Government Office Buildings Energy Consumption Index Research - by Means of Comparing Simulation and Real Energy Consumption

WANG Yichao[1], YAN Da,[1] LIU Ye[1], ZHANG Xiaoliang[1], LI Ting[1], LIN Lishen[1]

Building Energy Research Center, Tsinghua University, Beijing,China

ABSTRACT:
For a better result of building energy conservation, the reasonable building energy index is necessary. Considering there are so many differences among buildings, it's unreasonable that we only give a certain energy index to all kinds of buildings, even they are the same kind of buildings, the differences like the area, the number of people, the kinds of light will make the reasonable energy index different. On the other side, we can know a reasonable energy index of a building by do some detailed research, however, it's too complex so it's impossible for us to research every building. This paper, based on several investigations and simulations for government office buildings, gives out a new method: on the basis of one or more building models, and some important information by a simple investigations of the building, ignore those differences which are not important, and then calculate with the typical building model and the results of the investigation, make out the reasonable energy index, which is differ from energy index of other buildings. And it's possible that we can use the same method to give other kinds of buildings just like schools, hotels, hospitals and so on. What we need is just to do the same research like government office buildings.

What's more, in the process of research, we also answered another question: what are the important factors of building energy index. By comparing the real energy consumption which is provided by the respondents with the calculate result, we can found those factor which have an influence on building energy consumption. When those results are close enough, we can know that the factors we have found are important factors. The more building we research, the more factors we will found, the better energy index we give out.

Key words
Energy Index; Simulation; Calculation Method; Affect Factors

INTRODUCTION

With the development of economics, we're facing many energy problems, and the building energy conservation has become a very important thing. The public building is one of the most important kinds of building, it's necessary for us to know how to reduce the energy use of this kind of building. We have made some efforts on reducing the energy use of public buildings, and already made some achievements.

Meanwhile, we have already met some problems. Some buildings have much higher energy consumptions, but can hardly reduce them; the others still exist some energy wasting but the energy consumption is lower than most buildings. We think it's unfair to judge a building is energy saving or not by only the energy consumption.

Another question is the aim of energy conservation. Currently, the target of energy conversation we set is 5% per year, according to the energy consumption of the last year. The problem is, some buildings have adopted some measure of energy saving, such as reduce the number of lamps, some buildings have not. So the 5% is easy for those buildings which are not energy saving, but hard for the other. The result is we think those buildings are not energy saving have a better effort, this will make the energy conversation hardly be effective.

How we can solve these problems? The most important thing we think is what the reasonable energy index is, and then we can know this building is energy saving or not, and what the aim of the energy conservation.

However, there're many problems when we do this thing because it's a very complex problem. There're so many affect factors which can influence the energy use, just like the area, the number of people, the kinds of light and so on. And we must consider some reasonable factors so that we can give out a reasonable energy index.
There're some energy consumption evaluation system such as Energy Star, LEED, DGNB. However, these systems cannot give out a targeted energy index, because they cannot tell us why the energy index is reasonable. What's more, an energy index should be adjustable because it should be starting from the energy-saving targets, as determined by the managers. So we should have another method to give out the energy index, which can tell us how we use energy in the buildings.

On the other side, we can know a reasonable energy index of a building by do some detailed research and simulation. It means that we can know the reason for the energy index. The problem is we need to know the reason energy index of this kind of buildings, and we must consider those differences between them. It's impossible for us to research and simulate every building. So we should use another method, which can give a targeted energy index with a simple research because we must know some basic information about the building so that we can know the energy index.

In this paper, we will try to make out some method to give out the reasonable energy index, which can meet our need. It can tell us how this index come, as well as don't need complex survey. And we also will make the method we give out into practice, to verify the reliability of this method.

RESEARCH NETHODS

As mentioned above, the problem we want to solve is how we can provide a reasonable energy index.

In our opinion, to draw up a reasonable approach of energy index should be built on the basis of the measured data, because the method we try must consistent with the actual. On the other side, only we know the reason of the actual energy consumption,

we can know how to reduce them. Therefore, the actual data is necessary.

However, we cannot completely ignore the theoretical analysis. It's possible for us to simulate the energy consumption by a detailed survey. Based on an accurate simulation we may analyze the influence of every factor. On this basis, we can analyze which factor is more important, we consider them as the key factors. Only by those key factors, we can calculate the energy consumption, which is accurate enough for energy index. And this result only needs a simple survey because we only need the key factors. There may also be another question that measured data cannot cover all possible problems, and in this respect, the simulation are strongly operational. It is easier to get data for all possible scenarios by modeling and simulation. What we need to do is just changing the parameters we set.

Therefore, this study suggests that the whole idea of building energy consumption to determine the method of energy index is

1. still based on building situation and the measured energy consumption data
2. using modeling simulations to verify the measured data
3. using simulated and measured way of contrast to analyze the sensitivity factor of the energy consumption
4. considering the difference between the buildings to determine separately for each of its reasonable building index

Now, we need to build a typical model. First, select the most representative building for detailed research based on basic building information and building energy consumption. This way, we can obtain information on two aspects: on the one hand are the details of the building itself and the details of the building's major energy systems; on the other hand is a more detailed data of building energy consumption. Then use DeST to establish building models in order to simulate building energy consumption, and compare it with the real building energy consumption to verify the accuracy of the model.

After established a series of good building models, use them to explore the sensitive factors of energy consumption. For example, for a particular building, building no.1, we have established a typical model and has completed the comparison between the measured and simulated test. Then, through the comparison of building no.1 and building no.2's building information, you can get all of the differences between the two factors. In this case, gradually introduce these differences in factors to the model of building no.1, that is to say, set the original building no.1's parameters substitute for the parameters of building no.2 in the model, and recalculate simulate building energy consumption, then compare it with the building energy consumption of building no.2. If the difference between the two result is large, we can consider that the key factors affecting building energy consumption is still not included in the previous simulation. So, we introduce more differentiated factor for further calculations, until the difference between the two is small enough, then that differences in factors currently considered are able to reflect the different between this two building in terms of energy consumption.

Due to differences in the aspects of building size are impossible to be adjusted by setting parameters, so there may be a situation that we have considered all the factors still cannot make the simulation results correspond with the actual energy consumption, in which case you will need to maintain two buildings each model, both models are used as a need to use the model of energy index.

Eventually, we believe that we can find all the key factors and we can use several models to simulate most buildings. Therefor we can provide a reasonable energy index for each building, which we can know how this index come, and even provide some advices to how does the index can be achieved, which will make energy consumption more effective.

To build the typical building model, a detailed research is necessary. The main contents of the research includes the following sections:

The first part is the basic information of the building, including the age of the building, the construction area, the number of users, the basic usage, etc. It also includes detailed information on building energy consumption, such as air-condition energy consumption, light power energy consumption, the energy consumption per month.

The second part is a survey of the main energy system. Including air conditioning systems, office equipment and lighting systems, other energy-using equipment, and special function areas like kitchen, computer room.

The third part is the operation and management mode of research, mainly for air-conditioning system, including other systems.

By these information, we can simulate the energy consumption of buildings, including air-condition system, computers, lamps and so on. In this study, using DeST we calculate the energy consumption of lighting and air conditioning equipment and the building cooling load. And then we calculate by setting the chiller, such as COP, the curve of COP and the load rate, so that we can know the electrical consumption of air conditioning system. Meanwhile, according to the result of the research, we calculate the electrical consumption of its power equipment, including pumps, cooling towers and so on.

In addition to the energy consumption of the three-part, energy consumption in other parts of the building need to use different methods to deal with. We simply give a fixed energy index of these parts according to the result of previous research.

RESULTS

We choose 10 buildings as the typical buildings, due to limited space here to show only the result of one building as an example. The next table is the result of the research, including the building information, air-condition system information and other necessary information.

Table 1 Result for research

Name	**Building10**
Year	2006

Area	29000m^2
Number of Users	1045
Hours	8:00-17:00
Windows	Double glass
Shade	Window curtains
Air-condition System	FCU+OA
Chiller refrigerating Capacity	1343kW*3
Power of Chiller	259kW
Power of Cold Pump	37kW*3
Power of Cooling Pump	37kW*2
Power of Cooling Tower	11kW*3
Power of Lighting Power	4.8W/m^2
Power of Office facilities	225W/person
Air Conditioning Season	6.15-9.15

In addition, the number of pump and cooling tower in use is decided by the number of chiller in use. And the number of chiller in use is based on the temperature of the cold water.

After the detailed research, we can use those information to simulate the building load and the energy consumption. All the typical building energy calculation results and the real energy consumption we get from research we did are as follows. These results are based on only 2 models, and the differences between them is less than 10%, which we think is current enough.

Table 2 contrast of calculate result and real energy consumption

W/m^2	Calculate	Real
Building1	32.02	34.76
Building2	37.56	40.16
Building3	35.62	34.73
Building4	54.24	56.55
Building5	46.95	46.99
Building6	58.26	56.57
Building7	49.46	49.79
Building8	73.01	71.25
Building9	76.86	76.89
Building10	58.76	63.98

We also give out an energy index by limit the power of office facilities and lamps, and fix the system COP of air-condition system. This energy index is just according to these conditions, it can also adjusted according to the targets of energy conversation.

Table 3 result of energy index

W/m^2	Air-condition system	Lighting system	Office facilities	Other systems	Building energy index
Building1	5.86	9.23	8.19	7.63	30.92
Building2	7.32	9.23	16.62	5.00	38.17
Building3	9.15	8.89	25.05	2.00	45.08
Building4	7.99	9.23	16.62	10.73	44.56
Building5	7.28	9.23	20.10	7.20	43.82
Building6	10.77	9.23	13.13	28.29	61.42
Building7	6.98	9.23	20.10	19.74	56.05
Building8	8.77	13.71	27.54	10.06	60.07
Building9	14.26	8.85	38.37	32.60	94.08
Building10	8.13	9.10	17.71	14.03	48.98

CONCLUSION AND IMPLICATIONS

According to the simulation, it's a feasible plan only using several models to simulate more buildings. Therefore the method we provide is acceptable, it can reflect the feature of every building, and only need simple information instead of the complex survey.

In the simulation process of 10 buildings, the adjusted parameter is the sensitivity factor of the building energy consumption. Therefore, the sensitivity factors include at least the following elements: area; number of users; power of office facilities and lighting; schedules including people, lighting, facilities; fresh air system; COP of air-condition system including chiller, pumps, etc.; operation mode of air-condition system; window-wall ratio; envelope(don't need details, just the type of wall and windows).

Finally, by this method we can provide a reasonable energy index to most common office buildings. The most important advantage of this method is we clear the meaning of the energy index, which can let us provide an improved method much easier, and the method can also be more acceptable.