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Life Cycle Assessment of Typical Glass Wool Production in China

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Abstract. Glass wool is the roll felt product produced by melting and fiberizing glass and then adding adhesive for curing processing. It is well-shaped, thermally insulated and corrosion resistant and has low volume density, low thermal conductivity, good acoustic absorptivity and stable chemical properties. By taking 1t glass wool as the functional unit, this paper quantitatively obtains that the impact of the product on primary energy demand, greenhouse effect, acidification potential, photochemical ozone formation potential and respirable inorganics is 1.12×10^5MJ/t, 8×10^3kg CO_2 equivalent/t, 84.1kg SO_2 equivalent/t, 3.21kg NMVOC/t and 15.5kg PM2.5 equivalent/t respectively. This paper provides reference for enterprise's cleaner production and consumer's green material selection by making life cycle assessment for glass wool insulation material, quantifying the environmental load of glass wool product, identifying the environment hot spots in product life cycle and illustrating the environment compatibility of product.

Introduction

With the full scale implementation of building energy conservation policy and the increasing propelling of green and low carbon building, the application of building insulation materials develops rapidly. Glass wool is well-shaped, thermally insulated and corrosion resistant and has low volume density, low thermal conductivity, good acoustic absorptivity and stable chemical properties, etc., so it is valued by the building industry. Especially, after the issuance of No. 65 Fire Protection Decree which is known as the harshest decree, there is increasing demand for Class A insulation materials in construction markets throughout the country, which greatly propels the application of glass wool in buildings. Therefore, glass wool has important significance for the development of low carbon building and its fire safety.

Life cycle assessment (LCA) [1] is the standardized method for quantitatively and systematically assessing the impact of resource and energy consumption as well as pollutant discharge on the environment in product life cycle and is regarded as the best way to assess the environmental impact of products. It has penetrated into the key decision for all kinds of products in various industries at present. LCA method is introduced into the green building certification and Type III environmental declaration of building materials in many countries, and its application in carbon emission, cleaner production, ecological design and green purchasing fields has been widely accepted by the society. Therefore, making LCA analysis for glass wool, a kind of important building insulating material, has notable significance.

This paper calculates, analyzes and assesses the environmental impact of the production process of typical glass wool, for the purpose of illustrating the basic conditions of environmental load of glass wool in life cycle in China, so as to provide data support for the establishment of localized LCA database of glass wool and the environmental load assessment of low carbon building in life cycle.

Product Description

Glass wool is a kind of inorganic fiber thermal insulation and sound absorption material and is produced by burner blowing, steam vertical-blowing and centrifugal blowing [2]. As burner blowing method has high energy consumption and high slag-ball content, it has been replaced by centrifugal reeling method. Centrifugal reeling method is the main production technology for the present, which has low energy consumption and is free from slag-ball and pollution. The Saint-Gobain ISOVER TEL centrifugal technique is the most frequently used centrifugal technique for the present and is the originator for glass wool product. The specific technical process is as follows: mix raw materials such as quartz powder, dolomite, sodium carbonate and borax uniformly, then melt them into molten glass in melting furnace; spout out the molten glass through the nozzle of centrifuge which rotates at high speed by using the mixer of fuel gas and air, and shake out primary fiber via the leak hole of centrifuge, then pull the primary fiber into superfine fiber in circular combustion chamber, and finally make into glass wool by technologies such as shaping, settlement and gathering [2]. The chemical components of glass wool are mainly SiO_2 and Al_2O_3, where the content of SiO_2 is above 60%(w), and substances as CaO, MgO, alkali oxide and B_2O_3 additionally; the thermal conductivity of glass wool is 0.037~0.039W(m·K)$^{-1}$. Glass wool has certain mechanical strength and is easily-shaped, good in insulating property and resistant to corrosion and fatigue damage; it is widely applied in aviation, petrochemical filed, processing field and the like [3]. Formaldehyde-free environmental-friendly glass wool is made by making some adjustment for the raw material formula and formation technology of glass wool on the basis of traditional centrifugal glass wool to make raw wool suitable for the combination, curing and forming with new adhesive. See Fig. 1 for the production technology process. The product quality meets those specified in GB/T 13350-2008 *Glass Wool and Their Products for Thermal Insulation* [4] and GB/T 17795-2008 *Glass Wool Thermal Insulating Products for Building* [5].

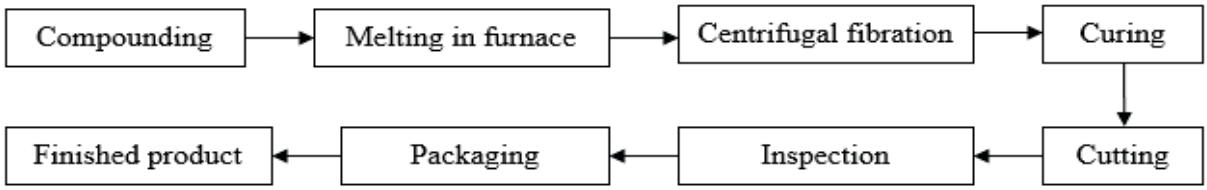

Fig. 1 Production technology process of glass wool product.

1) Compounding: weigh and mix materials according to the mix proportion;
2) Melting in furnace: melt at 1,000°C in natural gas furnace;
3) Centrifugal fibration: fiberize molten glass by high speed centrifuge and spray glue;
4) Curing: cure with curing furnace;
5) Cutting: cut into forms of different specifications;
6) Inspection: inspect whether the finished product complies with national standard;
7) Packaging: in bags;
8) Finished product: warehouse the accepted products.

Environmental Impact Assessment of Typical Glass Wool Production in Life Cycle.

System Boundary. The life cycle system boundary of glass wool product defined in this report is as shown in Fig. 2, covering from resource exploitation, raw & auxiliary material production and raw material transport, energy production, product production to product ex-factory (cradle-to-gate):

(1) Raw material production (cullet, sodium carbonate, borax);
(2) Auxiliary material production;
(3) Energy production (electric power);
(4) Transport (transport of main raw materials);
(5) Production of glass wool product;

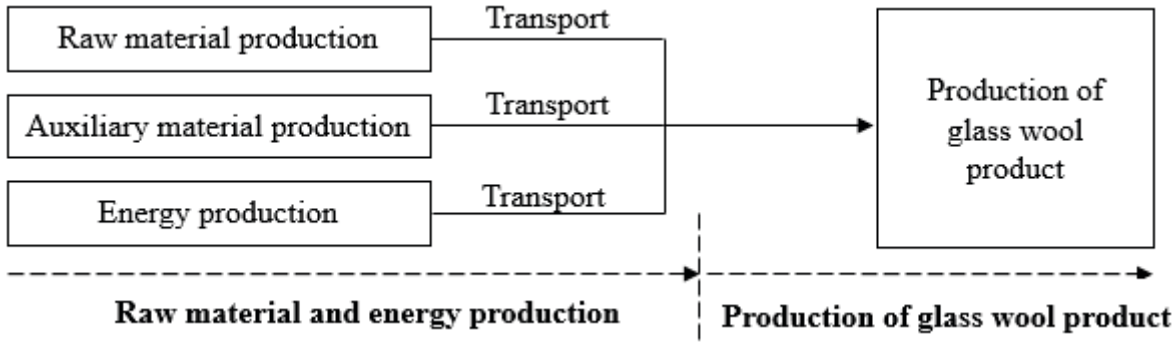

Fig. 2 Life cycle system boundary of glass wool product production.

Functional Unit. Production of 1t glass wool product is taken as the reference unit.

Inventory Data Regarding the Energy Consumption of Raw Materials for Glass Wool Product. The raw material consumption, energy consumption and transport data of unit product on the production site of glass wool board are obtained through deep investigation for typical glass wool manufacturer in China.

Table 1 Inventory data of raw materials and energy.

Name	Proportion (%)	Transport distance	Mode of transport
Cullet	85.89%	20km	By freight
Sodium carbonate	5.99	50km	By freight
Borax	8.12	1,000km	By freight
Natural gas	43.10	——	By pipeline
Electricity	56.90	——	Through State Grid

Data Adopted for the Environmental Impact Assessment of Glass Wool Product in Life Cycle. Site data includes the inventory data regarding raw materials consumption, energy consumption, pollutant discharge, transport and the like of glass wool product at production stage. Upstream data includes the inventory data regarding raw material exploitation and energy production as well as the inventory data regarding road transportation required for raw material transport; the upstream data of this report is taken from CLCD database. For Chinese Life Cycle Database (CLCD) [6], the data is taken from industry statistics and literature and represents the average of Chinese market.

Table 2 Source of the data adopted in various processes of glass wool product.

Systematic process	Data description	Data source	Time attribute	Geographic attribute
Cullet	Waste glass	CLCD	2013	China
Sodium carbonate	Soda ash	CLCD	2013	China
Borax	Sodium borate	CLCD	2013	China
Natural gas	Pipeline transportation (natural gas)	CLCD	2013	China
Electricity	Electricity of China Southern Power Grid	CLCD	2013	China
Road transportation	46t-grade diesel powered truck that travels 1km with load of 1t	CLCD	2013	China

Data Time Range. The model data in life cycle is based on the production data of enterprise in 2015 and the upstream data is based on 2013.

Principle of Acceptance or Rejection:

(1) All the energy inputs are listed;

(2) All the material inputs are listed;

(3) The inputs of auxiliary materials that are less than 0.01% of the total consumption of raw materials may be ignored;

(4) The discharges to atmosphere and water are listed;

(5) Substances and energy flows less than 2% in both inventory analysis and environmental impact contribution.

Environmental Impact Assessment of Glass Wool Product in Life Cycle. In the paper, the environmental impact of glass wool in life cycle is assessed with the general life cycle assessment analysis software eBalance that is developed by Integrated Knowledge for our Environment (IKE) [7-8]. IKE possesses independent intellectual property for eBalance. eBalance software adopts the names and units of substances in International Reference Life Cycle Data System (ILCD) and builds in the public version of Chinese Life Cycle Database (CLCD) and that of Switzerland Database in EU Life Cycle Database (ELCD) [7]. The LCIA methodology used for this research is CML. eBalance life cycle analysis software is used to make life cycle assessment for functional unit of glass wool product and to characterize its primary energy demand (PED), global warming potential (GWP 100), acidification potential (AP), photochemical ozone synthesis (POFP), respirable inorganics index (RI). The obtained calculation results of enterprises are as shown in Table 3.

Table 3 Environmental Iimpact assessment result of glass wool product in life cycle In: Ton (t).

Environmental impact category	Unit	Qty.
Primary energy demand (PED)	MJ/t	1.12×10^5
Global warming potential (GWP 100)	$kgCO_2$ equivalent/t	8×10^3
Acidification potential (AP)	$kgSO_2$ equivalent/t	8.41×10
Photochemical ozone formation potential (POFP)	kg NMVOC equivalent/t	3.21
Respirable inorganics index (RI)	Kg PM2.5 equivalent/t	1.55×10

Based on Table 3, the contribution of glass wool product on environmental impact at each life cycle stage is analyzed.

Table 4 Corresponding contribution of it glass wool product on environmental impact at each life cycle Stage.

Name	GWP	RI	POFP	AP	PED
Natural gas	1.80E-05	8.56E-07	6.51E-06	5.66E-07	1.28E-06
Sodium carbonate	1.65E-01	3.45E-01	1.19E-01	5.27E-01	1.67E-01
Sodium carbonate transport	3.18E-04	6.34E-04	4.87E-03	6.16E-04	2.21E-04
Grid power	4.88E-01	3.94E-01	4.99E-01	2.46E-01	4.95E-01
Borax	3.44E-01	2.53E-01	3.46E-01	2.21E-01	3.34E-01
Borax transport	1.20E-03	2.49E-03	2.88E-03	9.59E-04	1.08E-03
Cullet transport	1.82E-03	3.64E-03	2.79E-02	3.53E-03	1.27E-03

According to Table 4, the contributions of natural gas, borax transport, sodium carbonate transport and cullet transport on environmental impact are less than 1% and may not be counted into environmental impact assessment according to the principle of acceptance or rejection.

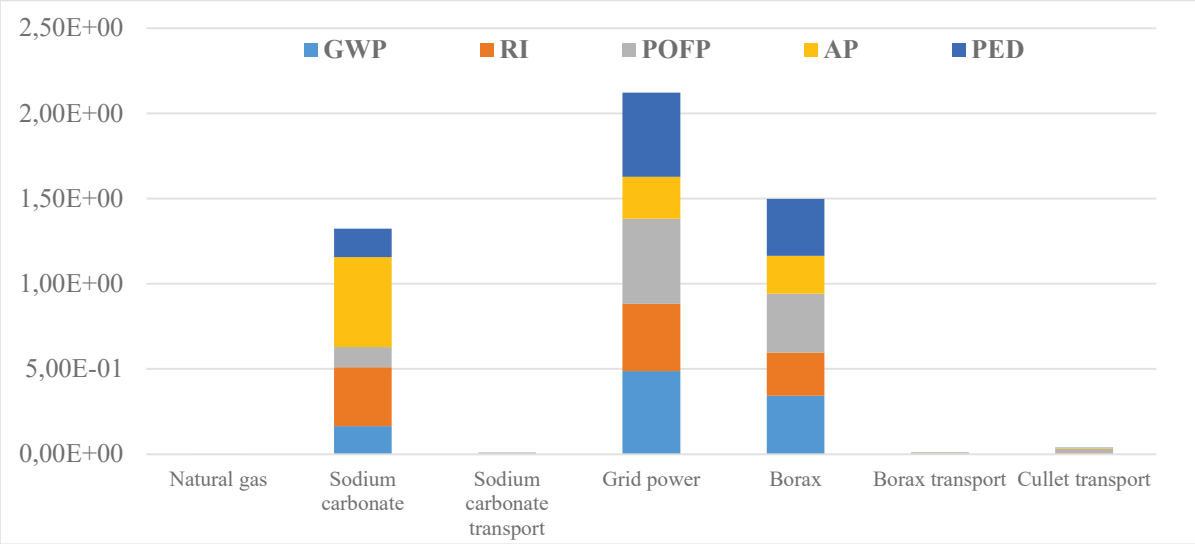

Fig. 3 Corresponding contribution of 1t glass wool product on environmental impact at each life cycle stage.

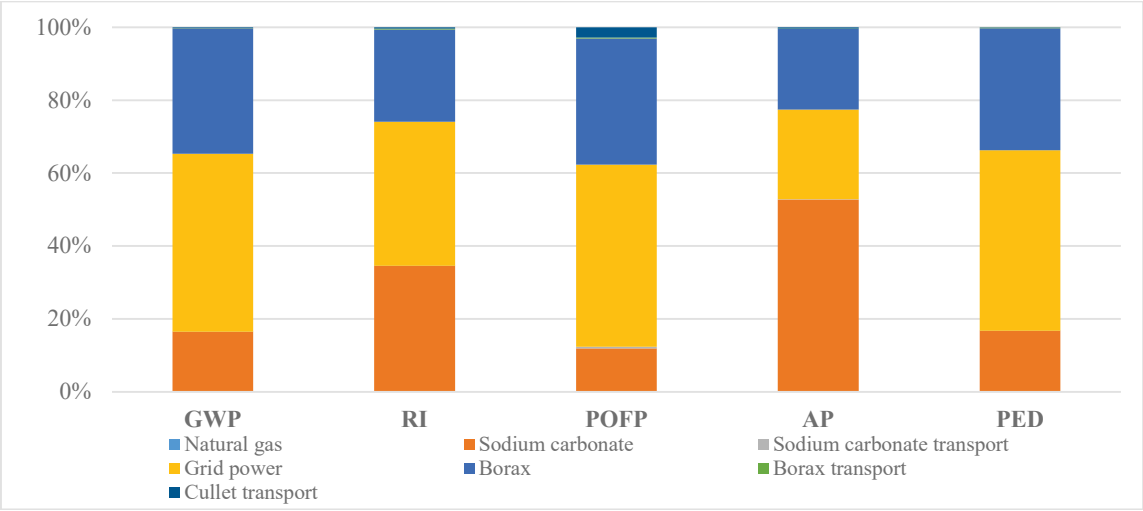

Fig. 4 Corresponding contribution of 1t glass wool product on environmental impact at each life cycle stage.

Fig. 3 and Fig. 4 show that: The environmental impact of glass wool in life cycle mainly comes from the energy consumption during production process; the environmental impact proportion of the resulting greenhouse effect is 49%, that of photochemical ozone formation potential, acidification and respirable inorganics are 50%, 25% and 39% respectively. Therefore, optimizing the production technology of glass wool and taking energy conservation and emission reduction measures to reduce energy consumption are very important for reducing the environmental impact of glass wool product in life cycle.

Conclusions

(1) The current environmental load situation of typical glass wool in China is analyzed by life cycle assessment method, and calculated with eBalance software. The functional units of typical glass wool product in China are: 1.12×10^5 MJ/t primary energy demand (PED), 8×10^3 kg CO_2 equivalent/t global warming potential (GWP 100), 8.41×10kg SO_2 equivalent/t acidification potential (AP), 3.21kg NMVOC equivalent/t photochemical ozone formation potential (POFP), 15.5kg PM2.5 equivalent/t respirable inorganics index (RI) and 2.02×10^{-6} CTUh toxicity to human - carcinogenic (CTU) respectively.

(2) For the glass wool product in China, energy production (including coke, electricity and diesel oil) is an important stage for the environmental impact in life cycle; the main raw material of glass wool is cullet whose environmental impact only takes the power consumption and water consumption during the recovery process into consideration, so the environmental impact of product in exploitation stage is small. The key to improve the overall environment performance of glass wool is to raise energy efficiency, reduce energy consumption and develop new combustion technology.

(3) The stage of glass wool production will generate the greatest greenhouse effect and the carbon emission in this stage accounts for more than 50% of the total carbon emission. Therefore, to reduce the greenhouse effect of glass wool in life cycle, effective ways that can be taken include reducing the energy consumption at production stage, raising energy combustion efficiency, and using advanced combustion technology.

Acknowledgements

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