Life Cycle Assessment of Rock Wool Insulation

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commissioned by
Flumroc AG

Uster, Juni 2012

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Imprint

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Version	441_RockWool_v3.0, 27/06/2012 13:56:00

Abbreviations and Glossary

a	annum (year)
ARA	Abwasserreinigungsanlage; engl. wastewater treatment
CED	Cumulative Energy Demand
CH	Switzerland
GLO	Global average
GWP	Global warming potential
KBOB	Koordination der Bau- und Liegenschaftsorgane des Bundes
KVA	Kehrichtverbrennungsanlage; engl. municipal waste incineration
LCA	life cycle assessment
LCI	life cycle inventory analysis
LCIA	life cycle impact assessment
NMVOC	non-methane volatile organic compounds
PE	Polyethylene
RER	Europe
tkm	ton kilometre, unit for transport services
UBP	Umweltbelastungspunkte; engl. eco-points

Summary

Flumroc is a rock wool producing company in Switzerland. The supply chain of the main feedstock, basalt, modelled in ecoinvent does not correspond to the latest technology anymore. An update of the basalt mining and the particle emissions of building machines equipped with particle filters is made. The new data is used to do an environmental impact assessment of the whole production chain of rock wool produced by Flumroc. The data on the production of rock wool are based on the latest company-internal ecobalance 2011.

The global warming potential, the total environmental impacts according to the Ecological Scarcity method 2006 as well as the cumulative energy demand of 1 kg of rock wool are determined. Two production stages are determined: "rock wool, at plant" and "rock wool, packed, at plant". This allows for the differentiation of the rock wool production itself and the additional activities such as the packing and the administration.

The updated life cycle assessment of rock wool shall be incorporated into the next version of the KBOB list 2009/1 which will be published presumably mid of 2012.

The production of 1 kg of rock wool causes 1.01 kg CO_2-eq greenhouse gas emissions and a total environmental impact of 1'023 eco-points (assessed with the ecological scarcity method 2006). The main drivers for both indicators are the direct emissions from the production plant as well as the feedstock (briquettes) and the hard coal coke used for the melting of the briquettes. The cumulative energy demand amounts to 15 MJ oil-eq/kg of rock wool produced. The hard coal coke dominates this indicator, followed by the energy consumption in the supply chains of some raw materials used in the process.

Compared to the environmental indicator results published in the KBOB list 2009/1, the environmental performance of the rock wool has improved. This is mainly due to a lower material intensity, the consumption of certified electricity (instead of the UCTE mix) and the revised particle emissions in the basalt mining resulting in considerably lower emissions.

Content

1 Introduction

1.1 Background

Flumroc is a rock wool producing company in Switzerland. The feedstock for rock wool is supplied from Swiss stone pits. The mining of basalt, as represented by the respective ecoinvent dataset, does neither reflect the latest technology nor Swiss conditions. For instance all the building machines and vehicles are equipped with particle filters nowadays. As the particle emissions contribute a significant part to the overall environmental performance of rock wool, Flumroc wants to adapt the data on the operation of building machines and vehicles in the basalt mining. Due to the differences mentioned, the basalt mining is revised and updated too.

Updated figures on the rock wool production by Flumroc are also available. In combination with the revised data on the supply chain Flumroc intends to update the assessment of the whole rock wool production chain.

1.2 Goal and Scope

This study aims for the adaption and the update of the inventory data on the rock wool production by Flumroc as well as the basalt mining, including the adaption of the particle emissions from building machines with particle filters. Based on the revised data, the whole production chain of rock wool is newly assessed and the environmental performance of rock wool is determined.

The functional unit of this study is 1 kg of packed rock wool at the plant.

A commercial LCA software (SimaPro, 7.3.3) is used to model the product system, to calculate the life cycle inventory and impact assessment results and to document the data (PRé Consultants 2012). Background data are represented by ecoinvent data v2.2 (ecoinvent Centre 2010).

The updated life cycle assessment of rock wool shall be incorporated into the next version of the KBOB list 2009/1 which will be published presumably mid of 2012.

1.3 Impact Assessment Methods

The following sets of indicators are used in this study:

1. Cumulative energy demand (CED)
2. Global Warming Potential 2007 (kg CO_2-eq)
3. Ecological Scarcity 2006 (UBP)

1.3.1 Cumulative Energy Demand (CED)

The CED (implementation according to Frischknecht et al. 2007b) describes the consumption of fossil, nuclear and renewable energy sources throughout the life cycle of a good or a service. This includes the direct uses as well as the indirect or grey consumption of energy due to the use of, e.g. plastics as construction or raw materials. This method has been developed in the early seventies after the first oil price crisis and has a long tradition (Boustead & Hancock 1979; Pimentel 1973). A CED assessment can be a good starting point in an environmental assessment due to its simplicity in concept and its easy comparability with CED results in other studies. However, it does not valuate environmental impacts and, as a consequence, cannot replace an assessment with the help of a comprehensive impact assessment method such as Ecological Scarcity 2006.

The following two CED indicators are calculated:

- CED, non-renewable (MJ oil-eq.) – fossil and nuclear
- CED, renewable (MJ oil-eq.) – hydro, solar, wind, geothermal, biomass

1.3.2 Global Warming Potential 2007 (GWP)

All substances that contribute to climate change are included in the global warming potential (GWP) indicator according to IPCC (Solomon et al. 2007). The residence time of the substances in the atmosphere and the expected immission design are considered to determine the global warming potentials. The potential impact of the emission of one kilogramme of a greenhouse gas is compared to the emission of one kilogramme CO_2 resulting in kg CO_2-equivalents. These so called global warming potentials are determined applying different time horizons (20, 100 and 500 years). The short integration period of 20 years is relevant because a limitation of the gradient of change in temperature is required to secure the adaptation ability of terrestrial ecosystems. The long integration time of 500 years is about equivalent with the integration until infinity. This allows monitoring the overall change in temperature and thus the overall sea level rise, etc.. In this study a time horizon of 100 years is chosen.

1.3.3 Ecological Scarcity 2006

The ecological scarcity method (Frischknecht et al. 2008) evaluates the inventory results on a distance to target principle. The calculation of the eco-factors is based on one hand on the actual emissions (actual flow) and on the other hand on Swiss environmental policy and legislation (critical flow). These goals are:

- Ideally mandatory or at least defined as goals by the competent authorities,
- formulated by a democratic or legitimised authority, and
- preferably aligned with sustainability.

The weighting is based on the goals of the Swiss environmental policy; global and local impact categories are translated to Swiss conditions, i.e. normalised. The method is applicable to other regions as well. Eco-factors were also developed for the Netherlands, Norway, Sweden (Nordic Council of Ministers 1995, Tab. A22 / A23), Belgium (SGP 1994) and Japan (Büsser & Frischknecht 2010; Miyazaki et al. 2004).

The ecological scarcity method allows for an *optimisation within the framework of a country's environmental goals*.

The environmental and political relevance is essential for the choice of substances. The environmental policy does by far not define goals for all potential pollutants and resources. Thus the list of eco-factors is limited. This particularly applies to substances with low or unknown environmental relevance in Switzerland and Europe (e.g. sulphate emissions in water bodies).

2 Life Cycle Inventory

2.1 Description of the Supply Chain

The inventory of the rock wool produced by Flumroc includes the production itself, the infrastructure as well as the packing of the rock wool products, the administration and the waste streams. As modelled in ecoinvent (Kellenberger et al. 2007), the production is divided into the rock wool production itself and the packaging of rock wool. The later also includes the administration and the waste treatment.

2.2 Manufacture of Rock Wool

The yearly output of Flumroc for the year 2011 in Switzerland is 57’412'523 kg. This includes the main products as mats and boards (55'838'291 kg) and fine granulated rock wool (1'574'232 kg).

The raw materials basalt and dolomite are no longer fed directly into the rock wool process as modelled in the current ecoinvent dataset. Nowadays, briquettes are fed to the process. The briquettes are produced externally. They consist of basalt, dolomite, cement and other additives. Furthermore, degraded material and wastes from the rock wool process as well as rock wool wastes from dismantled buildings are molten and processed into the briquettes (Fig. 2.1). The fabrication of the briquettes is modelled separately (Subchapter 2.3). In the dataset of rock wool manufacturing the transport of the briquettes to Flumroc is considered.

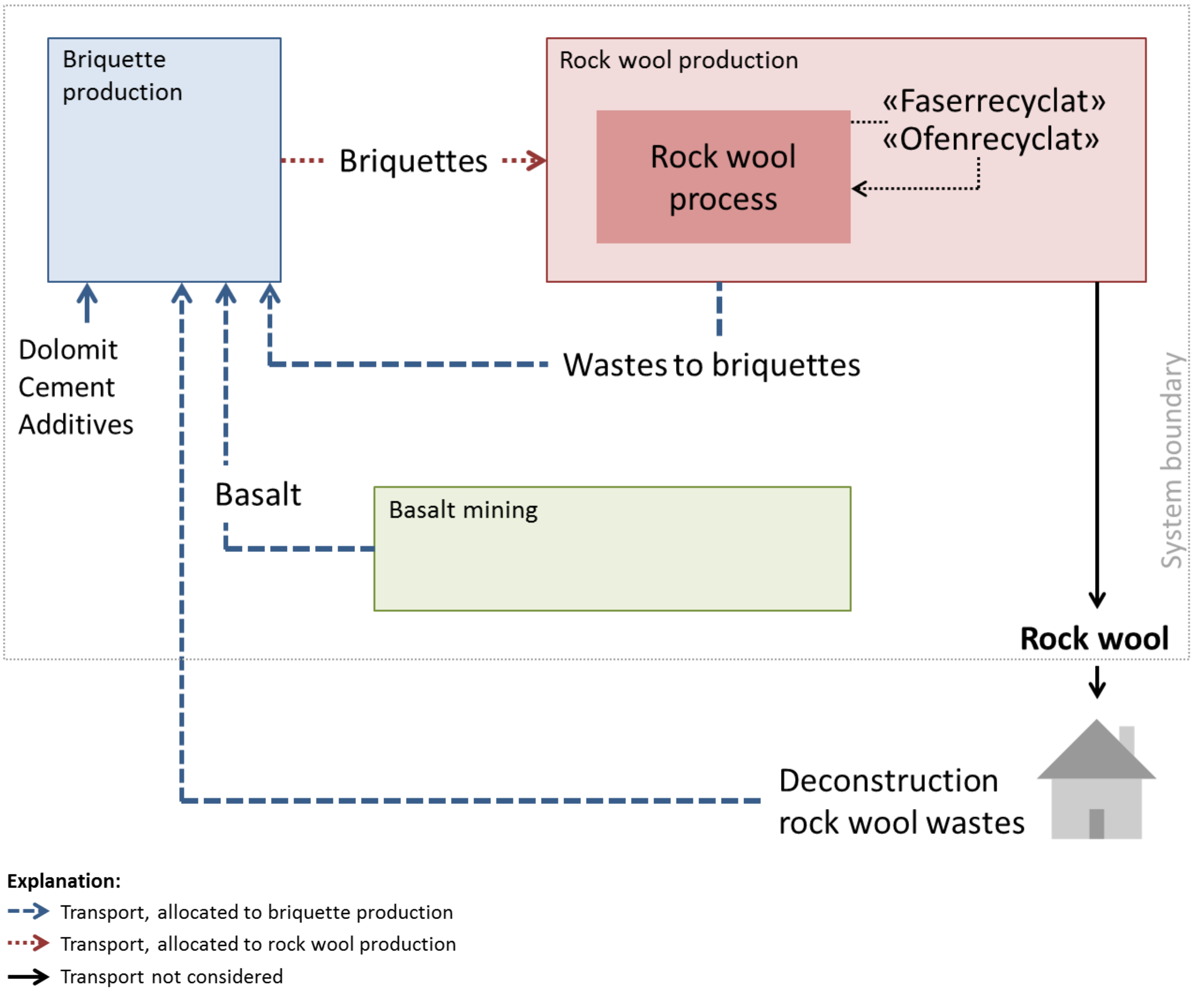

Fig. 2.1 Scheme of the material flows between basalt mining, the briquette production and the rock wool production. The reproduction is incomplete.

The energy and material balance is derived from data collected for Flumroc's annual corporate ecobalance[1]. The annual balance for 2011 is summarized in Tab. 2.1 to Tab. 2.4. It includes all materials and energy necessary for the production of rock wool. Furthermore the emissions to air and the final waste streams are considered. The transport services are based on transport distances specified by Flumroc[2] and on standard distances (Frischknecht et al. 2007a).

Flumroc consumes renewable electricity. As Flumroc cannot participate in the liberalised electricity market, they purchase electricity certificates (naturemade basic, ewz) in addition to the average electricity mix provided by the local electricity supplier.

The natural gas and electricity consumption are allocated to the two stages production and packaging according to the share of the position "Allgemein" on the total consumption of Flumroc.

The allocation of the dust to the different categories of particulate sizes is based on the "Emission Factor Documentation for Mineral Wool Manufacturing" (EPA 1998).

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1 Personal communication M. Mebold, Flumroc AG, April 2012

2 Personal communication M. Mebold, Flumroc AG, Mai 2012, Document LE-1005.xls

The CO_2 emissions derive not only from the burning of fossil energy carriers but also from the de-acidification of the dolomite. The latter contributes 8 % to the total CO_2 emissions.

Apart from rock wool, raw iron and district heat are produced in the rock wool fabrication by Flumroc. Both products are sold. The shares of the revenue from the raw iron sold and from the district heat sold on the total revenues from Flumroc are 0.5 % and 0.16 %, respectively[3]. The two outputs raw iron and district heat are therefore considered as by-product and leave the process without burdens. Thus the rock wool process is not modelled as multi-output process.

The infrastructure is modelled based on the ecoinvent datasets “rock wool, at plant” and “rock wool, packed, at plant” (Kellenberger et al. 2007).

[3] Personal communication M. Mebold, Flumroc AG, April 2012

Tab. 2.1 Energy and mass balance of the rock wool production for the reference year 2011. Part 1: inputs to the production system.

	Materials and energy flows Terms Flumroc	Unit (/year)	Amount	Allocation Rock wool (%)	Packed rock wool (%)	ecoinvent dataset name
Feedstock	Briketts	kg	62'975'620	100		briquette, Flumroc, at plant/CH
Energy	Elektrische Energie	kWh	16'996'500	60	40	electricity, medium voltage, certified electricity, at grid/CH
	Koks	MJ	312'775'291	100		hard coal coke, at plant/RER
	Heizöl		-			
	Dieselöl	MJ	2'455'881	100		diesel, burned in building machine/GLO
	Propangas (flüssig)		-			
	Erdgas	MJ	57'648'341	84	16	natural gas, high pressure, at consumer/CH
	Abfallholz		-			
Material input	Sauerstoff	kg	2'722	100		oxygen, liquid, at plant/RER
	Phenol	kg	1'212'260	100		phenol, at plant/RER
	Formaldehyd (37%ig)	kg	1'249'879	100		formaldehyde, production mix, at plant/RER
	Harnstoff	kg	75'870	100		urea, as N, at regional storehouse/RER
	Ammoniak (25%ig)	kg	37'606	100		ammonia, liquid, at regional storehouse/CH
	Ammoniumbicarbonat	kg	84'250	100		ammonium bicarbonate, at plant/RER
	Imprägnieröl	kg	129'353	100		lubricating oil, at plant/RER
	Gewerbesalz		-			
	Silan	kg	11'149	100		silane, at plant/RER
	Kalkhydrat	kg	67'200	100		lime, hydrated, packed, at plant/CH
	Salzsäure		-			
	Filtermaterialien		-			
	PE-Folien	kg	376'000		100	packaging film, LDPE, at plant/RER
	Einwegpaletten	unit	3'882		100	EUR-flat pallet/RER
	restl. Verpackungsmaterialien (Kartonboxen)	kg	41'300		100	corrugated board, mixed fibre, single wall, at plant/CH
	Alufolie	kg	29'490	100		aluminium, production mix, wrought alloy, at plant/RER & sheet rolling, aluminium/RER
	Glasflies	kg	30'900	100		glass wool mat, at plant/CH
	Kaschierungen	kg	146'720	100		kraft paper, unbleached, at plant/RER
	div. Konfektionsmaterial	kg	273'070	100		acrylic dispersion, 65% in H2O, at plant/RER
	Papier Administration	kg	4		100	paper, woodcontaining, LWC, at plant/RER
	Drucksachen	kg	93'988		100	paper, woodcontaining, LWC, at plant
	Reiniger	kg	510		100	alkylbenzene, linear, at plant/RER
Water input	Betriebswasser	m^3	250'130	100		Water, well, in ground
	Trinkwasser	kg	6'408'000		100	tap water, at user
Infra-structure	-	unit	0.025	100		rock wool plant/CH
	-	kg	100		100	industrial machine, heavy, unspecified, at plant/RER
Transport	-	tkm	6'736'227	>99	<0.1	transport, freight, rail/CH
	-	tkm	1'620'603	91	9	transport, lorry >28t, fleet average/CH

Tab. 2.2 Energy and mass balance of the rock wool production for the reference year 2011. Part 2: wastes.

	Materials and energy flows Terms Flumroc	Unit (/year)	Amount	Allocation Rock wool (%)	 Packed rock wool (%)	ecoinvent dataset name
Wastes	Haushaltsmüll (KVA)	kg	84'000		100	disposal, municipal solid waste, 22.9% water, to municipal incineration/CH
	flüssige Chemikalien		-			
	lösungsmittelhaltige Abfälle	kg	510		100	disposal, solvents mixture, 16.5% water, to hazardous waste incineration/CH
	Filtermaterialien		-			
	Altöl und Emulsionen	kg	1'180		100	disposal, used mineral oil, 10% water, to hazardous waste incineration/CH
	Reststoffdeponie		-			
	Inertstoffdeponie		-			
	Reaktordeponie		-			
Waste to recycling	Altpapier	kg	3'200		100	*Recycling, only transport considered*
	Drucksachen an Kunden	kg	93'985		100	*Output, only transport considered*
	Alufolienrecycling	kg	200	100		*Recycling, only transport considered*
	PE-Folienrecycling	kg	25'630		100	*Recycling, only transport considered*
Process waste	Kundenrecyclat		-			
	Abfälle für Brikettierung	kg	20'965'080			-
	Abfälle für Faserrecycling	kg	7'706'215			Internal use
	Abfälle f. Ofenrecycling	kg	984'910			Internal use
Waste water	Betriebswasser	kg	192'474'000	100		Water, to river
	Schmutzwasser (ARA)	m^3	26'460		100	treatment, sewage, to wastewater treatment, class 3
Emissions to soil	Direkte Bodenemissionen		-			

Tab. 2.3 Energy and mass balance of the rock wool production for the reference year 2011. Part 3: emissions from the production system. 100 % allocated to rock wool.

	Materials and energy flows Terms Flumroc	Unit (/year)	Amount	ecoinvent dataset name
Emissions to air	Luft		-	
	Feststoffe (Staub/Russ)	kg	3'669	Particulates (Allocation: 90 % <2.5 µm, 6 % >10 µm, 4 % >2.5 µm and <10 µm)
	Ammoniak	kg	31'787	Ammonia
	Arsen		-	
	Benzol		-	
	Blei	kg	3.4	Lead
	Cadmium	kg	0.55	Cadmium
	gasf. anorg. Chlorverb. (HCl)	kg	1'042	Hydrogen chloride
	Chrom	kg	0.27	Chromium
	gasf. anorg. Fluorverb. (HF)	kg	5.6	Hydrogen fluoride
	Formaldehyd	kg	5'410	Formaldehyde
	flücht. org. Kohlenwasserst. (VOC)	kg	152	NMVOC, non-methane volatile organic compounds, unspecified origin
	Kohlendioxid	kg	35'226'711	Carbon dioxide, fossil
	Kohlenmonoxid	kg	2'558	Carbon monoxide, fossil
	Kupfer	kg	0.52	Copper
	Nickel		-	
	Phenol	kg	7'435	Phenol
	Schwefeldioxid	kg	248'745	Sulfur dioxide
	Schwefelwasserstoff		-	
	Stickoxid	kg	60'461	Nitrogen oxides
	Wasser	kg	37'604'000	Water, CH
	Zink	kg	1.5	Zinc

Tab. 2.4 Waste heat from the rock wool production for the reference year 2011. 100 % allocated to rock wool.

Waste heat flows Terms Flumroc	Unit (/year)	Amount	ecoinvent module name
Abwärme für Raumheizung	MJ	4'000'000	*Internal use for heating*
Abwärme für Kupolofen	MJ	1'218'000	*Internal use for heating*
Abwärme Kühlwasser Seez	MJ	2'532'240	Heat, waste (to lake)
Abwärme Kupolofen-Vorwärmer		-	
Abwärme Kupolofen	MJ	21'344'400	Heat, waste (to air)
Abwärme Kühlbehälter	MJ	70'484'400	Heat, waste (to air)
Abwärme Sammelkammer	MJ	72'824'400	Heat, waste (to air)
Abwärme Härteofen	MJ	13'230'000	Heat, waste (to air)
Abwärme Kühlzone	MJ	11'383'200	Heat, waste (to air)
Oxidationsenthalpie CO		-	
Heisses Eisen / Schlacke	MJ	4'266'000	Heat, waste (to air)
Basalt Schmelzen	MJ	19'677'600	Heat, waste (to air)
Abwärme Produkt	MJ	2'541'600	Heat, waste (to air)
Abwärme Spinnradkühlwasser	MJ	22'449'600	Heat, waste (to air)
Abwärme Verpackung	MJ	3'772'800	Heat, waste (to air)
Abwärme Zeitausbeute, Anfahren, Stop	MJ	4'179'600	Heat, waste (to air)
Konvektion / Strahlung	MJ	2'019'600	Heat, waste (to air)
Trocknung Rohmaterial	MJ	9'187'200	Heat, waste (to air)

Tab. 2.5 Transport distances applied for different materials.

Materials and energy flows Terms Flumroc	**Distance Train** (km)	**Distance Lorry** (km)	**Source**
Briketts	-	19	Flumroc[4]
Koks	535		
Heizöl			
Dieselöl			
Propangas (flüssig)			
Erdgas			
Abfallholz			
Phenol	161		
Formaldehyd	506		
Harnstoff	584		
Ammoniak	342		
Ammoniumbicarbonat		168	
Imprägnieröl		857	
Gewerbesalz		258	
Silan			
Kalkhydrat		12	
Salzsäure			
Filtermaterialien			
PE-Folien		128	
Einwegpaletten		130	
restl. Verpackungsmaterialien (Karton-boxen)		125	
Alufolie		219	
Glasflies		405	
Kaschierungen		784	
div. Konfektionsmaterial		76	
Papier Administration		784	
Drucksachen		784	
Sauerstoff	100	50	Standard transport distances according to Frischknecht et al. (2007a)
Reiniger	600	50	
Municipal solid waste	-	10	
Hazardous waste	-	50	
Recycling material	-	50	

The unit process raw data of the rock wool production and the packaging are presented in Tab. 2.6 and Tab. 2.7.

4 Personal communication M. Mebold, Flumroc AG, Mai 2012, Document LE-1005.xls

Tab. 2.6: Unit process raw data of rock wool production.

	Name	Location	Unit	rock wool, Flumroc, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location			CH			
	InfrastructureProcess			1			
	Unit			kg			
product	rock wool, Flumroc, at plant	CH	kg	1			
technosphere	briquette, Flumroc, at plant	CH	kg	1.10E+0	1	1.24	(3,1,1,1,1,5,BU:1.05); Briketts, als Rohstoff, extern hergestellt; Flumroc
	acrylic dispersion, 65% in H2O, at plant	RER	kg	4.76E-3	1	1.24	(3,1,1,1,1,5,BU:1.05); div. Konfektionsmaterial; Flumroc
	aluminium, production mix, wrought alloy, at plant	RER	kg	5.14E-4	1	1.24	(3,1,1,1,1,5,BU:1.05); Alufolie; Flumroc
	ammonia, liquid, at regional storehouse	CH	kg	6.82E-4	1	1.24	(3,1,1,1,1,5,BU:1.05); Ammoniak, in Zerfaserung; Flumroc
	ammonium bicarbonate, at plant	RER	kg	1.47E-3	1	1.24	(3,1,1,1,1,5,BU:1.05); Ammoniumbicarbonat, in Zerfaserung; Flumroc
	diesel, burned in building machine	GLO	MJ	4.28E-2	1	1.24	(3,1,1,1,1,5,BU:1.05); Dieselöl; ecoinvent assumption: 50% for internal transports, 50% for fork lift; Flumroc
	electricity, medium voltage, certified electricity, at grid	CH	kWh	1.78E-1	1	1.24	(3,1,1,1,1,5,BU:1.05); elektrische Energie (60% Produktion, 40% Verpackung); Flumroc
	formaldehyde, production mix, at plant	RER	kg	2.18E-2	1	1.24	(3,1,1,1,1,5,BU:1.05); Formaldehyd, in Zerfasern; Flumroc
	glass wool mat, at plant	CH	kg	5.38E-4	1	1.24	(3,1,1,1,1,5,BU:1.05); Glasfliess; Flumroc
	hard coal coke, at plant	RER	MJ	5.45E+0	1	1.24	(3,1,1,1,1,5,BU:1.05); Koks, in Schmelzen; Flumroc
	kraft paper, unbleached, at plant	RER	kg	2.56E-3	1	1.24	(3,1,1,1,1,5,BU:1.05); Kaschierungen; Flumroc
	lime, hydrated, packed, at plant	CH	kg	1.17E-3	1	1.24	(3,1,1,1,1,5,BU:1.05); Kalkhydrat, in Zerfasern; Flumroc
	lubricating oil, at plant	RER	kg	2.25E-3	1	1.24	(3,1,1,1,1,5,BU:1.05); Imprägnieröl, in Zerfasern; Flumroc
	natural gas, high pressure, at consumer	CH	MJ	8.43E-1	1	1.24	(3,1,1,1,1,5,BU:1.05); Erdgas (83% Produktion, 17% Verpackung); Flumroc
	oxygen, liquid, at plant	RER	kg	4.74E-5	1	1.24	(3,1,1,1,1,5,BU:1.05); Sauerstoff, in Schmelzen; Flumroc
	phenol, at plant	RER	kg	2.11E-2	1	1.24	(3,1,1,1,1,5,BU:1.05); Phenol, in Zerfasern; Flumroc
	rock wool plant	CH	unit	4.43E-10	1	3.06	(3,1,1,1,1,5,BU:3); Infrastruktur; Flumroc
	sheet rolling, aluminium	RER	kg	5.14E-4	1	1.24	(3,1,1,1,1,5,BU:1.05); Alufolie; Flumroc
	silane, at plant	RER	kg	1.94E-4	1	1.24	(3,1,1,1,1,5,BU:1.05); Silan; Flumroc
	transport, freight, rail	CH	tkm	1.20E-1	1	2.09	(4,5,na,na,na,na,BU:2); Transport Materialien zu Flumroc; Flumroc, standard distances
	transport, lorry >28t, fleet average	CH	tkm	2.58E-2	1	2.09	(4,5,na,na,na,na,BU:2); Transport Materialien zu Flumroc und Entsorgung/Recycling Abfälle; Flumroc, standard distances
	urea, as N, at regional storehouse	RER	kg	6.01E-3	1	1.24	(3,1,1,1,1,5,BU:1.05); Harnstoff, in Zerfasern; Flumroc
resource, in water	Water, well, in ground	-	m3	4.36E-3	1	1.24	(3,1,1,1,1,5,BU:1.05); Betriebswasser; Flumroc
emission water, river	Water	-	kg	3.35E+0	1	1.58	(3,1,1,1,1,5,BU:1.5); Abfluss Wasser; Flumroc
emission water, lake	Heat, waste	-	MJ	4.41E-2	1	1.24	(3,1,1,1,1,5,BU:1.05); Abwärme Kühlwasser Seez; Flumroc
emission air, unspecified	Water, CH	-	kg	6.55E-1	1	1.58	(3,1,1,1,1,5,BU:1.5); Verdunstetes Wasser; Flumroc
emission air, low population density	Ammonia	-	kg	5.54E-4	1	1.32	(3,1,1,1,1,5,BU:1.2); Amoniak; Flumroc
	Cadmium	-	kg	9.52E-9	1	5.07	(3,1,2,1,1,5,BU:5); Cadmium, von Schmelzen; Flumroc
	Carbon dioxide, fossil	-	kg	6.14E-1	1	1.24	(3,1,1,1,1,5,BU:1.05); Kohlendioxid; Flumroc
	Carbon monoxide, fossil	-	kg	4.46E-5	1	5.07	(3,1,1,1,1,5,BU:5); Kohlenmonoxid, von Härten; Flumroc
	Chromium	-	kg	4.76E-9	1	5.07	(3,1,2,1,1,5,BU:5); Chromium, von Schmelzen; Flumroc
	Copper	-	kg	8.99E-9	1	5.07	(3,1,2,1,1,5,BU:5); Kupfer, von Schmelzen; Flumroc
	Formaldehyde	-	kg	9.42E-5	1	1.58	(3,1,1,1,1,5,BU:1.5); Formaldehyd, von Zerfasern; Flumroc
	Heat, waste	-	MJ	5.12E+0	1	1.30	(4,1,1,1,1,5,BU:1.05); Abwärme Produktion & Abwärme Stromverbrauch; Flumroc
	Hydrogen chloride	-	kg	1.81E-5	1	1.58	(3,1,1,1,1,5,BU:1.5); gasf. anorg. Chlorverb. (HCl); Flumroc
	Hydrogen fluoride	-	kg	9.73E-8	1	1.58	(3,1,1,1,1,5,BU:1.5); gasf. anorg. Fluorverb. (HF), von Schmelzen und Härten; Flumroc
	Lead	-	kg	5.92E-8	1	5.07	(3,1,2,1,1,5,BU:5); Blei; Flumroc
	Nitrogen oxides	-	kg	1.05E-3	1	1.58	(3,1,1,1,1,5,BU:1.5); Stickoxid; Flumroc
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	kg	2.65E-6	1	1.58	(3,1,1,1,1,5,BU:1.5); flücht. org. Kohlenwasserst. (VOC), Phenol and Formaldehyd separat;
	Particulates, < 2.5 um	-	kg	5.75E-5	1	3.09	(4,1,1,1,1,5,BU:3); Feststoffe (Staub/Russ), 90% ; Flumroc, EPA
	Particulates, > 10 um	-	kg	3.83E-6	1	1.62	(4,1,1,1,1,5,BU:1.5); Feststoffe (Staub/Russ), 6%; Flumroc, EPA
	Particulates, > 2.5 um, and < 10um	-	kg	2.56E-6	1	2.09	(4,1,1,1,1,5,BU:2); Feststoffe (Staub/Russ), 4%; Flumroc, EPA
	Phenol	-	kg	1.30E-4	1	1.58	(3,1,1,1,1,5,BU:1.5); Phenol; Flumroc
	Sulfur dioxide	-	kg	4.33E-3	1	1.24	(3,1,1,1,1,5,BU:1.05); Schwefeldioxid; Flumroc
	Zinc	-	kg	2.54E-8	1	5.07	(3,1,2,1,1,5,BU:5); Zink; Flumroc

Tab. 2.7 Unit process raw data of packed rock wool.

	Name	Location	Unit	rock wool, Flumroc, packed, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location			CH			
	InfrastructureProcess			1			
	Unit			kg			
product	rock wool, Flumroc, packed, at plant	CH	kg	1			
	electricity, medium voltage, certified electricity, at grid	CH	kWh	1.18E-1	1	1.24	(3,1,1,1,1,5,BU:1.05); elektrische Energie (60% Produktion, 40% Verpackung); Flumroc
	natural gas, high pressure, at consumer	CH	MJ	1.61E-1	1	1.24	(3,1,1,1,1,5,BU:1.05); Erdgas (83% Produktion, 17% Verpackung); Flumroc
	transport, freight, rail	CH	tkm	5.33E-6	1	2.09	(4,5,na,na,na,na,BU:2); Transport Materialien zu Flumroc; Flumroc, standard distances
	transport, lorry >28t, fleet average	CH	tkm	2.45E-3	1	2.09	(4,5,na,na,na,na,BU:2); Transport Materialien zu Flumroc und Entsorgung/Recycling Abfälle; Flumroc, standard distances
	alkylbenzene, linear, at plant	RER	kg	8.88E-6	1	1.24	(3,1,1,1,1,5,BU:1.05); Reiniger; Flumroc
	corrugated board, mixed fibre, single wall, at plant	CH	kg	7.19E-4	1	1.24	(3,1,1,1,1,5,BU:1.05); Restl. Verpackungsmat. (Kartonboxen); Flumroc
	disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	kg	1.46E-3	1	1.24	(3,1,1,1,1,5,BU:1.05); Haushaltsmüll (KVA); Flumroc
	disposal, solvents mixture, 16.5% water, to hazardous waste incineration	CH	kg	8.88E-6	1	1.24	(3,1,1,1,1,5,BU:1.05); lösungsmittelhaltige Abfälle; Flumroc
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	kg	2.06E-5	1	1.24	(3,1,1,1,1,5,BU:1.05); Altöl und Emulsionen; Flumroc
	disposal, packaging cardboard, 19.6% water, to municipal incineration	CH	kg	7.19E-4	1	1.24	(3,1,1,1,1,5,BU:1.05); Verpackungsmaterial; Flumroc
	EUR-flat pallet	RER	unit	6.76E-5	1	1.24	(3,1,1,1,1,5,BU:1.05); Einwegpaletten; Flumroc
	industrial machine, heavy, unspecified, at plant	RER	kg	1.74E-6	1	3.06	(3,1,1,1,1,5,BU:3); Infrastruktur Verpackung und Verfrachtung, Lebensdauer 20 Jahre; Flumroc
	paper, woodcontaining, LWC, at plant	RER	kg	1.64E-3	1	1.24	(3,1,1,1,1,5,BU:1.05); Papier Administration, Drucksachen; Flumroc
	packaging film, LDPE, at plant	RER	kg	6.55E-3	1	1.24	(3,1,1,1,1,5,BU:1.05); PE-Folien; Flumroc
	rock wool, Flumroc, at plant	CH	kg	1.00E+0	1	1.24	(3,1,1,1,1,5,BU:1.05); Steinwolle; Flumroc
	tap water, unspecified natural origin CH, at user	CH	kg	1.12E-1	1	1.24	(3,1,1,1,1,5,BU:1.05); Trinkwasser; Flumroc
	treatment, sewage, to wastewater treatment, class 3	CH	m3	4.61E-4	1	1.24	(3,1,1,1,1,5,BU:1.05); Abwasser, nach Umkehrosmose; Flumroc
emission air, low population density	Heat, waste	-	MJ	4.26E-1	1	1.30	(4,1,1,1,1,5,BU:1.05); Abwärme Produktion & Abwärme Stromverbrauch; Flumroc

2.3 Manufacture of Briquettes

The briquettes are the main feedstock for the rock wool production. They are produced from basalt, dolomite, cement and other additives. Degraded material and wastes from the rock wool process as well as rock wool wastes from dismantled buildings are added too.

The data derive from a questionnaire completed in 2008. The briquette producer confirms that the figures are still valid[5].

The basalt is supplied by two Swiss companies. The basalt mining is modelled separately, based on data from these two suppliers (Subchapter 2.4).

The additives are specified as ferrite and aluminium oxide. The product specifications show concentrations of 91 % Fe_2O_3 in the ferrite and 46 % of Al_2O_3 in the aluminium oxide. That corresponds to the materials “portafer, at plant” and “bauxite, at mine”, respectively, as modelled by ecoinvent.

The transport services of the rock wool recycling materials processed are allocated to the briquette production. The transport distance between the briquette producer and Flumroc is 20 km. For other transport services standard distances (Frischknecht et al. 2007a) are applied.

The infrastructure and the land use are not considered due to missing data.

The unit process raw data of the briquette production are presented in Tab. 2.6.

5 Personal communication, H. Vogt, Schollberg, March 2012.

Tab. 2.8: Unit process raw data of briquette production.

	Name	Location	Unit	briquette, Flumroc, at plant	UncertaintyType	StandardDeviation95%	GeneralComment
	Location			CH			
	InfrastructureProcess			0			
	Unit			kg			
product	briquette, Flumroc, at plant	CH	kg	1			
technosphere	dolomite, at plant	RER	kg	5.34E-2	1	1.24	(3,1,2,1,1,5,BU:1.05); Dolomit; Questionnaire supplier
	basalt, Flumroc, at mine	CH	kg	4.59E-1	1	1.24	(3,1,2,1,1,5,BU:1.05); Zernezer & Felsberger; Questionnaire supplier
	portafer, at plant	RER	kg	2.31E-2	1	1.30	(4,1,2,1,1,5,BU:1.05); Additive für Briketts: Eisenoxid; Questionnaire supplier, specifications, own assumption
	lime, hydrated, packed, at plant	CH	kg	9.03E-4	1	1.24	(3,1,2,1,1,5,BU:1.05); Weissfeinkalk/ calcium hydroxyde; Questionnaire supplier
	portland cement, strength class Z 42.5, at plant	CH	kg	9.45E-2	1	1.24	(3,1,2,1,1,5,BU:1.05); Zement für Briketts; Questionnaire supplier
	bauxite, at mine	GLO	kg	7.84E-2	1	1.30	(4,1,2,1,1,5,BU:1.05); Additive für Briketts: Aluminium Oxide (46%); Questionnaire supplier, specifications, own assumption
	electricity, medium voltage, at grid	CH	kWh	5.00E-3	1	1.24	(3,1,2,1,1,5,BU:1.05); Strom; Questionnaire supplier
	transport, freight, rail	CH	tkm	3.53E-2	1	2.09	(4,5,na,na,na,na,BU:2); Transport Material mit Zug; Standard distances, own assumptions
	transport, lorry >28t, fleet average	CH	tkm	4.22E-2	1	2.09	(4,5,na,na,na,na,BU:2); Transport Material, Kundenrecyklat (50km) und Abfälle aus Steinwollherstellung (20km) mit Lastwagen; Standard distances, own assumptions

2.4 Extraction of Basalt

Basalt is one of the main feedstock of the briquette production. It is purchased from Swiss suppliers.

The basalt supplied to the briquette production is modelled as weighted average of these suppliers even though they apply two different processes (surface and underground mining). All sites use the blasting technique. The rocks are then shipped to the respective gravel quarry where it is further broken and classified according to their size.

The data are collected from the suppliers by means of questionnaires. They refer to the activities of the year 2011. The production volume of the basalt mines analysed is several ten thousand tonnes each.

Neither of the suppliers specifies the total particle emissions. Therefore the particle emissions are modelled based on an adapted approach of Kellenberger et al. (2007). The adaption was necessary as the ecoinvent data show a deviation from the original data source (BUWAL 2001) by a factor of 100. According to BUWAL (2001) the total particle emissions from the limestone mining is 0.16 g/kg stone. Furthermore it states that 30 % of these emissions are

PM10 emissions. These figures are adopted in the basalt mining modelled in this study (see Tab. 2.9).

Tab. 2.9: Particle emissions from the basalt mining.

Particle emissions	Unit (/kg)	Amount
Total emissions	kg	1.60E-4
>PM10	kg	1.12E-4
<PM2.5	kg	8.00E-6
2.5<PM<10	kg	4.00E-5

The building machines used in the basalt mining are equipped with a particle filter. According to BUWAL (2000), the average effectivity of a particle filter is about 97.4 %. This factor is applied to the particle emission factor applied in the ecoinvent process “diesel, burned in building machine/GLO”. All other figures of that dataset are not changed.

The basalt suppliers provide data on the annual diesel consumption for different lorry categories. The transport services (tkm) are calculated based on the specific diesel consumption figures of the respective lorry categories provided by the different ecoinvent datasets (Spielmann et al. 2007).

The land transformation and occupation is calculated based on the assumption that the mining area is changed every 10 years (Kellenberger et al. 2007). The land use of underground basalt mining is obviously relatively low.

The unit process raw data of the average basalt mining are presented in Tab. 2.6.

Tab. 2.10: Unit process raw data of basalt mining.

	Name	Location	Unit	basalt, Flumroc, at mine	UncertaintyType	StandardDeviation 95%	GeneralComment
	Location			CH			
	InfrastructureProcess			1			
	Unit			kg			
product	basalt, Flumroc, at mine	CH	kg	1			
technosphere	explosives, tovex, at plant	CH	kg	2.97E-4	1	1.24	(3,1,2,1,1,5,BU:1.05); Sprengen; Questionnaire suppliers
	lubricating oil, at plant	RER	kg	7.53E-6	1	1.24	(3,1,2,1,1,5,BU:1.05); Öl für Motoren und Getriebe; Questionnaire suppliers
	electricity, low voltage, at grid	CH	kWh	2.16E-3	1	1.24	(3,1,2,1,1,5,BU:1.05); Strom; Questionnaire suppliers
	electricity, medium voltage, at grid	CH	kWh	7.95E-4	1	1.24	(3,3,2,1,1,5,BU:1.05); Strom für Aufbereitung; Questionnaire suppliers
	diesel, burned in building machine, with particle filter	GLO	MJ	3.35E-2	1	1.45	(4,3,4,2,3,5,BU:1.05); Diesel in Baumaschinen, MIT Partikelfilter; BUWAL 2000, own assumptions
	diesel, burned in diesel-electric generating set	GLO	MJ	2.56E-2	1	1.33	(3,3,2,1,3,5,BU:1.05); Heizöl für Stromproduktion im Berg; Questionnaire suppliers
	disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	kg	1.29E-5	1	1.24	(3,1,2,1,1,5,BU:1.05); Hausmüll; Questionnaire suppliers
	disposal, used mineral oil, 10% water, to hazardous waste incineration	CH	kg	7.27E-6	1	1.24	(3,1,2,1,1,5,BU:1.05); Altöl; Questionnaire suppliers
	building, hall	CH	m2	6.33E-7	1	3.09	(4,1,2,1,1,5,BU:3); Gebäude; Questionnaire suppliers
	tap water, at user	CH	kg	8.59E-3	1	1.24	(3,3,2,1,1,5,BU:1.05); Trinkwasser; Questionnaire suppliers
	transport, lorry 16-32t, EURO3	RER	tkm	1.44E-3	1	2.09	(4,5,na,na,na,na,BU:2); Für den Transport von Steinbruch nach Kieswerk; Questionnaire suppliers, own assumptions
	transport, lorry 16-32t, EURO5	RER	tkm	3.23E-3	1	2.09	(4,5,na,na,na,na,BU:2); Für den Transport von Steinbruch nach Kieswerk; Questionnaire suppliers, own assumptions
	transport, lorry >28t, fleet average	CH	tkm	1.15E-2	1	2.09	(4,5,na,na,na,na,BU:2); Für den Transport von Steinbruch nach Kieswerk; Questionnaire suppliers, own assumptions
resource, in ground	Basalt, in ground	-	kg	1.00E+0	1	1.24	(3,1,2,1,1,5,BU:1.05); Basalt;
resource, in water	Water, river	-	m3	9.91E-6	1	1.22	(4,3,1,1,1,1,BU:1.05); Flusswasser; Questionnaire suppliers
resource, land	Occupation, mineral extraction site	-	m2a	2.24E-4	1	1.62	(4,1,2,1,1,5,BU:1.5); assumed renewal phase: 10years; Questionnaire suppliers, own assumptions
	Occupation, industrial area, built up	-	m2a	3.19E-5	1	1.62	(4,1,2,1,1,5,BU:1.5); assumed lifespan: 50years; Questionnaire suppliers, own assumptions
	Transformation, from mineral extraction site	-	m2	2.02E-5	1	2.10	(4,1,2,1,1,5,BU:2); assumed renewal phase: 10years; Questionnaire suppliers, own assumptions
	Transformation, to mineral extraction site	-	m2	2.24E-5	1	2.10	(4,1,2,1,1,5,BU:2); assumed renewal phase: 10years; Questionnaire suppliers, own assumptions
	Transformation, from forest	-	m2	2.53E-6	1	2.10	(4,1,2,1,1,5,BU:2); assumed renewal phase: 10years; Questionnaire suppliers, own assumptions
	Transformation, to industrial area, built up	-	m2	6.38E-7	1	2.10	(4,1,2,1,1,5,BU:2); assumed lifespan: 50years; Questionnaire suppliers, own assumptions
air, high population density	Heat, waste	-	MJ	1.06E-2	1	1.24	(3,1,2,1,1,5,BU:1.05); Abwärme Strom; own assumption
	Particulates, < 2.5 um	-	kg	8.00E-6	1	3.18	(4,2,4,2,3,5,BU:3); Staubemissionen; 5%; BUWAL 2001
	Particulates, > 10 um	-	kg	1.12E-4	1	1.73	(4,2,4,2,3,5,BU:1.5); Staubemissionen; 70%; BUWAL 2001
	Particulates, > 2.5 um, and < 10um	-	kg	4.00E-5	1	2.19	(4,2,4,2,3,5,BU:2); Staubemissionen; 25%; BUWAL 2001

2.5 Disposal of Rock Wool

The disposal of rock wool describes the handling of the rock wool at the end of its lifespan, when the building is deconstructed. The disposal pathways and their shares are modelled based on assumptions. This is due to missing data.

In 1990 Flumroc produced roughly 40’000 tonnes of rock wool. Today the briquette manufacturer processes around 300 tonnes of rock wool waste from deconstruction sites.

Based on this ratio, it is assumed that roughly 1 % of the deconstructed rock wool is recycled. The rest is disposed in an inert material landfill.

Tab. 2.11: Unit process raw data of rock wool deconstruction waste treatment.

	Name	Location	Unit	disposal, rock wool, Flumroc, at plant	UncertaintyType	Standard Deviation 95%	GeneralComment
	Location			CH			
	InfrastructureProcess			1			
	Unit			kg			
product	disposal, rock wool, Flumroc, at plant	CH	kg	1			
technosphere	disposal, building, mineral wool, to final disposal	CH	kg	9.90E-1	1	1.68	(4,5,5,1,1,5,BU:1.05); Entsorgung in Deponie; 99% of rock wool deconstruction waste; own assumptions
	transport, lorry >28t, fleet average	CH	tkm	5.00E-4	1	2.09	(4,5,na,na,na,na,BU:2); Recycling, Verarbeitung zu Briketts; 1% of rock wool deconstruction waste; 50km; own assumptions

3 Cumulative Results and Interpretation

3.1 Overview

This chapter contains a description of selected cumulative results and their main drivers. All results are shown in Tab. 3.1 and in Fig. 3.1.

3.2 Global Warming Potential

The Global Warming Potential of the rock wool production is dominated by the direct emissions during the fabrication of the rock wool. They contribute over 60 % to the total greenhouse gas emissions, which amount to 1.01 kg CO_2-eq/kg rock wool. Around 10 % of the emissions are caused by the briquette fabrication. Further emissions are caused in the supply chain of hard coal, phenol and by the infrastructure (10 %, 8 % and 3 %, respectively).

The packing of the rock wool adds to the greenhouse gas emissions resulting in 1.03 kg CO_2eq/kg rock wool packed. The additional emissions are mainly caused in the supply chain of the PE foil.

3.3 Ecological Scarcity 2006

The production of one kilogram of rock wool results in a total of 1’023 eco-points. The emissions to the air have the highest contribution (90 %) followed by the two categories energy resources (5 %) and deposited waste (3 %). The emissions into surface water have a share of around 2 % too.

The main contribution in the production chain stems from the direct air emissions from the rock wool production site (41 %). The air emissions do not only include the greenhouse gas emissions but also the emissions of sulfur dioxide and nitrogen oxide. The phenol supply chain is the second biggest contributor. Around 21 % of the total environmental impact of rock wool is caused there. Hard coal contributes 13 % followed by the briquettes (10 %) and the production plant (7 %).

The environmental impacts of the packing of the rock wool derive mostly from the supply chain of the PE foil. Other contributions are minor. The total score is 1’051 eco-points per kilogram rock wool packed.

3.4 Cumulative Energy Demand

The total cumulative energy demand (CED) for the production of one kilogram of rock wool is 15.2 MJ. More than 90 % of the energy used is non-renewable. Hydropower is the most important renewable primary energy resource (6 %), followed by biomass (2 %). Other renewable sources have a minor share.

The main contributor to the total cumulative energy demand is the coke used for the melting of the briquettes (50 %). The phenol contributes 16 %, formaldehyde and the natural gas supply chain 7 % each. Around 5 % of the total CED is caused by the briquette production and the electricity supply, respectively.

The additional energy used in the packaging is mostly required in the production of the PE foil, in the electricity supply and in the paper production. One kilogram of rock wool packed has a CED of 16.7 MJ.

3.5 Summary of the Results

The results of the dominance analysis with regard to the indicators Global Warming Potential, Cumulative Energy Demand (total) and Ecological Scarcity are shown in Fig. 3.1 and Fig. 3.2. The graphs show the main contributors to the overall results of the rock wool production and the packed rock wool.

The direct emissions from the rock wool production site are very important with regard to the Global Warming Potential and the Ecological Scarcity of the rock wool (Fig. 3.1).

The energy used in the rock wool production contributes over 60 % to the total CED of rock wool and it is among the main contributors to the Global Warming Potential and to the Ecological Scarcity score. This considers only the energy supply chain of coke, natural gas and the electricity. The emissions from the burning of the energy carriers are accounted for in the direct emissions from the rock wool.

The infrastructure has a significant share in the final result of the Ecological Scarcity and a smaller one in the two other impact categories. The transport does not contribute significantly to any of the three indicators under study.

The briquette production is material and energy intense. The impacts of the briquette supply on the environmental performance of rock wool are therefore significant in all the impact categories considered.

The raw materials include the manufacturing and supply of all the materials and additives necessary for the production of rock wool (i.e. formaldehyde, phenol, aluminium foil, kraft paper, glass wool mat, dispersion, ammonia, ammonium bicarbonate, lime hydrated and urea). They are among the main contributors in all the impact categories considered.

The group of working materials used in the rock wool production do not cause large contribution among all the indicators under study. This group includes the manufacturing and supply of oxygen, silane and lubricating oil.

The packaging of the rock wool adds only a small fraction to the total environmental performance of packed rock wool (Tab. 3.1 and Fig. 3.2). The working materials (i.e. PE foil and the pallet) are the main contributors. The supply chain of the energy used in the packaging process is significant for the CED of the packed rock wool. However, it does not show up in the other impact categories. The transport, water use and the waste treatment of this production stage do not contribute significantly to the environmental performance of packed rock wool.

The disposal of the rock wool deconstruction waste is not considered in the dominance analysis. However, Tab. 3.1 shows that this stage causes minor environmental impacts compared to the rock wool production.

Tab. 3.1 Summary of the cumulative results of the rock wool production, packaging and its disposal.

Indicator	Unit (/kg)	Rock wool, at plant	Rock wool, packed, at plant	Disposal, rock wool
Global warming potential	kg CO_2-eq	1.01	1.03	0.01
Ecological Scarcity 2006	UBP	1023	1051	26.6
Total cumulative energy demand	MJ	15.2	16.7	0.39
Non-renewable energy demand	MJ	14.1	15.0	0.24
Renewable; hydro	MJ	0.85	1.31	0.002
Renewable; wood, solar and wind	MJ	0.27	0.39	0.0004

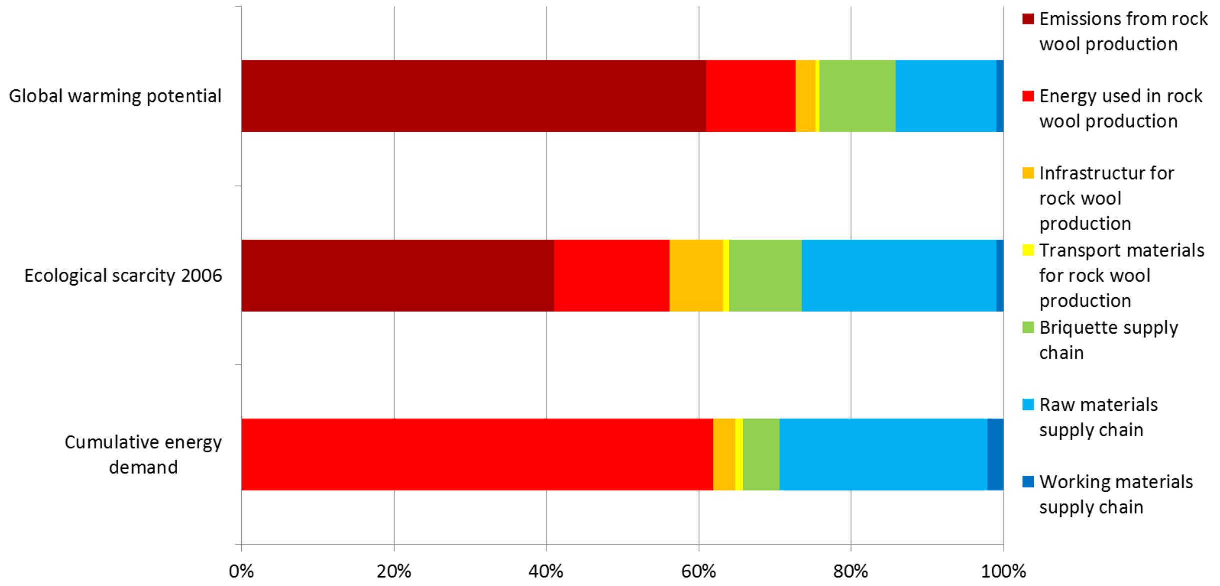

Fig. 3.1 Dominance analysis of the environmental impacts of 1 kg of rock wool produced by Flumroc. The results are scaled to 100 %.

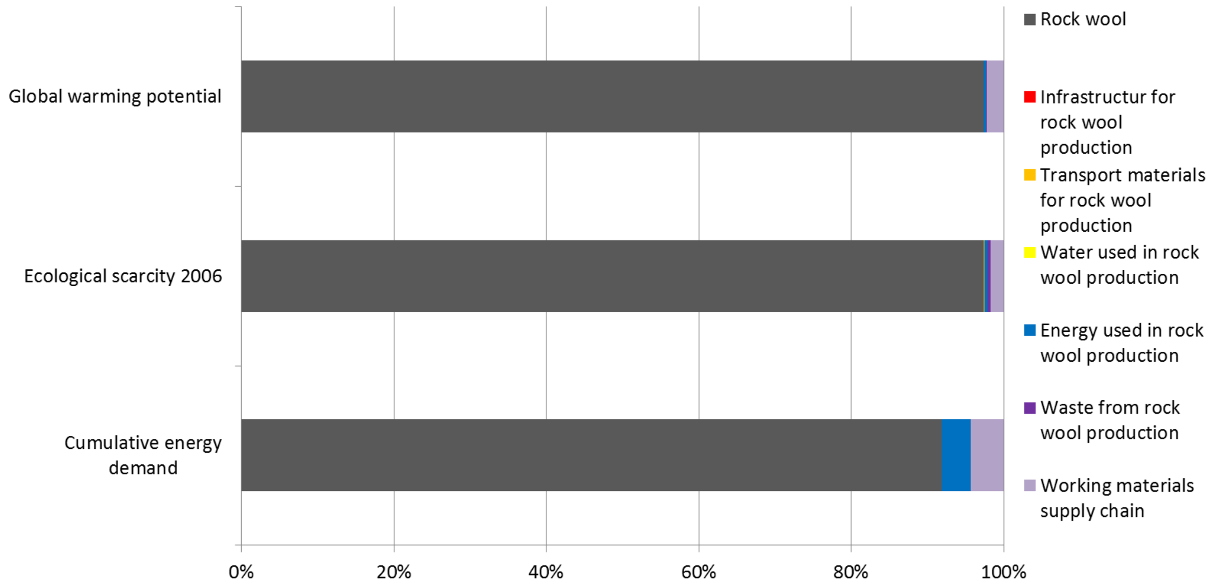

Fig. 3.2 Dominance analysis of the environmental impacts of 1 kg of packed rock wool. The results are scaled to 100 %.

3.6 Comparison to the KBOB list 2009/1, v2.2e

The comparison of the environmental indicator results of rock wool published in the KBOB list 2009/1, January 2011, with the results in this study shows a clear improvement in the environmental performance of the rock wool (see Tab. 3.2). There are several reasons for this development. The differences to the rock wool products modelled in ecoinvent v2.2 are discussed in the following. The second study (Flumroc 2009) is not available; the differences can therefore not be discussed in detail. Some major developments are also valid in this case though.

First of all there is a considerable reduction in the raw materials and working materials consumed, in the transport services as well as in the waste streams per kilogram rock wool produced. Only some materials are consumed in higher amounts than modelled in the ecoinvent process. Most emissions on the other hand have increased slightly. The emissions of carbon dioxide are 14 % higher than in the ecoinvent process. NMVOC, formaldehyde and particle emissions are lower than in the life cycle inventory of ecoinvent data v2.2.

There are two trends concerning the total greenhouse gas emissions. On one hand, the direct emissions from the rock wood production have increased; on the other hand, the material intensity of the rock wood production as well as of the briquette production (i.e. cement) have decreased. Furthermore, the electricity mix is changed from the UCTE mix modelled in ecoinvent to certified Swiss electricity with a much lower carbon intensity.

The developments described above have an impact on the total environmental performance of the rock wool too. However, the most considerable influence on the overall environmental impacts is due to the adjusted particle emissions in the basalt mining. While basalt mining and supply contributed more than 40 % to the cumulative environmental impacts of rock wool modelled in ecoinvent data v2.2, it contributes only little according to the new life cycle inventory presented in this study.

The change of the electricity mix as well as the considerable decrease in the diesel consumption affects the CED in a positive way. The total CED is lower; the demand for hydropower is higher. The slightly increased hard coal and natural gas consumption does hardly influence to total cumulative energy demand per kg rock wool.

Tab. 3.2 Comparison of the environmental impacts of rock wool analysed in this study to the results presented in KBOB list 2009/1, v2.2e.

Data source		This study		KBOB list 2009/1, v2.2e			
		Flumroc 2011		Ecoinvent 2.2		Flumroc 2009	
Indicator	**Unit (/kg)**	**Rock wool,**	**Rock wool, packed**	**Rock wool**	**Rock wool, packed**	**Rock wool**	**Rock wool, packed**
Global warming potential	kg CO_2-eq	1.01	1.03	1.08	1.13	1.05	1.10
Relative development previous to new				*-6.5 %*	*-8.8 %*	*-3.8 %*	*-6.4 %*
Ecological Scarcity 2006	UBP	1023	1051	2020	2080	1940	2000
Relative development previous to new				*-49 %*	*-49 %*	*-47 %*	*-47 %*
Total cumulative energy demand	MJ	15.2	16.7	na	na	na	na
Non-renewable energy demand	MJ	14.1	15.0	18.9	20.2.	15.1	16.5
Relative development previous to new				*-25 %*	*-25 %*	*-6.6 %*	*-9.1 %*
Renewable; hydro	MJ	0.85	1.31	0.52	0.54	1.35	1.38
Relative development previous to new				*+63 %*	*+143 %*	*-37 %*	*-5.1 %*
Renewable; wood, solar and wind	MJ	0.27	0.39	0.32	0.94	0.38	1.1
Relative development previous to new				*-15 %*	*-59 %*	*-29%*	*-65 %*

References

Boustead & Hancock 1979 Boustead I. and Hancock G. F. (1979) Handbook of Industrial Energy Analysis. Ellis Horwood Ltd., Chichester, England.

Büsser & Frischknecht 2010 Büsser S. and Frischknecht R. (2010) Ecological Scarcity Japan. ESU-services Ltd., Uster.

BUWAL 2000 BUWAL (2000) Partikelfilter für schwere Nutzfahrzeuge. Umwelt-Materialien Nr. 130. Bundesamt für Umwelt, Wald und Landschaft (BUWAL), Bern.

BUWAL 2001 BUWAL (2001) Massnahmen zur Reduktion der PM10-Emissionen. Umwelt-Materialien Nr. 136. Bundesamt für Umwelt, Wald und Landschaft (BUWAL), Bern.

ecoinvent Centre 2010 ecoinvent Centre (2010) ecoinvent data v2.2, ecoinvent reports No. 1-25. Swiss Centre for Life Cycle Inventories, Duebendorf, Switzerland, retrieved from: www.ecoinvent.org.

EPA 1998 EPA (1998) Emission factor documentation for AP-42 Section 11.18 Mineral Wool Manufacturing. United States Environmental Protection Agency, Research Triangle Park, retrieved from: http://www.epa.gov/ttn/chief/ap42/.

Frischknecht et al. 2007a Frischknecht R., Jungbluth N., Althaus H.-J., Doka G., Dones R., Heck T., Hellweg S., Hischier R., Nemecek T., Rebitzer G. and Spielmann M. (2007a) Overview and Methodology. ecoinvent report No. 1, v2.0. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.

Frischknecht et al. 2007b Frischknecht R., Jungbluth N., Althaus H.-J., Bauer C., Doka G., Dones R., Hellweg S., Hischier R., Humbert S., Margni M. and Nemecek T. (2007b) Implementation of Life Cycle Impact Assessment Methods. ecoinvent report No. 3, v2.0. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.

Frischknecht et al. 2008 Frischknecht R., Steiner R. and Jungbluth N. (2008) Methode der ökologischen Knappheit - Ökofaktoren 2006. Umwelt-Wissen Nr. 0906. Bundesamt für Umwelt (BAFU), Bern, retrieved from: www.bafu.admin.ch/publikationen/publikation/01031/index.html?lang=de.

Kellenberger et al. 2007 Kellenberger D., Althaus H.-J., Jungbluth N., Künniger T., Lehmann M. and Thalmann P. (2007) Life Cycle Inventories of Building Products. ecoinvent report No. 7, v2.0. EMPA Dübendorf, Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.

Miyazaki et al. 2004 Miyazaki N., Siegenthaler C., Schoenbaum T. and Azuma K. (2004) Japan Environmental Policy Priorities Index (JEPIX) - Calculation of Ecofactors for Japan: Method for Environmental Accounting based on the EcoScarcity Principle. 7. International Christian University Social Science Research Institute, Tokyo.

Nordic Council of Ministers 1995 Nordic Council of Ministers (1995) LCA-NORDIC technical report no. 10 and special reports no. 1-2., Kopenhagen.

Pimentel 1973 Pimentel D. (1973) Food Production and the Energy Crisis. In: Science, 182(4111), pp. 443-449.

PRé Consultants 2012 PRé Consultants (2012) SimaPro 7.3.3, Amersfoort, NL, retrieved from: www.esu-services.ch/simapro/.

SGP 1994 SGP (1994) Etude relative à la normalisation écologique des emballages en Belgique, raport final au ministre belge de la santé publique, de l'intégration sociale et de l'environnement, Liège.

Solomon et al. 2007 Solomon S., Qin D., Manning M., Alley R. B., Berntsen T., Bindoff N. L., Chen Z., Chidthaisong A., Gregory J. M., Hegerl G. C., Heimann M., Hewitson B., Hoskins B. J., Joos F., Jouzel J., Kattsov V., Lohmann U., Matsuno T., Molina M., Nicholls N., Overpeck J., Raga G., Ramaswamy V., Ren J., Rusticucci M., Somerville R., Stocker T. F., Whetton P., Wood R. A. and Wratt D. (2007) Technical Summary. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Spielmann et al. 2007 Spielmann M., Roberto Dones, Bauer C. and Tuchschmid M. (2007) Life Cycle Inventories of Transport Services. ecoinvent report No. 14, v2.0. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.