Programme Area: Distributed Energy

Project: Micro DE

Title: Review of in Market Buildings Control Systems, Technology Platforms and Standards

Abstract:

Please note this report was produced in 2010/2011 and its contents may be out of date. This deliverable is number 6 of 9 in Work Package 1. It summarises the current market position and technologies associated with the control of distributed energy systems at the individual dwelling level. It is split into 4 parts:

- Heating Controls : conventional controls for domestic hot water / storage and heating systems
- Advanced Controls : products which integrate existing control strategies to improve the performance of micro-generation systems within the built environment
- Thermal DE : control of heat pump and solar thermal systems
- Electrical DE : control of solar PV and micro-wind systems used for the generation of electricity

Context:

The project was a scoping and feasibility study to identify opportunities for micro-generation storage and control technology development at an individual dwelling level in the UK. The study investigated the potential for reducing energy consumption and CO2 emissions through Distributed Energy (DE) technologies. This was achieved through the development of a segmented model of the UK housing stock supplemented with detailed, real-time supply and demand energy-usage gathered from field trials of micro distributed generation and storage technology in conjunction with building control systems. The outputs of this project now feed into the Smart Systems and Heat programme.

ETI Project
Review of Current Domestic Home Automation Control Systems for Efficient Distributed Energy Management and the Challenges for the Future

Work document

Deliverable 1.6

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Review of Current Domestic Home Automation Control Systems for Efficient Distributed Energy Management and the Challenges for the Future

Summary

This report provides an overview of both in-market and developing control systems technology, platforms and standards for the integration of new Distributed Energy (DE) technologies into the home environment. Over the next decade, in order to meet commitments in reducing carbon dioxide emissions, the supply and management of UK energy will become far more complex with the central generation of energy and transport of fossil fuel giving way to local DE systems for both electricity and heat, driven by government incentive schemes and the evolution of the smart grid and smart metering. New electrical loads are also expected to appear, including plug-in battery vehicles and air-conditioning. The review examines the basic controls required for central heating systems and then identifies the diverse range of requirements of those controls currently offered in the market for renewable systems including solar-thermal, photovoltaic, wind turbine and heat pumps as well as for micro-generation alternatives. The trend is identified for more user friendly controls systems that optimize the performance of multiple home energy supply sources and multiple demand requirements into an integrated home automation system. The technology drivers that encourage this integration are identified, including the development of advanced wireless communications and smart appliances.

Review of Current Domestic Home Automation Control Systems for Efficient Distributed Energy Management and the Challenges for the Future

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Review of Current Domestic Home Automation Control Systems for Efficient Distributed Energy Management and the Challenges for the Future

Acronym Glossary

AHC	Advanced Heating Controls
AOC	Adaptive Occupancy Controls
AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
ASHP	Air source heat pump
BWEA	British Wind Energy Association,
CERT	Carbon Emissions Reduction Target
CESP	Community Energy Savings Programme
CH	Central Heating
COP	Coefficient of Performance
DE	Distributed Energy
DECC	Department of Energy and Climate Change
DER	Dwelling Emissions Rating kg CO_2/m^2 /yr
DHW	Domestic Hot Water
DLMS	Device Language Message Specification
EEPH	Energy Efficiency Partnership for Homes
EPSRC	Engineering & Physical Sciences Research Council
FIT	Feed In Tariff
GPRS	General Packet Radio Service (3G - 48kb/sec)
GSM	Global System for Mobile communications (2G - 9.6kb/sec)
GSHP	Ground source heat pump
4G	Fourth Generation wireless standard (4G)
HAN	Home Area Network
HPER	Heating Plant Emission Rate kg CO_2/kWh
HVAC	Heating, Ventilation and Air Conditioning
IDIS	Interoperable Device Interface Specifications
IGEM	Institute of Gas Engineers and Management
IHD	in-home display
M-Bus	A European standard for metering serial communications
NAN	Neighbourhood Area Network
OSI	Open Systems Interconnection
PSR	Plant Size Ratio
PV	Photo Voltaic
RHI	Renewable Heat Incentive
SAP	Standard Assessment Procedure
SEDBUK	Seasonal Efficiency of Domestic Boilers in the UK
SMS	Short Message Service
SOFC	Solid Oxide Fuel Cell
TDMA	Time Division Multiple Access
TCP/IP	Transmission Control protocol/ Internet Protocol
UMI	Universal Meter Interface
WAN	Wide Area Network
WPAN	Wireless Personal Area Network
ZigBee	A wireless protocol produced in the USA
Z-Wave	A wireless protocol produced in the USA

Review of Current Domestic Home Automation Control Systems for Efficient Distributed Energy Management and the Challenges for the Future

1.0 Forward and overview

The work covered in this report forms part of the Work Package WP1.6 and reviews the position of the current controls used for conventional heating and for DE equipment. Future developments in controls technologies and the challenges for the integrated home will be further informed by the outcomes of the field trials and data analysis covered in greater detail in WP 3.0.

This report logically divides into two sections, one that reviews the current generic range of control products used to meet the requirements of distributed energy (DE) management in the domestic environment and a second section that focuses on the linkages between DE equipment, smart metering and advanced home automation controls. The purpose of the first section is to identify any synergies that may exist between the current use of the individual discrete controls for conventional heating systems and existing DE installations. The second section focuses on the drivers that may influence the requirements of future whole house integrated controls systems and the evolving technologies that will help to achieve them. This overall structure is depicted in Figure 1.

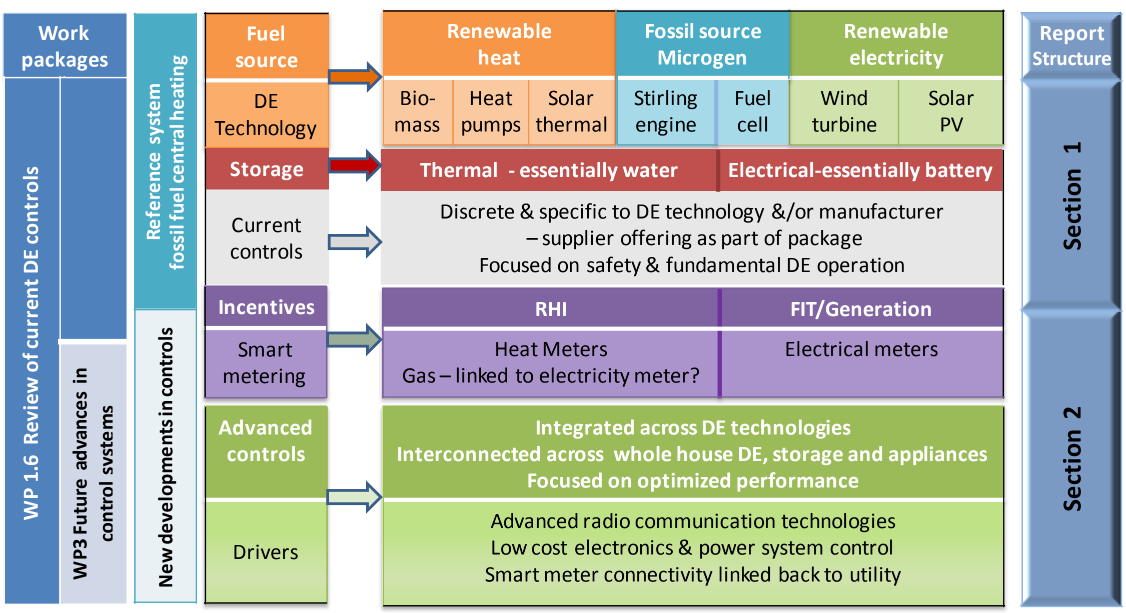

Figure 1: Synthesis of the DE elements addressed within the report

The generic range of DE products shown in Figure 1, are grouped according to energy source and the controls compared with those of conventional boiler and hot water centralized heating systems. They may be classed broadly as either renewable heat or electricity generation products, or products that utilize fossil fuels and produce both heat and electrical power. A number of essential controls are generally integrated directly into the products themselves, covering safety aspects and relating directly to the correct intrinsic functioning of the particular DE product. In addition there are a range of further controls that improve the operational performance of the product within its building operating environment. It is apparent that to date, since installations are generally specific to a single DE technology, that the appropriate additional controls are generally supplied directly by the installers of the individual systems and are often closely linked to the manufactures of the DE equipment itself. Storage of energy remains essentially through either hot water or batteries for electrical power.

The second part of the report looks at the technologies that are expected to influence the adoption of advanced controls that will further increase the contribution of DE equipment in achieving reductions in the

UK's CO_2 emissions. These are expected to be driven by the new government financial incentives and the requirement to introduce smart metering. In particular the development of new wireless communication systems and the use of the internet are seen as important enabling technologies to achieve home automation where optimal performance from the DE systems can be achieved.

2.0 Introduction – the link between modern control systems, smart metering and DE

In order to meet the agreed targets of reductions in energy consumption and greenhouse gas emissions by 2020, the government has initiated the introduction of "Smart metering" for gas and electricity for all housing in the UK over the next 10 years at no direct cost to the house owner. In addition the government is offering financial incentives for house owners to install renewable Distributed Energy (DE) systems, for example solar panels, heat pumps, etc., with options to "feed-in" any excess electricity back into the grid; the "Feed-In-Tariff" or FIT. It may therefore be expected that this will result in a significant challenge to currently available domestic control systems to optimize performance and achieve the desired energy savings from a complex mixture of new appliances and technologies. This is the key driver to review existing control systems, that are currently generally only applicable to individual device control, and assess their functionality in a multi-device complex environment, where in general retrofit of new appliance installations would be the norm.

This review of the current technological position of the control of residential appliances and home automation systems is therefore timely and starts from the current position of conventional heating control systems. It covers what is controlled and how, if at all, and if there is any connectivity between the diverse range of functional requirements of existing control systems and new DE applications in an integrated home environment. An attempt is made to correlate common control features and the direction in which future controls are developing. It is noted that the complexity not only of adding new devices to existing housing, but the added disruption of installing control links, will raise customer concerns over the priority of such purchases compared with the many other options available for allocating money to home improvement schemes. The development of wireless communications coupled with low power electronics is identified as a key driving force for enabling the integration of diverse control functions into the integrated home environment. Finally the current and potential future direction for the supply of such systems is reviewed, including the products supplied by technology providers, the integrated control system manufacturers and the linkages in the supply chain through the major energy supplier organizations and suppliers of advanced "smart" metering systems.

This report does not attempt to consider the detailed structure of control systems communicating between various sensors, actuators and Central Processing Units, CPUs, or analyse the benefits of control system architectures, but rather reviews the general, functional requirements of controls for DE systems. It does not therefore address such issues as preferred radio communication protocols, serial bus architectures or gateways between different systems, nor the preferences of control protocols in optimizing performance such as adaptive voltage source controls, etc. Additionally the control and communication systems adopted for some of the traditional remote monitoring applications related to burglar alarms and fire alarms are not evaluated in this report.

3.0 Overview of conventional discrete controls for domestic central heating

The basic layout of pipeline routes and the boiler/appliance for a conventional central heating and hot water cylinder system are shown in Figure 2. The external control linkages, for example to pumps and thermostats, using hard-wired connections are also indicated by dashed black lines. In addition the figure also shows additional pipelines and control linkage configurations for the DE technologies of solar thermal and air-to water heat pump that may be added to the system and which are discussed in greater detail later.

Modern domestic boiler systems usually integrate a number of control strategies within the appliance, in addition to those usually associated with external controls. Such controls are essential for the safety management of the appliance and are unlikely to be a part of an external energy management system. These controls may include the following:-

- Frost protection - using an internally mounted temperature sensor (often mounted directly on the circuit board)
- Hot water supply and return temperatures (often thermistors) for control of boiler cycling operation

- Overheat temperature thermostat control
- Pump over-run – to prevent excessive boiler temperatures and optimize heat output at switch-off
- Exhaust (flue) fan control – particularly in the case of condensing appliances - uses differential pressure sensors to ensure combustion products are removed from the property
- Ignition control, flame detection and gas/oil valve operation - avoids excessive unburnt fuel entering the appliance.
- Mains reset switch – provides a safety reset after a failure incident
- Hydraulic/mechanical controls such as pressure relief valves, non-return valves, expansion vessel pressure or boiler bypass management

Discrete domestic heating controls usually comprise the following hard-wired components:-

Basic

- Simple multiple on/off time switch – usually limited to a repeated 1-day cycle with 2 x on/off options

Conventional modern systems

- Simple programmer providing separate control of heating and hot water – usually with a 7-day cycle
- Room thermostat – usually with inbuilt accelerator to avoid hunting
- Cylinder thermostat – usually with a high/low temperature differential to avoid cycling
- Motorised control valves – either 1 x 3-way or 2 x 2-way to control water flow for heating/hot water
- Thermostatic valves for fitting to radiators to provide an element of room temperature control
- Safety alarms for natural gas, carbon monoxide and occasionally carbon dioxide
- Safety alarms for fire and/or smoke

The above applies to systems with regular boilers and a hot water cylinder, for combination boilers where hot water is heated directly with no hot water storage, separate control of hot water, cylinder thermostat, and control valves clearly do not apply.

Advanced systems

- Modulating boiler controls to improve part load efficiency
- Optimum start /(stop) – requires external temperature sensor and indoor temperature sensor
- Weather compensation
- Occupancy controls

4.0 Overview of conventional discrete controls for auxiliary heat sources

The addition of new local sources of energy supply to housing stock, for example solar thermal panels, has required that the manufacturers have had to supply the associated control systems with the equipment. These are therefore in general sold as individual discrete units, but may require some interaction with existing controls.

4.1 Solar thermal panels

For a solar thermal panel installation an additional water tank is normally required to store the heat gained from the installation, since this is generally at a lower temperature than water stored in a conventional domestic central heating/hot water system with conventionally sized radiators. A single dual heat exchanger tank is an alternative option. However, for the highest efficiency collectors (heat pipe and vacuum insulation) high temperatures can be regularly achieved even in winter conditions and a single tank is considered quite viable, shared between hot water and central heating. In the case of thermal solar panels, the control system must supply circulated water through the panel when there is a positive temperature differential between the water outlet of the panel and the solar storage tank as a result of incident solar radiation. The level of this differential is an important parameter in determining the ultimate efficiency of the solar contribution to the heating system. In advanced systems the circulating pump speed may be controlled for optimizing performance. In addition there are a number of safety functions that also need to be incorporated into the control system.

If there was a need to monitor efficiency of the panel then it would also be necessary to monitor the incoming solar radiation levels and the volume flow rate and temperature differentials, however, this would not be normal practice for a domestic installation. Figure 2 includes the basic control components and linkage elements, shown by dotted brown lines, for a thermal solar panel system. Several of the required safety features are usually incorporated into a non-electric hydraulic package, these including safety pressure release valves, pressure gauges, etc. It may also include easy filling and draining facilities. An example is shown in Figure 3.

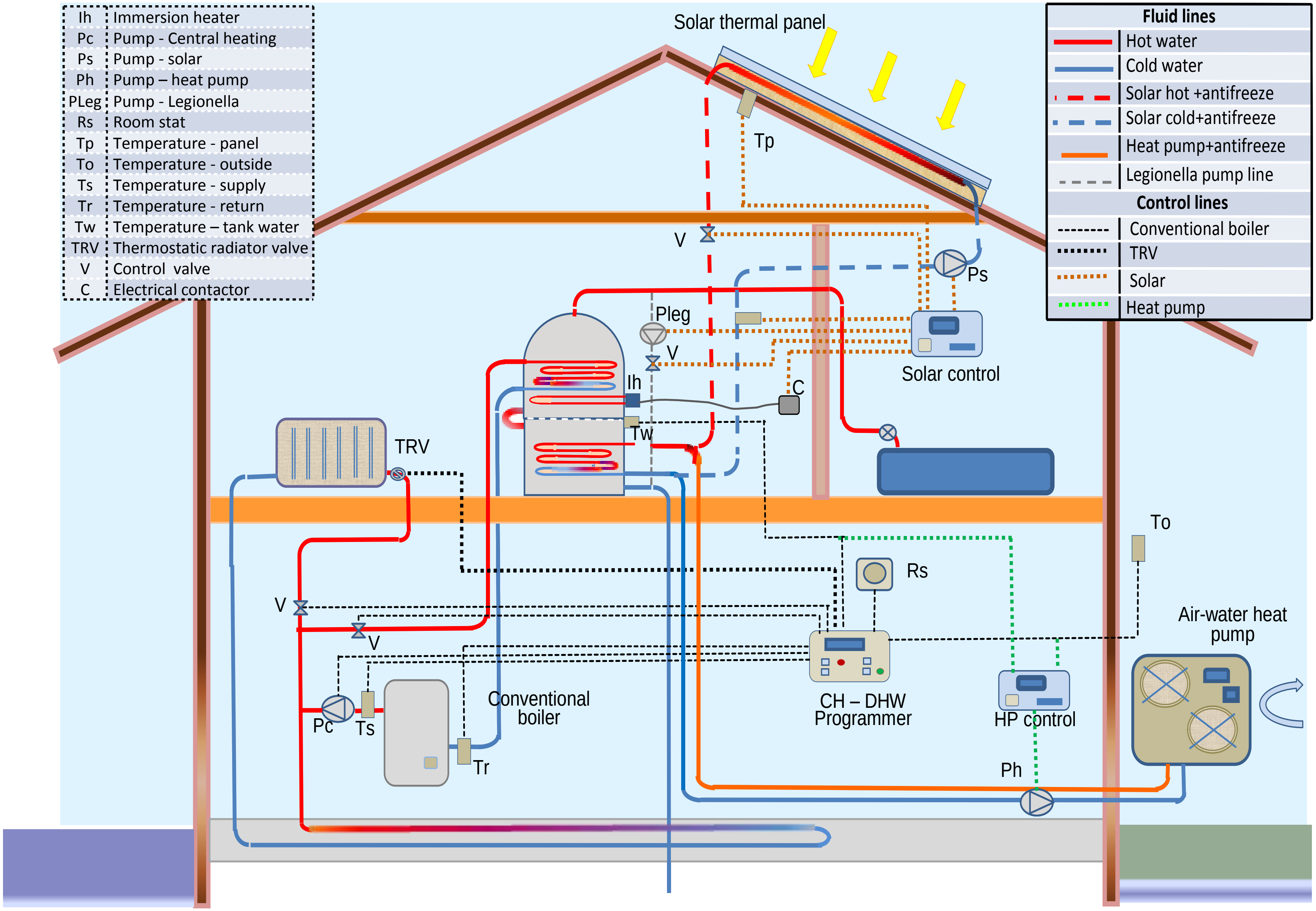

Figure 1: Basic conventional heating control system layouts with DE additions

The components include:-

- Pump for solar system
- Filling system for easy filling and sealing of system
- Flow indicator of fluid in system
- Isolation valves
- Non-return valve avoids thermo siphoning
- Pressure gauge
- Temperature gauge

Figure 4 shows an example of a dedicated controller unit the SHR52120 made by Drayton for the control of solar systems. It is supplied with two Pt1000 temperature sensors and can operate up to two solar pumps rated up to 4amps. Power consumption is 2W. The main functions of the controller are related to safety of the system, maintaining both acceptable maximum and minimum flow and storage temperatures.

http://www.draytoncontrols.co.uk

Figure 3: Example of packaged safety system for solar thermal panel control

Figure 4: Example of thermal panel control unit

A few further examples from an extensive array of manufacturer's individual products are included in Appendix 1 from a brief web survey of currently available products. This survey also covers further DE products covered in the next sections.

Solar tracking collectors have been developed in order to optimize collection efficiency, (these are often parabolic), however they have not seen favour for the domestic market as the added costs of the mechanical hardware and controller for tracking the sun, and the difficulty in physically locating, do not currently result in an economic benefit for low power applications.

4.2 Heat pumps

Heat pumps upgrade low grade ambient heat to supply higher temperature heat to meet the demand of radiators, warm air distribution or under-floor heating systems. Where the low grade heat is obtained from a heat exchanger buried horizontally in the ground, usually a substantial length of several hundred meters of plastic piping, or a vertically installed pipe in a bore hole, the heat pump is referred to as a ground source heat pump or GSHP. Where the heat is extracted from ambient air it is referred to as an air source heat pump or ASHP. Examples of both types of unit are shown in Figure 5.

Trianco AS Heat pumpTRI9003
http://www.trianco.co.uk

Dimplex S1 MEH Heat pump
http://www.dimplex.co.uk

Figure 5: Examples of an ASHP and a GSHP

In either case the output temperature supplied is usually adequate for warm air systems or under-floor heating systems, but falls short of the requirements of conventionally sized radiator systems. With state of the art heat pumps, supply temperatures of 60^{o}C are achievable, reducing the need for oversized radiators in wet systems. If sufficient additional insulation is installed in a renovated property then the original radiators may be sufficiently oversized to meet the lower heating demand load with lower supply temperatures. Another option in an upgrade installation is to use high efficiency convector radiators that operate on lower temperature flows. However, it is often necessary in wet systems to include a storage tank to buffer the lower heat pump output supply temperatures against the higher conventionally supplied boiler temperatures and to optimize the supply of heat to the property. Figure 2 again shows the basic arrangement of pipe-work and control lines for a heat pump system with, in this case, the links to sensors and pumps shown by green dotted lines. A separate control unit to manage the system is again included in the figure. Heat pumps are usually supplied as integrated packages which include all the essential controls and safety features required from a commercial product - see later in Table 4.

A modulating control of the heat pump is desirable (as opposed to an on/off control) and modern compressor systems use inverters to match supply to demand load, which also results in a low start-up current. Heat pumps still require an energy supply to operate. For domestic applications this is usually electricity, but in large installations gas is often used. They achieve a gain in supplied heat output over the energy required to operate. The measure of this performance is referred to as the COP or Coefficient of Performance. The output from heat pumps diminishes as the temperature difference between the heat source and the demand temperature increases. In the case of heat pump installations, GSHP or ASHP, the system is sized to meet only part of the maximum demand, based on capital cost, operating cost and performance. This means that an auxiliary heat source is required to supplement the heat pump. There is therefore a trade-off in operating cost when balancing the use of the heat pump, using high cost electricity, against say a boiler using lower cost gas. This is demonstrated in Figure 6 and Mitsubishi offer a controller that can optimize this region on a cost basis.

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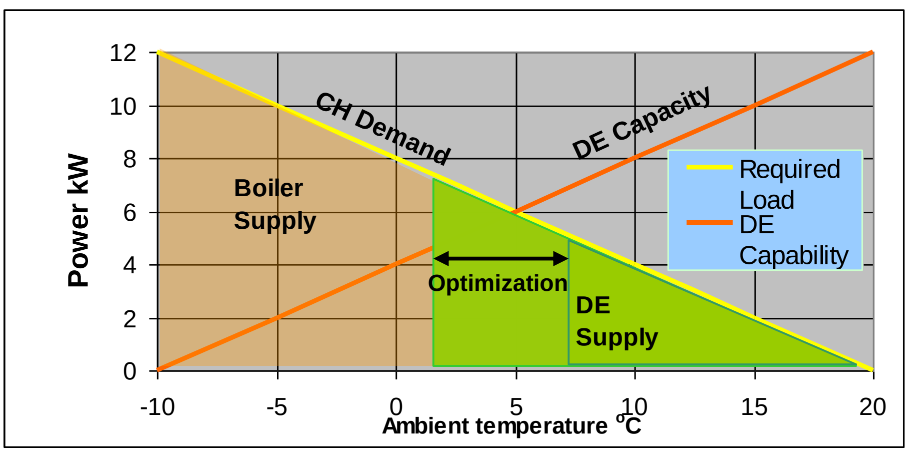


Figure 6: Optimization of performance on a cost basis

A further innovation in optimization is their use of a modulating control of the compressor. Mitsubishi use inverters to provide modulated control; matching demand to supply requirements and providing low start-up currents. Figure 7 from Mitsubishi shows the potential savings that can be achieved by operating at as low a temperature as possible to meet demand.

http://heating.mitsubishielectric.co.uk

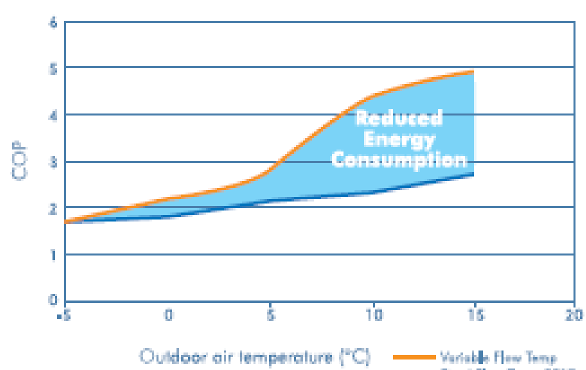


Figure 7: Energy savings from a modulating control

The basic function of a heat pump controller is to manage the performance of the refrigerant system and safety features. These include the following and a further example is included in Appendix 1.

- Capacity control through frequency inverter control
- Intelligent defrost scheduling
- Ambient temperature optimization adjusts set point of heat pump
- Legionella control by raising water temperature weekly
- Integration with other renewable energy sources – eg solar

This may be achieved within a dedicated controller chip that supplies all the required digital and analogue connections for temperature sensing and control outputs.

http://www.lodam.com

Daalderop have developed the “CombinAir”, a condensing boiler and air to water heat pump combination appliance. The basic controls for this are assumed to be built into the appliance.

http://www.daalderop.co.uk

4.3 Thermal storage

Thermal storage is an essential component of thermal DE systems as shown in Figure 2. The important aspect at the design phase is selecting the correct size of store as with the conventional storage medium of water, physical volume in domestic premises is usually highly restricted. A storage tank suitable for solar thermal or heat pump DE systems with back-up boiler and integrated with essential controls provides an optimal solution for space saving and fast installation. The unit shown in Figure 8 from Kingspan is a good example of how pumps, motorized valves supporting several zones, safety related components, and basic controls including thermostat and immersion heater are all incorporated into a single factory produced package.

http://heating.mitsubishielectric.co.uk

Figure 8: Kingspan FTC2 storage tank

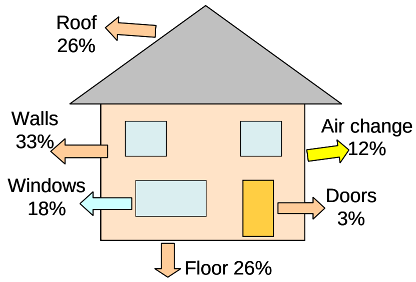
Although storage mediums other than water have been developed, that provide higher thermal capacity in smaller volumes ie. a greater specific heat of the medium; there is no indication that these have been adopted by any DE supplier to date.

The author believes that the use of a thermal store to store electrically generated energy, for example from wind turbine or solar PV may be a simple and cost effective option in terms of control strategies, avoiding the costly expense of inverters and grid-matching control systems – see later.

4.4 Ventilation with heat recovery

It is well established that as house insulation levels improve, then the contribution to heat loss from natural ventilation becomes a significant factor in the whole house energy bill. This is demonstrated in Figure 9 below. Typical contributions to whole house heat loss are shown and the table demonstrates that improvements to insulation levels (U Values) of structural items, excluding ventilation, result in ventilation becoming the dominant heat loss factor, in the example given being comparable to the equivalent of an overall 13 % improvement to the rest of the structure. Hence there is a market in ventilation with heat recovery systems.

Sealing the house to reduce ventilation losses then often leads to air quality issues. These can be mitigated by controlled forced ventilation systems and the further addition of heat recovery provides a measure of compensation for the heat loss. A further efficiency improvement can be achieved by preheating the incoming air through a solar heating panel. However, retrofit installation is usually considered an inconvenient process and controls are usually designed, integrated specifically into the whole package. Such controls may have set fan flow rates based on time, temperature and humidity. Balancing flows to individual rooms may be achieved through self regulating standard hydraulic pressure regulators installed in the ducts.



Structure of property	Typical losses	Example heat loss in KW	Reduction - except for ventilation				New heat loss	
			As %	As	Typical U value			
	Tot. %	**10**	**13**	KW	Reduction	As %	Tot.%	KW
Roof	26	2.6	22.6	0.8	0.4 to 0.15	37.5	19.37	0.975
Walls	33	3.3	28.7	1.0	1.6 to 0.5	31.25	20.48	1.031
Floors	8	0.8	7.0	0.2	1.1 to 0.8	72.73	11.56	0.582
Windows	18	1.8	15.7	0.5	4.3 to 2.5	58.14	20.79	1.047
Doors	3	0.3	2.6	0.1	3.0 to 2.0	66.67	3.973	0.20
Ventilation	12	1.2	23.4	1.2	none	0.0	23.84	1.20
Totals	100	10	100	3.84			100	5.035

Figure 9: Ventilation losses as a percentage of whole house heat loss

Whole house ventilation with heat recovery

Domestic systems are usually loft mounted and have multiple ducts exhausting warm damp air from bathrooms and kitchens and supplying tempered air to living rooms. Heat is exchanged between supply and exhaust flows through a cross-flow plate type heat exchanger offering efficiencies of up to 70%. Modern units use energy efficient DC fan motors and automatic controls are integrated into the unit.

http://www.nuaire.co.uk

Cooking hoods with heat recovery

A specific application for waste heat recovery is the cooker hood. They tend to be switched on when required, but in a highly insulated house may remain on for extended periods of time, particularly if the fan is very quiet. However, the overall usage is likely to be low and energy savings small, so integrating the cooker hood with a whole house ventilation system will help maximize savings. (SAP Appendix Q 2005)

Solar assisted ventilation

There are also ventilation systems that can be integrated with a solar panel to provide pre-heated fresh air.

Thermal wheels

For large air conditioning applications thermal wheels are employed to provide heat recovery from exhaust air and transfer it to incoming fresh air. The wheel is located between the supply and exhaust air flows and comprises thousands of small air flow channels that act to transfer heat from the exhaust air stream to the wheel. As it rotates at a slow constant speed new sections of the wheel continuously pass from the exhaust to the originally cooler supply air stream, enabling the heat to be transferred back into the incoming air. The efficiency of the process is in the order of 75%. The converse can be used for summer cooling. The author developed demonstration systems for office applications some 40 years ago, but they were never marketed. Control is simply linked to the need for fresh air, for example by measuring CO_2 levels indoors or by temperature differentials to achieve cooling in the summer months.

5.0 Overview of controls for auxiliary electrical power sources

There is some commonality between the requirements of control systems for both wind power and solar PV. These are discussed in the following sections.

5.1 Solar photovoltaic panels

Electricity generated by solar PV or wind is generally low voltage DC. In order to store the collected energy for off-grid use, one option is to use a rechargeable battery. For optimum performance and battery life expectancy, a battery controller can be used, usually rated at 12V and upwards of 10amps capacity.

To obtain 240V AC power an inverter is required to operate domestic appliances. These may generate true sine wave or, for less cost, a modified sine wave, although these may produce unacceptable hum in some applications. If the intention is also to feed power back into the grid, then a more expensive grid-tie inverter is required to stay in sync with the grid frequency and slightly exceed the grid voltage level.

A new product type of grid-tie inverter has recently been developed by Enphase Energy called a micro-inverter. These are fitted individually directly to solar panels and are claimed to provide a number of benefits, including improved efficiency and reliability. They are linked and can also communicate through the mains wiring connections to provide data that can then be sent to a server for analysis. Unit prices are in the range 230-400$.

http:// enphaseenergy.com

5.2 Wind turbine power

Wind turbines from the controls aspect are generally classed as:-

Off-grid – The output is not connected to the electricity grid and power is used locally. They usually have a DC output and require a battery store, which is typically lead-acid, since output is very variable. AC is generated from an alternator and converted to DC using a rectifier. A charge controller is required to extend battery life. An AC output system requires an inverter to provide a constant regulated mains voltage AC supply and for this it is important to match the load to the supply. As a consequence a range of power rated converters is available. A wind generator may be connected to other power production sources such as PV solar panels or a diesel generator (often referred to as a hybrid system). These again produce DC and combined with an inverter, produce AC. An off-grid hybrid combined system eg. with a diesel generator or photovoltaic panels may produce DC but is usually combined with an inverter to produce AC.

http://www.windandsun.co.uk/Inverters

The additional control components contribute to the overall cost of a wind turbine. A rectifier assembly unit is typically in the region of £30. An example of a regulator required to prevent overcharging is a pulse width modulation unit with a price for a 100W regulator in the range from £100 to £125 for up to 3 battery banks. For larger turbine outputs the costs rise as indicated below:-

- 100w reg. £104 turbine £700
- 300w reg. £404 turbine £1225
- 600w reg. £485 turbine £1600

Example costs for an entire wind turbine assembly are indicated in Table 1 below. In addition the pole or wall support is in the region of £400

http://www.ampair.com

Table 1: Indicative parameters and costs of small wind turbines

Power Watts	2000	1000	500	300	200
Voltage	120	48	36	24	12
Rated wind speed m/sec	9	9	8	7	6
“ “ “ mph	20.1	20.1	17.9	15.6	13.4
Blade diameter m	3.2	3.1	2.7	2.5	2.1
Price £	1800	1096	646	543	437
Batteries Ah	10 x 200	4 x 200	3 x 150	2 x 150	1 x 100
Price £	1500	600	330	220	75

Grid-connected – The output is connected to the electricity supply grid. As is the case with PV panels, the need for maintaining grid frequency and voltage standards, requires the use of sophisticated inverter technologies. An example product rated at 1.5kW from Mitsubishi is shown in Figure 10. Such a unit costs £750 excluding VAT, whilst a 3kW unit costs £1385 +VAT. It is therefore apparent that a major factor in a grid-connected system costs is the inverter unit.

Figure 10: A 1.5kW Mitsubishi inverter

A visit was made to a local wind turbine capable of supplying 11kW 3 phase to a small farm. The key elements of the system are shown in Figure 11. At this scale the controls not only require a substantial computing element but industrial sized contactors, circuit breakers and power factor correction. A log of many of the operating parameters and performance is held in the computer and can be down loaded by a wireless link. A smart meter is used to monitor import and export to the grid.

Figure 11: 11kW wind turbine with associated control panel and smart meter

5.3 Electrical storage

A report for the DTI in 2004 entitled “Status of Electrical Energy Storage Systems” produced by Swanbarton Limited concludes that for small-scale demonstration (for example in domestic applications or small commercial customers or small off-grid applications) low technical risk would be associated with the following currently available storage types:-

- Batteries: Lead acid, NiCd, Zebra, ZnBr
- Flywheels
- Emerging battery technologies would include lithium ion and vanadium flow batteries

www.ensg.gov.uk/assets/dgdti00050.pdf

More recently, an extract from a further report entitled ”Challenges of Electricity Storage Technologies” prepared by the APS Panel on Public Affairs Committee on Energy and Environment: May2007” is given below.

Extract from report

“The major challenges in using batteries for electrical storage are to make them both affordable and long-lived. Commercially available battery systems are not adequate for long term (>10 years) use. There is unanimous agreement that most large scale battery systems are currently too expensive for widespread deployment, and new manufacturing techniques are needed to reduce their cost.”

http://www.aps.org/policy/reports/popa-reports

From these reports it may be inferred that battery storage remains the key storage technology but that further advances are still required. Table 2 indicates typical energy and power densities available from various battery technologies. There is considerable interest in super capacitor technologies but current examples have very low storage capacity whilst the much voiced performance claims of EEStor using barium titanate have yet to be revealed.

Table 2: Battery technologies – basic properties

Storage medium	Energy density	Power density**	Individual cell voltage
	Wh/Kg	W/kg	Volts
Lead acid	40	10 - 100	2.1
Lithium ion	120 - 180	35 - 350	3.6
NiCd	75	4 - 200	1.2
Capacitor	6 - 15	4000	2.3
Ultra capacitor EDLC*	1 - 10	10,000	
Super capacitor (carbon nano tube)	60	100	

EDLC = Electric Double Layer Capacitor ** Depends very much on the rate of discharge – see below.

The Ragone plot, Figure 12 below, compares the performance of a range of electrochemical devices. It shows that ultracapacitors (supercapacitors) can deliver very high power but the storage capacity is very limited. On the other hand fuel cells can store large amounts of energy but have a relatively low power output. The sloping lines on the Ragone plots indicate the relative time to get the charge in or out of the device. At one extreme, power can be stored into, or extracted from, capacitors in microseconds. This makes them ideal for capturing regenerative braking energy in electrical vehicle applications. At the other extreme, fuel cells have a very poor dynamic performance taking hours to generate and deliver their energy. This limits their application in electric vehicle applications where they are often used in conjunction with batteries or capacitors to overcome this problem. Lithium batteries are somewhere in between and provide a reasonable compromise between the two.

http://www.mpoweruk.com/performance.htm

It is therefore apparent that there is a controls need to match the specific storage battery performance requirements with those of the DE system.

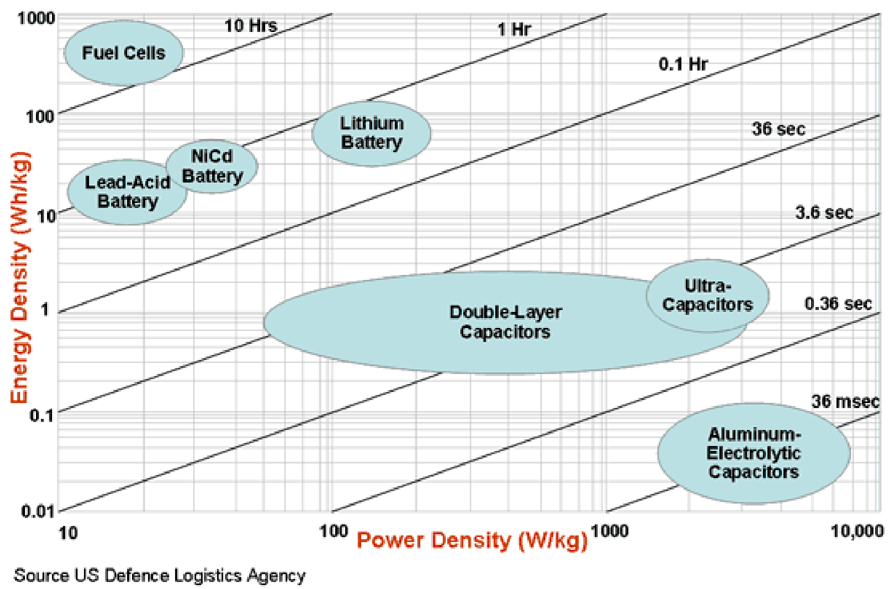


Figure 12: Ragone Plot of Electrochemical Devices

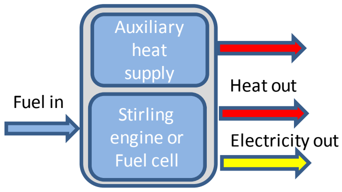
Flywheel developments have progressed to what is known as the third generation, but remain essentially at the research stage.

From the controls aspect, many battery packs now incorporate associated electronic circuits. These may be protection devices and circuits, monitoring circuits, charge controllers, fuel gauges, and indicator lights. Electronics for high power multi-cell packs also include cell balancing and communications functions. However, the controls associated with optimizing renewable energy with requirements are nominally independent of the battery type.

6.0 Summary of control requirements for micro-generation sources

In the development of products for the low carbon environment, a distinction may be drawn between products that utilize renewable energy sources, such as solar or wind, and products that employ more efficient methods of extracting both heat and power from existing primary fuels, primarily from natural gas. Note also that the FIT for micro-generation is considerably less than for renewable energy source generation (typically 10p/kWh compared with a maximum of 41.3p/kWh for solar)

The key developments in this area relate to engine driven devices and fuel cells. Figure 13 shows typical output values of the electrical and thermal components generated by Stirling engine and fuel cell systems.



Technology	Gas input	Effici-ency	Heat out	Electrical output	Auxiliary heating
Stirling engine	7.8kW	92%	6.2kW	1kW	18kW
Fuel cell	3.2kW	85%	1.7kW	1kW	15kW

Figure 13: Examples of Microgen technologies

It will be noted that although the electrical power produced is generally small compared with the whole house demand, there is a need to either modulate the electrical power output when heating is required, and/or supply power to the grid directly when heating is called for but minimal electrical power is required. These demonstrator and new market launch technologies integrate the required control sequences within the prototype units and at this stage of development it is not clear what the need will be for additional external controls.

6.1 Microgen developments

The Combined Heat and Power Association (CHPA), categorize 9 companies involved in Micro CHP and 19 under Small Scale CHP, the later being applicable to small commercial developments. However, only a few companies are involved in the development of domestic applications and shown below is a listing of some of the developing technologies that have been commercially launched or reached field trial testing for the residential sector in conjunction with major energy utilities. http://www.chpa.co.uk

- Baxi have commercialized their micro CHP Stirling engine development this year – the Ecogen. Figure 14 shows an extract from their brochure suggesting that the average electrical base load seldom exceeds the 1kW available power output from the microgen unit. On start up only the Stirling engine operates, ensuring that electrical power is produced and maximum use of the thermal output is achieved. Based on temperatures, if the system demand is greater than the available heating load then the auxiliary heating is introduced.

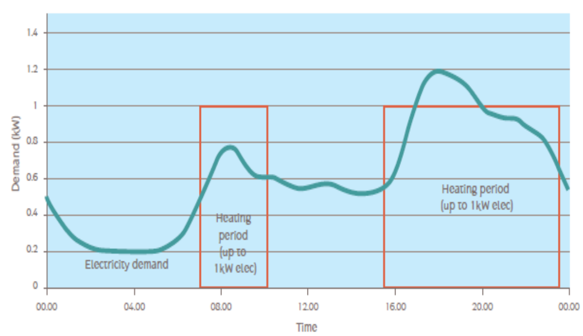


Figure 14: Baxi microgeneration comparison of thermal and electrical house loads

This product comes with full grid-connectivity (hardware and software) and all electrical power may be supplied simply through a single 3 core cable. The basic product comes with a range of controls including the following:-

- Programmer - two channels (CH & HW)
- Room load compensation
- Energy meter

Additionally, an outdoor temperature sensor for weather compensation, a hot water cylinder sensor and programmable room thermostat are available, all using low voltage wiring.

The savings achievable from the appliance are compared with conventional systems, but capital costs seem to be difficult to obtain without house surveys, etc. The Baxi web site suggests the unit price is £3000 and payback is 8.6 years including the benefit of the FIT.

http://www.baxigroup.com
http://www.baxigroupspecification.co.uk

- The Ceres Power group have developed a Solid Oxide Fuel Cell, SOFC, and field testing of units is in combination with British Gas. http://www.cerespower.com
- In addition, Ceramic Fuel Cells Ltd have developed "gennex", a SOFC that uses gas as its primary fuel. They have partnered with E.on to develop the product. http://www.cfcl.com.au
- Another novel development is by Genlec Ltd, where the conventional expander of a heat pump working fluid circuit is replaced by a scroll expander that produces a 1kW electrical output at 10% efficiency and combined with the heat pump has an overall appliance efficiency of 90%. This is integrated into their "Kingston" appliance. http://www.energetixgroup.com

7.0 Control requirements to link domestic appliances to DE power sources

Since electrical generation from DE sources does not necessarily coincide with normal demand patterns for electrical power, in order to optimize the use of the available DE electrical supplies, new strategies are required. One simple solution is to store excess electrical energy by conversion into useful heat in a thermal store through resistive heating if there is no demand for electric power. However, this is not necessarily the most efficient solution and a number of alternatives need to be considered, some of which are discussed in the section on new challenges for controls.

7.1 Voltage control energy savings

Vphase is an electronic unit that regulates the domestic supply to 220Volts and is fitted to the house supply after the fuse box. It is claimed that often the incoming supply voltage is well in excess of 220V, but appliances, and in particular motors such as found in washing machines, etc., operate satisfactorily at a lower voltage hence saving power. Modern electronics now makes the unit viable for domestic installation, the size being similar to the fuse box and the unit cost being about £250. Savings in specific appliance use are claimed to be as high as 17%.

http://www.vphaseplc.com

8.0 Summary of control requirements for all sources

In order to provide some structure to the range of parameters to be controlled, Table 3 suggests one possible way to collect controls into their logical groupings of heat and power management, whilst Table 4 compares the elements of control systems for thermal DE heating – conventional, solar and heat pump and Table 5 for electrical DE systems – PV and wind turbine at the building integration level. Tables 4 and 5 although somewhat speculative and probably incomplete, do suggest that there is a lot of similarity in the sensors and required controls of the different DE technologies in their respective two groups.

Table 3: Logical groupings for controllers

HEAT	POWER
Advanced Occupancy Controls	Advanced Occupancy Controls
Advanced Heating Controls	Advanced Heating Controls
DHW - Domestic Hot Water controls	DHW - Domestic Hot Water controls
Solar thermal Controls	Solar PV
Centrally controlled TRVs	Storage radiator control
Heat pump/ Air con controllers	Heat pump/ Air con controllers
Smart gas meters	Smart electrical meters
RHI – Renewable Heat Incentive	FIT - Feed-In Tariffs
Oil tank level monitors	Electric vehicles
Boiler safety control	Smart appliances for management of load

Table 4: Comparison of control systems – Thermal DE systems

Conventional central heating		
Control function	Sensors	Actuators/ Actions
Safety On/off	NA.	Main switch
Heat modulation	Outside air temp.	Modulating burner control
Frost protection	Outside temperature	Switch-on sequence
Ambient temp. compensation - CH	Outside air temp.	Burner modulation or on/off cycling
Summer/winter CH water circ. time	Time	Timer/ programmer
Domestic hot water	Hot water thermostat	Valve & pump control
Room temp.	Room thermostat	Valve & pump control
Timed heating	NA.	Programmer or timer
Burner safety Ignition sequence	Flame detection Thermocouple	Gas valve Flue fan

Heat pump		
Control function	Sensors	Actuators/ Actions
Safety On/off	NA.	Main switch
Capacity modulation	Outside air temp.	Compressor speed/frequency
Defrost	Evaporator temp.	Reverse cycle or electrical heater
Ambient temp. compensation - CH	Outside air temp.	Compressor modulation or on/off cycling
Summer/winter CH water circ. time	Time	Timer
Domestic hot water	Hot water temp.	Valve & pump control
Legionella cycles	Time - weekly	Pump & valve control
Supplemental heating	Diff. temp.	Control- valves/pumps
Solar panel integration	Multi-temps.	Advanced controller
Room temp. compensation	Room temp.	
Frost setting for accommodation	Outside temp.	
Customer options		

Solar thermal		
Control function	Sensors	Actuators/ Actions
Safety On/off	NA.	Pump switch
Capacity modulation	Outside air temp.	Compressor speed/frequency
Frost protection	Panel temp.	Valve -drain down
Ambient temp. compensation - CH	Outside air temp.	Pump modulation or on/off cycling
Summer/winter CH water circ. time	Time	Timer
Domestic hot water	Hot water temp.	Valve & pump control
Legionella cycles	Time - weekly	Pump & valve control
Supplemental heating	Diff. temp.	Control-valves/pumps
Solar panel integration	Multi-temps.	Advanced controller
Room temp. compensation	Room temp.	
Frost setting for accommodation	Outside temp.	
Customer options		

Table 5: Comparison of control systems – Electrical DE systems

Solar photo voltaic		
Control function	Sensors	Actuators/ Actions
On/off	NA.	Switch
Capacity modulation	NA	-
Off-grid	Current / voltage	Rectifier /DC regulator AC - inverter
On-grid	Frequency Voltage	Grid-tie inverter
Battery charge	Current	Charge controller
Domestic hot water	Hot water temp.	DC regulator?
Efficiency monitoring	Photocell/ solarimeter	Calculation
Safety – high voltage	Warnings	Install/service
Safety - lightning	NA.	Lightning conductor
Surface contamination	Power monitoring	Historic data analysis

Wind turbine		
Control function	Sensors	Actuators/ Actions
On/off	NA.	Switch
Capacity modulation	Wind speed / direction	Mechanical blade angle/ etc.
Off-grid	Current / Voltage	Rectifier /DC regulator AC - inverter
On-grid	Frequency Voltage	Grid-tie inverter
Battery charge	Current	Charge controller
Domestic hot water	Hot water temp.	DC regulator?
Efficiency monitoring	Wind speed	Calculation
Safety -mechanical	NA.	Regular servicing
Safety – high wind speeds	Cut-off systems	Voltage drop-out Blade feathering

9.0 New challenges for controls

The UK's energy infrastructure, markets and technology are becoming ever more complex as it embarks on the major changes required to de-carbonise society. Environmental and economic motivations are creating expectations and demands to address serious local and global problems. Over the next decade the supply and management of UK energy is going to get much more complex. Central generation by fossil fuel and transport of energy will soon start to give way to distributed generation of both electricity and heat. Besides renewable systems, such as solar-thermal, photovoltaic and heat pumps, micro-generation of heat and electricity in homes is expected to increase together with the adoption smart appliances. Large scale centrally generated renewables will impart an added burden of intermittency on the grid. New electrical loads will also appear, including plug-in battery vehicles and air-conditioning. The use of residential district heating schemes based on combined heat and power (CHP) is likely to become more widespread too. These innovations will go hand-in-hand with the continual physical refurbishment of buildings, together with the fitment of enhanced controls to manage energy effectively in these increasingly complex and interacting residential systems. Following from the above reviews of conventional-existing and evolving-new control systems, particularly for DE applications, it is apparent that there is a need for some consolidation and integration of controls as indicated in Figure 15 below. A discussion on some of the developments is provided in this section.

9.1 Optimizing availability of DE generated electrical power

The first option is export directly to the grid and the second is battery storage for domestic applications, and these have been discussed already. A third option is for electric vehicle battery or fuel cell charging and a fourth is optimizing the operation of domestic white goods by load sharing or shedding.

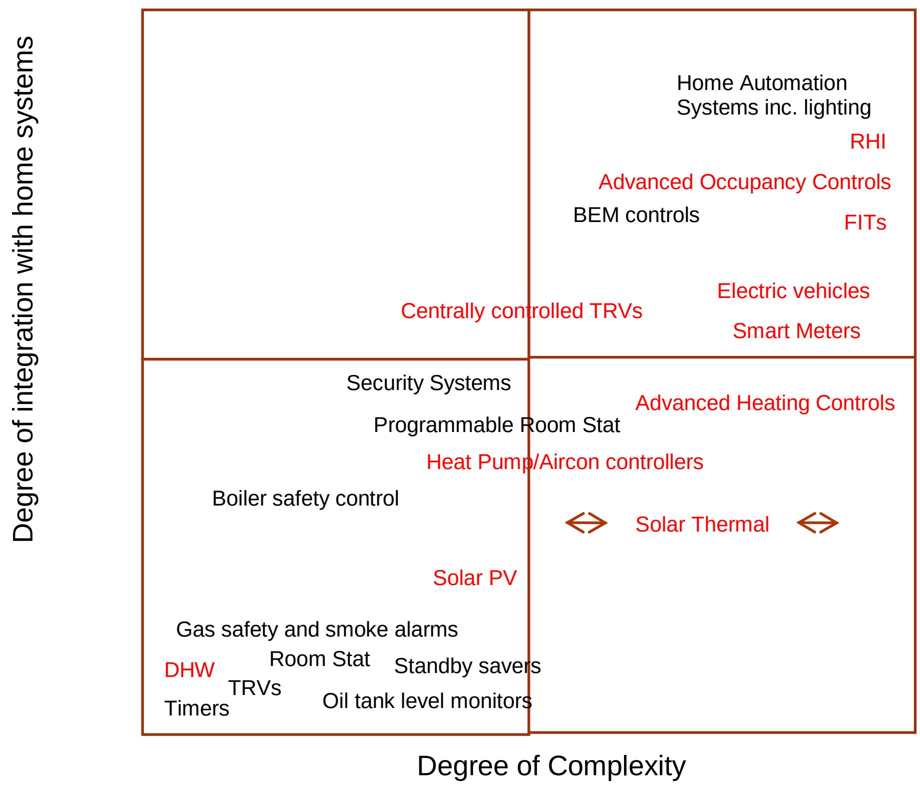


Figure 15: Controls Complexity – [Black] – as found – [Red] – Required Linkages

Electric vehicle charging

As the demand for electric vehicles grows there is concern about the grid being able to meet the recharging requirements from domestic premises, since the obvious demand will peak as people return home in the evening from work and plug in their vehicle for recharge. One option will be that the utility will determine power availability through the smart meter, but this will have a detrimental impact on the customer if their vehicle is inadequately charged. An alternative management of this system could be achieved by a home based controller that would determine how much charge is required and the time span available to achieve this. Coupled with the availability of the DE produced power, an optimized charging regime may be inferred.

Management of domestic electric appliances

Appliances such as refrigerators and freezers normally operate independently based on the demand of inbuilt thermostats. However, it is possible to delay operation if a wider band of temperature is acceptable, and improved temperature measurement is employed, hence providing a greater opportunity to use renewable electricity when it is available. Similarly, the time of operation of washing machines, clothes dryers and dish washers can also be controlled.

9.2 Solar thermal developments

The advanced technology employed in the most efficient solar thermal collectors now on the market, such as vacuum insulated heat pipes and selective absorbers, enable higher temperatures to be produced than previously with flat plate collectors, particularly under diffuse solar radiation conditions. This may enable reductions in storage size and better control strategies for storage to be employed.

9.3 Solar PV developments

Solar PV remains an expensive source of renewable energy in the UK and there is considerable development activity in this field aimed at increasing efficiency and reducing manufacturing costs. The costs of inverters, as in the case of wind turbines also contributes a cost burden if grid connected systems are considered. Of note are recent developments as discussed below.

Visit to CREST Laboratory

The CREST laboratory - Centre for Renewable Energy Systems Technology - is part of Loughborough University and has 50 staff. Their activities include PV developments and issues raised in a meeting included the following:-

- Solar PV costs are falling but it is still 20 years to breakeven in the UK without incentives.
- Particular areas of interest are vacuum glazing and electro-chromics.
- Focus on thin film Cu -In,Ga- Se_2 (CIGS) – best efficiency of 20%
    - Can be put onto stainless steel sheet and possibly polymer sheet in the future
- Focus on CdTe bifacial cells $40W/m^2$ – this is achieved through a double glazing unit coated on the inside with a 400nm thick PV coating. Loss of light throughput is apparently very small. This could be a major step forward in home glazing combined with renewables.
- Working on demonstration of mass production processes for CdTe through use of multi-units for pulsed DC powered magnetron sputtering (as opposed to rf sputtering) for the various depositions. This looks a very interesting approach to achieving a continuous mass production process that only requires a moderate vacuum environment as opposed to an ultra-high vacuum step process required for evaporation deposition. This could result in production costs of 40cents/W.
- Approximately 85% of solar cell production is currently based on first generation crystalline silicon
- Noted major USA investment in alternative energy of $150b over 10 years
- Predicted that all current glass manufacture would be consumed in PV panels
- 100MW sites for CdTe cells and programmes to extend to 600MW sites
- Exponential growth in production of PV – 8GW/year
- First Solar is the largest producer
- CdTe has efficiency of 10% - production of 1GW over last 4 years; 87 cents/watt to manufacture
- Crystalline silicon currently key
- Amorphous silicon set to expand

9.4 Heat metering

The combined improvements in efficiency and economics of solar collection systems and heat pumps coupled with the proposed introduction of the new Renewable Heat Incentive (RHI) from the UK government in April 2010 should encourage the increased application of such systems in UK properties. There is therefore a case to be made for the deployment of heat metering systems to encourage maximum customer use of the available heat produced. At present the government proposal is for the RHI to be based only on a "deemed" output of these systems based on assumptions in performance derived from SAP assessments. This approach will not encourage optimal use and there will be no feedback on the benefits actually derived, either in monetary terms to the owner, or to the government in terms of CO_2 reductions achieved.

Heat meters are common place in countries deploying district heating schemes, and ultrasonic non-invasive meters aim to reduce installation costs, although for new DE systems, the additional installation of an in-line heat meter would contribute little to overall costs. Importantly, if heat is metered, a market for trading heat locally may then be created. This heat trading could be between enterprises such as a school and its neighbouring community, or between neighbours with differing heat: electricity requirements. Heat metering also allows for central provision of energy from a communal renewable source, where buildings are in close proximity.

9.5 Wireless power transfer

There remains a fundamental problem of battery replacement in sensors required for home automation devices that are not readily connected to the mains electricity. However, wireless power transfer over any distance larger than the product size is extremely inefficient and raises questions about health. In April 2010 the Wireless Power Consortium announced the completion of Part 1 (covering interfaces) of an interoperability standard for wireless power transfer. The driver for this is essentially for mobile equipment applications but there may be applications for battery powered products in the controls aspects of the future home automation industry.

9.6 Power electronics

Developments in power electronics components, such as fast switching triacs, continue to provide useful savings for direct electrical power DE sources such as wind turbines and solar PV and for optimizing performance of electric motors, regulators and invertors.

9.7 Wind turbines

Interest is growing in the concept of using small wind turbines, for example 100w to 600w units in a wind farm for community use. The small size reduces environmental impact and the potential of larger production numbers offers the possibility of reduced capital costs.

The British Wind Energy Association, BWEA identify development activities that include:-

- Active pitch controls to maintain energy capture at very high wind speeds
- Adapting a single model to either on-grid or off-grid use
- Software and wireless display unit
- Inverters integrated into the nacelle (rotor hub)
- Electronics designed to meet stronger safety and durability standards
- Integrating turbines into existing tower structures, such as utility or lighting poles

http://www.wind-energy-the-facts.org

The author notes that the use of small wind turbines used simply to provide power to a heating element in a water storage tank does not seem to have been developed into commercial products. This would provide considerable savings in the cost of batteries, regulators and inverters, although some control management would be expected.

9.8 Battery technologies

The need for efficient low cost batteries has been highlighted as a requirement for renewable electrical power production. Of recent interest in this arena is the claim by the Massachusetts Institute of Technology (MIT) of using carbon nanotubes in Lithium-ion battery electrodes, providing a 10 fold increase in gravimetric energy, approaching the values of electrochemical capacitors.

http://physicsworld.com

9.9 Home automation

As the array of new and legacy technologies grows, a radically different approach will be needed for human interactions with these increasingly complex renewable energy systems that extend to storage and transport.

It is recognised that current human behaviour is a major obstacle to change and the expectation is that people will not have the time or knowledge to spend on making continuous, complex calculations to optimise their energy purchases and usage. For these complex interacting systems to work at optimum effectiveness, continuous automated monitoring with feedback will be needed to ensure that the installed systems work as intended by their designers. This demand for home energy requirements also needs to be matched by the next generation of DE systems with managed interaction with the supply utilities through the use of smart meters. The drivers for these are seen in particular to be major advances in reliable local wireless communication between devices, reductions in size and cost of intelligent programmers and integration with the smart grid. Each of these is discussed in further detail in the following sections.

10.0 Required standards for DE equipment control systems

Generally all electronic equipment must comply with EMI (Electro Magnetic Interference) and EMC (Electro Magnetic Compliance) standards. The amount of EMI created by electronic equipment must not exceed allowed levels; neither must electro-magnetic radiation from other sources interfere with the performance of the equipment. Additionally, depending on the location in which the equipment will be required to operate, it must comply with a range of environmental standards – for example electrical equipment required to work outdoors must particularly meet weatherproofing standards, or if in a hazardous environment, then it must meet explosion safety requirements (The ATEX Directive). Additional requirements may also relate to fire safety. There may also be requirements for interoperability according to the Interoperability Framework Initiative.

10.1 Solar thermal panels

Thermal solar panels are tested according to BS EN 12975-2, Thermal solar systems and components – Solar collectors – Part 2: Test methods. In Europe these may be certified by TÜV Rheinland® according to IEC 61646 & 61730. Electrical safety is covered by UL 1703 and fire safety according to UL for Class-A Fire Resistance.

SPF is an accredited Swiss test laboratory to EN 12976 - the test reports are recognized throughout Europe. The European standard is EN 12976 - Prefabricated systems for water heating. The International Standard is ISO / DIS 9459-5 - DST method to characterize the thermal performance. These tests are the basis for various international certifications such as - Solar Keymark. Memory, components and entire solar systems are tested in line with the EN 12977.

10.2 Solar PV panels

The main requirements relate to grid-connected units where inverters need to be approved. (see wind turbines below).

10.3 Wind turbines

The British Wind Energy Association, BWEA has adopted some standards for small wind turbine standards including the following:-

- IEC 61400-02
- BS En 61400 part2
- BS EN IEC 60335-1
- LV Directive 73/23/EC
- WEEE Directive 2002/96/EC
- RoHS Directive 2002/95/EC

For inverters the standards include DIN EN 60529; IP 65 and the EMC Directive 89/336/EC

G83/1: Recommendations for the connection of small-scale embedded generators (up to 16A per phase) in parallel with public low-voltage distribution networks.

- BS EN 61400 part 2 (1996): Wind turbine generator systems: Design requirements of small wind systems
- BS EN IEC 60335-1 (1994): Safety Of Household Electrical Appliances
- LV Directive 73/

10.4 Micro CHP

For micro-CHP devices the 2010 Building regulations will introduce specific requirements. These requirements are based on the Heating Plant Emissions Rate (HPER) for an appliance in a particular property. Additionally, there is a further complication in that there are different HPERs for different Plant Sized Ratios (PSR). This is the ratio of maximum appliance output to the design heat loss of the property.

10.5 Home automation

KNX technology is the worldwide standard for open, royalty free building control systems.
EN50090-EN13321-1 and ISO/IEC 14543.

11.0 Survey of stand-alone monitoring systems equipment available from energy suppliers

The major utility companies not only supply primary energy but also provide a wide range of energy related equipment and clearly have an interest in providing their customers with display and control systems that will link directly with their future smart meters. A detailed study was conducted for the Energy Saving Trust by the Centre for Sustainable Energy entitled “The smart way to display - exploring consumer preferences for home energy display functionality”. This report focuses on display requirements for energy monitoring devices. Appendix 3 identifies products already available or proposed.

12.0 Selection, justification and prioritization by householder to invest in new systems

For all retrofit investments where a customer might wish to install a renewable energy source, it is possible that from the customer stand point there may be a preference in their selection based on their existing energy mix. For example, if gas provides the current heating and hot water, then the preference may be to add a solar thermal system, whilst a customer that only has electricity may choose to add solar PV. Where the size of the accommodation is limited, eg. apartments for the elderly, sheltered housing, etc., conventional systems may have integrated storage with heating or a combi-boiler. In these cases space for additional solar storage may be severely constrained and alternative storage systems or materials may need to be considered.

12.1 Storage

These choices may well also be linked to the storage aspects of a system. In general, expected uptake of renewable energy in the first instance is likely to be for domestic hot water only. A conventional wet central heating system will have space for a storage tank, offering the space opportunity for additional solar storage capacity. Conversely, a customer that only has an electricity supply may already have night storage radiators hence providing a readily available storage medium for heating.

12.2 Priority for investment

For the customer to invest in a DE system, the key incentive is probably the financial return rather than the more esoteric issues of saving carbon emissions. Any such installation must then compete with the many other demands on family expenditure, as indicated in Table 6.

Minimum disruption during installation of the required controls will be as important as for the major appliance installation itself. The government incentive scheme is designed to make a DE installation an attractive investment, but the customer will need to be encouraged to make this decision by being able to see proof of the benefits of previous installations and clear indications of the savings that their own system will provide during subsequent active use. This later point will drive the need for clear and easily understood displays linked to control systems and is supported by the recent confirmation by the government of the requirement for displays associated with smart metering.

Table 6: Drivers for purchase of an automated home controller

What would be the driving reason to purchase & install an automated home controller?			
Function	**Specifics**	**Purchase of**	**Ranking**
Home improvement	Heating/hot water control	New boiler	
		New radiators	
Energy saving	Renewable heating	Solar panel	
	Renewable power	Solar PV	
Safety	Fire/smoke detectors	Individual detectors	
	Gas detectors CO; CH4	Individual detectors	
Security	Burglar alarms	Door/intruder sensors	
	Intruder monitoring systems	Cameras	
	Lighting control	Automated curtains	
Convenience	Garage door opener	Automated doors	
Remote functions	Control by phone	Additional alarms & security features	
	Control by internet	Home automation system	
Electricity Smart meter	Displays electrical power consumption	Free utility installation Future customer tariff selection. Future utility remote control	
Gas Smart meter	Displays gas consumption		

13.0 Wireless communication for home automation systems

13.1 Security of information

Retrofitting new energy saving equipment into existing housing stock and linking into an optimal control system with potential to export electricity to the grid will require several types of controller and currently significant house rewiring, which is both costly and disruptive, and is often unacceptable to home owners. Wireless technologies have advanced to a degree where they are the most likely immediate solution to the problem. Security vulnerability is an issue for consideration at either local, regional or enterprise level. In general most of the information deployed in any home automation system is simply of an appliance control nature and is of little interest to hackers. However, if the information relates to occupancy then there may be some concern. For domestic installations using radio networks then transmission distances are quite limited but may extend to many meters beyond the property boundaries. When control is managed at a community level, then the integrity and security of data over much greater distances must also be considered. Finally, the security of data relating to individual properties held at enterprise level must again be protected against attack. Fortunately, there are now several competing systems that have evolved to overcome the various problems identified with earlier conventional wireless systems, which particularly related to reliability, cross-interference with adjacent systems, limited functionality, physical size and power consumption issues. Below is a brief discussion of the functionality of several systems in relation to home automation.

13.2 Blue tooth

New developments may lead to in-house home automation functions in addition to providing remote mobile phone access to systems and that will integrate with other home automation features, particularly in the entertainment field.

Applications

Bluetooth is intended for non-resident equipment and its applications. The category of applications is outlined as the Wireless Personal Area Network (WPAN). Bluetooth is a replacement for cabling in a variety of personally carried applications and can also support fixed location applications such as smart energy functionality in the home (thermostats, etc.).

Bluetooth protocols simplify the discovery and setup of services between devices. Bluetooth devices can advertise all of the services they provide. This makes using services easier because more of the security, network address and permission configuration can be automated than with many other network types. Bluetooth is divided into Classes based on power ratings that indicate potential communication ranges. Improvements in performance are indicated by version numbers as indicated in Table 7.

Table 7: Blue tooth operating distances and data rates

Class	Maximum Permitted Power		Range (approximate)
	mW	dBmW	
Class 1	100	20	~100 meters
Class 2	2.5	4	~10 meters
Class 3	1	0	~1 meters

Version	Data Rate
Version 1.2	1 Mbits/s
Version 2.0 + EDR	3 Mbits/s
Version 3.0 + HS	24 Mbits/s
Version 4.0	24 Mbits/s

Number of devices

A master Bluetooth device can communicate with up to seven devices in a Wireless user group. This network group of up to eight devices is called a piconet. The devices can switch roles, by agreement, and the slave can become the master at any time. At any given time, data can be transferred between the master and one other device. The master switches rapidly from one device to another in a round-robin fashion. Simultaneous transmission from the master to multiple other devices is possible via broadcast mode, but is not often used. The Bluetooth Core Specification allows connecting two or more piconets together to form a scatternet, with some devices acting as a bridge by simultaneously playing the master role in one piconet and the slave role in another.

Low energy

On April 21, 2010, the Bluetooth SIG completed the Bluetooth Core Specification version 4.0, which includes Classic Bluetooth, Bluetooth high speed and low-energy protocols. Bluetooth high speed is based on Wi-Fi, and Classic Bluetooth consists of legacy Bluetooth protocols. A link layer in these controllers will enable internet connected sensors to schedule Bluetooth low energy traffic between Bluetooth transmissions. Expected use cases for Bluetooth low energy technology include sports and fitness, security and proximity and smart energy. Bluetooth low energy technology is designed for devices to have a battery life of up to one year such as those powered by coin-cell batteries.

13.3 Wi-Fi applications

The Wi-Fi Alliance is a trade association. The category of applications is outlined as WLAN, the Wireless Local Area Networks. Wi-Fi is intended as a replacement for cabling for general Local Area Network (LAN) access in work areas, and is used for residential equipment and its applications. Wi-Fi is a traditional Ethernet network, and requires configuration to set up shared resources, transmit files, and to set up audio links (for example, headsets and hands-free devices). Wi-Fi uses the same radio frequencies as Bluetooth, but with higher power, resulting in a stronger connection. Wi-Fi is sometimes called "wireless Ethernet". Wi-Fi requires more setup but is better suited for operating full-scale networks; it enables a faster connection and better range from the base station. The nearest equivalent in Bluetooth is the DUN profile, which allows devices to act as modem interfaces.

13.4 GSM

Home automation controllers most likely will need to communicate with a smart meter and be accessible from remote locations through the use of land-line or mobile phone. A GSM phone is a type of mobile phone that uses the Global System for Mobile Communications to send and receive phone calls. GSM is a digital standard first offered commercially in 1991 and is currently the most popular mobile phone transmission technology in the world. The GSM standard uses TDMA digital technology, which allows for three different voice calls to be placed in the same time slot, rather than one call using the old analogy "cell" phones. This is possible through digital compression that GSM then builds upon with the addition of encryption. A GSM phone takes up the same amount of transmission space as the old technology, but has the additional benefit of added security.

One of the benefits of a GSM phone is the addition of a SIM card, or "Subscriber Identification Module." This chip slips into the back of GSM phones and provides all of the users' personal information. This includes contacts and calendar information in most cases, and more importantly the subscriber's personal identification information. Having this information on a removable chip enables a GSM phone user to move a

SIM card between mobile phones and still receive voice calls to the same number. It also prevents the user from having to re-input personal information each time a new phone is purchased. In Europe and most of Asia, GSM is the standard used by everyone. Having one technology enables users to simply move their chips to different phones if they travel to different countries or in most cases use the same phone. This is in contrast to the US, with so many competing standards and difficulty transferring between carriers.

The adoption of GSM technology and GSM phones as a standard also paved the way for the rise of text messaging in many countries. While text messaging is starting to become popular in North America, it is nowhere near as popular as it is in Europe and Asia. Carriers in the US in particular use various technologies in addition to GSM and must then route text messages through third party gateways. GSM and GSM phones have found a significant boost due to Cingular Wireless becoming America's largest mobile provider. They have adopted GSM technology and promote the GSM phone's ease of use due to a swappable SIM card. Though the US still has many competing technologies, a GSM phone is the international choice.

13.5 Z-Wave

Within the home environment new wireless communications are becoming available. Z-Wave is a patented RF communication system protocol that uses Frame Acknowledgement Retransmission, Collision Avoidance, Frame Checksum Check and sophisticated Routing to assure reliable, full home coverage.

One example product, shown in Figure 16 is from the company Zensys. The ZM3102 Z-Wave® Module is a fully integrated RF communication module that uses the unlicensed Short-Range Device (SRD) frequency band of 902MHz-928MHz in the US and 868.0-868.6MHz in Europe. It is designed for wireless control and monitoring of residential products such as lighting and appliance control, energy management, access control, security applications and building automation. The module includes an integrated Z-Wave single chip that comprises an RF Transceiver, 8051 MCU core, SRAM, Flash Memory for Z-Wave Protocol and OEM Application software, as well as the system crystal, and RF front-end circuitry, Triac Controller, and a wide range of HW interfaces. This complete RF solution enables OEM customers to RF-enable their products without having to do the time consuming work of designing, verifying and optimizing the RF design, resulting in much faster time to market.

Figure16:
Z-Wave module

Part of the success of the communication protocol is the fact that many commercial organizations have formed an Alliance in order to promote applications and have developed specific products for both domestic and commercial/industrial applications. A license agreement is usually required in order to use the technology. The Alliance comprises 144 companies, of which 25 include the words “Home Automation” whilst 19 others make reference to support design services or distribution of home automation related equipment. Appendix 2 shows products from an arbitrarily selected 4 companies in the alliance.

www.z-wavealliance.org

13.6 ZigBee

The ZigBee™ protocol is a wireless mesh network; see Figure 17, and is specifically designed for low data rate sensors and control networks. The manufacturers claim that when compared against other wireless protocols, the ZigBee wireless protocol offers low complexity, reduced resource requirements and, most importantly, a standard set of specifications. It is built on IEEE 802.15.4, an open standard similar to Bluetooth. Whereas Bluetooth is currently limited to networking only a limited number of devices, ZigBee can achieve 64,000. Wi-Fi could also manage this number but the high speed available may not be required for home automation and it has a much higher power requirement.

There are a number of applications that can benefit from the ZigBee protocol including, but not limited to:

- Building Automation Networks
- Home security systems
- Industrial control networks
- Remote metering

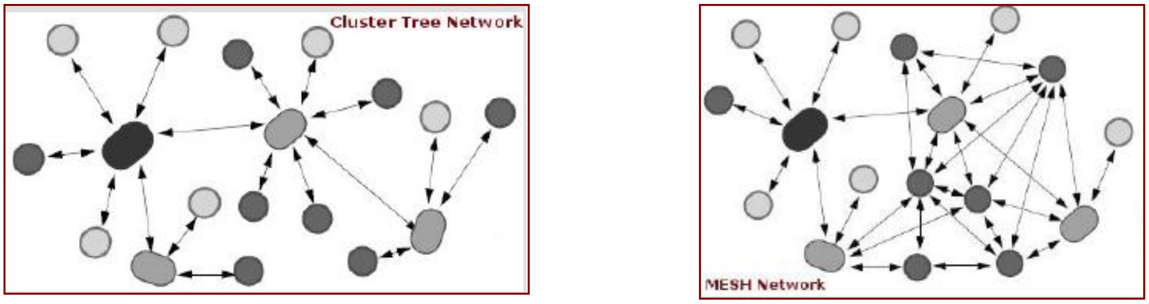


Figure 17: Cluster & Mesh Network architectures

Figure 18: ZigBee module

Zigbee is offered in two profiles, one is better suited to energy applications interfacing upstream, whilst the other supports the home area. In one product offering, **Error! Reference source not found.**Figure 18, from UControl Solutions, a 2.4GHz ZigBee RF module is integrated into a board with a PIC controller together with A/D and digital inputs and relay outputs. It will work with up to 65,000 nodes, which is far in excess of domestic requirements. Similarly to the Z-wave Alliance, the ZigBee alliance web site shows 12 promoter organizations, 160 participant companies and 184 companies adopting the technology.

http://zigbee.org

13.7 Industrial wireless networks

There are a wide range of manufacturers that have long standing in the supply of industrial/commercial communications, sensing and controls markets. These include the giants of the industry such as Satchwell and Honeywell. They have developed their own specific systems and protocols for managing the flow of data using both wire and wireless systems and interfacing with the well known standards names of, among others, field bus, profibus, Modbus and Nbus architectures and recently Millennial net, etc. They are well placed to provide communications systems particularly on the grid side of smart meters. These companies also offer a wide range of well known conventional hard wired products into the domestic markets, including programmers, control valves and thermostats and recently, new ranges of wireless based controls. One approach to maintaining their current bespoke wireless infrastructures is to provide universal interfaces to alternative systems.

14.0 Customer or utility first

Since there is a strong link between the control of new DE equipment in the residential market, and the need to measure its performance, in terms of energy efficiency and carbon reduction, there is a logical need to link measurements with a monitoring and control system linked to FITs and RHI. The smart meter linked to utilities is one of the most likely routes to provide this facility, although an alternative could be through the internet directly, providing all houses are fitted with a means of measuring energy consumption and have a method to connect to the internet. It is therefore important when considering controls platforms for residential systems, not only to consider the control actions themselves, but also to consider where the actual control system will be controlled from, ie. locally from within the premises, either physically within the equipment or centrally; or remotely, perhaps from a utility or third party energy service provider. The new Smart meters are to be integrated into a system referred to as an Advanced Metering Infrastructure, (AMI). They have higher functionality than the previous range of Automatic Meter Reading meters (AMR), which just collected meter readings electronically and were capable of transmitting this information to a local or remote meter reader.

The intention of the UK government is to install some 26 million electric and 22 million gas smart meters in all houses by 2020 in order to provide incentives for the customer to minimize fuel usage. At present the detail of the physical arrangements has not been finalized, but a new consultation document has just been issued that clarifies several of the key requirements including the fact that the utilities will underpin the main thrust of the installation activity and therefore, since customers may choose to change utility at any time, there must be a common interface between all customers and all utilities. There must therefore be a common set of standards that must be applied in all cases, but decisions on these have not yet been finalized. Further, since much of Europe is committed to adopting smart meter technologies, there is a strong desire of meter manufacturers to be able to have common EC standards. A summary of the control aspects of the latest briefing note are covered in the next Section.

14.1 The UK Smart metering implementation programme

In this section the key requirements the from the Government briefing note on smart meter implementation that effect controls aspects are provided. Several of these could impact directly on DE systems and on any advanced home automation controls.

Ofgem intends to introduce a package of measures in spring 2011, providing for consumer protections in areas such as remote disconnection, installation of new meters, and interoperability to provide suppliers with the necessary confidence to start installing smart meters and supports customers switching suppliers.

Within customer premises, the metering system will be a smart meter for gas and electricity, a home area network (HAN), and a wide area network (WAN). For domestic consumers, suppliers will also be required to provide an in-home display (IHD). IHDs will have dual fuel functionality so any second supplier providing gas or electricity in a dual fuel home can use the IHD provided by the first supplier. It will be at any second suppliers' discretion whether they wish to provide a second display.

A Statement of Requirements document has been produced by Ofgem, covering the requirements of the metering system. The Government's view is that a gas valve should be included in domestic meters. The Minimum functionality requirements of the IHD should include the ability to display the following:-

- current electricity and gas consumption
- historical consumption to enable consumers to compare current and previous usage
- information in pounds and pence as well as kilowatts and kilowatt hours, and the display must also present the information in a visual format which is non-numerical that enables customers to easily distinguish between high and low levels of consumption
- accurate account balance information
- information for both gas and electricity consumption

Suppliers will also need to consider the requirements of disabled customers when providing an IHD. For example, this may include the use of large display screens and bigger buttons. Customers will also be able to use their own display devices connected to the home area network if they so choose.

Communication of both gas and electricity data to and from smart meters in the domestic sector will be managed centrally. The central function will also provide a basis to simplify and improve industry processes, including change of supplier, and smart grid development. Communications functions scope will initially be limited to those that are essential for the effective transfer of smart metering data, and subsequently take on board meter registration from the network companies and Xoserve (a gas distributor's alliance). The central communications function will be a new licensed entity, which Ofgem will licence and regulate.

The proposed smart metering system functional requirements are designed to deliver the range of currently identified benefits, and to be able to evolve as the future requirements of smart grids become clearer. The functional requirements shall include the following:-

- The communications device should be modular or separate so it can be upgraded without replacing the meter
- "Last gasp" capability, which enables alerts to suppliers or network companies if the supply is interrupted
- The meter should have the capability to store at least 12 months of half hourly consumption data, to enable more effective and informed supplier switching and home energy management initiatives
- The meters and communications equipment will be able to be upgraded remotely through the download of firmware

- Supply License condition mandating rollout will oblige suppliers to install smart meters that comply with the Catalogue and Technical Specifications; these will be incorporated into the Smart Energy Code by Ofgem. This will ensure technical interoperability
- The gas valve should form part of the minimum requirements of all smart gas meters in the domestic sector
- A single HAN solution is not proposed by Ofgem, in recognition that there may not be a 'one size fits all option'. However there is a requirement that there should only be a single HAN within a customers premise where technically possible
- There is a requirement to limit the average power consumption of any mandated equipment in the consumer premise to 2.6W total
- The Gas meter communications is expected by Ofgem to be powered by a battery. Ofgem has proposed a functional requirement for a 15 year battery life under normal operating conditions (metrology, communications and valve operations where applicable). It is noted that battery life constraints mean that any battery powered device will need to operate less frequently, for example transmitting every 15 minutes (Gas) rather than every 5 seconds (Electricity) (as proposed for mains powered devices)
- Ofgem has proposed that the WAN module should be modular or separate from the electricity meter, with digital and physical security measures close to the meter. The programme will seek a level of WAN interoperability during the initial phase to ensure that consumers can switch between suppliers without the need to exchange the WAN module
- Meter design variants must also meet minimum functional requirements e.g. able to accommodate the likes of Economy 7 and dynamic teleswitching type tariffs
- No requirement for pulse outputs as it is unlikely it would be used when the functionality is already available in an enhanced form
- The consumer being present at the premises and acknowledges that certain criteria are met (e.g. appliances are off) when the supply is re-enabled after self or remote disconnection (which is distinct from outages due to supply faults)
- Pre-payment top up - the functional requirement includes the ability for remote (e.g. over WAN) and local top up
- Prepayment configuration - the functional requirements include that smart metering system has to support the emergency credit, overnight credit, friendly credit, debt recovery configuration and safeguards that are supported in token, card or key-based meters currently available. Also included are functionalities for new forms of disconnection such as trickle disconnection and time limited disconnection
- Health and Safety - any solution selected will have to meet national and EU obligations on Health and Safety
- Micro-generation - functional requirements include import / export metrology

The technical specifications for the HAN are yet to be defined by Ofgem, but solutions will need to be based on open and interoperable standards for any solution used. The WAN communications will be managed by the creation of a new central entity to identify and procure the most cost-effective solutions for smart metering data management and communications. The WAN communications module should be upgradeable without the need for the meter to be changed.

14.2 Meter manufactures current activities

To avoid demands on smart grid developers that technologies must adhere to specific communications protocols, there have been some moves by organizations to develop a Universal Metering Interface (UMI) that allows communications systems to be switched into, and out of, any smart meter. One such solution, which could be installed directly in the smart meter, is offered by Cambridge Consultants, based in the UK. Another has been developed by the U-SNAP Alliance in the United States. This alliance also seeks to build smart grid communications and devices that can be swapped throughout the power system without relying on a single protocol. Major firms including Google and GE are backing U-SNAP's efforts. Such solutions will allow for multiple communications standards to be deployed. Developers can continue releasing products that are based upon varying systems and no single standard would have to be favoured over another. At least one German meter manufacturer, Elster, has already committed to using UMI for its smart gas meters.

Choosing a single communications protocol is a difficult choice for developers of smart meters as well as other smart grid supporting technologies including smart appliances, software, and in-home energy management interfaces. Developers don't want to be confined by a protocol that is left behind when national standards are finally decided. In the UK, for example, it seems that the ZigBee protocol may be adopted while elsewhere in Europe M-Bus seems to be favoured, for example, in Germany and Holland, whilst in the US there are a range of options, including Zigbee and individual solutions such as web based and radio linked systems.

14.3 Meter and service suppliers linked to the smart grid

Again the control of residential devices is strongly linked to the development of the smart grid. Meter suppliers have strong historical associations and interfaces directly with the utilities themselves. The rollout of the meters will require a range of additional service suppliers and from these may be inferred indications of the technology directions that the individual utilities may adopt. A search of the web based on this premise has identified a few indicators.

Although broad requirements for interoperability have been set out by the DECC, currently there is believed to be slow movement towards both UK and a European standards. Cenelec, the body that sets electro-technical standardisation has a target deadline of 2012.

Three leading smart meter manufacturers, Iskraemeco, Itron and Landis+Gyr, have agreed interoperability standards across markets in Europe, the Middle East and Africa. They have demonstrated in tests that each company's smart meter technology is interoperable with the others'. In each case, the smart meters incorporate Interoperable Device Interface Specifications (IDIS) based on open international standards defined by the DLMS-User Association.

Itron – Has been selected by the Spanish utility Iberdrola as a partner in the first phase of a 100,000 smart meter trial. They will be responsible for the development and integration of an advanced meter management system, including the supply of meter data management software in the first phase.

Landis & Gyr - has commercialized the ultra-compact ultrasonic gas meter originally developed by British Gas. The meter is approved to BS EN 1359:1999, EN14236. This communicates with their electricity meter which in turn communicates with a home energy display both using low power radio. The electricity meter communicates with the utility via GSM as shown in Figure 19. The gas meter valve can also be remotely operated by the utility.

http://www.landisgyr.eu/en/pub/home.cfm

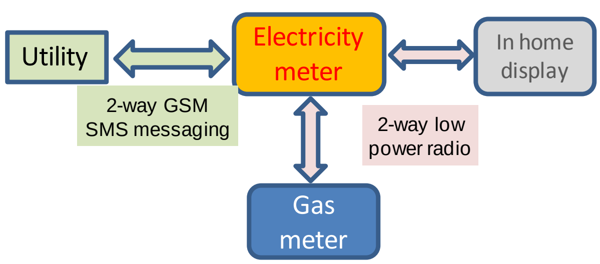


Figure 19: Landis & Gyr communication infrastructure

14.4 Requirements and Standards for Smart Meters

M-Bus - The Meter Bus was developed to fill the need for a system for the networking and remote reading of utility meters, for example to measure the consumption of gas or water in the home. This bus fulfils the special requirements of remotely powered or battery driven systems, including consumer utility meters. When interrogated, the meters deliver the data they have collected to a common master, which can, for example, be a hand-held computer, connected at periodic intervals to read all utility meters of a building. An alternative method of collecting data centrally is to transmit meter readings via a modem. Other possible applications in home electronic systems for the M-Bus are alarm systems, flexible illumination installations and heating controls.

15.0 UK energy utilities linked to energy saving activities and smart meters

Of particular note is the £10m Government funded/Ofgem managed "Energy Demand Research Project or EDR Project". This is a major trial with over 58,000 households taking part in trials and a further 16,000 households included in control groups. Over 17,000 households have had smart meters installed as part of the trial, many with both gas and electricity smart meters. The actual trials are being undertaken by four different energy companies (see later) but interim results may not be known until September 2010, with full results in early 2011. EDRP is expecting to be able to offer sub-sets of the data to interested researchers in the future. Of note from the trial are comparisons between clip-on energy monitors with visual display units and smart meters. However, technical information on the detailed configurations is not publicly available and therefore, from the controls aspect, details reported to date are of limited value except in general terms of functionality. Several setups are being tested and some general comments from interim progress reports are worthy of mention. The smart meter configurations under test include:-

- remote visual display of consumption and cost information of energy used for gas & electricity
- daily consumption information sent to the households' TV
- daily consumption information available on the internet
- linked to heat control units allowing customers to control their boiler through a wall panel whilst having access to accurate electricity and gas consumption data
- with an alarm which alerts the user to certain electricity consumption levels (load limiting alarm)
- with an energy savings reward tariff which rewards the user for limiting their energy use
- with a time of day tariff which rewards the user if they move their consumption to 'off peak' hour

Some general feedback on the options to date includes:-

- One trial investigates the impact of an energy feedback display that is incorporated into the household's heating thermostat/controller. This proved to be a difficult intervention to install, given the enormous variety of existing heating controllers and boilers. However, the preliminary findings suggest that there may be value in integrating energy feedback with existing devices with which people already use in the home.
- Customer feedback on VDUs includes a dislike of alarms that sound too frequently, a welcome for a distinctive 'traffic light' indicator on displays, and preference for energy use to be expressed in money rather than in kilowatt-hours. However, it is clear that different individuals prefer different features. Therefore the effectiveness of these devices might be determined by the quality of the design and functionality.
- One trial combines energy-saving tips with a financial incentive to reduce energy consumption. Households were offered a £10 voucher if they managed to keep their energy consumption below a target defined by their historical consumption. The effect of this incentive was immediate and dramatic with a pronounced fall in the electricity consumption of the group receiving the intervention. However, once the households had received their reward, their energy savings began to decline and were entirely gone around seven months later.
- Three rural communities targeted were each set a target to reduce their energy consumption by 10% with a substantial reward offered for success. In response, local people joined forces to develop and run energy-saving campaigns. When compared to geographically and demographically-matched controls, these communities have cut their electricity use significantly and are on course to receive their financial rewards. Also these trials have produced the biggest reductions in household energy consumption so far observed within the EDRP trials.

Some comments on smart meters from the trial on selecting the right technology

- Delivery of the trials so far has shown that one-size does not fit-all. Suppliers have to consider a range of factors in selecting the appropriate technology for a customer.
- Different geographical locations experience different signal strengths which can affect the ability of the meter to send or receive information.
- The location of a smart meter within the property is also important, eg. communications can be affected if the meter is in a metal box, in a basement, or is too far from the in-home display.

- The location or set up of a meter can mean that remedial work is required to move it, eg. if it is on an asbestos board, or if the smart meter is larger than the original meter and does not fit into the meter box.
- Installing smart metering in basements, blocks of flats, or communal housing tends to be difficult with regards to gaining access, getting a signal and utilising the Home Area Network (HAN).
- Practical issues affecting installation are generally obvious and easy to spot in a property however, in some cases technical problems may not be recognised until the meters and interfaces have been installed in a property for some time.

15.1 UK utilities activities on smart metering

A brief search of the web has identified a range of activities linked with the UK utilities. Again these activities may suggest the direction of smart metering and hence some of the linked associated control strategies. However, in most cases the search has demonstrated that the key activity of most companies is in providing competitive fuel prices, and many of the companies are simply linked to a major fuel producer. The companies explored are listed below:-

British Gas - Has announced plans to roll-out 1m Landis & Gyr dual fuel electricity and gas smart meters and provide householders with home displays. Existing standards will be used where possible. It has also appointed DHL to provide the distribution chain for its planned 16m smart meters. (a £17m, 5 year contract). Further, a division of Vodaphone, M2M (Machine to Machine), has entered into a partnership to provide SIM cards for reading gas and electricity meters in the home. The deal is part of the government scheme to roll out smart meters to 26 million UK homes.

EBICo – Supplied by SSE. http://www.ebico.co.uk

EDF Energy – Participant in the EDR Project

E.ON - Participant in the EDR Project. E.on also produce an energy monitoring product – Alertme (see section on energy monitoring products) and an energy monitoring kit suitable for home installation as shown in Figure 20. It comprises the following:-

- An energy monitor
- Power supply plug
- Transmitter
- Sensor jaw

Figure 20: The E.on energy monitoring kit

Data from the monitor can be downloaded to a pc and the supplied software enables the user to break down energy use by time and date as well as produce tables and charts.

First: Utility - The Google PowerMeter is a free electricity monitoring tool that receives data directly from a first: utility smart meter and displays detailed near-real-time information about how much electricity is being consumed on a personalised iGoogle homepage.

GoodEnergy - Invests in range of some 30 companies linked to renewable energy technologies, including the following as examples:- AlertMe - (Home automation), SAGE Electrochromics - (window coatings), Tendril - (Home automation) and Q-cells - (silicon cell manufacture)

Npower – Currently supplies smart meters to microgen customers. They have partnered with Arqiva, a communications infrastructure and media services company, to trial a smart grid ‘proof-of-concept’ network. Arqiva use FlexNet™, a long-range radio frequency relay system produced by the company Sensus, to communicate with smart meters over an 80 km^2 area around Reading in the south of England. It is expected to provide benefits in terms of reaching meters placed in basements or under stairs. They also offer an energy monitor that uses a clip-on sensor for the meter outlet as shown in Figure 21.

Scottish Hydro Electric – Is part of SSE. http://www.hydro.co.uk

Scottish & Southern Energy SSE – Is a participant in the EDR Project. SSE has also placed an order for £7 million of devices and services with Onzo that makes a display and wireless sensor kit that runs on energy harvested from the home electrical cable, see Figure 22. SSE has exclusive rights to their products and services in the UK and Ireland.

http://www.scottish-southern.co.uk

Atlantic Electric & Gas – Is part of SSE. http://www.atlanticeg.co.uk

Scottish Power - Participant in the EDR Project

OVO Energy - Currently do not provide smart metering. http://www.ovoenergy.com

Sainsburys – Service supplied by EDF

Southern Electric – Is part of SSE. http://www.southern-electric.co.uk

Spark Energy – Works with tenants and agents and is undertaking regional trials with smart metering partner Onstream – part of National Grid. The meter has on board memory & an embedded SIM card which records usage and meter reads and transmits the data as an SMS to the utility. The meters also include a digital display which can be toggled through to see reading, consumption, credit levels (if PAYG) etc.

http://www.sparkenergy.co.uk

Onstream - part of National Grid - Provide both gas and electric smart meters. They incorporate both wide area and local two-way communications. Both meters have integrated WAN and LAN communications allowing them to work independently of one another. Local area communications also enable the meters to communicate with In-Home Displays and smart appliances. The new electricity meter uses low levels of electricity, giving it a power consumption of only 0.55 watts when fully operational. The new meters also feature a roaming SIM, allowing the meters to detect the strongest available mobile network to transmit information to and from energy suppliers – see Figure 23.

Figure 21: Npower monitor

Figure 22: Onzo product from SSE

Figure 23: Onstream Smart meter

SWALEC – Is part of SSE. http://www.swalec.co.uk

The Utility Warehouse - No items identified.

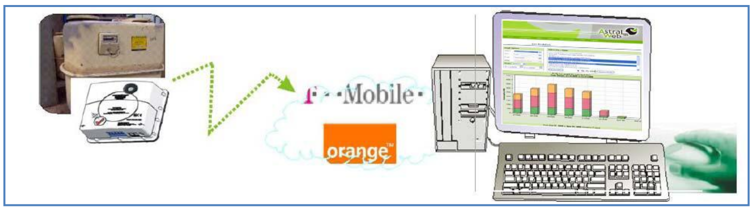
Utilita – No items identified. http://www.utilita.co.uk

15.2 Commercial premises and smart connections

Although the major utilities supply to both residential, commercial/industrial premises, there are also a number of companies that supply metering specifically to the commercial/industrial market. In these cases metering may be extended to include for example, water or heat metering. It is often suppliers to these markets that have to meet customer specific demands for greater functionality from the meter services and therefore Automated Meter Reading (AMR) has been more common in these applications. For example, a company might service a chain of supermarkets, a hotel group, a district council housing estate or a food outlet chain that requires specific details of their energy consumptions from the various sites. In these applications there is scope for value to be added to simple meter readings in the form of more detailed energy analysis, and this is often supplied by the meter companies. However, this review has not identified the potential for remote control of energy supply systems by the metering services supplier. Examples of the suppliers and communications technologies used in this market are provided below.

TruRead - This company uses smart meter products supplied by:-
http://www.truread.co.uk

Astraweb – This company offers a number of communication systems. The systems are supported by internet services for viewing the data. Examples from their web site, shown in Figure 24, include the following:-



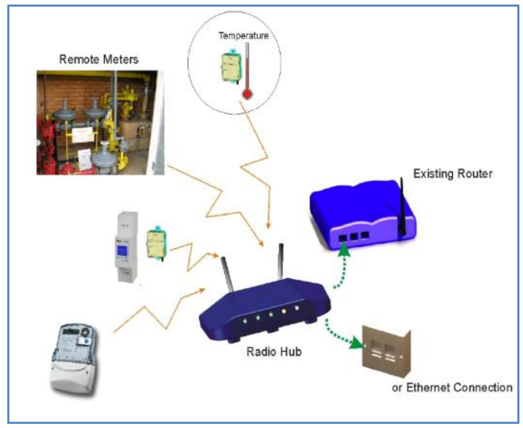


Figure 24: Examples of SMS communication (left) and Simple Low powered Radio (right)

Corona Energy – This company utilizes SMS from a unit connected to the meter to provide AMR services.
http://www.coronaenergy.co.uk

15.3 European utilities experiences

A review of European activities has not been undertaken. However it worthy of note that Italy has a complete country role out of smart meters and in Sweden, Gothenburg Energy is the first utility in Europe to implement a ZigBee-based communications infrastructure for a full rollout of an Advanced Metering Infrastructure, AMI, currently focused on electricity. BT Redcare has signed a deal with IMServ, an energy management firm, to deliver internet connectivity to 10,000 meters in the UK.

15.4 USA experience with smart energy platforms

In parallel with the UK initiative to install smart metering, President Obama has pledged to help US utilities install 40 million more smart meters – about 6% have been installed to date - (basically digital meters that create a 2-way connection with the power grid and the utility). Some smart energy solutions for consumers bypass smart meters and utilities and just help the interested consumer with a standard electricity meter. They are cheap and available online, but they provide less detailed data. On the other hand, utilities are exploring options for linking smart grid and home automation systems. What is clear is that the majority of products are wireless configured for home use and are often web enabled for communication with utilities.

Several companies have launched their first energy dashboards, some with online tools. A major difference between these products is whether companies will sell directly to the consumer or to utility partners to link with proposed smart meter installations. The utility-focused tools use smart meter information to provide a more in depth energy analysis whilst they can also be used to control smart appliances for utilities. Some manufacturers are introducing smart appliances. For example General Electric has said it could start selling some of its smart appliances — dishwashers, water heaters, microwaves and other devices embedded with communications technology. However, it is thought that this may be the longer term solution as new domestic appliance products replace old. There will therefore be an incentive for utilities to provide already developed energy management software and hardware for utilities and consumers.

http://Earth2tech.com

A web review of some of the options, either already available in the USA or under development provides an indication of the diversity of approaches that could be adopted, and Appendix 4 provides a more detailed listing of some of these. From this analysis Figure 25 provides an indication of a typical smart grid structure and indicates that there are possible separate individual zones of communication that are ultimately required to link a home DE appliance with the utility.

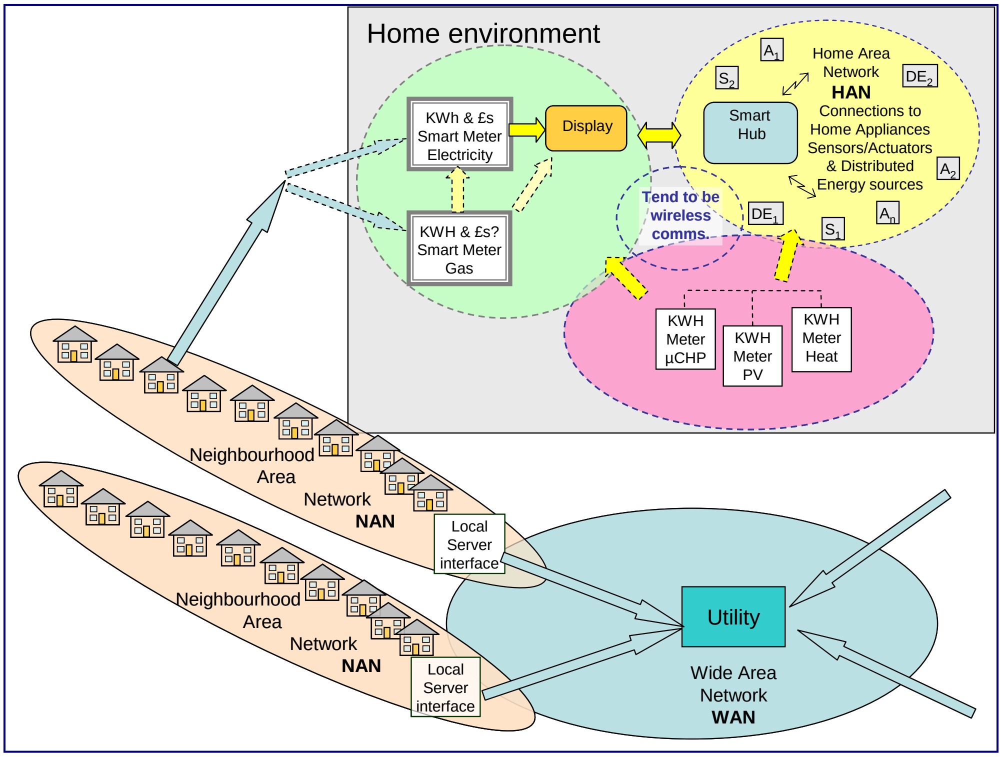


Figure 25: Schematic diagram of linkages between home automation and the smart grid

At the customer or home level (the Home Area Network or HAN), there needs to be a common set of communications protocols between the appliance control systems and the smart meter that may preferentially be met through a common home centre or hub. The timely development of efficient wireless communication protocols coupled with modern low cost and power consumption electronics presents the key opportunity to install wireless domestic systems with minimum time and interruption to normal daily life. At the basic level this can be as simple as plugging all equipment into the electric mains via low cost intelligent plugs. Within the local residential utility area (the Neighbourhood Area Network or NAN), the utility requires to collect community smart meter information, change tariff structures, etc. and the physical communication medium (eg. Optical fibre or cellular/GSM) and network protocols can be different from the home level. However, this activity could be linked directly with the next level shown in the diagram (WAN), if GSM or 4G communications were to be adopted. Collecting and transmitting all the required data from the NANs at the national level requires further utility infrastructure (the Wide Area Network or WAN). Again communication media and protocols may be different.

Appendix 5 shows a suitable platform for smart metering developed by Texas Instruments, TI, that includes modules for meter signal processing and various communications interfaces, including wired and wireless networks for HAN, WAN.

http://www.ti.com

16.0 New UK innovations in advanced home energy controls

There are a range of products that exist on the market that are probably more appropriate to small commercial installations rather than domestic applications because of their required specialist knowledge for setting up and installation. These are often derivatives of full building automation systems and are usually available from the major electronic control system companies such as Honeywell and Satchwell Controls. There are other suppliers of such equipment, one example, the WebBrick Controller, is shown in Figure 26. Some features of this device include a wide range of configurable inputs and outputs, including 4 analogue inputs and outputs, 12 digital inputs, 8 digital outputs, 4 mains voltage outputs, 1 volt free, plus a further range of digital outputs. It can be LAN, and web connected and includes 16 configurable weekly schedules.

http://www.Webbricksystems.com

Figure 26: WebBrick Controller 7.0 and screen display

A number of new home energy controller products are beginning to emerge on the market that promise to provide home energy savings in the order of between 10 to 20% by utilizing what is known as "Occupancy control". It is the intention of these products to replace conventional time clocks and thermostats and heating control programmers. Previous studies have found that existing home heating controls often make it difficult for people to cut fuel costs because they are too complicated to set correctly. By using intelligent software to learn the habits of householders, for example when hot water is required, when the occupants are at home and require heat and when other extraneous heat-producing devices are used, coupled with knowledge of the thermal response of the building to internal and external temperatures, then optimization routines are employed to provide the required time/temperature control for the home. If automated conditions are not considered adequate by the house holder, then adjustments to temperatures can be made and the system learns from these inputs. Major changes may be indicated by displaying the change in energy consumption that will result. A particular advantage of this overall approach is that the house owner does not necessarily need to understand the best way of optimizing the use of any particular appliance, enabling novel new energy saving technologies such as heat pumps and solar heating to be seamlessly integrated into the overall operating performance of the integrated house environment.

There is an issue of identifying when the home is occupied. There are indications that simply having a touch-switch to indicate in or out is not used adequately by the householder and alternative approaches are being studied. For example a simple door opening detector may suffice in some circumstances, or a PIR or microwave detector can be used to identify occupancy, but although this approach may be sufficient in for example a hotel room, it is more likely to require additional smart software to be reliable in a domestic house environment. Examples of these controls are available from Prefect Controls Ltd.

http://www.prefectcontrols.com

Finally, by linking these new control options through low cost, wireless communication interfaces to appliances, and back to utilities through broadband links or smart meters, minimal installation issues are perceived. Three products have been identified in this review.

AlertMe: Is a home automation product for monitoring and controlling energy usage, Figure 27. It comprises a home hub that communicates wirelessly with other AlertMe devices that include a meter reader and smart plugs. It uses a Zigbee standard protocol, 805.15.4, designed for low power, low data speed, robust, mesh networks for wireless Home Area Networks (HAN). This operates in the 2.4 GHz license free band, the same part of the spectrum as Wi-Fi and Bluetooth. The mesh network with self-healing properties, allows greater flexibility to find the best route as conditions change, such as doors being opened or closed, or new accessories are being added. Using an existing broadband connection, the AlertMe dashboard provides real-time two-way data flow, online and through a mobile which means that system updates are enabled. It uses the Google PowerMeter, as an online dashboard.

Figure 27: Alertme product

Cisco: Cisco have announced they expect to market a home energy management system with a table-top touch-display by the end of 2010. It will connect to the meter and appliances using wireless links and through a ZigBee network interface. A WiFi/Ethernet interface will provide communication with a home broadband gateway and possibly with utilities.

http://www.cisco.com

Green Energy Options: A company based in Cambridge, UK market a range of energy monitoring products. One called the Home Energy Hub, comes in three display options:- a small one-panel display, the Solo, which shows real-time pricing and consumption; the two-panelled Duet, which shows energy management of up to six appliances; and the Trio, which is a large touch-screen that can monitor up to 100 sensors.

http://www.greenenergyoptions.co.uk

PassivSystems: The system comprises a hub unit, a control unit and various sensors all connected via wireless technology, see Figure 28. The control unit, in addition to a set of progarm functions that enable basic operating times and temperatures to be entered, uses a simple set of four buttons to communicate with the user:-

- In - means there are people at home and that they are awake.
- Asleep - means everyone at home is in bed.
- Out - means no-one is at home for a while today.
- Vacation - means no-one is at home for more than one day.

Additional control is managed by occupancy override button(s) that may be located by the front door or in a bedroom.

Figure 28: PassivSystems home automation control panel and control centre

The hub is the central node of the secure mesh wireless *Home Area Network* (HAN) co-ordinating the communications with all of the sensors, switches, actuators, and displays in the home. It also connects to an existing broadband router using a standard Ethernet cable. This allows it to communicate securely with PassivSystems' online services, although the system also works independently for long periods of time.

An indication of prices are as follows:-

- Basic package - £395 plus £60-a-year service charge This includes the PassivHub, the PassivController, one temperature sensor, one occupancy button and the boiler controller.
- Basic package plus hot water management - £484 plus £80-a-year service charge.
- Installation costs will apply in addition, installation is expected to take around an hour and a half.

http://www.passivsystems.com

Wattbox: De Montfort University's (DMU) Institute of Energy & Sustainable Development (IESD) has designed a device called Wattbox through grant funding from EPSRC and E.ON. Twenty eight units will be tested as part of the "Retrofit for the Future" project funded by the UK Technology Strategy Board and will be customised to control a wide range of the advanced heating sources specified, including air and ground source heat pumps, wood chip burners, micro CHP, solar thermal and regular gas boilers. The programmer unit is shown in Figure 29.

Figure 29: Wattbox programmer

One feature of the device is that it dispenses with the conventional programmer operator interface and replaces this with buttons for "more heat" and "less heat and by using high accuracy temperature sensing instead of normal thermostats, further energy savings are possible.

http://www.wattbox.com

17.0 The market for controls

17.1 Costs of current heating controls

The well established domestic heating controls industry supplies a wide range of products in a competitive market. By way of example, a standard central heating controls pack may comprise a programmer, room and hot water tank thermostats and two control valves with prices ranging from £80 to £220 excluding VAT, depending on brand and level of sophistication.

A cost comparison of the increased prices between radio controlled and hard wired devices, such as programmers and thermostats, suggests that there is an increase of between 36 and 60%.

https://www.bhl.co.uk
http://www.discountedheating.co.uk

These figures compare favourably with the values determined in the next market analysis section.

17.2 Survey of future market for heating controls

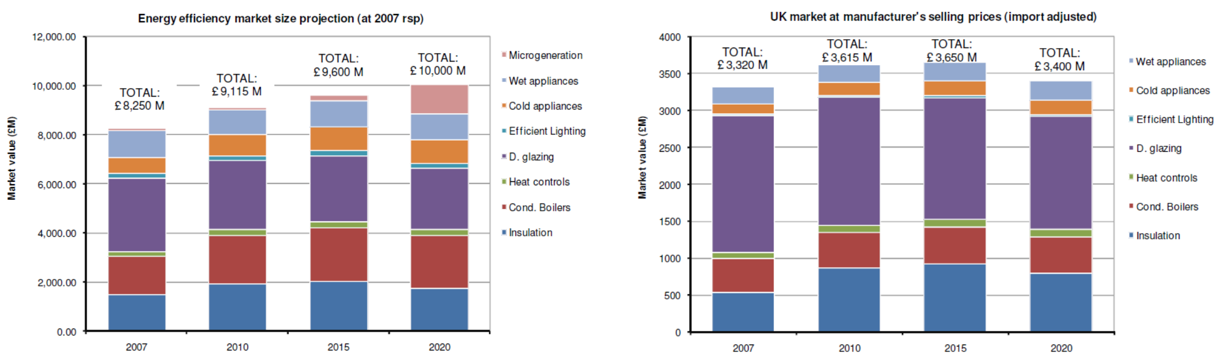
A survey of the web has indicated that most reports on market size are commissioned through marketing organizations and as a result reports in general need to be purchased. However, a recent report "An assessment of the size of the UK household energy efficiency market-November, 2008" was commissioned by the "Energy Efficiency Partnership for Homes", the EEPH and is available on-line. The sponsors for this organization include many of the major brand names in the domestic supply sector, including the heating appliance manufacturers.

http://www.eeph.org.uk

The report was undertaken by Element Energy Ltd.; Quantum Strategy & Technology Ltd. Some of the data in the report is taken from a further report by MBD - Market and Business Development, entitled "UK Residential Energy Efficiency Products Market Development" and is based on an established market model.

http://www.quantumst.co.uk
http://www.mbdltd.co.uk

Since the market for DE equipment is in its infancy it is difficult to predict the market size for the control systems component. The intention of this section is to try to extract some cross-correlation with the conventional controls component for heating systems and to achieve this, an attempt has been made to extract actual numbers from several of the graphs provided in the EEPH report. Figure 30 shows two graphs taken from the report predicting future market growth in the home appliance market. The focus is not particularly on DE products but more on the future market of the established home improvement product range in the energy efficiency market. The graphs include a component referred to as "Heat" controls.



(a) (b)

Figure 30: Projections of size (value) of household energy efficiency market

In Figure 30a the split is by major market sectors at 2007 retail selling prices whilst in Figure 30b the UK manufacturing component of the total market size is shown. In this case the market size has been adjusted to take account of the value of imported products, which is not retained in the UK economy. This has particular impact on the value of the appliance and lighting markets, which are heavily reliant on imports. Substantial manufacturing of boilers (and heating controls), double glazed windows and insulation products exists in the UK. However, the graph excludes Microgeneration products.

Some assumptions are required to interpret the data. Of the list of energy efficiency products, heat controls would appear only to relate to condensing boilers and further it is also assumed that the figures exclude integrated controls within individual appliances. In other words the heat controls relate to devices such as programmers and thermostats or generally perhaps a package of appropriate controls for a condensing boiler.

The boiler manufacturers expect that although new DE technologies will be deployed they will still require backup capacity. For example, Vaillant in a presentation on the future of gas boilers to the annual conference of the IGEM in 2009 predicts that there is a potential requirement for upgrade in "dual source" systems and controls for some 17m homes. The market potential for condensing boilers is also available in the EEPH report as shown in Figure 31.

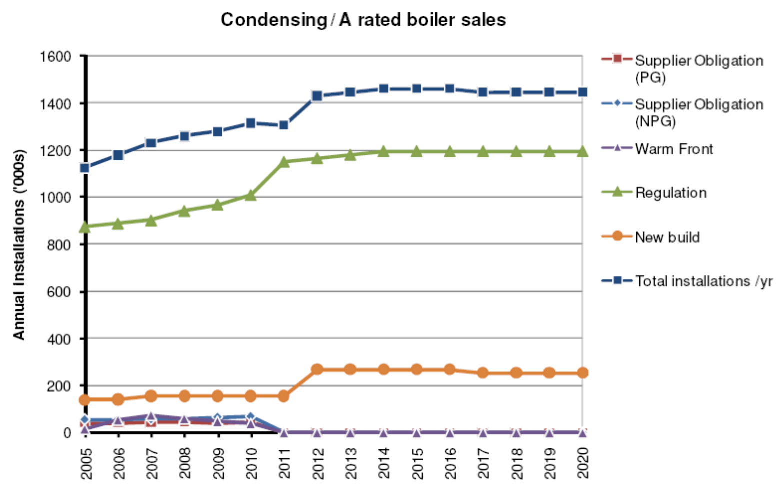


Figure 31: Predicted growth in condensing A-rated boilers from EEPH

The total market numbers have been extracted and are shown in row 1 of Table 7. From the two graphs shown in Figure 30, the size of the non-integrated controls market is a comparatively small component of the total energy efficiency market and remains fairly static at around 2%, whilst as a percentage of the condensing boiler market, it is nearer to 10%. The market value remains fairly static at £182m but rises to a projected peak of £243m in 2020 as shown in row 3 of Table 8.

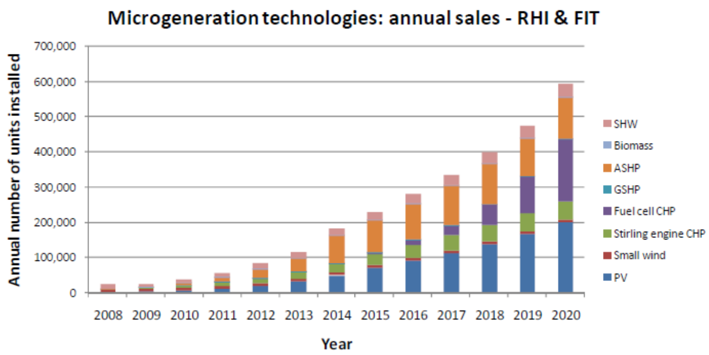
Table 8: Predicted controls market value

		Year >>	2007			2010			2015			2020		
Market for Condensing Boilers (CB) and heat controls			% of		Value	% of		Value	% of		Value	% of		Value
	Row		Total	CB	£m, m or £	Total	CB	£m, m or £	Total	CB	£m, m or £	Total	CB	£m, m or £
	No.	Number of CBs installed m			1.221			1.305			1.461			1.461
Total Energy efficiency market	1	Total market size £m			8250			9115			9600			10000
	2	Condensing boiler market £m	19		1558	21		1907	22		2139	21		2070
	3	Heat controls market £m	2	12	182	2	10	182	2	9	182	2	12	243
	4	Condensing boiler unit cost £			1276			1461			1464			1476
	5	Controls unit cost £			149			139			124			173
Total UK manufactured products market	6	Total sale prices £m			3320			3615			3650			3400
	7	Condensing boiler market £m	14		450	13		465	13		484	14		472
	8	Heat controls market £m	1.8	13.5	61	2.0	15.7	73	2.4	18.1	88	2.4	17.1	81
	9	Condensing boiler unit cost £			368			356			332			337
	10	Controls unit cost £			50			56			60			58

If only the value of the UK manufactured product market is considered then the corresponding values are shown in row 8 of Table 7. This shows that again the overall market share is similar at around 2 to 2.5% whilst the percentage of the actual condensing boiler sales is somewhat higher as 13.5 to 18% with a market value of £61m to £88m.

Combining the results for the heat controls markets gives the predicted sales and manufacturing costs per unit condensing boiler and unit control as shown in rows 4&5 or 9&10 in Table 7. In summary, the prediction is that the average manufacturing price of a controls unit is in the region of £50 and the market price in the region of £140.

Developing this theme and reviewing the predicted growth in sales of microgeneration equipment from the EEPH report, as shown in Figure 32 and assuming home automation controls not associated with an appliance are excluded, then assuming a value similar to the selling price of controls for domestic condensing boilers of £150 for all DE appliance controls, the value of the market may be estimated as indicated in the accompanying Table in Figure 32.



DE Technology	Annual No. of units installed			
	2007	2010	2015	2020
PV	0	5,976	68,293	198,049
Small wind	8,537	8,537	6,829	5,976
Stirling	0	2,561	27,317	52,927
Fuel cell	0	2,561	8,537	175,854
GSHP	1,707	2,561	3,415	3,415
ASHP	1,707	3,415	88,780	116,098
Biomas	1,707	3,415	3,415	4,268
Solar HW	11,951	6,829	22,195	34,146
Total number	**25,610**	**35,854**	**228,780**	**590,732**
Control unit cost £/ unit	136.901	**150**	173.89	201.59
Market value £m	**3.51**	**5.38**	**39.78**	**119.08**

Figure 32: Predicted number of installed UK DE technologies from EEPH & estimated market size*
* assumes average price of £150 per control unit for all technologies

Clearly, the unit price for the controls will depend on the DE technology employed and further refinements could be made to the prediction. A further issue of key interest will be just how much saving will improved controls provide to a DE technology.

17.3 Benefits expected from use of controls

It is not the intention of this report to determine relative efficiencies of the competing controls systems and DE technologies. However, a few comments are in order. Determining the overall gains in whole house energy efficiency achieved from the use of controls is a complex issue and may be inferred from a number of different approaches. However, the SAP approach identifies the following percentage improvement values:-

No thermostatic control of room temperature – regular boiler c………. -5%
A condensing boiler with weather compensator…………………………+3%
Heat pump with weather compensation…………………………………..+5%
Weather compensation……………………………………………………..+2%
Solar thermal installation……………………………………………………+12-15%

In the case of overall housing stock, improvements are measured more on the basis of reductions in the CO_2 emissions rate measured in kg CO_2/m^2 /yr – the Dwelling Emissions Rating (DER). For new build housing a reduction of 2% is achieved from modulation of heat output.

In the case of microgeneration equipment the efficiency is measured in terms of a Heating Plant Emission Rate (HPER) measured as kg CO_2/kWh. In the case of the Stirling engine system from Baxi, because the Ecogen is heat led, the HPER is for each kWh of heat generated, but the carbon value is for both heat and electric generation (as the electricity is a by-product).

http://www.baxigroup.com

APPENDIX 1: Examples of Manufactures Control Systems from Web Survey

Manufacturer: Vaillant **Web page:** vaillant.co.uk

Product ranges:

Air conditioning	✓	**Solar panels – flat plate**	✓	**Conventional boilers**	✓
Ventilation with heat recovery	✓	**Solar panels - evacuated**	✓	**Biomass boilers**	✓
Heat pump - ground source	✓	**Storage systems**	✓		
Heat pump – air to air	✓	**Control systems**	✓		

Control Systems - Key Functions:-

Solar differential controller

- Three time periods for auxiliary cylinder
- Monitors temperatures of the collector(s) & cylinder (up to 3 sensors).
- Controls solar pump - when sufficient solar energy is available to charge the cylinder.
- Controls requirements of auxiliary heat source - when there is insufficient solar energy
- Anti-legionella pump control
- Connection for auxiliary heater
- Display features: Numeric display
- Service/diagnostic feature
- Special functions: holiday; party; one time re-heat

AuroMatic 560

Programmable room thermostat

- Independent time control for central heating
- Can be used to time control the DHW
- 3 independent time windows per day
- Special functions: over-ride function, holiday function,
- Adjustable set-back temperature
- 3 room temperature profiles
- Calendar function for automatic summer/winter changeover

VRT 360; 360; 400

Wireless programmable room thermostat

- As above but wireless

Digital weather compensator

- As above with weather compensation
- Requires externally mounted temperature sensor
- Boiler requires an eBuS interface

VRC 430

Ventilation with heat recovery

- Set the required air volume for the building
- Set times for normal, low and boost operation,
- Automatically set by-pass control
- Provides energy saving (gain) information
- Diagnostic and servicing indications
- eBus compatible

Recovair

Manufacturer: Worcester - Bosh **Webpage:** www.worcester-bosch.co.uk

Product ranges:

Air conditioning	✓	**Solar panels – flat plate**	✓	**Conventional boilers**	✓
Ventilation with heat recovery	?	**Solar panels - evacuated**	✓?	**Biomass boilers**	
Heat pump - ground source	✓	**Storage systems**	✓		
Heat pump – air to air	✓	**Control systems**	✓		

Control Systems - Key Functions:-

Solar panel control

- User selectable hot water cylinder temperature.
- Automatic pump control
- New products family of intelligent heating controls for boiler and solar water heating systems.

TDS Solar controller

Air to water heat pump control

- Weather compensation control
- Peak domestic hot water use boost
- Thermostatic blending valve increases hot water availability
- Automatic supplementary extra heating when required

Air to air heat pump remote control

Air to air heat pump control

- Inverter technology – modulates with high demand

APPENDIX 2: Examples of Home Automation Products from the Z-Wave Alliance

Nb. The Z Wave Alliance lists 144 companies, all but 11 of which include 3-line product briefs. Of these 25 include the words “Home Automation”. 19 others make reference to support design services or distribution of home automation related equipment. Below is a selection of the “Home Automation” products.

2 gig Technologies Inc http://www.2gig.com

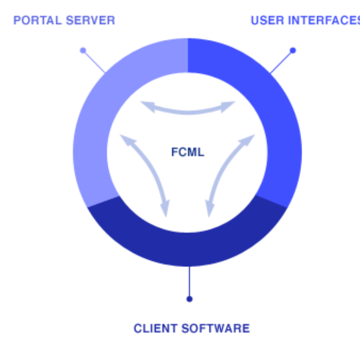
Functionality

- Mainly security
- HVAC & lighting control coming soon
- Quick arm – exit control
- Voice response
- Weather & forecast
- Touch screen
- GSM communications
- Over the air software updates
- 2 way cellular response
- Wireless thermostat
- Glass break sensor

Standards

CSFM listed
ETL listed to UL 985; UL 1023; UL 1365; ULC-S545-02; ULC Subject C1023; ANSI-/SIA CP- 01-2007

4Home, Inc. http://www.4home.com



A platform, named FLUID, has a distributed software architecture to meet each partner’s needs by including a full SDK for creating custom User Interfaces, modular design architecture, hardware independence, design using open standards when possible, support for most communication standards, and compatibility with the partner's existing infrastructure. It includes three components:

- Client software implemented as a set of modular OSGI-compliant bundles
- A portal server
- An interchangeable software suite of networked User Interfaces (UIs)

Functionality

All three components communicate with each other via FCML, an XML-based set of messages. FCML provides a unified abstraction layer to standardize communication throughout the Connected Home. The FLUID platform allows a variety of Connected Home Services (CHS) to be delivered to the broadband-connected home. Its flexible and modular design allows customized solutions based on specific application requirements to be supplied quickly.

Actiontec Electronics http://www.actiontec.com

The zControl™ provides ability to both monitor and control the home from remote locations. Together with its home networking and streaming capabilities, it integrates the electronic devices in the house giving access to almost every electronic item, from almost anywhere.

Functionality

Supported devices include the following:-

• Computer; IP Camera	• Z-wave enabled device
• Lights	• Thermostats
• Doors	• Windows
• Garage doors	• Shades and blinds
• Lawn and garden devices	• Motion Detectors

Features

- One interface to control all devices
- Intuitive interface
- Easy setup and configuration wizard
- Control devices from within or outside the home
- Auto-discovery of compatible devices
- Receive alerts or messages based on certain actions
- Monitor and record activity captured by each IP camera.*
- Works with any router or gateway

Aeon Labs http://www.aeon-labs.com

- A range of Z-Wave products for home automation

Features – all Z-Wave devices

- Door/Window sensor. Battery-powered magnetic door/window
- Z-Stick Series 2: Self powered USB dongle
- Minimote: Low-cost remote controller focussed on end user ease of use
- Home energy monitor: Low cost for the entire home
- Smart Energy Switch: Low cost appliance switch reports wattage usage
- Z-Stick Lite: USB Communication device
- Multi Sensor: Battery-powered motion, temperature and lighting sensor
- Smart Energy Illuminator: Low cost

APPENDIX 3: Examples of Electricity Monitors Offered for the UK Market

In this appendix four example products provide an indication of the many low-cost home energy monitors for electricity consumption sold in the UK, in this case from a company called Ecofreak.

http://www.ecofreak.co.uk

In all cases the unit comprises a clip-on sensor to fit around the incoming mains meter cable, a transmitter unit (wireless) and a receiver/display unit. Additional sensors may be purchased, hence providing a more in depth analysis of individual appliance consumptions. However, in general, the manufacturer will propose that in the first instance each appliance is switched on separately to identify its basic power consumption.

Control of appliances is entirely up to the user, who is expected to learn which appliances use the most power and apply appropriate energy reduction measures. Some companies link the user to sources of energy saving tips. The major issue with such devices is the longevity of interest by the customer and whether the savings achieved following initial installation and interest can be sustained. The EDR project will hopefully provide some answers to these questions.

Efergy Elite
Various display functions
433.52MHz Radio Frequency
Can be connected to PC

Wattson
Novel power consumption display
433MHz Radio Frequency
Can be connected to PC

Owl
Various display functions
433MHz Radio Frequency
Purchase of additional transmitter to connect to PC

Current Cost
Various display functions
433MHz SRD band Radio
Connects with up to 9 intelligent plugs
Connects to PC - Compatible with Google Powermeter

APPENDIX 4: Examples of USA Smart Platforms

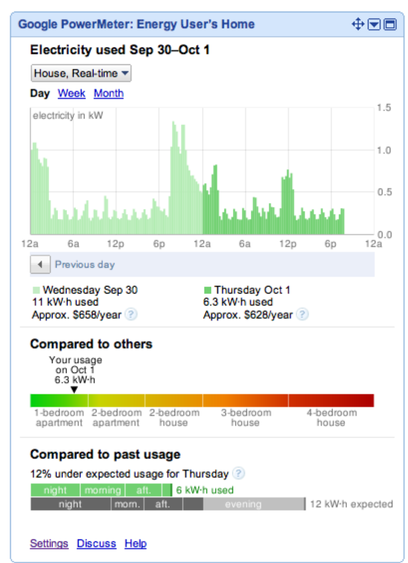
Agilewaves: A Resource Monitor tracks and manages energy, gas and water consumption in real time from web-enabled devices. The system, custom-designed for larger buildings and higher-end homes, needs to be installed by an electrician and can also be used to dim lights, turn on and off heating and cooling, and adjust smart appliances. http://www.agilewaves.com

Ambient: Uses internet protocol technology. http://www.ambientcorp.com

Energy Aware: PowerTab is a wireless energy display that collects current energy price and usage from smart meters. Comverge, a demand response company distributes the device in North America together with a range of load control and advanced metering equipment. http://www.comverge.com & http://www.energy-aware.com

EnergyHub: Makes a high-end energy dashboard that has a touch screen display, graphic and spreadsheet-type information, a web portal and a power socket/strip. The device will be sold direct to consumers online and through utilities. They have announced a partnership with the electric utility Consolidated Edison Company of New York (Con Edison). It will provide residential HVAC control, energy monitoring, and electrical appliance management together with total electricity and gas usage. The Consumer Web Portal gives residential customers detailed analysis of their energy usage, as well as remote control of their energy-consuming devices in the home. As two-way messaging platforms, the dashboard and Consumer Web Portal display energy prices and peak-demand warnings, send customers energy-saving tips, and manage demand response events. http://www.energyhub.com

The Energy Detective: The Energy Detective (or TED) is an energy management tool that is already available. The Charleston, S.C.-based company Energy Inc., behind TED, says its system can save home owners 10-20 percent on their monthly electricity bill. http://www.theenergydetective.com



Google PowerMeter: Google has introduced a free PowerMeter, its online energy information tool that can be accessed from any internet-enabled device. Google is working with device makers (Alertme in the UK) and is launching the product either as direct-to-consumer or through a utility. To date in the UK they have linked with First Utility. http://www.google.com/powermeter

GreenBox: Like Google, GreenBox is developing a web-based software energy tool. The team, founded by developers of the digital web platform Flash, is already working with utilities, including Oklahoma Gas and Electric and an as-yet-unnamed New York utility, and has also partnered with smart thermostat makers Energate and Golden Power Manufacturing. They have just been acquired by Silver Spring Networks. http://www.getgreenbox.com

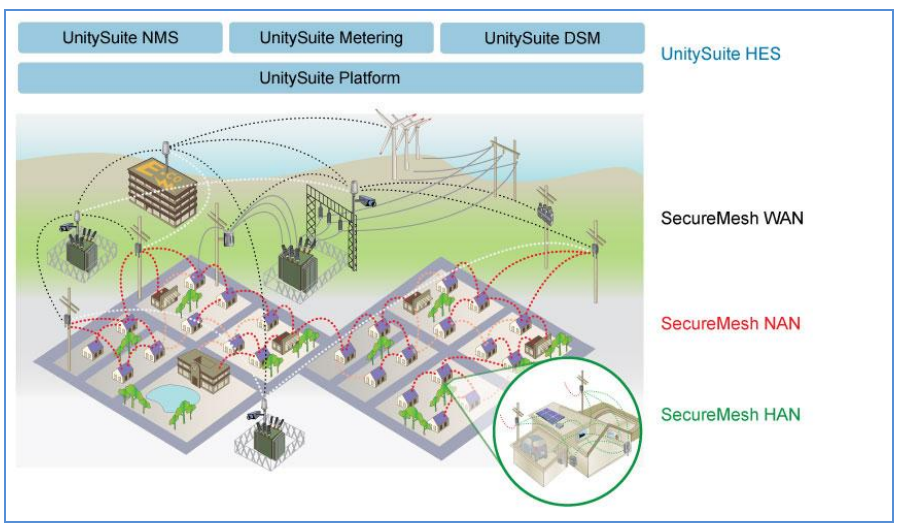
Intamac: Offers web-based applications managed service that will allow them to control energy usage in homes. Content is delivered over fixed and mobile broadband allowing end users to monitor and manage their energy consumption. The managed web platform also provides an API/SDK layer that allows easy and quick development of third party applications for connecting objects such as thermostats and smart plugs. They provide technology partner products and services through a ZigBee and Zwave gateway. Dynamic control of individual devices can also be delivered allowing new service propositions to be developed in identifying energy wastage and dynamically controlling these devices based on known or end user initiated profiles. http://www2.intamac.com/energy.

PowerMand: DreamWatts, produced by PowerMand Inc. provides a technology platform that uses a wireless ZigBee(R) energy management tool that focuses on making smart thermostats effective for cutting energy consumption. The company, which is partnering with facilities maintenance firms and utilities, provides a smart thermostat, an Internet gateway and a service running over their servers. http://www.powermand.com

SmartSynch: The platform combines a suite of IP-enabled smart meters, smartboxes and software solutions that use data collection, network management and predictive analytics. http://www.smartsynch.com

Tendril: Tendril is working with GE to develop software that will link GE's smart appliances to the grid and the utility back office. Their products include a wireless in-home energy display, a smart thermostat, a web-based energy portal, smart outlets and cell phone apps. The company offers its tools to utilities and is considering a direct-to-consumer approach. http://www.tendrilinc.com

Trilliant: Have developed an integrated, three-tier, virtual communications network architecture called "Secure mesh™" for utility Smart Grid applications. Each network provides the most appropriate required bandwidth and latency, ensuring the most effective and efficient use of each tier. The three tiers comprise the following:-



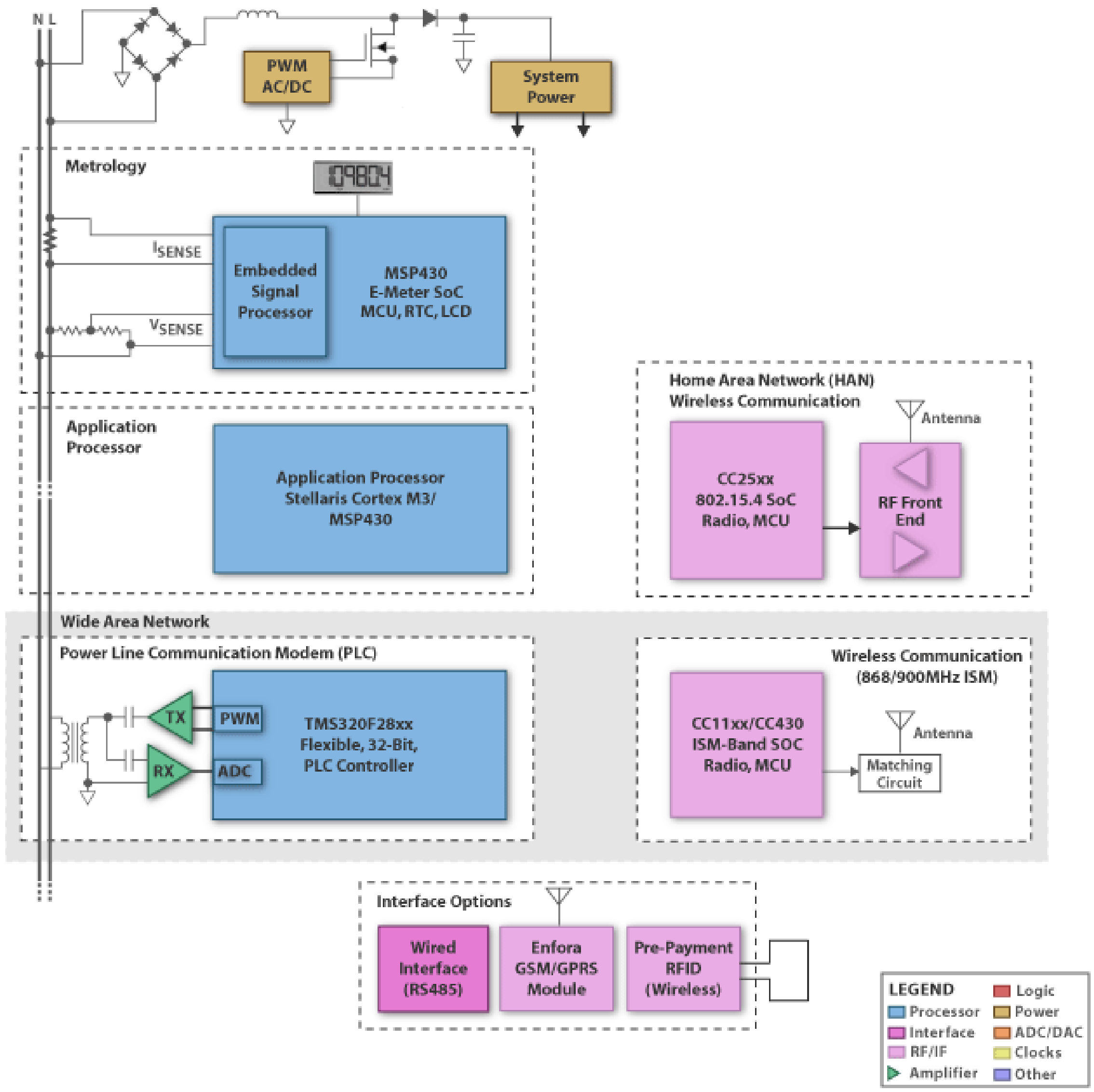
- A Wide Area Network (WAN) - a long range, high bandwidth and low latency self-healing mesh for utility distribution operations supports meter communications and in addition supports real-time utility functions such as distribution automation and substation video monitoring. It also provides connectivity to renewables and plug-in electric vehicles.
- A Neighbourhood Area Network (NAN) - a self-forming, self-balancing, and self-healing mesh for advanced metering infrastructure (AMI) capable of basic and advanced metering, integrated demand side management, and innovative consumer-centric programs.
- A Home Area Network (HAN) - enables home area applications through the network itself or optional third- tier HAN interface to emerging protocols such as ZigBee.

The network supports a variety of advanced C&I and basic residential electric meters, with a wide range of ANSI forms, voltages, and meter class ratings, equipped with a factory-installed, under-glass SecureMesh communications module. The module adds intelligence to the meter so that a basic residential meter can provide many of the functions of an advanced meter and support interval metering and billing. Each electric meter can report a power outage or restoration event to the head-end in real time, detect tampering by reporting changes in energy flow direction or a reverse flow after an outage and allows remote disconnect/connect through additional switching.

The network also offers battery operated modules, with an operational life of greater than 20 years, that can be retrofitted to the most commonly deployed small- and large-diaphragm gas meters. A gas-only network of enabled meters is also possible, as well as a mixed network of electric and gas meters.

APPENDIX 5: Smart Metering – Technical Platform from Texas Instruments

Major instrumentation companies such as Texas Instruments in the US have developed a range of modules that can be selected for integration into smart meters. An example is shown in their block diagram below.



http://focus.ti.com/docs/solution/folders/print/407.html