CIBSE National Conference 1997

Energy Efficient Buildings - What Is Integrated Design?

By

P G Jones *Building Energy Solutions Woodborough House, 10 Walkfield Drive, Surrey*
D Cheshire *Building Energy Solutions (now with ECD Energy and Environment Ltd)*
C Lillicrap *BRECSU, Building Research Establishment Ltd*

Summary

This paper proposes a definition of ***integrated design*** in order to improve use and understanding of the term and the concept throughout the construction industry. In particular, the paper considers the topic from an energy efficiency perspective as this plays a central role in design. The definition is supported by a discussion on the design process, and developing a design strategy. This is based on work carried out in editing the CIBSE Guide: *Energy efficiency in buildings* that will be published in the future.

1. Introduction

The term 'Integrated Design' is widely used but seems to represent something different to almost everybody in the industry. The lack of an accepted definition has resulted in a general misuse and abuse of the term and the concepts behind it. This paper simply provides one further view on the topic but seeks to clarify the industry's understanding and use of this rather vague and over used term. If we can reach a better understanding of the concept, it may lead to improved use of the approach. Clients would probably move to a more integrated energy efficient approach if they understood what the term actually meant, through a clearer definition.

This paper looks at the issue from an energy efficiency perspective as it is based on work carried out in editing the CIBSE Guide: *Energy efficiency in buildings* [(1)]. It is expected that the new Guide will be published in 1998. Although energy efficiency is not the greatest priority in designing buildings, it does play a central role. Most aspects of a design have an effect upon energy efficiency and it therefore lies at the heart of good integrated design. In general, better integrated designs lead to more energy efficient buildings. In many cases, the more emphasis placed on energy efficiency, the better integrated the final design.

2. Proposed definition

As energy efficiency is at the centre of good integrated design it is important to understand what an energy efficient building is:-

An energy efficient building provides the required internal environment and services with minimum energy use in a cost effective and environmentally sensitive manner [(1)]

A key factor in this definition is that there should be no reduction in comfort or services due to energy efficiency.

One of the more recent and useful definitions that helps our understanding of the integrated design process is provided by BSRIA [(2)] as follows:-

An integrated building design process is one which considers all aspects of a building, its environment and life cycle, and is undertaken by a team which includes all relevant professionals and stakeholders working together throughout the process rather than sequentially and independently [(2)].

This addresses the integrated design process very well from a 'management' perspective and it has therefore been used as a starting point. In particular, the definition stresses the importance of the team approach and the life cycle viewpoint that is a fundamental requirement in achieving integrated design. However, from an engineering perspective this definition does not indicate the integration required from a 'technical' viewpoint. To reach an integrated design it is essential to achieve harmony between building fabric, building services, human factors and climate. This must be considered at an early stage in the process and a clear design strategy should be developed to ensure that all the members of the team (including client representatives) have a strong understanding of the design intent [(3)]. We would therefore propose a definition as follows:-

An energy efficient integrated building design harmonises building fabric, services, human factors and external climate using an holistic design strategy developed at an early stage. It is achieved using a multi disciplinary team with all stakeholders working together throughout the process under a clear management structure, with a contract and brief that ensure all aspects of the building are considered including its internal environment, energy use and environmental impact throughout the building life cycle.

This encompasses the definitions mentioned previously and promises to improve our general understanding of the concept. However, the authors view this as a working definition which is unlikely to represent the final word on the matter and look forward to future development of the definition.

3. The Design Process

A clear plan of work is vital and various versions are available [(4)(5)]. The design team should ensure that the plan includes energy efficiency at all stages. Energy efficiency plays a central part in any good design and is exceptional in being cost-effective over the life cycle of the building. Energy efficient design should always include:

- identifying user requirements and designing to meet these with minimal energy use
- establishing an integrated design team with a brief and contract that promotes energy efficiency [(6)(7)]
- setting energy/power density targets at an early stage and designing within these
- designing for manageability, maintainability, operability and flexibility [(8)]
- checking that the final design meets the targets.

3.1 Factors that influence energy efficiency

Successful integration depends on an understanding of the interactions between people, building fabric and services as shown in Figure 1. This integrated approach necessitates the early collaboration of client, project manager, architect, quantity surveyor and engineer at the conceptual stage of the project.

The most significant influence in energy efficiency is often the way the building is used by the management and occupants. Activity, hours of occupancy, control settings etc. all vary enormously and represent the greatest unknown at the design stage. Designers need to take

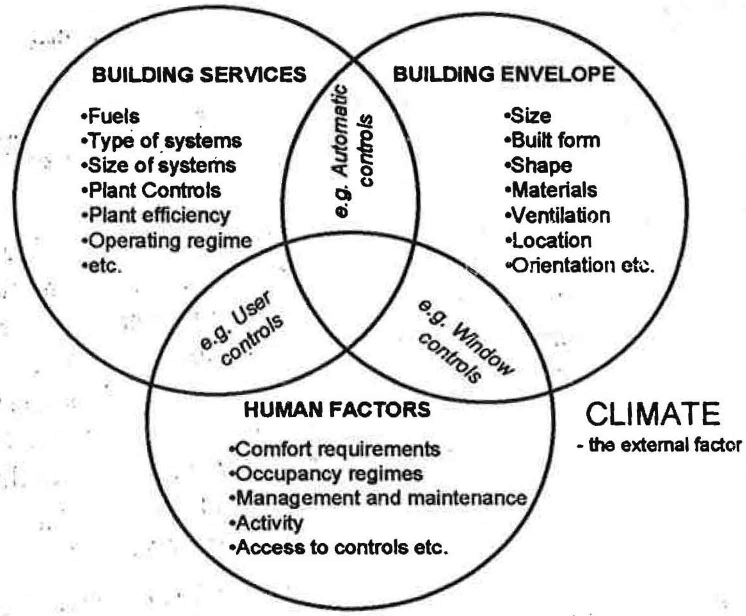

Figure 1 - Some key factors that influence energy consumption

account of this variability and promote better building management through improved design. A good management regime which is responsive to the need of the occupants and is fully in control of the building can have a major effect on energy consumption.

The integration of building envelope, services and 'human factors' should be covered in the brief and is a key part of the sketch design stage. The early design concept needs to be tested against the client's criteria, which normally include cost, quality of the internal environment and compliance with energy and environmental targets, e.g. using BREEAM [9]. If it does not meet the criteria then the design team should review the design concept or the client's requirements. This iterative process is essential in reaching an effective energy efficient design.

3.2 The design team

The multi-disciplinary design team should be appointed at the conceptual stage of the design, and must include client representatives. The success of integrated design depends on how the design disciplines interact and different disciplines should be able to proceed within an overall design strategy. Each team member should consider the energy implications of each design decision and the design team should obtain feedback from the client during the whole design process. The design team should:

- make the client aware of the implications that decisions have on life cycle costs
- assess installed power densities and provide projections of energy performance and running costs
- provide an energy efficient design that takes account of energy management and maintenance needs
- propose further options for energy efficiency, highlighting the potential benefits
- produce good documentation which makes the design intent clear.

3.3 The energy efficient brief

The energy-efficient brief should be no more complex than is appropriate for the type and size of building [6] [7] and should incorporate:

- client's requirements and investment criteria
- energy and power density targets

- environmental targets e.g. BREEAM credits
- life cycle costs
- intentions to include energy efficient equipment
- a requirement to undertake integrated design alongside all the above.

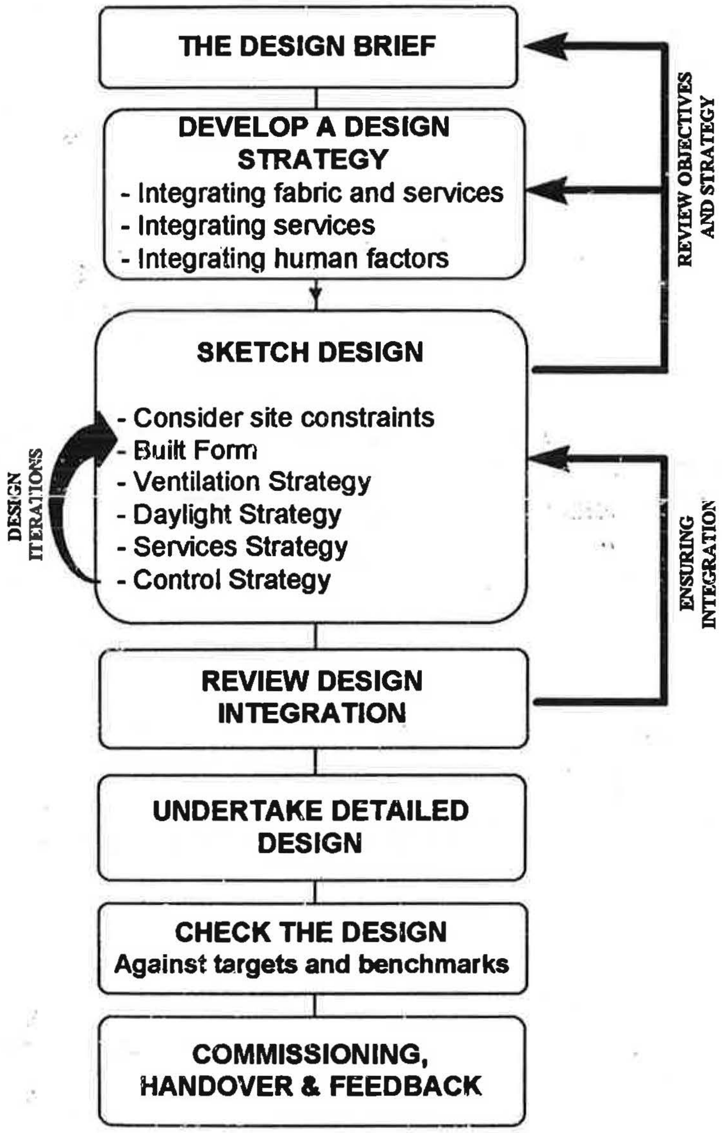

FIGURE 2 - Integrated design

3.4 The contract

The building design contract should promote energy efficiency by ensuring that all building professionals work together creatively to achieve an integrated and energy efficient design. Energy efficient buildings sometimes require greater professional skill and design input, and the team must have enough time at an early stage to formulate an integrated sketch design.

Each stage of a contract needs to ensure that the design intent is followed through to actual performance, and the predicted returns realised. Although this can act to enhance the fee component of a contract it ensures that the client's brief is addressed.

Fee structures based entirely on the capital cost of the building services may not encourage energy efficiency which can require more design input and a lower plant capital cost. Lump sum fees based on the estimated time spent are therefore becoming more common, allowing greater scope for energy efficient design.

4. Developing a design strategy

A coherent design strategy is at the heart of an energy efficient building. Building design is an iterative process; often requiring the designer to go back and re-think fundamental aspects of the design. Figure 2 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 nature of this are shown in Table 1.

BUILDING ENVELOPE	BUILDING SERVICES	HUMAN FACTORS
• climate excluding or climate responsive?	• heavily serviced, mixed mode or passive solutions?	• balance between central automation and local occupant controls?
• use the building fabric for thermal storage?	• utilise natural daylight/ventilation?	• responsive to occupancy/activity or fixed systems?
• heavyweight or lightweight?	• complex or simple systems/controls?	• do occupants require loose comfort bands or tight regimes?
• deep plan or shallow plan?	• use flexible comfort criteria?	• easy or difficult to manage?
• highly glazed or little glazing?	• use heat recovery and free cooling?	• easy or difficult to maintain?
• openable or fixed windows?	• use combined heat and power?	• allow for future flexibility?

Table 1: Issues that influence the energy efficient design philosophy

4.1 Integrating fabric and services

The first step in developing an integrated design is to balance the building envelope with the external and internal environments in order to minimise the need for services. The envelope should be seen as the primary climatic modifier supported by the services to trim conditions. Designs should avoid simply excluding the environment but should respond to factors like weather and occupancy, rather than limit them. The design philosophy should aim to 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, influence the need for air conditioning, the size, capacity and space required to accommodate central plant, as well as the air and water distribution systems. To reach an effective design may require several iterations.

Services Issues

COOLING	Deep plan may need greater cooling	Locate cooled zones on north facade to reduce potential cooling loads	Minimise solar gains	Minimise solar gains		Store heat in thermal mass and effect on response times
HEATING	Deeper plan reduces heat loss area	Position less heated buffer zones on north facade 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 to avoid solar gains	Increased glazing will increase daylight but may increase solar gains	Use atria to increase natural daylight		
NATURAL VENTILATION	Use shallow plan to allow natural ventilation	Draw air from north facade 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 & AIR CONDITIONING	Consider shallow plan with mixed mode to allow natural ventilation at certain times	Orientate 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
	DEEP PLAN/ SHALLOW PLAN	ORIENTATION	PERCENTAGE GLAZING	LIGHTWELLS & ATRIA	AIR TIGHTNESS	THERMAL RESPONSE

Fabric Issues

Figure 3 - Possible interactions between fabric and services
Select issues on the X and Y axis to see how these may interact

Avoiding or reducing dependence on mechanical plant e.g. air conditioning, can reduce capital and running costs. However, there are instances where air conditioning is unavoidable but the principles of integrated design still apply, thus reducing the size and complexity of the air conditioning system.

Figure 3 indicates some of the issues that need to be considered when integrating fabric and services.

4.2 Integrating services

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

Many energy problems can be traced to a conflict between building services [10]. An energy efficient design strategy should avoid these conflicts. Some of the key interactions are shown in Figure 4.

Although simultaneous heating and cooling can be minimised by good controls, it is possible that the problem rests with the basic design. For example, perimeter heating with core air conditioning may result in the two systems fighting, leading to further difficulties as occupants alter the controls to compensate for the problem.

Zoning services is an important factor in any integrated design. Services should be matched to the actual requirements of each area. Where areas have different requirements they 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 is advisable 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.

Heat recovery provides a means of integrating services. For example, integrating lighting and air conditioning systems by extracting air through luminaires allows heat recovery in winter and minimises summer cooling loads.

Many conflicts between different

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 through glazing	Use daylight linking controls to minimise use of electric lighting		
NATURAL VENTILATION	Consider mixed mode to use natural ventilation and avoid mechanical cooling when possible	Account for effect of open windows on heating loads		Balance solar gains from glazing with increased natural ventilation	
MECHANICAL VENTILATION & 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 e.g. VAV	Use natural ventilation instead of air conditioning where possible
	COOLING	HEATING	ELECTRIC LIGHTING	DAYLIGHT/ GLAZING	NATURAL VENTILATION

Figure 4 - Possible Interactions Between Building Services

Select issues on the X and Y axis to see how these may interact services are control issues. Excessive casual gains from lighting due to poor control can lead to significant cooling loads, particularly in summer, when daylight levels may be sufficient for lights to be turned off.

Mechanical cooling systems often operate when external air is sufficient for cooling purposes. Air conditioning systems may be running simply 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.

Although improved controls can often solve conflicts, the underlying reasons for the conflict should be sought before carrying a flawed design further.

4.3 Minimising requirements for services

Over-specification of services should be avoided in order to minimise capital and running costs [11]. Continually reviewing the need for services, the true demands likely to be made on the services and their complexity will improve energy efficiency and often results in a simpler building.

Building services engineers should challenge the assumptions underpinning the design in order to avoid over provision of services. For example:

- Are the design margins excessive?
- Are the design parameters unnecessarily restrictive, e.g. an attempt to control relative humidities to 50% $\pm$ 5% all year round?
- Is the plant over sophisticated, necessitating more complex controls with the likelihood that systems are difficult to understand and control?
- Have natural sources such as daylight and cooler outdoor air been used to the full?
- Does the overall design promote energy efficiency, or is it likely to result in high running costs.

At an early stage, it should still 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 BMS through budget cuts, thus retaining good control.

In general, a 'simple' approach is best in order to promote good installation, operation and maintenance [12]. 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. An over-serviced building does not necessarily mean a 'high quality' building [10].

4.4 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 whilst 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.

A building will only provide comfortable conditions and low running costs for the user if it can be readily managed, easily maintained and responds speedily to changing needs of occupants [8]. Manageability, maintainability and flexibility must be planned for at the design stage as rectifying the problems near completion, or when the building is occupied, seldom works and is always expensive.

5. Conclusions

The proposed definition should provide a clearer understanding of the concept of energy efficient integrated design and may improve the approach taken by some design teams. In particular, it is hoped that the definition will help engineers to overcome barriers to energy efficiency in discussions with clients and other members of the design team. Through a better understanding of the term, the definition may also encourage clients to move to a more integrated energy efficient approach.

It is not easy to define integrated design and this is far from the last word on the subject. The proposed definition should therefore be regarded as a working definition which will inevitably require further development in future.

Acknowledgements

Our thanks go to all those that have had an input to the *Energy efficiency in buildings* volume of the CIBSE Guide. In particular, Tony Johnson, John Webber and Bill Bordass. Our thanks also go to CIBSE, BRECSU (part of the Building Research Establishment Ltd) and EEWD (part of the Department of the Environment, Transport and the Regions) for allowing publication.

References

1. CIBSE Guide: *Energy efficiency in buildings* (to be published), CIBSE, London
2. Smerdon T (BSRIA) - CIRIA Workshop on Green Buildings, 7th November 1996, CIRIA, London
3. The Benefits of Including Energy Efficiency Early In The Design Stage, Good Practice Case Study 334 (BRECSU) (1997)
4. Plan of work for design team operation: RIBA Publications Ltd, 66 Portland Place, London
5. BS 8207: Code of Practice for energy efficient buildings (London: British Standards Institution) (1985)
6. Briefing the design team for energy efficiency in new buildings, Good practice guide 74: (BRECSU) (1994)
7. A Performance Specification For The Energy Efficient Office Of The Future, General Information Report 30 (BRECSU) (1996)
8. Bordass WT, Design for manageability, Buildings in the age of paradox conference, University of York, 1995
9. BREEAM Environmental assessment method: for new offices 1/90 (BRE) (1991)
10. Bordass WT, Bromley, Leaman AJ Comfort, control and energy efficiency in offices BRE Information Paper IP 3/95 (BRE) (1995)
11. Avoiding Or Minimising The Use Of Air Conditioning General Information Report 31 (BRECSU) (1996)
12. Bordass WT, Leaman AJ, Future Buildings And Their Services - Strategic Considerations For Designers And Their Clients, CIBSE National Conference, 1996