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Life Cycle Assessment of Rock Wool Board and EPS Board

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Abstract. Although outer wall thermal insulation technology is an effective measure for building energy-saving, the production of thermal insulation materials causes serious impacts on environment. In the present investigation the resource, energy consumption and environmental emission of the two kinds of thermal insulation materials were analyzed, from the acquisition of raw materials to production process based on Life Cycle Assessment (LCA). The result show that life cycle energy consumption of rock wool board is 415MJ per functional unit, proximately twice of EPS board's (220MJ). Overall, environmental impact indicators caused by rock wool board is more serious than EPS.

Introduction

In China, energy consumption of building takes a big part in energy consumption, the task of building energy efficiency is significant. With the gradual improvement in the energy conservation requirements, external thermal insulation has become a major form of energy-saving thermal insulation of walls, boasting of the most mature technology and the most extensive application[1]. At present, the composite system based in thermal insulation board is extensively adopted, mainly two kinds of insulation materials: expandable polystyrene (EPS) and rock wool, Thermal insulation materials EPS has a low thermal conductivity coefficient, a certain strength and toughness, forming easily, mature technology and so on. In recent years rock wool attracted much people's attention because of its non-inflammable performance.

The way thermal insulation layer located at the outside of the structure layer of walls can reduce the energy consumption of building in its operating stage, meanwhile the production of thermal insulation material add the energy consumption of building material production. So the building materials evaluation on energy and environmental impact has become a starting point for achieving "green building" [2]. As one of the several environmental management techniques, Life cycle assessment (LCA) addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of releases) throughout a product's life cycle[3]. Here, a cradle-to-gate life cycle study was conducted by using data for rock wool board and EPS board in China to calculate the environmental load during the phases of producing, manufacturing, and transportation based on LCA theory.

Goal and scope definition

This article sets 1 m^2 of building insulation board (rock wool board and expandable polystyrene (EPS) board) as the functional unit. The objectives of this article were as follows:

1) Quantify relevant inputs and outputs of the two kinds of insulation board for their life cycle from raw material acquisition through production.

2) Make a comparison between rock wool board and EPS board from environment impact.

Based on the scope of the LCA, the system boundary was illustrated in Fig. 1 and Fig. 2.

The process of rock wool board can be subdivided into four steps: raw material preparation, energy production, transportation, manufacturing processes. EPS board is made of expandable polystyrene resin, a co-product of petroleum refinery, and crude oil is the major raw material for EPS production.

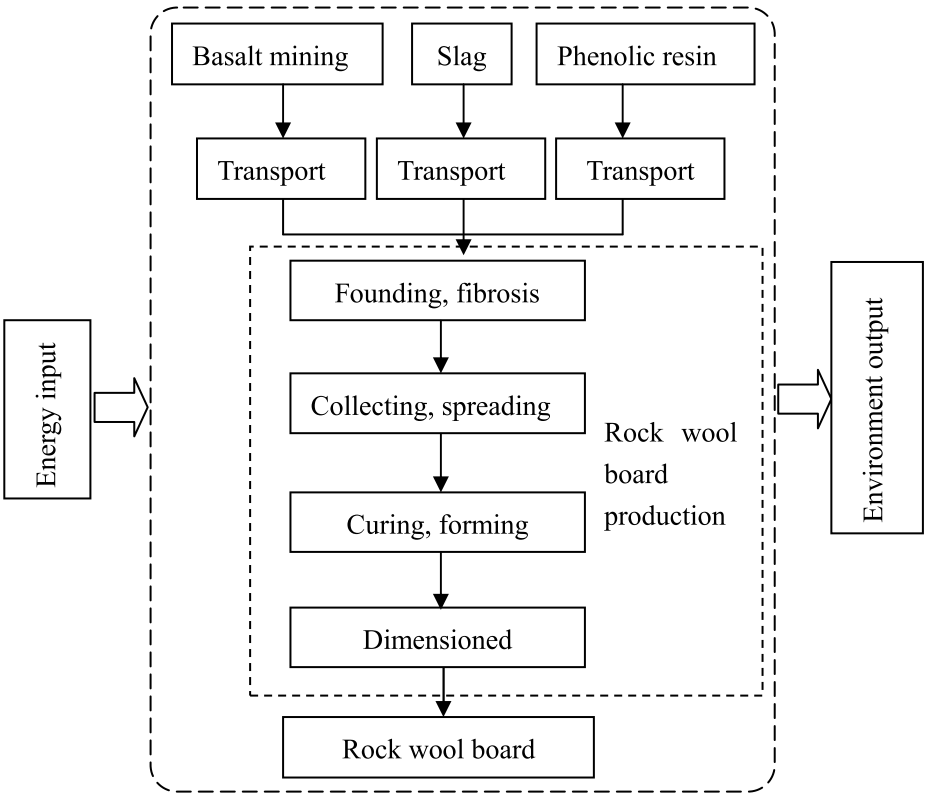

Fig. 1 System boundary of LCA for rock wool board

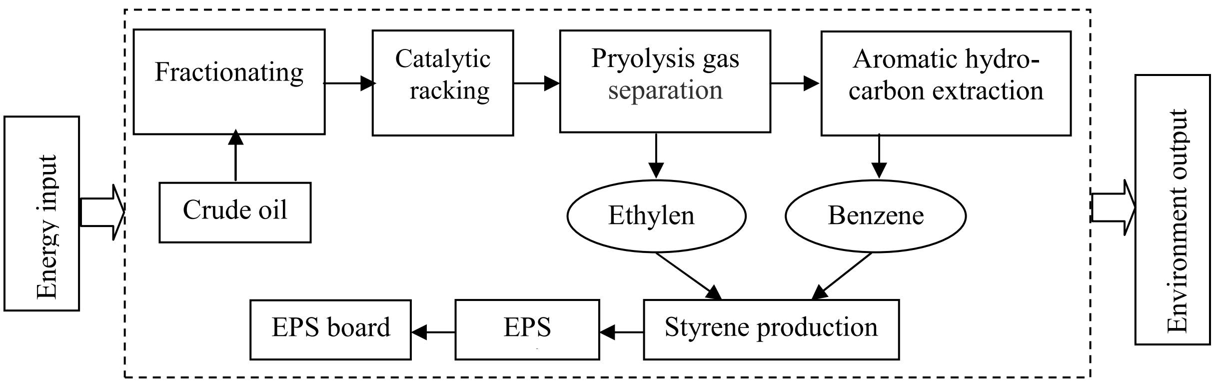

Fig. 2 System boundary of LCA for EPS board

Life cycle inventory analysis

Relevant data for rock wool production was collected through interviews at a typical factory, the main energy consumption is coke, electric power and diesel oil. Its raw materials consumption consists of basalt, slag and phenolic resin. Slag is the solid waste of blast furnace, the dosage of binder is very little. So only basalt was taken into account when calculate resource input. Data of EPS board production is obtained from dissertation of Su[4].

The data of resource and energy input were referenced from published dissertation and literature. Electricity is a major consideration in almost all of the life cycle assessment (LCA). The electric power used in production processes is mainly supplied by a national power grid. The emission factors of power plants were obtained from the data based on the situation of China, the inventory comes from Di[5].The inventory of other energy production is obtained from achievements of Yuan[6]. Part of the transport distance data were obtained from the survey. The transportation distance data of other raw materials were assumed to be 182 km (the average transportation distance of road transportation for goods in (2011). The environmental burden inventory of transportation is cited from achievements of Ma[7].

Air pollutants, among the wastes produced in material production processes, causing the most serious impact on the environment. The major waste included CO_2, CH_4, SO_2, NO_x, HF, and particulates. Data on liquid emissions except COD are unavailable because they are beyond the control of producers, and the impact of liquid waste will not be taken into consideration. Bulk solid waste mainly consists of rejected product which may become toxic at low levels to human beings and the environment, of which environmental impact could be ignored.

The life cycle inventory results for rock wool board and EPS board are illustrated in Table 1.

Table 1 Life cycle inventory of rock wool board and EPS board

	item	unit	Rock wool board	EPS board
Resource and energy consumption	Basalt	kg	1.13E+01	
	Coal	kg	1.65E+01	3.94E+00
	Crude oil	kg	1.63E+00	2.13E+00
	Natural gas	m^3	5.63E-02	1.25E-02
Releases to environment	CO_2	kg	3.92E+01	1.10E+01
	SO_2	kg	6.35E-02	7.56E-02
	NOx	kg	1.24E-01	4.47E-02
	CO	kg	7.98E-02	1.04E-02
	CH_4	kg	1.54E-02	3.38E-02
	NMVOC	kg	4.93E-03	9.31E-04
	PM	kg	1.25E+00	9.38E-03
	COD	kg	6.07E-04	9.38E-05
Energy consumption		MJ	4.15E+02	2.20E+02

Life cycle impact assessment

The life cycle assessment approach, developed by the Institute of Environmental Sciences (CML) of Leiden University, was used in this study. The impact assessment method consists of characterization, normalization[8,9]. Given the scope of this case study and relevant LCI, the environmental impact categories considered were: depletion of abiotic resources (ADP), global warming (GWP), acidification (AP), human toxicity (HT), photochemical (POCP), and eutrification (EP).

The normalization results of the three scenarios were listed in Table 2.

Table 2 Environmental impact indicators for rock wool board and EPS board

Impact categories	rock wool	EPS
ADP	1.25E-14	1.41E-14
GWP	1.02E-12	3.03E-13
AP	5.03E-13	3.57E-13
POCP	2.45E-13	1.24E-13
HT	2.37E-14	1.38E-15
EP	1.25E-13	4.50E-14
Total	1.93E-12	8.45E-13

Results and discussion

Figures 3 and 4 show the comparison of rock wool board with EPS board based on energy consumption and environmental impact indicator. It can be found that:

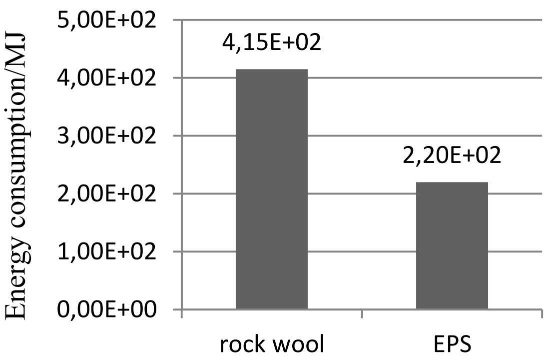

Fig. 3 Energy consumption of rock wool board and EPS board

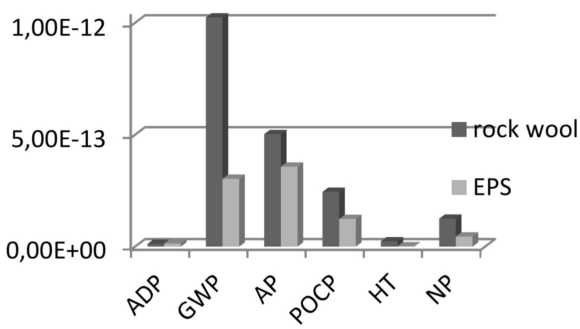

Fig. 4 Environmental impact indicators for rock wool board and EPS board

(1) Life cycle energy consumption of rock wool board is 415MJ per functional unit, proximately twice of EPS board's (220MJ).

(2) On the whole, environmental impact indicators caused by rock wool board is more serious than EPS, except ADP, the reason is that there was much industrial slag used as raw material in the process of rock wool board so that natural resource was saved in some degree. Crude oil is the basic raw material for EPS production, which accelerates ADP of life cycle of EPS board.

(3) GWP caused by rock wool is three times of EPS'. Because there is more fossil fuel used in the rock wool production, which lead to the large amount of CO_2 emission, while CO_2 was the major gas to cause greenhouse effect in materials production. The gases that contribute to acidification were mainly SO_2 and NO_x. These two kinds of gas emission also owe to fossil fuel combustion.

Conclusion

This study explored the building insulation board (rock wool and EPS) production in China, and calculated the energy consumption and environmental impact indicators through their life cycle according to the LCA procedure. Compared with rock wool board, the EPS board has obvious advantage in terms of energy consumption and environmental impact.

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