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Air Conditioning Cold/ Heat Source Analysis of the Inclusion of Monetary Values of Environmental Damage Based on the LCA Theory

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Abstract: This is an analysis of the effect on the technical solutions when monetary values of externalities are included in a model for selecting air conditioning cold/heat sources. The focus of the study is on heating and cooling using conventional and seawater source heat pump systems. The included monetary values of damage to the environment and health are those resulting from atmospheric emissions and water-body toxicity. An environmental impact assessment model is presented based on the theories of Life Cycle Assessment (LCA) and Willingness - to - pay (WTP). The analysis makes it possible to compare the technical and economic differences of the air conditioning system based on business economics to a system with greater emphasis on socio-economics. This model is applied to assess the environmental impacts of two systems. The results show that by considering externality costs, the total discounted cost of the new system would be approximately equal to the conventional one.

Key words: air-conditioning cold/heat sources; Life Cycle Assessment (LCA); Willingness-to-pay (WTP); monetary values of environmental impact

1. INTRODUCTION

Globally and nationally, commercial buildings contribute significantly to resource consumption, as well as to other environmental impacts, such as air emissions and solid waste generation. For example, 27.8% of China's total primary energy consumption in 2002 is consumed by buildings, in which HVAC system accounts for 30-40% of the life cycle primary energy consumption. China's heavy reliance on coal to power its overcharged economy has already made it the world's second-largest producer of greenhouse gases, second only to United States. Speeding up the development of green, energy-efficiency buildings and Sustainable Energy technology is a significant move towards the realization of sustainable development in China.

The sustainable development in HAVC system is not only to reduce energy consumption but also to reduce environmental impact in the course of energy conversion and utilization. So the designs of HVAC systems should pay more attention to the improvement of energy efficiency and try to lighten the environment load

Quantitative analysis of environmental impact can't be done by traditional methods of economic analysis for their self- limitation. Now life cycle assessment method has been used in HVAC systems to gain the integrated environmental impact value through environmental impact assessment of air condition's cold and heat source [1]. But monetary values of environmental impacts haven't been calculated. However, during a project decision-making process, the goal is to make big profits and the cost of clean energy is higher than general energy; thereby the advantages of new technology could not be shown and thus hampered the development of new energy and technology.

At present, the effects on the technical solution including monetary values of externalities have been used to optimize energy systems in developed countries [2]. In China studies on social WTP for environmental impacts based on the LCA theory have begun to develop and have been successfully applied to multi-story resident buildings [3-4]. The main objective of this study was to analyze the effect of monetary values of externalities included in a model of selecting air conditioning's cold/heat sources. The environment impact of two systems is assessed. This method could be used to select HVAC system and help governments environmental impacts of two systems are assessed .This method could be used to select HVAC system and help governments frame favorable policy.

2. ENVIRONMENTAL IMPACTS MODEL OF HVAC SYSTEM

The section is discussed how to quantitate the environmental effect based on inventory results and how the effect can be evaluated using monetary considerations.

2.1Inventory Analysis

The main difference between different air conditioning cold/heat sources is the type and amount of energy consumption, generally measured by standard coal and electricity. The LCA of standard coal and electricity production and heating with standard coal-burning have been finished in our country. The emission inventories are shown in table1-2[5-6].

2.2 Categories of Environmental Impact and the Equivalent Factors

According to the emissions during the operation, correlative impact categories are given. Different equivalent factors are selected to calculate category indicators. As an example, the relative contributions of different gases to climate change are commonly compared in terms of carbon dioxide equivalents using Global Warming Potentials (GW). Table3 provides the equivalent factors for common impact categories in this LCA studies.

2.3 Monetary Evaluation Model of Environmental Impact

Weighting factor is made on the basis of costs related to environment consequences. Willingness to pay (WTP) is based on avoidance /prevention/damage costs. Since government policies and decisions play a leading role in the process of environmental protection in developing countries, the weights derived from environmental taxation may be a consensus by representatives of the public. In this way, the economic value is expressed. Eqs. (1)- (2) illustrate this [3]:

$$w_i = \sum_j e_{ij} c_{ij} \tag{1}$$

Where w_i =weighing factors, e_{ij} =monetary factors of the waste and its unit is expressed in effect indicator (as an example, the per unit of sulfur dioxide is "Yuan/kg eq. SO_2), e_{ij} =potential effect factors, it related to the amount of the contamination as well as its contaminative ability.

Eq. (2) provides an example how potential effect factors can be calculated [4].

$$e_{ij} = f_j \cdot a_j / \sum_j \left(f_j \cdot a_j \right) \tag{2}$$

Where f_j =potential effect of per unit contamination j , a_j =average annual amount of contamination j

Tab.1 Inventory results for electricity production (gram /MWh)

Inventory analysis	CO_2	SO_2	NO_X	COD	CO	SS	Particles	Solid wastes
Electricity production	1141200	10296	5220	32.4	2772	198	9540	46800

Tab.2 Inventory results for standard coal energy production and burning (gram/ton)

Inventory analysis	CO_2	SO_2	NO_X	COD	CO	SS	Particles	Solid wastes
Coal production	26077	264	60	15	29	29	88	-
Coal burning	2684000	2980	13540	-	590	-	17000	250000
Total	2710077	3244	13600	15	619	29	17088	250000

Tab.3 Environmental impact category and equivalent factors

Impact categories	Equivalent factors	Impact categories	Equivalent factors
Global warming	gCO_2/g	Acidification	gSO_2/g
Eutrophication	gNO_3-/g	Suspended particles	g
Water-body toxicity	gPb/g	Solid wastes	g

3. MONETARY EVALUATION OF ENVIRONMENTAL IMPACT

Dalian is selected as a sample of the research and all the data come from General Environmental Quality Reports of Dalian Environmental Protection Bureau.

3.1 Monetary Values of AC

The main contaminants which caused acidification are SO_2, NO_x and NH_3. The data of the emissions and monetary weighting factor of Dalian in 2004 can be obtained from published reports [7-8]. Based on table.4 and Eq. (1) (2), the weighting factor of AC is 0.57yuan/kgeq SO_2. The meaning of it is that WTP is 057yuan when acidification impact per functional unit is added in Dalian.

3.2 Monetary Values of Water-Body Toxicity and Suspended Solids

The main contaminants which caused water-body toxicity are heavy metals and their compounds. Based on table.5 and Eq. (1) (2), the weighting factor of WT is 7.82yuan/kgeqPb. Suspended solids have hardly poisoned the water-body and only SS is considered. According to emission tax, the weighting factor of water-body Suspended solids is 0.25yuan/kg.

3.3 Monertary Values of GW

CO_2 contributes more than 50% effect to the greenhouse gases as a whole. The emission of carbon dioxide emission of China in 2002 reached 4.08 billion, being the world second. It is 1.53 times that of ten years ago and covering 13% of the world's total amount.

Tab.4 Weighting factor of acidification potentials

Contaminations	AC equivalent factors($kgSO_2/kg$)	Average annual amount(106kg/a)	Potential effect factor	Monetary factors (yuan/kg SO_2)
SO2	1.0	103.1	0.51	0.63
NO_X	0.7	112.5	0.39	0.63
NH_3	1.88	11.3	0.1	0.07

Tab.5 Weighting factor of water-body toxicity potentials

Contaminations	Toxicity equivalent factors($kgSO_2/kg$)	Average annual amount(10^6kg/a)	Potential effect factor	Monetary factors (yuan/kg Pb)
Hg	500	0	0	1400.00
Cd	500	10	0	140.0
Cd^{+6}	10	10	0	35.0
Pb	1	0	0	28.0
As	1	10	0	35.0
Cyanide	1	1890	0.03	14.0
Oil similarity		375000	0.65	7.0
Volatilization hydroxybenzene	10	17930	0.32	8.8

China which has ratified the protocol and is not required to reduce carbon emissions will confront with great pressure from international community in the post Kyoto Protocol age.

Such suggestion has been proposed as to introduce carbon tax to limit the greenhouse gas emissions. Base on some literatures, if the operated power plants make technical reformation, the cost of reducing the emission of CO_2 will be $80 per ton [9]. According to Clean Development Mechanism in China, the price of CO_2 is about 33-50yuan/ton. Recently the study on how carbon tax influences China's Economic Growth has been done and the tentative price has been proposed [10].

Summarized above-mentioned prices, the price of 80yuan/ton CO2 is adopted as a weighting factor of GW in the study.

3.4 Monetary Values of NE

The main contaminants which caused eutrophication are NH3-N, total P and COD. According to table6 and Eq. (1) (2), the weighting factor of AC is 1.47yuan/kgeq NO_3^- .

3.5 Monetary values of SA and Solid Wastes

According to table7, the weighting factor of SA is 0.23yuan/kg. According to emission taxes, the weighting factor of solid waste is 0.25yuan/kg.

3.6 Monetary Values of Coal and Electricity's Environment Impact

The functional units of standard coal and electricity are per ton and per MWh. According to table3-7, table8 illustrates monetary values.

From Table 8 shows that the environmental cost of producing per MWh electricity is 236.76yuan, and the cost of producing and burning per ton standard coal is 582.56yuan.

4. APPLICATION

The hotel is about 42,000m^2 where the building is close to the sea. The total heating and cooling demand are 4680MWh and 3600MWh, respectively. Based on seawater temperature conditions, the seawater air-conditioning system (SWAC) was proposed. Seawater is transported into the production through two high-density polyethylene pipelines. The inlet depth is about 10m and the distant to the plant is about 100m. The water flow is driven by the static pressure difference between the seawater surface and the inlet water room.

The price of electricity is 0.795yuan/kWh, and standard coal with an energy value of 8.14kWh/kg has a price of 700yuan/ton.

Investment and operational costs of two systems are shown in table9-10 with an interest rate of 6%, the annuity of 0.103 over 15 years and taking consideration of monetary value.

From Table 9, it can be shown that with the same electricity price SWAC system are 50 thousand Yuan and 16.6% higher than the conventional system both in investment cost and operational cost. Only in terms of economics does the former system have no superiority over the latter.

Tab.6 Weighting factor of eutrophication potentials

Contaminations	AC equivalent factors (kg NO_3^-/kg)	Average annual amount(106kg/a)	Potential effect factor	Monetary factors （yuan/kg NO_3^-）
NH3-N	4.01	11.3	0.54	0.88
TP	32.0	0.84	0.32	2.8
COD	0.23	53.2	0.14	0.7

Tab.7 Weighting factor of suspended particles potentials

Contaminations	Average annual amount(106kg/a)	Potential effect factor	Monetary factors (yuan/kg)
Soot	25.45	059	0.28
Dust	17.37	0.41	0.15

Tab.8 Monetary values of environment impact of coal and electricity

Impact category	GW	AC	NE	SA	SS	SW	Total
Electricity(MWh)	225.37	7.95	0.05	2.19	0.03	1.17	236.76
standard coal(ton)	565.07	7.28	0.02	3.93	0.01	6.25	582.56

Tab.9 Operation and investment costs (10^4yuan)

Description	SWAC	Conventional
Investment cost	946	720
Annuity	97	74
Cooling cost	51	69
Heating cost	166	130
Maintenance cost	38	29
Total of cost	352	302

Tab.10 Operation and investment costs (including monetary values of environment impact) (10^4yuan)

Description	SWAC	Conventional
Investment cost	946	720
Yearly financial cost	97	74
Cooling cost	51	69
Heating cost	166	130
Maintenance cost	38	29
Environment cost	49.0	72.9
Total of cost	401	374.9

Table 10 shows that if monetary values of environmental impact are taken into account, the former is 26 thousand Yuan and 6.9% higher than the latter both in investment cost and operation cost, respectively. The former is almost equal to the latter in terms of economics.

4. DISCUSSION AND CONCLUSION

Based on LCA and WTP theories, monetary values of environmental impact of air-conditioning are evaluated and included in the technical solution to select air-conditioning systems. The method makes it easier to assess the new technology and system in a more comprehensive and more intuitionistic way.

The results show that by taking into account the externality costs the total cost of the new system would be approximately equal to the conventional system. If such advantages as eliminating noise, saving valuable space in the buildings and saving fossil fuel are taken into consideration, the new system is more likely to be accepted. In addition, carbon tax has great contribution to monetary value of environmental impact. Therefore, how to frame a feasible carbon tax becomes very important for extending the new technology and system.

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