THE TECHNOLOGY PROGRAMME

DTI TECHNOLOGY PROGRAMME

Internet-enabled monitoring and control of the built environment

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WP2 Report: REVIEW OF AVAILABLE CONTROLS, ACTUATORS AND SERVICES OFFERED

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Summary

Increasing awareness of the extent energy and environment e-services can contribute to energy efficiency and demand reduction targets instigated a review of the current status of the technology. This is specifically focusing on an assessment of the potential e-services that can be implemented using Internet-enabled monitoring/control systems. The hardware/software infrastructure enabling Internet-enabled monitoring/control has been designed to accommodate a plethora of potential e-services. The required hardware to enable delivery of each e-service has been identified; the features of 'ADAM' devices were reviewed; and requirements for the development of additional devices investigated. In order to produce a listing of the set of devices required for the delivery of all e-services, a survey and market research was carried out to identify devices currently available and those under development. Additional hardware devices were identified and selected based on the usefulness, quality, reliability, value for money, and compatibility with the existing ADAM system. In order to ensure compatibility between the ADAM system and a wide selection of third party sensors, modifications to the ADAM system communications protocols had to be undertaken, which were enacted by ADAM and University of Strathclyde.

1. Background

EPBD (EC Directive on the Energy Performance of Buildings)[1]

The EC EPB Directive came into force on 4th January 2003 with all member states being given 3 years grace to build up relevant systems and measures to transpose and implement the requirements. On 4th January 2006, the directive's minimum requirements become legally binding in all member states.

Energy performance certificate (Article 7): Member States shall ensure that, when buildings are constructed, sold or rented out, an energy performance certificate is made available to the owner; or by the owner to the prospective buyer or tenant, as the case might be. The validity of the certificate shall not exceed 10 years, with special requirements for public buildings. The range of recommended and current indoor temperatures and, when appropriate, other relevant climatic factors may also be clearly displayed.

Inspection/ assessment of heating and cooling plant/ installations (Article 8 & 9): Establish a regular inspection of boilers fired by non renewable liquid or solid fuel of an effective rated output of 20 kW to 100 kW. Boilers of an effective rated output of more than 100 kW shall be inspected at least every two years. Ensure the provision of advice to the users on the replacement of boilers, other modifications to the heating system and on alternative solutions which may include inspections to assess the efficiency and appropriate size of the boiler. Air Conditioning Systems with the capacity of over 12kW should be regularly inspected (Interval up to Member States).

Inspection by independent qualified bodies (Article 10): Member states shall ensure that the certification of buildings, the drafting of the accompanying recommendations and the inspection of boilers and air conditioning systems are carried out in an independent manner by ***qualified experts***.

Metering and energy awareness (Article 11)*:* Member States may establish a fund to subsidise the delivery of energy efficiency improvement programmes and measures. These shall include the promotion of ***energy auditing*** and, where appropriate, improved ***metering and informative billing***.

Better energy billing (Article 13): Member States shall ensure that, in so far as it is technically possible, financially reasonable and proportionate in relation to the potential energy savings, final customers… are provided with competitively priced individual meters that accurately reflect ***actual energy consumption*** and that provide ***information on actual time of use***.

Energy efficiency policy in UK

Budget 2006 declared the investment of 5 million pounds with energy suppliers for energy feedback devices [The UK's Fourth National Communication under the United Nations Framework Convention On Climate Change].

Energy review (DTI) 2006 [2] says:

> *"In our homes people need more information about the amount of energy we use and its environmental impact. We should require energy suppliers to provide their customers with more information about their energy use over time and advice on saving energy. There are other tools coming that will also help householders. Trials are starting this year to test the impact of a range of modern technologies in providing real-time information to households about their energy use. And the new Home Information Packs, provided to all new buyers and tenants, will include comprehensive data on the energy efficiency of the house."*

Energy saving effects from better energy bills, real-time displays for households, smart meter for homes and businesses were focused as main measures in implementing low carbon energy policy.

Energy Feedback Effect

Energy feedback effect energy consumers change behaviours or habits to reduce energy use by obtaining the information of energy use.

Types of energy feedback,

- Direct feedback: Users can see the energy meter on demand via PC or Web interface.
- Indirect feedback: energy suppliers provide information (e.g. more accurate energy bill with relevant information) after they process raw data.
- Inadvertent feedback: learning by association (a by-product of technical, household or social changes)

According to Darvy [3], who carried out a literature review study on the energy feedback effect, the 4-15 % of energy reduction was made through the direct feedback while 0-10 % through indirect feedback (see table 1). It appears that ***direct feedback***, alone or in combination with other factors, is the most promising single type, with almost all of the projects involving direct feedback producing savings of 5% or more. The highest savings – in the region of 20% - were achieved by using a table-top interactive cost- and power- display unit; a smartcard meter for prepayment of electricity (coinciding with a change from group to individual metering); and an indicator showing the cumulative cost of operating an electric cooker.

Darvy pointed:

> "*Feedback is a necessary but not always a sufficient condition for savings and awareness. It should not be treated in isolation: this is also a clear lesson from this review. The range of savings, as well as the accompanying detail, shows the importance of factors such as the*

condition of housing, personal contact with a trustworthy advisor when needed, and the support from utilities and government which can provide the technical, training and social infrastructure to make learning and change possible."

It implies that energy information should be shared by stakeholders so that they participate in the energy action effectively. Technologies should support such an energy partnership.

Table 1: savings demonstrated by the feedback studies.

savings %	Direct Feedback (n= 21)	Indirect feedback (n= 13)	Studies 1987-2000 (n=21)	Studies 1975-2000 (n=38)
20 %	3		3	3
20 % of peak			1	1
15-19 %	1	1	1	3
10-14 %	7	6	5	13
5-9 %	8		6	9
0-4%	2	3	4	6
Unknown		3	1	3

source: Darby S. (2006), making it obvious: designing feedback into energy consumption, Environmental Change Institute, University of Oxford [4]

Smart metering

Definition of 'smart meter' by Industry Metering Advisory Group(2006) of OFGEM [7] :

"Smart meter is a catch-all term for a modern, innovative meter which offers customers clearer information about the energy they are using. This could range from a simple addition to a basic meter, allowing it to display consumption in pounds and pence, to a high-tech version which sends meter readings direct to suppliers or helps you keep track of the carbon emissions your energy use is producing."

The basic functionalities of smart meter are as follows[6].
- to measure consumption over representative periods to legal metrology requirements;
- to store measured data for multiple time periods;
- to allow ready access to this data by consumers as well as by suppliers or their agents.

In addition to the basic functionalities, at least more than one of the following functionalities should be included.

- to provide analysis of the data and a local display of the data in a meaningful form to the consumer or as part of a smart housing solution;
- to transfer consumption data to the supplier or his agent for the purposes of accurate billing without requiring access to the home;
- to provide a payment facility for one or more supplies;
- to measure, and record information as to the continuity and quality of the supply and provides this and other data to the Distribution Network Operator for purposes of system operation, planning, and loss assessment;
- to permit remote control (e.g. interruption and restoration) of specific consumer circuits or equipment for the purposes of agreed load management;
- to allow display of price signals for different time periods as part of a cost reflective tariff for the purposes of demand response;
-to allow for remote change of tariff, debt or other rates for utility charging without requiring access to the home;

and, where a consumer has microgeneration equipment installed:

-to provide a facility to measure energy export and/or generation, where required for official purposes.

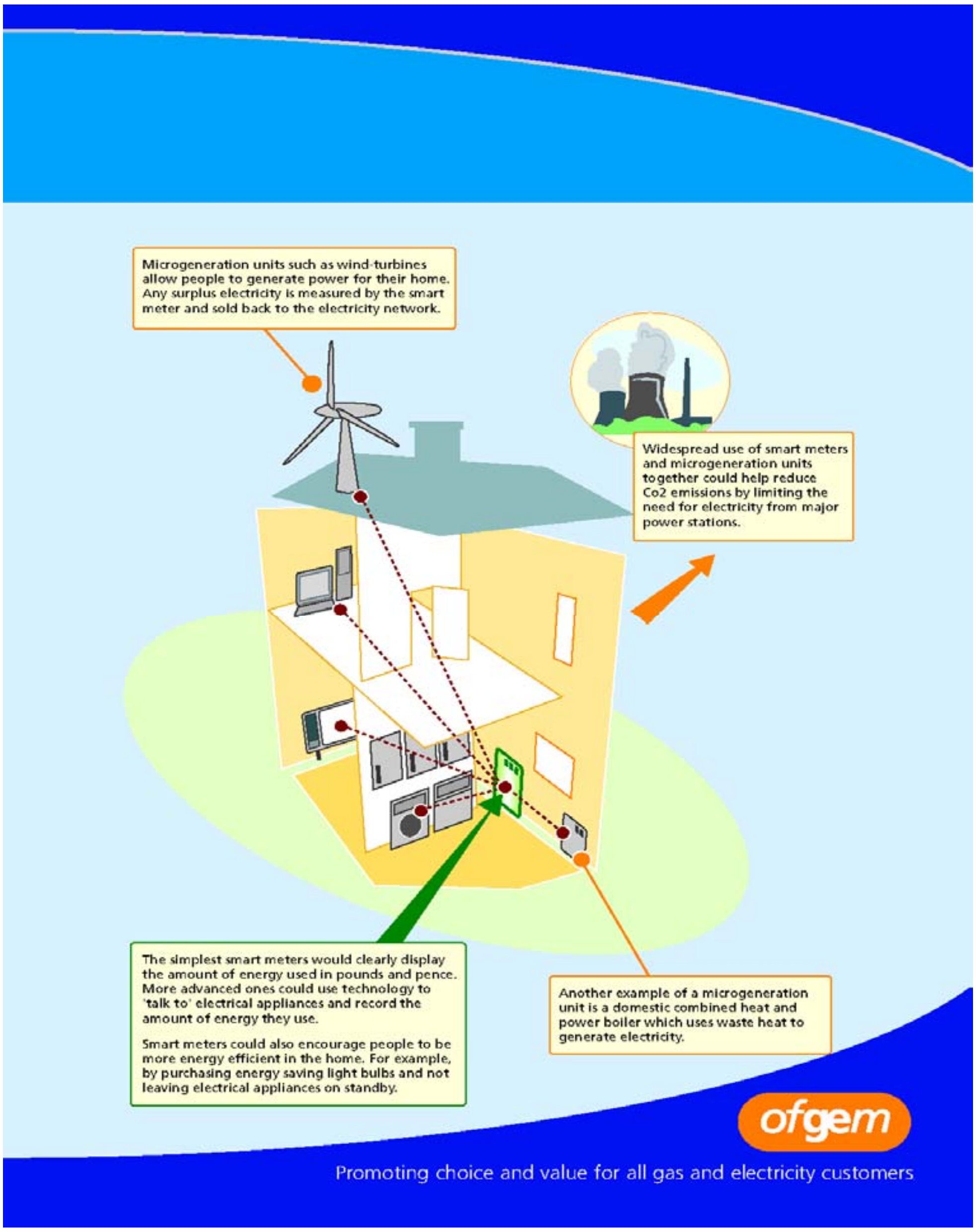


Figure 2: smart metering (OFGEM, 'What is a smart meter?' [15])

Indoor Air Quality and health issues

- As energy-related building regulations are reinforced, and energy saving measures are adopted in buildings, energy conservation is likely to decrease ventilation rate, which lead to indoor air quality declines. Indoor Air quality is an important environmental issue with implications for human health.

- up to 50 % schoolchildren suffer from asthma and allergy, and it doubled over the past 20 years[10][11]. Impact of ventilation rate in homes on asthma and allergy among children were found[12].

-Recent studies have shown a significant influence of the indoor environment on peoples productivity[13][14][15]. 20-60 % of occupants in offices suffer from symptoms associated with sick-building syndrome (SBS), which include headache, fatigue and irritation of mucous membranes. The scientific evidence, based on a recent European review, indicate that our door air supply rates below 25 L/s per person in commercial and institutional buildings are associated with an increased risk of SBS, increased short-term sick leave and reduced productivity. In typical office buildings the cost of people is a factor 100 higher than energy cost. It is crucial to maintain healthy indoor environment to ensure sustainable business as well as reduction of energy saving cost.

- A large number of studies (including more than 100,000 people) indicated that living or working in 'damp' building has association with not only health effects such as cough, wheeze, allergies, but also general symptoms (e.g. tiredness, headache etc), irritation and airway infection[10][16].

- Temperature, humidity and ventilation rate are generally associated with people heath and office workers productivity. To control indoor environment as desired, monitoring such parameters is essential.

New EPBD IEQ standard

- There are a number of CEN standards developed recently in relation to the new European Energy Performance of Buildings Directive (EPBD). One (voluntary) standard deals with Indoor Environmental Quality (IEQ) relevant in the context of energy performance of new and existing buildings. The 'IEQ EPBD standard' is called prEN 15251:2005, "Criteria for the indoor environment including ***thermal, indoor air quality, light and noise***".

- prEN 15251 presents IEQ EPBD demands such as design criteria for dimensioning of buildings and HVAC systems, indoor environment parameters(e.g. temperature, humidity, CO_2 , Air change rate, air velocity, noise)for energy calculation, evaluation of the indoor environment and long term indicators, ***inspection and measurements of the indoor environment in existing buildings***, and classification and certification of the indoor environment.

-the standards shall constitute an ***integrated and interacting methodology*** for the calculation of the energy use and loads for heating and cooling, ventilation, domestic hot water, lighting, natural lighting, passive solar systems, passive cooling, position and orientation, ***automation and controls***, and auxiliary installations ***necessary for maintaining a comfortable indoor environment.***

- Therefore, the effect on energy performance of automation and controls will be included in each system's performance instead of being treated as a separate system.

<u>references to IEP EPBD</u>

- ISO EN 7730-2005: Ergonomics of the thermal environment- analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort effects.

- ASHARE 55-2004: thermal environment conditions for human occupancy

- CR 1752: Ventilation of buildings- design criteria for the indoor environment

- EN 13779: Ventilation for non-residential buildings- performance requirements for ventilation and room-conditioning system.

2. Overview of Proposed Energy and Environment Information System (EEIS)

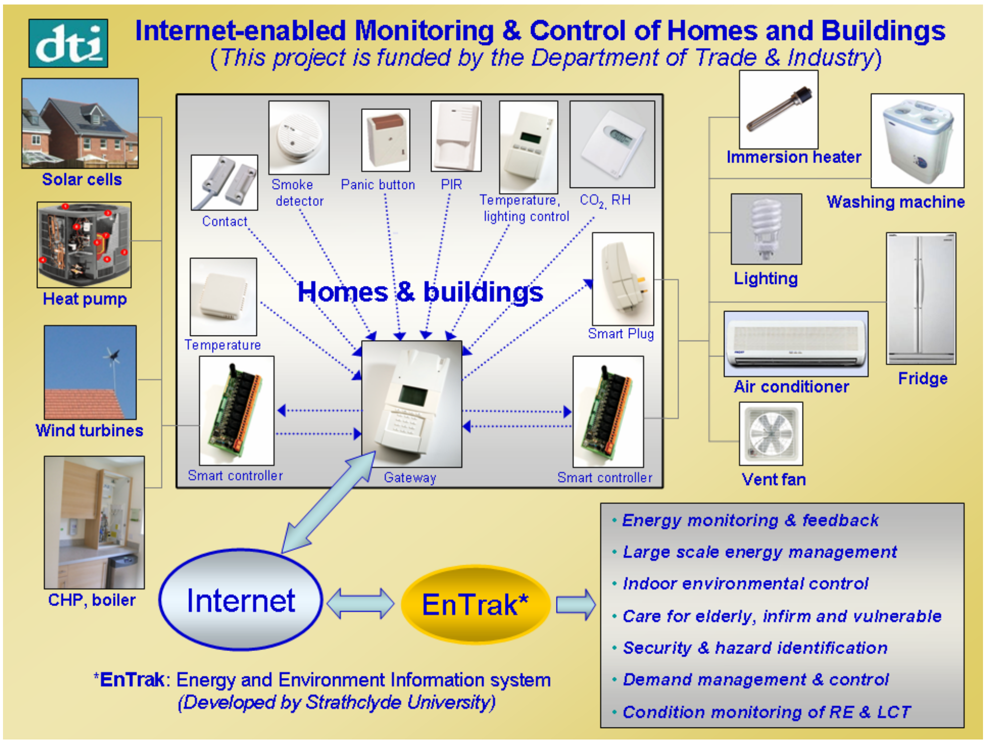


Figure 2: System overview of The Energy Environment Internet Service.

The internet enabled Energy Environment Information System (EEIS) has been established on the basis of utlising an existing communication infrastructure between monitoring/controlling devices and the back-end e-service system. This system will process and manage captured data and use this to inform and implement a new range of services for energy, healthcare and safety within homes and the workplace. The elements of the EEIS are shown in Figure 1 above. Internet-enabled gateway systems placed in built environment act to co-ordinate the acquisition of data and implementation of a series of control actuations using sets of short-range Radio–Frequency (RF) sensors/actuators customised to the particular e-service being enacted. The data obtained for a given site is transferred to a central service centre, named 'EnTrak', placed at some arbitrary location on the Internet. The data are conflated with the private data arriving concurrently from other sites within a given serviced region. Software agents in EnTrak then operate on the aggregated data in order to extract service-specific information for onward transmission to a related energy service.

This energy service provider adds value by interpreting the data and providing the actual energy/environment service to prospective clients including citizen, local authorities, utilities, ESCO and Renewable Energy system suppliers. On the other hand, control commands from the energy service provider will also be delivered to devices scattered in the service region. In addition to the energy service, other e-services will be integrated in the same infrastructure. The following sections describe these potential e-services.

3. Potential services and devices required

A) Energy monitoring and feedback

This service reports on the accumulated data relating to energy use, cost (breakdown, comparison) and indoor thermal environmental conditions. It is aimed to increase energy awareness at home level as well as community level. The historical profiles stored in EnTrak help users to appreciate long-term trends and compare the change over time. Aggregated information will be provided for local authority (or utilities) to analyse energy use pattern and customers behaviour while individual profile information allow occupiers to make on-line bench-mark test with energy use for similar house types.

This real time monitoring/alert system will improve the capability of detecting problems and reacting to them in a timely manner. For example, the service system can issue alert messages (e.g. e-mail, SMS) according to the data values to prevent excessive energy use.

This service can be delivered to home owners, local authorities, utilities, building stock managers.

Devices required to enact this service are as follows.

Sensors and actuators	Location
Temperature	Indoor (rooms), outdoor
Electricity meter (pulse)	Main electricity meter
Gas meter (pulse)	Main Gas inlet pipe
Occupancy (PIR)	Indoor (rooms)

B) Security and hazard identification

The service offers protection to home-owners from emergency or hazardous situations. As the security system is built on the hardware infrastructure of the Smart home, it can also use other condition parameters (e.g. temperature, occupancy etc). By using comprehensive data the emergency situation can be more clearly identified and informed to external parties. For example,

- After detecting intruder by door contact, activate alarm (or switch on all lights) and send alert messages to police and relatives when it is associated with intruder rules.

- When sensing panic button pressed, send alert messages to relatives and care services.

- When detecting smoke, check CO and CO_2 levels as well. If fire-identifying rules conclude it as an emergency situation (i.e. fire), send alert messages to occupiers and relevant organisations (i.e. fire brigade) and activate warning sign e.g. alarm/ flashing lights.

The service will be delivered to: occupiers, public services (police, fire brigade, care takers). Devices required for this service are as follows.

Sensors and actuators	Location
Temperature	Indoor (rooms), outdoor
Occupancy (PIR)	Indoor (rooms)
CO	Kitchen or Plant room
CO_2	Indoor (rooms)
Smoke	Public room
Gas (LNG)	Kitchen
Contact	Doors, windows

C) Indoor environment control & Care for elderly, infirm and vulnerable

The service is aimed to increase levels of health care in the home as well as at community level. The historic profiles stored in EnTrak help users appreciate long-term trends and compare changes over time. Real-time monitoring allows individual owners and local authorities to react to health care issues, effectively. For example, the service system can issue alert messages (e.g. e-mail, SMS) according to data values to alleviate health risk. This real time monitoring/alert system will improve the capability of detecting problems and reacting to them in a timely manner. In the case of elderly care, for example, the alerts can be sent to relevant authorities (e.g. emergency services) as well as occupants.

Unhealthy or a hazardous indoor environment will be assessed by relevant algorithms associated with environment parameters (e.g. temperature, humidity, CO and CO_2). For example, when elderly occupiers are exposed to a cold environment (i.e. air temperatures are below that of comfort levels) for sustained periods of time, it could flag up an emergency situation for elderly occupiers which must be detected; and relatives and health care authorities informed (i.e. cold alarm). Such a service could even implement actions when alarms are raised by switching on the heating system to minimise further risk to the occupant. The detected conditions can be graded into several levels according to the degree of temperature and the time duration. Temperature and humidity data monitored within a house or a room are converted with meaningful information associated with occupants' health and safety (e.g. level 1 green: safe, level 2: risk to health, level 3: dangerous).

In the same way, alarm messages are issued with different levels depending on the situations. For example, CO concentration above 35 ppm for short periods of time should activate the alarm system in hazardous mode, whereas lower, longer term CO concentration (e.g. 10-35 ppm) should give a warning message to occupier of a potential health risk. Health risks and exposure time according to CO levels are categorised: 35 ppm - max allowable for continuous exposure of healthy adults in any 8 hour period (OSHA regs), 200 ppm - headaches, nausea after 2-3 hours, 400 ppm - frontal headaches in 1-2 hours, life-threatening > 3 hours, 800 ppm - dizziness, nausea, convulsions in 45 minutes; unconscious in <2 hours; death in 2-3 hours.

This service could be delivered to occupiers, local authorities, public health care services or care for the elderly or vulnerable.. The following devices are required for the service.

Sensors and actuators	Location
Temperature	Indoor (rooms), outdoor
Humidity	Indoor (rooms)
Occupancy (PIR)	Indoor (rooms)
CO_2	Indoor (rooms)
CO	Kitchen or Plant room
Panic button	Selected places
Switch	Heating plant/ appliance

D) Demand management and control

This service is designed to provide home-owners/ occupants with load management and control measures that allow them to be proactively be involved in energy saving schemes. The simple application of this control system to home appliances, for example, will enable demand/ load control to be enacted remotely through the Web-based interface. Coupled with real-time monitoring as per service A and B, the remote control capabilities of this service may enable prompt user action in response to problematic incidents.

The control function of this service allows ‘moveable’ loads such as fridge/ freezers to be switched off at times of high demand, restructuring the load profile to one more favourable to the supply network. Coupled with the renewable energy system condition monitoring, the demand profiles of home appliances can be reshaped depending on the availability of renewable energy supply, thus facilitating better integration of renewable technologies. For example, schedule-based on/off control of washing machine, weather condition-predicted control of hot water storage (i.e. immersion heater), switching on/off of refrigerator while maintaining set point temperatures with a tolerance range, switching on/off of lighting with daylight control priority etc.

To coordinate these control options, a Web-based interface could be designed to offer information on the current status of appliances and the options for control (i.e. switch on/off by user, scheduled program, utility control). Through this interface, users select the appliances to control at Stage 1, while the status of the selected appliances is displayed at Stage 2. The status is distinguished by the colour according to the electrical power status (i.e. on, standby, off). The cost savings are predicted on the basis of the financial benefits that the utility may offer when the utility control option is selected.

The service will be delivered to individual energy users (e.g. occupiers).

Sensors and actuators	Location
Temperature Temperature (appliances) Relay Switches (appliances) Illumination	Indoor (rooms), outdoor Refrigerator, Hot water storage tank Refrigerator, Hot water storage tank Home appliances, light Rooms

E) Large scale energy management

In addition to the demand management and control service above (D), this service provides control authority to utilities or energy managers for large-scale energy management and energy trading, expecting that regional aggregated load control will reduce cost to utility companies of network maintenance. While comprehensive electricity generation and fuel use information are managed in EnTrak, control instructions are delivered to individual actuators installed in premises in a given region. Utilities or local authorities can get support for energy supply strategies or policies as well as gaining immediate reaction to addressing dynamic energy utilisation. It enables local authorities to monitor systematic building stock performance in support of legislative requirements and local energy action planning.

Along with demand management and control services, for example, the control option will have an advanced control scheme such as the sharing of control intervention with utilities. This means that utilities can take control of appliances in individual homes that may have a suitable contract. Users give control access permission to a utility while, in return, they receive a financial benefit through a reduced tariff. Then, the utility can manage their peak load by adjusting the home electricity load within a reasonable range. For instance, the set-point temperature of heating/cooling systems within contracted customers' homes may be adjusted down to reduce the peak loads. Such dynamic control could be achieved by the server module in the EnTrak system via the Internet.

It also provides infrastructure for an advanced energy trading system on the basis of real-time information on the price of electricity. Coupling with utility net metering, new or renewable energy systems such as the Micro CHP electricity generation systems can be controlled for more ‘network friendly’ connection to the main electrical supply. The utility net meter tracks net power usage, spinning forward when electricity is used from the grid, and backwards, generating a credit, when the Micro CHP system creates more electricity than is used.

This service can be delivered to owners/occupiers, utilities and local authorities. The required devices for this service are following.

Sensors and actuators	Location
Bi-direction Electricity meter Gas meter (pulse) Temperature Temperature (appliances) Relay Switches (appliances) Illumination	Main electricity meter (import/export) Main Gas inlet pipe Indoor (rooms), outdoor Refrigerator, Hot water storage tank Refrigerator, Hot water storage tank Home appliances, light Rooms

F) Remote condition monitoring of renewable and low carbon technologies

This service is designed to maintain a reliable energy supply from Renewable and Low Carbon technologies. It monitors system operational conditions to identify potential problem which lead to malfunction or inefficiency. When potential faults are identified, a warning alarm is raised enabling precautionary actions to be implemented e.g. practitioners dispatched to the sites before a complete break down, so-called before-service.

Typically, fault detection or performance degradation algorithms for energy systems require comprehensive data including weather, nominal capacity, expecting energy generation, real generation, historical patterns and so on. Coupling of locally monitored data with other associated data remotely managed in EnTrak will provide a cost-effective detecting system. For example, electricity generation from PV system installed in a building can be compared with expected energy generation calculated with a simulation program in EnTrak. This accommodates and processes information on the specification of the PV system, historically accumulated generation data and other relevant data e.g. solar availability. The fault detection system will also be equipped with a communication interface to owners, system operators or providers so that stakeholders are informed regularly of the performance of the plant and can take appropriate actions immediately as any abnormalities occur.

In the case of micro-Combined Heat and Power (CHP), energy provided in the form of both heat and generated electricity will be informed to users in a time series statistical format. For example, the Web user interface can display a digital readout of useful information such as: how much electricity and thermal energy the micro-CHP system is producing, instantaneous fuel consumption, current and the cumulative electricity/ thermal energy production and time averaged fuel consumption of the micro-CHP system.

The service will be delivered to new and RE energy system suppliers, estate managers and owners/occupiers.

Sensors and actuators		Location
Micro CHP	Bi-directional current flow Electricity meter Gas meter	Micro CHP electricity generator
PV	Irradiance Temperatures	Surface of PV pannels
Solar collector	Irradiance Temperatures	Surface of solar collector
Heat pump	Temperatures	

4. The ADAM system

To implement the proposed on-line energy service system and demonstrate the e-services described above, an Internet-enabled smart home system manufactured by a Manchester-based company 'ADAM international', is employed. Using the ADAM system, specific sensors and actuators are installed in built environment (e.g. home, office) and communication protocols are established with the external data management server, 'EnTrak'.

<u>Specification of ADAM devices</u>

The SMART programmer, the core of the ADAM SMART System, employs RF technology to communicate with and control wireless devices located in the system. The wireless SMART sensor PLUS monitors room temperature in degrees Celsius and ambient light level in Lux. It can be powered from either a 9-12 vdc regulated power supply or a 9v battery. The SMART Plug provides wireless control of any appliance when integrated with the ADAM system. A built-in radio transceiver operates a 6.3 amp relay output under instruction from the SMART programmer or from the manual override. The SMART controller is ideally located close to a high concentration of control points (i.e. adjacent to the consumer unit, or in the boiler room). It supports 8 relay outputs for switching, 4 analogue inputs for temperature or light level monitoring and 4 digital inputs for alarm monitoring.

Providing extended range (up to 50 m indoors, and 200 m line of sight externally), the RF signals are relayed between devices from the SMART programmer to the SMART controllers, SMART sensors, and SMART plugs. Additional sensors such as CO, Gas, CO_2, electrical meters, thermal meters and irradiance sensors can be added into the current ADAM system through hard wiring to the SMART Controller or other SMART devices.

The following gives the specification of the current range of ADAM devices.

The SMARTprogrammer
- Linux based O/S
- telnet protocol, HTTP, mSQL to communicate with external systems

The SMARTtplus sensor
-voltage
- temperature
- light (0-100% lux)
-analogue input (temperature) to used for additional sensor
-display panel to allow users to set control point

The SMART sensor
-voltage
-temperature
-digital input – for additional sense (e.g. alarm button)
-

The SMART controller
-8 relay output
-4 analogue input (0-5 v)
-4 digital input
-12 vdc supply input
-auxiliary 12 vdc output
-wireless communication with the Smart programmer
-re-route wireless signals increase range if necessay

Communication system

Between the Smartprogramer and wireless Smart device: RF
Between the Smartprogrammer and the e-service centre (EnTrak): Internet, http
Between third party and Smart programmer via Smart controller or Smart plus, there is limitation in the range to the data exchange channels (e.g. voltage output 0-5 Vdc).

Features

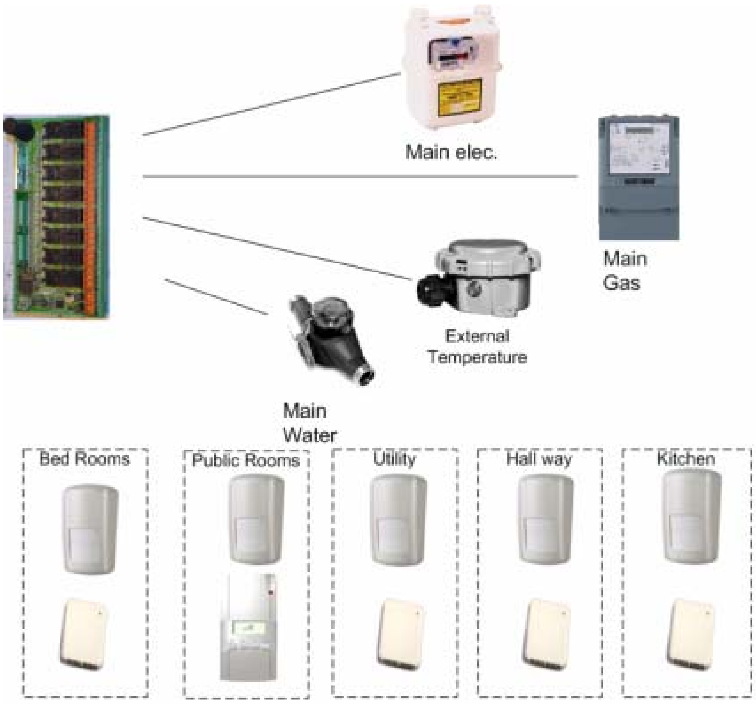
- Extendibility to non-propriety equipment because of the additional channel enabling connection to third party devices (digital or 0-5 v).
- Compatibility with EnTrak, as it uses similar database technology (i.e. mSQL used in the Smartprogrammer is compatible with mySQL in EnTrak)

- There are possible risks in term of communication security as the HTTP used for the web user interface and data transaction between the Smartprogrammer and EnTrak is not a secure technology. Therefore, communication security should be reinforced in near future by replacing the communication protocol with more secured one (e.g. HTTPS).

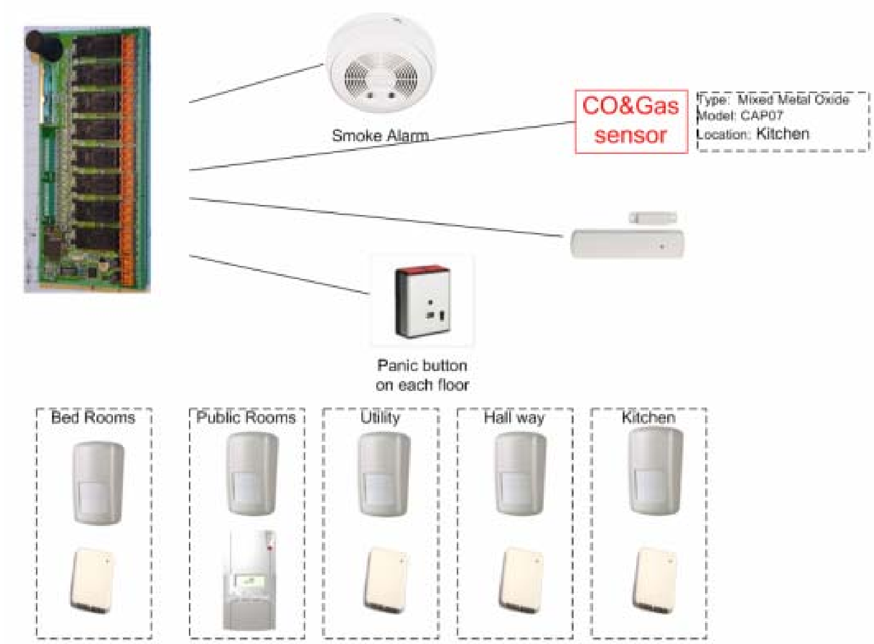
5. ADAM-based packages for e-services

The ADAM hardware system, including sensors has been developed to offer some form of energy management and control to building appliances. However a limited range of sensors are currently available and therefore limit the types of internet services which can currently be offered. In order that all the identified e-services can be made available, additional devices (sensors/ actuators) need to be developed or added to the range. These can either be dedicated ADAM devices or from third party control manufacturers with common communications protocols. A list of additional devices required to offer specific e-Services has been collated and is listed as follows:

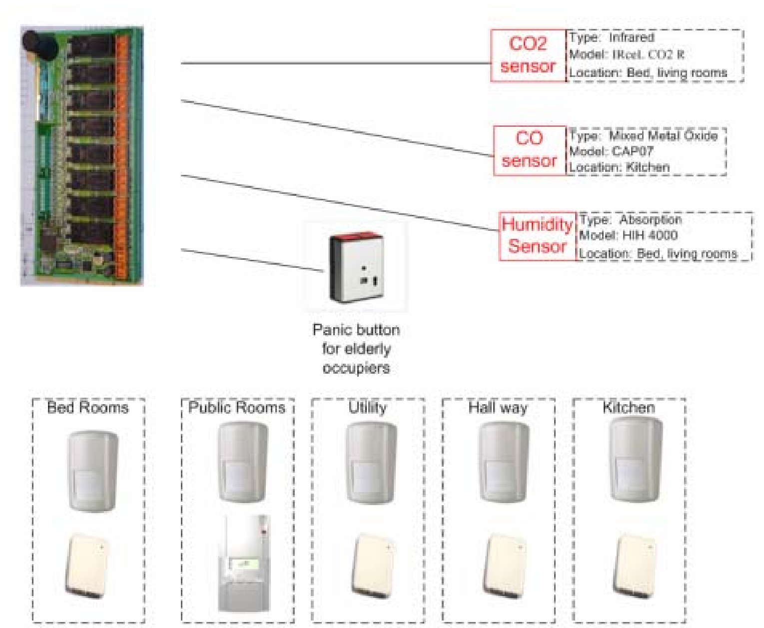
<u>Energy monitoring and feadback</u>
Additional devices required:



<u>Security and Hazard Idnetifaction</u>
Additional devices required: CO & Gas sensors

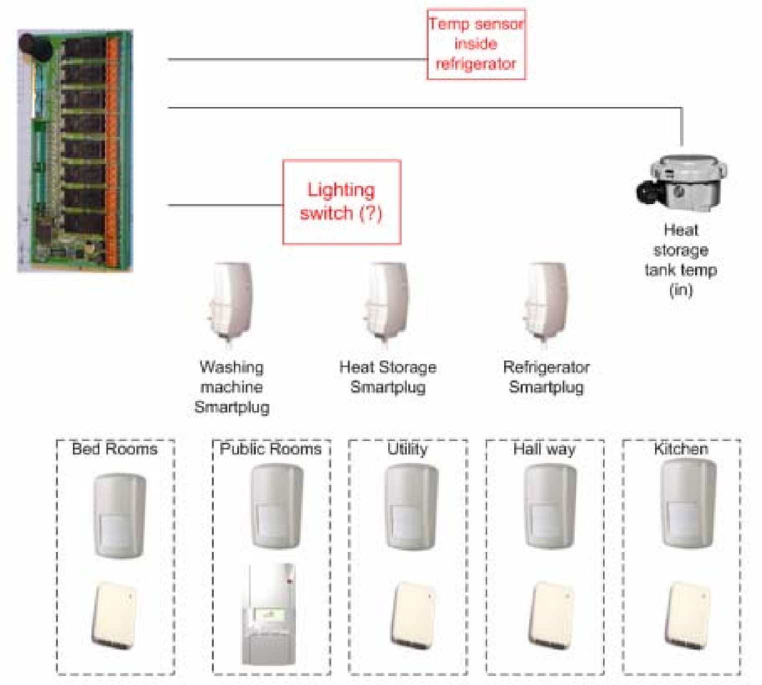


<u>Indoor Environment control & elderly, infirm and vulnerable</u>
Additional devices required: CO2, CO, Humidity sensors



<u>Load management</u>

Additional devices required: temperature sensors, switches to be installed in appliances



Large Scale Energy management

- Same as energy monitoring and feed back.

Remote Condition Monitoring

Additional devices required: irradiance sensor (for solar intensity energy systems such as PV and solar thermal collectors are exposed to), two way electrical metering (import/ export) to be installed when micro generation systems are deployed (e.g. micro-CHP, PV, small scale wind turbine)

6. Additional devices required for completion of the device packages

Market research has been undertaken to establish the current status of control sensor availability and identify the most suitable products in terms of cost, accuracy, and compatibility with the ADAM system. Table 1 shows a list of sensors currently available on the market. Costs of sensors depend on tolerance, accuracy and sensing types. There is some variation in the ranges of output and supply power for each sensor type.

The followings summarise the features of each sensor.

CO Sensor

In general, there are two kinds of sensor types available: Semi-conductor (Mixed Metal Oxide) and Electrochemical. These range in price from 44 to 262.8 pounds sterling, depending on the sensitivity. Mixed Metal Oxide types are typically designed for large volume low cost application and suitable for use in continuous gas background (e.g. car garage). The mechanical operation of Mixed Metal Oxide based sensors is simple and long-lived. On the other hand, Electrochemical type sensors are relatively complex, but provide greater accuracy in concentration measurement. These typically measure CO concentration and have an alarm function activated when the threshold of detected CO concentration levels are exceeded. Electrochemical CO sensors are generally more expensive than semi-conductor type. However, there is a CO detector (model: CHCO) combined with Gas senor which has reasonable cost and provides good accuracy (i.e. 30-300 ppm). This is considered to be a suitable sensor for the security and hazard identification service.

Relative Humidity

Relative humidity sensors are widely available but typically only for large volume OEM orders. There are a number of independent RH sensors to be connected externally. However the rage of prices are higher (i.e. over 61 pounds). The sensors with external data connector are over 160 pounds.

CO_2

Most Carbon Dioxide sensors are based on infrared sensing technology. The desirable range of CO_2 concentration sensing should be 0-3000 ppm for Indoor Air Quality assessment. Devices currently available range in price from 179- 262.40 pounds sterling. One such sensor available is a combined CO_2 RH and temperature sensor. As CO_2 and RH are key indicators of indoor air quality and environment control, these should be installed in the same position.

Electricity meter and heat flow meter

These are required for the condition monitoring service of new and renewable energy systems. Electricity and heat flow meters should have appropriate size and capacity for the system being monitored. The ME161 Meter (Households single phase meter) [17] and Superstatic 440 (heating/cooling energy meter) [18] are popular sensors used by micro-generation and renewable energy system providers such as Whispergen, a micro-CHP manufacturer. Solar Panel manufacturers use the 3/4" qp1.5 Supercal / Superstatic 440 on their systems.

Irradiance sensor

The price range of irradiance sensors is broad, going from 100 to 1567 pounds serling depending on the level of accuracy required and spectral distribution to be monitored. There are two different types of irradiance sensors: pyranometer and silicon solar cell (Si-sensor). The difference between pyranometer and Si-sensor is as follows:

- pyranometers have a glass dome, Si-sensors a flat glass plate (introducing a cosine error);
- pyranometers use a thermopile to measure the temperature on a black absorbing area, Si-sensor measures short-circuit current across the cell junction ;
- pyranometers have a spectral response function of nearly 1 at wavelengths between 350 and 3500nm, Si-sensor respond to wavelengths between 400 and 1100 nm, but with a spectral response function of 0.6; and

- pyranometers are certified by WMO (World Meteorological Organisation) to be first class, second class or secondary standard.

The sensitivity of irradiance sensors for the condition monitoring service is not crucial. Silicon solar cell sensors provide fair accuracy with reasonable price. It is also used by RE manufacturers and researchers throughout the EU.

Additional sensors to complete the devices required for e-services were selected on the basis of cost, accuracy and compatibility with the ADAM system. It was found that the range of signal output and power supply requirements is a barrier to connect additional third party sensors to the ADAM system as currently configured (i.e. SmartControler analogue input channel band limited to 5V). To aid compatibility, the existing ADAM system requires some minor modifications to make input channels with 0-10 Vdc range thus accommodating the majority of additional sensors. The selected sensors are listed in Table 2.

Table 1: list of sensors currently available on the market.

Comment [cmj1]: Min, list the sensor supplier/ manufacturer

Additional sensors	Feature (accuracy)	Manufacturer /supplier	Data input Power supply	Cost (pounds)
CO	Model: CAP07 Type: Mixed Metal Oxide Range: 0-400 ppm	City Technology / SST sensing Ltd.	Output: 0-5 Vdc (linear) or 0-10 Vdc Supply: 9-12 Vdc	44.62
	Model: MF420-IR-LC Type: ElectroChemical Range: 0-300 ppm	J.Dittrich/SST sensing Ltd	Output: 4-20 mA Supply: (at least) 14 Vdc	262.8
	Model: CO100A Type: EletroChemical Range: 30-300 ppm	Duomo	Output: 4-20 mA Supply: 12- 24 Vdc	160.00
CO_2	Model: MF420IR-CO2 Type: Miniature infrared sensor Range: 0-3,000 ppm (i.e. 0-0.3 Vol %) Accuracy: ± 2 %	J.Dittrich/SST sensing Ltd	Output: 4-20 mA or 0-10 V Supply : 24 Vdc	262.4
	Model: IRceL CO2R Type: Infrared Range: 0-5000 ppm	City Technology / SST sensing Ltd.	Output: Supply 3-5 Vdc (3.3 Vdc recommended)	178.4
	Model: GMW115 Type: Non-Dispersive InfraRed Range: 0-2000ppm	Vaisala	Output: 4-20mA, 0-10 V Supply 24 V AC/DC	168
RH	Model: HIH 4000 series	Honeywell	0.958 V at 0 %RH 4.07 V at 100 RH Supply 4.0-5.8 Vdc	35 (Only available for

				high volume OEM order)
CO_2+RH	Model: EE80-2CTFD04 Type: Non-Dispersive Infrared Technology (NDIR) for CO2, Capacitive for RH. Range: 0-2,000 ppm Accuracy: ± 2 % (CO2)	E+E elektronik	Output: 4-20 mA or 0-10 V Supply : 24 Vdc	231.25
CO+GAS detector	Model: CHCO Type: Combined Natural Gas & Carbon monoxide Range: 30-300 ppm for CO	DUOMO	Output: relay on TWA[1] for CO, LEL[2] for GAS Supply: 230 Vac	75.67
Electricity meter	Model: ME161 Type:	ISKRAEMECO /DMS Ltd	Output: pulse	35.00
Thermal meter	Supercal 531 Type: invasive	Sontex/DMS Ltd	Output: outputs 0-20mA, or 0-10V Supply : 12..24 V dc	256.20
Irradiance sensor	Model: Si-10TC Type: Silicon Cell Range: 0-1000 W/m^2	Ingenieurbüro Mencke & Tegtmeyer	Output:0-10 V Supply: self powered	100
	Model: SP111 Type: Silicon Cell Range: 0-2000 W/m^2	Campbell Scientific Ltd.	Supply: self powered	167
	Model: CMP3 Type: Pyranometer Range: 0-2000 W/m^2	Campbell Scientific Ltd.	Supply: self powered	530
	Model: CM11 Type: Pyranometer Secondary standard, high quality Range: 0-4000 W/m^2	Campbell Scientific Ltd.	Output: 0-10 mV Supply: self powered	1567

Table 2: Additional sensors to augment the ADAM system.

Devices (model)	Model /Manufacture	Features	Cost (Pounds sterling)**
CO + Gas Sensor	CHCO detector / DUOMO (http://www.duomo.co.uk)	- Combined CO and Gas detector - CO, Gas alarm relay SPDT - Catalytic sensor for gas - Electrochemical sensor for CO - 230 VAC - Output: relay (maximum relay load 10A) - Supply 230 Vac	75.67

[1] TWA: Time Weighted Average
[2] LEL: Low Explosive Limit

CO_2 + Relative Humidity + temperature	EE80-2CTFD04 /E+E elektronik (www.epulse.com)	-Non-Dispersive Infrared Technology(NDIR) -Range: 0-2,000 ppm -Output: 4-20 mA or 0-10 V -Supply : 24 Vdc -Accuracy: 50 ppm ± 2 % -RH sensor type: Capacitive -LC Display: altering CO_2 (ppm)/ T('C)/RH(%)	231.25
CO_2	GMW115/Vaisala (www.vaisala.com)	-Non-Dispersive Infrared (NDIR) -Range: 0-2000 ppm -Output: 4-20 mA or 0-10 V -Supply: 24 AC/DC -Accurancy: 50 ppm ± 2 %	168.00
Electricity meter	ME161 Single* Phase 100amp /ISKRAEMECO	-Domestic Electricity Meter with Pulse output -Single phase (up to 5 kW) -Open collector output available. -Output pulse	35.00
Heat meters with static flow parts	Supercal 531 + Superstatic meter* /Sontex SA	-This thermal energy meter consists of a Supercal 531and a pair of temperature sensors. -Invasive heat meter (i.e. installed in the pipe work) -Supercal 531 240 V powered integrator two open collector pulse outputs of energy & volume Pt500 sensors & 1/2" x 34 mm Pockets. -Output: analogue module 2 outputs 0-20mA, or 0-10V -Supply power : 12..24 V dc	256.20
Solar radiation	Si-10TC /Ingenieurbüro Mencke & Tegtmeyer	-Silicon Solar cell -Output: 0-10 V per 0 to 1000 W/m^2 (Irradiance) or 4-20 mA -Supply: 12 to 28 Vdc	126

** the prices exclude VAT.

7. Conclusion

The requirements of Internet-enabled monitoring/control system have been identified and a review of the market driving forces related to energy-related policy and measures undertaken. A set of e-Services has been defined to meet defined requirements. A review of the current devices available from ADAM international (a project partner) has been undertaken and these assessed for their feasibility and applicability to the e-Services identified. Additional devices for completing the device portfolio enabling these e-Services to be implemented have been identified and there compatibility with the ADAM system discussed. Through the course of this survey and research, appropriate products available in market were selected by a selection criteria consisting of cost, accuracy and compatibility with existing ADAM devices.

The integration of various services within a common communication infrastructure can make for cost effective service provision e.g. the combination of security with energy services. To make the proposed services commercially viable, all required devices including additional third party sensors should be configured with a common communications protocol and data signal range consistent with the base system (i.e ADAM). ADAM has agreed to make modifications to their SMART Programmer in order that new channels are available to accommodate the data signals from third party sensors.

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