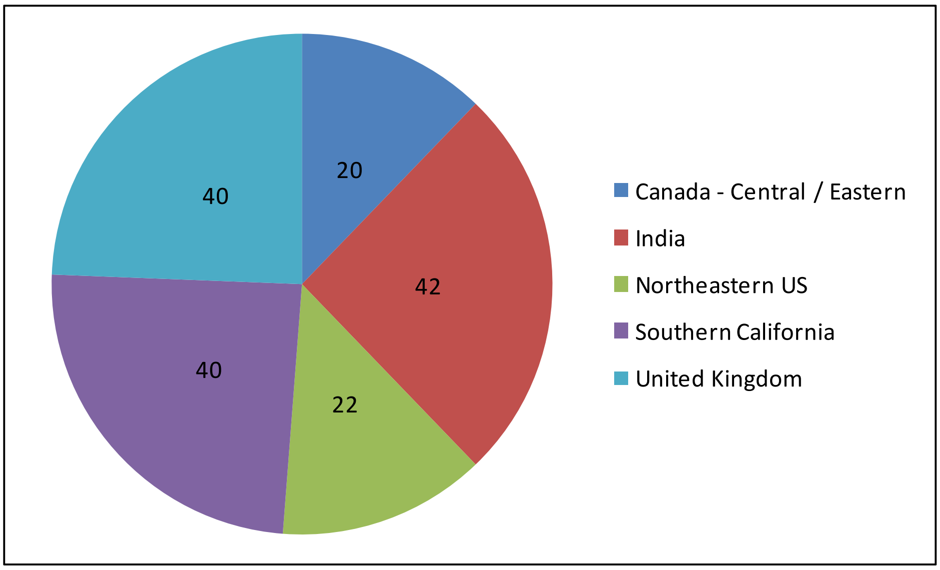
68. Prolong the lifespan of energy consuming devices within a building

69. Educate building occupants to be energy-efficient when using a building

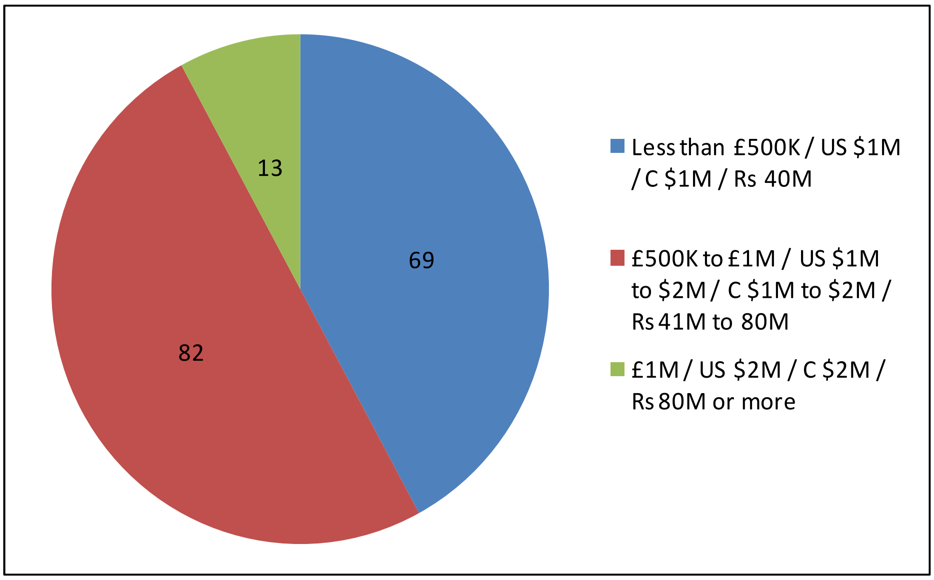
APPENDIX 2: PROFILE OF SURVEY RESPONDENTS

Total sample size: 169

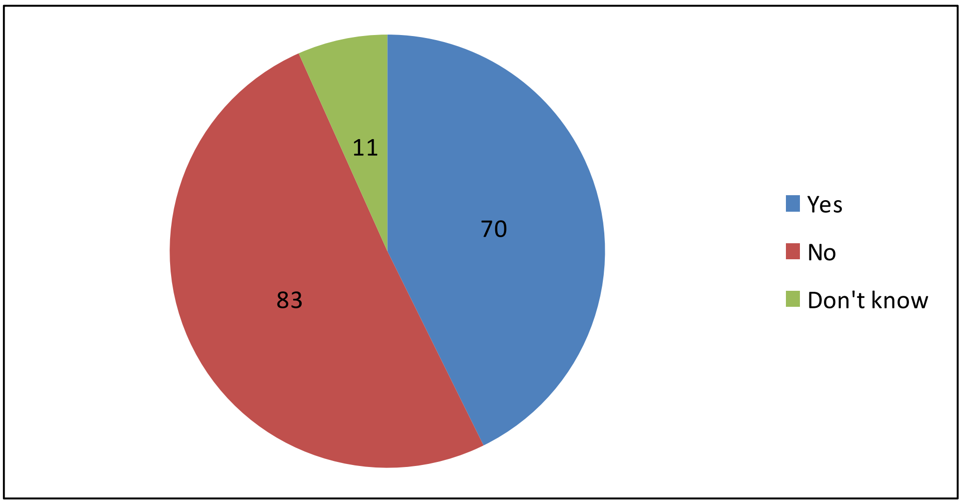
Country / Region



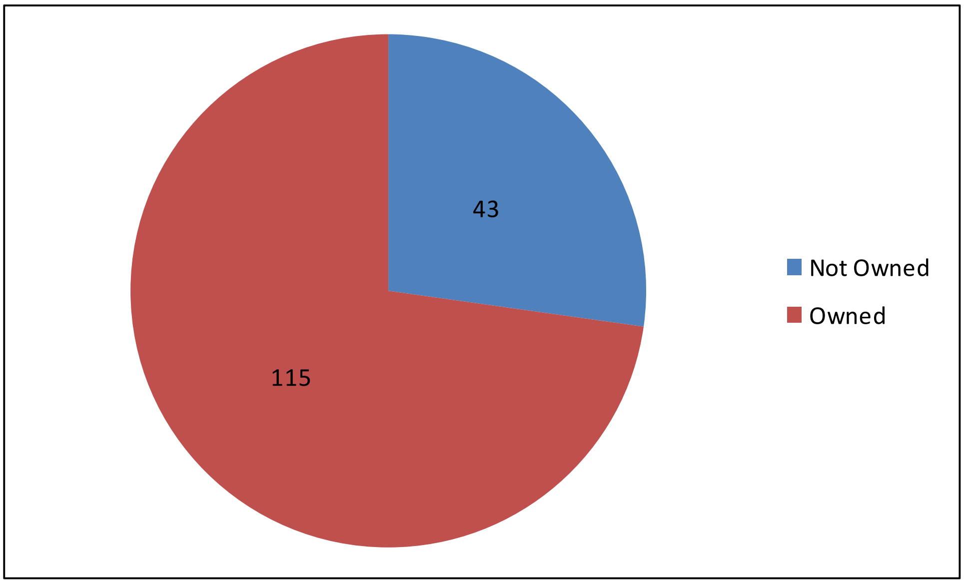
Total Annual Energy Budget



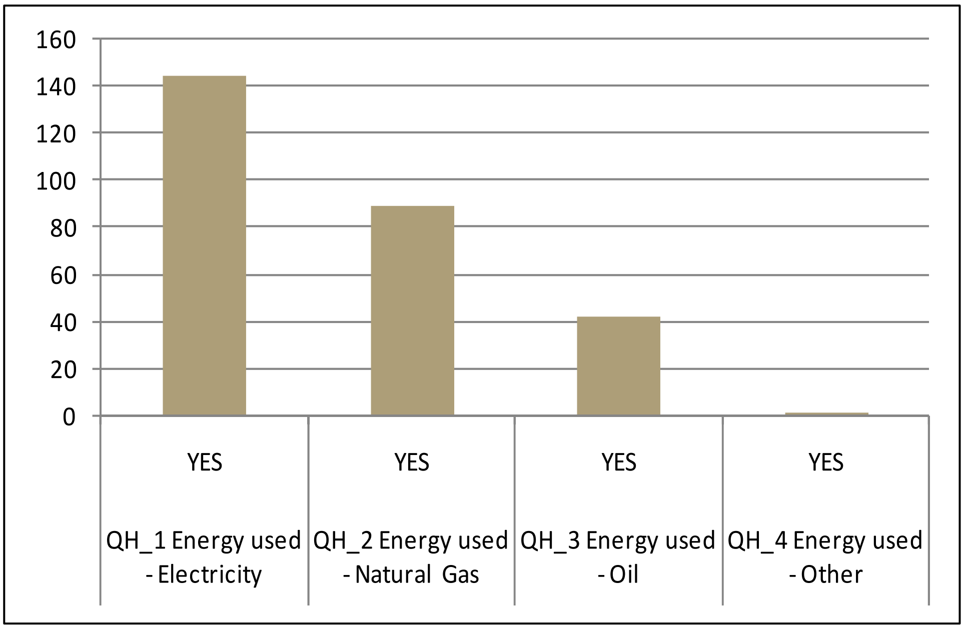
Public sector



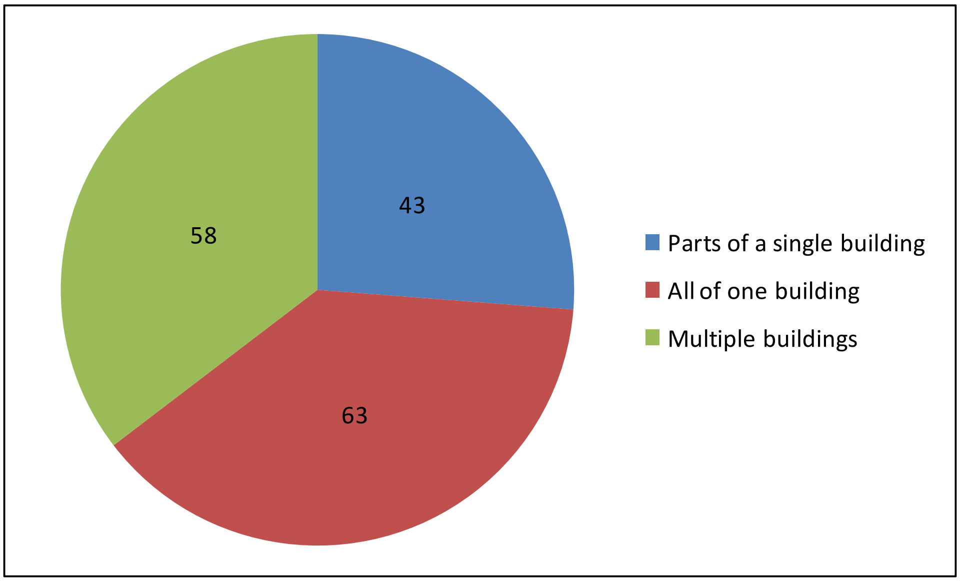
Owned / Not Owned



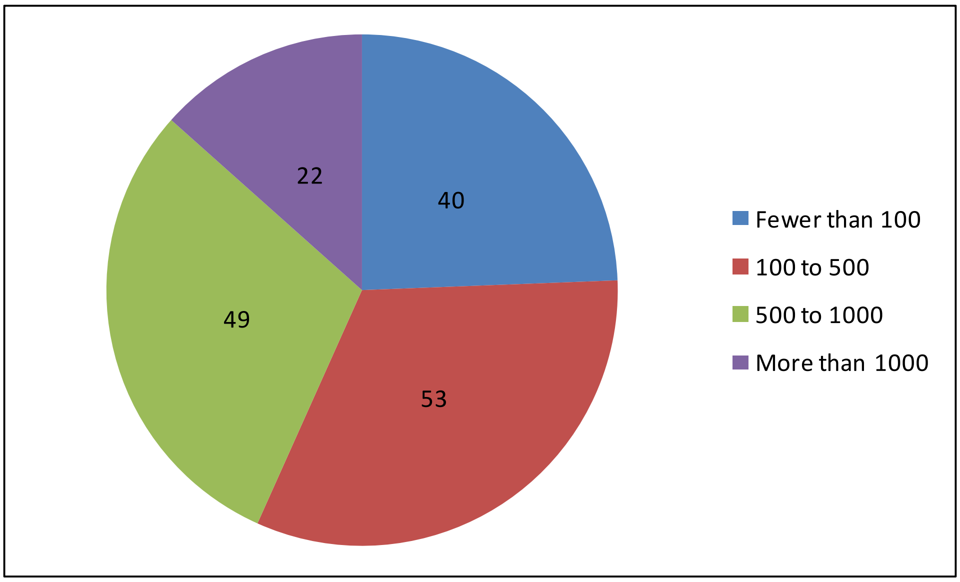
Types of Energy Used



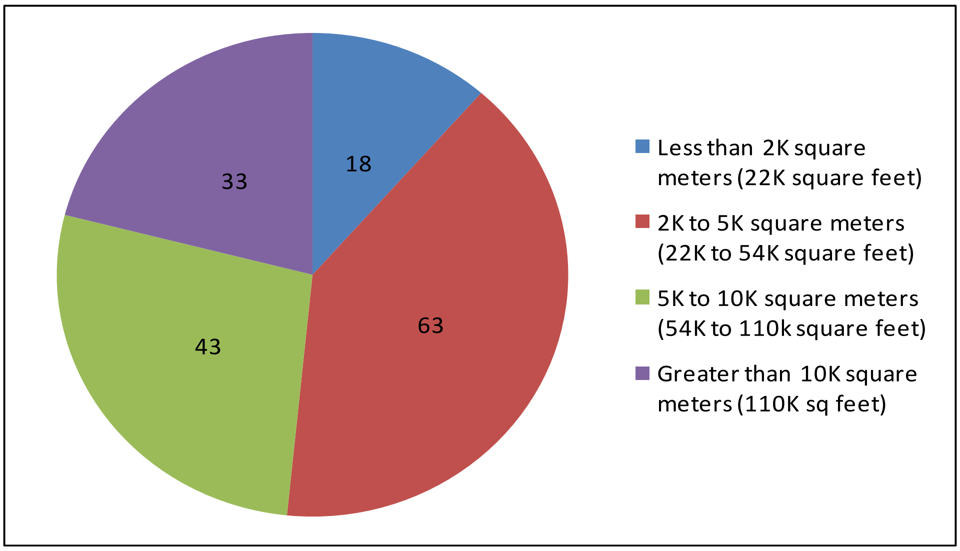
Number of Buildings Managed



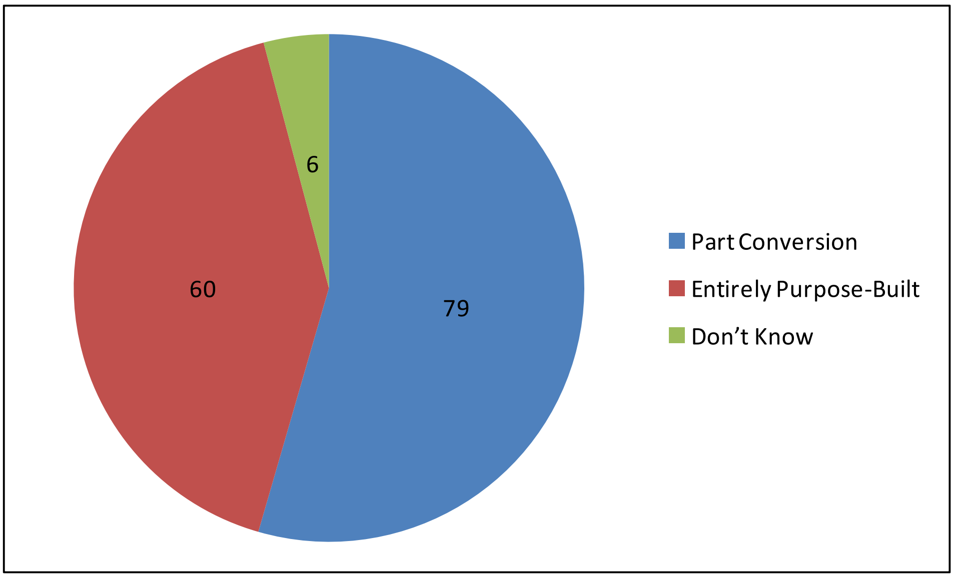
Number of persons using building(s)



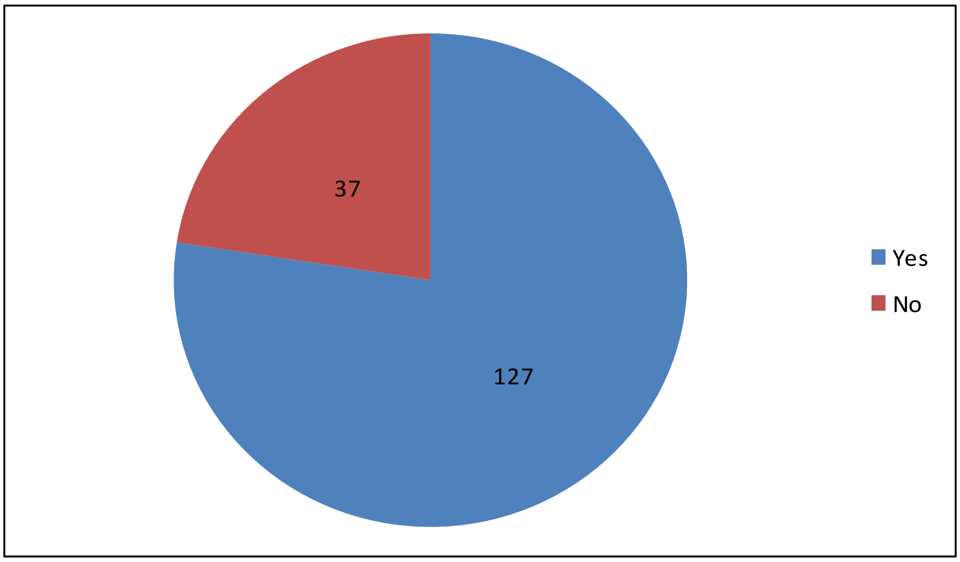
Building size



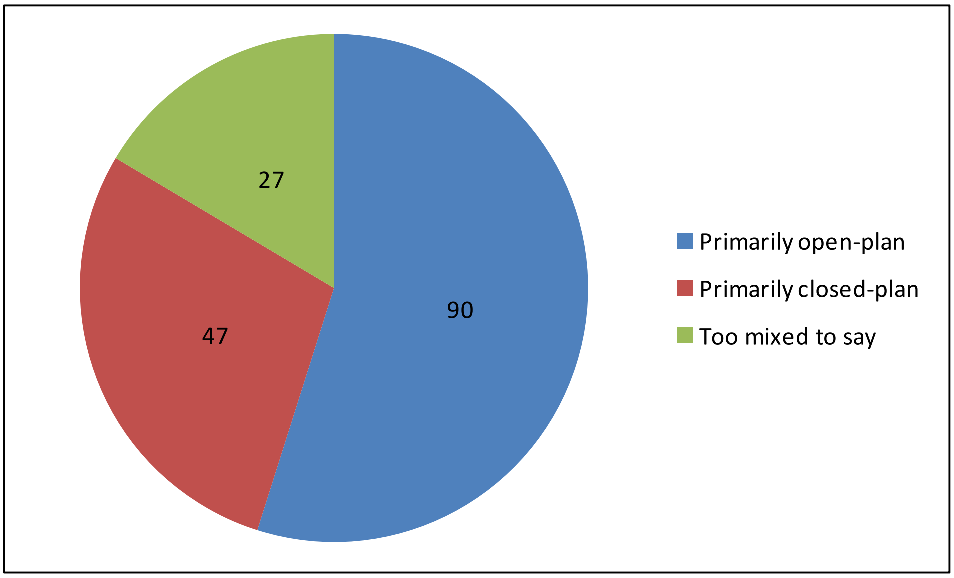
Building conversion



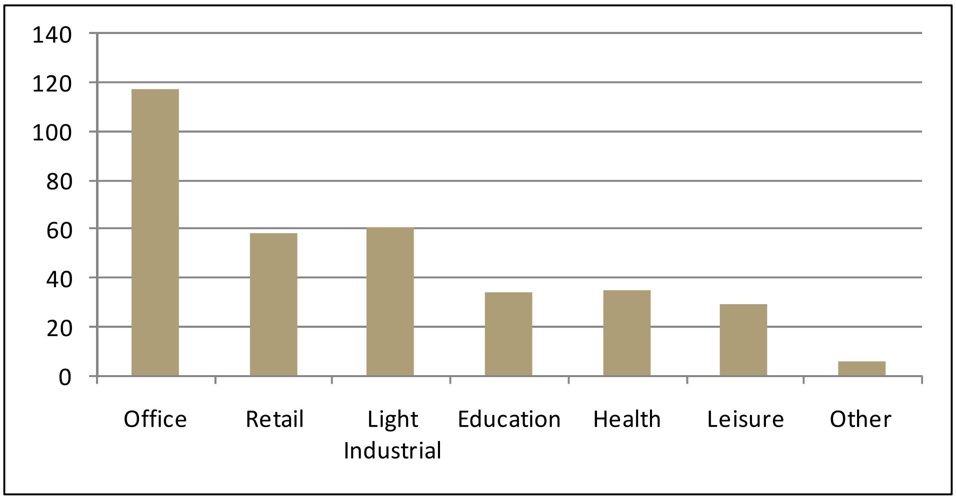
Energy use altered as a result of renovation in last 20 years



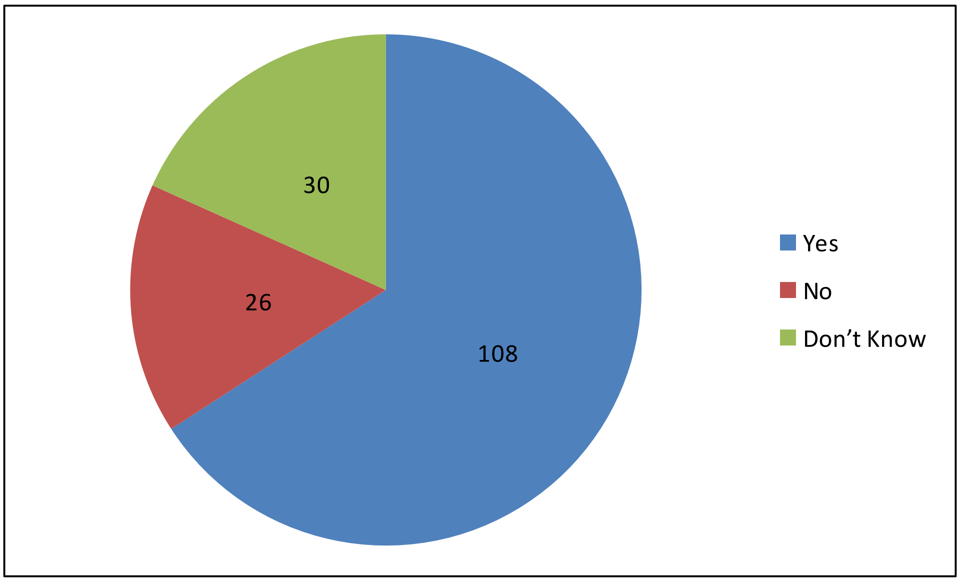
Interior building layout



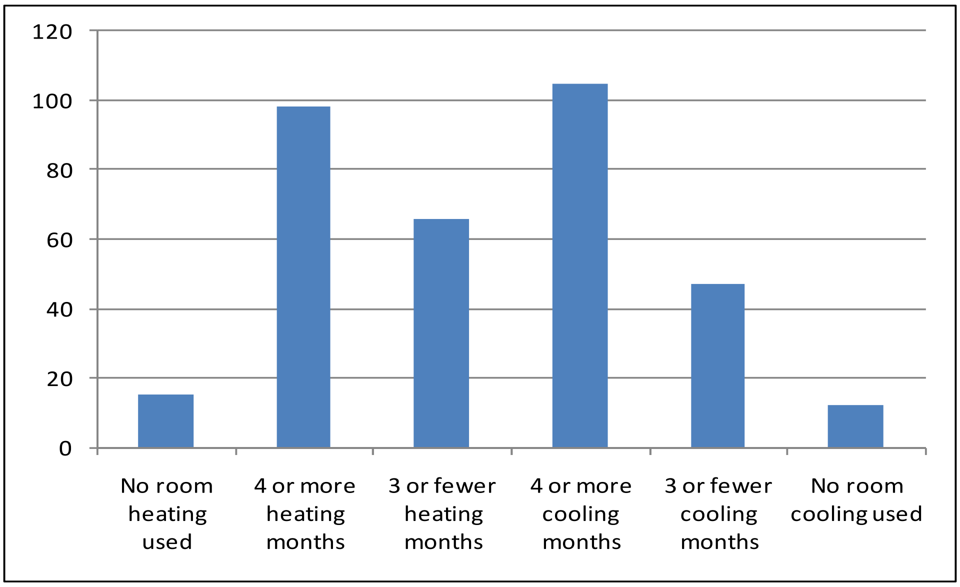
Primary Building Use



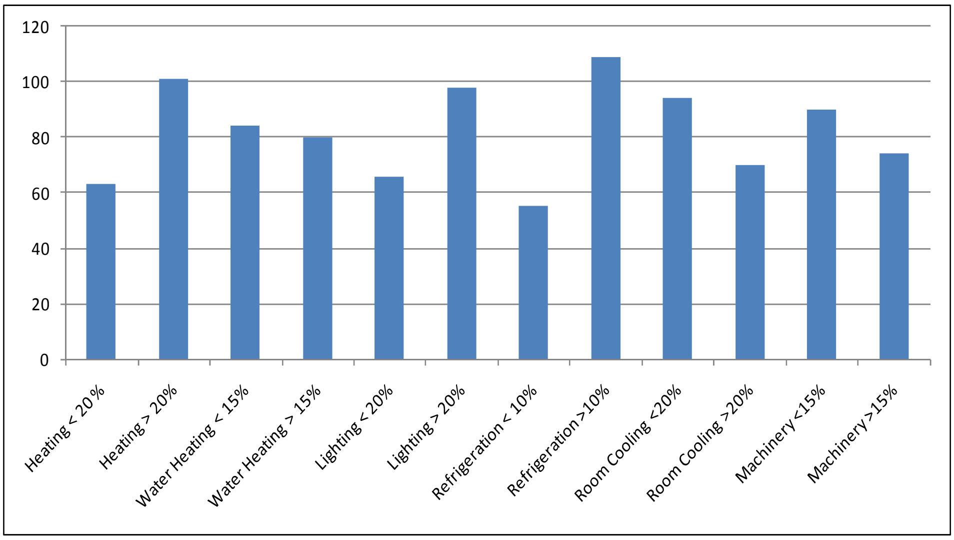
Plans to install on-site electricity generation



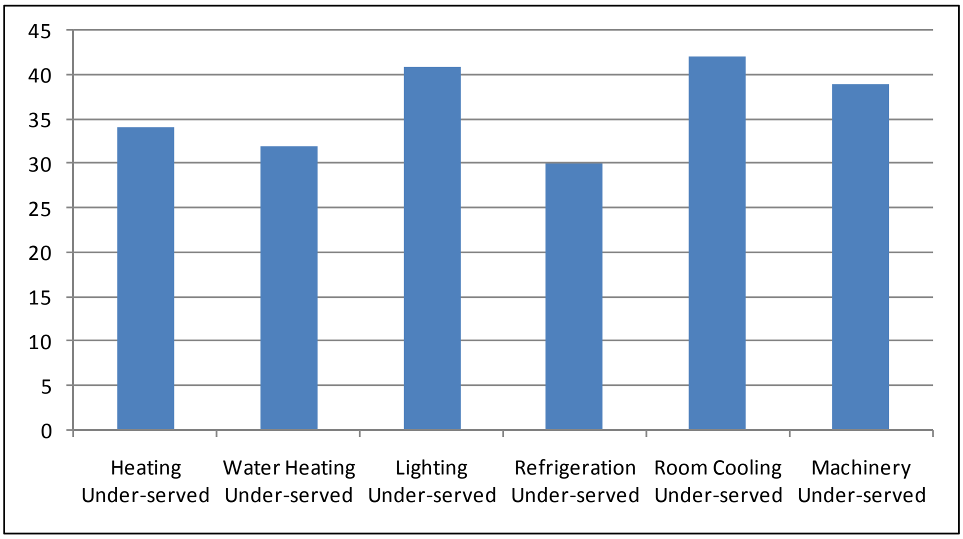
Months per year room heating / cooling



Spend per energy use as a percentage of total energy budget



Desire to make energy efficiency improvements per energy use



Important time periods for monitoring energy use