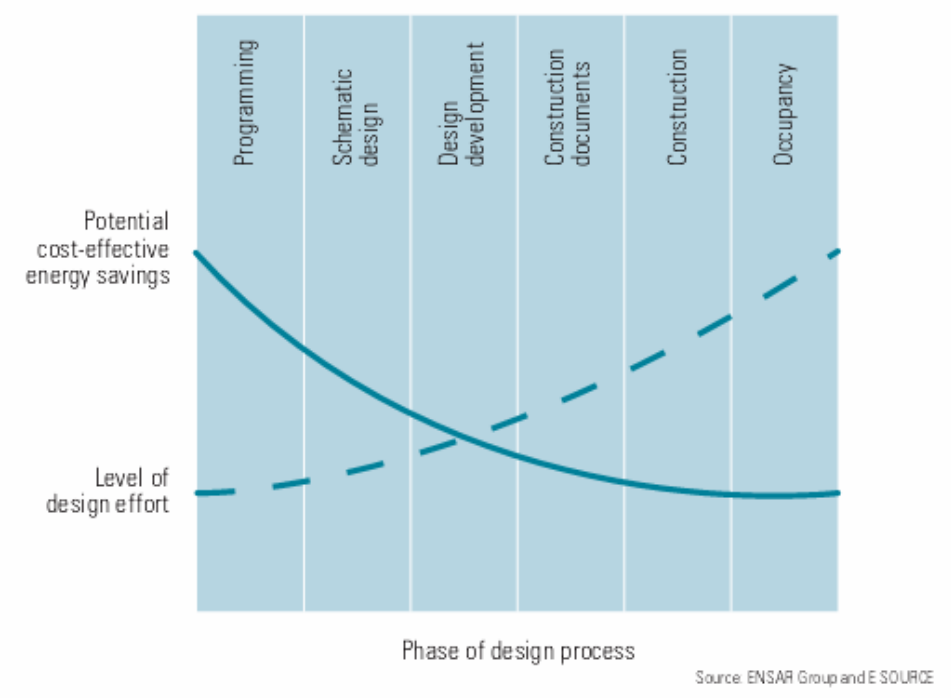
SECTION 5 DESIGN & CONSTRUCTION PROCESS



ENERGY EFFICIENCY BUILDING DESIGN GUIDELINES FOR BOTSWANA

Revision 1

September 2007

ENERGY EFFICIENCY BUILDING DESIGN GUIDELINES FOR BOTSWANA

Sections:

CONTENTS

5. DESIGN & CONSTRUCTION PROCESS

5.1. Overview

This section addresses the subject of the design and construction process and its impact on building energy performance in Botswana.

The following topics are covered in this section:

- Project cost and energy efficiency.
- Procurement systems and their implications for energy performance.
- Integrated design methods.
- Construction and Commissioning.

5.1.1. Project cost and energy efficiency

The relationship that exists between project cost (capital and recurrent) and energy efficiency is described.

5.1.2. Procurement systems

The process and methodology by which the design, construction, operation and demolition of buildings is implemented has gone through dramatic changes over past 30 years in many countries of the world. A number of different approaches to procurement of design services are now implemented, including competitive tendering, turnkey development and Public / Private Partnership. The implications of these approaches with regard to improving energy efficiency are considered, as well as the relationship between initial cost, life-cycle cost and energy efficiency.

5.1.3. Integrated Design Methods.

Substantial improvements in energy efficiency have been achieved through the development and implementation of what is known as 'integrated design'. This is essentially a holistic approach to the design, construction, operation and demolition of a building.

5.1.4. Construction and Commissioning.

The effort that has gone into achieving an energy efficient building design can easily be compromised in the construction process if adequate supervision and coordination is not provided to ensure that the critical aspects of the building meet the design requirements.

The systematic application of commissioning to both new and existing buildings has been found to be a highly cost effective means to ensure that the building and all its systems are functioning as intended. It can lead to dramatic improvements in energy efficiency, and overall environmental performance.

5.2. Project Cost and Energy Efficiency

Over the past two or three decades there has been an increasing concern for energy efficiency generally, including in the building sector. This has been driven by the increasing cost of conventional sources of energy, as reserves of fossil fuel are becoming more scarce, as well as the impact of our rapidly increasing energy consumption on the local and global environment in the form of pollution and climate change.

This has resulted in a change in the way in which building costs are viewed and assessed. Previously the main concern was with the initial construction cost of a building, and in many cases this is still the only cost that is taken into consideration in the design stages of a building project. The project manager is asked to prepare project budgets, and decisions are based largely on an assessment of whether the client can afford particular features or finishes in the building.

There is a growing awareness that the initial construction cost is only one aspect of the overall building cost, and that future costs of operation, maintenance and ultimately demolition may be as important or even more so over the total life of the building. There are many choices of material, design, equipment or finishes that influence 'life-cycle' cost in different ways. Some choices may lead to reduced life-cycle cost and save on the construction cost as well. Others may reduce life-cycle costs and have no influence on construction cost, and many interventions may require a trade-off between increased construction cost resulting in reduced life-cycle cost.

Life cycle cost is defined more fully in **Section 12, Life-Cycle Cost Analysis**. This also gives a brief introduction to various methods of calculating LCC, as well as references to more detailed information.

5.3. Procurement Systems.

When a client needs a construction project to be implemented, the first requirement is usually for some professional advice to assist with preparing the design brief and getting started on the process of design and construction.

The conventional approach to this has often been to employ a project manager who becomes the client's agent and manages the project. The project manager then engages an architect to lead the design phase of the project. In many cases the client may employ an architect directly, who then also takes on the functions of project manager.

Until recently this was also the most common approach taken by the Botswana Government. Recently however a number of other procurement options have been tried, including:

- Competitive tendering for consultancy services.
- Turnkey development.
- Public, Private Partnership (PPP).

These different procurement methods have considerable implications on the financial and other motivations that influence the work of the consultants. These are discussed in the following sections with particular reference to energy efficiency and energy conservation.

5.3.1. Conventional appointment of consultants.

In this case the choice of consultant is based on their reputation for capability, professional integrity, and capacity to carry out the work for a reasonable fee. Fees may be negotiated, but are usually based on agreed standard rates that are set by professional institutes. The initial stages of a project may be paid on an hourly or lump sum basis, but the major portion of fees is generally calculated as a percentage of the contract sum related to that consultant's scope of work. The consultant therefore does not have a financial incentive to reduce contract cost. He or she does have an incentive to reduce the work required of them in completing the project.

Such a consultant has no particular motivation to reduce life-cycle cost, except in so far as this is included as a concern in the design brief. Some may also see it as a fundamental objective in their work, and seek to achieve this as a matter of course.

Choices that reduce construction cost will result in reduced fees, and those that increase construction cost will lead to increased fees.

The arrangement is based on an assumption of professional integrity, which should ensure that these financial motivations do not affect the consultant's work in any way. This is to some extent reinforced by the codes of conduct that Professional Institutions require their members to adhere to. In practice it is perhaps rather naïve to assume that all consultants have the integrity to totally disregard the financial implications to themselves of decisions that are made in the design and project management process.

5.3.2. Competitive tendering.

Recently the Botswana Government changed the standard method of procurement for consultants to a competitive tendering process. A 'terms of reference' (ToR) is prepared and advertised. Consultants prepare tenders that are submitted through the Public Procurement and Asset Disposal Board. Typically the 'two envelope' system is used, whereby the technical and financial proposals are submitted in separate envelopes. The technical proposals are first evaluated against a set of criteria. The financial proposals of those tenders that score higher than a certain minimum on the technical evaluation are then opened, and the best value tender is selected.

Generally competitive tendering has resulted in greatly reduced fees compared to the use of standard fee scales. This is a benefit to the client in that it reduces the portion of project budgets that is spent on fees. It also means that consultants are required to carry out the same amount of work for a lower fee. They are therefore under considerable pressure to minimise their costs in terms of hours spent and the cost of their professional staff (which is generally related to the level of qualification and experience). This may make them reluctant to spend additional time investigating the life-cycle cost implications of different strategies to reduce operating costs generally and energy consumption in particular.

The consultant's terms of reference (or design brief) therefore becomes an even more important document and it is essential that environmental considerations and energy performance requirements in particular are clearly defined.

There is also now more of a need to verify that the consultant is actually addressing the requirements of the ToR. On large projects it may be advisable to hire an independent consultant to confirm this. The commissioning procedure (see below) can also help to verify performance against targets, but at that stage it may be too late to correct fundamental design issues.

If the tender is based on percentage rates, then the financial motivation regarding changes in construction cost versus life-cycle cost will be similar to those for the directly appointed consultant.

If the tender is based on a lump sum fee, then there will be neither a fee incentive to increase the construction cost, nor a fee penalty if it is reduced.

5.3.3. Turnkey development.

The turnkey procurement method is a radical departure from the traditional relationship between client, consultant and contractor. The design consultants now become part of the same team as the contractor, and tender for a project as a joint venture. The division of the payment between contractor and consultant is decided between them and does not concern the client.

The challenge in this system is to ensure that the client's requirements in terms of function, performance and quality are achieved. For larger projects this will often require the client to hire an independent consultant to supervise the project and provide expert advice throughout.

With this system the interests of the contractor and the design consultants are aligned, and they have a financial motivation to reduce costs once a contract has been signed, in order to maximise their profit. This could result in decisions that result in increased life-cycle costs to achieve reduced construction cost, since the turnkey developer has no further involvement in the project once the contract is completed.

As with the competitive tender procedure, it becomes more important to have a watertight design brief, and a means to verify compliance with the brief.

5.3.4. Public, Private Partnership.

Public, private partnership is a relatively new concept in procurement that is rapidly gaining popularity for medium to large-scale public infrastructure projects, including public buildings. Essentially it takes the turnkey concept further, such that the contractor's team (the concessionaire) not only designs and builds the project, but also arranges finance, and manages the project for its entire life (or at least a substantial portion thereof). The client in this case pays for the project through 'unitary' payments that include for maintenance, building staff, rental, finance, etc. These are calculated as annual payments but are usually paid in monthly instalments rather like a lease charge.

Utility costs such as electricity and water are treated as 'through costs' that are paid by the concessionaire and then charged to the client, with an agreed mark-up for profit.

The concessionaire therefore has no direct incentive to design and operate the building in such a way as to minimise energy or water use, since the client covers the cost of these.

The Request for Proposals (RFP) may however include requirements relating to environmental considerations, energy efficiency, and life cycle costing. The extent to which each proposal addresses these will then be considered in the evaluation of the proposals, and will be one of many criteria used for selecting the successful proposal.

The PPP process includes a procedure to verify that the completed project meets the targets and requirements of the RFP. This is implemented by the concessionaire under the supervision of a client's representative, and stringent penalties are charged for any failures to comply. At this stage however it is of course too late to rectify any fundamental design faults.

5.3.5. Fee incentives for energy efficiency.

In some countries including the USA a system of fee incentives and penalties has been introduced for certain projects, to provide a direct financial incentive to consultants to achieve energy efficiency and other objectives. In this case a certain portion of the fees is retained by the client until the initial commissioning process has been completed, during which the performance of the building is monitored. If it is found that the building achieves or exceeds the performance targets, the consultants are rewarded with a bonus. If performance falls

short of the targets, the consultants are penalised. In some cases there may even be ongoing rewards for achieving operation and maintenance cost targets.

An example of a performance based design contract is provided on the following page.

The Performance Contract Between North Clackamas School District No. 12 and Boora

The Performance Contract supplements the traditional professional services agreement between the owner and the architectural/engineering (A/E) firm. The prologue to the Performance Contract stresses the commitment of the School District to "architectural lighting, HVAC, and energy management systems that operate efficiently, provide a high quality of occupant comfort, and are easily maintained and serviced."[19] Key features follow:

- *Compensation and target*—The owner agrees to compensate the A/E firm an additional $104,575 for the services needed to achieve the target level of performance. In the event that the building fails to meet the target level of performance, the owner and the A/E firm agree to work together to ensure that the building meets the desired performance.

- *Shared savings*—If the building exceeds the target of 44 percent, the owner agrees to split the added savings equally with the A/E team for a period of two years.

- *Modifications*—In the event that the building design is modified in a way that adversely affects expected energy performance, the owner and the A/E firm agree to renegotiate the target level of performance.

- *Performance*—The base and target levels of performance will be adjusted for factors that are not under the control of the A/E firm. These include computers; office, lab, and classroom equipment; weather; schedules of operation; hot water use; utility rates; and special uses.

- *Commissioning*—The purpose of commissioning is to ensure that systems are operating according to their design intent and that they are providing proper indoor air quality, comfort, and energy efficiency. The commissioning process will result in a properly functioning facility, properly trained operation staff, and documentation that describes system design intent and commissioning procedures.

5.4. Integrated Design Methods.

There are substantial opportunities for improving the environmental performance of buildings through what has become known as 'integrated building design' (sometimes also known as 'integrated energy design').

The concept requires a re-thinking of the approach to building design from the one that is traditionally used.

Traditionally there has been a tendency to separate out different systems of a building, with each consultant solving the problems that relate to their expertise in relative isolation. Of course from time to time they come together to look at the implications of each other's work on the building as a whole, and to coordinate the 'points of contact'.

Usually the design process begins with the architect who develops an overall design concept, including the aesthetic and spatial layouts for the building.

A structural engineer takes the concept, ensures that it is structurally feasible, and works out the structural system that can support it.

A mechanical and electrical engineers then design the HVAC, lighting and other services systems, trying to fit these into the building as efficiently as possible.

If one is included in the team, then the landscape architect will be required to create a suitable surrounding for the building.

The integrated design approach, in contrast, views the building and its surroundings as a whole, comprised of all the different systems interacting with each other to achieve the optimum performance in every respect. There is a deliberate process of looking for opportunities that can arise from these interactions to achieve improved energy efficiency, comfort, quality, beauty, etc.

A number of tools have been developed that can help to achieve a successful integrated design process, some of which are briefly described below.

INTEGRATED BUILDING DESIGN

The complete building design concept integrates the different system design concepts.

- Landscape / environmental design concept.
- Architectural design concept.
- Thermal design concept.
- Structural design concept.
- Mechanical and Electrical design concept.

5.4.1. Integrated design coordinator.

From the beginning of the project, a specialised energy consultant is appointed by the client to act as integrated design coordinator. This person is responsible for ensuring that the different members of the design team take into consideration the opportunities that arise in the work of other members, and facilitates the creative interaction between them.

He or she is responsible for assessing the life cycle cost implications of different alternative approaches that may be suggested by the team, and coordinates the process of selecting the most appropriate combination of design decisions.

5.4.2. Structured methodology.

The integrated design approach requires a greater amount of interaction between the consultants, and a more creative and less formal relationship in the stages where the different design concepts are integrated. However, because much of the design work is carried out concurrently, it is essential that the interaction is facilitated by effective structures for the technical communication.

Details regarding CAD draughting protocols such as layer names and colours, pensize tables, drawing file names, revision numbering, etc. can make an important difference to the effectiveness of communication between consultants.

Communication channels and media should be agreed on at the beginning, with the integrated design consultant acting as the link between other consultants, to ensure that each has the information that they need at each stage.

Communication with the client, contractor and users must also be effectively managed, so that they are included in decisions where appropriate, have the information that they need, but are not overloaded with unnecessary information.

Key requirements for integrated building design to be successful:

- The client is convinced of the benefits of this approach and is willing to invest time and money to achieve these.
- Energy efficiency is included as an important objective in the design brief.
- The work of the design consultants is coordinated towards achieving the agreed objectives.
- The construction process is monitored and managed effectively.
- The end users and building operators are trained in the operation and maintenance of the building.

5.4.3. Incentives.

As can be expected, the integrated design process is not easy, and cannot be achieved without some cost. It will not therefore be generally adopted by choice by consultants unless there is a clear incentive to do so. Much of the potential benefit is only enjoyed by the building owner and / or users during the building's life time, in the form of reduced energy and other operating costs, better comfort, and a higher quality environment generally. The improvement in these areas can be quite dramatic, with up to 60-70% reduction in energy cost being achieved in certain projects compared to similar, conventionally designed buildings. There is therefore a need to develop an incentive package to compensate the design team for the additional work that is required. This can be done in two distinct ways. One option is to simply pay increased fees up front for the increased service. The alternative is to link the fee to the performance of the building, so that the consultants receive a bonus and / or pay a penalty based on the actual performance of the completed building.

5.4.4. Timing of design decisions.

The timing of design decisions is critical to the success of integrated design.

The cost of making changes increases exponentially with time as the design becomes more detailed, whereas the opportunity to achieve energy savings declines. This is illustrated in the graph in Fig. 5.1.

Options become more and more limited, and aspects of the design get “locked in”. This implies that if a change has to be made that does not fit in with decisions already taken, it will be more expensive since it requires numerous changes to other aspects of the design that have proceeded on the assumption of the original decision – effectively turning back the clock and starting over in many aspects of the design. It is therefore worth taking the time to carefully consider the options relating to all the design concepts and how they interact with each other early on in the process, to avoid the need to discard large amounts of detail design work later when a more effective solution is suddenly identified.

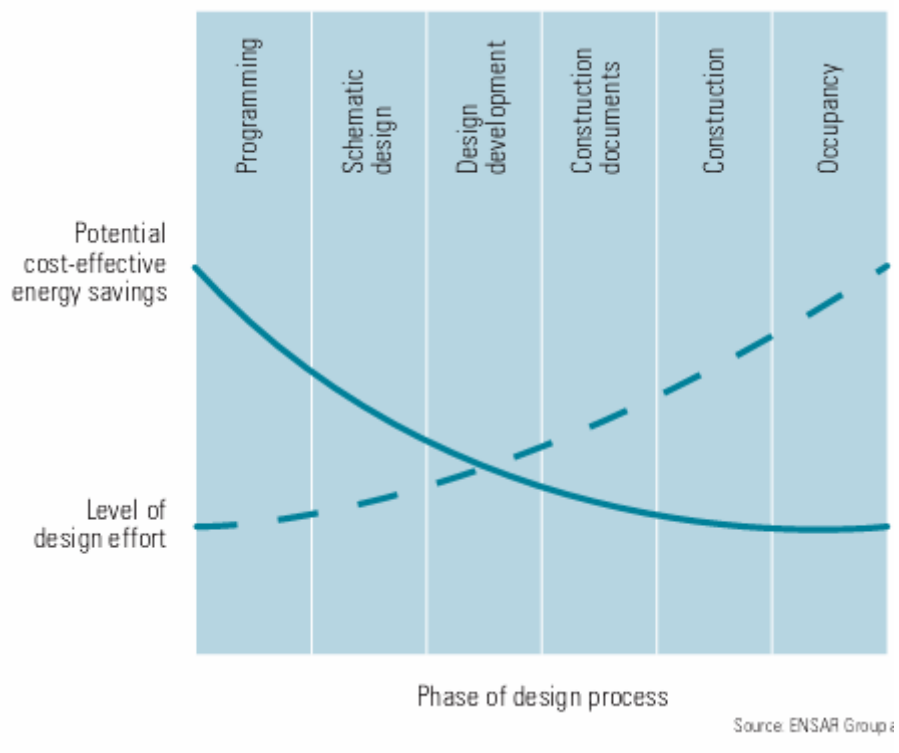


Fig. 5.1 Cost / benefit of design change with regard to energy savings. (Source: ENSAR Group)

5.4.5. Construction.

Design of an energy efficient building is only the first stage. The benefits will only be realised if the construction of the building is carried out in accordance with the design. In practice the quality of work varies greatly from one site to another, and is influenced by many factors, including the quality of the design drawings and specifications, skills of the artisans, contractor's quality control systems, supervision by the consultants, etc.

The contractor should understand the concepts behind the design, so that he / she is aware of the purpose for particular specifications and details.

The work on site needs to be regularly inspected and checked to ensure that details that are particularly relevant to energy performance are properly constructed. This requires appropriate training for the people involved whether this is the resident engineer, clerk of works, architect, or others.

Details that are of particular relevance to energy performance include:

- Proper installation of damp proofing membranes.
- Avoidance of thermal bridges, e.g. in cavity walls.
- Installation of insulation according to specifications.
- Seals in ductwork and fittings to avoid leaks.
- Duct insulation.

5.5. Commissioning.

"Commissioning is a systematic process of ensuring that all building systems perform interactively according to the contract documents, the design intent and the owner's operational needs." (The Building Commissioning Guidelines, EDR)

The importance of the commissioning process for a building has recently been recognised, particularly as a means to reduce operating costs in general and energy costs in particular. It has been found that a carefully managed, comprehensive commissioning procedure for new buildings can greatly reduce the number of problems that are experienced with building systems in the initial period of occupation, and also improve energy performance.

For existing buildings it can be an effective way to identify systems that are not functioning optimally, and to rehabilitate a building to a state where it is functioning optimally resulting in reduced operating and energy costs.

5.6. Resource Material

5.6.1. Books and Papers

Energy Design Resources. Design Brief. Performance Based Compensation.
http://www.energydesignresources.com/resource/33/

Energy Design Resources. “The Building Commissioning Guidelines”.
http://www.energydesignresources.com/resource/37/

5.6.2. Web resources

EDR. Energy Design Resources
http://www.energydesignresources.com/

EERE Building Technologies Program Home Page
http://www.eere.energy.gov/buildings/

SBIC. Sustainable Buildings Industry Council.
http://www.sbicouncil.org

U.S. DOE Energy Efficiency and Renewable Energy (EERE)
http://www.eere.energy.gov/

WBDG - Whole Building Design Guide
http://www.wbdg.org/