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# A REVIEW ON COST OPTIMIZATION TECHNIQUES IN ENERGY EFFICIENT BUILDING (MARCH 2018)

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**ABSTRACT**

The energy performance of a building is determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use. it includes the heating energy needs, cooling energy needs , energy needed to avoid overheating to maintain the envisaged temperature conditions of the building and domestic hot water needs. Investments made for energy efficiency of a building can be compared with the capital cost investments, which is necessary on the input side of the energy system to produce a similar amount of peak capacity or annual energy production. Usually, the capital costs of efficiency are higher than comparable investments in increased supply. There are additional operating costs of efficiency compared to substantial operating costs for inward energy options. In addition, energy efficiency investments generally have much shorter lead times than energy supply investments, a particularly important consideration in countries where the demand for energy services is growing rapidly. This paper deals with literature review of cost optimization techniques for energy efficient buildings. Here a number of sixteen journals were reviewed on this topic. Reviews of these papers were done to identify different energy efficient techniques that could be used in a building from planning phase to operational phase. These papers also express about 10-20% optimization of energy and cost Using the data used in reviewed papers, a methodology for studying the various techniques could be identified.



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## INTRODUCTION

T he energy efficiency of a building is the extent to which the energy consumption per square meter of floor area of the building is measured. There are established energy consumption benchmarks for each type of building under defined climatic conditions. Benchmarks can be applied mainly to types of energy, embodied energy of building materials, electrical consumption for external lighting, heating, pumps, fans, ventilation, cooling, air conditioning, lighting and controls, maintenance, office or other electrical equipment. The benchmarks used may vary with the country and type of building. Investments in energy efficiency in a building can be compared with the capital cost investments necessary on the input side of the energy system to produce a similar amount of peak capacity or annual energy production. Usually, the capital costs of efficiency are higher than comparable investments in increased supply and there are no additional operating costs of efficiency compared to substantial operating costs for inward-side options. Reducing power and energy requirements in buildings can reduce the capital cost required and the running costs of the operating systems. Hence paper reviews about an integrated system of energy efficient constructions procedures which helps to optimize the overall life cycle cost of energy efficient buildings.

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### Review of cost optimisation techniques in energy efficient buildings

The review of these papers are categorized into 5 segments based on the stages of work in construction of a building and also stages in analysis of energy and cost.

**Energy Efficient Designing**

Pacheco *et al*. (2012) provides an overview of building design criteria that can reduce the energy demand for the heating and cooling of residential buildings. The variables that are related to building shape and which influence heating and cooling requirements are climate, compactness index, life cycle and shape factor of building. The implementation of these measures in the project design phase contributes to reduce the final cost of the building. Factors with the greatest repercussion on the final energy demand are building orientation, shape, and the ratio between the external building surface and building volume. And he concludes that more energy-efficient building design may not necessarily coincide with more economical or more environmentally friendly designs. Another study conducted by Ryozo Ooka and Kazuhiko Komamura (2009) proposes a new optimal design method for building energy systems. This method provides the most efficient energy system, best combination of equipment capacity and best operational planning for cooling, heating, and power simultaneously with respect to certain criteria such as energy consumption, CO2 emission, etc. The ‘‘Genetic Algorithms (GA)’’ optimization method, was used to resolve nonlinear optimization problems. This method optimizes both equipment capacity and operational control planning simultaneously by using a modified GA called MIGA &helpful to design energy systems for buildings. The results shows that the proposed method has sufficient capability for determining the optimal design and has to be applied to very complex energy systems with appropriate modifications. Weimin Wang *et al*. (2005) presents a multi-objective optimization model that could assist green building design. Life cycle analysis methodology is employed for evaluating design alternatives for both economical and environmental criteria. The multi-objective GA model proposed in this paper can be used to locate optimum or near optimum green building designs for given conditions. Using expanded cumulative energy consumption as the indicator the optimization problem can be simplified by incorporating all considered impact categories into one objective function.

**Energy Efficient Materials and Services**

The energy embodied in a building is that used to extract, process, manufacture and transport building materials and components. As improvements in the operational energy efficiency of buildings are made, the relative significance of embodied energy forms a higher proportion of the total amount of energy used over the lifetime of a building. Y.G. Yohanis *et al*. (2014) suggested that initially embodied energy in a building could be as much as 67% of its operating energy over a 25-year period. The variation of life-cycle, embodied energy, operational energy and capital cost as a function of building parameters was found out. The cost of operational energy is the lowest for a glazing ratio of about 15% for an operating life of 60 years; however, when delivered energy only is considered, the cost of operational energy reduces to the lowest value as glazing ratio is reduced to zero. Low energy buildings have attracted lots of attention in recent years. In contrary, Jan Siroky *et al*. (2011) discusses about the general methodology to reduce energy consumption using minimum retrofitting and current energy sources, but instead of making use of advanced control techniques. Model predictive control (MPC) and weather predictions was used to analyze the energy savings achieved in a building heating system. It was shown that the energy savings potential for using MPC with weather predictions for the investigated building heating system were between 15% and 28% depending on various factors, mainly insulation level and outside temperature. In contrast to the current building control techniques, MPC is based on a non trivial mathematical background that complicates its usage in practice. But its contribution to reduction of a building operation cost is so significant that it is expected that it will become a common solution for so-called intelligent buildings in a few years.

**Operation and Maintenance of Energy Efficient Buildings**

James E. Braun(2002) describes an investigation into the use of building thermal capacitance as a means of reducing the operating costs associated with maintaining adequate comfort conditions in buildings (termed "dynamic building control"). The approach utilized in this study was to use dynamic optimization techniques with the help of computer simulations of buildings and their associated cooling systems for a range of conditions in order to determine the maximum possible savings. Results shows that peak electrical use and energy cost can be reduced through best management of the intrinsic thermal storage within building structures. However, the cost savings depend strongly on several factors including building thermal capacitance utility rate structure, weather, air handling system, the occupancy schedule, and part-load characteristics of the cooling plant, For maximum peak reduction, the best method is to pre-cool the building to a lower temperature than by minimizing energy cost. Yusuf Latief et al. (2017) suggested the purpose of optimization in the research improves building performance with some of green concept alternatives. Research methodology is mixed method of qualitative and quantitative approaches through questionnaire surveys and case study. On the basis of the maintenance and operational phase with the Life Cycle Assessment Method successful optimization functions in the existing green buildings was assessed. Choosing optimization results were based on the most effective cost to refund and the largest efficiency of building life cycle.

The six categories in GREENSHIP assessment are Appropriate Site Development (ASD), Energy Efficiency and Refrigerant (EER), Water Conservation (WAC), Material Resources and Cycle (MRC), Indoor Air Health and Comfort (IHC), and Building and Environment Management (BEM). The improvement can be done by the development of storm water management system, pedestrian, railway/ bus station, public facility, landscape area, and vegetation. Information flows in the built environment have traditionally focused on the design and construction phases. Sergio Rodriguez- Trejo *et al*. (2017) presents a methodology and a decision support system to help obtaining, categorizing and trading off sustainability and facility management values using subjective driven priorities from top-level management. A structured information delivery enabled by BIM protocols, established at the project’s inception prevents information loss during the project’s development which facilitates the correct and complete set of information given at hand over of buildings, and increases their efficient use during operation. These can be subsequently included within the project tender and bidders’ BIM Execution Plans. The AHP is used to obtain priorities about the values from the client and other involved stakeholders from a strategic perspective. The tool will also help to monitor the performance of the project design with the national sustainability and the client targets as the project progresses. The proposed tool was presented within the context of Qatar but it could be applied in other countries.

**Energy Modeling**

Hai-xiang Zhao *et al*. (2012) reviewed recently developed models for solving the problem, in cost optimization which include elaborate and simplified engineering methods, statistical methods and artificial intelligence methods. The engineering model shows large variations. The statistical model is relatively easy to develop but its drawbacks are also obvious, that are inaccuracy and lack of flexibility. ANNs and SVMs are good at solving non-linear problems, making them very applicable to building energy prediction. Research mainly concentrates on applying these models to new predicting problems, optimizing model parameters or input samples for better performance, simplifying the problems or model development, comparing different models under certain conditions. Each model is being developed and has its advantages and disadvantages, therefore it is difficult to say which one is better without complete comparison under the same circumstances. Christina Diakaki et Al. (2009) investigated the feasibility of developing a independent multi-objective optimization model for the decision problem that will allow the consideration of as many available options possible without the need to be combined and/or complemented by any other method such as simulation, multi-criteria decision analysis techniques, etc. Maximum number of possible alternative solutions and energy efficiency measures was also considered for this study.

He also stated that no optimal solution exist for this problem and it was due to the competitiveness of the involved decision criteria. A simple case study was investigated to check the feasibility of the approach. However, it was also found out, that when the energy efficiency improvement problem is faced in its real-world dimensions, it possesses inherent difficulties that complicate both the modeling and the solution approach. The energy embodied in a building is that used to extract, process, manufacture and transport building materials and components. Similar to improvements made in the operational energy efficiency of buildings, the relative significance given to embodied energy of building materials forms a higher proportion of the total amount of energy used over the lifetime of a building. Y.G. Yohanis and B. Norton (2002) describes that embodied energy cannot be predicted accurately due to lack of reliable and accurate data; there is a wide variation in the data available. During the operation phase, the increase in embodied energy is due to repainting, re-carpeting, replacement of lamps and systems, and major periodic modeling and refurbishment due to changes in tenancy. He also mentioned about the variation of embodied energy, life-cycle operational and capital cost as a function of building parameters. The demand for space heating of residential buildings can be reduced by minimizing air leakage, improved insulation and by heat recovery of air from ventilation. The relative importance of the energy used throughout the production phase will increase and influences optimization aimed towards minimizing the usage of life cycle energy, as the energy for building operation decreases. The life cycle primary energy use of buildings also depends on the energy supply systems. Leif Gustavsson and Anna Joelsson (2010) conducted an investigation on primary energy usage and CO2 emission for the production and operation of conventional and low-energy residential buildings. The focus is on minimizing the final energy use or the purchased energy in the operation phase, while the energy use of the other phases is often neglected. Few analyses have been performed on total life cycle energy use of low-energy houses. Some of the life cycle studies made conclude that the operational energy is still most important, while others show that 40–60% of the life cycle energy is used in the production/construction phase. It is essential to consider both the production and operation phases when minimizing the life cycle primary energy use of buildings. The few other life cycle studies of low-energy buildings performed have shown comparable relationships between primary energy use in production and space heating although the relations were not presented in this transparent way. Hence, more life cycle analysis of low-energy buildings is needed. The choice of buildings materials influences the production energy, and the wood framed building required less energy than the functionally identical concrete-framed building.

**Integrated Energy Efficient Systems**

Lamberto *et al*. (2015) suggested that across the different phases of the building life cycle such as design phase, construction phase, commissioning phase, operation phase and eventually refurbishment phase, is to improve building and system performances in terms of economics and comfort. The fundamental topics considered for building life cycle are generally, insulation, thermal capacity, control of environmental conditions, solar geometry, internal air quality, etc. environmental impact and durability. Numerical simulation tools and optimization methods are needed to properly evaluate all the key performance indicators simultaneously, unveiling the existing gaps and identifying possible synergies and strategies in the performance estimation and decision-making processes for the building life cycle. The methodology focuses on three levels of analysis, construction components, lumped thermo-physical properties and thermal energy demand for heating and cooling with respect to climate. The visual and analytical tools presented enable the comparison of the performance in terms of heating and cooling with respect to the variations in the design parameters as well as in climate data patterns.

Finally, the fundamental results of the research made a “short circuit” between the methods, models and tools used in the different phases of the building life cycle, in order to enable multiple feedback processes and to establish dialogue among different disciplines and specialists. In another paper, the scheduling problem of building energy supplies is considered with the practical background of a low energy building. The objective function is to minimize the overall cost of electricity and natural gas for a building operation over a time horizon while satisfying the energy balance and complicated operating constraints of individual energy supply equipment and devices. The uncertainties are captured and their impact is analyzed by the scenario tree method. Xiaohong Guanet *et al*. (2010) uses Numerical testing was performed with the data of the pilot low energy building. Opportunity and desirable infrastructure of micro grid technology improves the energy consumption in buildings. various energy sources and loads can be optimized and coordinated so as to improve the operational energy of building. The testing results show that significant energy cost savings can be achieved through integrated scheduling and control of various building energy supply sources.

It is very important to fully utilize solar energy and optimize the operation of electrical storage. Seulki Han *et al*. (2017) developed a new optimization-based framework to design and analyze renewable energy systems for the residential sector. To achieve this, he first simulated different scenarios for integrated energy systems, which include different types of renewable resources and various new technologies along with the existing technologies in the current energy system. This study provides a useful approach for identifying system configuration, major cost-drivers, and cost effectiveness for CO2 reduction of energy supply system to the residential sector, along with practical recommendations. Although this design and analysis framework is already reasonably promising, our work could be further improved by including different energy-related issues such as the management of greenhouse gas emissions, planning long-term investment strategies, plans of integration with existing infrastructure, consideration of safety and environmental impacts.

In another paper Arvind Chel *et al*. (2017) explains that there are four broad ways to reduce the energy consumption of building which ultimately results in mitigating emissions of CO2 emissions through energy conservation. Firstly comfort passive building design and its orientation for harnessing solar energy. Secondly low embodied energy materials for building construction. Thirdly energy efficient domestic appliance to conserve the building operational energy and finally Building integrated renewable energy technologies.

The first aspect is related to the prior design before construction of a solar passive building techniques adapted all over the world not only for passive heating/cooling but also for day lighting the building. Second aspect is to use low embodied energy building materials for building construction is t and the using energy efficient equipments is used to reduce operational energy in the building is the third. Finally, the building has to include utility of integrated renewable systems. When the building energy is completely met by renewable energy system then it is known as a highly energy efficient or zero emission green building. The economics of various renewable energy systems is given for the acceptance of these technologies as compared to the conventional energy sources.

**Conclusion**

Different papers were reviewed classified on the basis of various stages of construction and use of energy. Cost optimization of energy efficient techniques is the need of the hour so that everyone can afford buildings which consume less energy. Only a few published documents discusses the optimization method which considers planning to maintenance phases of construction. Therefore it is essential to propose a new model which optimizes cost of energy efficient buildings considering all stages in construction viz. planning to maintenance phase of a building. The above mentioned gap area is a relevant area which could be considered. Further work in the topic could be improved by including different energy-related issues such as the management of greenhouse gas emissions, planning long-term investment strategies, plans of integration with existing infrastructure, consideration of safety and environmental impacts.

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