Active Building Design Guide

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Guidance for the design of Active Buildings that combine renewable energy technologies, energy storage and intelligent controls to support local and national energy networks and help meet UK climate change targets

Credits

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Editorial Note

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Contents

0 Introduction

This document forms part of a toolkit, providing information on the core principles of an Active Building and the key design considerations related to each principle.

Purpose

- Provide an explanation of an Active Building
- Provide key benefits of an Active Building
- Provide key design considerations related to each Active Building principle

The document should be read in conjunction with the following documents:

- Active Building Code of Conduct
- Active Building Project Template
- Active Building RIBA Plan of Work Checklists
- The Active Classroom Case Study
- The Active Office Case Study
- Active Building Technology Showcase
- Active Building Glossary
- Active Building Frequently Asked Questions

Use of the Active Building Interactive Process Flow Diagram will assist navigation through these documents and other useful resources.

0 Introduction

"An Active Building supports the energy network by intelligently integrating renewable energy technologies for heat, power and transport"

Active Buildings are environmentally responsive buildings – responding to their natural environment, the built environment they occupy and the energy environment they interact with.

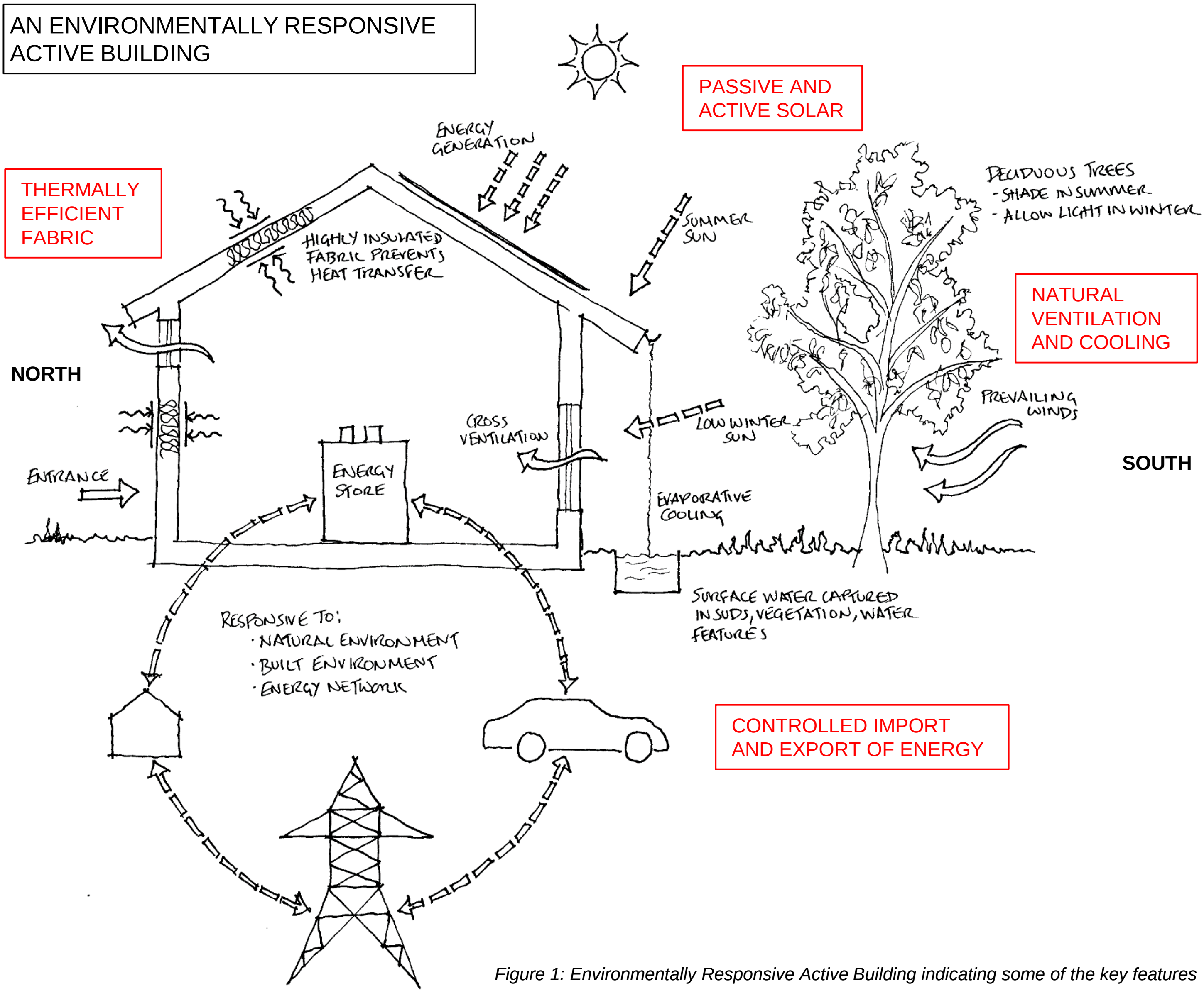


Figure 1: Environmentally Responsive Active Building indicating some of the key features

The starting point for an Active Building is an **efficient building fabric** and **optimised passive design** to reduce operational energy. Regulated loads are further minimised using **energy efficient systems**. Where practicable building loads are met using building integrated or onsite **renewables**. In addition to reducing peak loads, and preventing oversizing of plant, the inclusion of **electrical** (including **electric vehicles**) and **thermal storage** allows **interaction with micro-grids** and the national energy network to be managed. **Intelligent control** is essential for an Active Building, both for the control of building systems and to manage interaction and trading with the grid. Ongoing and consistent **data capture** will enable analysis and insight to feedback into the Active Building design process, and optimisation and refinement of predictive control strategies.

0.1 The 6 Core Active Building Principles

1. **Building fabric and passive design** – integrated engineering and architecture design approach including consideration of orientation and massing, fabric efficiency, natural daylight and natural ventilation. Designed for occupant comfort and low energy by following passive design principles.

2. **Energy efficient systems with performance monitoring** - intelligently controlled & energy efficient systems to minimise loads - HVAC, lighting, vertical transportation. Data capture via inbuilt monitoring to enable performance validation, optimisation and refinement of predictive control strategies; including dissemination of performance data to building occupants.

3. **On-site renewable energy generation** - renewable energy generation to be incorporated where appropriate. Renewable technologies should be selected holistically, given site conditions and building load profiles combining, where applicable both photovoltaic and solar thermal technologies.

4. **Energy storage** - thermal and electrical storage should be considered to mitigate peak demand, reduce the requirement to oversize systems, and enable greater control, with a view to supporting the local infrastructure through time shifting of demand and controlled export; and enabling flexible control to enable virtual power plant integration.

5. **Electric vehicle integration** - where appropriate Active Buildings integrate electric vehicle charging. Combined Charge Systems (CCS) with local control and the option of either virtual power plant (VPP) aggregated control or frequency response should be considered. As technology develops, bi-directional charging will allow electric vehicles to deliver energy to buildings as required, participate in demand side response and work with the wider building control systems.

6. **Intelligently manage integration with micro-grids & national energy network** – in addition to intelligent controls, Active Buildings manage their interaction with wider energy networks, e.g. demand side response, load shifting & predictive control methods, aiming to minimise uncontrolled import or export of energy by effectively utilising the storage assets.

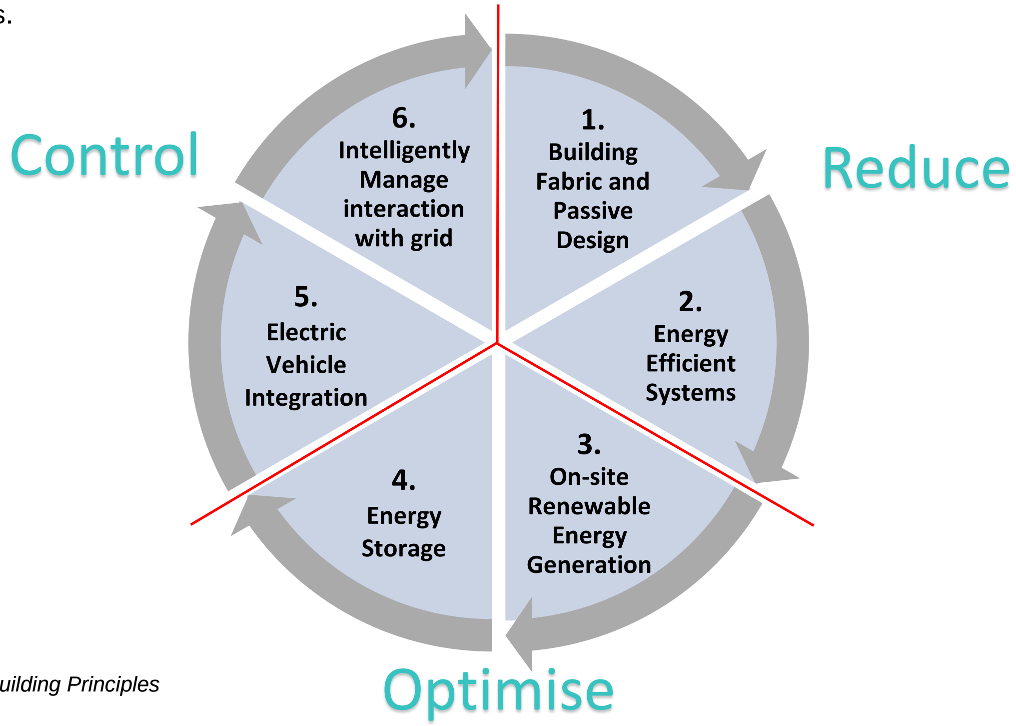


Figure 2: The Active Building Principles

The novel feature of Active Buildings is their ability to function as part of a de-centralised power distribution system – the benefits become significant when Active Buildings are aggregated through connecting buildings together, managing their energy and ensuring energy is distributed appropriately to meet needs.

0.2 Comparison with other Environmental Standards

Some of the most widely used environmental assessment methods include:

- Methods that consider the whole building, including its site and location, such as **BREEAM** (est. 1990), **LEED** (est. 2000), and **the** **Living Building Challenge** (est. 2006).
- **Green Globes** (est. 2004) provides personalised improvements to organisations for design, construction and operation of their buildings.
- Some methods focus on health and wellbeing of building occupants. These include the **WELL Building Standard** (est. 2014) and **Active House** (est. 2010).
- **Passivhaus** (est. 1991) focuses on reducing the heating demand of buildings.
- **Ska** (est. 2005) was developed by the RICS for fit outs of non-domestic buildings.
- For retrofit, there is the relatively new **Energiesprong** approach, developed in the Netherlands (can also be applied to new buildings); as well as a version of Passivhaus, known as **Enerphit**.
- And there are others developed for particular countries, such as **Green Star** and **NABERS** in Australia; and **Estidama**, developed specifically for the Middle East.

While Active Buildings would meet compliance with most of the criteria set out within these methods, there are several measures that make an Active Building stand out from other “green” buildings:

1. The way an Active Building interacts with local and national grid networks, such that the building is able to control its interaction with the grid, utilising storage assets to work and support local infrastructure; for example, presenting a flat load profile to the grid – by controlling energy flows.
2. The level of data collection from an Active Building, the management of that data, and the way it is fed back into the building’s operating system to optimise building performance.
3. The use of integrated energy storage for both heat and power, utilising battery storage and EVs for electricity; and either latent or thermochemical storage for storing thermal energy.

0.3 Energy Use Intensity (EUI) Targets

The total EUI targets for Active Buildings should align with the 2030 targets set by the **RIBA** and **LETI**, as shown in the following table:

	RIBA 2030 Targets		**LETI 2030 Targets**		
	Domestic	Non-domestic	Residential	Offices	Schools
Energy Use Intensity (EUI)	< 35kWh/m^2/yr	< 55kWh/m^2/yr	< 35kWh/m^2/yr	< 55kWh/m^2/yr	< 65kWh/m^2/yr
Space heating demand	15 - 20kWh/m^2/yr for all buildings		< 15kWh/m^2/yr for all buildings		

Table 1: RIBA 2030 and LETI 2030 Targets

Note:

- The figures given exclude renewable energy contribution
- The figures are based on gross internal area (GIA) of buildings
- Total EUI = energy use measured at the meter

0.4 Context

As a response to the Climate Emergency, the UK and Welsh Governments have committed to achieving several energy and carbon reduction targets within the next 30 years. The main targets are listed in Table 1 below.

2020	• **Energy Performance of Buildings Directive (EPBD)** - reduce GHG emissions by 20% below 1990 levels • EU 20-20-20 – 20% less GHG emissions, 20% of EU energy from renewables, 20% better energy efficiency • UK Renewable Energy Strategy – 30% of electricity, 12% of heat and 10% of transport energy to come from renewable sources (to meet EU 20-20-20 targets) • Climate Change Strategy for Wales – 3%/yr target less GHG emissions - 40% reduction below 1990 levels
2025	• Construction 2025 – 50% lower emissions from construction and built environment • UK housing: Fit for the future? – No gas connections to new housing developments • Future Homes Standard & Updated **Parts L & F** of the Building Regulations
2030	• Clean Growth Challenge – halve the energy use of new buildings • RIBA 2030 Challenge
2040	• Road to Zero Strategy – at least 50%, and up to 70% of new car sales and up to 40% of new van sales to be ultra low emission by 2030. No new petrol and diesel cars and vans by 2040
2050	• Paris Agreement to limit global temp to ‘well below’ 2ºC using pre-industrial temp as baseline. Long-term goal for near net-zero emissions • Climate Change Act– to cut GHG emissions by 100% below 1990 levels (amended 2019)

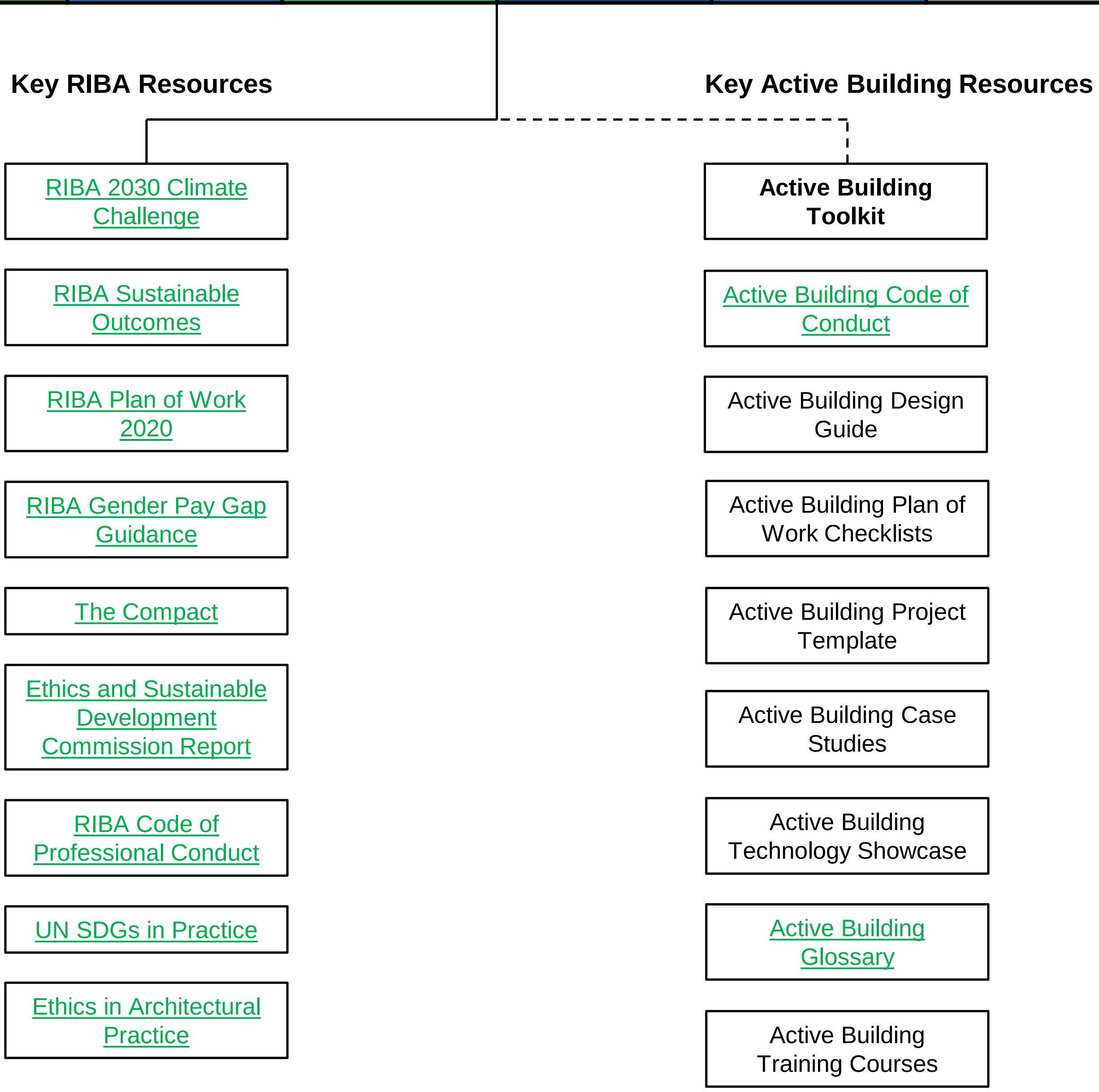
Table 2: Current Climate Change targets relating to buildings

In addition to these, Wales is the only country to have their own **Wellbeing of Future Generations (2015) Act**, which all construction projects in Wales must comply with. Also in 2015, all United Nations Member States adopted the 17 United Nations Sustainable Development Goals, which should be embedded in all construction projects – see page 10 for details.

0 Introduction

0.5 Link to the United Nations Sustainable Development Goals (UN SDGs)

1 **No Poverty**	**2** **Zero Hunger**	**3** **Good health and wellbeing**	**4** **Quality Education**	**5** **Gender Equality**	**6** **Clean Water and Sanitation**
7 Affordable and Clean Energy	8 Decent Work and Economic Growth	9 Industry, innovation and Infrastructure	10 Reduced Inequalities	11 Sustainable Cities and Communities	12 Responsible Consumption and Production
13 Climate Action	14 Life Below Water	15 Life On Land	16 Peace, Justice and Strong Institutions	17 Partnerships for the Goals	



Key RIBA Resources

- RIBA 2030 Climate Challenge
- RIBA Sustainable Outcomes
- RIBA Plan of Work 2020
- RIBA Gender Pay Gap Guidance
- The Compact
- Ethics and Sustainable Development Commission Report
- RIBA Code of Professional Conduct
- UN SDGs in Practice
- Ethics in Architectural Practice

Key Active Building Resources

- **Active Building Toolkit**
- Active Building Code of Conduct
- Active Building Design Guide
- Active Building Plan of Work Checklists
- Active Building Project Template
- Active Building Case Studies
- Active Building Technology Showcase
- Active Building Glossary
- Active Building Training Courses

*Designers should use the language of the Sustainable Development Goals to encourage clients and other design professionals to join the challenge and increase progress (Source: **A Decade of Action**)*

0.6 Key Benefits of the Active Building Approach

Stakeholder	Key Benefits

Building Owners	• Lower Whole Life Costs, lower fuel bills
	• Potential to generate income from the building and develop new business models
	• From Data Collection:
	  ◦ Enable Building Performance Evaluation (BPE)
	  ◦ Fast fault detection and remediation
	  ◦ Develop Planned Maintenance Schedules – improving facilities management, optimising energy use and saving money
	  ◦ Develop Predictive Control Strategies to optimise energy use
	• Occupant comfort throughout the year
	• Simple controls and operation
	• Meet decarbonisation targets
	• Engagement with end users on their energy consumption

Project Delivery Teams (designers, contractors, installers, suppliers)	• Meet environmental assessment targets (see page 8) • Help fulfil commitments to achieving the United Nations Sustainable Development Goals (UN SDGs) (see page 10) • Honour commitment to the Climate and Biodiversity Emergency declaration • Reputational benefits • Meet decarbonisation targets (company, personal, national and global) • Increased understanding of building performance versus building design • Generate data to inform future work
Wider Environment	• Less stress on local and national grid networks, due to energy balancing • Contribute to decarbonisation of both heat and transport • Improved air quality • Lower Greenhouse Gas (GHG) Emissions

Table 3: Key benefits of the Active Building approach

0.7 Integrated Project Delivery Team

A collaborative approach should be adopted on all Active Building projects, as identified in the **Active Building Code of Conduct**.

Active Building projects are most successful when a fully integrated project delivery team (PDT) is employed from the project inception, to enable holistic design and instil a collaborative working culture. It is recognised, however, that this is not always possible at the outset of a project due to challenges such as financial arrangements and planning uncertainties. Therefore, the responsibility to consider an integrated approach to design will fall on the client. Once employed, all members of the PDT must be aware of the core principles and ultimate aims of an Active Building, and to ensure that the client and PDT do not deviate from this core aim.

Procurement methods to enable implementation of an innovative approach within building projects are needed. Adopting a more collaborative approach between the whole design and delivery team will necessitate a move away from the risk-averse, blame culture that has tended to dominate the construction industry to date.

Project Strategy

The starting point for any Active Building project is to undertake an analysis with the client to determine a project strategy and targets. This strategy should establish:

- Project-specific conditions and targets
- Regulations and standards to be followed
- National or local environmental goals
- Client requirements
- Global goals to be addressed
- Review of other Active Building projects

Once developed, this strategy can then be used to produce the **Project Brief** and included in all contractual documents issued throughout the project.

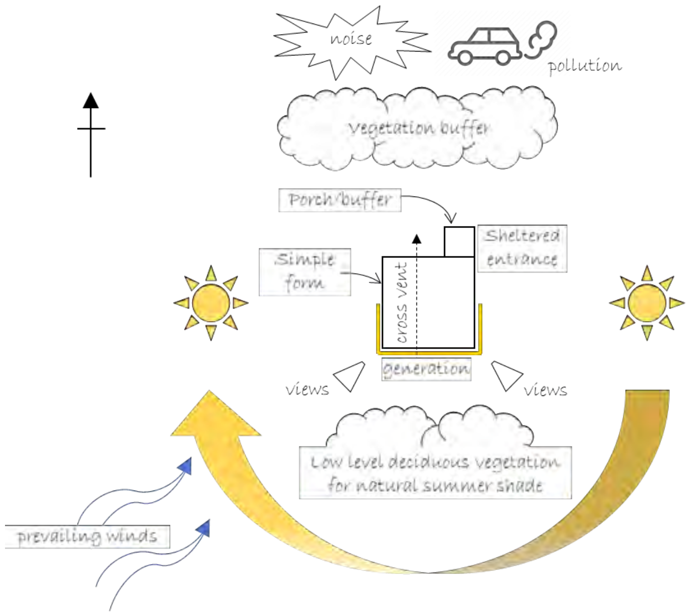
1 Building Fabric & Passive Design

Integrated engineering and architectural design approach including consideration of orientation and massing, fabric efficiency, natural daylight and natural ventilation. Designed for occupant comfort and low energy by following passive design principles.

1.1 Key Design Considerations

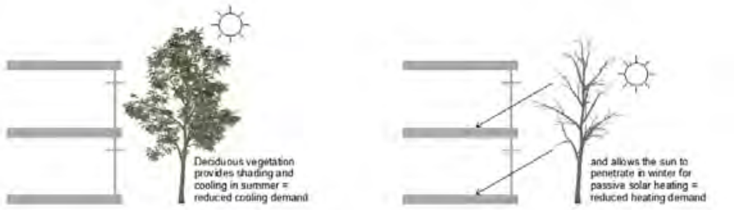
1.1.1 Siting of building

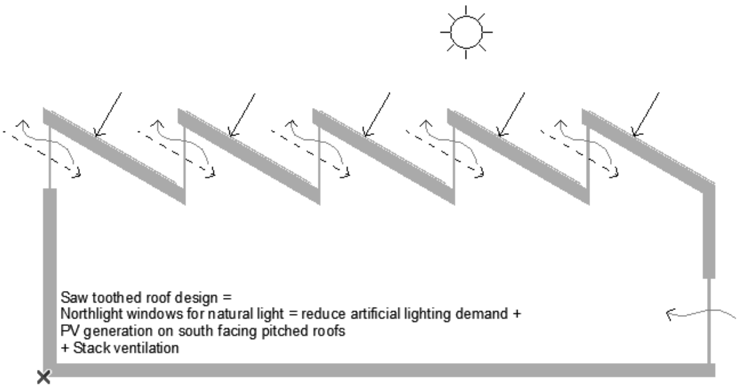
- If considering use of passive and/or active solar energy, ensure unshaded, south facing facades and/or roofs are available. East and west facing surfaces can also be utilised.
- Undertake early modelling to predict impacts of siting, orientation and correlation with anticipated use profiles
- Consider opportunities for green infrastructure around the building to:
    - Reduce flood risk
    - Include biodiversity
    - Improve health and wellbeing of occupants
    - Provide an attractive site
    - Improve air quality
    - Act as an acoustic or pollution buffer
    - Make use of passive cooling and/or shading
- Position within the site to avoid noise or pollution sources. Levels of noise or pollution may influence choice of ventilation system.



1.1.2 Orientation of building

- Energy generation opportunities
- Inclusion of green infrastructure, such as living walls
- Ventilation strategy (e.g. if using natural ventilation, openable windows should correspond to the prevailing wind direction - high air pressure on the windward side moves air into the building and low air pressure on the lee face draws air out of the building)
- Shelter, e.g. positioning entrance doors away from prevailing winds and/or including lobbies in design
- Location of glazed elements
- Treatment of glazed elements:
    - for natural light
    - for passive solar gains
    - to avoid overheating and excessive heat loss
    - for natural ventilation
    - for views





1 Building Fabric & Passive Design

1.1.3 Building Fabric

- Reduce the energy demand of the building through thermally efficient fabric: minimising heat transfer between the exterior and interior of the building, i.e. to reduce thermal loss from the building in winter months (reducing heating requirement) and to reduce thermal gains in summer months (reducing cooling requirements).

    - Consider all elements of the building fabric– floors, walls, roofs, windows and other glazed elements such as rooflights, curtain walling, entrance screens, glazed facades

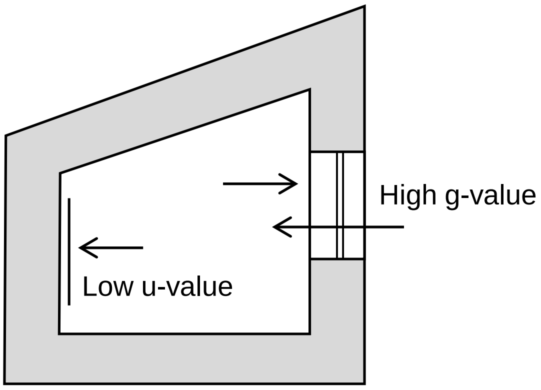
- Renewable energy generation has a better chance of matching the demand profile of a building with a thermally efficient fabric

- Determine ventilation strategy at an early stage, as this will affect the level of air-tightness required – for use of a mechanically ventilated and heat recovery system (MVHR), for example, an air-permeability of <3 m^3/m^2h @50pa is recommended, although MVHR can also be effective at lower air-tightness levels

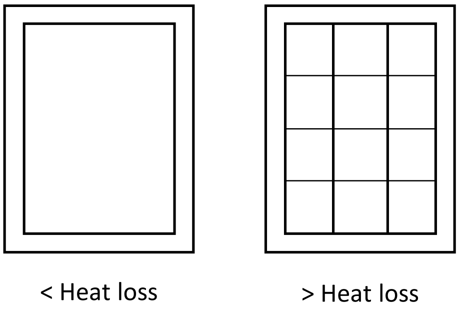
- Design out thermal bridges as far as possible through a simple building form with minimal junctions

- Building form factor will affect heating or cooling load

- Embodied carbon:
    - Specify low embodied carbon materials where possible
    - Specify locally sourced materials where possible
    - Undertake early Life Cycle Assessment, in accordance with the RIBA Plan of Work 2020.



- Window design
    - Frame to glazing ratio - most of the heat loss is through the frame, so a window with more transoms and mullions will have higher heat losses.
        - Planning context may influence this
    - The materials used for window frames, e.g. timber is more insulating than aluminium or steel
    - Type of glazing
    - Size of opening
    - Ratio of solid wall to glazed area
    - Orientation of window
        - Glazing will perform differently on different elevations. For example:
            - South facing windows can reduce heating demand as they enable solar gain during the winter months, and are easy to shade in the summer to prevent overheating.
            - North facing windows provide good daylight, without creating glare issues, but suffer higher heat losses during the winter.
            - Windows on east and west facades experience greater fluctuations as they experience more extreme conditions at different times in the day, i.e. morning glare on east elevations and afternoon glare as well as overheating from west facing windows.
    - Position of window within the wall construction
        - The position of a window within the external wall zone can also affect performance, particularly around the perimeter. To avoid thermal bridging around window frames, it is best to locate a window within the insulation zone.
    - Proportion of solid wall to glass
        - A building should be designed to provide sufficient levels of natural light and ventilation. However, the proportion of glazed elements to solid walls is important when designing a building for maximum energy efficiency.
    - Direction of opening, e.g. inward opening allows use of external shutters/louvres



1.1.4 Natural Light

- Building type: direct sunlight for passive solar gains in winter can reduce heating loads for houses; whereas office buildings require light rather than solar gains to avoid glare issues and overheating

- Poor design of natural light can result in greater energy demand

- Light shelves or mirrored louvres can boost natural light, particularly in deep plan buildings, or in rooms with single aspect glazing. These can be combined with solar shading devices

- In deep plan buildings, consider using rooflights, sun tubes, courtyards or atria to provide additional natural light

- Space planning, including building service zones, should take into consideration the use of solar gains. For example, in dwellings, the living spaces might be located on south-west side of the building, with service zones located to the north and bedrooms facing east.

- Fully glazed facades present a challenge to the environmental design of buildings. They are usually highly energy intensive, due to overheating and glare issues in summer months and thermal losses in winter, meaning the internal environment must be artificially controlled for most of the year.

1.1.5 Cooling

- Consider use of passive design features to reduce the need for mechanical cooling and air-conditioning, such as:
  - Water features
  - Vegetation on or around the building – e.g. summer solar gain can be reduced by trees. Vegetation has the added advantage of improving air quality and absorbing sound.
  - Shading devices (that don’t compromise daylighting)
  - Deep window reveals
  - Recessed balconies
  - Roof overhangs
  - Building form
  - Use of courtyards

1.1.6 Energy

- Consider building footprint and spatial requirements – the bigger the building, the greater the energy consumption. Efficient space planning is key.

- Use performance targets for energy consumption, embodied carbon, water use and wellbeing as set out in the **RIBA 2030 Climate Challenge**

- Utilise **Passive House Planning Package (PHPP)** design tool

- Use Good Homes Alliance (GHA) **Overheating Tool** (for new homes)

- The design of glazed elements will affect the heating and cooling demand

- Use **CIBSE TM54** methodology to accurately predict energy demand where possible

1.1.7 Water

- Mitigate flood risk through Sustainable Urban Drainage Systems (SUDS), such as:
  - Green roofs and living walls
  - Soft landscaping areas
  - Permeable paving
  - Soakaways and swales
  - Ponds and wetlands

- Consider rainwater harvesting if appropriate

- Consider greywater recycling

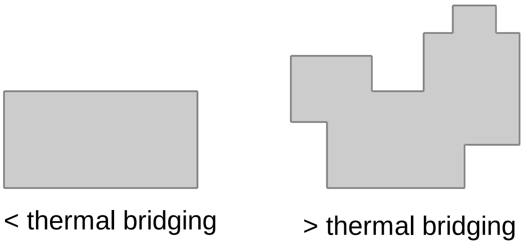
1.1.8 Ventilation

- Ventilation strategy is affected by:
  - Site location, e.g. in urban or polluted areas, natural ventilation may not be appropriate
  - Site layout
  - Building orientation
  - External spaces
  - Relationships to other buildings (particularly in urban environments) e.g. avoid creating wind tunnels
  - Vegetation on and around the building
  - Materials used on and around the building
  - Building air-tightness – for use of MVHR systems, 3 m^3/m^2h @50pa is recommended
  - Use of thermal mass
  - Equipment used within the building

1 Building Fabric & Passive Design

1.1.9 Heating

- The heating demand of a building is affected by the following passive design factors:
  - Building type
  - Location, including altitude and local climate
  - Building shape or form
  - Inclusion of features such as balconies, external porches
  - The amount and type of glazing
  - Levels of insulation
  - Airtightness of the building envelope
  - Ventilation design



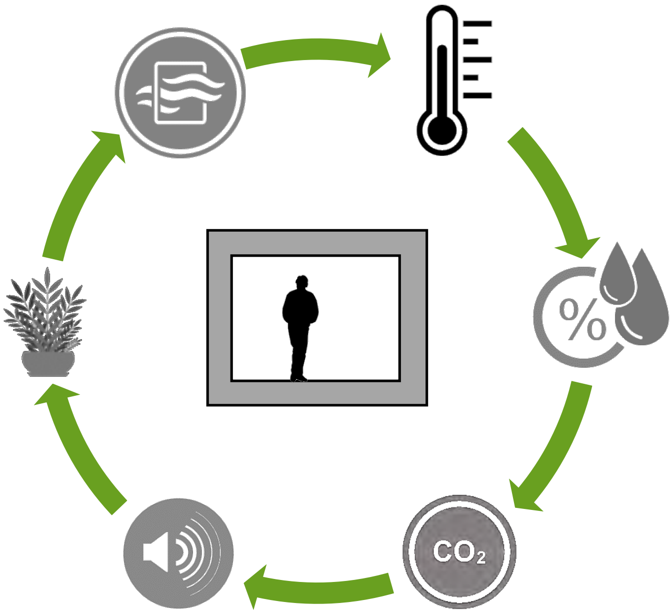
Simple building form = less junctions = less opportunity for thermal bridging + better form factor

1.1.10 Acoustics

- Incorporate acoustic solutions into the design of a space – acoustic solutions can either blend in to a space or stand out as design features

1.1.11 Indoor Air Quality

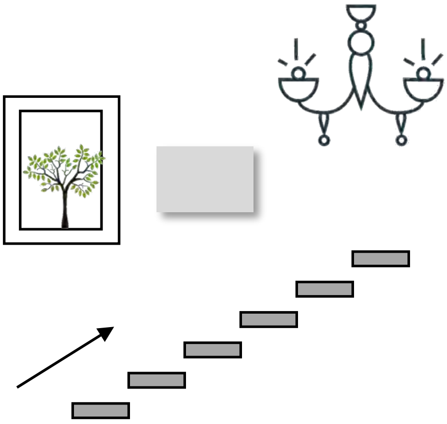
- Indoor Air Quality (IAQ) refers to the air quality within buildings and relates to the health and comfort of building occupants. Understanding and controlling common pollutants indoors is critical to ensuring IAQ promotes good health and wellbeing for building occupants. Appropriate levels of ventilation will help ensure good IAQ. Internal finishes, fixtures and fittings will affect IAQ.



1.1.12 Vertical Movement

- Prioritise use of staircases for vertical circulation where possible for health and wellbeing reasons and to reduce energy consumption from use of electrically operated lifts. This can be achieved through:

  - Location of staircases (in a more prominent position than lifts, e.g. close to main entrance/reception)
  - Use of attractive features, such as windows and artwork in stairwells
  - Aesthetics – design that entices people to use the staircase, through the temptation of an interesting journey through a building, for example
  - Width of staircase
  - Good lighting
  - Use of views
  - Use of biophilic elements
  - Posters reminding occupants of health benefits



1.1.13 Construction Method

While the choice of construction method is not specified for Active Buildings, the ease of achieving the required insulation thickness, airtightness and insulation continuity should be considered when making the decision on construction types. An engineered solution, manufactured off-site using modern methods of construction (MMC), is likely to offer the best performance, but if this is discounted for financial and/or other reasons, then a high level of site supervision will be essential to ensure the performance levels of the building envelope are achieved (and is highly recommended whatever the construction method). MMC have benefits that align with *Construction 2025* targets, including:

- ✓ Faster construction time
- ✓ Reduced construction costs: reduced labour hours and less construction site overheads
- ✓ Improved construction quality – controlled environment
- ✓ Improved health and safety: factory environment = safer working conditions, less work at heights, less weather impacts
- ✓ Lower impact on the environment – less environmental impact, less waste generated

However, MMC is not without it's issues and care must be taken in detailing MMC constructed buildings, particularly the junctions between modules or panels and junctions with other construction techniques, to ensure the factory quality is continued into the site works and final installation.

*Table 4 Comparison of typical construction methods (Source: **How to Build a Passivhaus: Rules of Thumb**)*

External wall construction	Advantages	Disadvantages
Masonry Cavity Wall	• Materials are readily available • Construction method is familiar to local labour • Excellent thermal storage and soundproofing • No danger of interstitial condensation • Cheapest construction method	• Slower construction method • More difficult to check quality and continuity of insulation • More care is needed in services design and installation - badly installed back boxes can create weak points • Longer structural drying out period needed - will affect first season's heating demand
Timber Frame	• Speed of erection • Easy to monitor quality of construction • Airtightness testing can be carried out early during the build	• Additional studs needed to form openings = extra thermal bridging • Danger of moisture build up in the timber frame (solved be ventilating the cavity adequately)
Solid masonry with external insulation	• Insulation and structure are separated = less thermal bridging • Quality assurance is easier • No cavity trays = less thermal bridging • Internal work will not damage the airtightness layer	• External render can be easily damaged • Thermal bridging occurs with heavier cladding if supported off internal structure • Contractors often lack skills and experience to minimise thermal bridging • To reach high standards, systems are expensive
Structural insulated panels	• Off-site construction ensures accurate tolerances and quality • Ease and speed of erection	• Some modification may be needed to meet high performance standards, particularly for thermal bridging
Volumetric construction	• Off-site construction ensures accurate tolerances and quality • Ease and speed of erection	• Detailing between modules needs careful attention – fire risks and thermal bridging, for example • Transportation costs – can be high depending on proximity of factory to site • Safety in craning modules into position

Construction Methods used in Active Building projects to date:

- Active Pod – Structurally Insulated Panel System (SIPS)
- Active Classroom – Steel-framed panelised system
- Active Office – Steel-framed modular system
- Active Homes Neath – Timber frame and SIPS

1.2 Advice

- Close quality assurance (QA) monitoring on site is essential to ensure:
    - Details are constructed correctly, particularly to avoid thermal bridging and excessive air leakage
    - Any substitution of specified materials or systems align with the Active Building principles

- Undertake in-situ thermography and air-tightness testing both during and post construction to identify any significant thermal bridging issues that could impact on the building's performance

- Notes of caution:
    - Conflicts: views, site orientation, shading, window positions, areas of glazing, acoustics, IAQ
    - Consideration of how users operate their buildings, e.g. opening windows
    - Available fuel sources – most appropriate solution
    - Access to local contractors that can build systems specified: < risk = < cost + < failure
    - The need to get specification and detailing right at the start of a project
    - The most cost effective way of working, e.g. it is better for the Architect to collaborate with the contractor
    - Are materials and construction methods chosen more expensive to build?
    - Embodied carbon of materials and construction method
    - Are materials selected readily available? And is there a local supply chain in place to deliver the chosen construction method?
    - Is construction method suitable for adaptation, e.g. how to maintain airtightness when undertaking future renovations, end of life (design for deconstruction?)
    - When specifying solutions such as mechanical ventilation with heat recovery (MVHR), schedules for changing air filters for example need to be included in the building documentation
    - Site location and selection of appropriate solutions accordingly (According to the **Met Office**, there are 11 climate zones in the UK)
    - Possibility of future developments impacting on design (e.g. solar energy being blocked by a new building in the future)

1.3 Resources

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2 Energy Efficient Systems

Intelligently controlled & energy efficient systems to minimise loads - HVAC, lighting, vertical transportation. Low carbon solutions for heating. Data capture via inbuilt monitoring & standard naming schemas to enable optimisation and refinement of predictive control strategies.

2.1 Key Design Considerations

2.1.1 Adaptability

Design for adaptability, considering medium and long term changes in technology, demographics, climate and future working practices, such as flexible working strategies (e.g. designing for demountable partitioning, highly zoned control systems, modular central and local services).

2.1.2 Controls

Controls are critical to reduce energy consumption, but are often value-engineered out to save costs. It is essential that all parties understand the importance of controls and the role they play in helping to reduce overall operational costs associated with running the building.

2.1.3 Heating

- ➢ Model predicted energy loads based on the building fabric and passive design attributes

- ➢ The building's internal gains must be recognised, from passive solar, occupants and equipment

- ➢ Effects of energy use for cooling, fans, pumps and space heating should be considered

- ➢ Select space heating system to provide the lowest total cost-in-use solution, whilst avoiding gas:
  - Prioritise low carbon solutions to be used in conjunction with renewable energy sources where possible. Examples:
    - solar thermal
    - combined heat and power (CHP)
    - air source heat pumps (ASHPs)
    - ground source heat pumps (GSHPs)
    - ground to air heat exchangers (GAHEs)

- ➢ Consider low carbon heat networks where practical

- ➢ In selecting a low carbon heating system consider:
    - Acoustics
    - Availability of skilled installers
    - Users knowledge of systems
    - Site specific conditions

2.1.4 Ventilation

- ➢ Natural, mechanical or a combination - mixed-mode:
  - Mixed mode is applicable for situations where internal heat gain precludes the use of natural ventilation via passive measures alone:
    - Either the whole building could be operated on air-conditioning during peak summer conditions and natural ventilation at all other times;
    - Or, air-conditioning could be used in targeted areas that experience consistently excessive heat gain, or are used intermittently (such as meeting rooms), with the rest of the building utilising natural ventilation.

- ➢ For mechanical ventilation, specify an MVHR system – to provide the ventilation needs for the building, including fresh filtered air whilst retaining most of the energy that has already been used in heating the building:

  - MVHR systems can be used in conjunction with renewable energy generation. To be effective, an air-tightness of <$3m^3/m^2$.h @ 50 Pa is recommended.

- ➢ Airflows need careful consideration to provide adequate fresh air while preventing draughts. Too much air infiltration could also result in high space heating energy consumption

- ➢ The application of solar assisted ventilation via solar chimneys, wind towers and atria can be considered to promote adequate airflow in deep plan buildings without resorting to fan energy use.

- ➢ Consider use of simple ceiling mounted fans to provide air movements in spaces

LETI Future of heat:
- Fossil fuel free
- Limit peak heat loss to $10W/m^2$
- Report average carbon content of heat ($g/Co_2/kWh/y$)
- Limit dead leg of hot water pipework to 1 litre

2.1.5 Cooling

- Minimise need for cooling through passive design and building fabric
- Consider appropriate set points for cooling systems – for instance, comfort levels are often maintained or artificially reduced to 'lower than required' temperatures in summer, where a set point of 24ºC may be sufficient for occupancy comfort
- Avoid distributing large volumes of cooled air, to avoid use of significant quantities of fan energy and long lengths of ductwork
- Low carbon alternatives to conventional mechanical cooling should be considered where the heat gain characteristics are such that a natural ventilation solution will not sustain acceptable comfort conditions throughout the year, such as:
    - An **indirect evaporative cooling system**, where supply water is cooled through a conventional cooling tower. In this system the exhaust air stream is humidified and cooled. This coolth is then transferred to the supply air via a high efficiency heat exchanger.
    - **Groundwater** can be used as a viable cooling source, offering a more stable source temperature than that achieved with evaporative cooling. Water is abstracted from well depths of between 5m and 50m at a temperature of approximately 10ºC. This application is limited to sites with suitable conditions and approval of local authorities.
    - **Surface water** from rivers, lakes or docks, can offer a possible alternative, depending on site location and approval of local authorities; although, the environmental impact of using such sources for heat rejection must be fully evaluated. While temperature fluctuations in source water will naturally be greater, the cooling effectiveness should be greater than that offered by evaporating cooling techniques.

Cooling distribution for the above systems is via water circuits feeding chilled ceilings or cooling panels and will need to consider dehumidification due to the presence of a low temperature surface. Chilled ceilings and cooling panels obviate the need for high volume air distribution systems. If only a small part of the building requires cooling, the benefits are marginal if demand can be met with decentralised units.

- Use of night-time purging or north intake bypass systems can reduce the need for mechanical cooling, such as air-conditioning. Overnight purge can reduce accumulative overheating experienced during prolonged warm spells. Care is needed to avoid over cooling during the night, which could trigger heating first thing in the morning. Use of appropriate deadband settings will avoid this issue.

2.1.6 Lighting

- Specify energy efficient lighting systems, for low energy consumption and reduced cooling demand
- Where possible, consider integration of high efficiency task lighting with scheme lighting to reduce overall demands
- Incorporate energy saving features into lighting systems to reduce use of artificial lighting, such as:
    - **Daylight dimming sensors** to realise savings from maximising daylighting – lights react to external weather conditions. Where daylight dimming is employed, suitable response times are required to avoid obvious and distracting fluctuations in artificial light adjustments as clouds or other external influences are detected.
    - **Digital Addressable Lighting Interface** (DALI) controls to enable automating control of light fittings dependant on occupancy requirements
    - **Passive infra-red (PIR) sensors**, linking lighting use to occupancy. Where PIR occupancy sensors are employed, appropriate adjustments an options for reducing premature switching off may be required.
    - **Absence detection** which enable users to switch on a light manually when they enter a room, but sensors detect when the room becomes vacant and switches off the lights automatically, linked to pre-set timers.
- Assess visual comfort of lighting installations to ensure the well-being of occupants, taking into consideration aspects such as lighting flicker, glare, aesthetic impressions of internal finishes, etc.

2.1.7 Water

- Prioritise reducing water over recycling it
- Rainwater harvesting systems have advantages and disadvantages:
  - Only consider where viable and economically feasible, for use in landscape irrigation, for toilet flushing and washing machines
  - When using rainwater harvesting, use simple water butts without pumps where possible, to reduce energy demand
  - Rainwater harvesting can reduce the strain on storm water or combined sewers and reduce the amount of mains connected water use
  - Use of rainwater harvesting could increase a building's carbon emissions compared to mains water supply and will increase maintenance requirements
  - Options for rainwater harvesting:
    - **Gravity-fed system** – water is collected from the roof, taken to a tank in the ground, pumped into a header tank at high level and gravity-fed down to devices. Spare renewable energy could be used to charge the header tank when available, although power consumption of the water pump can be relatively minor in comparison to other building systems.
    - **Indirect feed system** with a break-tank which allows small amounts of water to be drawn off without pumping
- Greywater harvesting involves collecting water from baths or showers for use in toilet-flushing
- Waste energy from showers can be harvested using a simple heat exchanger around the incoming mains cold water supply. This can be simple to implement if designed in to the system early enough.
- Specify water saving devices, such as:
  - Water-saving shower heads - aerated or non-aerated
  - Low-flush or dual flush toilets
  - Sensor operated controls for taps and toilet flushing
  - Knee or foot operated controls
- To reduce energy required for hot water supplies, always ensure pipes and tanks are well-insulated to reduce losses

2.1.8 Combining systems for efficiency

- All building services should work together in one optimised system, optimised to make the best use of available energy, whether generated on-site or grid-supplied, and be capable of distributing the energy in the most appropriate and efficient way.
- Robust system controls are essential to ensure systems operate effectively
- Embedding metering devices and sensors into energy systems is essential to:
  - Enable issues to be identified and resolved quickly
  - Provide feedback on actual building performance
  - Enable the development of planned maintenance strategies
  - Enable optimisation of system to save energy and operational carbon
  - Enable the development of predictive control strategies
  - Educate building occupants on their energy consumption and how the energy used is provided
  - Enable controlled import and export of energy, based on factors such as grid Carbon Intensity (CI) or cost.
- Careful commissioning is essential to ensure all systems installed operate efficiently and are optimised to provide the environment required, while minimising energy use
- Building users must be trained in the correct operation of the installed environmental systems and must understand the overall energy strategy and Active Building design philosophy
- Building user manuals should be provided
- Part of the handover strategy should include a building review (similar to an MOT for motor vehicles) after the first year of operation

2.2 Advice

- Before embarking on design of building systems, it is essential to know the occupancy profile
- Ensure low carbon systems selected fit into the overall energy strategy for the building
- Utilise '**CIBSE TM54: Evaluating Operational Energy Performance of Buildings at Design Stage**' to accurately predict energy consumption
- Implement design measures and key performance indicators described in the **LETI Climate Emergency Design Guide**
- Never underestimate the size of ductwork and other building services equipment
- Air flows in buildings are complex and should be modelled as accurately as possible in design stages
- Data sheets for technologies are not 100% reliable. They often do not consider how particular technologies or equipment work as part of an overall system. Bear this in mind when specifying
- Position, size and layout of plant rooms is critical to the successful operation of the building. Plant rooms should be fully modelled during design stages, including air flows around equipment, maintenance access, etc
- Consider exposed services – better maintenance access, more efficient design and installation, less materials (no ceilings)
- When modelling energy consumption, include all consumers, including network sockets, fire alarm panels, comms panels, etc – these are often not factored into energy modelling but can be high consumers when accumulated
- When modelling energy consumption and generation, the load profiles (when energy is used, not just total requirements) is as important as the total energy consumption. Time shifting possibilities for significant loads, bearing in mind any roundtrip efficiencies or sacrificial losses (thermal decay from hot water tanks for example), should be considered.
- Incorporate plenty of metering. This is essential for data capture for fault detection, maintenance strategies, etc. As a minimum, regulated and unregulated loads should be understood, so that heating and hot water demand can be compared to estimated, for example. Loads such as EV charging should also be separated, again to ensure that the building operation can be compared to design performance. Ensure metering is installed and commissioned correctly
- It is highly advisable to appoint a Quality Assurance (QA) professional to monitor site activities, oversee installation and ensure building services are installed correctly in accordance with design specifications.
- Employ HVAC Control Specialist as early in the project as possible
- The HVAC Controls Contractor should provide all aspects of the control systems, hardware and software for the MEP controls
- At commissioning stage, the HVAC Controls Contractor must test connectivity between systems and ensure that data is being captured as specified.
- Communication is critical in Active Buildings – ensure enough network sockets are included

2.3 Checklist for Building Services

To avoid spatial and routing issues that could affect the overall architectural design strategy and aesthetics, building services must be considered early in the design process (RIBA Stage 2 – 3) in an Active Building, as services are integral to the overall holistic building design. If not considered properly, this could result in aesthetic compromises and sub-optimum building performance. Mechanical and electrical schematic layouts will not provide sufficient detail to enable scrutinization of system design. Considerations for designers include:

- Ease of access for maintenance, upgrading, adaptability and renewals, applicable to:

    - Cable and ductwork runs
    - Connection and metering equipment
    - Energy storage systems
    - Control boxes

- Design of cable routes and how these can be integrated into the overall architectural design:

    - Small power
    - Communications/data
    - Fire
    - Lighting

- Length and optimal routes for cables and ductwork

- If using heat pumps:

    - Location (ASHPs external, GSHPs can be located internally)
        - Ease of access for maintenance
        - Distance surrounding heat pump
        - Acoustic considerations
        - Away from vegetation
        - Away from direct sunlight
    - Design of base
    - Length of pipe runs
    - Insulate pipe runs with weatherproof pipe lagging

- Is surge protection needed? If so, where will the surge protection device (SPD) be located?

- Is lightning protection needed? If so, where will it be located?

2.4 Resources

1. Clegg, P. Bradley, K. Fielden, R. Gething, B. 2007. *The Environmental Handbook*. Right Angle Publishing Ltd, London, UK.

2. Evans, H.M.A. 2016. *How Buildings Work*. RIBA Publishing, RIBA Enterprises Ltd, Newcastle-upon-Tyne, UK.

3. LETI. 2020. *Climate Emergency Design Guide*. https://www.leti.london/cedg

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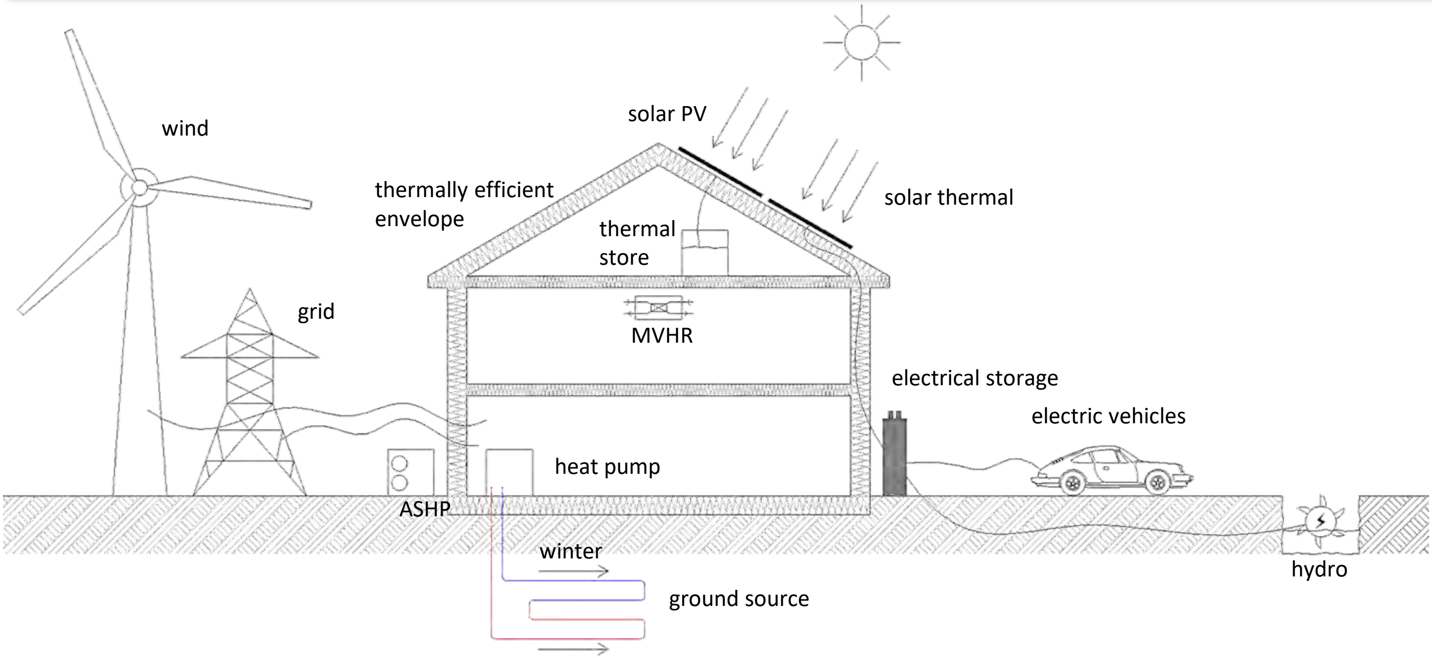
3 On-Site Renewable Energy Generation

Renewable energy generation to be incorporated where appropriate. Renewable technologies should be selected holistically, given site conditions and building load profiles.



3.1 Key Design Considerations

3.1.1 Technology Selection

- Select energy generation source to suit the site location. Some of the questions you might consider:
  - Could solar energy be a viable solution? This will be dictated by geographical location, micro-climate, orientation, shading, available surface area to building volume, aesthetics
  - Is there a water source (stream, river, lake) nearby that could be utilised?
  - Is the site exposed? Is there space to include a wind turbine?

- Decisions on which technology to use and the size of generation system needed will be affected by:
  - Planning constraints
  - Predicted energy consumption and use profile
  - Site conditions
  - Building type
  - Aesthetics
  - Clients requirements – drivers
  - Cost
  - For heat: source temperature required, peak temperature required, heating system to be used
  - Maintenance requirements
  - Available generation area

- If using building integrated photovoltaics (BIPV), roof dimensions may be determined by the size of PV modules.

- If using BIPV, positioning of junction boxes may determine roof design, e.g. if junction boxes are on the underside of modules, a cable void should be formed in the roof build up; if junction boxes on top side of modules, these must be protected from the elements, positioned for e.g. under ridge flashing.

3.1.2 Spatial Considerations

- Ensure sufficient spatial arrangements for connected equipment – charge controllers, inverters, battery storage

- Size of renewable energy generation system will depend on purpose:
  - To meet demand
  - To exceed demand (with controlled export) – smart controls and storage needed (and/or electric vehicle integration)

3.1.3 Maximising benefits

- Combining energy generation with energy storage will enable maximum use of generated energy

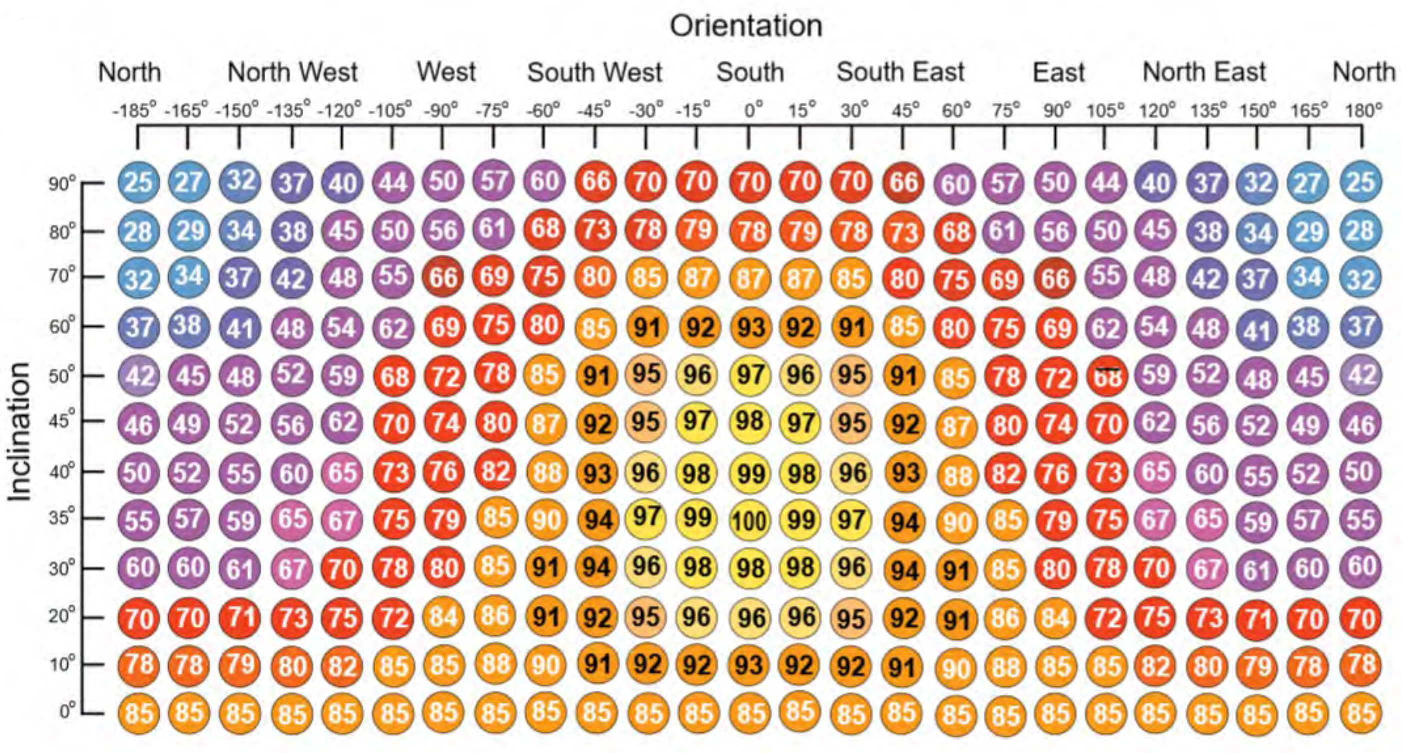
3.1.4 Maintenance

- Allow access for maintenance and replacing parts

- Plan for external control of storage systems that are considered for inclusion in aggregation systems and for control of energy. This could include communications protocols such as RS485, MODBUS, or similar, to enable control of charge and discharge of storage systems.

3.2 Solar Energy

The following diagram, taken from "***A Guide to the Installation of Photovoltaic Systems***", is useful to aid design of solar arrays, illustrating the affect of orientation and inclination on PV performance in the UK. This is particularly useful to consult when positioning buildings on a site, as it demonstrates the possibility of generating energy from solar with non-optimum orientations or roof pitches.



Inclination	North			North West			West		South West				South			South East			East		North East				North
	-185°	-165°	-150°	-135°	-120°	-105°	-90°	-75°	-60°	-45°	-30°	-15°	0°	15°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
90°	25	27	32	37	40	44	50	57	60	66	70	70	70	70	70	66	60	57	50	44	40	37	32	27	25
80°	28	29	34	38	45	50	56	61	68	73	78	79	78	79	78	73	68	61	56	50	45	38	34	29	28
70°	32	34	37	42	48	55	66	69	75	80	85	87	87	87	85	80	75	69	66	55	48	42	37	34	32
60°	37	38	41	48	54	62	69	75	80	85	91	92	93	92	91	85	80	75	69	62	54	48	41	38	37
50°	42	45	48	52	59	68	72	78	85	91	95	96	97	96	95	91	85	78	72	68	59	52	48	45	42
45°	46	49	52	56	62	70	74	80	87	92	95	97	98	97	95	92	87	80	74	70	62	56	52	49	46
40°	50	52	55	60	65	73	76	82	88	93	96	98	99	98	96	93	88	82	76	73	65	60	55	52	50
35°	55	57	59	65	67	75	79	85	90	94	97	99	100	99	97	94	90	85	79	75	67	65	59	57	55
30°	60	60	61	67	70	78	80	85	91	94	96	98	98	98	96	94	91	85	80	78	70	67	61	60	60
20°	70	70	71	73	75	72	84	86	91	92	95	96	96	96	95	92	91	86	84	72	75	73	71	70	70
10°	78	78	79	80	82	85	85	88	90	91	92	92	93	92	92	91	90	88	85	85	82	80	79	78	78
0°	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85

3.2.1 Do’s and Don’ts of solar for electricity generation:

Do	Don’t
• Avoid shading from other buildings and vegetation if possible	• Locate near features that could shade panels, e.g. flues, dormers, service cowls (roofs)
• Model shading affects	• Shade with deep reveals, overhangs, or balconies (facades)
• Maximise available generation area, or size to meet demand, depending on the aims and objectives of a project	
• Consider suitable shading mitigation technology options, such as micro-inverters or power optimisers, if seasonal or partial shading is of concern	

3.2.2 Do’s and Don’ts of solar for heat generation:

Do	Don’t
• Size collector for heating and/or hot water demand, accounting for any potential shading	• Oversize system
• Provide storage vessel to buffer heat generated	• Position in a shaded location (see above)
• Ensure provision of sufficient generation area	
• Consider the end use temperatures required and select suitable generation and consumption pairings	

3.2.3 Solar PV Choice will depend on:

- Planning constraints
- Aesthetics
- PV area to volume ratio
- Main driver
- Available surface area
- Predicted energy consumption
- Site conditions
- Building type

3.2.4 Solar Thermal Choice will depend on:

- Planning constraints
- Site conditions
- Maintenance requirements
- Predicted energy consumption
- Heating system
- Aesthetics
- Source temperature required
- Building type
- Peak temperature required
- Available surface area

3.3 Advice

- ➢ Use software packages to aid system design and sizing of proposed PV generation system at early design stage, e.g.:
    - **https://www.pvsyst.com/**
    - **https://ec.europa.eu/jrc/en/pvgis**
- ➢ Clearly define example usage scenarios and expected logic outputs
- ➢ Use one contractor for renewable energy generation, energy storage and control system installations if possible
- ➢ When designing for building integrated technologies, such as PV, the size of the PV panels, access for maintenance, cable routes, will dictate the roof design
- ➢ Local consumption of relatively low power generation could be more effective than long wiring runs to centralised storage systems. Example uses could include using locally generated energy to operate electric blinds to reduce solar gain when power generation is available, or the operation of destratification or air circulation fans when power is available.
- ➢ Where available external surface area is constrained, consider the appropriateness of combined systems such as solar thermal and PV combined (PVT).
- ➢ If installing small PV arrays, e.g. PV windows, consider how the power generated from that element can be used most effectively

3.4 Resources

1. MacKay, D.J.C. 2009. *Sustainable Energy – without the hot ar.* UIT Cambridge Ltd, Cambridge, UK, (Free download: www.withouthotair.com)

2. RIBA. 2019. *RIBA 2030 Climate Challenge*. https://www.architecture.com/-/media/files/climate-action/riba-2030-climate-challenge.pdf

3. SPECIFIC. 2020. www.specific.eu.com

4. Rawlings, R. 2009. *Capturing solar energy, CIBSE Knowledge Series: KS15*. The Chartered Institute of Building Services Engineers, London, UK.

4 Energy Storage

Thermal and electrical storage should be considered to mitigate peak demand, reduce the requirement to oversize systems, and enable greater control.

4.1 Key Design Considerations

4.1.1 Electrical

- Electrical storage is essential to enable optimum use of electricity provided by renewable energy generating technologies and the grid

- The most widely used form of electrical storage is batteries (refer to Active Building Technology Showcase)

- Electrical storage enables:
  - management of the lulls (periods with little or no solar energy production) and slews (short-term changes in either supply (a lot of solar energy) or demand (a large power draw))
  - the maximum use of renewable energy, storing the energy as it is generated for when it is needed – hence reducing the amount of grid-electricity needed and hence reducing energy bills
  - building owners to choose when to use their solar energy and when to export it to the grid, demand shifting grid-connected electricity usage, through a smart control system
  - reduced pressure on the grid
  - export of both spare power being generated at a point in time, or previously stored power to time-shift export, enabling peak shaving or tariff benefits, in the right circumstances and with agreements could mitigate the high cost of local grid upgrades required for high power, but intermittent load profiles. Energy storage acts as a buffer to enable this – careful consideration of this operation is required.

- Electrical storage can store energy for relatively short periods of time (up to 2 days) but relies on a smart system combining storage with demand-side response, shifting load profiles, for longer periods

- The energy storage control system will determine when to switch appliances on, when to charge electric vehicles, the optimum time to charge the batteries and when to export energy to the grid.

- When designing energy storage, future scenarios could consider the use of EVs as an additional route to provide flexible storage (see Principle 5). Smart charging and bidirectional charging functions enable 'vehicle-to-grid' (V2G) technology to allow EVs to export electricity back to the grid. V2G is unlikely to be widely available until after 2025.

- Location
  - close to generation to minimise losses
  - safe, self-contained area
  - ventilated space to avoid heat build-up

- Spatial requirements for storage and associated systems, including space needed around equipment

- Electrical storage technologies have high capital costs, so systems should be sized carefully, according to the purpose of the storage, e.g.:
  - For self sufficiency
  - To optimise electricity use
  - To reduce operational carbon
  - To take advantage of time-of-use tariffs or trading opportunities

- The efficacy of storage solutions can be measured according to different criteria:

  - Energy density (or how much energy is stored per kilogram of storage system), although for static applications (buildings), the volume of storage is likely to be more important than weight
  - Storage form factor
  - Modularity
  - Instantaneous power draw (also tied to inverter power)
  - Full roundtrip efficiency (amount of energy available for use compared to energy put in, including inverter losses, as well as losses related to battery chemistry)
  - Lifetime (how many cycles of energy storage can be delivered before the system needs refurbishing)
  - Maximum rate at which energy can be pumped into or out of the storage system (power per kg)
  - Duration for which energy is stored in the system; cost of the system; and safety

Specification decisions will include:

- Cycle lifetime
- Maintenance requirements
- Roundtrip efficiency
- Self-discharge rate
- Weight
- Cost
- Energy density
- Instantaneous power available
- Controllability
- Capacity required

Summary of electrical storage benefits

1. To reduce the capacity of renewable energy generation needed to help achieve carbon reduction targets by improving the utilisation of the intermittent renewable energy generation, i.e. a smaller PV array could be considered, if used in conjunction with storage. However, from an economic viewpoint, it can be better to oversize PV array (and limit peak output via inverters), rather than install a small PV array with battery storage (in 2020).

2. To reduce operational carbon by importing electricity when the carbon intensity (CI) of the grid is low (regardless of demand) and exporting electricity to the grid when the CI is high. (Note: this could have wider implications on the grid networks if all buildings operated in this way)

3. To save money, by importing electricity from the grid when the price is low and using stored electricity or exporting to the grid when the price is high.

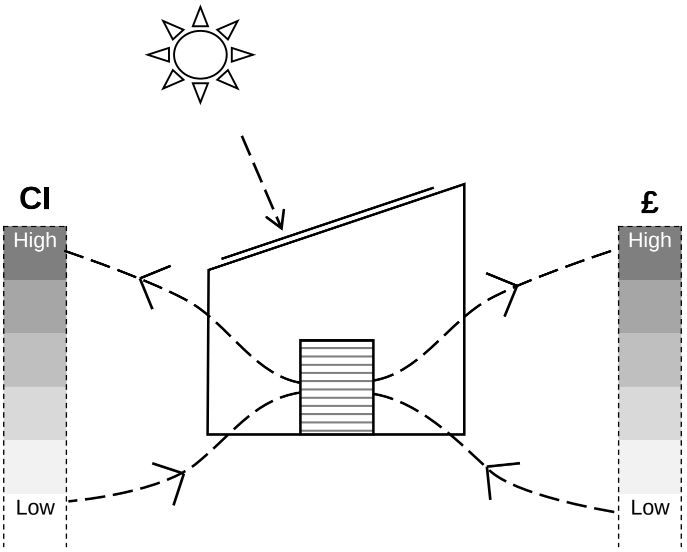
4. To enable system balancing, storing electricity generated from renewable sources when yield is high and utilising stored energy when generation is low.

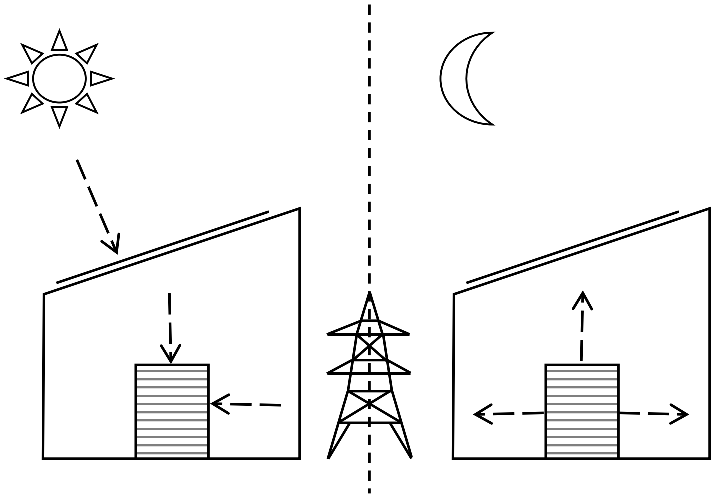
5. To store electricity during times of network stress or to overcome network constraints.

6. To reduce peak loads

7. To improve the utilisation of grid supplied electricity and defer investments in transmission and distribution network reinforcement (wider benefit).

8. To provide grid support via frequency response or external control via an aggregated virtual power plant (VPP), in conjunction with an appropriate control system.





Note: for any of these benefits to be realised, a robust control system is essential.

4 Energy Storage

Common Terminology Explained

Roundtrip efficiency:	The roundtrip efficiency of electrical energy storage for buildings is the roundtrip AC-to-DC-to-storage-to-DC-AC energy efficiency of the storage bank, or the fraction of energy put into the storage that can be retrieved. Different chemistries (lithium ion, flow cell, lead acid, etc) will have different round trip efficiencies. Most energy used in buildings is consumed as AC (albeit sometimes changed back to DC by local power bricks). The inverter efficiency has a role too - efficiency is affected for both battery and inverter based on instantaneous power - under sized inverters in domestic systems can be installed so that they operate for more time at their maximum power efficiency, for example.
Maximum charge rate:	The limit at which the system can charge the storage bank
Minimum state of charge:	The relative state of charge below which the storage bank is never drawn, specified as a percentage of the total capacity. Most batteries are not meant to be fully discharged. The minimum state of charge is typically set to 30-50% in order to avoid damaging the storage bank by excessive discharge. Some chemistries (flow cells, for example) are purported to cope with being fully discharged without impact on lifetime – making them suitable for static storage applications (such as in buildings).

4.1.2 Thermal Storage

- Thermal storage should be considered to realise the true benefits of a solar heating system, storing heat generated until the heat is ready to be used
- There are three types of thermal storage:

Storage Type	Period	Description	Energy Density
Sensible	Short Term (days)	Utilises heat capacity of material • Water • Thermal mass of building • Thermal mass of ground	30 kWh/m^3
Latent	Short-mid Term (weeks)	Heat physically changes a material either by melting, crystallisation or evaporation. • Organic or non-organic phase change material (PCM)	70 kWh/m^3
Thermochemical	Long term (inter-seasonal)	Heat stored through a thermochemical process by passing warm air over a salt in matrix (SIM)	140-830 kWh/m^3

Refer to Active Buildings Technology Showcase for examples.

4.2 General Considerations for all Energy Storage

- Purpose:
  - To assist grid interactions, via time shifting of significant demand or remote control via some grid health measure (frequency, voltage, etc)
  - For self-sufficiency/resilience

- Space requirements

- Location:
  - Close to generation to minimise losses
  - Safe - self-contained area for safety, ventilated space to avoid heat build-up

- For storage such as water tanks, ensure high levels of insulation to minimise heat losses

4.3 Resources

1. Bloomberg NEF. 2019. *New Energy Outlook 2019*. https://about.bnef.com/new-energy-outlook/#toc-download

2. Energy Rev. 2019. *Policy & Regulatory Landscape Review Series. Working Paper 1: Electricity storage and electric vehicles.* https://www.energyrev.org.uk/media/1238/energyrev_working-paper_storage-and-evs_20190912pdf.pdf

3. Energy Savings Trust. *Energy Storage*. https://energysavingtrust.org.uk/renewable-energy/energy-storage

5 Electric Vehicle (EV) Integration

Where appropriate Active Buildings integrate electric vehicle charging. As technology develops, bi-directional charging will allow electric vehicles to deliver energy to buildings as required.

5.1 Key Design Considerations

- ➢ EV charging requirements should be determined before sizing energy generation and energy storage systems

- ➢ Identify the power requirements to inform the electrical design

- ➢ Location of chargers in relation to building and electrical connections

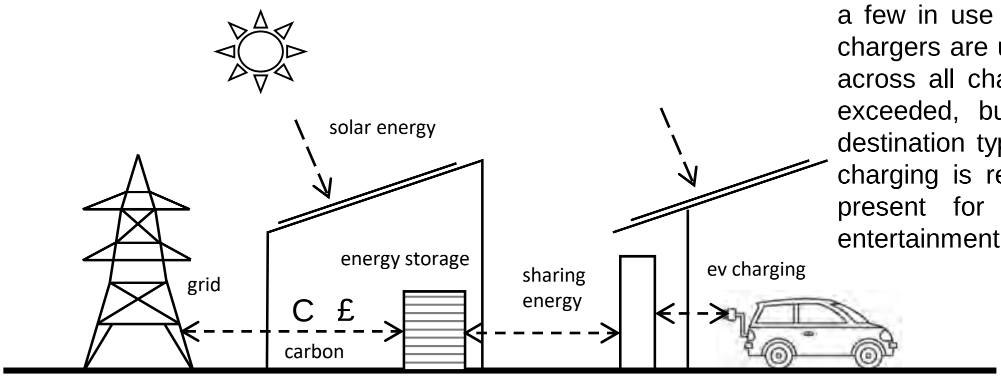
- ➢ Impact on site layout

- ➢ Identify the types and quantities of EVs that charging facilities are required for. Types of EV charging facilities provided:

  - For electric cars, motorcycles and vans
    - Charging spaces adjacent to the building
    - Charging spaces within the carpark, maybe used in conjunction with PV parking canopies
    - Roadside chargers for use when street parking is the only option (kerb or lamppost options)

  - For electric bicycles and scooters
    - Bicycle shelter with integral PV
    - Bespoke e-bike charging shed

  - For electric buses (schools, airports, large manufacturing facilities)
    - Charge points outside building and in coach parks



- ➢ Smart chargers can shift the time of day when an EV charges or modulate the rate of charge at different times. This allows the building owner to change the speed of charging or delay the onset of charging based on variables such as demand, CI of grid, or as a response to price signals. Always specify smart chargers:

  - EVs can assist with the smart operation of an Active Building if bidirectional functions are included, by running their chargers in reverse, putting power back into buildings or the grid, at times of peak electricity usage or electricity shortage (not yet available in 2020).

  - Smart chargers can respond to the value of electricity, as well as the car user's requirements. For example, the charger could satisfy the user's requirements when the sun is shining and switch off the charger when the sun is obscured, or when other forms of demand increase, hence providing a useful service in balancing the grid. They could also be programmed to extract from the grid when the price of electricity is lowest and feed into the grid when the price for electricity import is highest.

  - Electric vehicles can add significant energy load to a building – controlling their charging regime will ensure they take energy either when need is identified through calendars, or when the building demand is low.

  - Smart charging will protect both the building owner and the grid, which would otherwise be put under huge stress through the electrification of transport.

  - Load management of multiple chargers - when only a few in use charge rates are high but, as more chargers are used, the available load is distributed across all chargers. This ensures capacity is not exceeded, but maximises charging stations for destination type charging – i.e. longer, but slower charging is reasonable as vehicle is likely to be present for long periods (office car parks, entertainment venues, etc)

5.2 Types of EV Chargers for cars and vans

There are generally two main types of charging required:

- **Destination charging** - where people travel to a location and stay for a period of time (slower charging feasible, but with more stations
- **Utility charging** - such as motorway service stations – as much charge as quickly as possible (similar to a fuel station)

Charger Type	Capacity	Description
Ultra-Rapid	100 – 350kW DC only	Capable of charging a 100% electric car up to 80% in 30 minutes. Often used in motorway service stations.
Rapid	50kW DC, 43kW AC	Allows EVs to charge at their maximum rated speed. Can deliver 100 miles of range in 10 minutes. Compatible with most EVs.
Fast	7 – 22kW	Depending on the size of the car battery, these can charge a car in around 4 hours. Often found on the street and in car parks.
Slow	Up to 3kW	The most common type of charger, often used in workplaces and homes. A standard charge can take 6 – 12 hours to charge a battery fully – suitable for top ups or overnight charging

Some EV chargers use AC electricity and some use DC:

AC Chargers (22kW or less): Maximum charge rate is determined by the vehicle hardware – the charge point is an energy source for AC power and the vehicle inverts it using onboard hardware. This means that some cars will charge at 22kW and some will only charge at a maximum of 7kW, depending on the vehicle model.

DC Chargers: DC chargers bypass the vehicle inverter to provide DC energy, The vehicle communicates with the charger to control the charge rate – either CHAdeMO or Combined Charging System (CCS) protocol and connections. Hence most DC chargers have two cables, although they can often only support one in use at a time.

5.3 Advice

- For home owners, there is a UK Government funded grant available through the ***"Electric Vehicle Homecharge Scheme"***, which offers homeowners a 75% contribution towards the cost of one charge point and its installation up to a maximum of £350 (including VAT) per household or per eligible vehicle.

- Check Planning Policy and Local Planning Guidance to determine the minimum provision of EV charge points required.

- If manging a fleet of EVs, consider fitting geotags or other tracking devices to each vehicle to provide locations of vehicles and information on their state of charge. If linked to a car booking system, it can be a helpful way of checking availability.

5.4 Resources

1. Clarke, J. 2020. *Active Building Technology Showcase*. https://www.specific.eu.com/wp-content/uploads/2020/09/Active-Building-Technology-Showcase-v1.pdf

2. Energy Rev. 2019. *Policy & Regulatory Landscape Review Series. Working Paper 1: Electricity storage and electric vehicles.* https://www.energyrev.org.uk/media/1238/energyrev_working-paper_storage-and-evs_20190912pdf.pdf

6 Integration with Grids

In addition to intelligent controls, Active Buildings manage their interaction with wider energy networks, e.g. demand side response, load shifting & predictive control methods.

6.1 Key Design Considerations

Ultimately, Active Buildings aim to reduce the energy demand of buildings on the energy networks and, to do this, intelligent, proactive, energy management is essential to enable control of the energy profile, such as to display a 'flat' demand profile externally. This is achievable through the controlled use of sensors, metering, power tags, heat meters, forecasting, trading, optimization and monetarization. The aim of an Active Building is to have no uncontrolled import or export of energy. Characteristics of an electrical demand management strategy include:

- Reducing the building's demand on the grid
- Equipping the Building Management System (BMS) with the ability to forewarn occupants of likely load peaks in advance
- Enabling flexibility and reducing peak loads, which reduces costs and eases pressure on the grid, and the creation of business models which allow value creation
- Demand Side Response (DSR) provides an opportunity for Active Buildings to play a role in the operation of the electricity grid by reducing or shifting their electricity usage during peak periods in response to time-based rates or other forms of financial incentives. This enables dynamic energy pricing, as well as reducing grid stress
- Predictive controls, based on weather forecasts or occupancy calendars
- Self-learning optimization, based on price or carbon intensity. Weather forecasting is also a factor when making decisions on how much energy to import or export, and when, e.g. when price is low, energy should be imported, but it may get cheaper and there may not be any capacity left to take more charge. Energy trading in this way is similar to trading on the stock exchange, i.e. using informed decisions, which may or may not provide the optimum outcome.
- Vector optimization - selecting the preferred energy source based on weather forecast, for example.

In designing the strategy, consideration should be given to:

- National grid auxiliary services, e.g. aggregation of batteries and frequency response.
- Reducing peak demand, which is more important than overall levels of generation without a flexible approach to deployment, i.e. flexibility and reducing peak loads, hence reducing costs, not adding pressure on the grid, considering new business models, allowing value creation and enabling critical value extraction.
- The technical effects on local grid phases for sudden load or dump conditions.

6.2 Demand Side Response (DSR)

DSR describes a type of energy service that large-scale industrial and commercial consumers of electricity can use to help keep the grid balanced. DSR participants either decrease or increase their facility's power consumption when they receive signals (requests for help) to do so, thereby helping the grid to maintain its 50Hz frequency.

As well as offering financial benefits, using DSR offers huge benefits to the Grid, helping stabilise the UK's electricity supply and enabling more use of renewable energy.

Opportunities for aggregated DSR (using smaller systems working in concert) to enter these energy trading markets are emerging and trials are underway (2020). Flexibility and control via an external source are vital for participation in these types of schemes.

LETI Demand Side Response:

- Develop a Demand Side Response Strategy
- Design to reduce peak electrical demand
- Incorporate active demand response measures (e.g. storage and controls)
- Influence occupant behaviour – display and report energy demand and generation

6.3 Microgrids

There are an increasing number of companies developing smart grid solutions, which will play a key role in the transition to a low-carbon energy economy. Some of these are highlighted below:

SNRG (Senergy): a design and technology company focused on creating and integrating solutions to develop Zero-Carbon Co-Living Communities.

Power Transition: An Integrated Microgrid as a Service (iMaaS) software platform designed to help solve the challenges of the energy sector.

Sero Energy: provide an energy management service for homes, using the lowest cost and lowest carbon energy is used. They do this by combining all the homes they manage, with smart forecasting and energy storage; which enables them to buy electricity in bulk like a commercial user at the times of day or night it is cheapest; which means they can drive down costs for residents, while providing services that help support more renewable energy on the National Grid.

The **Electric Corby** Community Interest Company (CIC) supports a range of community project, such as:

- Etopia Corby: a development of 47 eco homes
- YourCommunity.Energy: a connected smart energy network that enables more renewable electricity generation with the aim of providing reduced energy costs for residents and businesses.

Evergreen Smart Power: A software platform connecting domestic devices to form a Virtual Power Plant (VPP) which rewards householders for their flexibility in energy usage. This is currently being trialled through a project called **FRED**.

Carbon Track: a technology company that connects energy distributors and energy consumers, delivering embedded networks, VPPs and facilitating smart grids.

SOLshare Case Study

Access to electricity per head of population in Bangladesh is amongst the lowest in the world. Using the **SOLshare** platform, Bangladesh now has the biggest Solar Home System in the world, helping communities to build an electricity grid from the bottom up, starting by interconnecting homes within villages, then connecting villages together. This decentralised community energy micro-grid means homes become the energy grid (or power station) for the whole country. This provides a reliable power supply, that is democratic, efficient and helps local economies.

How it works: Homeowners with solar panels and battery storage can purchase a box that allows them to buy and sell energy between homes. If they can't afford solar panels and batteries, they can still buy the box, which allows them to buy energy when they need it.

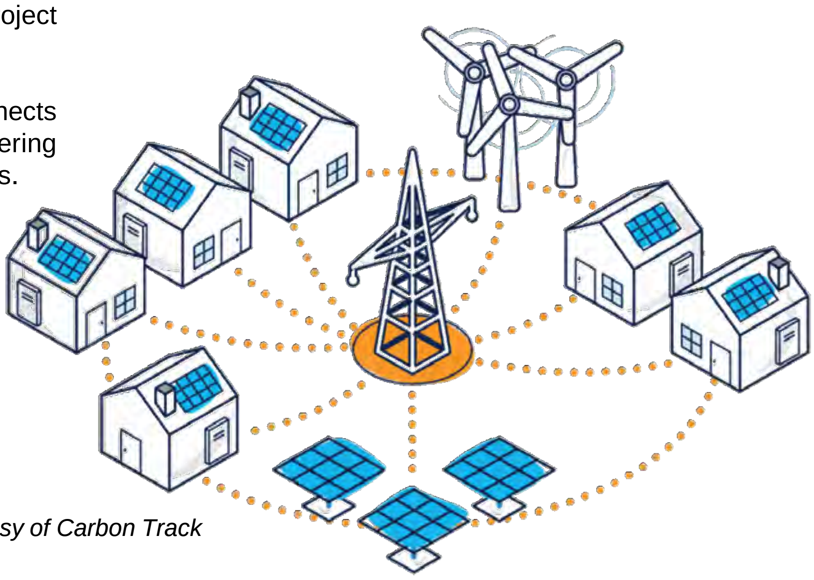


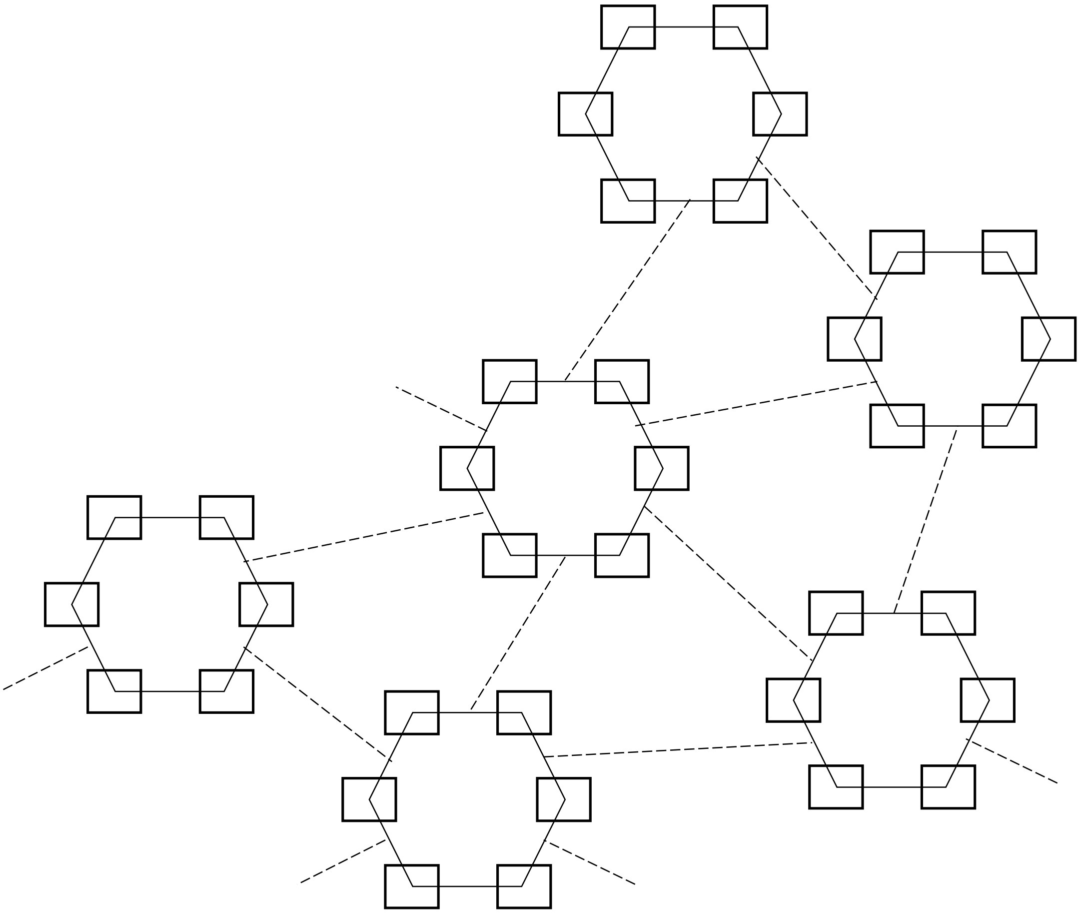
Image courtesy of Carbon Track

6.4 Advice

- Carry out preliminary investigations with the relevant Distribution Network Operator (DNO) to determine export capacity at an early design stage
- Set out a clear control strategy with energy generation and storage installer

6.6 Resources

1. CarbonTRACK. 2019. *Help shape the energy future*. https://carbontrack.com.au/
2. Electric Corby CIC. 2013. *Homepage.* https://www.electriccorby.co.uk/
3. Evergreen Group. 2020. *Smart Power for Smart People*. https://evergreensmartpower.co.uk/
4. National Grid. 2020. *Carbon Intensity API*. https://carbonintensity.org.uk/
5. Power Transition. 2020. *Homepage.* https://ptvolts.com/
6. SNRG. 2020. *Homepage*. https://www.oursnrg.com/
7. UK Power Network Services. 2020. *Introduction to Power Networks*. https://ukpowernetworksservices.co.uk/insights-and-news/introduction-to-microgrids/



7 Data Capture

7.1 Introduction

Robust data monitoring and capture systems are critical to enable true Building Performance Evaluation (BPE). To improve building performance, the best research we can do is to go back into a building and understand how it works.

The success of an Active Building depends on the management of the building and its services - the design should facilitate effective management of services, which can be achieved through the data capture system. To facilitate data capture, all environmental services should be sub-metered to allow the use of lighting, fans and pumps, space heating, hot water supply, etc to be distinguished. Sub-metering provides a greater insight into how a building is performing, including energy consumption and generation, and a measure of the energy efficiency of the building fabric and services. It will also allow excessive consumptions to be diagnosed more readily.

Benefits of data monitoring:

- Enable issues to be identified and resolved quickly
- Provide feedback on actual building performance
- Enable the development of planned maintenance strategies
- Enable optimisation of system to save energy and operational carbon
- Enable the development of predictive control strategies
- Educate building occupants on their energy consumption and provide an understanding of how the energy they are using is provided
- Enable controlled import and export of energy, based on factors such as grid Carbon Intensity (CI) or cost.
- Undertake Whole Life Cost (WLC) reporting.
- Provide feedback to occupants on their energy performance, via a robust database and energy display.
- Undertake Building Performance Evaluation (BPE), including Post Occupancy Evaluation (POE).

Tips:

- Determine what you want to capture from the data and how the data collected will be used before deciding on data collection system. For example, data may be used to measure consumption against generation; to monitor indoor air quality (IAQ), such as room temperatures, relative humidity, CO2 levels, etc, it is necessary to know details of the building fabric and external environmental conditions.

- Sub-metering of the following data is useful:
    - Heating
    - EV charging
    - Non-regulated loads
    - Regulated loads

- Consider how building occupants might engage with data captured:
    - Select systems that are simple to operate and easy to manage, e.g. SolarEdge – 1 system can monitor PV installation, EV charging, battery storage, and immersion diverter
    - Access rights to the data
    - Front-end visualisation

Collection frequency should be based on the end use for the data and the type of data - temperatures are unlikely to change rapidly so sub minute monitoring is unlikely to be useful. High frequency monitoring of energy generation can be useful but also presents data storage and analysis issues. If the aim is to understand costs or carbon impacts then 15 minute or 30 minute averages would be sufficient (grid carbon intensity is updated at 30min intervals, as are most of the modern time of use tariffs (e.g. Agile Octopus).

7.2 Active Learning Loop

One important benefit of data capture is that it can be used to inform future building projects, using the learnings from previous projects. We refer to this as an Active Learning Loop in a “Design, Construct, Evaluate, Improve” cycle.

Several databases exist to encourage learning in this way, but they tend to be under-utilised, due to the inherent ‘blame culture’ that exists within the construction industry. These include:

- **CarbonBuzz** – an RIBA, CIBSE platform
- **AECB Low Energy Buildings Database**
- **UKGBC Net Zero Case Study Catalogue**

Data from all Active Building projects should be captured in an open access database for a more collaborative, research-led future construction industry. This is the only way the construction industry will be able to meet the climate change targets set locally, nationally and globally.

Visualising energy data to building occupants will also help encourage more efficient use of energy in buildings, hence reducing carbon, as described on page 40.

Figure x: The Active Learning Loop

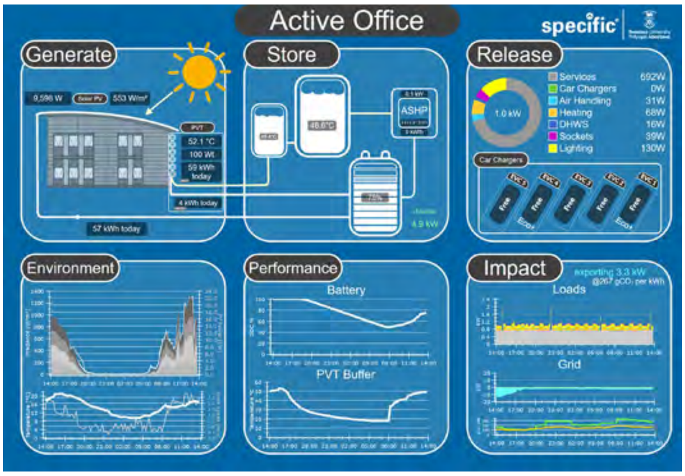
LETI Data Disclosure Recommendations:

- Metered data
- Report – upload 5 years of data to CarbonBuzz platform

7.3 Visualising data capture

This is important to:

- Increase awareness and educate building users on their energy consumption
- Identify patterns in energy behaviour
- Act as a nudge to building users to:
  - Reduce their energy consumption completely
  - Match their demand to the building's generation
  - Shift their energy demand to times of day when grid supplied energy is cheaper or has a low carbon intensity factor

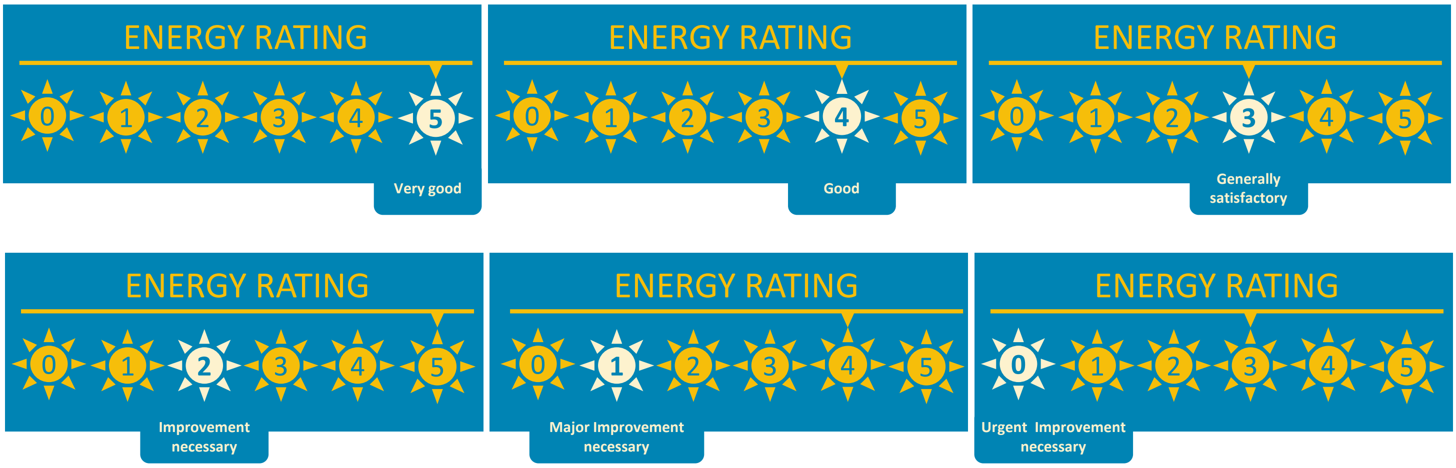


This display screen is located in the entrance foyer of the Active Office and show all the energy flows of the building at all times of the day.

Display Energy certificates

From January 2013, DECs are mandated on all public buildings larger than 250m^2. They should display the actual energy performance of a building for 12 months of operation, rating a building between A and G, where A is highly efficient and G is the least efficient. However, these are not mandatory for all buildings and are not commonly displayed.

Perhaps, there could be a much simpler energy display mechanism for all non-residential buildings, akin to the well-recognised Food Hygiene Rating, displayed prominently in catering facilities across the UK. This could be reviewed annually based on actual data from a building and would have the benefit of acting as a quick engagement tool easily recognised by all. It would look something like this:



In a similar way to a DEC, this would enable the occupier to identify what may be done to improve building energy management, building services, etc., therefore reducing energy consumption and CO_2 emissions. There are, of course, issues with this. If a building is rated 0 – 2, for instance, it may be difficult to make the necessary improvements, as it may be difficult to trace exactly where the faults lie (extensive metering and data capture will help with this) and, once identified, it could be difficult to put right. Contractual arrangements with contractors tend to stop after the construction defects period. To mitigate this, there would need to be contracts in place with BMS controllers, or a Facilities Manager who has full access to all the systems. Both of these options have challenges.

7 Data Capture

7.4 Energy End Use Groups

The table below describes the main building energy end-use groups in buildings.

End-use group	Description
Space heating/cooling	Likely to bt the largest component of building energy use. Correlated to climatic region, control strategy, and occupancy patterns. Parameters to consider include external temperature, internal temperature, outdoor humidity, wind speed, heating/cooling system set points
Domestic Hot Water	Second largest component of building energy use. Defined as the energy required to heat hot water to an adequate temperature for occupant and appliance use. Used for personal hygiene and cleaning. Correlated to the number of occupants, preference, bath/shower, frequency and duration of bath/shower, energy rating of appliances, etc.
Lighting	Correlated to building type, occupancy profiles, and the types of lighting systems such as halogen lamps, fluorescent lamps, LED, etc.
Cooking	Correlated to the type of cooking device, such as gas hob, electric oven, microwave, number of occupants etc.
Small power/appliances	Devices include personal computing, electronics and kitchen appliances. Energy use correlated to occupancy
Systems	Devices or equipment that operates continuously in the background, includes communications equipment, fire alarm protection and alert devices, WiFi devices
Process Loads	Unregulated loads associated with processes taking place within the building that require energy. These can be significant in industrial or engineering buildings
EV charging	Depending on how many EV charge points are included, this could be the largest energy use.

7.5 Building Loads

It is important to be aware of the load categories for developing control strategies that schedule building activities, energy storage activities and grid import/export. Building loads typically fall into the categories described in the table below:

<table>
<tr><th colspan="4">Load mix</th></tr>
<tr><td colspan="3">Non-storable Load</td><td>Storable Load</td></tr>
<tr><td colspan="2">Non-shiftable Load</td><td>Shiftable Load</td><td rowspan="3">Power consumption decoupled from end-use service: Batteries, heating, cooling, DHW, EVs</td></tr>
<tr><td>Non-curtailable Load (Baseload)</td><td>Curtailable Load</td><td rowspan="2">Power consumption can be moved without affecting the end-use service: Laundry, dishwasher, tumble dryer, vacuum cleaner, etc</td></tr>
<tr><td>Power consumption cannot be shifted or interrupted: Security alarm, fire alarm, control systems, freezer, refrigerator, etc</td><td>Power consumption cannot be shifted, but the load can be interrupted: Lighting, computers, TV, etc</td></tr>
</table>

The loads listed in Table X are not exhaustive. Some buildings may also have other loads not mentioned in the table.

7.6 Data Capture Priorities

Any data captured from systems will enable fault detection in addition to optimising energy consumption, balancing energy flows and learning about actual performance of systems against information provided at design stage. Table x below lists the suggested monitoring to include in an Active Building.

Energy Consumption Data	**Benefit/Value**
Space Heating Circuits	Measure how much energy is needed to provide temperature setpoint. Potential issues in maintaining setpoint include open windows and doors and building fabric issues. Enable fault detection
Domestic Hot Water System	Measure amount of energy (kWh/litre) needed to meet demand. If low hot water usage then self discharge could be significant. Monitoring when it is used could enable improved efficiencies linked to generation (ensuring legionella control is maintained)
EV Charging	Measure impact of EV charging on overall energy consumption
Services - Comms equipment, fire alert equipment, security devices	Measure baseload energy consumption of the building Ascertain whether any energy savings could be made to baseload
Lighting	Measure performance of lighting against designed performance
Small Power - Sockets, unregulated energy	Measure unregulated energy consumption
Air Handling Systems	Measure amount of energy needed to provide required ventilation levels
Indoor Air Quality – room temperature (ºC), CO_2 level (ppm), relative humidity (%), occupancy (binary), windows/ventilation (% open)	Ensure comfort levels are maintained Identify any system faults, underperforming of systems, or design faults
Environmental Data	
External ambient air temperature (ºC)	Measure real life performance of energy generation technologies
Solar irradiance (W/m2)	Measure real life performance of energy generation technologies
Wind speed (km/h) and direction (degree)	Measure effects of wind speed and direction on performance of systems
Humidity (%)	Measure the affect of moisture in the air on generation and consumption
Rainfall (mm)	Measure the affect of rainfall on energy generation and consumption
Weather forecasting	Enable decision making on import and export of energy, depending on predicted weather
System Data	
Battery State of Charge	Help optimise control of energy flows Measure performance against depth of discharge
Lifetime coefficient of performance (LTCOP) of heat pumps	Measure actual efficiency of heat pumps against anticipated performance
Temperature of thermal store	Measure amount of energy needed to maintain store at required temperature
Daily Generation & Consumption (kWh/m^2)	Determine whether the building is Net Zero Energy
Carbon intensity of Grid (CI)	Control export and import of energy accordingly
Energy Source – on-site generation, grid	Measure true operational carbon of the building
Energy prices	Control export and import of energy accordingly

7 Data Capture

Load profile and specific parameters will vary depending on building type. Table x below shows typical building loads and parameters influencing energy consumption in **residential buildings**, as an example.

Building Location	**Kitchen**
Region	Cooking – Hob, Oven, Microwave, Grill, Toaster
City	Kettle
Number of occupants	Coffee Machine
From 08.00 to 13.00	Food processor
From 13.00 to 19.00	**Refrigeration**
From 19.00 to 00.00	Refrigerator
From 00.00 to 08.00	Freezer
Architectural Characteristics	**Washing**
Year of construction	Washing machine
Size of property	Tumble dryer
Walls and roof materials and colour	Dishwasher
Level of insulation	**Cleaning and ironing**
Shading	Vacuum cleaner
Refurbishment activities	Iron
Building Services Systems	**Lighting**
Heating – control, heat source, emission system	Filament lamps, halogen lamps, fluorescent lamps, LED lamps
Cooling – type, energy class, no. of rooms served	**Audio/Video**
Domestic Hot Water - type	TV, monitor, DVD players, home theatre
Solar Thermal Collectors	Radio, stereo, hi-fi
Flat/vacuum	**Computing/Internet**
Number of modules	Desktop PC
Angle of Pitch	Laptop/tablet
Orientation	Printer
Solar PV Array	**Personal care**
Peak power	Hairdryer
Angle of Pitch	Hair straightener
Orientation	**Other equipment**
	Power tools, lawnmower, etc

7.7 Building Performance Evaluation (BPE)

According to the Building Services Research and Information Association (BSRIA), "Building Performance Evaluation (BPE) *"is the process of evaluating the performance of a building, with Post Occupancy Evaluation (POE) being one of its major parts."*

BPE can be carried out in new, existing and refurbished domestic and non-domestic buildings, to help deliver effective and efficient buildings. The BPE process and associated activities should be applied at the project stages listed below and used to help inform project development, enhance delivery, optimise performance and provide feedback:

1. Concept and Design stage
2. Construction stage
3. Pre-occupancy stage
4. Post-occupancy evaluation (POE) stage

The following flow diagram shows a suggested process that should be followed when undertaking BPE on building projects, adapted from Stevenson in her book **'Housing Fit for Purpose'** :

1. Auditing

- Documentation review:
    - Health and safety strategy and standards
    - Spatial quality and layout strategy
    - Construction strategy
    - Environment systems and 'smart' control/metering strategy
    - Maintenance strategy
    - Sustainable strategy
    - Handover and induction strategy
- Equipment and resource use audit:
    - Water survey
    - Usability survey

2. Physical evaluation of building fabric

- Physical evaluation methods:
    - Construction audit
    - Photographic construction survey
    - Thermal imaging survey
    - Air permeability
    - Fabric heat-loss testing
    - Co-heating test
    - Moisture movement through the fabric
- Re-commissioning of services:
    - Document analysis
    - Inspection list
    - Ventilation, heating and hot water systems

3. Monitoring of environmental qualities

- In-use monitoring of equipment:
    - External environment
    - Indoor air quality
    - Temperature and humidity
    - Thermal comfort survey
    - Lighting
    - Acoustics
    - Occupancy patterns
    - Window and door opening

4. Surveys, interviews and focus groups

- Surveys
- Questionnaires
- Interviews
- Focus groups

5. Ethnography

- Observation
- Diaries
- Routines
- Videos

Data integrity - if making decisions based on data then the accuracy of the data must be evaluated. For example, correlation of sub metering and power consumption profiles with the main MID DNO meter would provide cross check of data gaps in power monitoring

7.8 Resources

1. BRE, 2018. *Post-Occupancy Evaluation (POE)*. https://www.bre.co.uk/page.jsp?id=1793
2. BSRIA. 2020. *Building Performance Evaluation*. https://www.bsria.com/uk/consultancy/building-improvement/building-performance-evaluation/#:~:text=Building%20Performance%20Evaluation%20(BPE)%20is,domestic%20and%20non%2Ddomestic%20buildings.
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4. RIBA and Hay, R. Bradbury, S. Dixon, D. Martindale, K. Samuel, F. Tait, A. 2016. *Pathways to POE, Value of Architects*. University of Reading, RIBA. https://www.architecture.com/knowledge-and-resources/resources-landing-page/post-occupancy-evaluation#available-resources
5. Stevenson, F. 2019. *Housing Fit for Purpose*. RIBA Publishing, London, UK

8 Carbon

8.1 Introduction

The UK Green Building Council (**UK GBC**) define the embodied carbon of a building as a consequence of the total carbon emitted during the creation of the individual elements of the building, added to the carbon emitted during the construction process.

The carbon emitted during the operation of a building depends on the efficiency of the building and the ease of maintaining the building using low carbon technologies. Operational carbon is also dependent on the life of the building, the ease of dismantling and the ability to re-purpose building elements, spreading the embodied carbon over as long a period as possible. (Source: **National Federation of Builders**)

Both embodied and operational carbon must be reduced if the UK is to meet its decarbonisation targets and should be fundamental to all design decisions.

8.2 Key Design Considerations

- Low carbon site considerations for an Active Building:
  - Site location
  - Access to existing cycle routes and footpaths
  - Access to public transport
  - Landscaping within the site curtilage:
    - Promote biodiversity
    - Reduce runoff – minimise hard surfaces, maximise green spaces and other permeable surfaces
    - Provision of outdoor exercise facilities
    - Provision of cycle shelters
    - Provision of EV charge points for a variety of EVs (see Principle 5)

- Adopt a life cycle assessment (LCA) methodology early in the project and use available databases in selecting materials and technologies (see page 35)

- All members of the Project Delivery Team should understand, record and publish their carbon footprint and then work to reduce it. This will be needed for calculating the carbon contribution to a project of all stakeholders.

- Work with your client and contractors to develop designs, specify products and use processes that can help reduce the embodied carbon of a project.

- Educate all stakeholders regarding the challenges, urgency and solutions to reduce carbon dependency on the carbon emissions from the construction industry.

- Use performance targets to drive down embodied and operational carbon of a building by all stakeholders involved in the building project.

- Consider use of Government Soft Landings to ensure that the operational carbon matches the original design parameters.

8.3 Carbon Offsetting

In their **Embodied Carbon Primer**, LETI describe offsetting as the use of carbon negative activities to remove greenhouse gases from the air and store them for long periods of time.

Net Zero Embodied Carbon is difficult to achieve currently (2020). While it should not be relied on to reduce carbon emissions from building projects, carbon offsetting can be used to help achieve Net Zero; and most carbon offsetting measures are beneficial, even if Net Zero can be achieved through embodied and operational savings. Some possible carbon offsetting measures include:

- Tree planting on-site or within the community
- Reducing energy demands of existing buildings by adding insulation and more efficient heating and cooling systems
- Including additional renewable energy generation
- Using a clean local energy supplier
- Investing in renewable energy schemes
- Supporting local community schemes

It is, however, difficult to accurately measure the benefits of carbon offsetting and it is not recommended to use this as a replacement for true Net Zero measures.

Further information can be found in Appendix 10 (p.109) of LETI's **Embodied Carbon Primer**.

> *"Life Cycle Assessment (LCA) is an environmental management tool that examines the environmental burden of a product or process over its entire life, from production, through use and on to disposal and recycling."[1]*

8.4 LCA Methods

Assessing Whole Life Carbon (WLC) of buildings is necessary to mitigate against global warming caused by 'human generated' greenhouse gas (GHG) emissions to the atmosphere, commonly referred to as carbon emissions. Here are just some of the available assessment methodologies:

BS EN 15978:2011 - Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method

Sets out the calculation method to assess the environmental performance of a building, based on LCA for both new and existing buildings, providing a description of the object of assessment, system boundaries applicable at the building level, procedures used for inventory analysis, a list of indicators and procedures for calculation, reporting and data requirements. There are four main stages to carrying out an LCA:

1. Goal and scope definition
2. Inventory Analysis
3. Impact Assessment
4. Interpretation and Improvement

The bulk of the data collection takes place during the *inventory analysis* of an LCA, where inputs and outputs to the product are determined - inputs include the materials and energy required to make a product; and outputs are the waste and quantities of emissions caused by the production process.

RICS Methodology
Mandates a whole life approach to reducing carbon emissions within the built environment. It sets out specific mandatory principles and supporting guidance for the interpretation and implementation of the BS EN 15978 methodology.

openLCA
A freely available framework for LCA to enable the development of flexible models using Open Source software.

BRE IMPACT
IMPACT for LCA is a specification and database for software developers to incorporate into their tools to enable consistent LCA and Life Cycle Costing (LCC). IMPACT compliant tools work by allowing the user to attribute environmental and cost information to drawn or scheduled items in the Building Information Model (BIM), taking quantity information from the BIM and multiplying this by environmental impact and/or cost 'rates' to produce an overall impact and cost for the whole (or a selected part) of the design. The results generated by IMPACT allow the user to:

- analyse the design to optimise cost and environmental impacts.
- compare whole-building results to a suitable benchmark to assess performance, which can be linked to building assessment schemes.

The overall aim of IMPACT is to integrate LCA, LCC and BIM.

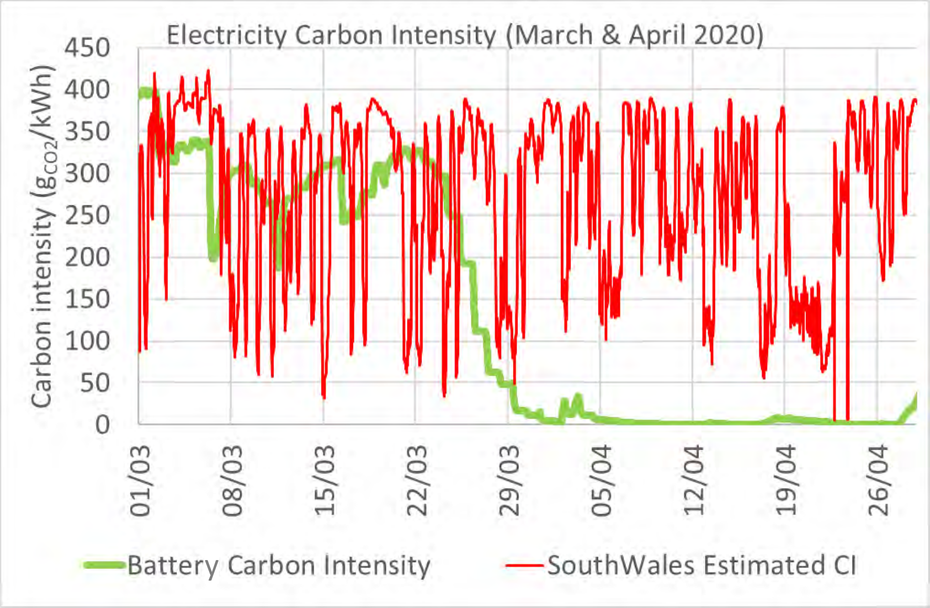
One Click LCA
A fast LCA and LCC web-based tool, compliant with IMPACT, with access to a large LCA database. The tool is also compliant with BREEAM and many other green assessment methods.

The Inventory of Carbon and Energy (ICE) Database by Circular Ecology
The ICE database is the world's leading source of embodied energy and carbon data and is free to download.

Hawkins\Brown Emissions Reduction Tool\ (H\B:ERT)
H\B:ERT is a Revit-based tool that enables design teams to quickly analyse and clearly visualise the embodied carbon emissions of different building components and construction material options at any time during the design process. This is also free to download.

8.5 Operational Carbon

The National Grid Electricity System Operator (ESO) has developed a Carbon Intensity (CI) forecast of the electricity grid in Great Britain, with a regional breakdown. This can be utilised to determine the CI of all the electricity consumed by a building at any time of the day. To use the Active Office as an example, the graph below indicates the difference between the CI of electricity used from the battery to that of the CI of the grid. The grid CI of South Wales is higher than most other regions in Great Britain, due to the location of Tata Steelworks in Port Talbot. The graph below clearly demonstrates the impact use of renewable energy sources and energy storage can have on the operational carbon of a building.



CI of the batteries at the Active Office compared to the CI of the grid for March and April 2020 (Source: https://carbonintensity.org.uk/)

8 Carbon

8.6 Resources

1. RIBA. 2019. *Embodied and whole life carbon assessment for architects*. https://www.architecture.com/-/media/gathercontent/whole-life-carbon-assessment-for-architects/additional-documents/11241wholelifecarbonguidancev7pdf.pdf

2. RICS. 2018. *Whole Life Carbon Assessment for the Built Environment*. https://www.rics.org/uk/upholding-professional-standards/sector-standards/building-surveying/whole-life-carbon-assessment-for-the-built-environment/

3. World Green Building Council. 2019. *Bringing embodied carbon upfront.* https://www.worldgbc.org/news-media/bringing-embodied-carbon-upfront

4. https://www.carbontrust.com/

5. https://www.carbonfootprint.com/

6. BSI. 2020. *PAS 2080: Carbon Management in Infrastructure Verification*. https://www.bsigroup.com/en-GB/our-services/product-certification/product-certification-schemes/pas-2080-carbon-management-in-infrastructure-verification/

7. Wrap. *Designing out waste: a design team guide for buildings*. https://www.modular.org/marketing/documents/DesigningoutWaste.pdf

8. BRE. 2020. *Background to the Green Guide to Specification*. https://www.bregroup.com/greenguide/page.jsp?id=2069

9. Circular Ecology. *Net Zero Carbon Construction*. https://circularecology.com/

10. Cabinet Office. 2013. *Government Soft Landings*. https://www.cdbb.cam.ac.uk/system/files/documents/GovernmentSoftLandingsSection1Introduction.pdf

11. LETI. 2020. *Embodied Carbon Primer*. https://www.leti.london/ecp

9 Whole Life Cost Approach

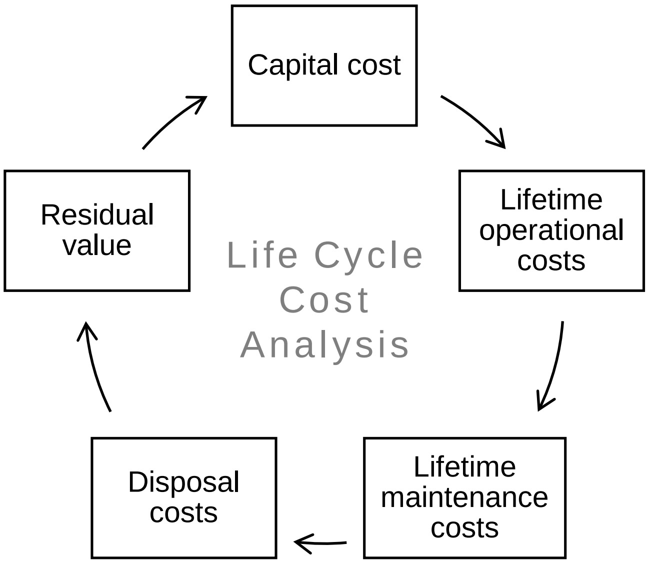
> *"Life-Cycle Cost Analysis (LCCA) is a method for assessing the total cost of facility ownership. It takes into account all costs of acquiring, owning, and disposing of a building or building system. LCCA is especially useful when project alternatives that fulfil the same performance requirements, but differ with respect to initial costs and operating costs, have to be compared in order to select the one that maximizes net savings."* Source: **Whole Building Design Guide**

In designing and delivering an Active Building project, it is critical to consider the life-cycle cost (LCC) of the building over its expected lifetime. Often, convincing a client to spend more on capital cost in order to gain savings during the lifetime of a building can be difficult, particularly with speculative developments, or where capital and operational costs are attributed to different budget holders (departments or companies). However, it is possible to prove added value to a building for even speculative developments, for example, proving it is possible to achieve higher rental value or a higher price (if selling) because it is an Active Building, based on the savings in operational costs. If we are to meet the target set out in Construction 2025 to reduce whole life costs of a building by 33% by 2050, different business models are needed.

While the LCC of a building relates to costs associated directly with construction and operation, the whole life cost (WLC) includes additional costs such as land, income generated from a building and support costs associated with the activity within a building. WLCs are usually calculated by clients, using LCCs prepared by construction industry professionals. (Source: **Willmott Dixon**)

In a report produced by the BRE entitled ***'Green Buildings Pay'***, it was reported that investors are increasingly demanding high quality properties with low risks and that investors are increasingly attracted to buildings which have certificated sustainability credentials. Often organisations require a project to achieve a specific sustainability accreditation..

Organisations can be more flexible when negotiating investments in low energy buildings because the risks are lower, environmentally certified buildings are often easier to let, and tenants in such buildings are more loyal, resulting in lower vacancies.



Architects can demonstrate value to their client, partly through the use of case studies, but also by undertaking an early LCCA, during the project development.

If sustainable assessment tools, such as BREEAM, are being used, credits for undertaking LCCA at RIBA Stages 2 or 3, and again at Stages 4 and 5, are available.

9.1 Resources

1. BS ISO 15686-5:2017 – Buildings and constructed assets. Service life planning. Life-cycle costing.
2. PD 156865:2008 - Standardized method of life cycle costing for construction procurement. A supplement to BS ISO 15686-5.
3. BS 8544:2013 - Guide for life cycle costing of maintenance during the in use phases of buildings
4. Chase, J. 2019. *Solar Power Finance Without the Jargon*. World Scientific Publishing Europe Ltd, London, UK
5. Cinquemani, V. 2020. *SustainABLE: How to Find Success as a Sustainability Professional in a Rapidly Changing World*. Independently published, UK.

10 Active Building Skills

10.1 Continuous Professional Development

Often new technologies are not specified due to the lack of evidence or awareness of their existence. The role of trusted organisations such as the Building Research Establishment (BRE) or academia should be to provide inciteful views on technology efficacy and challenges. Additionally, more independent demonstration of technology and control capabilities is required to provide confidence and information on availability and performance.

As well as maintaining an awareness of the latest technologies, it can also be challenging to maintain up to date knowledge on regulations, policies and standards, in the constantly evolving construction and energy landscapes. The value of spending time training and undertaking research in practice should not be underestimated. Setting aside time for research and training has many benefits:

- To help plan careers
- To strengthen business
- To update knowledge
- To acquire new skills and specialisms

Here are some resources that could help create a skills roadmap for companies and individuals working in the construction industry.

RIBA Core CPD

The RIBA CPD Core Curriculum sets out 10 areas for CPD for all RIBA Members. A CPD Programme of seminars is developed every year to provide Architects with all the CPD they need. Other methods of achieving the 35 hours of CPD required each year, include seminars, articles, podcasts, online learning, factory tours, site visits and trade show visits.

Recommendation: **Plan your CPD activities and research work at the beginning of every year, identifying what new skills or knowledge updates you want to achieve.**

Materials and Manufacturing Education Training and Learning (Metal) Swansea University

Metal is an industry demand-led project originally established to upskill people in the field of Advanced Materials and Manufacturing through the provision of short, 10 credit courses at level 4 and above. It is a work-based learning scheme that focuses on technical training modules to address skills shortage and provide industry skills required to thrive in a knowledge-led sector. In 2020, Metal teamed up with SPECIFC to offer a selection of Active Building courses to construction industry stakeholders:

- Active Building Taster Sessions
- E-learning modules
- CPD seminars
- Short training courses (1 – 3 days)
- Toolbox talks for site inductions

Recommendation: **Sign up to and encourage Contractors working on Active Building projects to sign up to one of the courses offered**

Supply Chain Sustainability School (SCSS)

The SCSS is a free industry wide collaboration, with a vision to be "A world class collaboration to enable a sustainable built environment". It is applicable for everybody working in the Construction, FM, Homes and Infrastructure sectors in England, Scotland and Wales. Once registered, members complete a self assessment, which provides them with an action plan for their own individual training needs. Services include:

- Training and networking events
- E-learning modules
- Online training resources

Recommendation: **Only employ Contractors who are signed up members of the SCSS and recommend everyone working on the project signs up**

Construction Industry Training Board (CITB)

The CITB supports the skills needs of the British construction sector, set up to help the construction industry attract talent and to support skills development. It does this by providing training courses and apprenticeships.

Recommendation: **Encourage the project delivery team to engage with CITB, accessing apprenticeship schemes and training courses**

Green Register

Established in 2000, the Green Register trains construction professionals from all disciplines of the construction industry to build better, more sustainable buildings. Their courses are delivered across the UK and cover all aspects of sustainable building practices from healthy buildings, passivhaus and retrofitting older buildings through to highly technical training sessions on the holistic management of heat, moisture and air tightness.

Recommendation: **Look out for their courses and events, sign up to their CPD training courses, search their register for sustainable construction professionals, become a member**

Other relevant Training Providers

https://www.tatasteelconstruction.com/en_GB/services-and-downloads/Continuing-professional-development-courses

https://www.rehau.com/gb-en/pvcu-windows-doors--composite-curtain-walling/passivhaus-products-and-services/rehau-forum-london/continuous-professional-development

https://www.greenbuildingstore.co.uk/services/training-cpds/free-cpds/

https://www.cat.org.uk/courses-and-training/

https://www.aecb.net/

https://www.thermalearth.co.uk/training