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LIFE CYCLE INVENTORY

FOAMGLAS®
PITTSBURGH CORNING (SCHWEIZ) AG

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1. INTRODUCTION

FOAMGLAS® is a thermal insulation product manufactured and distributed throughout the world by Pittsburgh Corning Europe (PCE) und Pittsburgh Corning Corporation. FOAMGLAS® is produced in the form of slabs and pre-cut shapes. It is chiefly used as an insulation material throughout the building industry in addition to being employed for a range of specialized industrial applications. The main application areas in buildings are: flat roofs, underground walls, floors and terraces/car park decks. For the European market, FOAMGLAS® is produced at three production sites in Tessenderlo (BE), Schmiedefeld (D) and Klasterec (CZ). In 2005, the production site in Tessenderlo produced approximately 320'000 m^3 of FOAMGLAS® products of varying densities. This corresponds to 39'200'000 kg FOAMGLAS® products per year when calculating with an average density of 122.5 kg/m^3. Of this amount, approximately 70'000 m^3 were delivered to Switzerland, including Lichtenstein, and 7'700 m^3 were delivered to Austria.

In terms of quantity, the main product is the FOAMGLAS® board, T4 WDS, which is used for roof insulation (e.g. compact roof systems). Because of its industry prevalence, the T4 WDS production process can be regarded as being representative for all FOAMGLAS® products. 95% of the European consumption of this FOAMGLAS® board is produced in Tessenderlo. A negligible 5% is produced at the site in Germany. The market share of FOAMGLAS® products on the foam glass market for flat roof insulation in Europe is nearly 100%. Electricity use for the production volume delivered to Switzerland, France, the Netherlands and Austria, is covered by renewable energy certificates.

OBJECTIVE

Current environmental data cited in the ecoinvent inventory database[1], which is used to assess the environmental impact of buildings and building components by architects, building contractors and building authorities, no longer reflect the present environmental impact of the foam glass production process in Europe. For this reason, an updated inventory has been designed which shall in future replace the old life cycle inventory in the ecoinvent[2] database. It will focus on the publication of reliable and adequate inventory data in compliance with the ISO 14040 series without comparative assertions. The life cylcle inventory (LCI) covers the production of FOAMGLAS® from cradle to gate[3] including upstream processes.

Data ascertainments were conducted by collaborators of Pittsburgh Corning Europe in Tessenderlo in cooperation with BAU- UND UMWELTCHEMIE Beratungen + Messungen AG. An accompanying external critical review according to ISO 14040:1997 §7.3.1 was carried out by

1 ecoinvent Centre, ecinvent data, V1.2, Final reports ecoinvent 2000, March 2005

2 ecoinvent Centre, ecinvent data, V1.2, Final reports ecoinvent 2000, March 2005, listed dataset with the index number 1114

3 Production of raw and auxilary materials, power supply, disposal and transports before the final product leaves the production site.

EMPA[4]. EMPA had full access to the data considered in this study which is required for data validation and for a future integration in the ecoinvent database.

The presented data collection on raw materials is based chiefly on measurements (e.g. raw materials and packing materials) at the production facility in Tessenderlo. Energy consumption is measured by gas and electricity meters and is cross-checked with theoretical calculations. Data on the wear-and-tear of parts and material quality were obtained from delivery orders and from their yearly consumption across the entire production volume. Transport distances include transport from the supplier to the production facility. All data are average values for the overall production of this product per year.

Modelling principles according to ecoinvent-report 1 are used. All data, assumptions, units, energy and emission considerations and naming rules are implemented as proposed in this report. Transport distances are calculated according the chapter Transport services in ecoinvent-report No. 1[5].

Background data for upstream processes, raw material, power supply and disposal services etc. are taken from ecoinvent v.1.2.

4 Swiss Federal Laboratories for Materials Testing and Research

5 ecoinvent-report no. 1, overview and methodology, Data V. 1.2, 2004

2. RESERVES, RESOURCES AND RAW MATERIALS

FOAMGLAS® insulation materials are made from recycled, mechanically cleaned float-glass (68%) and feldspar (25%) in raw material quality. Small amounts of salt cake, soda ash, iron oxide, manganese oxide, sodium nitrate and carbon black - all in technical grade quality - are added to the raw material mix. Electricity is used for the melting process and raw mix production. Natural gas is used for the production process.

Further information on the reserves and resources of FOAMGLAS® raw materials can be found in part I on gravel products and part VII on lime products in the ecoinvent report no. 7.

PHYSICAL PROPERTIES

The product inventoried in this study is an insulation slab 40 mm to 200 mm in thickness with a thermal conductivity λ_R of 0.040 W/mK and a density of 110 kg/m^3.

CHEMICAL PROPERTIES

FOAMGLAS® consists of glass (>99% by weight) and small amounts of hydrogen sulphide and carbon dioxide. The product is resistant to rodents, vermin and insects, as well as being rot proof, resistant to ageing, resistant towards acids (except hydrofluoric acid) and chemical substances, especially organic solvents.

3. SYSTEM CHARACTERISATION

The system boundary considered for this inventory is shown in Fig. 1 and Annex I. The inventory data for FOAMGLAS® is based on production values for 2005 and represents the product T4 WDS which is one of a number of different FOAMGLAS® products manufactured in Tessenderlo, Belgium with a density of 110 kg/m^3. In terms of quantity, T4 WDS is the most important FOAMGLAS® product and its manufacturing process is representative for FOAMGLAS® products. 95% of T4 WDS sold on the European market is produced in Tessenderlo. A negligible 5% is produced at the site in Germany.

Due to the market monopoly of FOAMGLAS® products in Europe, the technology employed at the production site in Belgium is the de facto, current technology for producing FOAMGLAS® in Europe.

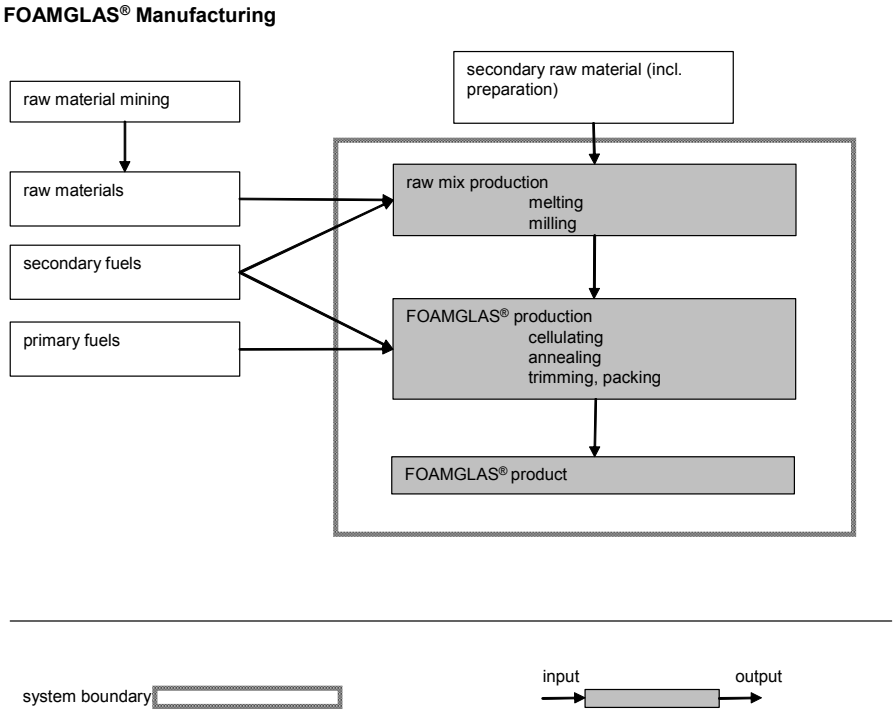

Fig. 1: System boundaries considered of the FOAMGLAS® production process

Over the past several years, the use of sand has been completely, if gradually, superseded by the use of recycled glass. Today, more than half of the recycled glass employed is directly injected in the ball mill (milling) without melting, allowing for a large reduction in energy input.

Details of the present manufacturing process are schematically shown in Fig. 2. The first step of the FOAMGLAS® production process consists of the raw mix production, a raw material conditioning process which includes the process-storage of raw materials in a silo, weigh batching of raw materials, melting of raw materials in an oven and milling in a ball mill. Raw materials such as: recycled glass, feldspar, iron oxide, salt cake, soda ash, manganese oxide, sodium carbonate and sodium nitrate are added to the melting furnace and heated to approximately 1250 ˚C. The melting furnace is an electronic furnace equipped with glass melting molybdenum electrodes. The molten glass flows from the melting oven into the continuously fed ball mill where the glass is rapidly ground to colloidal fineness (approximately 10 micron or finer) with the help of corundum cylinders as a grind medium. Another batch of crushed recycled glass is added to the ball mills without melting.

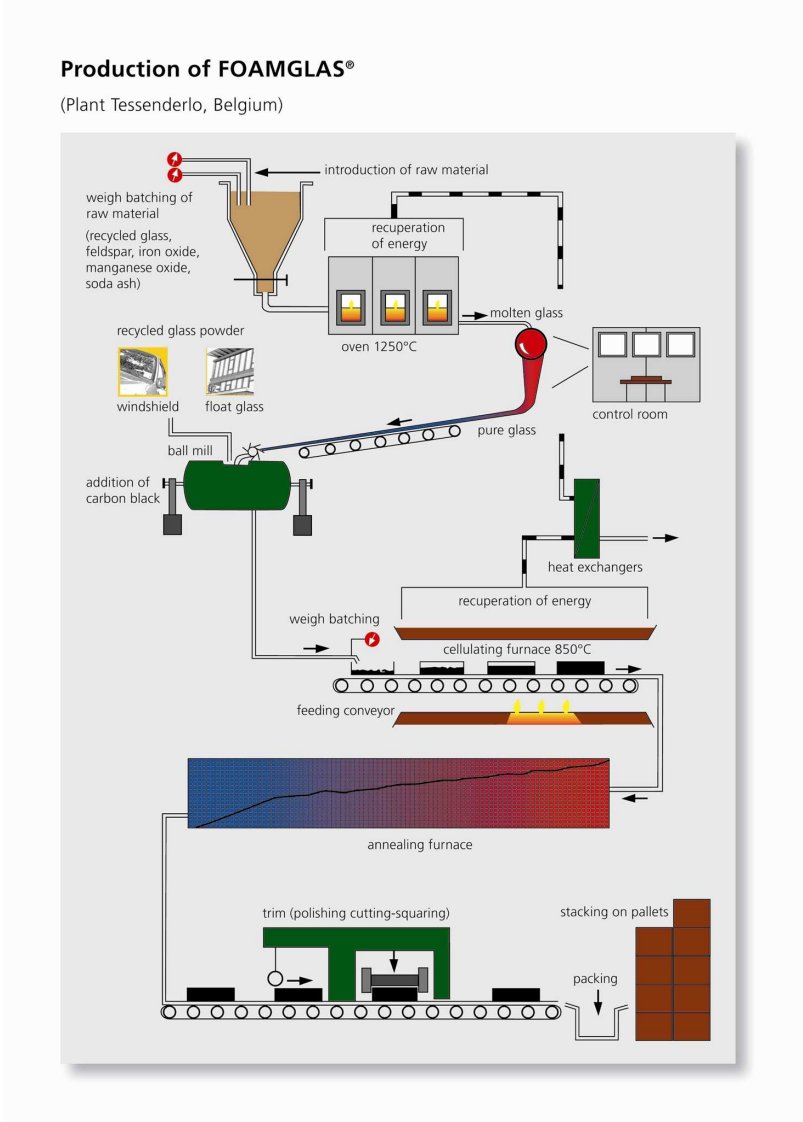

Fig. 2: Production process of FOAMGLAS® insulation material

During the second step - the virtual production process - the milled raw material mix undergoes a foaming procedure in steel moulds coated with clay and aluminium hydroxide at 850˚C in the

cellulating gas furnace (> 1000 kW) and is subsequently cooled down in the annealing furnace. Finally the cold foam glass cuboid is cut into pieces, packed and stored.

An overview of the raw materials and energy used to produce FOAMGLAS® is given in Table 1.

Table 1: Input of raw materials and energy input for 1kg of a FOAMGLAS® product

Raw materials	
Recycled glass	8.14E-01 kg
Feldspar	2.58E-01 kg
Soda ash	4.62E-02 kg
Iron oxide	2.77E-02 kg
Manganese oxide	2.62E-02 kg
Carbon black	6.15E-03 kg
Salt cake	5.38E-03 kg
Sodium nitrate	2.46E-03 kg
Energy	
Natural gas	1.16E+01 MJ
Electricity	1.83E+00 kwh
Diesel	9.62E-02 MJ
Heating oil	4.23E-02 MJ

Electricity and natural gas are the fuels used in the production of FOAMGLAS®. 63% of the electricity is consumed by the melting oven (compare Table 2). About 18.5 % is used for the grinding or milling process in the ball mills and some 18.5% is used for supplementary systems and processes such as trimming, packing and for storage. Natural gas is used solely for the cellulating and annealing furnace. Diesel fuel and heating oil is used for the operation of fork lifts and buildings.

Table 2: Electricity use for the production of 650 kg FOAMGLAS® T4WDS

Production step		**Electricity consumption**
Raw mix production	Oven (melting)	613 kwh
	Ball mill (milling)	180 kwh
FOAMGLAS® production	Supplementary systems and trimming, packing, storage	180 kwh
		Natural gas consumption
FOAMGLAS® production	Cellulating and annealing furnace	208 Nm^3

Heat emissions from the melting oven and annealing furnace are reused in the production process. The electricity used for FOAMGLAS® production is provided via both the local electricity grid and via renewable energy certificates which consist of 2.2% wind energy and 97.8% hydro power. These certificates are provided and controlled by the independent Renewable Energy Certificate System[6] (RECS) and sold in Tessenderlo by Fa. Electrabel[7]. The production facility in Tessenderlo currently has certificates for production for Switzerland, Austria, France and the Netherlands. Certificates which are reserved for products delivered to Switzerland and Austria are valid until at least 2009 and cover the use of electric power up to 20'000'000 kWh, corresponding to a production quantity of 90'000 m³ FOAMGLAS® products with an average density of 122.5 kg/m^3. In 2005, approximately 70'000 m^3 FOAMGLAS® products were delivered to Switzerland and 7700 m^3 to Austria[8].

At the production facility in Tessenderlo, production lines are split up as shown in Fig. 3 in accordance with the grinding process in the ball mill. The FOAMGLAS® production-line 11 produces solely for Switzerland and Austria which makes it easy to attribute the quantity of used, certified energy to respective products and countries.

6 http://www.recs.org

7 Renewable Energy Certificates are RECS (Renewable Energy Certificate System)-certified and delivered by Fa. Electrabel, Belgium

8 Pittsburgh Corning Europe, Personal communication, Hans Strauven, 2006

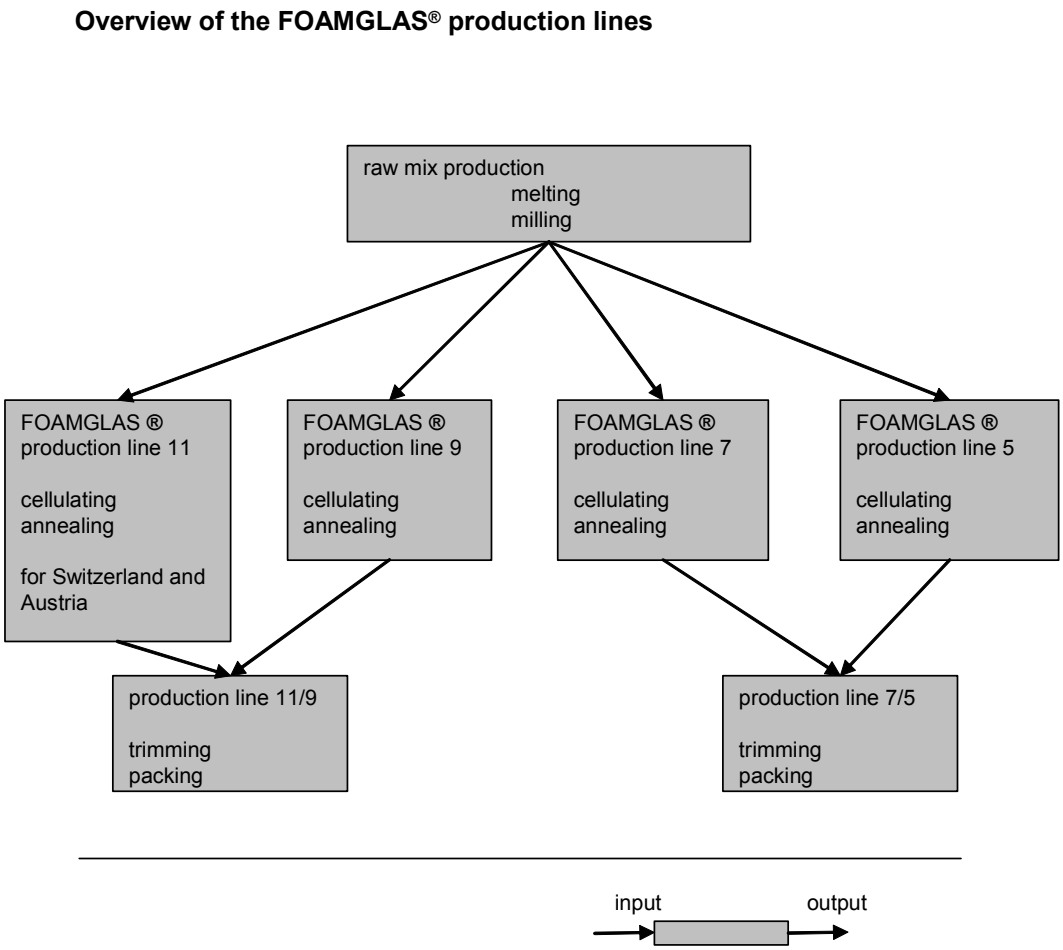

Fig. 3: Common and separated production steps for all countries at the production facility in Tessenderlo

TRANSPORTS

Most raw materials are produced by and purchased from suppliers in Europe. As a result, the transport of raw materials is chiefly done by 40 t lorries. A negligible amount is transported by train and ship, e.g. carbon black which comes from overseas. Transport distances for road transports are estimated and calculated by the use of a route planning system[9]. An overview of the transport distances is given in

Table 3.

[9] http://www.reiseplanung.de

Table 3: Overview of transport distances

Raw materials	Approximate transport distance with lorries
Recycled glass	100 km
Feldspar	350 km
Soda ash	75 km
Iron oxide	25 km
Manganese oxide	100 km
Sodium nitrate	75 km
Salt cake	1000 km
Carbon black	550 km
Aluminium hydroxide	625 km
Clay	150 km
PE-Foil	100 km
Cardboard	100 km
Pallet	35 km
	Approximate transport distance by barge
Carbon black	1150 km

PARTS: WEAR-AND-TEAR

In the FOAMGLAS® production process, a number of parts are subject to abrasion or corrosion and therefore need to be periodically replaced. Parts which must commonly be replaced include: molybdenum electrodes which are used for the melting process, corundum cylinders which serve as cylinder material for the milling process and the chromium steel moulds which are used for the foaming process. Abrasion of saw blades (97% Fe, 3% Cr) in the trimming process is included in the inventory but is of minor significance. The wear-and-tear of conveyors is too minimal to be of note[10].

PACKING

The packing facility consists of: conveyor belts, a foil machine and a shrink tunnel that is run on electric power. FOAMGLAS® T4 WDS are delivered to construction sites as shrink wrapped, PE-foil

[10] Pittsburgh Corning Europe, Hans Strauven, Personal communication, 2006

(LDPE), 0.135 m^3 parcels (measuring 0.5 m x 0.45 m x 0.6 m) with a corrugated cardboard cover element (0.45 m*0.6 m). The cardboard quality is a simple corrugated cardboard made from recycled fibres. The approximate net weight of a parcel is 14.85 kg. A delivery pallet usually includes 12 parcels with a net weight of 178.2 kg which are covered with a PE-foil sheet on the top and are wrapped with PE-foil (LDPE). For deliveries: 10 kg, pure softwood, one-way pallets are used instead of 22 kg EUR-flat pallets. Every fourth pallet comes back to the factory in good shape and can be reused, which results in a reuse frequency of 0.25 or a multiplication of the pallet use by 0.75 (compare Table 4).

Table 4 shows the packing materials used for one ready-for-delivery pallet.

Table 4: Packing materials used for one ready for delivery pallet of FOAMGLAS® T4 WDS measured by weight

Packing Material	kg per parcel	Packing film per parcel	Thickness	Total per pallet
PE-shrink foil for parcel	0.133 kg	1.8 m^2	80E-6 m	1.596 kg
Cardboard	0.1015 kg	0.45 m * 0.6 m		1.218 kg
PE-foil sheet			100E-6 m	0.196 kg
PE-shrink foil for pallet			100E-6 m	0.786 kg
10 kg pure softwood one-way pallet				7.5 kg

Electrical heating is used for shrink wrapping of FOAMGLAS® parcels. For the pallet packing elastic PE-foil is applied without heating.

WATER AND AIR USE

Processed air is used at every production step for supplementary systems. A mix of tap water and ground-water-derived industrial water (that is pumped at plant) are used in the oven, the ball mill as well as in the cellulating furnace. Table 5 shows the air and water use for the production of 650 kg FOAMGLAS®.

Table 5: Air and water use for the production of 650 kg FOAMGLAS®T4WDS

Water and air use	
Process air	2.75 Nm^3
Tab water	0.024 Nm^3
Industrial water	0.154 Nm^3

LAND-USE

The area used for the FOAMGLAS® production in Tessenderlo is approximately 0.17 km^2. Of that, 62'926 m^2 is vegetation, 44'197 m^2 is traffic area and 63'939 m^2 is industrial space with buildings. Land occupation is calculated by dividing the total area (0.17 km^2) by the total amount of FOAMGLAS® products per year on the occupied area (39'200'000 kg/a). Land transformation is

calculated by dividing the total area by the total life time production assuming a production of 39'200'000 kg/a over an estimated period of 50 years. Production halls occupy an area of 35'826 m^2 and the cubature of the multi-storey buildings is estimated to be about 5'400 m^3.

EMISSIONS TO AIR, WATER AND SOIL

Particulate matter (PM) is produced at different production steps: in the melting process, in the ball mill, in the cellulating furnace and during trimming. In the ball mill and the cellulating furnace no particulate matter emissions occur due to the re-circulation of unfiltered air in a closed loop system. The melting oven and trim station are equipped with sinter plate fabric filters from Herding[11] for emission control which perform better than 1 mg/m^3 air. Sinter plate fabric filters from Herding perform better than F9 Filters according to information from Herding. F9 Filters have a filtration efficiency for particulates > 2.5 µm higher than 99% in compliance with EN 779. Therefore pollutants of concern in the FOAMGLAS® production are particulate matter less than 2.5 micrometers and all emissions to air are assumed to be smaller than 2.5 µm. The particulates > 2.5 µm retained by the filter from the melting oven go into to the brick production (compare in Table 6 output to brick factory). The particulates retained by the filter of the trimming process which are mostly bigger than 20 µm are reused as raw material in the production process.

Table 6 shows data on maximum particulate matter emissions calculated from filter efficiency, ie. the retained amount of particulates which go to the brick factory or go back to the oven and the production volume in Tessenderlo. For the calculated particle size distribution in Table 6 granulomorphometric analysis data from the oven filter was used.

Table 6: Calculated particulate matter per kg FOAMGLAS® T4WDS

Particulate matter (PM)	**Oven**		**Trim**	
	kg		kg	
PM >10	9.34E-02	output to brick factory	2.29E-01	input to oven
PM10-PM2.5	6.24E-02	output to brick factory	1.53E-01	input to oven
<PM2.5 (fine dust)	1.47E-6	emissions to air	4.42E-05	emissions to air
Totale particulate matter (TPM)	1.56E-01		3.82-01	

Gaseous emissions to air occur either by the processing of raw materials from the melting of raw materials, cellulation and trimming or by emissions from combustion processes (i.e. heating and burning of fuels). Combustion emissions are the primary gaseous pollutants. Calculated emissions from processing raw materials are small and carbon dioxide emissions are in the order of 1-2% by

[11] Herding Filtertechnik, http://www.herding.ch, 2006

weight. Emissions from processing raw materials are indicated in the flow chart in the annex and do not include the emissions from burning processes as they are included there.

Waste water is treated at the communal waste water treatment facility with the exception of the elimination of aluminium-oxide which is filtered out at the production facility.

In the production process, solid waste accrues at different production steps. General waste such as steel, other metals, electronics, plastics, batteries and paper is gathered in different containers in the factory and recycled. Damaged moulds go back to the steel supplier, where they are repaired or recycled.

4. LIFE CYCLE MODULES IN ECOINVENT

In future, there will be three different modules available for FOAMGLAS® in the ecoinvent database.

- Foam glass at plant (RER)
- Foam glass at regional storage Switzerland (CH)
- Foam glass at regional storage Austria (A)

The foam glass at plant (RER) module will cover the cradle to gate analysis. It includes all pertinent information necessary to using the foam glass eco-data correctly. It shows all input and output flows of the product, the allocation to the modules in ecoinvent, the sources and the standard deviation for each datum. The dataset also includes data for administration, packing, solid waste, emissions from processing of raw material and the infrastructure, including its land-use, the buildings and the machines used.

The ecoinvent module foam glass at regional storage Austria (A) and Switzerland (CH) takes into account the use of renewable energy certificates which are attributed to the production volume of these countries. The certificates are reserved for the aforementioned countries and are not credited to the general module foam glass, at plant. The additional transport distances to the centre of distribution in Switzerland and Austria are taken into account as following. From BE-3980 Tessenderlo to Austria AT-4050 Traun 877 km was brought to account and 587 km to Switzerland CH-4702 Oensingen.

In general, the data quality of the datasets foam glass at plant is high due to the monopoly situation of the product FOAMGLAS® in Europe. The company Pittsburgh Corning Europe has been collecting data for the last three years and has been given full access to all data for this inventory update. Where data uncertainties occurred they were estimated with the help of the pedigree matrix and according to relevant ecoinvent documents.

5. ANNEX I

FOAMGLAS® material flow for 650 kg T4WDS