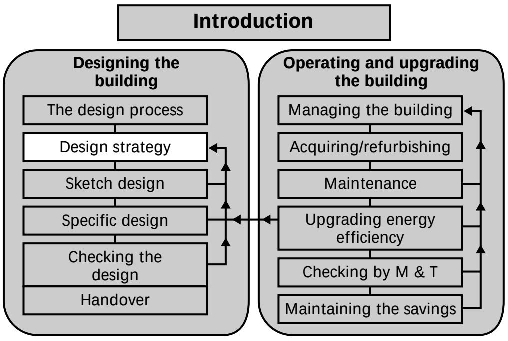
3 Developing a design strategy



A coherent sketch design is at the heart of an energy efficient building(1–4). This section outlines how to develop an integrated design strategy in line with the principles at the front of this Guide. Section 4 contains more detail on site considerations, built form, ventilation, daylighting and fuel selection.

3.0 General

Building design is an iterative process, often requiring design teams to re-think fundamental aspects of the design. Figure 3.1 indicates how an energy efficient design can be achieved through an integrated approach.

An overall design philosophy should be established to underpin the whole design process. Some key issues that have a strong influence on the energy efficient design philosophy are shown in Table 3.1.

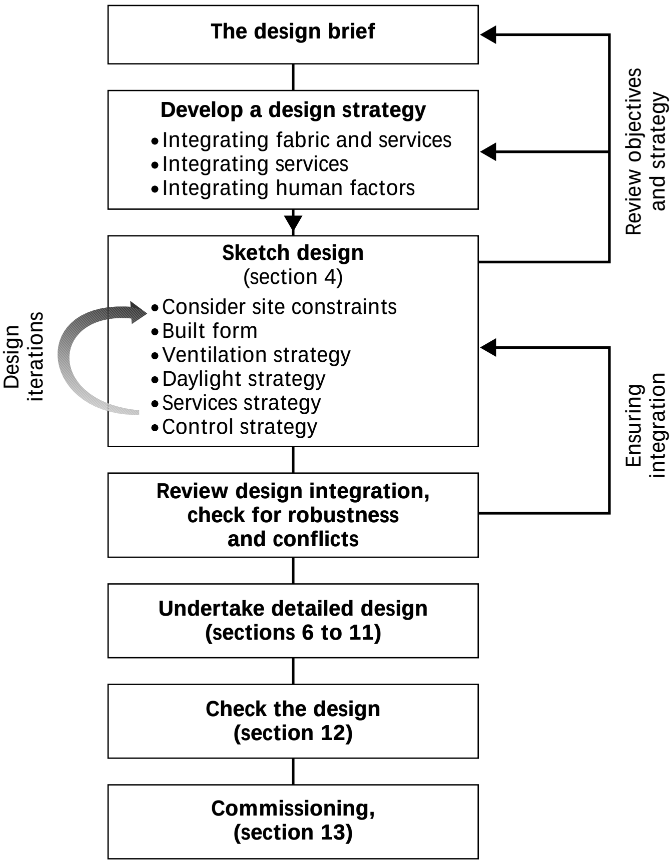


Figure 3.1 Integrated design

3.1 Integrating fabric and services

The first step in developing an integrated design is to establish the function of the building envelope as the primary climatic modifier, supported by the services to trim conditions. Good fabric design can minimise the need for services. Where appropriate, designs should avoid simply excluding the environment, but should respond to factors like weather and occupancy and make good use of natural light, ventilation, solar gains and shading, when they are beneficial.

For example, decisions taken on the provision of daylight will directly influence the window design, the amount of glazing and the type of glass. They will also affect the building's susceptibility to solar gain and influence:

— the need for solar control and/or air conditioning
— the size, capacity and space required to accommodate central plant
— the air and water distribution systems.

Several iterations may be needed to reach an effective design as it is tested against the performance criteria of:

— cost
— quality of the internal environment
— space requirements
— energy use

Table 3.1 Issues that influence the energy efficient design philosophy

Building envelope	Building services	Human factors
Climate excluding or climate responsive? Use building fabric for thermal storage? Thermally heavyweight or lightweight? Deep or shallow plan? Highly glazed or little glazing? Openable or fixed windows?	Heavily serviced, mixed mode or passive solutions? Use natural daylight/ventilation? Complex or simple systems/controls? Use flexible comfort criteria? Use heat recovery and free cooling? Use combined heat and power?	Balance between central automation and local occupant controls? Responsive to occupancy/activity or fixed systems? Do occupants require loose comfort bands or tight regimes? Easy or difficult to manage? Easy or difficult to maintain? Allow for future flexibility?

Select issues on the x and y axes to see how they may interact

Sevices issues	**Deep plan/ shallow plan**	**Orientation**	**Percentage glazing**	**Lightwells and atria**	**Airtightness**	**Thermal response**
Cooling	Deep plan may need greater cooling and mechanical ventilation	Consider locating cooled zones on north façade to reduce potential cooling loads	Minimise solar gains	Minimise solar gains	Take care that facilities for summer cooling are airtight in winter	Store heat in thermal mass and effect on response times
Heating	Deeper plan reduces heat loss area	Position less heated buffer zones on north façade to reduce heat loss	Solar gains contribute to heating	Minimise heat loss via atria i.e. avoiding heating	Minimise air infiltration to reduce heat loss	Store heat in thermal mass and effect on response times
Electric lighting and daylight	Use shallow plan for maximum daylight penetration or lightwells/atria	Calculate sun angles and use north light or shading to limit solar gains	Increased glazing will increase daylight but may also increase solar gains and need for shading	Use atria to increase natural daylight		
Natural ventilation	Use shallow plan to allow natural ventilation	Draw air from north façade to give cooler air	Ventilation depends on number of openable windows	Use atria to encourage natural air circulation	Seal building envelope and allow only controlled ventilation	Utilise effect of thermal mass on response of building to external conditions
Mechanical ventilation and air conditioning	Consider shallow plan with mixed-mode to allow natural ventilation at certain times	Orientated to avoid solar gains	Reduce percentage glazing to minimise effect of solar gains on air conditioning	Consider atria with mixed mode to allow natural ventilation and daylight at certain times	Ensure building envelope is sealed	Utilise effect of thermal mass on response time of air conditioning

Fabric issues

Figure 3.2 Interaction between fabric and services

— robustness

— ease of operation.

Avoiding dependence on mechanical plant, e.g. air conditioning, can reduce capital and running costs. Where air conditioning is unavoidable, the principles of integrated design can still help to reduce the size and complexity of the system, and hence its capital and running costs.

Figure 3.2 indicates some of the issues that need to be considered when integrating fabric and services. For example, a low percentage glazed area may result in higher lighting loads than expected. However, a large glazed area may not be helpful if the blinds have to be used to limit glare.

3.2 Integrating services

The next step is to ensure that the services operate in harmony without detrimental interaction or conflict. For example, the levels, control and efficiency of lighting have a significant effect on the need for cooling. It may also be appropriate to reconsider the building form so that more use can be made of daylight if this minimises energy demands for lighting and cooling.

Many energy problems can be traced to a conflict between building services. An energy efficient design strategy should avoid such conflicts. Some of the key interactions are shown in Figure 3.3.

Select issues on the X and Y axes to see how they may interact

	Cooling	**Heating**	**Electric lighting**	**Daylight/ glazing**	**Natural ventilatiion**
Heating	Avoid simultaneous heating and cooling				
Electric lighting	Reduce incidental gains from lights to minimise cooling	Include contribution of lighting towards heating			
Daylight/ glazing	Minimise solar gains to reduce cooling loads	Minimise heat loss and maximise useful heat gain through glazing	Use suitable switching and daylight linking controls to minimise use of electric lighting		
Natural ventilation	Consider mixed-mode to use natural ventilation and avoid mechanical cooling where possible	Account for effect of open windows		Balance solar gains from glazing with increased natural ventilation. Avoid conflicts between window opening and blinds	
Mechanical ventilation and air conditioning	Use free cooling and 'coolth' recovery	Use heat recovery	Reduce electric lighting to reduce loads on air conditioning	Solar gains from glazing may increase loads on air conditioning, Heat loss may require simultaneous perimeter heating	Use natural ventilation instead of air conditioning where possible, or consider mixed-mode

Figure 3.3 Interaction between building services

Simultaneous heating and cooling can be a major problem. Although this can be minimised by good controls, sometimes the problem originates from the basic design. For example, perimeter heating with core air conditioning may result in wasted energy if controls are adjusted by the occupants to compensate for local discomfort.

Zoning services is an important factor in achieving an energy efficient integrated design. Services should be matched to the actual requirements of each area. Areas with different requirements should not be heated, cooled, or lit to the same standards. Zones should be established in relation to the building, its occupancy and use, and the means of supplying the services. Generally, it helps to establish the same zones for different services to minimise conflict. For example, where a heating zone overlaps a cooling zone there is potential for simultaneous heating and cooling.

Excessive casual gains from lighting due to poor control can lead to significant cooling loads. This is particularly true in summer, when daylight levels may be sufficient for lights to be turned off. Good lighting control, including suitable manual override, can help to avoid this problem.

Mechanical cooling systems often operate when the external air could be used for cooling. Air conditioning systems may operate solely to negate the heat added to the air by the fans. The change to 'free' cooling and/or natural ventilation during winter can save significant energy, when humidification is not required.

Heat recovery provides a means of integrating services. For example, integrating lighting and air conditioning systems by extracting air through luminaires enables a proportion of the energy consumed by the lamps to be recovered to supplement heating in winter. The summer cooling load is also reduced by preventing a proportion of the lighting heat load from entering the room. The light output of fluorescent lamps also increases due to the lower operating temperature, although overcooling must be avoided.

Many conflicts between services are control issues (see section 5). However, the underlying reasons for conflict should be identified and eliminated to prevent carrying a flawed design forward. It is not good policy to hope that the control system will resolve these conflicts.

3.3 Minimising requirements for services

Over-specification of services should be avoided in order to minimise capital and running costs(5). Continually reviewing the need for services, the true demands likely to be made on them, and avoiding unnecessary complexity will improve energy efficiency and will often result in a better building.

Building services engineers have a responsibility to challenge the assumptions underpinning the design in order to avoid over provision of services. An over-serviced building does not necessarily mean a 'high quality' building(6,7). For example:

— Are the design margins excessive? (See section 4.)

— Are the design parameters unnecessarily restrictive? (For example, attempting to control relative humidity to 50 ± 5% all year round in an office.)

— Is the plant over sophisticated, necessitating more complex controls and increasing the likelihood that systems will be difficult to understand and control?

— Have natural sources such as daylight and cooler outdoor air been used to the full?

— Is the overall design intrinsically energy efficient, or is it likely to result in high running costs?

At an early stage, it should be possible to modify the design to reduce the capacity, size and complexity of the services. This can reduce the capital cost of the services without having to remove features from the design. For example, reducing the need for air conditioning by adopting a mixed mode approach could prevent the loss of a well-specified building management system (BMS) through budget cuts, thus retaining good control.

In general, a 'simple' approach is the best way of promoting good installation, operation and maintenance(6,7). Simple services promote a good understanding of how the building and plant are intended to work. This generally improves building management and hence energy efficiency.

3.3.1 Optimising internal heat gains

Internal gains arising from occupants, equipment, lighting and solar radiation, etc. will normally offset a significant part of the fabric and ventilation heat losses. This can reduce heating plant capacity and running costs provided that the controls can respond to changes in internal gains, preventing overheating.

In summer, these heat gains can increase the need for mechanical cooling. To allow passive control of summertime temperatures, the level of heat gains within the space should be kept to a minimum(8–10).

To minimise energy consumption, it is important to establish a balance between the benefits of the gains in winter and the disadvantages in summer (11,12). Office case studies(6) suggest that too many buildings use over elaborate methods to remove or avoid heat that could have been designed out. Common problems included:

— excessive window area with inappropriate or non-functioning solar control systems: reasonable window sizes (say 30% of main facade area) with simple, useable blinds and control devices are often preferable (see section 4).

— inefficient lighting: some 'passive' offices had installed lighting loads of 25 W/m^2, while good practice is 10–12 W/m^2 to achieve 400 lux (see section 8).

— poor lighting control: often caused by a lack of appreciation of the associated human factors, e.g. occupants objecting to frequent automatic switching.

— unnecessary internal heat gains: gains can be either from inefficient office equipment; excessive operation or poor location.

— over-design: can occur through over estimation of heat gains, particularly office equipment (see section 11). Recently there has been a trend to more realistic equipment gain levels (typically 10–15 W/m^2 in many offices) and to treat higher gains as 'specials'.

3.3.2 Optimising natural ventilation

Establishing a ventilation strategy can help to minimise the need for services(8) (see section 4). Natural ventilation can be optimised by the following measures:

— Question the need for full air conditioning: a passive or mixed mode approach may reduce capital cost.

— Further reduce the need for mechanical ventilation in mixed mode designs; e.g. improved zoning can lead to the separation of areas of high heat gain and result in smaller plant.

— Enhance window design to prevent poor usability. Too often there are not enough types of opening, insufficient user choice, and operational difficulties because window control gear is unsuitable or out of reach

— Use stack-assisted ventilation, often via roof lights in atria, to help ventilate deep plan buildings. Air outlets should be at least 3 m above the windows of the uppermost floor to prevent upper floors becoming much warmer than lower floors. In addition, people sitting near ventilation stacks or atria are not always as tolerant of high summertime temperatures as those sitting near external windows.

— Consider storing heat in the fabric during the day and removing it at night. Case studies(6) have indicated that windows for night ventilation need to be more useable, weather-tight and secure. Fan-powered systems often consume too much additional electricity and yet provide inefficient cooling(13).

3.3.3 Optimising daylighting

Daylighting should be an integral part of an overall lighting strategy (see section 4). Natural lighting may be optimised by:

— ensuring that electric lights remain off when there is sufficient daylight

— ensuring that daylight does not produce glare as this can lead to a blinds-down/lights-on situation, particularly where there are display screens

— ensuring that daylight is useable through good distribution using splayed reveals, light shelves, prisms etc.

— avoiding dark internal surfaces which absorb useful daylight

- introducing light into deep plan rooms by means of light wells or atria in order to minimise the use of electric lights
- ensuring that lighting controls take account of daylight availability, workstation layout and user needs; careful integration of manual and automatic control often provides the most effective solution.

It is essential to achieve a balance between useful daylight and unwanted solar gains. Increased daylight may result in less use of electric lighting and hence reduced cooling loads. However, increased solar gains during the summer could outweigh the benefits.

3.3.4 Thermal storage

Using the building itself as a passive thermal store can sometimes improve energy efficiency. In particular, night cooling of the building fabric is possible by passing cool night air across internal surfaces or through ventilation ducts in the structure (see section 4). It may be possible at the sketch design stage to further optimise the thermal response of the building to allow better use of the fabric as a storage medium. This requires a balance between:

- thermal capacity
- thermal response
- insulation levels
- complexity of controls.

All these should be matched to the occupancy patterns and method of heating and cooling being employed.

Active thermal storage devices have often been used effectively to smooth out peak demands, reducing the peak capacity of plant(14). This can also help to keep plant operating at improved load factors and better efficiencies. Thermal storage can result in reductions in plant capital costs due to lower capacities, although the costs of the storage and the more complex controls can outweigh the savings. Reduced efficiency can arise from losses where there are less favourable operating regimes. For example, in the case of ice storage where chiller COPs tend to be reduced and pumping increased.

3.3.5 Heat recovery

Heat recovery systems can form a fully integrated part of a design, resulting in lower running costs and possibly reduced plant capacities. These systems most commonly recover heat from ventilation systems, using devices such as heat wheels or run-around coils to recover energy from exhaust air, then use it to pre-heat or pre-cool supply air. There must be sufficient energy being rejected at times when it can be used to justify the added complications and running costs of installing heat recovery devices (see 6.3.5 and 19.3.4).

3.3.6 'Free' cooling

Generally, 'free' cooling uses the cooling capacity of ambient air to directly cool the space. External air at say 10°C can be used to meet a cooling load and hence reduce the energy consumed by mechanical refrigeration plant (see 6.3.4).

Because the maximum cooling requirement usually coincides with maximum outside temperature, free cooling is unlikely to reduce the peak cooling load or size of chiller. However, it can reduce the running hours of the chiller and associated equipment, particularly when internal gains occur all year. These savings usually occur at lower cooling demand and hence at lower chiller efficiencies. Enthalpy controls are generally used in air recirculation systems to increase automatically the amount of fresh air when the ambient conditions can provide a useful cooling and/or dehumidification effect.

Free cooling can also be achieved using a mixed mode (changeover) approach. Fan energy consumption can be reduced by shutting-off the air conditioning system in winter, provided that adequate ventilation is maintained by natural means. Free cooling can also be obtained direct from cooling towers (see section 7).

3.3.7 Minimising distribution losses

Minimising the distribution lengths of ducts and pipework by siting pumps and fans as near to the loads as possible reduces transport losses. Distribution lengths are influenced by:

- the shape of the building
- the number and location of plant rooms
- the provision of space for distribution (riser shafts and ceiling voids).

This emphasises the need for an integrated design to ensure that plant room requirements are properly considered at the earliest design stage. It may be possible to reduce transport losses by decentralising plant, although this should be balanced against possible reduced plant efficiencies and increased maintenance costs. Usually, it is more energy efficient to transport hot water to a heater battery than warm air to a terminal unit.

Significant energy savings can also be achieved by reducing unnecessary pressure drops in the system by the careful sizing, routing and detailing of ductwork and pipework. In particular, pinch points or index runs require much higher pressure drops than much of the rest of the system.

3.4 Integrating human factors

Ensuring that management and occupants' requirements are met is a central part of energy efficient design.

Buildings and services that are responsive to the needs of the occupant are generally more successful in achieving comfort, acceptability and efficiency. Occupants usually prefer some means of altering their own environment while management will require good overall control of systems. Comfort levels do not always need to be within a tight specification to achieve an acceptable environment. Controls are the main interface between the occupants and the building services; these are discussed further in section 5.

A building will only provide comfortable conditions and low running costs for the user if it can be readily managed and easily maintained, and if it responds speedily to the changing needs of occupants(15). These attributes must be planned for at the design stage since rectifying problems near completion, or when the building is occupied, seldom works and is always expensive.

3.4.1 Manageability

Many buildings do not realise their full potential for energy efficiency, often due to over complex design, effectively making them difficult to manage and sometimes unmanageable(15). Newer buildings tend to be more complex in order to service an increasing range of activities, facilities and user needs. Avoiding unnecessary complexity and agreeing management requirements can improve energy efficiency but demands a strategic approach at an early stage. The energy efficient management of buildings is covered in more detail in section 14.

Potential conflicts need to be kept to a minimum and interactions between systems anticipated, rather than left to chance. Systems should default to 'off' or 'standby', not allowed to by-pass or be left on continuously. They should also operate robustly, rapidly and predictably, giving intelligible responses, especially during intense use. Good ergonomic design, rapid feedback and clear diagnostics are essential features in the design, not optional extras.

It is important to take account of the different points of view of designers, managers, users and corporate decision-makers. This approach helps to reduce misunderstandings between members of the design team, between the design team and client and within the client group. Effective strategy combines vision, clarity, attention to detail and requires regular review.

3.4.2 Maintainability

Ease of maintenance will influence future energy efficiency and should be addressed at the design stage. The requirements of space, position, access, repair and replacement of services should be considered so that equipment can be commissioned, monitored and maintained. Designers should include adequate access and monitoring facilities. It should be easy to check or change features such as set-points, control authority, filter elements, and chiller efficiencies, and also for alarms and faults to be registered quickly and easily.

The specification should also make clear the need for, and extent of, properly planned operating and maintenance procedures so that the design targets for the minimum use of energy are achieved. Energy efficiency will only be achieved in practice if the building is operated as the designer intended. Maintaining buildings for energy efficiency is covered in section 16 and in various BSRIA publications(16,17).

3.4.3 Flexibility

Inflexible designs can become prematurely redundant, whereas designing for flexibility can influence future energy efficiency. Flexibility is often best achieved by considering future adaptation of the building and its services and planning contingency strategies, rather than trying to create all-purpose spaces and systems. For example, one might allow space in plant rooms for upgrades, space for cooling coils in the air handling units and provision for additional cooling capacity in spaces where occupancy and equipment densities may increase.

References

1 *A performance specification for the energy efficient office of the future* GIR 30 (London: Department of the Environment, Transport and the Regions) (1995)

2 *Avoiding or minimising the use of air-conditioning — A research report from the EnREI Programme* GIR 31 (London: Department of the Environment, Transport and the Regions) (1995)

3 Baker N V *Energy and environment in non-domestic buildings. A technical design guide* (Cambridge: Cambridge Architectural Research/Building Research Energy Conservation Support Unit) (1994)

4 *Daylighting in buildings* Thermie Maxibrochure (Building Research Energy Conservation Support Unit/OPET) (1994)

5 *Best practice in the specification for offices* (Reading: British Council for Offices) (1997)

6 Bordass W T and Leaman A J Future buildings and their services — Strategic considerations for designers and their clients *CIBSE National Conference 1995* (London: Chartered Institution of Building Services Engineers) (1995)

7 Bordass W T, Bromley A K R and Leaman A J *Comfort, control and energy efficiency in offices* IP3/95 (Garston: Building Research Establishment) (1995)

8 *Natural ventilation in non-domestic buildings* CIBSE Applications Manual AM10 (London: Chartered Institution of Building Services Engineers) (1997)

9 *CIBSE Code for interior lighting* (London: Chartered Institution of Building Services Engineers) (1994)

10 *Internal heat gains* CIBSE Guide A7 (London: Chartered Institution of Building Services Engineers) (1986)

11 *Calculation of energy demands and targets for the design of new building and services* CIBSE Energy Code Part 2(a) Heated and naturally ventilated buildings (London: Chartered Institution of Building Services Engineers) (1981)

12 Baker N V and Steemers K *The LT Method 2.0. An energy design tool for non-domestic buildings* (Cambridge Architectural Research/Building Research Energy Conservation Support Unit)(1994)

13 Barnard N *Dynamic energy storage in the building fabric* TN 9/94 (Bracknell: Building Services Research and Information Association) (1994)

14 *Ice storage systems* CIBSE Technical Memoranda TM18 (London: Chartered Institution of Building Services Engineers) (1994)

15 Bordass W T and Leaman A Design for manageability *Proceedings of Buildings In The Age Of Paradox* (York: Institute of Architectural Studies, University of York) (1995)

16 *Building services maintenance* BSRIA Reading Guide RG6/95 (Bracknell: Building Services Research and Information Association) (1995)

17 Parsloe C *Design for maintainability* AG 11/92 (Bracknell: Building Services Research and Information Association) (1993)

Bibliography

Fundamentals ASHRAE Handbook (Atlanta, GA: American Society of Heating, Refrigeration and Air Conditioning Engineers) (1997)

HVAC Applications ASHRAE Handbook (Atlanta, GA: American Society of Heating, Refrigeration and Air Conditioning Engineers) (1995)

Window design CIBSE Applications Manual AM2 (London: Chartered Institution of Building Services Engineers) (1987)

BS 8206: 1985: Lighting for buildings: Part 2: Code of practice for daylighting (London: British Standards Institution) (1985)

BS 8207: 1985: Energy efficiency in buildings (London: British Standards Institution) (1985)

Halliday S and Smerdon T Feedback as part of the building design process *CIBSE National Conference 1995* (London: Chartered Institution of Building Services Engineers) (1995)

Brown A and Steemers K Integrating shading and daylighting for energy efficiency and comfort *CIBSE National Conference 1995* (London: Chartered Institution of Building Services Engineers) (1995)

Bordass W T, Bromley K and Leaman A Are you in control? *Building Services Journal* (April 1993)

Energy efficiency in offices — a technical guide for owners and single tenants ECON 19 (London: Department of Environment, Transport and the Regions) (1997)

Jaunzens D and Bordass W T Building design for mixed mode systems *CIBSE National Conference 1995* (London: Chartered Institution of Building Services Engineers) (1995)

Air-to-air heat recovery CIBSE Research Report RR2 (London: Chartered Institution of Building Services Engineers) (1995)

Thermal storage: Environmental benefits CIBSE Research Report RR6 (London: Chartered Institution of Building Services Engineers) (1998)

Engineering design calculations and the use of margins CIBSE Research Report RR4 (London: Chartered Institution of Building Services Engineers) (1998)