Active Building Centre

ABC'S Approach to Building Energy Systems Integration

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Introduction

Whilst most of the elements required for active buildings already exist, to achieve an efficient, effective and well-functioning active building, they must be integrated. Integration should not be an afterthought but something that is considered at all stages of the energy hierarchy pyramid as introduced in ABC's Blueprint (see Figure 1) and with the overall objective of achieving the optimum balance of Comfort, Cost and Carbon for a particular situation (ABC's three Cs; see Figure 2).

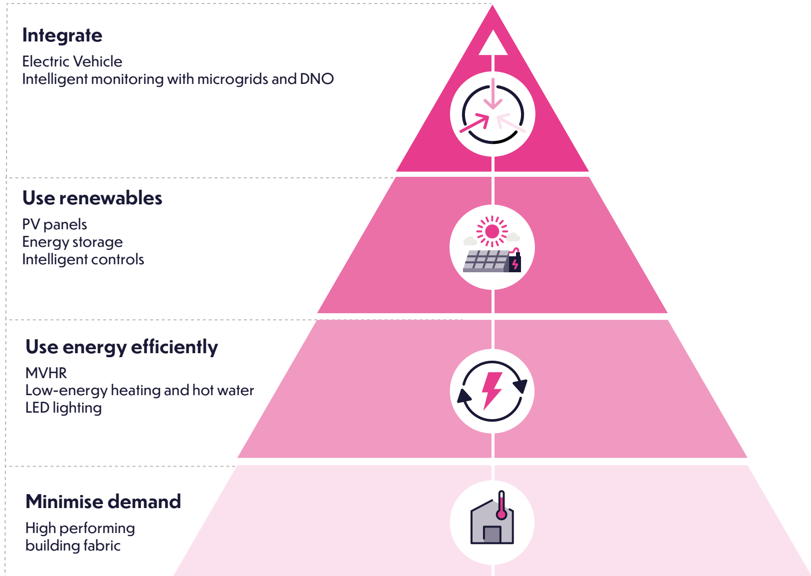

Figure 1. *The energy pyramid*

Following the principles of the hierarchy, for a new building or development the overall energy demand should first be minimised as far a possible through passive design approaches (mindful of embodied carbon and the balance of capital and operating cost) to 'minimise demand' (see Figure 1). For an existing building, it is important to explore the potential to improve fabric performance and hence reduce overall and peak energy demand. In all cases it is essential to understand the fabric behaviour of the building using modelling, analysis and, for existing buildings, physical testing and monitoring, in order to inform the selection, connectivity and integrated operation of components of the overall building energy system. The approach specified in BS 40101[i] provides a consistent way of determining a building's current performance.

Moving up the pyramid shown in Figure 1, the next step is to 'use energy efficiently'. In order to do this, it is necessary to map (using monitoring or modelling) the profile of energy demand over the day and year for key energy end uses, typically space heating (and cooling), domestic hot water and ventilation. Equipment can then be 'right sized' to optimise its operational efficiency and hence minimise the embodied carbon in the equipment itself. For example, a small, occasional, space heating requirement may be better provided by discrete direct electric heating giving radiant or convective heat, rather than by a whole-house wet underfloor heating system with a heat pump or boiler which, while potentially having a smaller operational carbon impact, has a much larger embodied carbon content. Deciding on the right equipment for a specific situation may also involve considering potential energy storage (power or heat) and options for low-carbon, low-cost supply (e.g. variable/time-of-use tariff or heat network connection). This in turn leads to iteration with the third level of the pyramid, 'use renewables', which focuses on generating and storing energy, enabling its use to be 'time shifted' in relation to when it is drawn from the national grid or locally generated.

Finally, we reach the fourth level of the pyramid, that of 'integration', which is the topic of this document. The following sections will cover many aspects of building (and broader development) energy system integration, drawing on learning from ABC's laboratory and demonstrator projects to highlight aspects of integration that work well, or that with the right knowledge and skill can be made to work well, and those where technical, contractual or other barriers exist. Finally, recommendations are made, drawn directly from ABC's contemporaneous experiences, to help to unblock the upscaling of the deployment of well-integrated active buildings.

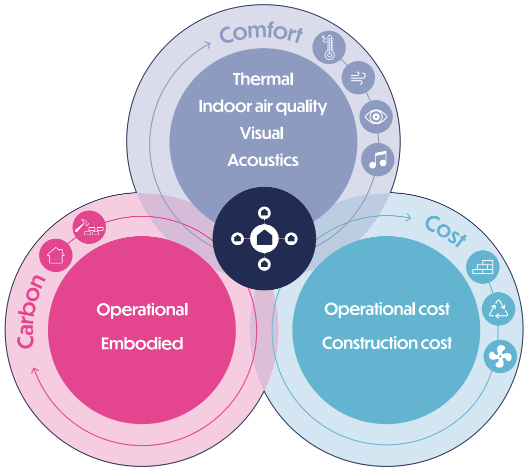

Figure 2. *The balance*

Why integrate?

The overriding reasons to integrate the elements of building energy systems within a building or group of buildings are to maximise the use of low-carbon energy and, in order to do this, manage the time mismatch between availability of low-carbon energy and time of demand for energy.

At an individual household or building level, active energy devices

- take low carbon energy from onsite sources (e.g. PV, solar thermal, heat from surrounding ground or air) and from the grid when there is a surplus (in some cases this is supported by low tariffs)
- store energy that is not needed immediately for later use and/or export energy that will not be needed either back to the grid or to other users, and
- distribute stored and 'real-time' energy to energy-using equipment when required and according to strategies that ensure all uses are satisfied.

Taken together, these enable the property to operate at net zero or better, whilst providing for the comfort and convenience of occupants at lowest practical operating costs. Effective integration of these elements within a building enables it to be operated as a single system and, with well-designed user interfaces, to operate with minimum need for occupant intervention whilst giving occupants the opportunity to override default operation when required.

For reasons such as capital cost and embodied carbon, sometimes planning or listed building constraints or physical space limitations, not all buildings can be expected to reach or exceed individual net zero performance, but integration of the elements that can be incorporated still provides added benefits beyond using them independently. On-site energy storage also gives occupants extra reassurance by providing continuity of supply in the event of power failure.

By grouping together multiple buildings, such as in a housing scheme or business park, some of the benefits of integration can be increased and some of the costs reduced, for example by sharing in the cost and use of larger batteries. As the total capacity of a common stored energy source can be drawn on by any of the connected properties, this can also provide greater flexibility and apparent capacity through diversity. The Trent Basin project explores variants of development scale integration, including any benefit that can be gained from allowing a private market for energy amongst the householders. Such arrangements are not allowed under current regulations but the project obtained special dispensation, called a derogation, from Ofgem, to explore this model. If regulations were to be revised to allow such private 'behind-the-meter' markets, this could open up new business models, provide potential for landlords of homes (e.g. Registered Social Landlords) or business premises (e.g. shopping centre or business park owners) to optimise energy management across their co-located property portfolios and modulate energy flows in and out of the wider national grid.

This leads us to consider the benefits to the national grid of integration at building or development scale. There are many locations where the national electricity grid is already constrained, meaning that new developments are unable to proceed because electricity supply cannot be guaranteed. At the same time, there are infeed constraints on the grid where the grid cannot accommodate the infeed of power from renewable energy generation. Integration at building or development level has the potential to even out the peaks and troughs of demand on the grid (in turn reducing the need for top-up generation from non-renewable sources), including responding to real-time tariff signals to stimulate export or import by the building energy systems. This could unblock development opportunities, increase the renewable energy supply and ease the pressure on grid reinforcement.

So, at many levels, integration of building energy systems offers great potential for the transition to a net zero built environment and national grid.

Design and selection of technologies

Good integration of active building technologies starts with designing for integration,and considering which functions and services (heating, hot water, EV charging; see Figure 3) need to be supported by the building energy system (these are inside the system boundary) and which factors from outside the system boundary need to be taken into account. These external factors include the potential connection to different energy supplies such as grid electricity, private wire or community battery storage and heat networks and the tariff and monetary charging arrangements, including any potential to export from the building. The system boundary can be identified by considering who has control of and responsibility for the various technologies. The specification of the performance, interoperability and control strategy of the technologies inside the system boundary is part of the design of the building, to be implemented through the procurement and construction process.

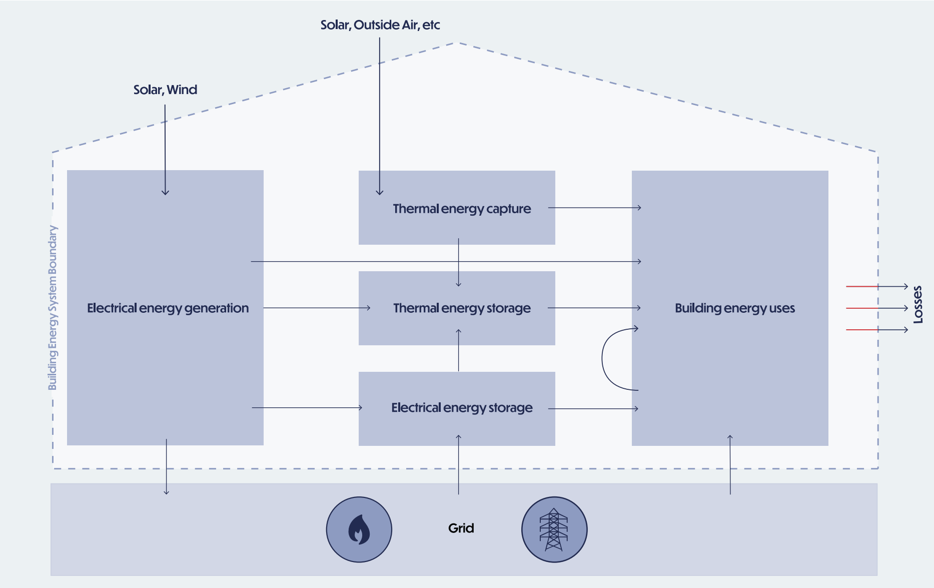

Figure 3. Considerations inside and outside the building energy system boundary

The design also needs to take into account physical constraints and requirements (e.g. whether there is space for an electric battery or hot water storage), usability by the intended occupants and projections of future trends both within the system boundary (e.g. bi-directional EV charging/discharging) and outside (e.g. in energy cost and carbon factors, grid constraints and resilience to potential power cuts). It should also consider adaptability to accommodate replacement system elements in the event of failure or technical advancement, maintenance and data capture for system optimisation and potentially contribution to general learning.

A good example of a project designed for integration from the start is ABC's Y Twyni, which had well defined employers' requirements and tender documents setting out in details the scope of the solution and specifications. This allowed the contractor to cost the project appropriately and also ensured that there were no oversights which may have led to discrepancies further down the line.

ABC's Cross Hands East project shows the importance of a balanced approach between designing the building externally (form and fabric) and designing the services to augment the architectural design to achieve the desired building performance. Projects with integrated systems should ensure that there is a defined set of criteria for system acceptance in the tender documents with defined test scenarios, so that there can be assurance that the whole system is working as specified once installed.

Unfortunately, the regulatory requirement to use SAP for new-build homes and RdSAP for existing homes to demonstrate compliance with performance standards currently fails to reflect the benefits of many elements used within active buildings and amongst groups of buildings. In several of the ABC projects the use of such compliance tools as design aids led to a less good solution than ABC subsequently proposed (and in some cases succeeded in having adopted) based on dynamic simulation modelling.

In the Marleigh project, design based on compliance tools had led to discarding air source heat pumps as a viable heating technology, but ABC's analysis demonstrated these would be the best heating method in all dwellings with the intended high level of fabric performance and would further reduce CO_2 emissions as the grid decarbonises further. Where PV was to be included, planned generation capacity was increased to meet a greater proportion of peak demand, with surplus diverted to battery storage or EV charging. The Trent Basin project highlighted the fact that only electricity export to the grid was recognised in SAP/RdSAP and not that exported to a communal battery. Such failures of the compliance tools to keep up with advances in technology lead developers and those delivering grant-funded programmes to make sub-optimal choices when designing homes for sale or specifying home upgrades.

Designing an integrated energy system is therefore a substantial undertaking, requiring many pieces of information and different aspects to be considered. There are currently very few companies or individuals who can offer this service, especially at domestic scale and particularly from a technology-agnostic perspective, as was clearly demonstrated in ABC's Marleigh project. Consultants typically only cover part of the whole system or provide only a proprietary system, locking the client into a collection of elements that might not all be appropriate for the particular situation.

This might force a designer down the route of using a particular technology, e.g. air source heat pump for space heating, where an alternative technology, say radiant panels, might be a better solution in a Passivhaus dwelling from a whole life carbon perspective. Where a client does use a consultant to design an integrated system for domestic application, this is currently a very individual, bespoke service that is not affordable unless spread across a large number of properties. Costs also flow through to higher costs for installation and commissioning. Attribution of responsibility and physical integration challenges also arise unless all elements are designed and installed by the same company as experienced in the Trent Basin project.

Procurement

Procurement in any emerging sector is a challenge, where suppliers fear taking on risk and responsibility. In the construction sector, which unfortunately is still more risk averse and adversarial than many, the difficulties in procuring products and services required to achieve an integrated active building are substantial. Whilst many innovative providers of technologies (both hardware and software) are willing to collaborate in delivering an integrated building energy system, accepted contractual practice makes it difficult for such collaborative approaches to gain traction in the sector. Amongst registered social landlords (RSLs) and in public sector project procurement, frameworks tend not to extend to building energy systems, usually delegating them to main contractors who themselves have limited access to more innovative options, as ABC encountered in the Cross Hands East project.

Procurement was also a challenge in ABC's Y Twyni project, where there were challenges in appointing a main contractor at the start due to price fluctuation and material availability on the market. The pool of experienced suppliers in this area is also limited, with either large reputable organisations that come at a price or smaller and more agile players that may not have longevity.

Better evidence and information on CO_2 and (especially in the case of Registered Social Landlords) comfort (wellbeing) and cost (of operation) could nudge that sector to deliver active new-build homes and public sector buildings. Also, if fully considered in government grant programmes for upgrading homes and public sector buildings, this evidence and information could ensure that active solutions are also included when improving existing buildings. For large housebuilders, extremely tight cost control and established industry practices deter any deviation from the familiar. A shift to evidence-based performance compliance using a standard such as BS 40101,[ii] coupled with net zero trajectory targets is one approach to unlocking this barrier.

Installation and commissioning

When it comes to the installation and commissioning of building energy systems there is sadly a dearth of skilled practitioners. The skills required include plumbing, electrical, mechanical and, in many cases, data management and software. With appropriate overall management and leadership, it is possible for some aspects of installation and commissioning to be disaggregated, but as the overall system is required to be physically 'integrated' and operate as a single system, multiple traditional skills are often required simultaneously either in the same individual or a close functioning team. In the case of standard house types in similar climatic conditions it is possible to design a system that can be replicated in each home and tailored to a particular situation, for example to take account of different electricity distribution tariff options. In these cases, the installation may be made fairly formulaic and hence less prone to error.

Where a main contractor has little direct knowledge of integrated building energy systems, it is quite likely that separate elements will be installed by different suppliers and, for a variety of reasons, may present incompatibilities in physical communication, integration and control. Even using a very well- respected main contractor, the Trent Basin project wrestled with this integration challenge. This reinforces the need for good system design, which includes detail design of interoperable elements, the physical installation and configuration of equipment, coupled with good communication and oversight to ensure the elements are all installed correctly and thus able to be connected and appropriately integrated.

With their Marleigh project, ABC wanted to demonstrate integration in practice. The client selected the SolarEdge solution which is a fully integrated configuration that maximises the PV generation and integrates with the EV charger, battery storage and the heating system. The PV energy generated could be used for the electrical load in the house as well as the EV charger, and any excess would be diverted to the hot water (multi-coil) tank which feeds into the heat pump, helping to reduce the energy demand (pre-heated water).

There were challenges in getting hold of some elements of the Solar Edge solution due to long lead times, specifically the EV charger. The client was keen to progress on this and looked at alternative solutions, but these didn't provide any integration capability. ABC emphasized the implications of choosing alternative solutions, and engaged with the technical team and the installers to persuade them to wait for the Solar Edge solution. This example highlights that it is key to consider integration from the start and to ensure that tender documents and specifications clearly refer to the requirements for integration.

The move towards more modular and volumetric off-site manufacturing of dwellings offers the opportunity to install building energy systems in a more controlled factory environment which, if standard solutions can be used, will avoid introducing the variation in the installation of such systems that often occurs. It also offers an opportunity for innovators to develop building energy system solutions specifically for this market, with attendant benefits in reliability, in-use maintenance and servicing.

Control strategy and user involvement

Whilst the end objective of the control function is to optimise the 3 Cs – Comfort, Carbon, Cost – the detail of the strategy to be adopted will be driven by the system resources available and the demands of the building and its occupants. For example, a building with PV and a storage battery will need to balance the needs of immediate use with maintaining an adequate level of charge in the battery to support essential uses in case of power failure.

Figure 4 shows a possible configuration of a home energy management system for a single dwelling. It is not exhaustive – it does not, for example allow for gas cooking, but it shows most of the devices which might be incorporated.

Wherever a device can draw energy from multiple sources, and in some cases where a device can deliver energy to multiple sinks, control intervention is needed to ensure correct routing. These points are shown as red circles in the diagram. In general, these control points can be regarded as simple switches selecting one out of multiple sources/sinks. It is the control of those switches that presents the challenge.

Of particular interest is the connection between PV and the storage battery, where control is operative at both ends of the link. In this situation it is crucial that negotiation takes place between the two control functions to ensure that they do not conflict.

At each control point an algorithm must make a decision to select one route over others. The factors influencing the decision will vary with the device and may be complex. Clearly the design of such a control system is not a trivial matter. The exact form of the algorithms will depend on the devices connected, how they are anticipated to be used and on the activities of the occupants from time to time.

As demonstrated in the Trent Basin project, even when occupants have been fully engaged and are keen on realising the benefits of an active home, most users will not wish to be involved in the day-to-day operation of the energy system, and allowing them to be invites the possibility of incorrect operation. Whether they take part in the initial commissioning and strategy choice is matter for individual preference.

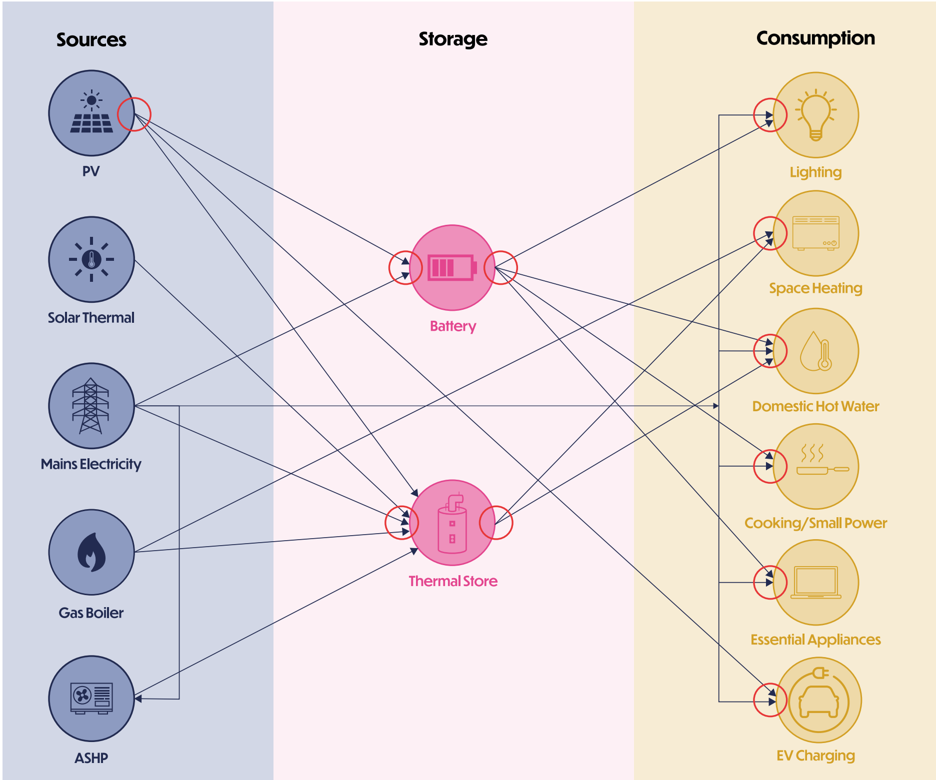

Figure 4. *Conceptual home energy management system*

It is important, therefore, that a control system is capable of operating autonomously once set up, whilst allowing users to override operation to respond to specific short-term requirements. Systems ideally should also be able to optimise their own operation to achieve set targets for energy consumption and cost, and in response to changes outside the system, such as a revision of energy tariffs and timings.

In the Cross Hands East Project, tenants will sign up to a Green Lease which will provide, through metering and monitoring, intelligence on utilisation to support decision making around operations and potential investment in battery storage.

The extent to which the function can be autonomous is influenced by the willingness of the occupants to be involved. Total autonomy allows the system to operate with no intervention by the occupants, but cannot respond to changes in demand, for example when the occupants change the time of day when they are out of the house.

Many controllers have been developed with operation along this spectrum, including some using machine learning techniques, but it has not been possible to create a solution that suits all users. It is likely that the degree of autonomy in a control system will have to be left as a parameter to be chosen at design stage, along with the system configuration, by reference to the known or likely user. It is also possible to 'divide and conquer' in some situations, with some functions being handled separately from the main building energy system such as in the domestic example in the box below.

Whatever the degree of autonomy, the *Householder Guide* is crucially important in ensuring correct operation and satisfaction for the occupants. Some developers and Registered Social Landlords are beginning to make available on-line versions of householder guides which can be revised to ensure they always reflect the technology installed, and can also provide additional user assistance through embedded videos.

Domestic example

Consider a typical modern house built or refurbished to achieve optimum energy usage, using a water tank heat store for domestic hot water (DHW), mechanical ventilation with heat recovery (MVHR) for ventilation and most space heating, and with an air-source heat pump (ASHP) providing heat to the water tank and hence to the space heating hot water coil.

Heating is needed at a low level for approximately 100 days of the year, peaking in mid-winter when it will need to be supplemented using a hot water coil in the MVHR supply to habitable rooms. MVHR plus good insulation results in all parts of the home being in one temperature zone – the concept of room by room/time of day heating disappears. If the MVHR is run continuously at constant speed, then the space heating can be simply controlled by a single thermostat.

The DHW system is self-contained – it draws heat from the store when needed. No control is needed beyond maintaining the temperature of the heat store.

The efficiency and cost effectiveness of the heat pump are governed by the temperature of the incoming air, compressor speed and the cost of the electricity used. The ideal heat pump controller will look at the predicted demand profile the predicted PV output, predicted low-cost tariff periods, and (if present) predicted battery availability (capacity both to accept and release charge), to determine when the heat pump should be run, and at what speed.

Electric vehicle (EV) charging has the potential to make best use of PV generation by storing the generated power and releasing it as needed using vehicle-to home (V2H) technology but only if it is controlled in an integrated manner as part of the whole system. Many current EVs being shipped in Europe are V2H compatible, needing only a software update to become operational as home battery systems and some are now becoming available in the UK.

The integrated controller will need to manage the EV charger (V2H), the heat pump, and the PV output (if capacity exceeds 3.6kW). It will need to know future energy demands and supplies (EV usage, weather, occupancy, low-cost (or dynamic time of use) tariff periods), in order to determine when the EV should be charged/discharged, when/how the heat pump should be run, and whether to compensate for excess PV export, for example by diverting excess power to heat up the heat store.

An EV battery being charged/discharged between 20% and 80% of rated capacity will have a usable home capacity of perhaps 45 kWh per day. If the vehicle is not being fully used on the road, then it has the potential to:

- accept all of the home PV output, and then discharge this during 'dark' periods (running the cooker, fridge freezer, washing machine, lighting etc.)
- be charged from the grid during low-tariff periods, and then provide the power during the rest of the day – maximising the percentage of power usage from the lower-cost tariff
- be the power source for the heat pump – i.e. the heat pump can then be run in an optimal manner (e.g. optimal speed, highest air temp period of the day) regardless of when and from where the electricity was obtained.

The cost benefit in terms of energy bills should be balanced with the increased battery usage which may shorten its life.

Adaptation and maintenance

Can you 'fit and forget' a building energy system? Maybe for a little while, but to continue to get the maximum benefit from an integrated building energy system it will require basic maintenance and servicing to keep all the elements operating well, and it will probably also need to be adjusted or reconfigured (unless it is really smart and self-learning) to suit changes in parameters that affect the control of the system. For example:

- occupancy patterns may change, with the resident or building occupier needing space heating/cooling and hot water at different times of the day
- the supplier of grid electricity may offer new tariffs that are more attractive, changing the times at which it is better to use grid or stored electricity. Some companies have begun to offer dynamic tariff pricing to encourage customers to shift their energy use to periods of low demand. Dynamic feed-in tariffs are also now available, and both require either intervention or smart response to make the most of these opportunities
- an element of the system may fail and need to be replaced, maybe with something that differs from the original element through obsolescence, different supplier or manufacturer or just a new, improved, version of the failed element.

Some of the changes can easily be made by the householder or occupant, but others may be better handled through a software upgrade (which can be remotely applied) or will need a visit to recommission the whole system. In most situations the *Householder Guide* will also need updating to keep up with the installed system.

Increasingly, individual system components are equipped with embedded monitoring of their own operation. This can be used to check operation of the individual elements and aggregation of these data can be used to check and sometimes dynamically adjust the operation of the whole system to optimise its own operation. ABC has ensured that monitoring of both building energy systems and time-related internal environmental conditions (in accordance with BS 40101[iii]) have been included in all its projects, together with occupant feedback where possible, so that these data can be used for learning and to inform the design and operation of active buildings. It would be a significant contribution to the development of active building knowledge and insight if an accessible repository of suitably anonymised data could be made available for public use to support the growth of this sector.

Interoperability, standards and compliance

A functioning energy management system requires the collaborative working of a number of individual devices – typically energy generating, storing and consuming. If they are to do so successfully, they should be able to communicate and respond to information about other devices and external influences.

Some suppliers of energy management products provide for communication amongst their products but the optimum design of a management system depends on the nature of the energy sources and demands, and no single manufacturer can anticipate and provide for every possible combination. Consequently, it should be made possible to assemble a management system using components from different suppliers and make them work together. Interoperability is the specified ability of a product to work successfully with others.

The first step in developing a product to be interoperable with others is to define how it will interact with other devices. A standard provides a set of design parameters that are shared amongst all developers of interoperable devices. Such standards generally emerge from protracted negotiations amongst early developers and are usually owned by an organisation set up for the purpose and funded by the participants. Later entrants are faced with a difficult commercial decision whether to comply with the standard or diverge to create their own ecosystem, which potentially excludes other technology providers from connecting their own technology.

The adoption of a standard is only a starting point for a design. Ensuring that it results in true interoperability requires substantial testing of its compliance with the standard. Compliance testing is often undertaken – for a fee – by the standard owner organisation and will involve subjecting the device to a battery of tests designed to uncover any failure of interoperation. Often events are organised at which manufacturers are invited to operate their products in an environment containing many other manufacturers' products to demonstrate full interoperability. One of ABC's objectives has been to provide such an environment on a semi-permanent basis in which both clients/specifiers and suppliers could test and refine an integrated system prior to procurement or deployment.

Interoperability first requires physical communications. This much is obvious. Less obvious is the need for a common format for the information to be exchanged so that it can be understood, and a protocol for requesting information, disclosing capabilities, reporting status, issuing commands and responding to them. Finally, the data content of communications – the semantics – must be defined so that meaning can be extracted from them.

Generally separate standards exist for physical communication and for data format and content, and they can usually be chosen independently. Additionally, the set of possible messages and their meanings must be defined, often interactively to suit the devices involved.

In terms of physical communications there is a broad separation into wired and wireless systems. Wired systems include Ethernet, Broadband and several specialised systems such as Modbus, C-Bus and CAN bus, plus some simple point-to-point systems such as RS485. Where a wired system is adopted, early design input is needed to incorporate the wiring into the building. In most cases Category 5 or 6 cable is chosen because it is cheap, capable of high data rates and can support Ethernet or be adapted to other systems if necessary.

Wireless systems include Wi-Fi, Bluetooth, Zigbee for short range as well as mobile phone systems for longer distances. Wireless communication offers flexibility at the cost of susceptibility to interference and possibly security. Zigbee, administered by the Connectivity Standards Alliance (CSA), is emerging as the method of choice because it offers mesh communication giving reliable communication throughout a building.

In respect of data format and protocol, the Internet Protocol (IP) has been in use for many years and is well established in both wide area and local area networks. Its variants – UDP for isolated message transmission and TCP for connection-orientated communication – are normally supported by off-the-shelf components which are cheap and easily obtained. Although there are proprietary protocols in use in specialised situations, IP is the natural choice for a widely used standard.

To be useful to a system integrator, a standard should be widely adopted by manufacturers and readily accessible to users. This is often slow to happen. The Matter standard, proposed by Amazon, Apple, Google and the CSA and now adopted by many others including Ikea, Samsung and Schneider, is an attempt to create such a standard by drawing together and building on subsidiary standards – IP and Zigbee for example – to produce a comprehensive specification. It encompasses other aspects of building management such as lighting and security but is also well suited to energy management. At present few compliant devices exist but if the standard gains sufficient momentum it will become a beneficial feature of any energy management system component.

The communication systems and protocols are there to carry information and commands from and to system components but do not determine how decisions are made throughout the system. This requires a control strategy. Whilst it is possible to envisage a distributed control methodology where each device decides what to do based on information from other devices, at present, coordinated management requires an overarching supervisor that can control all aspects of operation. The design of the control algorithms used is possibly the most demanding aspect of developing an energy management system, not least because it must be individually tailored to the specific set of components involved and to the demands of the building and users it serves.

Several different approaches have been taken, including a fixed algorithm assuming a typical set of devices, a local application updatable remotely, or full external control via an Internet connection. The choice will be driven by cost, desired flexibility and the skill of the integrator.

Industry practice and supply chain challenges

Whilst it is usual practice to include building management systems in larger commercial buildings, this is not the case in domestic and smaller scale non-domestic developments. Housebuilders and main contractors who work predominantly on smaller buildings operate to long-established practices ingrained in standard contractual arrangements. These established arrangements invoke assumptions about the way a building is serviced with power, heating and hot water, which tend to push any consideration of integrated energy systems down to the second or third tier of the supply chain and to later stages of detailed design.

It is clear from the projects that ABC has been involved with that, ideally, integrated building energy systems need to be designed in at the outset and co-designed with the building fabric to achieve the right balance of fabric performance and low carbon energy use in order to achieve overall low carbon, and good levels of comfort and cost. In some projects ABC was able to provide support from the early stages of design, or to revisit the early design, thus improving the overall outcome, whereas in others critical decisions had already been made which limited the benefit that could be achieved through the incorporation of integrated building energy systems. Irrespective of the stage at which ABC became involved in a project, they found that it was necessary to sustain involvement through the remainder of the building (or scheme) delivery and early occupation period to prevent the active elements being dropped from the project, reduced in scope or incorrectly implemented. On reflection, this is not surprising when set against the weight of established practice – it is easier (less risky and more comfortable) for supply chain participants to perpetuate a familiar way of doing things, than change to a new way, with new products and new contractual arrangements and interactions.

Main contractors are used to having well demarcated areas of responsibility for the installation of building services – electricians, plumbing and heating – with well established interface points. Design details such as pipe layout are often left to the tradesperson as part of the installation process. In moving to an integrated building energy system, main contractors and clients tend to favour a single supplier who they can hold responsible for the initial delivery of the whole system and for its ongoing operation, at least during the defects liability period. This makes it difficult for suppliers who only supply elements of a system to gain market traction for their products and does not encourage the establishment of companies taking on the role of system integrators who would then be required to take on contractual responsibility for the whole system.

A further key constraint on the widescale adoption of integrated building energy systems is the availability of multiskilled individuals and teams who can work across mechanical, electrical, plumbing, electronic hardware and software to design, install, configure and programme integrated systems. Energy Systems Catapult has identified that low carbon heating installation and technology integrations are two of the four top job roles where there is a skills gap to decarbonise UK homes for Net Zero (see here).

Some new approaches are being adopted that focus directly on the delivered energy performance in terms of the guaranteed supply of hot water and internal environment for a set cost and/or amount of energy, not dissimilar to a mobile phone contract bundle. Energiesprong is perhaps the most successful approach to this so far in the UK, the concept having been imported from The Netherlands around 2015 and tuned to suit UK energy (and other) regulations. Originally intended to be used for holistic upgrade of existing properties, the approach is now also applicable in new-build situations. The Energiesprong approach has now been applied to 173 properties across nine schemes in the UK. The contractor (also known as the Solution Provider) provides a Performance Guarantee, ensuring that the operational energy use and generation meet the approved design.

The Performance Guarantee encompasses the elements shown in Table 1 with specific metrics tailored to each particular scheme. These targets apply per property across a scheme.

Performance element	Performance Guarantee typical target
Space Heating Energy Demand	Less than 40 kWh/m²/yr
Hot Water Allowance	Between 100-140 litres/day @ 45°C
Net Energy Consumption	Less than 1,500 kWh/yr
Tenant energy costs	Less than prior to the retrofit (based on same utility prices)
Internal Temperatures	18°C in bedrooms and 21°C in all other rooms during heated perios (9 hrs weekdays, 16 hrs weekends)
Resident Electricity Use Allowence	2,300 kWh/yr

Table 1. *Energiesprong Performance Guarantee*

Wider context

Outside the scope of physical construction other factors also impede the wide-scale deployment of integrated building energy systems. In several instances ABC found that reliance on SAP and RdSAP for designing and verifying the environmental performance of new build and of upgrades to existing buildings, acts against good integrated energy system practice. This is partly due to difficulties in representing individual system elements and their integrated impact in the SAP system, although this has been addressed to some extent in SAP 10.2 with similar changes expected for RdSAP later in 2023. For non-domestic buildings the inclusion of a dynamic electricity carbon factor which is also weather dependent (using CIBSE 2016 weather files) in Part L Building Regulations is also a step in the right direction.

As SAP/RdSAP calculations are also used in planning application decision making, in public procurement and to approve any set of upgrade measures subject to government-supported upgrade programmes, this presents a barrier to delivering the most appropriate new buildings and building upgrades for a net zero future.

Better methods for designing new buildings and building upgrades do exist and have been used by ABC in their projects. If methods such as these were permitted as alternatives to SAP/RdSAP (and the resultant EPC rating), it would be much easier to scale up the adoption of active buildings generally and to demonstrate the benefit of specific integrated building energy systems.

In January 2023, a key recommendation of the independent review of net zero 'Mission Zero'[IV], prepared by Rt Hon Chris Skidmore MP asserted that the EPC system (which uses SAP and RdSAP to determine the EPC rating) does not work for net zero and recommended that EPC ratings are migrated to a new more holistic Net Zero Performance Certificate. If adopted, this recommendation has the potential to drive improved design and selection of integrated building energy systems.

Regulations governing the supply and distribution of electricity are understandably robust, as evidenced by the requirement to obtain a derogation from Ofgem for the 'behind-the-meter' system trialled in the Trent Basin project. In the same project it was also found that rules that do not permit transfer of ownership of power supply cables from the Distribution Network Operator (DNO) can hamper the establishment of community energy networks for sharing and direction of power, requiring duplication of cabling with associated cost. This is likely to prove an insurmountable financial barrier for new-build community energy networks and even more so for the conversion of existing developments of schemes.

Another lesson learnt from Trent Basin was the complexity of integrating a community energy system based on shared PV mounted on privately owned properties. This impacts construction, mortgageability, property insurance and the sale and purchase of the affected homes. Practically, such impediments render physically distributed yet shared energy systems totally unviable for developers of homes for general market sale. Such schemes of energy sharing, and behind-the-meter trading or distribution may work for Registered Social Landlords (and private landlords) who retain ownership of the dwellings, and have removed any potential for them to be sold to individuals through their tenancy agreements.

Conclusion

ABC's experiences over the last couple of years illustrate that the design and delivery of integrated building energy systems are still at a fairly immature level, especially in domestic buildings and amongst groups of buildings. However, innovation activity in this area in the UK as well as overseas is vigorous, with communication and physical interfacing standards emerging. Smaller product developers are enthusiastic to collaborate and ready to scale up.

Barriers and challenges to the adoption and integration of technologies arise from the representation and 'scoring' of active building technologies both individually and when integrated to create smart building energy systems, especially at a domestic scale; from the regulatory context; and from established construction practice. The biggest challenge is perhaps the availability of appropriately skilled workforce from design through to site installation, configuration and then for through-life maintenance.

Whilst by no means exhaustive, the following suggestions are offered that could reduce the barriers and increase the extent and speed of deployment of integrated building energy systems, especially in new and existing domestic scale buildings and developments:

1. Major clients and public sector bodies should be encouraged to require equipment manufacturers to use a named common standard for physical and information connectivity to improve interoperability and integrated operation.
2. BRE, enabled by relevant government departments, should improve and extend the functionality of the publicly accessible Product Characteristics Database (PCDB), used for SAP and RdSAP calculations, to enable system elements to be selected based on requirement specification and incorporated into whole system designs.
3. Clients and architects should seek to include energy system integrators (either consultants or 'design and install' contractors) in the building design team, in domestic scale developments (to a large extent these are already used in non-domestic projects). These would probably come from the building services engineering sector.
4. Accepting that energy systems integrators will be few and far between for many years to come, publicly procured projects and key sectors such as social housing should be encouraged to devise template system architectures for particular building architypes and fabric performance variants. These could then be procured and tailored in a mass-customisation fashion to suit the specific buildings and situations. If such an approach was adopted, it is likely that self-learning would rapidly develop for such systems to streamline the customisation process.
5. Large clients and government-supported programmes should incorporate the development of collaborative supplier groups and systems integrators into their procurement at Tier 2 supply chain level (i.e. requiring their main contractors to take on this responsibility).
6. In order to compensate for the current shortfall in skills and capacity for installers of integrated building energy systems, manufacturers and suppliers should be encouraged to pursue a mass customisation strategy, enabling the same basic solutions to be used across similar buildings with individual tailoring.
   They should also be encouraged to collaborate to reduce the complexity of systems as far as practical by developing simplified installation procedures for off-site pre-assembly (or full assembly in the case of volumetric construction) and on-site final assembly.

7. At the same time, skills certification bodies should be encouraged to devise (or specify) training for a new breed of installers, allowing cross-training of those with some of the necessary skills and qualifications.

8. Clients and regulations should allow for the energy performance of buildings to be demonstrated at design stage using modelling and analysis tools that better account for energy system technologies and their integrated operation (maybe the proposed Net Zero Performance rating system proposed in the Skidmore review), and for this 'as designed' performance to be verified in operation using measured and monitored data, using a standard approach, such as that specified in BS 40101[v], to ensure that expected energy and emissions performance is achieved. As soon as is practical, require this to be adopted in programmes supported by government grants, energy company obligations and in procurement where public funds are used, approvals made by Homes England or equivalent and in planning applications.

9. Companies and organisations should be encouraged to use actual CO_2 emissions performance (derived from measured energy use and time-of-use emissions factor rather than EPC ratings) when calculating corporate and organisational scope 1 and scope 3 CO_2 emissions.

10. Subject to learnings from projects such as Trent Basin, Ofgem and the UK and devolved governments should be encouraged to progress changes to the regulations governing the sale and purchase of energy, to enable private transactions 'behind-the-meter' (i.e. connection to the national grid) thus creating new business opportunities which in turn will drive better energy management, easing load fluctuations on the national grid and defer the need for reinforcement and/or alleviate constraints on new development.

i British Standards Institution (BSI) (2022) *BS 40101:2022 Building Performance Evaluation of Occupied and Operational Buildings (Using Data Gathered from Tests, Measurements, Observation and User Experience. Specification.* London: BSI.

ii See i above.

iii See i above.

iv Press Release: Net Zero Review. UK Could Do More to Reap Economic Benefits of Green Growth.

v See i above.