Establishment of Typical Building Models in Each Climate Regions in China and Research of Adaptability of Energy Saving — Research of Adaptability of Energy-saving Technologies in the Standard of 65% Energy Saving of Buildings

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ABSTRACT

From the perspective of energy efficient technologies, this thesis will, taking hot summer cold winter region represented by Shanghai as example, discuss the technological path to realize 65% energy saving in different building types by using energy consumption simulating software—Energyplus and typical building models in China, and also provide research method for similar researches in other regions.

First, thirteen types of building models in five climate regions respectively represented by Harbin, Beijing, Shanghai, Guangzhou, Kunming will be established by EnergyPlus, and these models will act as the baseline models for discussing adaptation of energy efficient techniques under the design standard of 65% energy saving.

Then, different techniques will be gradually added to the baseline models according to certain economic principle to test if present mature techniques can achieve the requirements of energy-saving standard, and to obtain the economic techniques combinations which can realize 65% energy saving in different types of buildings.

KEY WORDS: Typical building models, Research of adaptability of energy saving technologies, 65% energy saving

INTRODUCTION

In *Decision of State Department about improving energy saving work*, building energy saving, as key sector, has following requirements: new-built apartments and public building must implement strictly the design standard of 50% energy saving, and centrally administered municipalities and advanced districts can implement the design standard of 65% energy saving. “65% energy saving” means saving 65% energy of local residential universal design energy consumption in 1980. Heating energy consumption is required to drop to 8.75 kg/㎡.

Adaptive researches of building energy efficiency are very mature abroad. However, related researches in China merely focus on specific projects and there are no systematic energy consumption studies on different geographical and climatic characteristics and building type. As a result, this paper will systematically generalize and study on building energy consumption of typical models of Chinese buildings with whole building energy analysis tool—EnergyPlus. In this paper, Shanghai is taken as an example and the results of other places can refer to it.

RESEARCH METHODS

1. Determination of Energy-saving target: In the light of the fact that establishment of typical models is dependent on today’s standards and the measured data, and represents today's average energy consumption level, 65% energy saving means saving 30% of energy of today’s 50% energy saving level. As a result, the target of the research is saving 30% energy of typical models.
2. Choice of types of buildings: There are as many as 13 typical building models which are mentioned above. The adaptability of the energy-saving technologies is closely related to air conditioning system. Therefore, 6 building models (listed as follows) with representative air conditioning system are selected in the thesis.

Table 1. Model of high-rise office building

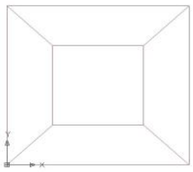
Gross floor area: 19200 ㎡; Shape coefficient: 0.1; Number of floors: 12; Area ratio of window to wall: 40%; Building orientation: South; Story height: 4m	
Building functional partition: office area 	Air conditioning system: chiller+ boiler; fan coil + new wind Lighting power density: 8W/㎡
Equipment power density: 12W/㎡	Occupant density: 5 ㎡ per person

Table 2. Model of multi-storey office building

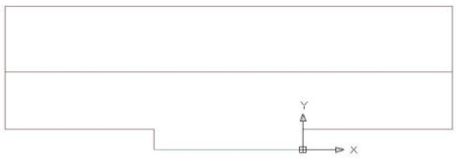
Gross floor area: 3800 ㎡; Shape coefficient: 0.17; Number of floors: 5; Area ratio of window to wall: 35.5%; Building orientation: South; Story height: 3.6m	
Building functional partition: office area	
Air conditioning system: Split air-conditioning	Lighting power density: 8W/㎡
Equipment power density: 12W/㎡	Occupant density: 4 ㎡ per person

Table 3. Model of multi-storey residential building

Gross floor area: 1069 ㎡; Shape coefficient: 0.28; Number of floors: 3; Area ratio of window to wall: 18%; Building orientation: South; Story height: 2.8m

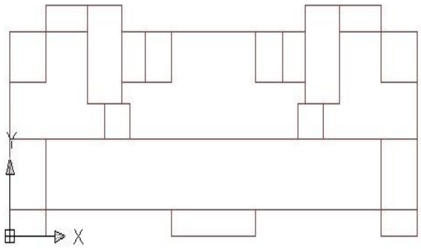
Building functional partition Kitchen, bathroom, bedroom, living room, study room, stairwell, balcony	
Air conditioning system: Split air-conditioning	Lighting power density: 7W/㎡
Equipment power density: kitchen: 18W/㎡; bathroom: 3W/㎡; living room, bedroom, study room: 5W/㎡; balcony, stairwell: 0W/㎡	Occupant density: Living room, bedroom, study room, balcony: 10 ㎡ per person; kitchen: 8 ㎡ per person; bathroom: 5 ㎡ per person; stairwell: 15 ㎡ per person

Table 4. Model of high-rise residential building

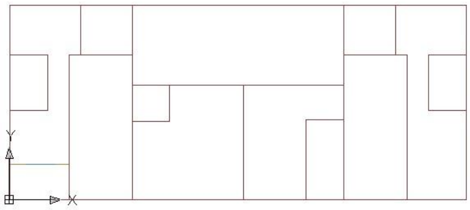
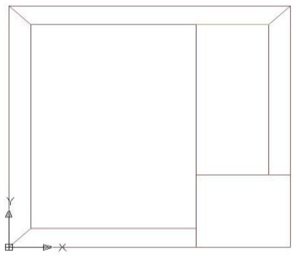
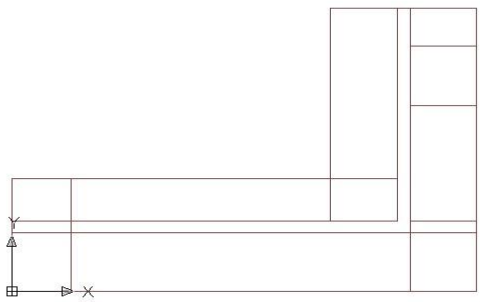
Gross floor area: 3262 ㎡; Shape coefficient: 0.28; Number of floors: 13; Area ratio of window to wall: 14%; Building orientation: South; Story height: 2.9m	
Building functional partition kitchen, bathroom, bed room, living room, stairwell	
Air conditioning system: Split air-conditioning	Lighting power density: 7W/㎡
Equipment power density: kitchen: 12W/㎡; bathroom: 3W/㎡; living room, bed room: 8W/㎡; stairwell: 0W/㎡	Occupant density: bed room, living room, study room, balcony: 10 ㎡ per person; kitchen: 8 ㎡ per person; bathroom: 5 ㎡ per person; stairwell: 15 ㎡ per person

Table 5. Model of shopping mall

Gross floor area: 33800 ㎡; Shape coefficient: 0.7; Number of floors: 1 underground floor and 7 floors; Area ratio of window to wall: 10.9%; Building orientation: South; Story height: 3.5m	
Building functional partition 1^{st}-6^{th} floor are standard floors: shopping area, stairwell 7^{th} floor: restaurant, kitchen, stairwell Underground floor: garage	
Air conditioning system: chiller + boiler; All air system	Lighting power density: garage: 5W/㎡; shopping area: 15W/㎡; stairwell: 11W/㎡;

	restaurant, kitchen: 13W/㎡
Equipment power density: shopping area: 1W/㎡; stairwell: 1W/㎡; kitchen: 50000W; restaurant: 20000W	Occupant density: garage: 200 ㎡ per person; shopping area: 3 ㎡ per person; stairwell: 20 ㎡ per person; restaurant: 3 ㎡ per person; kitchen: 5 ㎡ per person

Table 6. Model of hotel

Gross floor area: 23316 ㎡; Shape coefficient: 0.25; Number of floors: 12; Area ratio of window to wall: 42%; Building orientation: South; Story height: ground floor: 5m, the rest: 3.5m	
Building functional partition 1st floor: lobby, cafe, store, laundry, storeroom, equipment room, spare room1, spare room2 2nd floor: restaurant1, restaurant2, kitchen1, kitchen2, spare room1, spare room2, corridor 3rd-12th floor: guest room1, guest room2, guest room3, guest room4, spare room1, spare room2, corridor	r 
Air conditioning system: chiller+ boiler; fan coil + new wind	Lighting power density: lobby: 10W/㎡; store: 6W/㎡; laundry, storeroom, equipment room, spare room, corridor: 3W/㎡; cafe, restaurant, kitchen: 8W/㎡; guest room: 10W/㎡
Equipment power density: lobby, store, restaurant: 6W/㎡ cafe, laundry: 13W/㎡; kitchen: 20W/㎡; guest room: 9W/㎡	Occupant density: lobby, restaurant: 10 ㎡ per person; cafe, restaurant: 8 ㎡ per person; store: 5 ㎡ per person; storeroom, spare room: 20 ㎡ per person; equipment room: 10 ㎡ per person; guest room: 15 ㎡ per person; corridor: 50 ㎡ per person

The six building models mentioned above are typical and can represent the other models.

3. Economic analysis of energy-saving measures: This research gives an answer to how to realize energy-saving target (65% energy saving) with more economical energy-saving technologies. Investment recovery period is the most commonly used method of technical and economic evaluation.

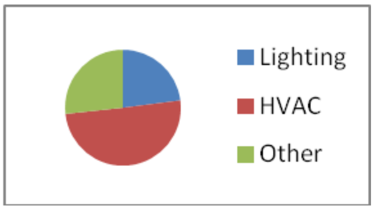
A general economic analysis is given in Table 7:

Table 7. Summary table of economic analysis of energy-saving measures

Analysis of the construction cost of energy-saving measures	Optimization of building envelope	Cost of building insulation: 80.5RMB/m2; Ordinary insulating glass: 300 RMB/m2; Low-E glass: 550 RMB/m2. The difference value between them is the increased cost.
	Optimization of delivery system	Price of inverter: 2000 RMB, for each fans and pumps; Fan coil system: 150 RMB/m2; Radiant ceiling: 2000 RMB/m2. The difference value between them is the increased cost.
	Optimization of cold and heat sources	Equipment costs of geothermal heat pump and construction costs of drilling on ground source side. Cooler: 0.5 RMB/W, heat pump: 0.9 RMB/W; Increase of equipment costs of heat pump is the difference value between them. Construction costs on ground source side: 1. 16 RMB/m2
	Optimization of daylighting	Daylighting control system and translucent envelope structure：1600 RMB/m2
Energy costs in Shanghai	Electricity costs	0.885RMB/kWh (Shanghai industrial and commercial electricity)
	Gas costs	2.35RMB/m3 (Shanghai natural gas costs)

4. Effect of energy-saving technology on several kinds of buildings—example of multi-storey office building:
The air conditioning system of multi-storey office building: split air-conditioning. Preliminary analysis is as follows.

Table 8. The energy consumption of a typical model

<table>
<tr><td>Electricity Intensity [MJ/m2]</td><td>Initial value</td><td rowspan="5">
</td></tr>
<tr><td>Lighting</td><td>58.26</td></tr>
<tr><td>HVAC</td><td>127.69</td></tr>
<tr><td>Other</td><td>67.69</td></tr>
<tr><td>Total</td><td>253.63</td></tr>
</table>

HVAC accounts for a larger proportion of energy consumption, as is shown in the Table 10. Beside the conventional measures such as optimization of building envelope, sunshading and daylighting are also applied in multi-storey office building to reduce lighting energy consumption. In order to avoid negative impact of sunshading on daylighting, dynamic fenestration is applied as well, so that light transmittance varies according to the changes in indoor illumination.

The application of energy-saving technology:

1) Exterior insulation (30mm EPS board)

EPS board is a common kind of exterior insulation material in engineering.

2) Roof exterior insulation (30mm XPS board)
XPS board is a common kind of roof exterior insulation material in engineering.
3) Low-permeability low-E glass
Technical structure from inside to outside: 6mm ordinary glass, 4mm air, 3mm ordinary glass, 4mm air, 6mm low-permeability low-E glass.
4) Daylighting
Two Reference Points are set in every district of multi-storey office building and control the district with scale factor of 0.5. The location of Reference Point is shown in Figure 1. Stepped Control is set in lighting control. Lighting power density of the lowest step is 0, and the density of upper steps increases by degrees. Illumination of Reference Point is set to 300lux.

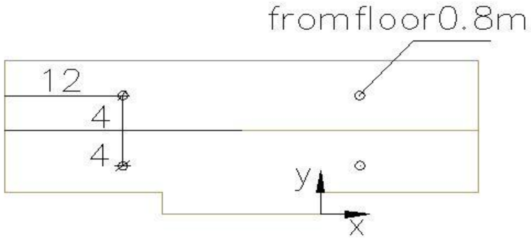


Figure 1. The location of Reference Points

5) Dynamic fenestration (optional)
In line with daylighting, dynamic Venetian exterior fenestration is selected. The control strategy is “always perpendicular to the sun”.
6) Ordinary external shading with rolling shutter (optional)
External shading shutters with high visible light transmittance material can work together with daylighting in winter and transition season.
The effect of energy saving:
With the combined application of sunshading and daylighting, the simulation results of energy consumption of multi-storey office building are shown in Table 9:

Table 9. Energy consumption of multi-storey office building

Electricity Intensity [MJ/m2]	Initial value	EPS exterior wall+ XPS roof+ low-E glass	EPS exterior wall + XPS roof+ low-E glass+ daylighting	EPS exterior wall+ XPS roof+ low-E glass+ daylighting+ dynamic fenestration	EPS exterior wall + XPS roof+ low-E glass+ daylighting+ common external shading
Lighting	58.26	58.26	11.32	11.93	12.73
HVAC	127.69	118.55	117.46	116.32	117.66
Other	67.69	67.69	67.69	67.69	67.69
Total	253.63	244.5	196.47	195.93	198.08

1) As can be seen from Table 11, daylighting has a good effect on office building energy saving. Even if applying ordinary external shading with materials of high visible light transmittance, there will be negative impact as well; while auxiliary

method of dynamic fenestration is slightly helpful. But it is worth noting that, if without suitable control strategy, there will be little effect on its overall energy-saving.

2) The combination of applications of EPS exterior wall, XPS roof, low-E glass, daylighting and dynamic fenestration leads to 22.75% reduction of energy consumption.

RESULTS

In the previous section demonstrated detailed energy saving analysis of multi-storey office building. Because of limited space, the analysis process of the other five buildings is omitted, and energy-saving results of 6 typical buildings are listed in Table 10.

Table 10. Summary table of energy-saving effect of building technologies in typical buildings of hot-summer and cold-winter region

Building type	Applied technologies	Energy-saving effect
Multi-storey office building	EPS exterior wall, XPS roof, low-E glass, daylighting and dynamic fenestration	22.75% energy saving
High-rise office building	Option one： EPS exterior wall, XPS roof, low-E glass, daylighting, dynamic fenestration, efficient units and air conditioning water system(large temperature difference and small flow rate)	18.98% energy saving
	Option two: EPS exterior wall, XPS roof, low-E glass, daylighting, dynamic fenestration and ground source heat pump	38.41% energy saving
Multi-storey residential building	EPS exterior wall, XPS roof, low-E glass, inner sunshading	6.104% energy saving
High-rise residential building	EPS exterior wall, XPS roof, low-E glass, inner sunshading	5.69% energy saving
Shopping mall	Option one: EPS exterior wall, XPS roof, low-E glass, fresh air cooling, exhaust heat recovery, energy-saving lamps	18.84% energy saving
	Option two: EPS exterior wall, XPS roof, low-E glass, fresh air cooling, exhaust heat recovery, ground source heat pump	28.2% energy saving
	Option three: EPS exterior wall, XPS roof, low-E glass, fresh air cooling, exhaust heat recovery, energy-saving lamps, ground source heat pump	More than 30% energy saving
Hotel	EPS exterior wall, XPS roof, low-E glass, venetian external shading, ground source heat pump	35.03% energy saving

Combined with simulation results of energy consumption of related technologies, payback period of four major technologies are shown in Figure 2:

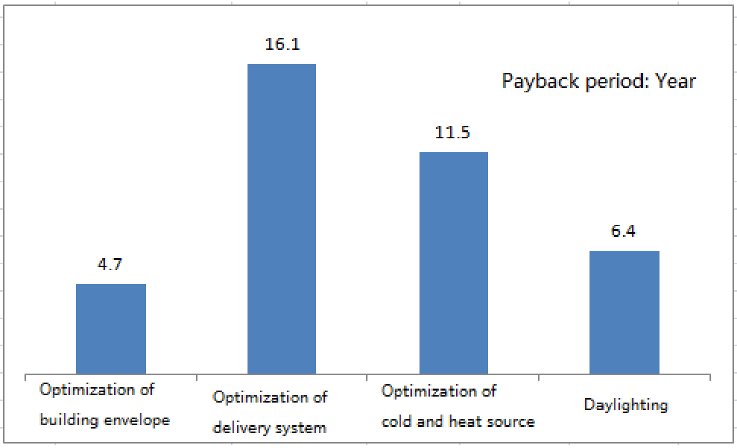


Figure 2. Payback period of four major technologies

Relatively, optimization of building envelope achieves the best economy, and daylighting ranks the second. Optimization of cold and heat source ranks the third, and optimization of the delivery system is the least economical.

CONCLUSION AND IMPLICATIONS

From the point of energy-saving technologies, measures, required to achieve 65% energy-saving target, are discussed in the thesis. In fact, the energy consumption is closely related to building orientation, shape coefficient, area ratio of window to wall, etc. To different regions and building types, orientation of model and shape coefficient may not be the most appropriate. Therefore, the study of 65% energy-saving needs more strict and comprehensive discussion, and more comprehensive consideration. In the respect of economy, because of lacking data, there is no checking of economy of energy-saving technologies, which needs to be further investigated.

Besides, there are 65 kinds of typical models of buildings in different types and climate regions, which need further investigation.

In conclusion, the sophistication level of this thesis is far less complete than that of documents like US ASHRAE energy-saving design instruction manual. And sincere cooperation of a large team, adequate funding, and large amounts of supporting data are all we need in the future.

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