Study on Investment Income Calculation Method of Building Energy Saving

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Abstract. With the rapid development of China economy and society, the resource shortage and other problems become more obvious and even aggravate increasingly. The energy problem attracts more and more attention from various countries in the world. The energy use is involved with all sides of life. Protecting environment, saving energy and realizing sustainable development are great challenge that we should face. The whole course is involved with energy consumption, including building engineering, engineering construction, completion and delivery for use. According to investigation, the building energy consumption accounts for about 25~40% of energy consumption in the whole world, so the building energy saving will be key for energy saving. The purpose of this paper is to establish the investment income model of building efficiency, provide tool for scheme optimization, and analyze and verify the model correctness by examples. Also, this paper puts forward the problem and solution of building energy saving and looks ahead the development prospect of building energy saving. It is to accelerate the whole society to concern and support the application of green building in real estate development and to promote the sustainable development.

1. Introduction

The building energy consumption includes energy consumption during construction and use. The energy consumption during construction includes the energy consumption during production and transportation of building material, building structure member and building equipment and during building construction and installation. The energy consumption during use includes the energy consumption for heating, ventilating, air conditioning, illuminating, household appliances, elevator and cold and hot water supply during the use of housing building and structure [1-3]. The specific realization course of building energy saving is, during the planning, design, construction (reconstruction, extension), modification and use of building, to implement the energy-saving standard, adopt the energy-saving technology, process, equipment, material and product, improve the heat-insulating performance and heating and cooling efficiency, intensify the operation management of building energy consumption system and utilize the renewable energy so as to reduce the energy consumption for heat supply, air conditioner heating and cooling, illuminating and hot water supply when the indoor thermal environment quality is guaranteed. When the building comfort and living and work quality are guaranteed and improved, the reasonable and effective use of energy resource during the use of building can reduce energy consumption and improve energy efficiency [4-5].

2. Problems in Building Energy Efficiency Work

2.1. Low Awareness of Building Energy Efficiency

The persons employed in the field of building are of different background and level. Many persons have huge shortfall in basic building energy-saving knowledge and they rarely think about the importance of energy saving and environmental protection to the society too much. In case of selection of building, many owners attach more importance to the building appearance and its internal structure but ignore the role of energy saving in the humanized design. In order to meet the consumer demand, therefore, the developers establish their planning focus on appearance and structure design but ignore the input to building energy saving. This not only increases the survival cost of owner but also is extremely unfavorable for social sustainable development. Meanwhile, this also reflects the absence of social responsibility [6-8].

2.2. Obstructed Exchange of New Technology

The quality demand for domestic building is greatly improved against the background of continuous renewal and development of technology. Therefore, the improvement of relevant standard and assessment system and the establishment of new building use standard cannot be separated from the input of new technology and new equipment However, it should be noted that the current domestic building sector seldom has an authoritative technical exchange platform for them to realize the in-depth discussion about the use and management mode of energy saving technology. Particularly, the great growth of building scale in recent years enables that the input speed fails to meet the demand of total building increase. This not only aggravates the energy consumption problem but also causes the resource waste, environmental pollution and other social issues [9].

2.3. Imperfect Laws and Regulations

The implementation of building energy saving objective is a systematic engineering system, which is involved with many design standards, building water and electricity and other contents and also needs the support from many governmental agencies including economy, construction and other functional departments. Therefore, it is necessary to establish the appropriate laws and policies based on building energy saving to enable that the implementation of each building management measure has laws to abide by. Also, it is necessary to enhance the supervision on responsible persons to guarantee the effective implementation of building energy saving work [10].

3. Investment Income Model of Building Energy Efficiency

The building energy saving is mainly involved with the energy consumption for power supply and distribution, heating, ventilating, air conditioning, illuminating, household appliances, elevator and cold and hot water supply during the use of housing building and structure. The building energy saving methods are as follows: 1. optimize the cold and heat sources, utilize the cooling tower and solar energy instead of air conditioning and heating equipment; 2. conduct the energy-saving modification for existing equipment. For example, lay the heat insulating material on building external wall, coat the super-lubricative high polymer material in water pump; 3. Develop and utilize the new energy, such as low grade heating energy and biomass energy in the atmosphere. The analysis of investment income model of each technology is based on the typical building energy saving technology and is given below.

3.1. Cooling Technology of Cooling Tower

Technical principle: increase the temperature control system and heat exchange equipment based on original cooling tower. In case of outdoor temperature lower than $15℃$, stop the original refrigerating unit but directly use the cooling tower to meet the cooling requirement so as to realize the energy saving purpose.

Scope of application: a place where the cooling is required in case of outdoor temperature lower than 15℃, including

Public building: large-sized data center, commercial office building, metro station, terminal building, etc.

Industrial factory building: process cooling water system in chemical industry, manufacturing, food, pharmaceutical processing and other factory buildings.

The cooling technology parameters are shown in Table 1.

Table 1. Cooling technology parameter table of cooling tower

Classification	Name	Variable	Unit	Remark
Input parameter	Rated water supply of refrigerating unit of original cooling water system	W	kW	From site nameplate
Built-in parameter	Investment of unit cooling capacity	300	Yuan/kW	
Output parameter	Total modification investment	Q	10,000 Yuan	
	Payback period	t	Yuan	2-4 years (direct output in result)

(1) Investment calculation

Total investment per kW cooling capacity $Q_0 = 300$ Yuan/kW

Total project investment $Q_0 = Q_0 \times P$

(2) Economical calculation

Average investment payback period: 2~4 years

A computing example of cooling technology is as shown in Table 2.

Table 2. Computing example table of cooling technology

Rated power of refrigerating unit of original cooling water system/kW	400	Cooling cop	5
Rated cooling capacity of refrigerating unit of original cooling water system/kW	2,000	Project investment/10,000 Yuan	60
Static payback period/Year		2~4 years	

3.2. Direct-Expansion Solar-Assisted Heat Pump

Technical principle: This system is based on the air source heat pump to integrate heat collecting equipment and evaporating equipment and utilize the solar energy and air energy to improve the unit efficiency under low temperature mode.

Scope of application: this is applicable to following scenario in case of ambient temperature of: -30℃~50℃

Hot water supply and cooling/heating air conditioner for commercial building, industrial building and civil building.

Calculation method: the economic analysis parameters of direct-expansion solar-assisted heat pump (water heating usage scenario) are shown in Table 3.

Table 3. Economic analysis parameter table of direct-expansion solar-assisted heat pump (water heating usage scenario)

Classification	Name	Variable	Unit	Remark
Input parameter	Daily water consumption	S	Ton	
	Equipment investment	25,000	Yuan/Ton	
	Electricity price	K	0.8 Yuan/kWh	System built-in
	Annual water consumption days	H	365	Generally calculate as per whole year operation
	Heating COP	COPh	5	Unit nameplate, not greater 6
Output parameter	Total modification investment	Q	10,000 Yuan	
	Payback period	t	Yuan	
	The calculation result is subject to the general split air conditioning unit.			

Computing method (water heating usage scenario)

Total project investment $Q=2500 \times S \div 10000$

Cost reduction (calculated as per hot water of 60℃ for 20℃ normal temperature)

$$q = S \times 365 \times 1000 \times 4.2 \times (60-20) \div 3600 \times (\frac{1}{0.95} - \frac{1}{cop_h}) \times K \div 10000$$

Payback period $t = Q \div q$

Table 4 is a computing example of direct-expansion solar-assisted heat pump (water heating usage scenario).

Table 4. Computing example table of direct-expansion solar-assisted heat pump

Daily water consumption (Ton)	10		
Project investment (10,000 Yuan)	25	Annual amount of electricity-saving (10,000 kWh)	14.5
Annual revenue (10,000 Yuan)	11.6	Static payback period (Year)	2.16

3.3. Water Pump Coating

Technical principle: the super-lubricative high polymer material is coated in water pump to reduce the friction loss of runner, realize the energy efficient rate up to 5~15% and reduce the water pump maintenance frequency.

Scope of application: 100Kw above water pumps which are of continuous operation in the fields of steel and iron, power plant, chemical industry, chemical fiber, paper making, prevention and other sectors.

Calculation method: the calculation method of water pump coating is shown in Table 5.

Table 5. Calculation method table of water pump coating

Classification	Name	Variable	Unit	
Input parameter	Water pump power	P	kW	
	Operating hours	T	8,000h	Generally take 8,000h
Built-in parameter	Estimated investment coefficient	δ	10,000 Yuan/kW	System built-in
	Energy efficient rate	η	5%	System built-in
	Electricity price	K	0.8 Yuan/kWh	System built-in
Output parameter	Total modification investment	Q	10,000 Yuan	
	Payback period	t	Year	

(1) Investment calculation

Project investment cost: $Q = P \times \delta$

δ: estimated investment coefficient (10,000 Yuan/kw), taken from the table 6.

Table 6. Corresponding Table of Water Pump Power and Estimated Investment Coefficient

Water pump power (kW)	Estimated investment coefficient (10,000 Yuan/kW)
100	0.030
200	0.026
300	0.024
400	0.020
500	0.019
600 above	0.018
In case of power range, take the lower limit.	

(2) Economical calculation

Project electricity-saving amount: $E = P \times T \times \eta$

P: rated pump power (kW);

T: Water pump operating hours (h)

η: Modification energy efficient rate (%), empirical value: 5%,

Project cost reduction: $q = E \times K$

K: Local electricity price, Yuan/ (kWh);

Payback period: $t = Q \div q$

Abstract of computing example is shown in Table 7:

Table 7. Computing example table of water pump coating

Water pump power (kW)	100	Annual operating hours (h)	8,000
Project investment (10,000 Yuan)	30,000 Yuan	Annual amount of electricity-saving (10,000 kWh)	40,000kWh
Annual revenue (10,000 Yuan)	32,000 Yuan	Static payback period (Year)	1 year
This computing method is not applicable to those water pumps of triple stages and above.			

3.4. Intelligent Drying Technology

Technical principle: this is to convert the low-grade heat energy of 5℃ above in the atmosphere into the heat energy up to 90℃ by air source heat pump for drying purpose in production.

Scope of application: this is applicable to the drying process not greater than 90℃ in the fields of wood, tobacco, Chinese herbal medicines, aquatic product, cereal, food and other product production and processing sectors.

Calculation method (applicable to wood industry): the calculation method of intelligent drying technology is shown in table 8.

Table 8. Calculation method table of intelligent drying technology

Classification	Name	Variable	Unit
Input parameter	Wood consumption of original wood drying room	M	m^3
Built-in parameter	Intelligent drying equipment investment	3,000	Yuan/m^3
Output parameter	Total modification investment	A	10,000 Yuan
	Payback period	Within 2~3 years	Year
	Use the intelligent drying control, heat recovery technology and positive moisture removal technology to shorten the drying period, reduce the drying cost by about 30% (including environmental protection benefit, government award and labor cost).		

(2) Investment calculation

Total modification investment: $A=M*3000/10000$

3.5. Combined Heat and Power System of Modular Biomass Energy

Technical principle: utilize the anaerobic digestion of organic waste to produce the biogas. The treated biogas can be used as the fuel of modular combined heat and power generator to generate power and heat. This is featured by rapid installation and plug-and-play and can realize the overall energy use efficiency up to 85%.

Scope of application: it has the unit generating capacity of 50kW-2,000kW and is applicable to the treatment and use of organic wastes from agricultural and sideline product processing, agriculture and stock-raising, food processing, paper making, refuse landfill, etc.

Calculation method (high-concentration organic wastewater): the calculation method of combined heat and power system of modular biomass energy is shown in Table 9.

Table 9. Calculation method table of combined heat and power system of modular biomass energy (high-concentration organic waste water)

Classification	Name	Variable	Unit
Input parameter	Daily quantity of organic waste water	t	t/day
Built-in parameter	Biogas production per tonne of waste water per day	22.4	m^3/t
	Unit investment of biogas generating pit	1,500	Yuan/m^3
	Unit investment of modular biogas purification system	2,500	Yuan/ (m^3/d)
	Lower heat value of biogas	6	kW/ m^3
	Generating efficiency of modular combined heat and power system	38%	
	Modular combined heat and power equipment	7000	Yuan/ (kW)
	On-grid price	1.25	Yuan/ (kWh)
	Annual operating hours of unit	8,000	h
Output parameter	Total modification investment	Q	10,000 Yuan
	Payback period	Pt	Yuan

(1) Calculation of generating power

Generating power $P=t \times 22.4 \div 24 \times 6 \times 0.38$

$t \times 22.4$: Gas production of biogas equipment (m3/d)

Volume of biogas generating pit $v = t * 22.4 / 0.8$

(2) Investment calculation
Total modification investment
$$Q = t*22.4/24*2500/10000 + P*7000/10000 + 1500*V/10000$$
(3) Calculation of investment payback period
Payback period$= Q/(P*8000*1.25/10000)$
Abstract of computing example is as shown in Table 10.

Table 10. Computing example of combined heat and power system of modular biomass energy (high-concentration organic wastewater)

Project name		A biogas modular unit	
Quantity of organic wastewater (t/d)	40	Power of combined heat and power generation (kW)	85.1
Project investment/10,000 Yuan	237	Annual electricity production/10,000 kWh	68
Annual revenue/10,000 Yuan	85	Static payback period/Year	2.8

4. Conclusion
The building energy-saving investment income model and energy-saving optimization program proposed and designed in this paper can obviously reduce the energy consumption, improve the energy use efficiency and reduce the pollutant emission. The building energy saving is a major event to implement the sustainable development strategy. Currently and in the coming years, the leaders at each lever shall attach more importance to the progress of building energy saving and enhance the administrative supervision for building energy saving to create a brand-new outlook for building energy saving work.

Acknowledgements

References
[1]   Zhu Yanping, Hu Hao, Study on economic evaluation of ecological building project [J]. Building construction, 2006, 28(3):203-204.
[2]   Yu Shanqing, About building energy saving standardization. China standardization. 2000(1):15-18.
[3]   Qi Ming, Building energy saving references in USA, British, Canada and other countries. Building material industry information, 2009(6):12-14.
[4]   Yun Yingwei, Wu Xiangguo, Fan Fengli, Status analysis and countermeasure of Chinese building energy saving [J]. Academic journal of Chongqing University of Science & Technology (natural science edition), 2006, 8(1):62-65.
[5]   Liu Haojiang, Fan Rong, How far are we from energy-saving building - simple analysis of energy-saving building development status and prospect [J]. China Science and Technology Information, 2005(17):140-163.
[6]   Lang S.W. Progress in energy-efficient standards for residential buildings in China [J]. Energy and Buildings, v36, n12, December, 2004, p1191-1196.
[7]   Jiang Yi, Study on China building energy saving strategy [J]. Chinese Engineering Science, 2011, 13(6):30-38.
[8]   Yang Ling, Analysis of application of green and energy-saving construction technology in building engineering [J]. Building engineering technology and design, 2015 (6): 309.
[9]   Hu Pingfang, Xiang Caiwang, Current characteristics of Chinese building energy consumption [J]. Academic journal of Wuhan Urban Construction University, 1998(3):86-88.

[10]   Shen Tang, Mao Xianjun, Zhang Tianhong. Development and application of green intelligent building new technology [J]. Jiangsu Building Material, 2009.