Built Environment Journal *Vol. 5, No. 2, 1-11, 2008*

DESIGN PROCESS FRAMEWORK TO ACHIEVE AN ENERGY EFFICIENT BUILDING

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ABSTRACT

Energy performance of buildings can be improved through adoption of energy efficiency measures. Past studies suggest that dealing with energy efficiency measures is not a straightforward affair. When adopted together they are likely to pose interactive effects which if well considered will amplify their energy efficiency potential. The opportunity to improve energy performance of buildings depends on whether or not energy efficiency measures are properly considered and eventually carried through in the building design process. The consensus is thus the production of an energy efficient building is a deliberate act that requires a clear design process strategy. A recent study has identified a set of characteristics of energy emphasis integrated design process model: referred to as the Energy Design Process (EDP) criteria. This paper reviews the characteristics of design process framework of two case studies, in relation with the EDP criteria. The results indicate that generally both cases had components of an integrated design process in place. Two main aspects of the EDP criteria which were not closely adhered to, were identified as, (1) timeliness in initiating a fuller design effort, and (2) the tools used for assessment of energy efficiency measures.

Keywords: energy efficiency measures, design process framework, integrated design process

1. INTRODUCTION

In Malaysia, the building sector energy efficiency agenda was introduced in 1989, in the form of *the Malaysian Energy Efficiency Guidelines* (Malaysia Ministry of Energy Telecommunications and Posts, 1989). However back then, the guidelines was not followed by serious enforcement measures, thus did not impact much on the building industry. In 2001, in a more determined effort, the government reintroduced the guidelines in the form of a Malaysian standard code of practice, *MS 1525; the Code of Practice for Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings* (Department of Standards, 2001). In early 2002, two prime local authorities, namely the Kuala Lumpur City Hall (KLCH) and the Putrajaya Corporation (PJC), began to enforce the Code on all new office projects. This marked a new phase of energy efficiency implementation in Malaysia.

Past studies in the energy efficient design approach maintains that dealing with energy efficiency design measures is not a straightforward affair as these measures are not entirely independent (Todesco, 1998, de Wilde et al., 2002). When adopted together, they are likely to pose interactive effects that either amplify or diminish their energy efficiency potentials. For example, maximising daylighting may lead to a reduction of energy use for artificial lighting, but causes increase in solar heat gain. As such, selection of energy efficiency measures requires considerable thought and an overall understanding of the interactive implications of various means.

To address the issue on handling interactive interdisciplinary measures, researchers suggest a need for a systematic and integrated design approach (Balcomb, 2002). This view is supported by other researchers on the design process field for example Rivard (1995), Macmillan et al. (2001) and Larsson and Clark

ISSN 1675-5022

(2000) who have demonstrated that during the design phases, there is substantial scope for reducing energy consumption of buildings.

This paper presents in brief the characteristics of design process environment that facilitate the implementation of energy efficiency building projects. Deliberations is based on literature review on this subject matter, supplemented by description of two case studies of energy conscious office building projects in Malaysia. The study findings identify aspects of design process environment that need to be addressed to support energy efficiency design pursuit in the country.

1.1 Models of Integrated Design Process

Suggestions on means to incorporate energy issues in the design process are numerous. As early as in the 1980s, researchers, namely Meyer (1983) and Burberry (1983) have identified and mapped out energy conscious steps to be taken during the design process. Burberry (1983) termed these steps as 'thermal decisions'. In another effort, Szokolay (1984) proposed a checklist of tasks, information, tools and products according to the four prime stages of design, namely pre-design, sketch design, detailed design and final evaluation stages. He refers this flow chart as the energetics in design.

Efforts to promote a better design process framework heightened in the 1990s, with general consensus that better integration will lead to improved building performance as a whole (Todesco, 1996, Oppenheim, 1995). The argument is that such an approach provides the team synergy that offers better opportunity to enhance energy performance. There are several forms of design process framework that aim for better design integration as a whole, such as *participatory approach* (Oppenheim, 1995), the *Energy Design Process* (Hayter et al., 2001), *Whole Building Design Approach* (NIBS, 2004) and *Integrated Design Process* (Todesco, 1998).

It can be observed that these integrated design process frameworks place particular emphasis on the sequence of integration in terms of the timing and activities to be taken.
Table 1 summarises the steps of integration as suggested by three prime integrated design process proponents; the Task 23 IDP Guide, the Participatory Design Approach (PDA) and the Whole Design Approach (WDA).

Table 3-3: Steps of integration according to the key stages of building design

Task 23 IDP Guide source: (Lohnert et al., 2003)	**PDA Energy Brief** source: (Sustainable Energy Authority Victoria, 2003)	**Whole Design Approach** **9-step Energy Design Process** source: (Hayter et al., 1999)
PRE-DESIGN STAGE		
STEP 1. Establish performance targets	Establish energy budget and energy objectives for the project. State any prescriptive energy requirements. Establish operational variables. Set out methodology for accounting for energy efficiency during project. Define consultant types and their respective roles and responsibilities regarding energy efficiency during the project.	1. Create a base-case building model to quantify base-case energy use and costs. 2. Complete a parametric analysis to determine sensitivities to specific load components. 3. Develop preliminary design solutions. [The design team brainstorms possible solutions]

CONCEPTUAL / SCHEMATIC STAGE		
STEP 2. Minimise heating and cooling loads and maximise daylighting potential. **STEP 3**. meet these loads by an optimum use of solar and renewable technologies and use of efficient HVAC systems. **STEP 4.** iterate the process to produce at least two, and preferable three, concept design alternatives, using energy simulations.	Determine concept design to comply with energy budget based on prescriptive requirements and stated operational variables. Demonstrate consideration of various options against a lifecycle assessment process.	4. Incorporate preliminary design solutions into a computer model of the proposed building design. Energy impact and cost effectiveness of each variant is determined by comparing the energy with the original base-case building and to the other variants. Those variants having the most favourable results should be incorporated into the building design. 5. Prepare preliminary set of construction drawings. [These drawings are based on the decisions made in Step 4].
DESIGN DEVELOPMENT STAGE		
Define materials pre-selected in previous phases. Specifications of materials checked for environmental performance. Do system optimisation, including fine-tuning. Final design and sizing of technical plants and systems. Review environmental performance and cost.	Detailed design checked against energy budget.	6) Identify an HVAC system that will meet the predicted loads. The HVAC system should work with the building envelope and exploit the specific climatic characteristics of the site for maximum efficiency. Often, the HVAC system is much smaller than in a typical building.
Ensure design documents are in detailed form. Construction documents and specifications to include detail information on measurement & validation requirements. Provide a final commissioning plan for owner/contractor, and include all relevant building construction elements and technical systems.	Contract (tender) documentation checked against energy budget objectives prior to pricing. Pre-tender energy budget established. Detailed design information passed onto the constructors.	7) Finalize plans and specifications. Ensure the building plans are properly detailed and that the specifications are accurate. The final design simulation should incorporate all cost-effective features. Savings exceeding 50% from a basecase building are frequently possible with this approach.
CONSTRUCTION STAGE		
Relevant drawings and documents to be made	Construction design checked for compliance with energy	8) Rerun simulations before design changes are made during

available. Information on energy and environmental to be included. Commissioning of partial systems, such as thermal quality of building envelope and air tightness.	budget and energy objectives including any prescriptive requirements. Detail of energy efficiency accounting procedure agreed and applied.	construction. Verify that changes will not adversely affect the building's energy performance.
PRE-OCCUPANCY / BUILDING HAND-OVER		
Guarantee of materials must be part of commissioning. All necessary tests (such as air tightness) must be completed before the final commissioning. Facility manager to be part of the commissioning procedure.	Active and demonstrable program of building tuning and adjustment to suit occupancy and actual operation. Final demonstration of compliance with energy budget, energy objectives and any prescriptive requirements.	9) Commission all equipment and controls. Educate building operators. A building that is not properly commissioned will not meet the energy efficiency design goals. Building operators must understand how to properly operate the building to maximize its performance.

Design process conditions that support an energy efficiency pursuit have been reviewed by the author elsewhere (Ibrahim, 2006) and is not covered in this article. From the review, characteristics of an energy emphasis integrated design framework were clustered into identifiable topics which form what is referred to as the Energy Design Process (EDP) criteria.

The criteria are as follows:

EDP 1 Energy efficiency intent and planning

- Set energy efficiency objectives and strategies
- Set performance target so that team members remain united in meeting this objective
- Gather relevant data to support energy efficient design
- Carry out related research

EDP 2 Earlier and fuller collaboration

- Architects and M&E work together to strategise energy efficiency approach, before actual design activities begin.
- Follow the following steps of integration: PLAN out measures, APPLY BUILDING DESIGN measures that minimise load and maximise passive means, APPLY EFFICIENT SYSTEM DESIGN measures, reiterate the process for design alternatives.

EDP 3 Integrated design considerations

- Understand impact between architectural design measures:

- Envelope design take into account interactive energy-related design issues, namely orientation and configuration, site condition, daylighting, cooling, ventilation and building fabric.
- Design and sizing of mechanical equipment and electrical system consider envelope efficiency.

- Zoning of air-conditioned space to take into consideration internal planning and envelope efficiency.
- Cost analysis and checks on energy performance targets conducted as an ongoing exercise.

EDP 4 Preparation for occupancy

- Undertake proper commissioning
- Building maintenance team set up early, to ensure energy efficiency intentions are understood and carried through during the occupancy stage.

EDP 5 Enhanced design team

- Team members to be familiar with energy efficiency design needs
- Include experts if necessary. Most recommended is the inclusion of ana energy consultant who is capable of providing support on energy matters which include conducting energy simulation study.
- Client and end-user are active participants in the design process.

EDP 6 Tools support to test implications of energy efficiency measures.

- Computer tools support to test implication of energy efficiency measures. Ideally, simple tools at pre-design and schematic stage (such as Energy-10). More sophisticated tools at detailed design, such as Energy-Plus and APACHE Sim.

2 CASE STUDY DESCRIPTION

2.1 Ministry of Energy, Water and Communication building at Putrajaya (MEWC)

[occupied since 2004]

The MEWC is four-storey in height with a built up of 16,000 m^2. The Ministry of Energy, Water and Communications (MEWC) building in Putrajaya was completed in 2004. The MEWC was developed as part of a government building office complex at Parcel E, Putrajaya. Putrajaya is Malaysia's new Federal Government Administrative Centre. Building development in the Putrajaya is being developed in Parcels. Designs are to comply with the Putrajaya design guides. The project is unique as it involved a Danish energy consultant, DANIDA. DANIDA's role was to help make the building a showcase and as testimony to the cost effectiveness of the building's efficient energy-use performance as well as its benefits to the environment. The intention of the project is to demonstrate that low energy consumption buildings, pose minimal adverse environmental impact, can be developed without incurring exorbitant costs.

The aim of making the MEWC building as an energy efficiency demonstration project however, came after the schematic design was completed. Currently the energy performance of the MEWC is being monitored and assessed.

As the MEWC was part of an overall parcel development, the design of MEWC building experienced similar design constraints of time, cost and regulatory controls. The building cost had to be comparable to other similar government buildings in Putrajaya and that no additional project time was to be considered so as to avoid disruption on the overall parcel development schedule. Regulatory control limits the building overall form and choice of envelope design solution.

A range of energy saving techniques was implemented in the building which includes design and behavioural control means, such as optimally shaded facades and well insulated roof, lowering of lighting and equipment load density, deployment of energy efficient cooling system and lighting control sensors.

2.2 Securities Commission Headquarters building (SCHQ)
[occupied since 1999]

The Securities Commission building (SCHQ) houses the Securities Commission and its training arm, the Securities Industry Development Centre. The building is located within the scenic surroundings of Bukit Kiara in Kuala Lumpur. Project was completed in February 1999 and acclaimed to be an example and a Malaysia's masterpiece on high-tech and energy efficient building. The building has built up area of approximately 100,000 m^2.

The SCHQ was conceived as part of a design competition which called for a premier intelligent office building with a view of achieving a holistic and energy efficient design that provides flexible office work environment. The client's brief was prepared by a facility management company, which clearly outlined the clients' spatial needs and aspirations. In the brief, the client specifically requested for a 'transparent', 'a premier, high performance building'. The project was designed by a renowned Malaysian architect, Hijjas Kasturi Architect Sdn. (HKAS). In preparation of the competition design submission, HKAS sought for environmental design advice from Battle Mc Carthy, a UK based environmental engineer.

The building comprise of 18m deep office space which is predominantly lit by natural daylight from all sides. The 44m wide atrium provides light into the centre of the building whilst the external wall is entirely of double skin glass wall envelope to allow natural daylight in as well as providing maximum view to the outside. Although the building is fully glazed externally, with the use of quality glass material, incorporation of a thermal flue, deep roof overhangs and vertical and horizontal louvers, it results in low Overall Thermal Transfer Value of 35 W/m^2. There are two energy efficient innovations introduced in this building, namely the thermal flue envelope system and ductless underfloor air-conditioning displacement system.

2. ANALYSIS OF THE DESIGN PROCESS APPROACHES

Having described the two case studies, this section discusses the case study description according to the EDP criteria. Table 2 tabulates the comparison between the EDP criteria and the design process approaches of the MEWC and SCHQ.

Legend:
√√ - generally in compliance with EDP
√ - partly considered
X - not considered

Table 2: Comparison between the MEWC and SCHQ design process conditions against the EDP criteria

EDP criteria	MEWC	SCHQ
1. ENERGY EFFICIENCY INTENT AND PLANNING		
Expressed energy efficiency intent Set energy objectives and performance target so that team members remain united in meeting this objective.	√ End-user initiated energy efficiency pursuit. Strong back up by project developer. The project brief requested for a low energy building. Energy target was set at detailed design stage.	√ √ End-user cum building owner initiated energy efficiency pursuit. Energy saving projection was stated in the architectural design brief. Energy efficiency measures were identified early.
Research on design measures Element of research on energy-related design measures.	√√ Research on daylight and energy use of current premise conducted.	√√ Project brief prepared by a facility management team. Outlined end-users current and

	Energy consumption study of the existing premise.	future functional needs, aspiration and objectives. Research on envelope design and under floor air-conditioning distribution
2. EARLIER AND FULLER COLLABORATION *Architects and M&E work together* to strategise energy efficiency approach, before actual designing begins.	√ Architects worked on their own to conceptualise and develop it into a design scheme. The energy consultants and M&E engineers appointed at detailed design stage, when the design have been confirmed and agreed by the client.	√ Architects worked on their own to conceptualise and develop it into a design scheme. Environmental engineers assisted the architect during the schematic design stage. M&E engineers were however appointed at detail design stage, when the design have been confirmed and agreed by the client.

EDP CRITERIA	MEWC	SCHQ
3. INTEGRATED DESIGN CONSIDERATIONS [refer section 5.3.1.3] Impact between architectural design measures Envelope design resolved at schematic stage, taking into account interactive energy-related architectural design issues, namely orientation and configuration, site condition, daylighting, cooling, ventilation and building fabric.	√√ The architect generally considered these factors in their scheme. Later at detailed design stage, the envelope was reviewed and tested in terms of daylight and heat gain criteria. CFD analysis was used to study the air quality, air and heat movement in the atrium.	√√ The architect generally considered these factors in their scheme. Environmental performance was reviewed by the environmental engineer. The assessment was initiated at schematic design, and continued to detail design stage. CFD used to analyse the air quality, air and heat movement for the double skin wall system.
Impact between architectural and system design measures Design and sizing of mechanical equipment and electrical system take into account envelope efficiency Zoning of air-conditioned space to take into consideration internal planning and envelope efficiency.	√√ Design and sizing of equipment considered envelope efficiency. √√ Internal planning considered daylight potential due to envelope design.	√√ Design and sizing of equipment considered envelope efficiency. √√ Internal planning considered daylight potential due to envelope design.
Ongoing cost and energy performance Cost analysis and energy performance analysis performed as an ongoing exercise.	√√ Energy performance assessment and cost estimation exercises were ongoing.	√√ Cost estimations were ongoing but no additional energy analysis conducted as the project progressed. This was because the measures

		were already thought out at early design stage, and there was little change to the measures from then on.
4. PREPARATION FOR OCCUPANCY	√√	√√
Undertake proper commissioning Building maintenance team set up early to follow through energy efficiency intentions.	Proper commissioning were done. Building operation and maintenance team were set up early. Key maintenance personnel attended project progress meetings at implementation stage.	Proper commissioning were done. Energy unit were established. DANIDA, the energy consultant followed Key personnel were involved in the commissioning.
5. ENHANCED DESIGN TEAM	√√	√√
Include energy consultant Clients play an active role	Energy consultant, and relevant specialists – CFD analyst, daylight expert were brought in at detail design stage to review and detail out the schematic design. Building owner and users represented in project meetings.	Environmental engineers were engaged at schematic stage, primarily to advice on the technical aspects of the double envelope design. The client was represented in essential project meetings.
6. TOOLS SUPPORT	√	√
Computer tools support to test implication of energy efficiency measures. Ideally, simple tools at pre-design and schematic stage (such as Energy-10). More sophisticated tools at detailed design, such as Energy-Plus and APACHE Sim.	CFD simulation for atrium. Energy-10 was used at detail design stage to check the overall performance of the energy efficient measures.	Computer tool (CFD analysis) was used to ensure optimum envelope system. No computer tools used for energy optimisation purposes.

3. RESULTS AND DISCUSSION

The SCHQ is a project driven by an environmental will, present in all design members contributing to the realisation of the project. The environmental agenda constitute the core issue of the project and it was a design priority identified at the onset of the project. It was realised through a systematic and planned approach whereby detailed programmes were formulated, and input from an environmental expert was brought in early in the design stage.

There was sufficient schematic design time to carry out research and seek out latest solutions in energy efficiency and look around for experts in this field.

The architects and M&E engineers for the SCHQ were keen promoters of the energy efficiency concept and design innovation, and had previous experiences in handling high performance project nature such as the Telekom Headquarters and the KLIA. In order to ensure continuity in terms of environmental advice the architects sought for support from an environmental engineering consultant based in London, right from the start of the project. All of the above provide for a very sound foundation for promoting and achieving the energy efficiency agenda. Most importantly, the project was driven by a highly motivated client, striving for the environmental and energy efficiency course.

The MEWC was intended to be low energy building when it was first mooted. The design will, in terms of pursuing the energy efficient agenda was therefore present right from the start of the project. This can be regarded as one of the major factors contributing to the success of the project. However the idea of making the building a low energy demonstration project only came after the schematic design was finalised.

The architect was working independently in conceiving the schematic design, guided by a general design need for an energy efficient building. The M&E engineer and energy consultant was engaged at the end of the schematic design stage. In the absence of a more systematic framework, the architect had to define or formulate an energy efficient framework for the MEWC. The MEWC design was conceptualised in 2 weeks - a typical deadline for most Putrajaya projects. The building was one of the sub-parcels within a large office complex. Within that time frame the architect had also to coordinate with the architects designing the sub parcels within the complex. In reality there was not much time available to adequately address design issues at depth and much was done intuitively. Within the short period of time the architects employed general design rules and common sense in dealing with energy issues such as introduction of natural ventilation and daylight at office lobby, and introduction of solar shadings for all facades and orientation. At that point the perception of the concept of energy efficiency was notional and not comprehensive and intensive.

The architect for the MEWC was given 2 months to develop the schematic design into detailed design. It was only at this stage that they had the support of other disciplines such as the engineers and energy consultant. The energy consultant played a major role in justifying the choice of energy efficiency measures to adopt.

4. SUMMARY OF CASE STUDY DESIGN FRAMEWORK

The following describes the characteristics of the design framework for the two case studies, according to the six EDP criteria identified earlier.

EDP 1: Energy efficiency intent and planning

- In both case studies the energy efficiency pursuit was deliberate, whereby it was identified as a design priority at the pre-design stage. The energy efficiency intent for the SCHQ was more thorough, clearly expressed and planned. In the case of the MEWC, the client particularly requested for a low energy building, and the detailed plans followed suit at detailed design stage.
- the clients were initiators for the energy efficiency pursuit for both case studies. In the case of the SCHQ, the end-users were also the building owners. For the MEWC, the end-user was the Ministry of Energy, Water and Communication and naturally they wanted to set a good example of an energy efficient building. The project developers were also keen supporters of the energy efficient pursuit;
- the energy efficiency agenda was driven by the design team.

EDP 2: The design process

- the sequence of the design activities for both buildings is reflective of the procurement method adopted. Both projects adopted the design and build procurement method, which means the main contractor for the MEWC and the construction manager for the SCHQ were appointed before detailed design were finalised. With the appointment of the main contractor / construction manager, the design team members were novated to be part of the contractor's team;
- the design process was hierarchical. The architects were engaged at the schematic design stage, and they practically worked on their own to conceptualise the building design. In the case of

the SCHQ, the architect took the initiative to consult an environmental engineer on general issues regarding the buildability and practicality of the double skin wall system;
- the M&E were engaged at the detailed design stage, when the design were already confirmed and agreed by the client.

EDP 3: Integrated design Design considerations
- at the schematic stage, the architects for both projects applied general design rules to come up with the schematic design. They applied common practice design principals and common sense in reducing heat gain and applying natural daylighting. In other words their methodologies were not empirical. Later at the detailed design stage, the envelope design was reviewed and tested in terms of daylight, heat gain and ventilation / air flow criteria.
- the shape of both buildings were primarily influenced by statutory and contextual factors. Planning controls determined the building line and restricted the building height, the percentage of window against the opaque wall, and the need to blend with the façade treatment of the adjacent and neighbouring buildings. Contextual factors affecting the building form were site topography and surrounding development;
- the design and sizing of equipment by the M&E took into account thermal efficiency of the envelope system, and the zoning of air-conditioned space took into account daylight potential due to envelope design.
- Cost is an important aspect of ensuring the design measures get selected. Cost estimation for both cases were treated as ongoing to check for the cost effectiveness of the energy efficiency measures.
- The progressive checking on energy performance due to the design measures was carried out by the MEWC team. No further energy performance studies were carried out during the design process for the SCHQ.

EDP 4: Commissioning and preparation for occupancy
- The commissioning for both the projects were carried out systematically, involving the building management teams who eventually manage the operation and maintenance of the completed buildings; and
- The building management teams for both projects participated in the later design stage to ensure that they understand the energy efficiency aspects of the buildings.

EDP 5: Enhanced team
- MEWC engaged an energy consultant to advice on energy matters, and other relevant specialists – CFD analyst, daylight experts were brought in at detailed design stage to review the schematic design. For the SCHQ, the scope of work was carried out by the environmental engineer;
- The end-users for both cases were actively involved in the project, whereby they were represented in essential project meetings.

EDP 6: Design aids and computer tools
- The MEWC carried out energy optimisation analysis using *Energy-10*. No energy optimisation analysis was carried out for the SCHQ.

5. CONCLUSIONS

In conclusion it can be seen that there are similarity in the overall approach of the design process adopted in both cases. The differences are mainly in terms of the overall energy efficiency objectives, namely the desired target, choice of design means and energy efficiency measures adopted for the buildings. The SCHQ, a building of high prestige and architectural quality, is an example of a product of an innovative energy efficiency approach, while MEWC adopts a contemporary sensible design solution, which demonstrates that low energy can be achieved through careful application of common energy efficient features, without incurring exorbitant costs.

The design process adopted for both cases generally had components of an integrated design process in place. There are however two aspects of the EDP criteria which were not closely adhered to, namely timeliness in initiating a fuller design effort, and the tools used for assessment of energy efficiency measures.

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