Department of Environmental and Energy Process Engineering
Montanuniversitaet Leoben
Franz-Josef-Straße 18
avaw.unileoben.ac.at
A-8700 Leoben

Accredited Laboratory according to ISO 17025

Preliminary Report

Recycling of Cooling and Freezing Appliances Containing Vacuum Insulation Panels (VIPs)

Client:

CECED – European Committee of Domestic Equipment Manufacturers
Blvd Brand Whitlock 114
1200 Brussels

Contact person: **Ms Kamila Slupek**

Agent:

Montanuniversitaet Leoben,
Department of Environmental and Energy Process Engineering
Chair of Waste Processing Technology and Waste Management (AVAW)
Franz-Josef-Straße 18
8700 Leoben

Contact Persons:
Univ.Prof.Dipl-Ing.Dr.mont. Roland Pomberger and **Dipl.Ing. Renato Sarc (PM)**

Magdalena Prommegger, BSc and **Stefan Eferdinger, BSc**

Leoben, 22.08.2013

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List of Abbreviations

%	percent
°C	degree Celsius; unit of temperature
AVAW	Waste Processing Technology and Waste Management; of German "Abfallverwertungs-technik und Abfallwirtschaft"
AWG	Austrian Waste Management Act; of German "Abfallwirtschaftsgesetz"
C&F	cooling and freezing
CECED	European Committee of Domestic Equipment Manufacturers; of French "Conseil Européen de la construction d'appareils domestiques"
CENELEC	European Committee for Electrotechnical Standardization; of French "Comité Européen de Normalisation Électrotechnique"
CFC	chlorofluorocarbon
cm	centimetre; unit of length
e.g.	for example; of Latin "exempli gratia"
EAG-VO	Austrian WEEE Ordinance; of German "Elektroaltgeräteverordnung"
EERA	European Electronics Recyclers Association
ElektroG	German WEEE Act; of German "Elektrogesetz"
EPA	Swiss Environmental Protection Act
etc.	and so on; of Latin "et cetera"
EU	European Union
EWC	European Waste Catalogue
GWP	global warming potential
HC	hydrocarbon
HCFC	hydro chlorofluorocarbon
HFC	hydro fluorocarbons
i.e.	that is; of Latin "id est"
kg	kilogramme; base unit of mass
KrWG	German Recycling Management Act; of German "Kreislaufwirtschaftsgesetz"
LLDPE	linear low density polyethylene
MG	material group
mm	millimetre; unit of length
ORDEE	Swiss Ordinance on the Return, the Take Back and the Disposal of Electrical and Electronic Equipment
ORRChem	Swiss Ordinance on Chemical Risk Reduction
PCB	polychlorinated biphenyl
PCT	polychlorinated terphenyl
PET	polyethylene terephthalate
PM	Project Manager
q.v.	which see; of Latin "quo vide"
QZ	cross flow crusher; of German "Querstromzerspaner"
RoHS	Restriction of Hazardous Substances Directive
t	tonnes; unit of mass
T	temperature;
VFC	volatile fluorocarbon
VHC	volatile hydrogen carbon
VIP	vacuum insulation panel
VOC	volatile organic carbon
WEEE	Waste Electrical and Electronic Equipment
WFD	Waste Framework Directive

A. Introduction

The chair AVAW has been assigned by CECED to investigate the European status quo on usage of vacuum insulation panels (VIPs) in cooling and freezing household appliances. The project contains the following phases:

- Phase 1 (elaborating of present legal, material specific as well as technological aspects)
- Phase 2 (realisation of small technical (lab-size) tests and establishing of testing schemes)
- Phase 3 (carrying out of large-scale tests and evaluation of project results)

A.1 Problem Statement

VIPs or so-called vacuum insulation panels have been used as insulation materials for different purposes, e.g. buildings, houses etc. Recently also the producers of cooling and freezing (C&F) household appliances have started to use VIPs as insulation material in their products. Compared to the commonly used PU-foam, VIPs have better insulation properties. For this reason, the storage volume of C&F appliances can be increased. It can be expected that the amount of mentioned “new” appliances will increase. Therefore, it has to be investigated if conventional treatment and recycling plants are suitable for this “new” waste streams and what technical adjustment and optimisation is needed. Finally, the influence of different materials, used as VIP on output streams (e.g. metals, non-metals etc.) from treatment plants is discussed.

A.2 Objective

Within this project, the following aims should be achieved:

a) effect on a range of available recycling technologies;
b) effect on occupational health and safety conditions at the recycling plants;
c) calculation of the recyclability rate, taking into account state of the art technologies;
d) impacts on economic value of other output fractions from contamination with this material;
e) secondary raw materials potential depending on the panel type.

A.3 Anonymisation Scheme

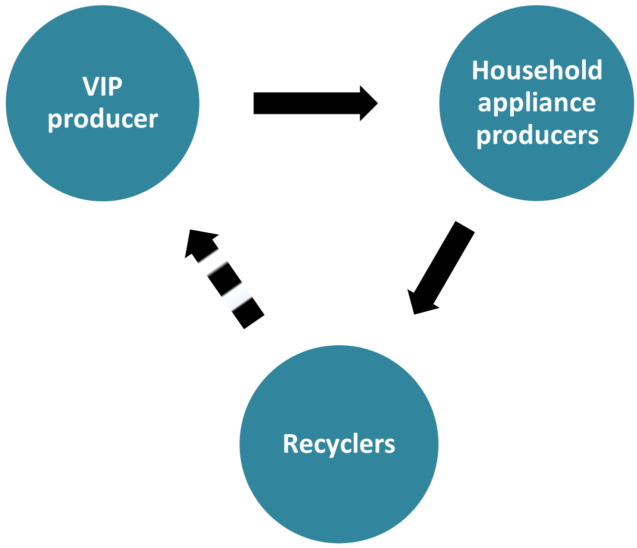
According to the received data from CECED, several different household appliance producers, as well as a number of VIP suppliers and many household appliance recyclers have been considered. Due to investigations via internet, several other household recyclers were found and contacted per email.

The names of the producers, the suppliers, the recyclers and the names of VIPs were anonymised in the present project. Therefore, the names of the companies and products are separated in three types of anonymous abbreviations:

- VIPS-1, VIPS-2 etc.: VIP suppliers
- HHR-1, HHR-2 etc.: household appliance recyclers
- HHP-1, HHP-2 etc.: household appliance producers

A.4 Vision for the End of the Project

Based on the thought of sustainability approach, the ultimate goal of the project is, to close the recycling-circle, as shown in the following image.



B. Legal Framework

With the objective of conservation of natural resources, laws were enacted to prescribe how to recycle household appliances. The statutory provisions of conditioning cooling and freezing appliances (C&F appliances) will be explained in this chapter. In particular, the European Union law, the German law, the Austrian law and the Swiss law.

B.1 Legal Situation in the European Union (EU)

European Union law has direct effect or indirect effect on the national laws of the European Union member states.

- A regulation at EU level is a legislative act of the European Union that is in force as law in all member states immediately. It does not depend on any implementing measures.
- A directive at EU level is a legislative act of the European Union, which needs to be transferred into national law of the member states without weakening the aims of the directive.

There are a lot of different regulations for the conditioning of C&F appliances. The general legislative act is the Waste Framework directive, which includes the European waste hierarchy. More detailed information about the treatment and the recycling rates of cooling and freezing appliances are in the WEEE Directive. The RoHS Directive is also important for the recycling of waste electrical and electronic equipment (WEEE) because it deals with the use of certain hazardous substances in electrical and electronic equipment.

Table 1 shows an overview, how Austria and Germany (as representatives for EU member states) have included the directives of the European Union in national law.

Table 1: Transposition of the European Directives in Austria and Germany

<table>
<tr><th>Directive (European Union)</th><th>Austrian Law</th><th>German Law</th></tr>
<tr><td>Waste Framework Directive (WFD),
2008/98/EC</td><td>Abfallwirtschaftsgesetz
(AWG)</td><td>Kreislaufwirtschaftsgesetz
(KrWG)</td></tr>
<tr><td>Waste Electrical and Electronic Equipment Directive (WEEE Directive),
until July 2012: 2002/96/EC;
since July 2012: 2012/19/EU</td><td rowspan="2">Elektroaltgeräteverordnung
(EAG-VO)</td><td rowspan="2">Elektro- und Elektronikgerätegesetz
(ElektroG)</td></tr>
<tr><td>Directive on the Restriction of Hazardous Substances (RoHS),
until June 2011: 2002/95/EC;
since June 2011: 2011/65/EU</td></tr>
</table>

B.1.1 Waste Framework Directive (WFD)

The directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (q.v. [WFD]) came into force on 12 December 2008 and it had to be included into national law until 12 December 2010. The directive describes the meaning of waste and the treatment of waste. Cooling and freezing appliances turn to waste, when the definition of the term “waste”, according to WFD Article 3(1) is fulfilled: **waste** means any substance or object which the holder discards or intends or is required to discard.

In Article 4 the European waste hierarchy is described. This hierarchy is divided into the five following points which shall apply as a priority order in waste prevention and management legislation and policy.

(a) Prevention;
(b) preparing for re-use;
(c) recycling;
(d) other recovery, e.g. energy recovery; and
(e) disposal.

Figure 1: Five Step Waste Management Hierarchy
source: http://ec.europa.eu/environment/waste/framework/index.htm

According to Article 3 of the Waste Framework Directive, the terms of the waste management hierarchy, shown in Figure 1, are defined in the following way.

Prevention means measures taken before a substance, material or product has become waste, so it is possible to reduce the incoming waste.

Re-use means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.

Recycling means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

Recovery means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.

Disposal means any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy.

In Annex III of the Waste Framework Directive the following 15 properties of waste, which render it hazardous, are listed:

H 1 **'Explosive':** substances and preparations which may explode under the effect of flame or which are more sensitive to shocks or friction than dinitrobenzene.

H 2 **'Oxidizing':** substances and preparations which exhibit highly exothermic reactions when in contact with other substances, particularly flammable substances.

H 3-A **'Highly flammable'**

— liquid substances and preparations having a flash point below 21 °C (including extremely flammable liquids), or

— substances and preparations which may become hot and finally catch fire in contact with air at ambient temperature without any application of energy, or

— solid substances and preparations which may readily catch fire after brief contact with a source of ignition and which continue to burn or to be consumed after removal of the source of ignition, or

— gaseous substances and preparations which are flammable in air at normal pressure, or

— substances and preparations which, in contact with water or damp air, evolve highly flammable gases in dangerous quantities.

H 3-B **'Flammable':** liquid substances and preparations having a flash point equal to or greater than 21 °C and less than or equal to 55 °C.

H 4 **'Irritant':** non-corrosive substances and preparations which, through immediate, prolonged or repeated contact with the skin or mucous membrane, can cause inflammation.

H 5 **'Harmful':** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may involve limited health risks.

H 6 **'Toxic':** substances and preparations (including very toxic substances and preparations) which, if they are inhaled or ingested or if they penetrate the skin, may involve serious, acute or chronic health risks and even death.

H 7 **'Carcinogenic':** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce cancer or increase its incidence.

H 8 **'Corrosive':** substances and preparations which may destroy living tissue on contact.

H 9 **'Infectious':** substances and preparations containing viable micro-organisms or their toxins which are known or reliably believed to cause disease in man or other living organisms.

H 10 **'Toxic for reproduction':** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce non-hereditary congenital malformations or increase their incidence.

H 11 **'Mutagenic':** substances and preparations which, if they are inhaled or ingested or if they penetrate the skin, may induce hereditary genetic defects or increase their incidence.

H 12 Waste which releases toxic or very toxic gases in contact with water, air or an acid.

H 13 **'Sensitizing':** substances and preparations which, if they are inhaled or if they penetrate the skin, are capable of eliciting a reaction of hypersensitization such that on further exposure to the substance or preparation, characteristic adverse effects are produced.

H 14 **'Ecotoxic':** waste which presents or may present immediate or delayed risks for one or more sectors of the environment.

H 15 Waste capable by any means, after disposal, of yielding another substance, e.g. a leachate, which possesses any of the characteristics listed above.

B.1.2 Waste Electrical and Electronic Equipment Directive (WEEE Directive)

The directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (q.v. [WEEE]), called waste electrical and electronic equipment (WEEE) directive, became European law by 13 February 2003. All EU member states had to implement the WEEE directive by 13 August 2004 into national law.

The WEEE directive set targets for collection, recycling and recovery of all types of electrical goods which are divided in the following ten categories (as per Annex IA and Annex I of WEEE directive 2012/19/EU respectively):

1. Large household appliances
2. Small household appliances
3. IT and telecommunications equipment
4. Consumer equipment
5. Lighting equipment
6. Electrical and electronic tools (with the exception of large-scale stationary industrial tools)
7. Toys, leisure and sports equipment
8. Medical devices (with the exception of all implanted and infected products)
9. Monitoring and control instruments
10. Automatic dispensers

According to Annex IA, cooling and freezing appliances count among the category of point 1, called "Large household appliances". This means that, according to Article 7(2a) of directive 2002/96/EC:

- the required rate of recovery for cooling and freezing appliances shall be increased to a minimum of **80%** by an average weight per appliance, and
- component, material and substance reuse and recycling shall be increased to a minimum of **75%** by an average weight per appliance, as illustrated in Figure 2.

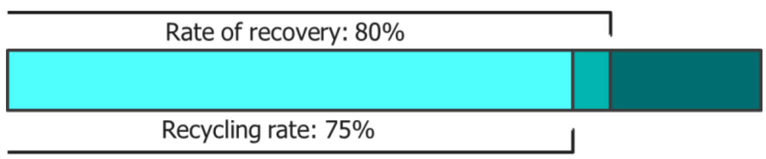


Figure 2: Required Rates of Recovery and Recycling according to WEEE directive 2002/96/EC

EU member states shall ensure that by 31 December 2006 at the latest a rate of separate collection of at least **four kilograms** on average per inhabitant per year of WEEE from private households is achieved according to Article 5(5).

The **principle of producer responsibility**, first mentioned in the directive's introduction in passage 5, is described under the introduction's passage 12 as "one of the means of encouraging the design and production of electrical and electronic equipment which take into full account and facilitate their repair, possible upgrading, reuse, disassembly and recycling." According to passage 20 of the WEEE directive's introduction "each producer should be responsible for financing the management of the waste from his own products, to give maximum effect to the concept of producer responsibility."

The manufacturers of electrical and electronic equipment have to mark their products with the symbol which is shown in Figure 3.

Figure 3: The WEEE symbol

B.1.2.1 Recast – WEEE Directive 2012/19/EU

As per directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) "*a number of substantial changes are to be made to Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE). In the interests of clarity, that Directive should be recast*." [WEEE2]

The classification of cooling and freezing appliances into category 1 "large household appliances" is defined in Annex I of the WEEE directive 2012/19/EU.

The principle of producer responsibility is also mentioned in the new WEEE Directive and in Article 7(1) is even claimed that each member state shall ensure the implementation of the producer responsibility principle. The other passages in the introduction of directive 2002/96/EC were adopted in the new directive as well.

Change of Recovery Targets for Cooling and Freezing Appliances

Concerning the change of the minimum recovery targets and the reuse and recycling rates, there are two phases mentioned in Annex V:

1) Minimum targets applicable **from 13 August 2012 until 14 August 2015** for cooling and freezing appliances
   - 80% shall be recovered, and
   - 75% shall be recycled.

This means that until August 2015 the rates do not change (see Figure 2).

2) Minimum targets applicable **from 15 August 2015 until 14 August 2018** for cooling and freezing appliances
   - 85% shall be recovered
   - 80% shall be prepared for re-use and recycled.

This means that both the recovery as well as the recycling rate should be increased by 5% based on the required rates in WEEE directive 2002/96/EC. The new rates are illustrated in Figure 4.

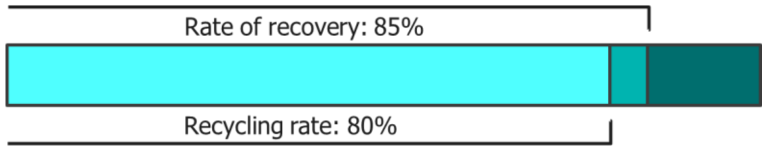


Figure 4: New Required Rates of Recovery and Recycling according to WEEE directive 2012/19/EC

B.1.3 Directive on the Restriction of Hazardous Substances (RoHS)

The directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (q.v. [RoHS]), called restriction of the use of certain hazardous substances in electrical and electronic equipment, came into force in January 2003. The EU member states had time until August 2004 to implement this directive into national law.

The target of this directive is to banish the following hazardous substances in electrical and electronic equipment by 1 July 2006 (as per Article 4(1)):

- Lead (Pb)
- Mercury (Hg)
- Cadmium (Cd)
- Hexavalent chromium (Cr^{6+})
- Polybrominated biphenyls (PBB)
- Polybrominated diphenyl ether (PBDE)

B.1.3.1 Recast - RoHS Directive 2011/65/EU

As per directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, "*a number of substantial changes are to be made to Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment. In the interest of clarity, that Directive should be recast.*" [RoHS2]

B.2 Legal Situation in Austria

With the amendment in 2011 of the Austrian Waste Management Act 2002 (q.v. [AWG]), the European Waste Framework Directive was implemented into Austrian law. The Austrian Waste Management Act contains the general definition of waste as well as targets and principles concerning the European waste hierarchy. Both the WEEE Directive and the RoHS Directive are transposed into national law by the Austrian WEEE Ordinance (q.v. [EAG-VO]). From 2006 onwards, a rate of separate collection of at least 4 kg on average per inhabitant per year of electrical and electronic equipment is defined. For cooling appliances, refrigerators and freezers, the required rate of recovery is 80%, the rate of re-use and recycling is 75% related to the average weight per appliance. In Table 2 both relevant legal acts in Austria are apparent.

Table 2: Relevant Austrian Legal Acts

English Translation	Original Austrian Title
Federal law of Austria on a sustainable waste management (**Waste Management Act 2002**)	Bundesgesetz über eine nachhaltige Abfallwirtschaft (**Abfallwirtschaftsgesetz 2002 - AWG 2002**)
Ordinance of the Federal Minister of Agriculture and Forestry, Environment and Water Management on Waste Prevention, Collection and Treatment of Waste Electrical and Electronic Equipment (**WEEE Ordinance**)	Verordnung des Bundesministers für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft über die Abfallvermeidung, Sammlung und Behandlung von elektrischen und elektronischen Altgeräten (**Elektroaltgeräteverordnung – EAG-VO**)

B.3 Legal Situation in Germany

Since June 2012, there is a revised version of the German Recycling Management Act (q.v. [KrWG]), due to the European WFD. The German Recycling Management Act of 2012 implements, as well as the Austrian Waste Management Act, the five step waste hierarchy of the European Union. In Germany, the two European directives (WEEE Directive, RoHS) were together transposed into national law with the German WEEE Act (q.v. [ElektroG]), lastly changed in February 2012. All mentioned rates (rate of separate collection, rate of recovery, rate of re-use/recycling) are taken one to one from the European WEEE Directive. Both relevant legal acts in Germany concerning the recycling of WEEE are shown in Table 3.

Table 3: Relevant German Legal Acts

English Translation	Original German Title
Act for Promoting Closed Loop Recycling and Ensuring Environmentally Sound Waste Disposal) (**Recycling Management Act**)	Gesetz zur Förderung der Kreislaufwirtschaft und Sicherung der umweltverträglichen Bewirtschaftung von Abfällen (**Kreislaufwirtschaftsgesetz - KrWG**)
Act Governing the Sale, Return and Environ-mentally Sound Disposal of Electrical and Electronic Equipment (**WEEE Act**)	Gesetz über das Inverkehrbringen, die Rücknahme und die umweltverträgliche Entsorgung von Elektro- und Elektronikgeräten (**Elektro- und Elektronikgerätegesetz - ElektroG**)

B.4 Legal Situation in Switzerland

Although Switzerland is not an EU member, it has a national CECED association and is a European country with high standards concerning waste management. The Environmental Protection Act (q.v. [USG]) is the main legitimate act in Switzerland to regulate the national waste management and the protection of environment. The Swiss Federal Office for the Environment (FOEN) is actually working on a revision of the Ordinance on the Return, the Take Back and the Disposal of Electrical and Electronic Equipment (q.v. [VREG]) to implement the amended WEEE Directive. This revision is supposed to be in force in 2013. With the Ordinance on the Reduction of Risks relating to the Use of Certain Particularly Dangerous Substances, Preparations and Articles (q.v. [ChemRRV]) in 2005 Switzerland put an ordinance into force that is equivalent to the RoHS. In Table 4 the three relevant legal acts are obvious.

Table 4: Relevant Swiss Legal Acts

English Translation	Original Swiss Title
Federal Act of 7 October 1983 on the Protection of the Environment (**Environmental Protection Act, EPA**)	Bundesgesetz vom 7. Oktober 1983 über den Umweltschutz (**Umweltschutzgesetz, USG**)
Ordinance of 14 January 1998 on the Return, the take back and the Disposal of Electrical and Electronic Equipment (**ORDEE**)	Verordnung vom 14. Januar 1998 über die Rückgabe, die Rücknahme und die Entsorgung elektrischer und elektronischer Geräte (**VREG**)
Ordinance of 18 May 2005 on the Reduction of Risks relating to the Use of Certain Particularly Dangerous Substances, Preparations and Articles (**Chemical Risk Reduction Ordinance, ORRChem**)	Verordnung vom 18. Mai 2005 zur Reduktion von Risiken beim Umgang mit bestimmten besonders gefährlichen Stoffen, Zubereitungen und Gegenständen (**Chemikalien-Risikoreduktions-Verordnung, ChemRRV**)

C. Present State – Phase 1

This chapter deals with the information received from CECED, information found by internet researches and information from companies, which were contacted in writing. The first part of this chapter focuses on vacuum insulation panels, their physical properties, their components and their effect on health. The focus of the second part of this chapter is the recycling technology of cooling and freezing appliances (C&F appliances).

C.1 Identification of VIPs Used by Household Producers

To quote the received documents by CECED, the estimated effective life time of appliances containing VIPs is about 10 to 15 years in average. Additionally, it is known that mainly appliances of energy class A++ and A+++ contain VIPs. The amount of cooling and freezing appliances containing VIPs sold per year ranges from 1,000 to 213,000 units – this is a really wide range and does not allow any concrete estimation. This is why in chapter C.2.1 the collected amounts of WEEE and particularly the collected amounts of C&F appliances in Europe are represented.

The received VIPs from the suppliers for the testing scheme could be classified into the following six different material groups (also see Figure 5). These six material groups represent the basis for all tests described in chapter D “Testing Scheme – Phase 2”.

- Material group 1 (paperlike), received from VIPS-4, VIPS-6, VIPS-10, VIPS-14;
- Material group 2 (white fleece), received from VIPS-4;
- Material group 3 (glass woollike), received from VIPS-13;
- Material group 4 (grey powder), received from VIPS-15;
- Material group 5 (brown powder), received from VIPS-7, VIPS-10;
- Material group 6 (black powder), received from VIPS-9;


paperlike


white fleece


glass woollike


grey powder


brown powder


black powder

Figure 5: Different Material Groups of the Vacuum Insulation Panels

C.1.1 Specifications of VIPs

Vacuum insulation panels are high performance thermal insulations. They are used in the building technology as well as in refrigerators and freezers. Their high specific thermal resistivity enables new solutions for slim, but still energy efficient insulations.

In Figure 6 the thermal conductivity in W m^{-1} K^{-1} of VIPs is compared with the thermal conductivity of other substances which are commonly used as insulation materials in the building construction industry. The U-value (thermal transmittance) in W m^{-2} K^{-1} is a function of the thickness (represented in mm). It is conspicuous that VIPs perform better than the other materials, concerning the specific thermal resistivity (reciprocal of thermal conductivity), despite their low thickness.

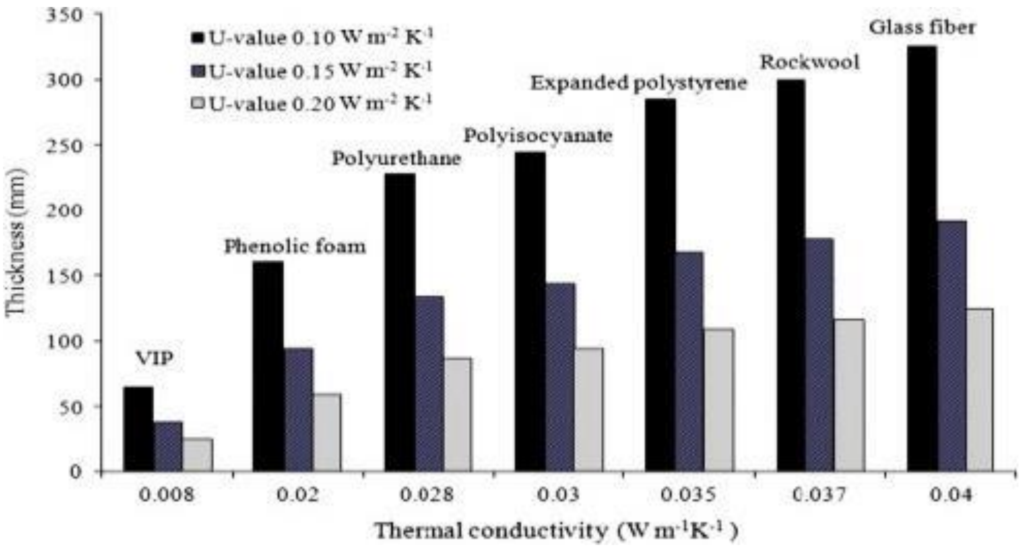


Figure 6: Comparison of the Thermal Conductivity of Different Insulation Materials [Alam]

Although VIPs are not built in singularly in cooling and freezing appliances, but rather always in a combination with PU-foam, the two types of insulations compete with each other. PU-foam is needed to completely foam out the insulation gaps where the VIPs are fitted in.

The big advantage of VIPs compared to PU-foam is, as already mentioned, the lower thermal conductivity. Specific examples and a comparison of both materials are shown in Table 5. That is the reason why appliances containing VIPs can be built with a thinner insulation wall than appliances with a PU-foam insulation. An interesting detail is that the position of the VIP has an influence on the energy efficiency of the whole appliance (Table 6). There is also a big difference concerning the density between VIPs and PU-foam:

- VIP: 150-300 kg/m^3
- PU foam: 30-35 kg/m^3

Table 5: Comparison of PU-foam and VIPs concerning the Thermal Conductivity

Thermal Conductivity [mW/m*K]	
VIP *(specific examples)*	**PU-foam**
5	20
3.5	20
2 to 3	20

Table 6: Influence of VIP's Position on Energy Efficiency

Position of VIP	**Energy efficiency improvement**
door	10%
door + both lateral sites	20%
door + both lateral sites + back site	30%

Structure of VIPs

The structure of VIPs used in refrigerators and freezers differ only marginally from the VIPs used in the building construction industry. The main components of a vacuum insulation panel are:

- Multilayer Envelope (prevention of air inlet);
- Highly-porous core material, e.g. fibreglass (stabilisation against atmospheric pressure);
- Getters (collection of gases leaked through the membrane to ensure vacuum);

In Figure 7, the schematic of a building construction VIP is represented.

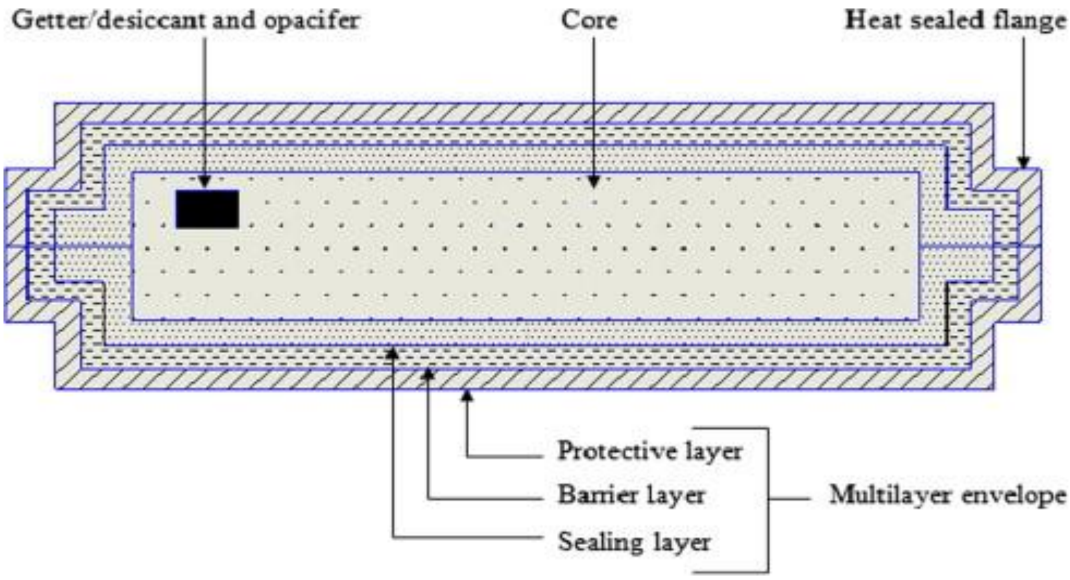


Figure 7: Schematic of a VIP from the Building Construction Industry [Alam]

According to the information of one VIP supplier, the components of the multi-layered envelope film are LLDPE (linear low density polyethylene), Nylon, PET (polyethylene terephthalate) and aluminium foil, as shown in Table 7. The total thickness of this film is about 95 µm.

Table 7: Components of VIP Multi-Layered Envelope Film according to VIPS-4

Sub-assembly	Component	Thickness [µm]	Density [g/cm³] (at 20°C)	Mass%
Multi-layered envelope film	PET	12.5	1.38	15.58
	Nylon	25	1.14	25.73
	Al Foil	7	2.70	17.07
	LLDPE	50	0.922	41.63
	Sum	**95**		**100**

Data about densities from internet research.

Based on the data of VIPS-4, concerning the multi-layered envelope film, two pie charts were designed (see Figure 8 and Figure 9). In Figure 8 the composition of the VIP film based on thickness is shown, and in Figure 9 the mass percentage of these film components is represented. The calculation of the mass percentage was done with the aid of the densities of the components. The individual densities are from an internet research (q.v. [AuKu], [Chpdia] and [GESTIS]).

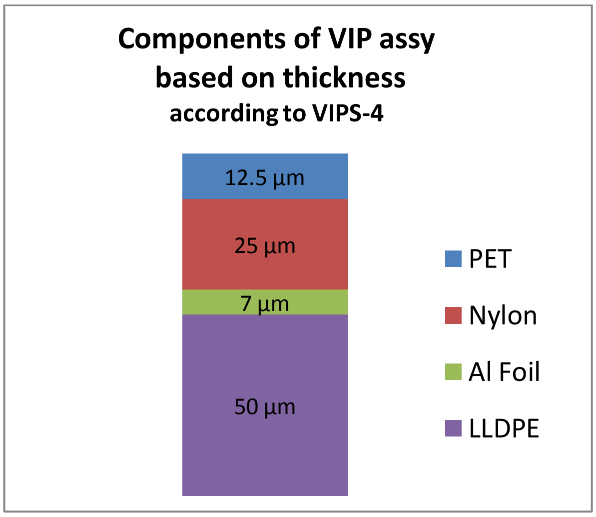


Figure 8: Graphic Representation of the Thickness of the VIP Film Components according to VIPS-4

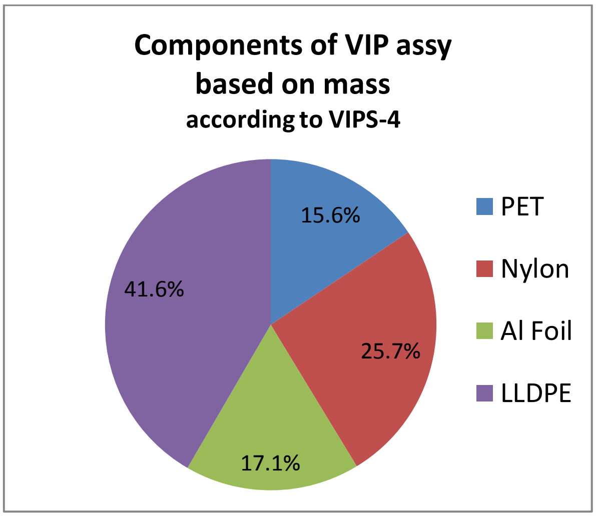


Figure 9: Pie Chart of the VIP Film Components based on Mass according to VIPS-4

Based on the safety data sheets and other info-sheets received from CECED, the main components on VIPs of some different VIP suppliers are summarised in Table 8. Every column represents one VIP supplier, with the exception of the third column, which represents two suppliers who have the same descriptions. Concerning the description of the VIP's envelope only three suppliers made specifications, that is why some fields are empty.

Table 8: VIPs' Components of Various VIP Suppliers (anonymised)

Description	VIPS-1	VIPS-4	VIPS-7 / VIPS-9	VIPS-11	VIPS-12
Core material	Chopped fibre glass	Glass board	Silicon dioxide	Amorphous silica (50-100%) Silicon carbide (1-20%)	Micro dispersed silica
Envelope	Multi-layered barrier film	see Table 7	-	Polymer filament (1-12%)	-
Getter	Nano getter	Calcium oxide	-	-	-

C.1.2 Specifications of VIP Containing Appliances

According to the documents of CECED, there are several different cooling and freezing appliances with various weight categories and corresponding VIP masses. Some specific examples of these various weight categories are shown in Table 9 and Table 10. In these two tables the third column (percentage of VIPs in appliance) is shown as additional information and not sent by CECED; only the first two columns are quoted from the CECED data. In contrast to Table 10, Table 9 includes a fluctuation rate of the appliance weight and VIP weight.

Table 9: VIPs' Weight Portion in C&F Appliances (data from CECED)

Appliance weight [kg]	VIP weight [kg]	Percentage of VIPs in appliance [%]
100	9	9.0
70	2	2.9
74	4	5.4
78	8	10.3
77	8	10.5
132	4	2.9
77	3	4.4

Table 10: VIPs' Weight Portion in C&F Appliances with Fluctuation Rates (data from CECED)

Appliance weight [kg]	VIP weight [kg]	Percentage of VIPs in appliance [%]
45-105	0.5-2.5	2.0
45-93	0.5-2.5	2.2
140-150	2.5-9	4.0
120-130	2-8	4.0
80-90	3-8	6.5

The information of these two tables is also represented in two bar diagrams: Figure 10 (based on data of Table 9) and Figure 11 (based on data of Table 10). In these two following bar diagrams the calculated average weight of the appliances and of the VIPs is shown on the right side.

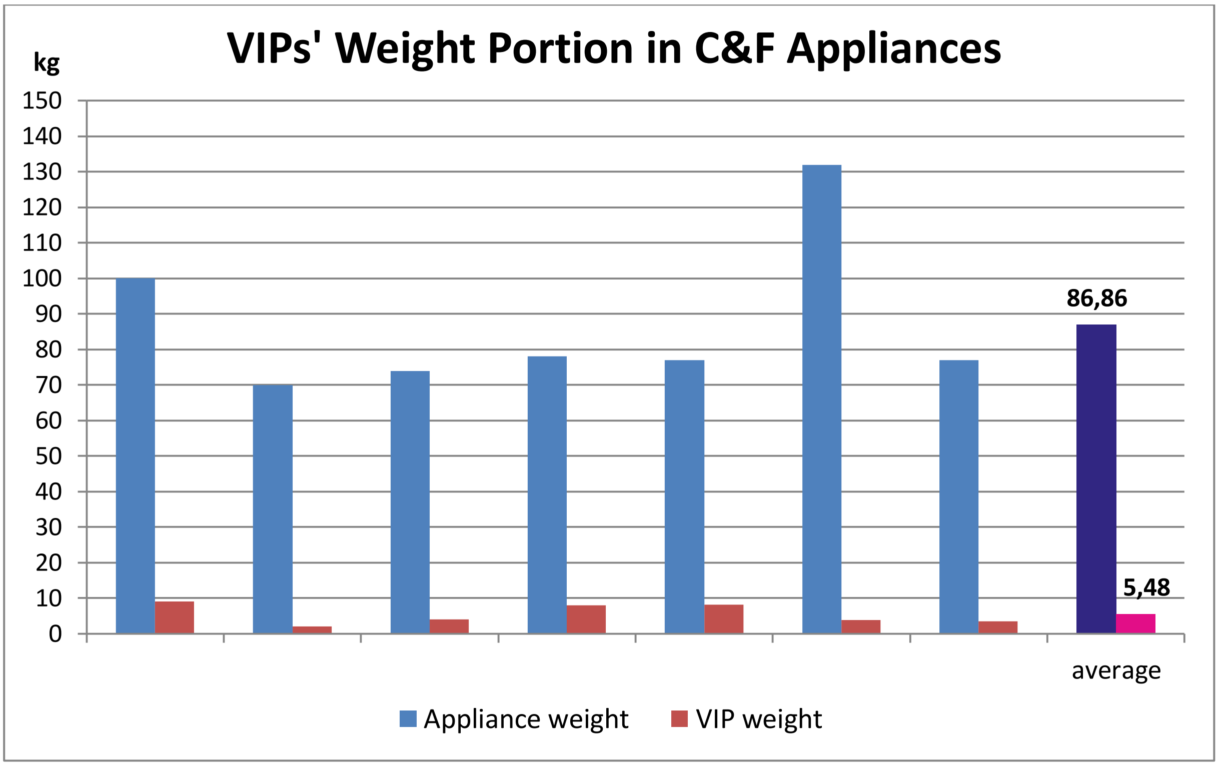


Figure 10: VIPs' Weight Portion in C&F Appliances (based on data from CECED)

The fluctuation rates shown in the following figure are based on the minimum and the maximum weights shown in Table 10. Due to the wide range of the weight data, clear allocation is not possible.

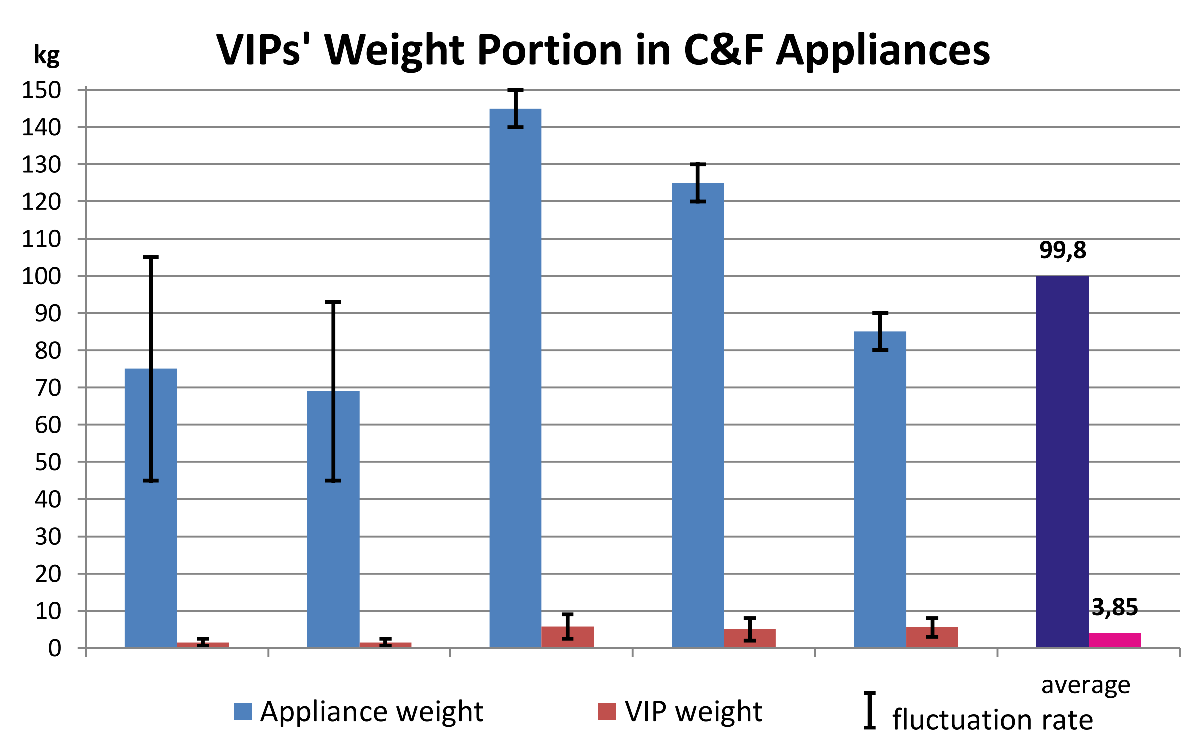


Figure 11: VIPs’ Weight Portion in C&F Appliances with Fluctuation Rates (based on data from CECED)

To quote the data by CECED, the average weight of a cooling and freezing appliance containing VIPs is 56 kg with 0.24 to 1.75 kg of VIPs in it. This would say that the percentage of VIPs in an appliance ranges from 0.43% to 3.13%. But there is a discrepancy between this average percentage and the calculated averages, which are based on the appliance weights and the corresponding VIP weights received by the CECED. These calculated weight averages are shown in Table 11, as well as in Figure 10 and in Figure 11 on the right side.

Table 11: VIPs’ Average Portion in C&F Appliances (calculation based on data by CECED)

Appliance weight [kg]	VIP weight [kg]	Percentage of VIPs in appliance [%]
86.86	5.48	6.3
99.80	3.85	3.9

The difference between the received average weight from CECED and the calculated average based on the specific examples of CECED is quite large. The question is which portion is representative for the European market.

To quote the report from 2011 created by Renato Sarc and Josef Adam at Montanuniversitaet Leoben (q.v. [Sarc]), a C&F appliance of category A++ contains about 5% of VIPs (see Figure 12). This percentage is in line with the received data from CECED.

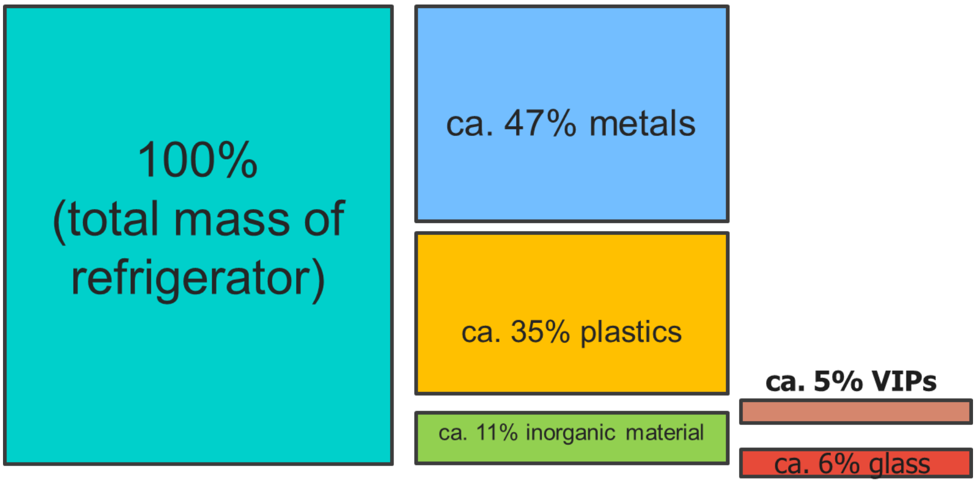


Figure 12: Mass Balance of C&F Appliances Based on an A++ Cooling Appliance [Sarc]

C.1.3 Safety Data Sheet

Based on the received safety data sheets from CECED, a summarised safety data sheet was created (see Appendix II) in accordance with the REACH regulation (Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency).

C.2 Recycling of Cooling and Freezing Appliances

In this chapter the recycling of C&F appliances as well as some ideas of the recycling of VIPs are described. Because collected appliances represent the basis or rather the resource for the recycling, the first part of this chapter deals with the collection rates of WEEE in Europe.

C.2.1 Collection Rates of WEEE in Europe

As required in the WEEE directive, 4 kg WEEE per head have to be collected per year in every EU member state. In the following figure it is shown that many countries have already achieved the collection target of 4 kg WEEE per head, but some countries like Latvia, Lithuania and Romania have not reached the 4 kg line in 2010, as to be seen in Figure 13. The information is taken from the European Environment Agency (q.v. [EEA]).

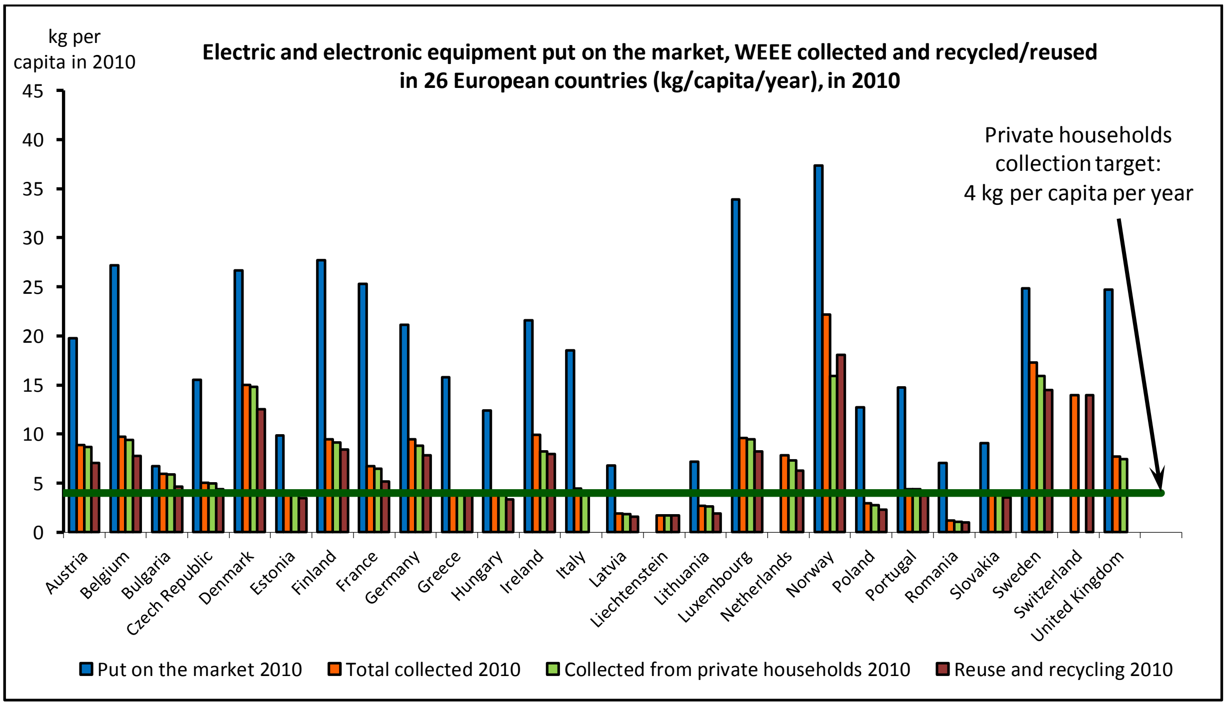


Figure 13: Electric and Electronic Equipment Put on the Market, WEEE Collected and Recycled/ Reused in 26 European countries (kg/capita/year), in 2010 [EEA]

In the following Table 12 the exact figures of the WEEE collection rates of 29 European countries in 2010 are shown in tonnes as well as in kg per capita, ranked by kg/capita. Both, the total amount of collected WEEE in tonnes and the relative amount in kg per capita are important. The total amount gives us an impression, how much appliances there have to be recycled. The relative amount helps to compare the countries with one another. The information is taken from Eurostat as well as from a SENS Report (q.v. [Eurostat] and [SENS]).

Table 12: Collection Rate of WEEE in 2010 of European Nations ranked by kg/capita

Nation		tonnes	kg/capita	Nation		tonnes	kg/capita
1	Sweden	161,444	15.90	16	Portugal	46,673	4.40
2	Norway*	107,767	15.80	17	Italy	268,216	4.20
3	Switzerland*	107,730	15.47	18	Estonia	5,630	4.20
4	Denmark	82,931	14.80	19	Slovenia	8,674	4.00
5	Luxembourg	4,823	9.40	20	Greece	46,527	3.90
6	Belgium	105,556	9.30	21	Hungary	40,521	3.90
7	Finland	50,867	9.10	22	Slovakia	21,916	3.90
8	Germany	777,035	8.80	23	Malta	1,535	3.40
9	Austria	74,256	8.70	24	Cyprus	2,609	3.20
10	Ireland	44,431	8.20	25	Spain	158,099	3.20
11	United Kingdom	479,356	7.40	26	Poland	112,246	2.80
12	Netherlands	129,747	7.30	27	Lithuania	8,928	2.70
13	France	433,959	6.40	28	Latvia	4,287	1.90
14	Bulgaria	45,056	5.90	29	Romania	26,247	1.10
15	Czech Republic	52,989	5.00				

*no member of the EU

The following Figure 14 is corresponding to Table 12 and illustrates in four different colours visually the height of the WEEE collection rates of the countries. In Table 12 as well as in Figure 14 it is conspicuous that Sweden and Norway have by far the highest per capita collection rates, although Germany has with 777,035 tonnes of collected WEEE in 2010 by far the highest mass of WEEE compared to the other European countries.

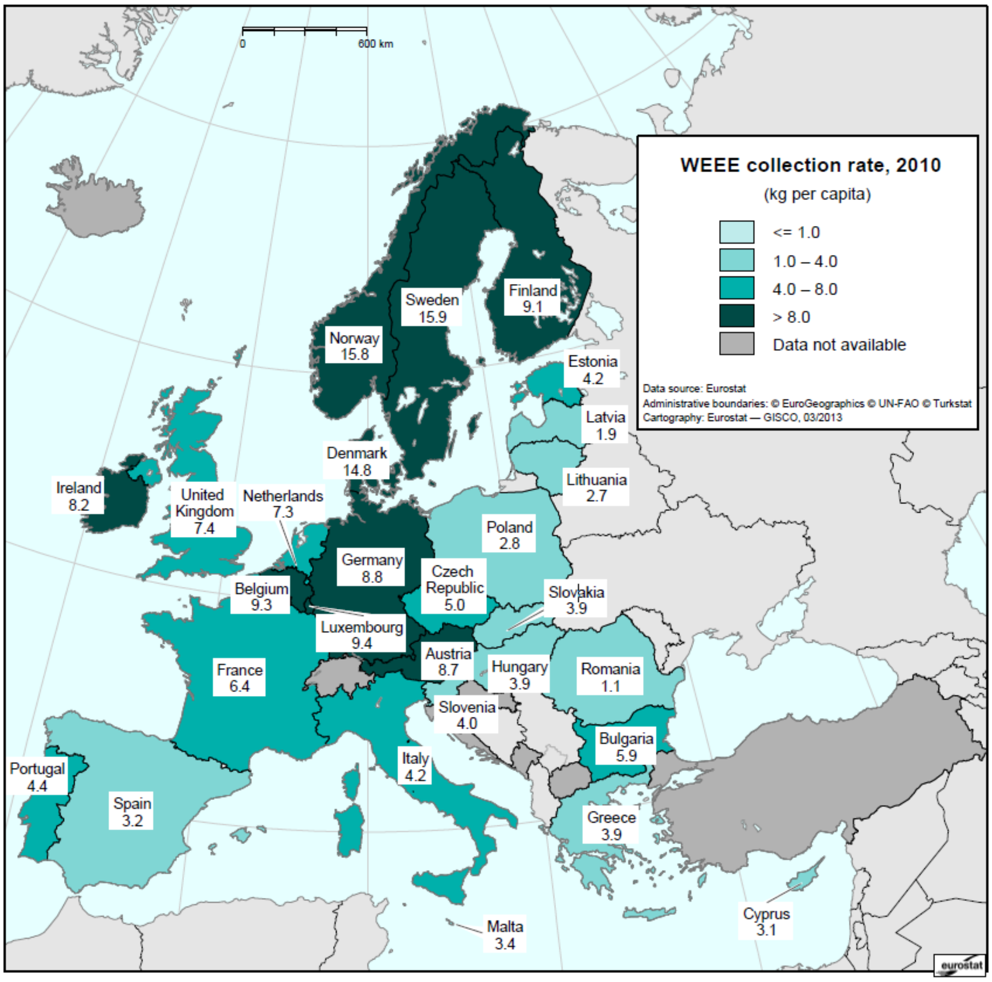


Figure 14: Collection Rate of WEEE in 2010 of European Nations in kg/capita [Eurostat]

For the recycling of C&F appliances it is important to know how many tonnes of old cooling and freezing appliances are collected. This is why the following figures were designed. In Figure 15 it is illustrated, how big the percentage of large household appliances (category 1 appliances according to WEEE directive) is based on the total amount of collected WEEE. On the right side of this diagram it is also shown the European average, where large household appliances represent the half of the amount of collected WEEE.

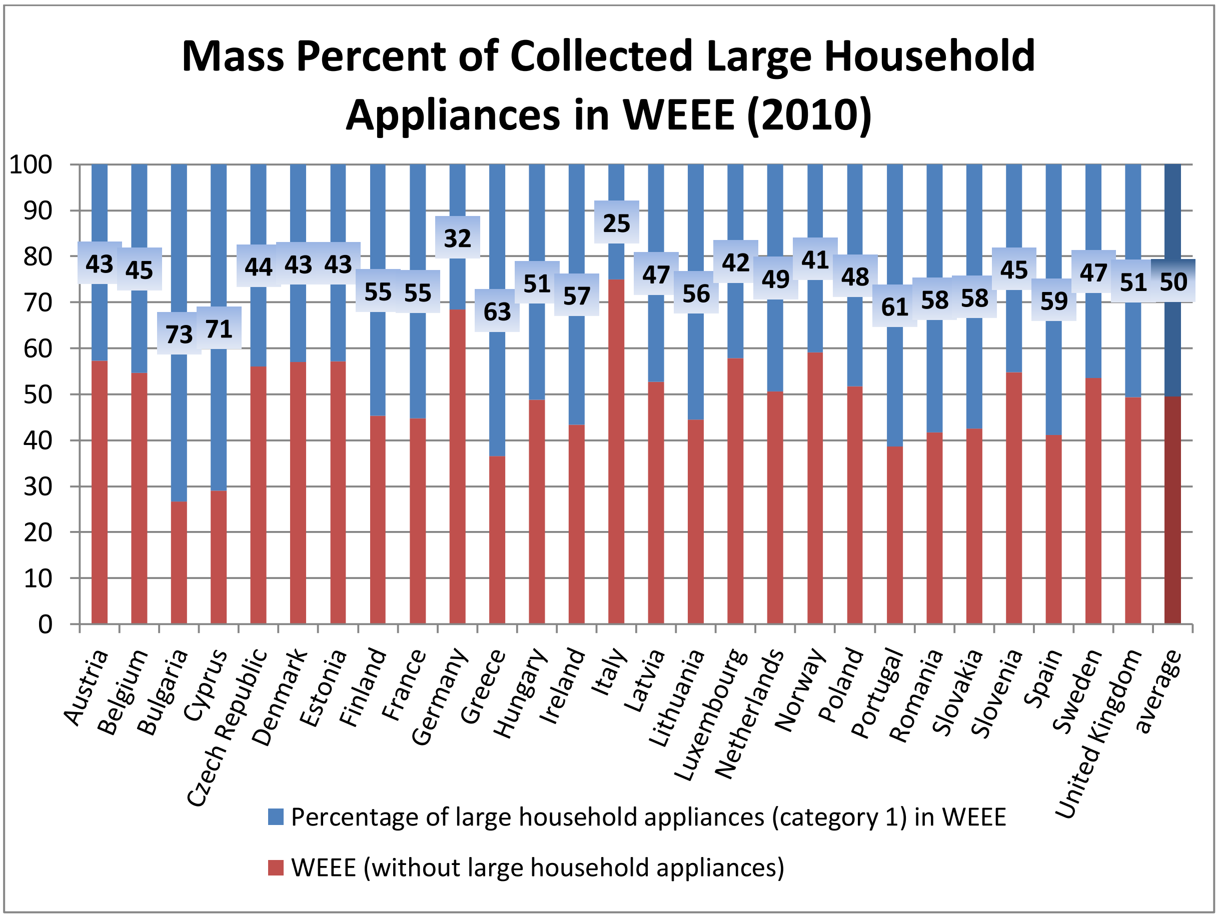


Figure 15: Mass Percentage of Collected Large Household Appliances in WEEE in European Countries (2010) [Eurostat]

C.2.1.1 Collection Rates of WEEE in Austria

The information about the collection rates of WEEE in Austria from 2006 to 2009 is taken from the Austrian Waste Management Plan 2011 (q.v. [BAWP]). In Table 13 the figures based on the Austrian Waste Management plan are shown. The ratio of cooling and freezing appliances in WEEE was sinking about 5% in these four years, although the collection rate of cooling and freezing appliances is nearly stable.

Table 13: Development of Collected C&F Appliances in Austria (2006 – 2009) [BAWP]

Description	Unit	2006	2007	2008	2009
Collected mass of C&F appliances	t	15,882	13,914	14,290	14,761
Percentage of C&F appliances in WEEE	%	25.36	21.56	21.83	19.53
Collected mass of C&F appliances per capita	kg per capita	1.98	1.73	1.78	1.84

In Figure 16 the development of the percentage of collected cooling and freezing appliances is represented. It is obvious that the percentage of the collected cooling and freezing appliances in Austria was decreasing in the period from 2006 to 2009, although the total amount of WEEE was increasing in this period. The percentage of the collected large household appliances, which represent the category 1 appliances listed in Annex I of WEEE directive 2012/19/EU, is rather stable.

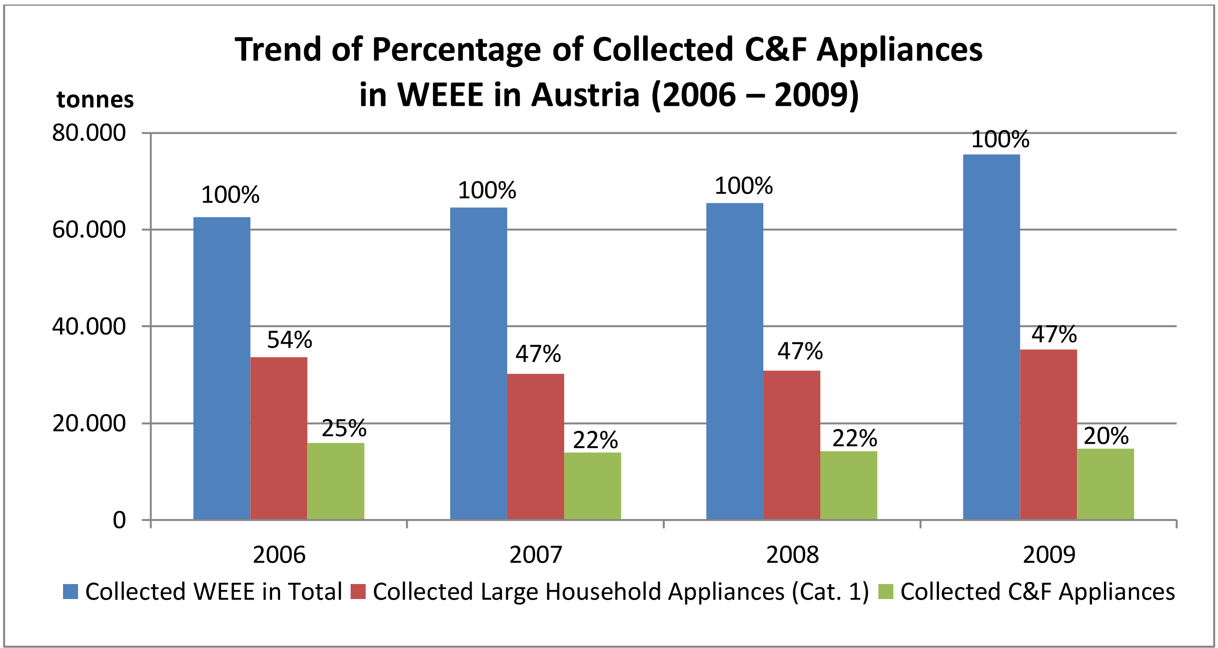


Figure 16: Trend of Percentage of Collected C&F Appliances in WEEE in Austria (2006 – 2009)

C.2.1.2 Collection Rates of WEEE in Germany

In Germany all data concerning the collection of WEEE is administrated by "Stiftung Elektroaltgeräte Register" (EAR). Stiftung EAR sends the report of the annual flow of WEEE amounts to the German Federal Environment Agency. The bar diagram in Figure 17 is based on these annual reports of the German Federal Environment Agency [UBAg].

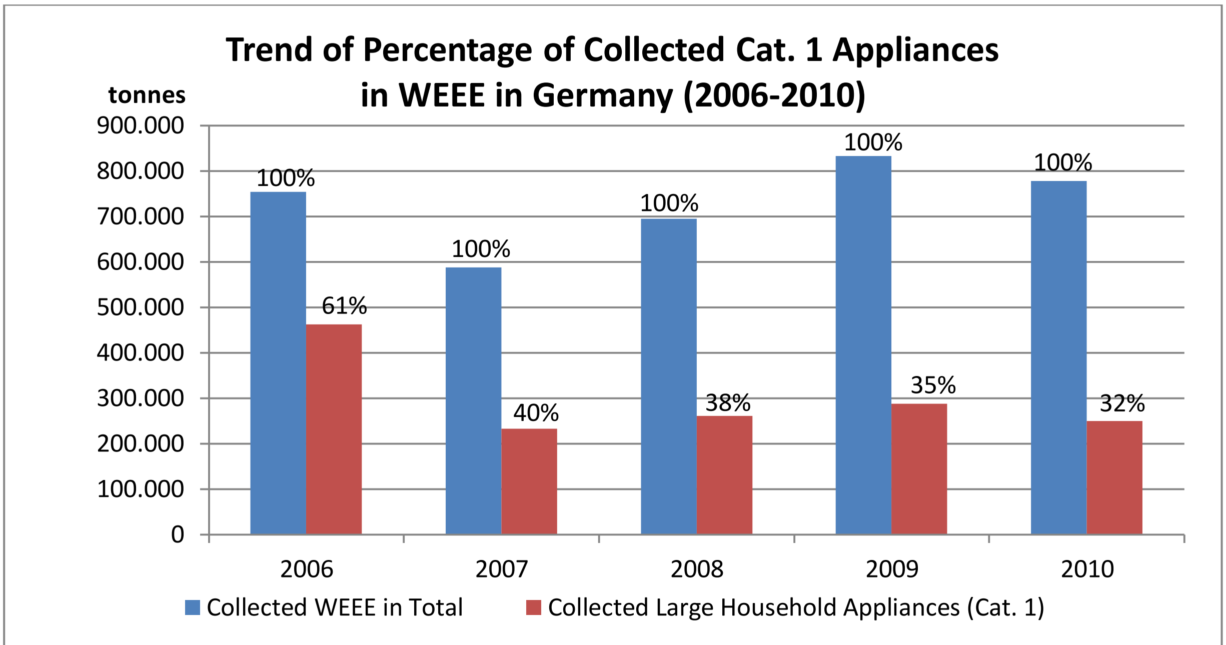


Figure 17: Trend of Percentage of Collected Cat. 1 Appliances in WEEE in Germany (2006-2010)

As shown in Figure 17, there is no clear trend for the amount of large household appliances in Germany. The total amount of collected WEEE also heavily fluctuated in the period from 2006 to 2010. Concerning the amounts of C&F appliances, only data about the amount of collections was available (q.v. [EAR]). This is why Figure 18 was created. It simply shows how many collections were made for Collection Group 2 (SG2), where C&F appliances belong to, as a percentage of the total performed collections. SG2 does not only consist of C&F appliances, but also of other WEEE, like oil-filled radiators and air handling units.

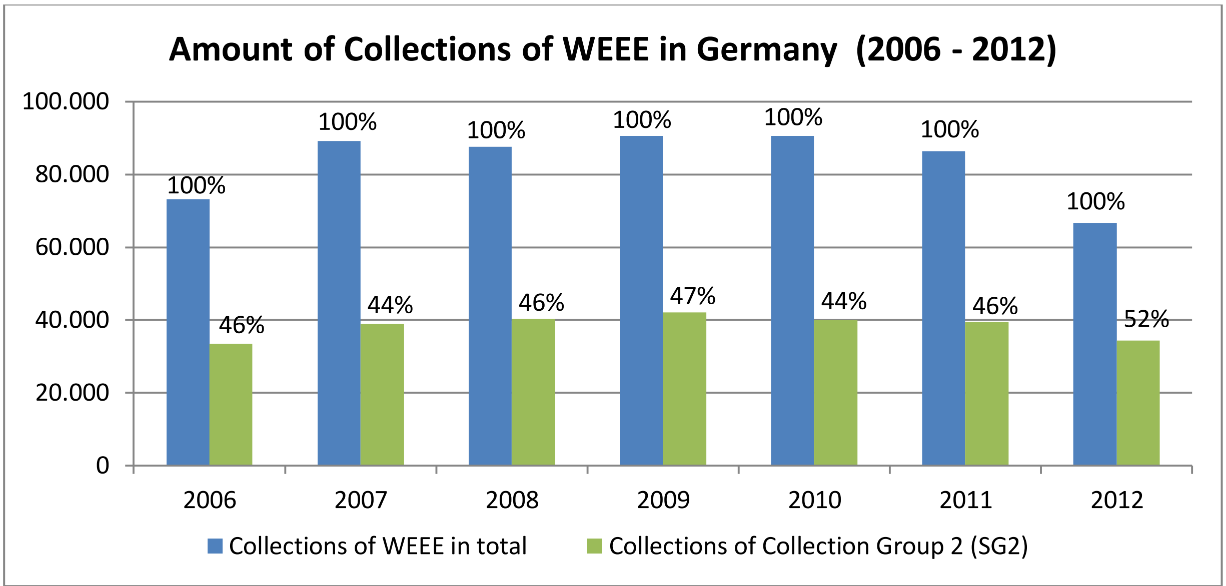


Figure 18: Trend of Collections of WEEE in Germany (2006 – 2010)

C.2.1.3 Collection Rates of WEEE in Switzerland

The Report of the Technical Inspectorate 2011 of SENS, SWICO Recycling and SLRS ([SENS2]) represents the basis of the data shown in Figure 19.

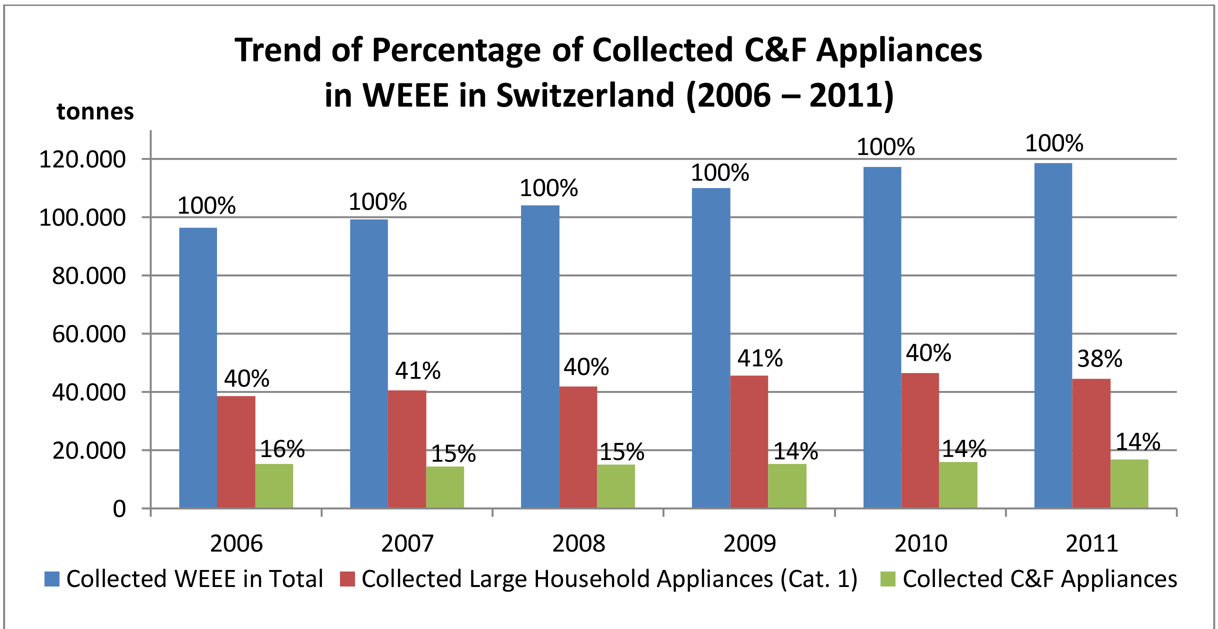


Figure 19: Trend of Percentage of Collected C&F Appliances in WEEE in Switzerland (2006-2011)

In Switzerland the amount of collected C&F appliances was continuously raising since 2007, but the increase of the amount of the collected WEEE in total was even higher; that is why the percentage of the C&F appliances was falling.

C.2.2 Recycling Technology of Cooling and Freezing Appliances

When it comes to the technology of the recycling plants where refrigerators and freezers are treated, the legal framework is the most important basis. There are several regulations and standards in the field of the recycling of cooling and freezing appliances. They are the topic of the first part in this chapter. The second part is the technical part, where the state of the art of recycling plants is represented.

C.2.2.1 Legal and Normative Background of the Recycling Technology

Majority of the cooling and freezing appliances that are currently recycled still contain chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs), although they are prohibited since the mid-1990s by Council Regulation (EC) No 3093/94 of 15 December 1994 on substances that deplete the ozone layer. This regulation banned the manufacture of ozone depleting gases, like CFCs and HCFCs, and regulated their treatment. The amended version is the regulation (EC) No 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer. Because of several amendments of the regulation (EC) No 2037/2000 it was recast in the regulation (EC) No 1005/2009 of the European Parliament and of the Council of 16 September 2009 on substances that deplete the ozone layer. They all result from the Montreal Protocol which was agreed on 16 September 1987, when the dramatic depletion of the ozone layer over the Antarctica has been noticed. Currently, the 9th edition of the Montreal Protocol on substances that deplete the ozone layer is available.

Hydro fluorocarbons (HFCs) were introduced to substitute CFCs and HFCFs, and are still used in the manufacture. In the mid-1990s, manufacturers started to substitute refrigerants like CFCs with hydrocarbons (like isobutane in the compressor cooling system). Cyclopentane serves as a substitution of CFCs, as blowing agents for the polyurethane foam insulation. According to a report of the United Nations University in 2007 about the WEEE Directive (q.v. [UNU]) the hydrocarbons used in cooling and freezing appliances do not deplete the ozone layer. Their global warming potential is typically 3 or 4, i.e. below the GWP threshold of 15 set by Annex II of WEEE directive 2002/96 EC. [UNU, page 86]

According to Annex VII of the WEEE directive 2012/19/EU the following points have to be fulfilled:

- As a minimum the following substances, preparations and components have to be removed from any separately collected
    - Chlorofluorocarbons (CFCs),
    - Hydro chlorofluorocarbons (HCFCs),
    - Hydro fluorocarbons (HFCs) and
    - Hydrocarbons (HCs).

- Equipment containing gases that are ozone depleting or have a global warming potential (GWP) above 15, such as those contained in foams and refrigeration circuits: the gases must be properly extracted and properly treated. Ozone-depleting gases must be treated in accordance with Regulation (EC) No 1005/2009. [WEEE2]

The European standard EN 50574 (current edition: EN 50574:2013[1]) with the title "Collection, logistics & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons" supports the WEEE directive 2002/96/EC. This standard, which was accepted by CENELEC (European Committee for Electrotechnical Standardization) on 26 March 2012, seeks to reduce the environmental impact caused by WEEE, which contain substances that if released untreated to the atmosphere could contribute to ozone depletion or global warming. It says how substances with a high global warming potential and/or ozone depletion potential are removed from WEEE and subsequently treated so as to significantly reduce environmental impacts. [EN 50574]

The CECED, the WEEE Forum and the European Electronics Recyclers Association (EERA) in common created the following two guidelines, which describe the state of the art of the recycling technology in Europe and which were later integrated in the previously mentioned standard EN 50574.

- Requirements for the Collection, Transportation, Storage and Treatment of Cooling and Freezing Appliances containing Hydrocarbons (HC) of 18 October 2006;
- Requirements for the Collection, Transportation, Storage, Handling and Treatment of Household Cooling and Freezing Appliances containing CFC, HCFC or HFC of 21 December 2007;

In Austria two standards are important for the recycling of C&F appliances:

- ON S 2106 "Recycling and disposal of waste electrical and electronic appliances" and
- ON S 2107 "Requirements to be met by companies collecting and treating waste electrical and electronic equipment".

Both are mostly implemented in the Austrian WEEE Ordinance (q.v. [EAG-VO]) and the Austrian Ordinance on Waste Treatment Obligations (q.v. [AbfbeVO]).

The most relevant documents for the recycling of cooling and freezing appliances in Europe are summarised in Table 14 .

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[1] EN 50574:2013 is equal to EN 50574:2012 + AC:2012 (summary of EN 50574:2012 05 and EN 50574/AC:2012 11).

Table 14: Relevant Legal and Normative Regulations for the Recycling of C&F appliances

Type and No.	Title	Date
Regulation (EC) No 1005/2009	regulation on substances that deplete the ozone layer	16. 09. 2009
Directive 2012/19/EU	directive on waste electrical and electronic equipment (WEEE Directive)	04. 07. 2012
European standard EN 50574:2013	Collection, logistics & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons	01. 07. 2013

C.2.2.2 State of the Art of the Recycling Technology

As already mentioned in the previous chapter, the European standard EN 50574:2013 contains instructions how to remove ozone depleting or global warming substances. The treatment in this standard is divided in three steps:

1. **Step 1 treatment**: removal of volatile fluorocarbon (VFC), volatile hydrocarbon (VHC) and oil from the refrigerating system
2. **Step 2 treatment**: removal of VFC, VHC from insulating foam
3. **Step 3 treatment**: converting VFC, VHC as a part of the treatment process into compounds that do not deplete the ozone layer

VFC is an organic chemical compound consisting of carbon and fluorine atoms (in some cases also with chlorine and/or hydrogen), which is able to change phase when used as a refrigerant or produce cells in plastic structure of an insulating foam when used as a blowing agent. Common commercial designations for these materials are R12, R11 for CFCs, R22, R141b for HCFCs and R134a for HFCs. VHC is an organic chemical compound consisting entirely of hydrogen and carbon, which is able to change phase when used as a refrigerant, or produce cells in plastic structure of an insulating foam when used as a blowing agent. Common designations for volatile hydrocarbons are R290 for propane, R600a for isobutane, R1270 for propene and RC601 for cyclopentane. Mixtures of VHC are also possible. [EN 50574]

Figure 20, which is based on a figure in a report about the treatment WEEE from the Environment Agency Austria [UBAa, page 54], illustrates the different paths of the treatment of C&F appliances in Austria for the year 2006. Nearly all Austrian recycling plants only perform the previously described Step 1 and Step 2.

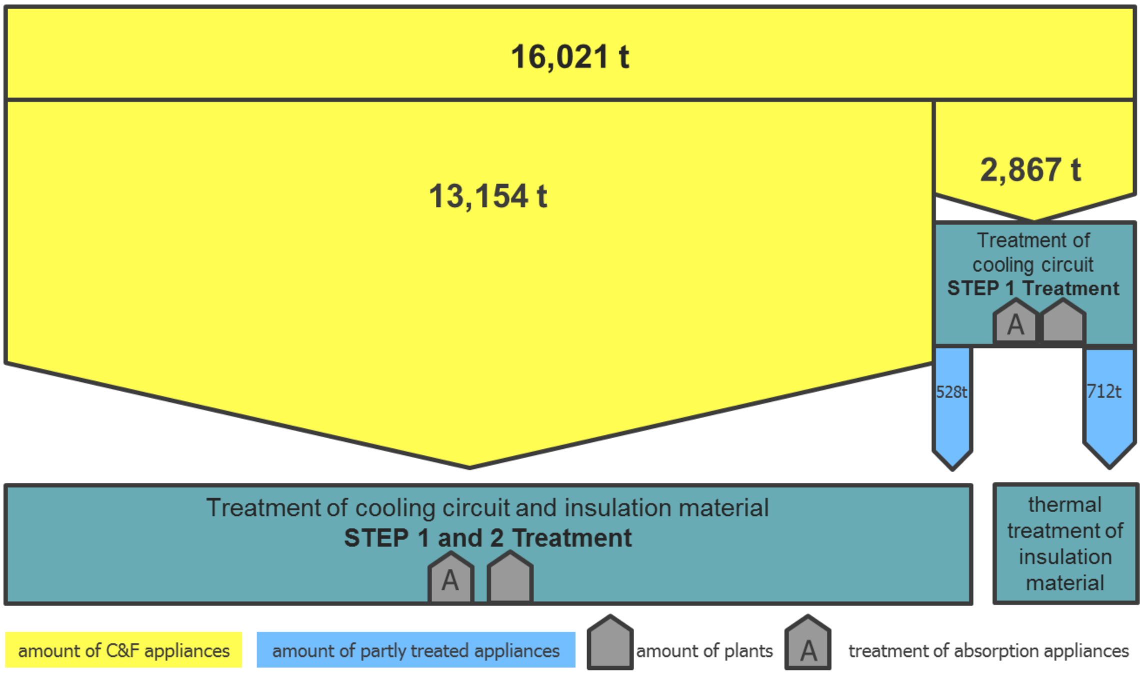

Figure 20: Overview of the Treatment of Cooling and Freezing Appliances in Austria (2006)

The feedback of the contacted recycling companies and plant construction firms (only 28 answered although 84 were contacted) was nearly consistent. All recyclers who answered work based on the treatment scheme described in EN 50574. It is mentionable that nearly all recyclers focus on the first two treatment steps and often speak about a treatment with the "common 2 step principle". The third step is often outsourced, because of its very labour-intensive working steps.

Based on the information received from the recyclers and the plant construction firms, seven different process flow sheets were created (see Appendix II).

Description of the Simplified Process Flow Diagram

The flow sheet, shown in Figure 21, represents the summarised result of all received information from the contacted recyclers as well as from the contacted plant installers. The seven process flow sheets in Appendix II are the basis for this simplified flow diagram. Every single step is described in the following points.

Manual Removal

First of all the incoming refrigerators and freezers are manually unloaded by disassembling all removable parts, like glass, mercury-switches, cables, compressors and capacitors.

Step 1 Treatment

This step is clearly described in EN 50574:2013 with the following points:

1. All refrigerants and all oil shall be removed from the refrigerating system;
2. All refrigerants shall be separated from oil;

3. All oil shall be contained within a closed system until the concentration of refrigerant is below 0,2 mass% VFC; NOTE The VFC content should be measured and expressed as concentration of R12 in the oil;
4. No residual VFC within the oil shall be allowed to be released to the atmosphere;
5. The total mass of refrigerants removed from the refrigerating system (sum of VHCs and VFCs) shall be monitored and documented continuously. [EN 50574]

The practical procedure of removing all refrigerants and oil happens with the help of a special **suction unit**. To guarantee the complete emptying of the oil/refrigerant mix, the suction unit is installed on the deepest point of the cooling circuit. The **separation** of oil and the refrigerants (R11, R12 etc.) is realised by heating up the mixture. As a result, the refrigerants degas and are collected in special tanks while the oil remains liquid.

Crushing Machine and Separation

The refrigerators, which do not contain any liquids due to the suction unit, but still have blowing agents in the insulation materials, are crushed. There are several crushing or chopping units on the market, for instance a cross flow crusher, a two-shaft shredder or a four-shaft shredder. To reduce the danger of fire and explosion, an inert atmosphere is created by using gaseous nitrogen (N_2). The output material mix from the shredding unit, the size of which varies from 20 to 40 mm, is separated by several succeeding separators. In a first step the very light PU-foam particles are removed, for instance with the help of a zig-zag-separator. These separated particles have to be treated very carefully to ensure that all blowing agents are captured and are not released untreated to the atmosphere (described in the next passage “Step 2 Treatment”). By a magnetic separator, e.g. an overband magnet, the ferrous material like iron is separated from the non-magnetic material. The remaining fraction is passed over an eddy current separator, where it is separated into non-ferrous metals (e.g. copper and aluminium) and plastics. At last, the two metals (copper and aluminium) are separated from each other.

Step 2 Treatment

This step, which applies to WEEE containing insulating foam with either VFCs or VHCs, is clearly described in EN 50574:2013 with the following points:

1) The treatment of appliances in step 2 is normally carried out with step 1 treated appliances (called “cabinets”);
2) Insulating foam shall not be manually removed; NOTE 1 Future insulation material technologies may necessitate a manual dismantling of insulating foam.
3) The crushing of cabinets and the separation of crushed fractions shall be performed in a way that emissions of VFCs and VHCs to the atmosphere are minimised according to national legislation;
4) The residual content of VFCs contained in the separated metal and plastics fractions shall be minimised;

5) The residual VFCs within the crushed insulating foam shall not be released to the atmosphere. They shall be converted into compounds that do not deplete the ozone layer; NOTE 2 The conversion into non-ozone depleting substances is necessary according to EC Regulation No 1005/2009.
6) The total mass of blowing agent (sum of VHCs and VFCs) removed from the insulating foam shall be monitored and documented continuously. [EN 50574]

In practice, the PU-foam particles coming from the crushing unit are often transported to a **pelletizer**, where they are pressed into pellets**;** sometimes also to a grinder, where they are ground up to a PU-meal. At the same time, the remaining blowing agents are sucked out (**matrix degassing**). With the help of a so called cryocondensation, where very low temperatures are used to condense volatile compounds like the blowing agents, the VHCs and VFCs are recovered and collected in closed vessels.

Step 3 Treatment

Although the third step treatment is equally important as the previous two steps, most recyclers have it outsourced to other recycling plants. Only a few of the recyclers do this step in their own plants.

Related to this step, the standard EN 50574:2013 says:

Where the VFCs are being converted on site into compounds that do not deplete the ozone layer, continuous recorded input data for raw gas and output data for clean gas shall be monitored and documented continuously. The documentation shall include mass flow and concentration of VFCs to demonstrate that the conversion is effective. [EN 50574]

One way to treat the VFCs is to destruct them in a high temperature incineration. It is also possible to work with a hydrolysis and convert the CFCs into hydrochloric acid, fluoric acid and carbon dioxide.

Output Materials

Every bolt, which reaches over the system boundary in Figure 21, stands for an output material. Some of them have to be destroyed, for instance in an incineration plant, others can be recycled or even sold, like the following materials:

- iron;
- PU- pellets or PU-meal;
- plastics;
- non-ferrous metals like aluminium and copper.

Some recyclers use the PU material, where the blowing agents have been removed by step 2 treatment, as oil or chemical binder. Other recyclers use them as substitute fuels.

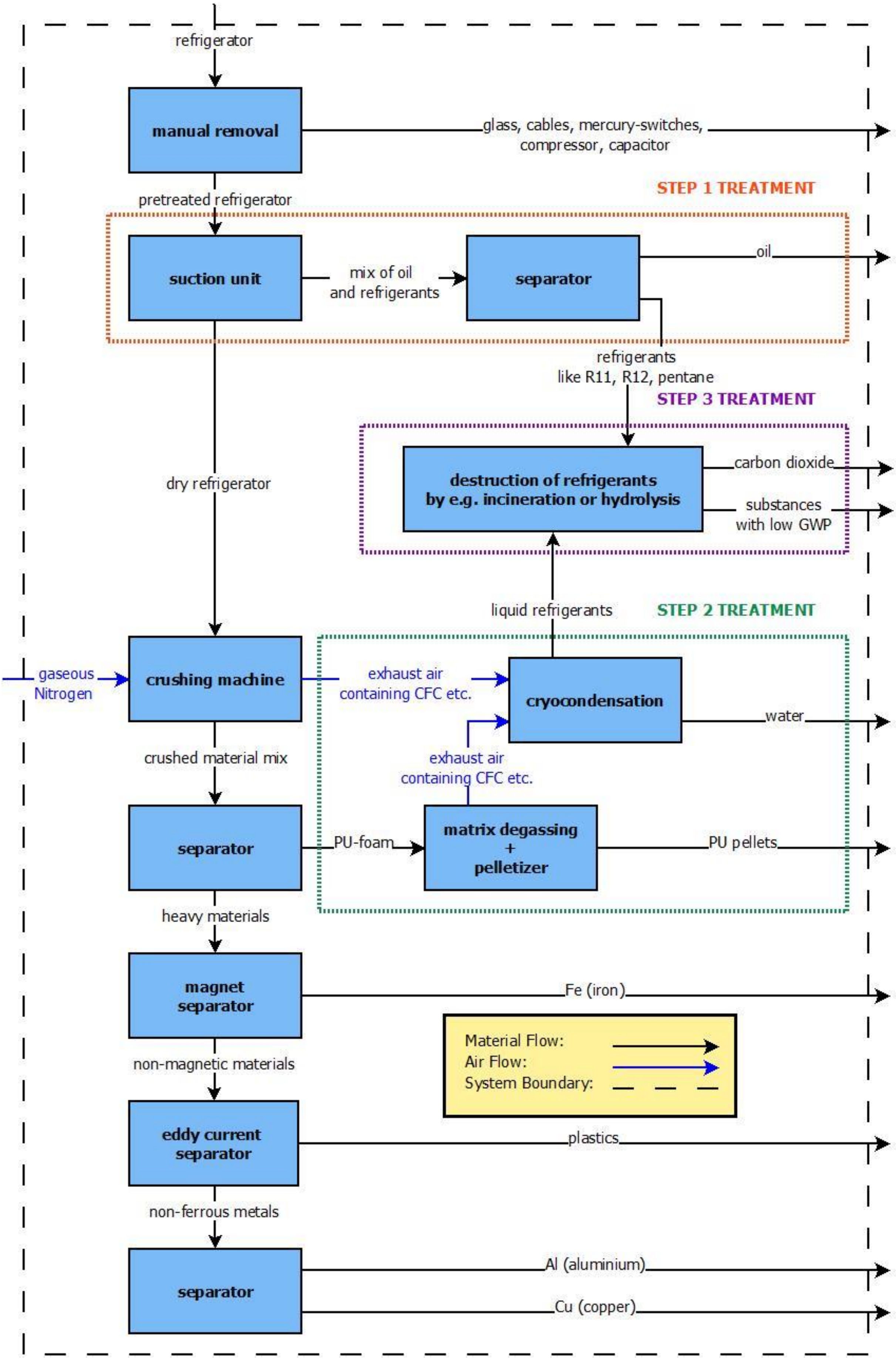

Figure 21: Simplified Process Flow Diagram of a Prevailing Recycling Plant for Refrigerators

As already mentioned in chapter C.1.2 in Figure 12, a modern A++ refrigerator consists of the following materials (based on [Sarc]):

- ca. **47 mass% metals** (material recycling possible)
- ca. **35 mass% plastics** (material and thermal recycling possible)
- ca. **11 mass% inorganic material**
    - ca. **6 mass% glass** (material recycling possible)
    - ca. **5 mass% VIPs**

To compare the mass balance of a modern A++ appliance (see Figure 12) with a conventional CFC containing refrigerator, the following tables were created based on a report of the TU Vienna from 2006 (see Table 15).

Table 15: Mass Balance of a CFC containing C&F Appliance [TU Vienna]

Material	Mass%
ferrous metals	43.04
compressor	19.10
plastics	15.00
PU-foam	9.92
non-ferrous metals	6.18
glass	2.17
CFC (sum)	0.89
oil	0.64
electronics	0.60
rest	2.46
total	100%
weight in average	ca. 41 kg

non-ferrous metals	100%
aluminium	89%
copper	11%

compressor	100%
iron	90%
rest (e.g. copper)	10%

CFC	100%
blowing agents	70%
refrigerants	30%

In the following two tables (Table 16 and Table 17) the main input materials, as well as the main output materials of refrigerator recycling plants, are listed. Although the waste codes are only based on the European Waste Catalogue (EWC) 2002, there are two different descriptions. One description refers to the Austrian code system according to ON S2100, which classifies waste in different material groups. The other description refers to the EWC 2002, which divides waste based on its origin. Due to the detailed list of the Austrian Catalogue, both descriptions are mentioned in these two tables.

Table 16: Input of Refrigerator Recycling Plants [EWC] [ON S2100]

EWC Code	**Description** according to the EWC 2000	**Description** according to Austrian OEN S2100
16	*Wastes not otherwise specified in the list*	
16 02	*Waste from Electrical and Electronic Equipment*	
16 02 11	Discarded equipment containing chlorofluorocarbons, HCFC, HFC	Cooling and freezing appliances with CFC-, HFC- and HC-containing refrigerants (e.g. propane, butane)
16 02 13	Discarded equipment containing hazardous components other than those mentioned in 16 02 09 to 16 02 12	Cooling and freezing appliances with CFC-, HFC- and HC-containing refrigerants (e.g. propane, butane)/ Cooling and freezing appliances with other refrigerants (e.g. ammonia in absorption refrigerators)
20	*Municipal Wastes (Household waste and similar commercial, industrial and institutional wastes) Including separately collected fractions*	
20 01	*separately collected fractions (except 15 01)*	
20 01 23	Discarded equipment containing chlorofluorocarbons	Cooling and freezing appliances with CFC-, HFC- and HC-containing refrigerants (e.g. propane, butane)
20 01 35	Discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components	Cooling and freezing appliances with other refrigerants (e.g. ammonia in absorption refrigerators)

Table 17: Output of Refrigerator Recycling Plants [EWC] [ON S2100]

EWC Code	**Description** according to the EWC 2000	**Description** according to Austrian OEN S2100
14	*Waste Organic Solvents, Refrigerants and Propellants (except 07 and 08)*	
14 06	*waste organic solvents, refrigerants and foam/aerosol propellants*	
14 06 01	Chlorofluorocarbons, HCFC, HFC	CFC-containing refrigerants, propellants and solvents
16	*Wastes not otherwise specified in the list*	
16 02	*Waste from Electrical and Electronic Equipment*	
16 02 09	transformers and capacitors containing PCBs	PCB- and PCT-containing electrical equipment
17	*Construction and Demolition Wastes (including excavated soil from contaminated sites)*	
17 04	*metals (including their alloys)*	
17 04 11	cables other than those mentioned in 17 04 10	cables
19	*Wastes from Waste Management Facilities, Off-site Waste Water Treatment Plants and the Preparation of Water Intended for Human Consumption and Water for Industrial Use*	
19 10	*wastes from shredding of metal-containing wastes*	
19 10 01	Iron and steel waste	Iron- and steel waste
19 10 02	Non-ferrous waste	aluminium/ copper/ non-ferrous metals
19 10 04	fluff-light fraction and dust other than those mentioned in 19 10 03	Residues from shredding (fluff-light fraction)
19 12	*wastes from the mechanical treatment of waste (for example sorting, crushing, compacting, pelletising) not otherwise specified*	
19 12 02	Ferrous metal	Residues of mechanical treatment of waste/ iron and steel waste
19 12 03	Non-ferrous metal	aluminium/ copper/ non-ferrous metals/ residues of mechanical treatment of waste
19 12 04	Plastic and rubber	Polyurethane foam/ acrylic glass/ residues of mechanical treatment of waste and other plastics
19 12 05	Glass	Residues of mechanical treatment of waste
19 12 12	other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11	Residues of mechanical treatment of waste

Regarding these two tables shown above, the question raises, which code according to the European Waste Catalogue 2002 would fit to VIPs. In the following table, there are some proposals summarised:

Table 18: Proposed Waste Codes for Vacuum Insulation Panels [EWC] [ON S2100]

EWC Code	**Description** according to the EWC 2000	**Description** according to Austrian OEN S2100
17	*Construction and Demolition Wastes (including excavated soil from contaminated sites)*	
17 06	*insulation materials and asbestos-containing construction materials*	
17 06 04	insulation materials other than those mentioned in 17 06 01 and 17 06 03	Glass fleece/ mineral fibres
19	*Wastes from Waste Management Facilities, Off-site Waste Water Treatment Plants and the Preparation of Water Intended for Human Consumption and Water for Industrial Use*	
19 10	*wastes from shredding of metal-containing wastes*	
19 10 04	fluff-light fraction and dust other than those mentioned in 19 10 03	Residues from shredding (fluff-light fraction)
19 12	*wastes from the mechanical treatment of waste (for example sorting, crushing, compacting, pelletising) not otherwise specified*	
19 12 09	Minerals (for example sand, stones)	Residues of mechanical treatment of waste
19 12 12	other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11	Residues of mechanical treatment of waste

C.2.3 Recycling of VIPs

Concerning the recycling of VIPs, there is not much information available. Within the framework of this report it was tried to get as much information as possible by asking recycling companies, VIP suppliers and by internet researches.

According to the responses of the few recycling companies, who have answered, some of them never even heard something about vacuum insulation. One recycler said that they have once made a shredding test with VIPs, but due to the “poor market share of VIP containing appliances” they dealt only superficially with VIPs. The leading opinion is that appliances, containing VIPs, should be separated after the first step from the other appliances.

An interesting patent was found from the year 2001. In the United States Patent No.: US 6.266.941 B1 of 31 July 2001, there is a description of producing a Vacuum Heat-Insulating Panel. This description mentions the possibility of using recycled material for producing a new one. This is shown in Figure 22, at the beginning of the flow sheet.

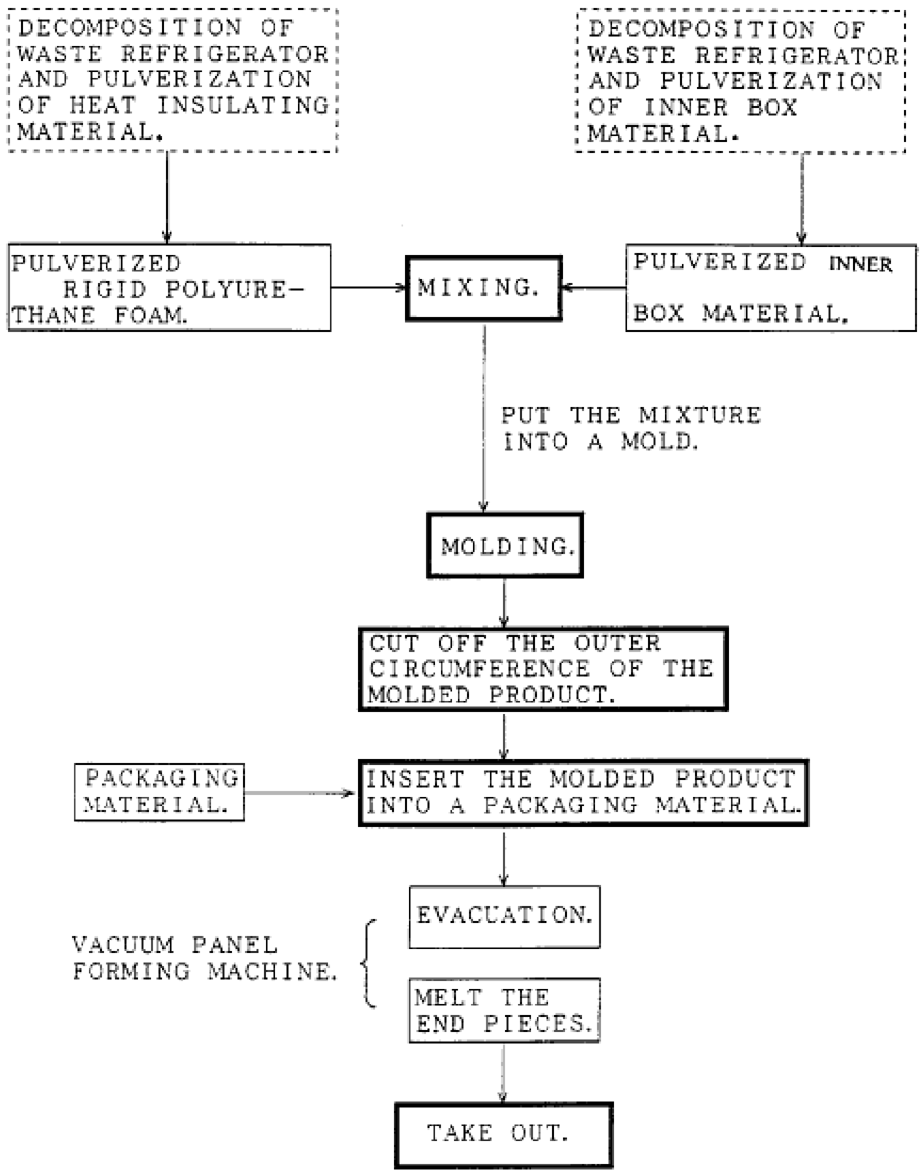

Figure 22: Possible Variant to Recycle VIPs [US Patent]

Another interesting patent from Panasonic Corporation, created in 2003 (European Patent No.: EP 1 527 863 B1), describes a method for recycling thermal insulating material containing rigid urethane foam and vacuum insulation material which has inorganic material as core material. In this patent, eight different recycling methods of those thermal insulation materials are shown. These methods mainly differ in the variable core materials from the vacuum insulation material.

Figure 23 is a flow chart depicting a method for recycling refrigerators and a method for producing vacuum insulation material as a recycled article. According to the patent in Figure 23, waste refrigerators which have been carried to a waste-treatment facility first undergo discriminating process 1 so as to be divided, in accordance with the indications on the outer boxes of the refrigerators, into multi thermal insulation material type refrigerators with a glass fiber assembly as the core material, and single thermal insulation material type refrigerators. [EP Patent]

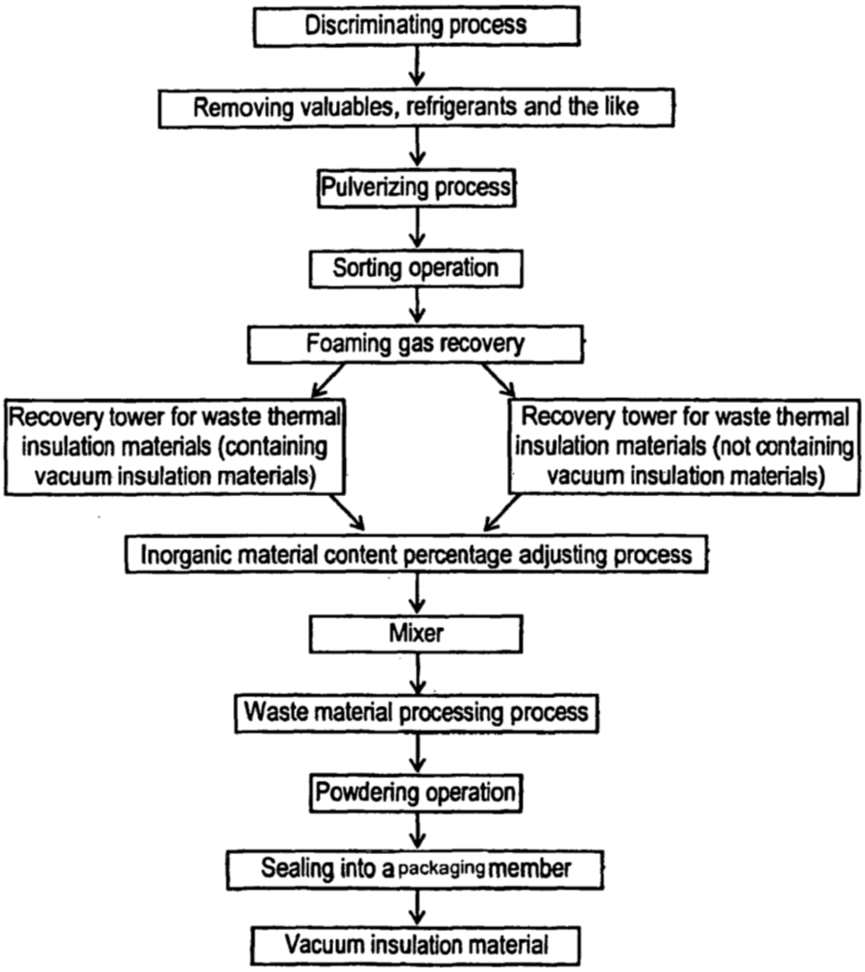

Figure 23: Method for Recycling Refrigerators and Producing Vacuum Insulation Material as a Recycled Material [EP Patent]

Figure 24 depicts a method for the recycling of thermal insulation material containing rigid urethane foam and vacuum insulation material which has glass fibre as core material. The thermal insulation materials are cut out as integral units with the rigid urethane foam. After this separating process the material gets crushed. Foaming gas which is in the urethane foam is recovered in a recovering process. In the next steps the waste material from grinding is mixed and sorted, to get a uniform quality to ensure the possibility of reusing the material. At the end, the material is mainly composed of glass fibre. After melting at a high temperature and centrifugation it can be used again. [EP Patent]

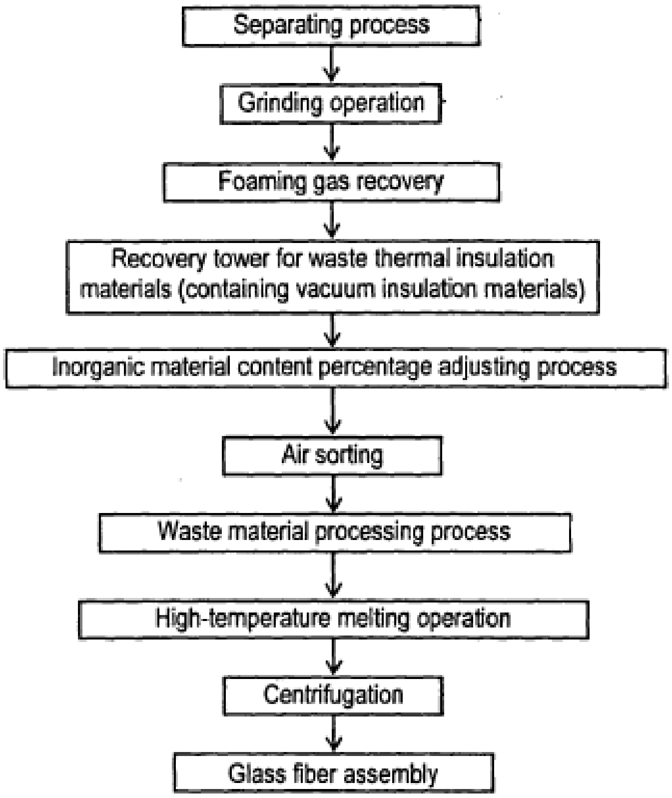

Figure 24: Method for Recycling Insulating Material from VIPs [EP Patent]

D. Testing Scheme – Phase 2

In this chapter the small technical tests as well as an analytical test are described, which were realised on 19, 20 and 21 March 2013 in Graz and Leoben. These small technical tests were necessary to determine possible health and safety conditions at the recycling plant. They are the basis for planning and organising the large-scale practical tests. For these tests, nine different VIP packages, received from seven different suppliers, were tested. The investigated VIPs were classified into six different material groups as shown in Table 19.

The small technical tests are divided in two types of tests:

- Shredding test in Graz (chapter D.1);
- Sieving analysis in Leoben (chapter D.2);

The preparation of the material for the analytical part of the tests, an X-ray fluorescence analysis (XRF analysis) as well as the XRF analysis itself were realised in Leoben at the Montanuniversitaet (see chapter D.3).

Table 19: Classification of Investigated VIP Material Groups

Abbreviation	Material Group	Description	Supplier	Picture of Material
MG1	material group 1	paperlike	VIPS-6, VIPS-10, VIPS-14, VIPS-4	
MG2	material group 2	white fleece	VIPS-4	
MG3	material group 3	glass woollike	VIPS-13	
MG4	material group 4	grey powder	VIPS-15	
MG5	material group 5	brown powder	VIPS-7, VIPS-10	
MG6	material group 6	black powder	VIPS-9	

D.1 Shredding of VIPs

The testing location of the shredding test on 19 March 2013 was the technical centre in Graz. For shredding the received VIPs, a four-shaft shredder (shown in Figure 25 and Figure 26) with a 25 mm screen was used. With the help of a band conveyor (shown in Figure 25) the shredded material was moved from the four-shaft shredder into buckets, where the shredded material was collected.

Table 20: Used Equipment for Shredding Test

Used Equipment	four-shaft-shredder with a 25 mm screen	UNTHA, 12/2005 model, type RS40-4.S, serial number: RS432875480mm
	band conveyor	

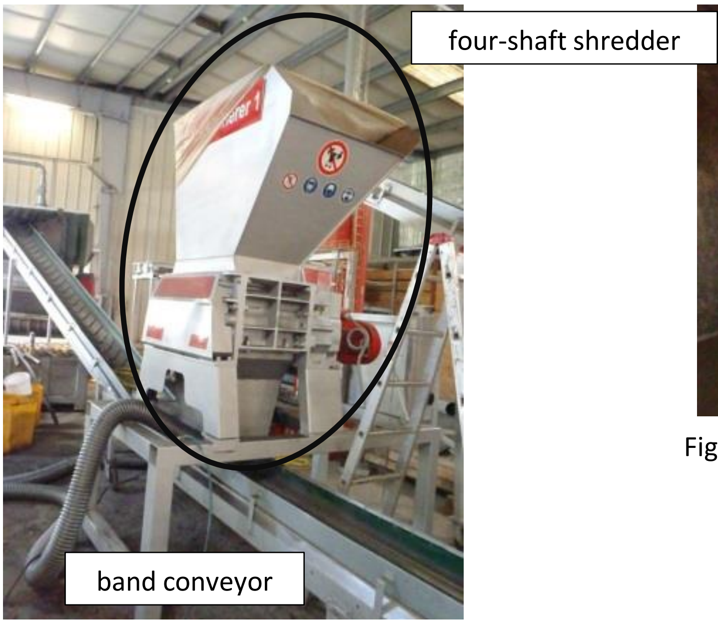

Figure 26: Top view of four-shaft shredder

Figure 25: Used four-shaft shredder and band conveyor

The working principle of the used four-shaft shredder (Figure 27) is to cut the material with the main and secondary cutters as long as the shredded material is small enough to fall through the screen.

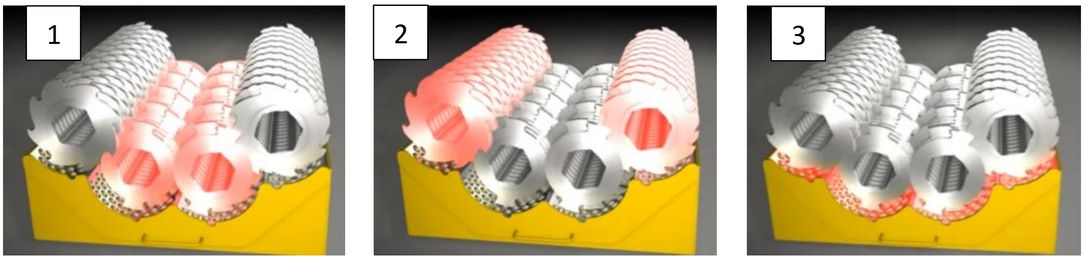

Figure 27: Main cutters (1), secondary cutters (2) and screen (3) of a four-shaft shredder [UNTHA]

All material groups (MG1 to MG6 successively) were shredded easily by the four-shaft shredder. In the following pages the input and output material of every material group is shown. The occurred problems are also described.

D.1.1 Material Group 1 – Paperlike

The paperlike material only caused a small formation of dust. In the following Figure 28 the input and the output material is shown.

Input: **Output:**

Figure 28: Input and Output Material of Material Group 1 (paperlike)

D.1.2 Material Group 2 – White Fleece

This material caused a heavy formation of dust as shown in Figure 29 and in the first output image of Figure 30.

As additional information, it has to be mentioned that the smoke alarm in the testing plant was switched off. Otherwise the heavy formation of dust would have set off alarm and the emergency forces would have been alerted. This happened once, when another material in this plant was tested. The fire service and the police were alerted, which caused avoidable costs. This could represent a problem in a recycling plant of refrigerators.

In Figure 30 the input and the output material is shown.

Figure 29: Formation of dust of MG2

Input: **Output:**

Figure 30: Input and Output Material of Material Group 2 (white fleece)

D.1.3 Material Group 3 – Glass Woollike

While shredding the glass woollike material, the great increase of volume was remarkable. In Figure 31 the input and the output material is shown. The formation of dust while shredding this material was negligible in comparison with MG2. The dwell time in the shredder was very long.

Input: **Output:**

Figure 31: Input and Output of Material Group 3 (glass woollike)

D.1.4 Material Group 4 – Grey Powder

Material group 4 caused a heavy formation of dust, as shown in the first output image of Figure 32, comparable to MG2. Because of the powdery matrix, the dwell time in the shredder was short.

Input: **Output:**

Figure 32: Input and Output of Material Group 4 (grey powder)

D.1.5 Material Group 5 – Brown Powder

As noticeable in Figure 33, where the input and output material is shown, the shredding process of material group 5 again caused a heavy formation of dust. The dwell time was again very short.

Input: **Output:**

Figure 33: Input and Output of Material Group 5 (brown powder)

D.1.6 Material Group 6 – Black Powder

Material group 6 also caused a heavy formation of dust and had a short dwell time in the shredder because of the powdery matrix of the core material. In the second output image of Figure 34, the dust is clearly visible due to the direct sunlight.

Input: **Output:**

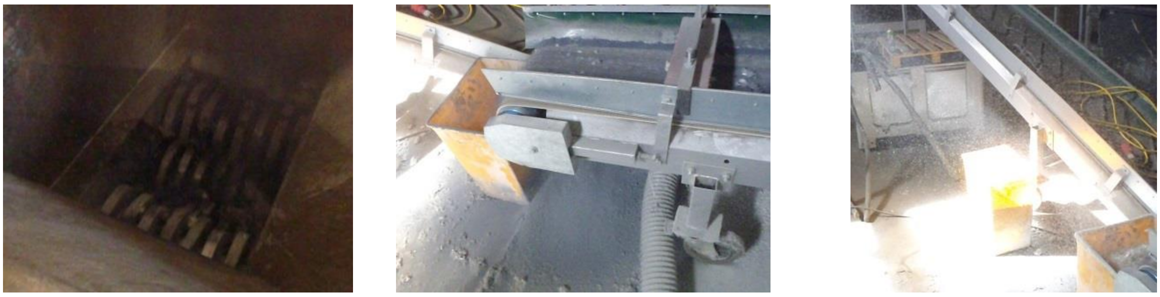

Figure 34: Input and Output of Material Group 6 (black powder)

D.1.7 Summary

Regarding the shredding test, all materials except MG1 (paperlike) and MG3 (glass woollike) caused a heavy formation of dust while the shredding process. That is why the use of dust masks, safety goggles, as well as whole body suits is recommendable.

The fact that the smoke alarm in the testing plant was switched off to avoid an alert of the emergency forces, is important for further possible investigations of these material groups. This could represent a problem in a recycling plant of refrigerators.

D.2 Sieving Analyses of Shredded VIPs

With the sieving analyses, which were carried out on 19 and 20 March 2013 in Leoben at the Chair of Waste Processing Technology and Waste Management, the shredded material groups MG1, MG2, MG3, MG4 and MG5 were investigated[1]. The target was to determine, whether a separation of aluminium from the core material by sieving could be possible. Two types of sieving analysis were realised (one dry and one humidified), because refrigerators might be humid in refrigerator recycling plants:

- Sieving analyses with dry shredded material
- Sieving analyses with humidified shredded material (15 mass% water)

Due to these two types, it was also a target to determine, if there is a difference between the dry and the humidified material, because the same material was sieved twice. Based on the mesh opening of the shredder's screen of 25 mm, the following sieve openings were used for both sieving analyses (in total 7 levels): 20 mm, 16 mm, 10 mm, 6.3 mm, 4 mm, 2 mm and a sieve bottom. In Figure 35, the used sieve tower with six sieves and the bottom are represented on a mechanical shaker. As shown in Table 21, the total masses of the sieved materials vary. This variation results from the difference of the materials' densities, because the goal for the sieving analyses was to work with similar volumes, not masses.

Figure 35: Sieve Tower on Mechanical Shaker

Table 21: Sieving Analyses of Dry Materials

dry material	total mass [g]	> 20 mm [g]	> 16 mm [g]	> 10 mm [g]	> 6.3 mm [g]	> 4 mm [g]	> 2 mm [g]	< 2 mm [g]
MG1	**346.9**	53.5	38.7	63.2	35.1	14.8	7.4	134.2
MG2	**775.3**	35.1	85.4	126.4	92.8	64.6	90.0	281.0
MG3	**281.2**	9.6	6.1	77.6	103.6	37.9	6.2	40.2
MG4	**363.5**	37.3	25.6	62.4	99.8	45.2	21.0	72.2
MG5	**434.6**	13.9	31.3	157.7	101.0	18.3	12.4	100.0

[1] Due to the characteristics of MG6, being very powdery and dusty, it was refrained from a sieving analysis of MG6.

Based on the total masses of the first sieving analysis, the water content of approximately 15 mass% was calculated, because the same material was sieved twice. The results of the sieving analyses of the humidified material are shown in Table 22.

Table 22: Sieving Analyses of Humidified Materials

humidified material	total mass [g]	added water [g]	> 20 mm [g]	> 16 mm [g]	> 10 mm [g]	>6.3 mm [g]	> 4 mm [g]	> 2 mm [g]	< 2 mm [g]
MG1	**399.8**	66.1	214.5	1.7	63.7	48.2	17.2	7.5	47.0
MG2	**901.3**	140.2	56.1	65.6	178.2	134.0	76.1	111.0	280.3
MG3	**316.8**	50.1	77.8	22.8	111.8	68.9	25.6	3.0	6.9
MG4	**422.2**	65.1	47.2	35.2	55.1	87.1	65.9	24.8	106.9
MG5	**498.0**	80.3	60.1	48.4	118.7	84.9	13.8	6.3	165.8

In chapter D.4 every sieve of the analysed materials is shown in a series of photos as well as the resulted particle size distribution.

D.3 XRF Analysis of VIPs' Core Materials

Because the core materials of MG5 and MG6 have been already analysed by an X-ray fluorescence analysis within the report written by Renato Sarc and Josef Adam in 2011 [Sarc], only the core materials of MG1, MG2, MG3 and MG4 were analysed. Before analysing, they had to be grinded with the help of a ball mill to ensure that the material is homogenous and powdery. The results of the XRF analyses are shown in chapter D.4.

D.4 Results and Interpretation of the Testing Scheme

This chapter contains the results and interpretations of these results of the previous described tests. On the following pages the results of every single material group (MG1 to MG6) are summarised. In the interests of clarity, all created diagrams and photos of the concerning material group are represented on one single page, so that this page can serve as a kind of data sheet.

D.4.1 Results of Material Group 1 (paperlike)

During the shredding process, MG1 did not cause dust problems and was easily shredded by the four-shaft shredder.

The sieving of the dry material resulted in a high fine fraction, as shown in Figure 36. Regarding the sieving analysis of the humidified MG1 (Figure 37), it is conspicuous that the sieve > 16 mm looks nearly empty while the sieve > 20 mm looks quite crowded. Although the material was sieved for nearly 25 minutes (all other materials were sieved for about 10 minutes), there was no noticeable change in the first sieve. A probable explanation for this phenomenon is that the fine fraction gets sticky when humidified and remains on the bigger particles. That is why the particles, which had fallen through the 20 mm sieve when being dry, got too big as to fall through. All particles that passed the first sieve were small enough to also pass the 10 mm sieve. A separation of the aluminium from the core material could not be determined.

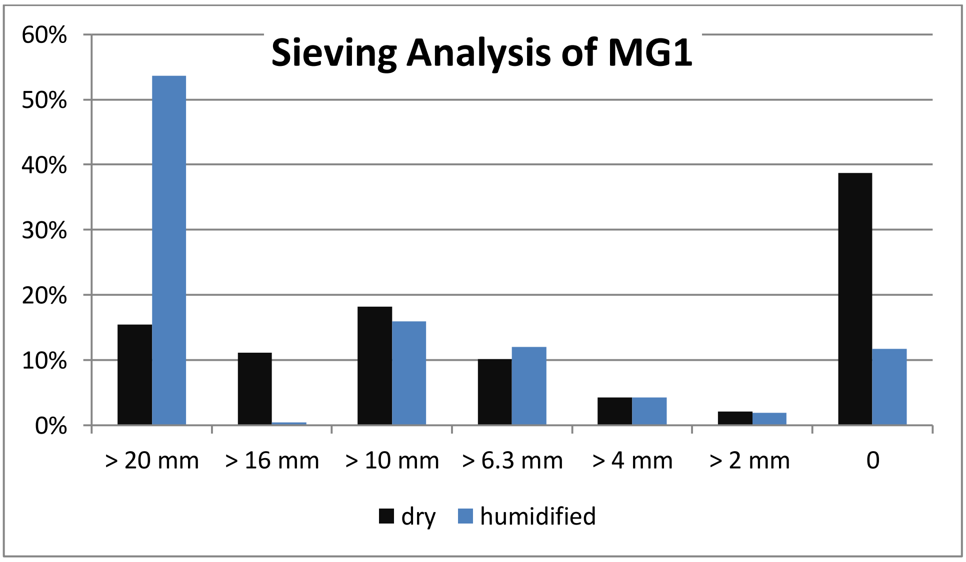

Figure 36: Comparison of dry and humidified MG1

The preparation of the core material for the XRF analysis in the ball mill was carried out without difficulties. According to the XRF analysis (also see Table 23), the main components of the core materials of MG1 are silicon dioxide (69%), sodium oxide (14%), calcium oxide (about 9%) and magnesium oxide (about 4%). In comparison with the main components of the other material groups, sodium dioxide seams characteristic for this material and explains its bright white colour. The high ash content of 99.73% proves that nearly the whole core material is inorganic.

Sieving Analysis of MG1

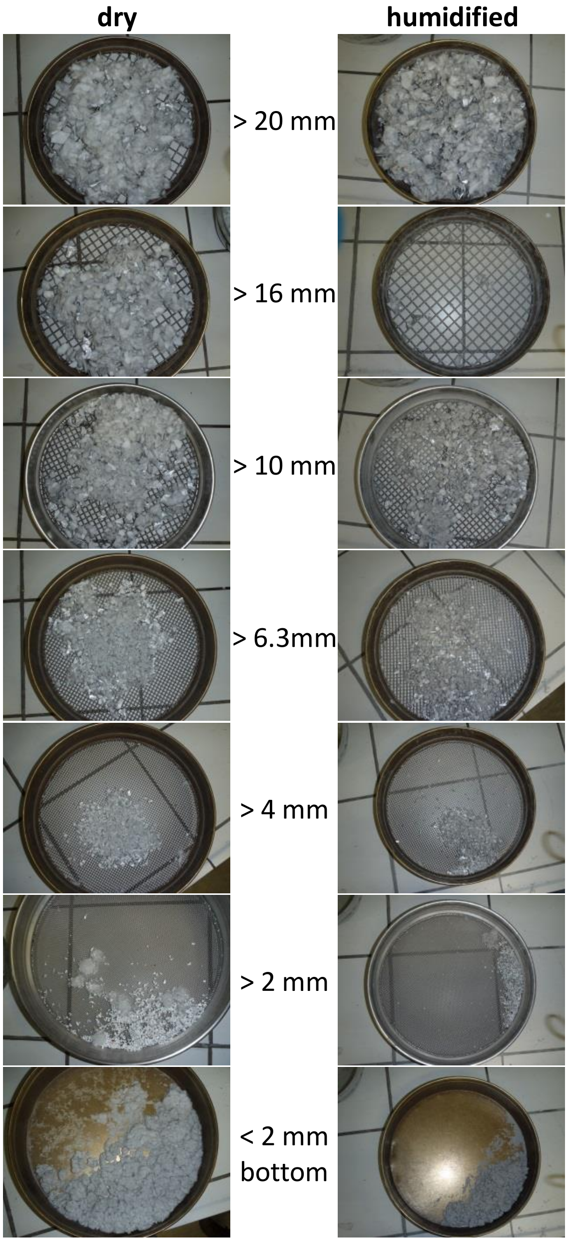

Figure 37: Series of Sieving Analysis of MG1

Preparation for XRF Analysis of MG1

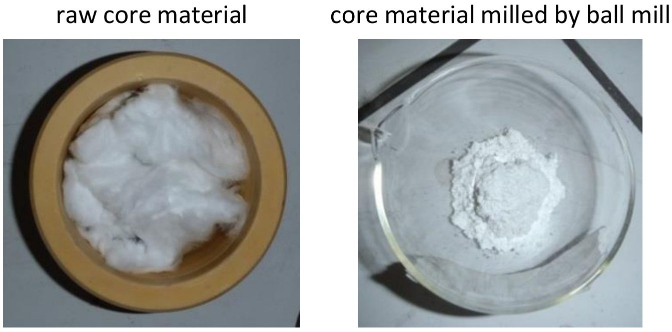

Figure 39: Raw and milled MG1 (paperlike)

Results of the XRF Analysis of MG1

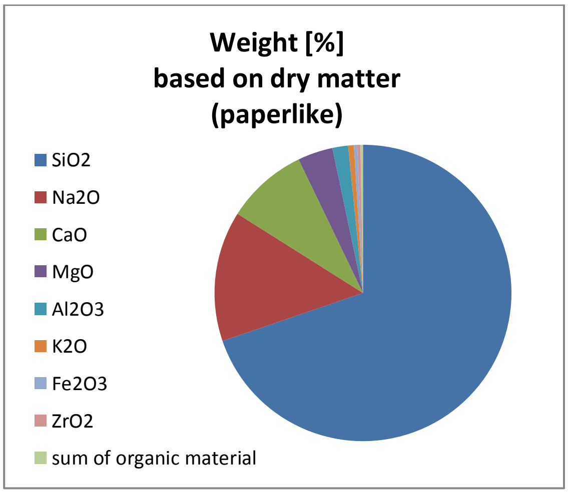

Figure 40: Mass Balance of MG1 (paperlike)

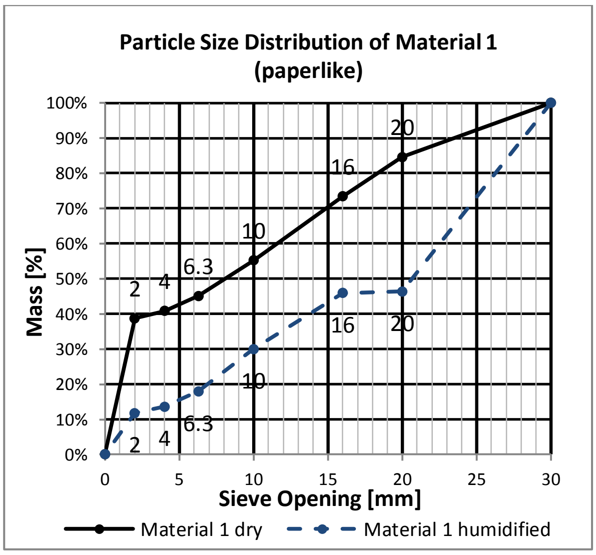

Figure 38: Particle Size Distribution of MG1

Table 23: Results of XRF Analysis of MG1

Evaluation of XRF Analysis of Material 1 (paperlike) (Sample Number: 0127-13-00)		
Compound	**Chemical Formula**	**Weight [%]**
silicon dioxide	**SiO_2**	**69.08**
sodium oxide	**Na_2O**	**14.09**
calcium oxide	CaO	8.81
magnesium oxide	MgO	3.79
aluminium oxide	Al_2O_3	1.70
potassium oxide	K_2O	0.62
iron(III) oxide	Fe_2O_3	0.36
zirconium dioxide	ZrO_2	0.34
ash content (sum of inorganic material)		**99.73**
loss on ignition (sum of organic material)		**0.27**
Total (inorganic and organic material)		**100**

D.4.2 Results of Material Group 2 (white fleece)

This material caused a heavy formation of dust during the shredding test.

Within about 10 minutes, each of the two sieving analyses was accomplished. In Figure 42 it is recognisable that the aluminium is well separated from the core material in both sieving analyses. The reason for this is that the shredded core material is quite small and does not show the character of sticking on the aluminium, even when humidified. Similar to MG1, it is noticeable (see Figure 41 and Figure 43) that the humidified material shows a lower fine fraction than the dry material. However, the effect that humidified small particles stick on the bigger particles and remain so in the upper sieves, is compared to MG1 only very weakly reflected in MG2.

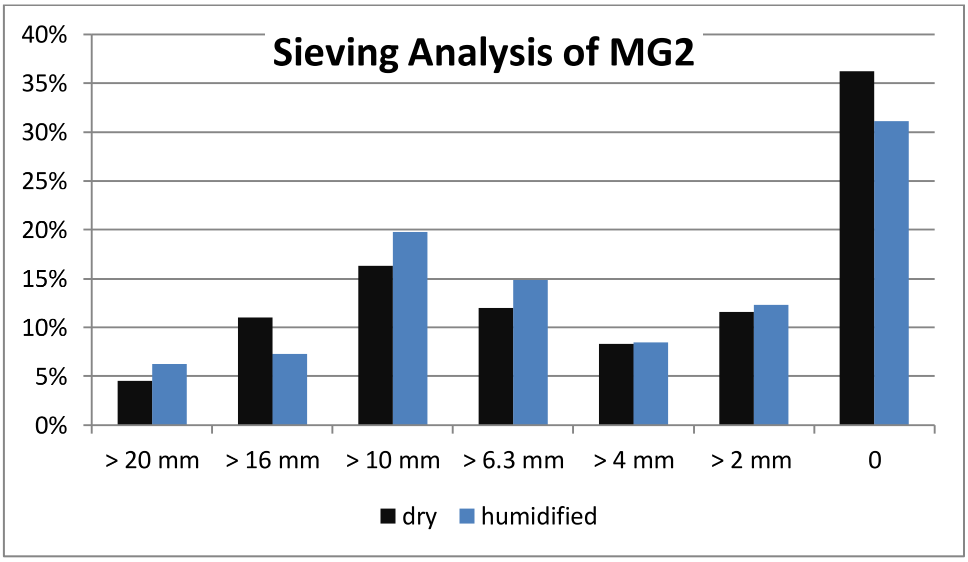

Figure 41: Comparison of dry and humidified MG2

The preparation of the core material for the XRF analysis with the help of a ball mill represented no problem. According to the results of the XRF analysis (Table 24), its main components are silicon dioxide (54%), calcium oxide (25%) and aluminium oxide (about 14%). The small percentage of the organic material proves that the material is nearly completely inorganic.

Sieving Analysis of MG2

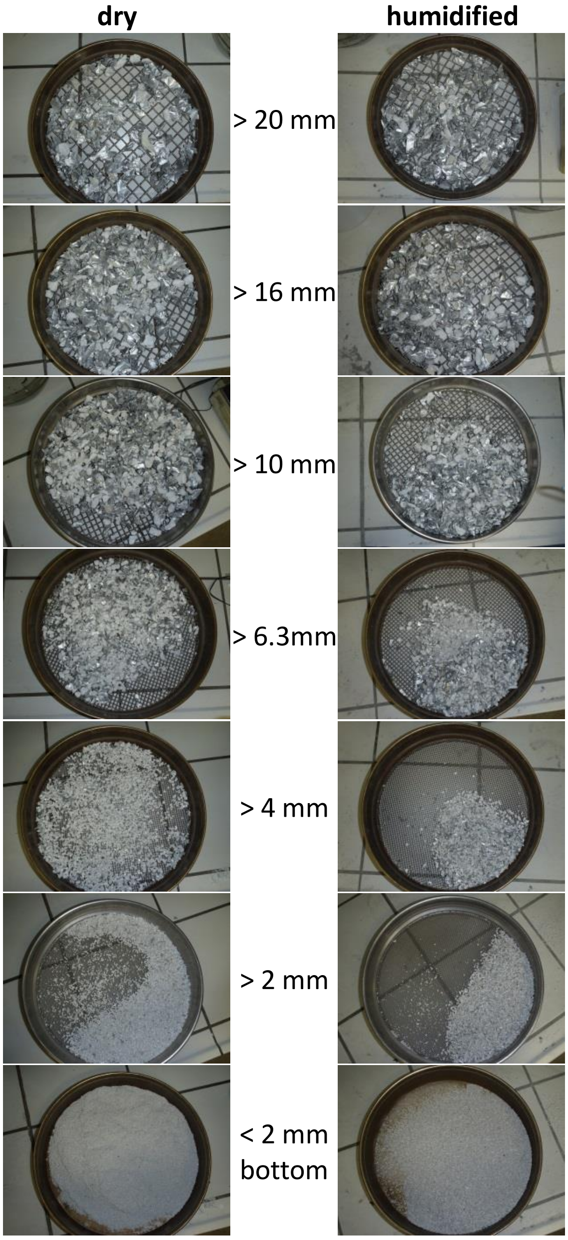

Figure 42: Series of Sieving Analysis of MG2

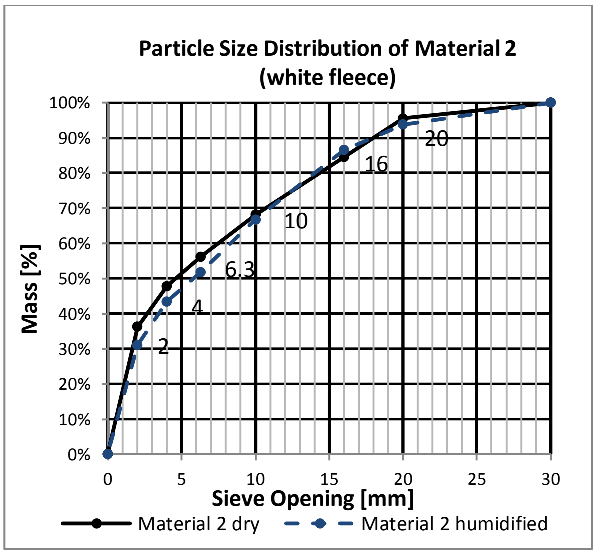

Figure 43: Particle Size Distribution of MG2

Preparation for XRF Analysis of MG2

raw core material   core material milled by ball mill

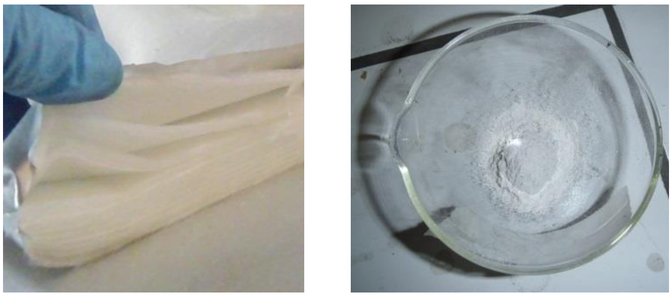

Figure 44: Raw and milled MG2 (white fleece)

Results of the XRF Analysis of MG2

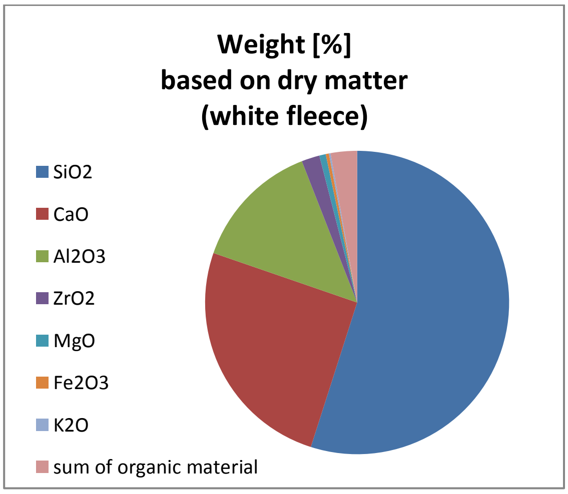

Figure 45: Mass Balance of MG2 (white fleece)

Table 24: Results of XRF Analysis of MG2

Evaluation of XRF Analysis of Material 2 (white fleece) (Sample Number: 0128-13-00)		
Compound	**Chemical Formula**	**Weight [%]**
silicon dioxide	**SiO_2**	**54.08**
calcium oxide	**CaO**	**24.97**
aluminium oxide	**Al_2O_3**	**13.57**
zirconium dioxide	ZrO_2	1.90
magnesium oxide	MgO	0.67
iron(III) oxide	Fe_2O_3	0.33
potassium oxide	K_2O	0.18
ash content (sum of inorganic material)		**97.24**
loss on ignition (sum of organic material)		**2.76**
Total (inorganic and organic material)		**100**

D.4.3 Results of Material Group 3 (glass woollike)

While shredding this material, a great increase of volume was noticeable. This effect also caused a rather high dwell time in the shredder.

Regarding the results of the two sieving analyses, they strongly remind on MG1. The biggest fraction (> 20 mm) of the humidified material has increased enormously compared to the dry material. The difference between the dry and the humidified material is shown very clearly in Figure 46. A separation of the aluminium from the core material was not achieved.

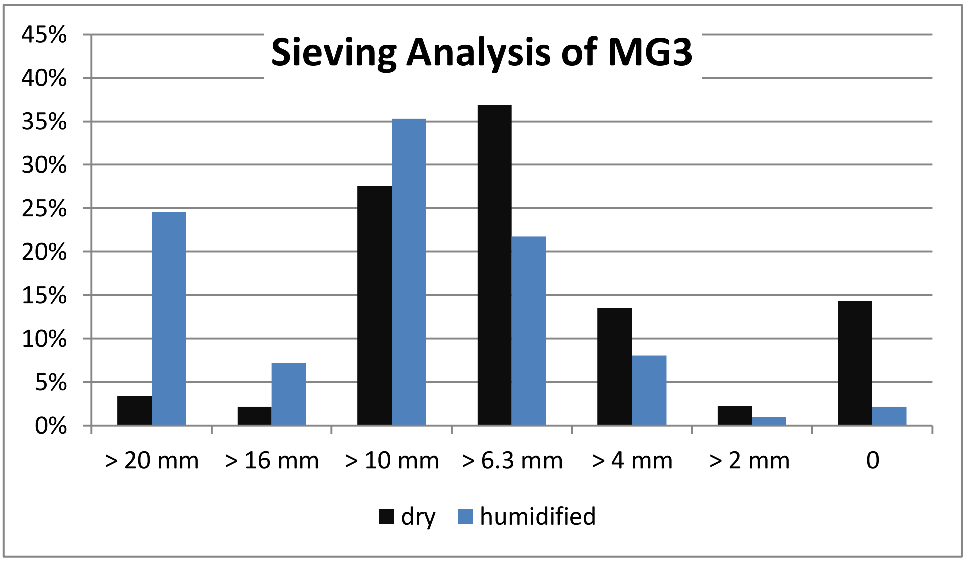

Figure 46: Comparison of dry and humidified MG3

In opposition to the other materials, MG3 represented a big problem during the milling process in the ball mill. The first trial to grind the glass woollike material resulted in strange looking pellets, which did not change their form although the material was milled for about 30 minutes. Before milling the material again, it was cut into small stripes. This time the milling process was successful. According to the carried out XRF analysis (Table 25), the main components of the core material are silicon dioxide (51%), calcium oxide (30%) and aluminium oxide (14%). This material also shows a high percentage of ash content.

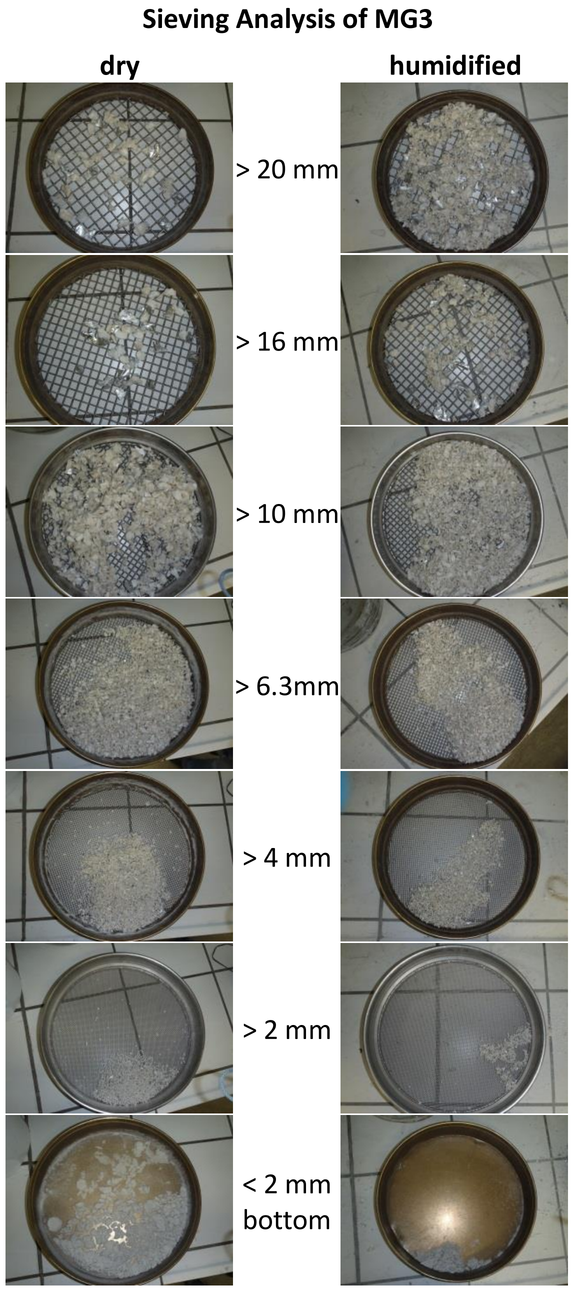

Figure 47: Series of Sieving Analysis of MG3

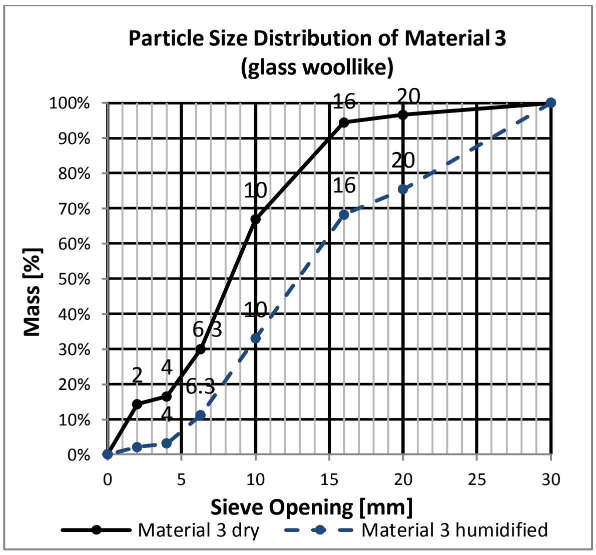

Figure 48: Particle Size Distribution of MG3

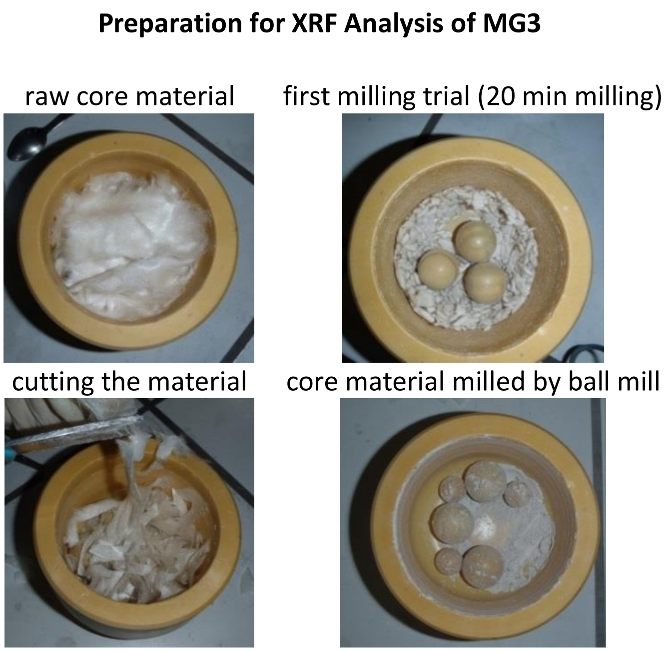

Figure 49: Steps from raw to milled MG3 (glass woollike)

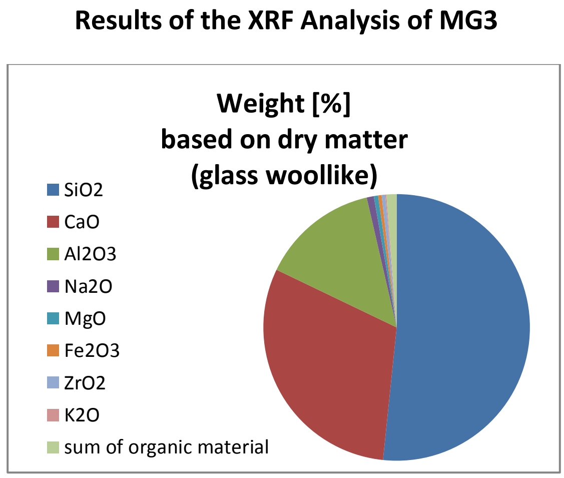

Figure 50: Mass balance of MG3 (glass woollike)

Table 25: Results of XRF Analysis of MG3

Evaluation of XRF Analysis of Material 3 (glass woollike) (Sample Number: 0129-13-00)		
Compound	**Chemical Formula**	**Weight [%]**
silicon dioxide	**SiO_2**	**51.03**
calcium oxide	**CaO**	**30.13**
aluminium oxide	**Al_2O_3**	**14.10**
sodium oxide	Na_2O	0.85
magnesium oxide	MgO	0.52
iron(III) oxide	Fe_2O_3	0.42
zirconium dioxide	ZrO_2	0.43
potassium oxide	K_2O	0.13
ash content (sum of inorganic material)		**98.78**
loss on ignition (sum of organic material)		**1.22**
Total (inorganic and organic material)		**100**

D.4.4 Results of Material Group 4 (grey powder)

This material caused during the shredding process a heavy formation of dust.

The results of the two sieving analyses (see Figure 51) show a contrary character to the previously described materials. The fine fraction in the humidified material is bigger than the fine fraction in the dry material. As represented in Figure 52, a quite good separation of the aluminium from the core material was achieved.

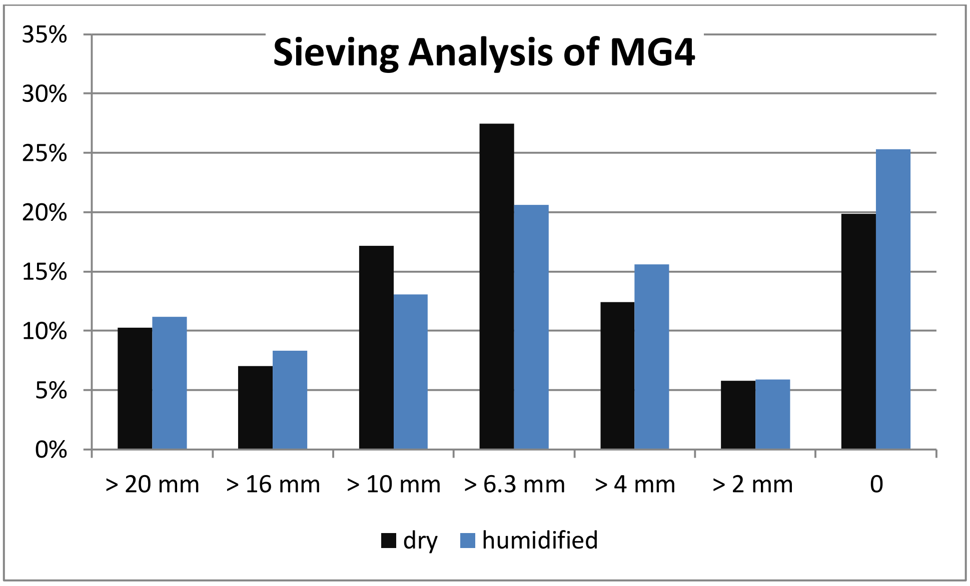

Figure 51: Comparison of dry and humidified MG4

Although a long milling time (about 50 minutes) was necessary, no other pre-treatments were required to grind the core material of MG4 for the XRF analysis. The results of this analysis (see Table 26) show that nearly the entire core material consists of silicon dioxide with 98%. The ash content is also very high with nearly 99%.

Sieving Analysis of MG4

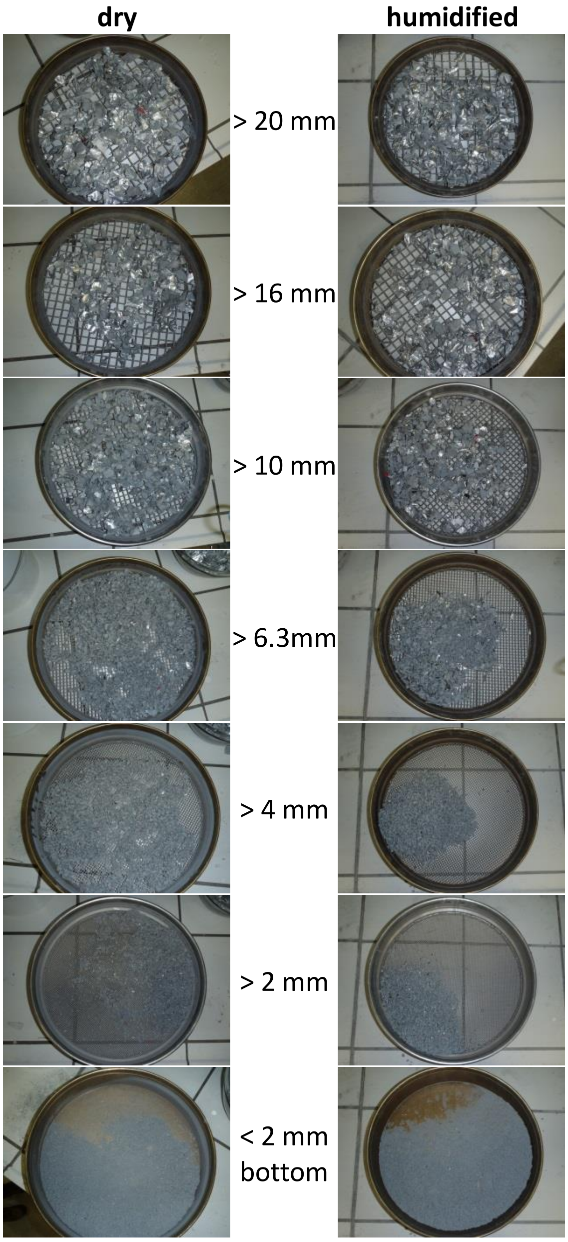

Figure 52: Series of Sieving Analysis of MG4

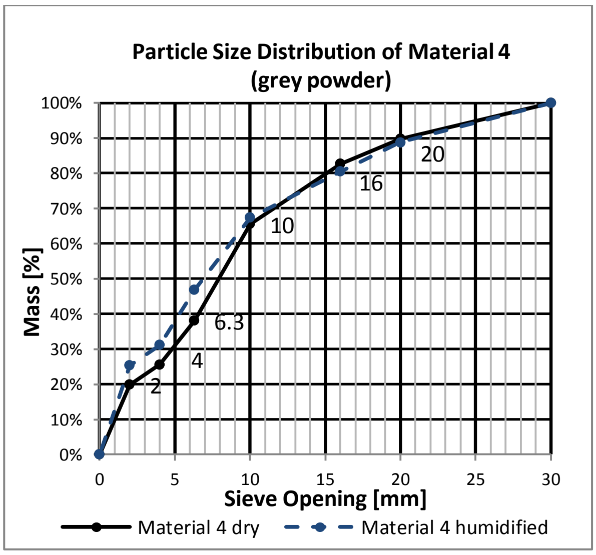

Figure 53: Particle Size Distribution of MG4

Preparation for XRF Analysis of MG4

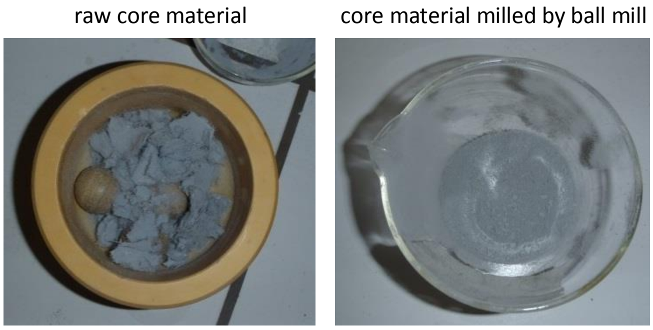

Figure 54: Raw and milled MG4 (grey powder)

Results of the XRF Analysis of MG4

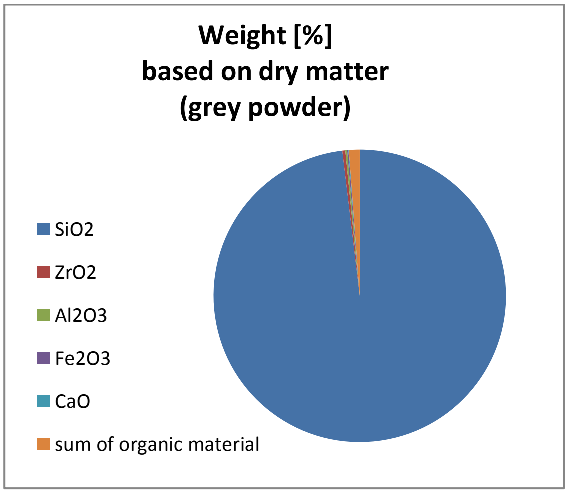

Figure 55: Mass balance of MG4 (grey powder)

Table 26: Results of XRF Analysis of MG4

Evaluation of XRF Analysis of Material 4 (grey powder) (Sample Number: 0126-13-00)		
Compound	**Chemical Formula**	**Weight [%]**
silicon dioxide	**SiO_2**	**98.01**
zirconium dioxide	ZrO_2	0.33
aluminium oxide	Al_2O_3	0.21
iron(III) oxide	Fe_2O_3	0.13
calcium oxide	CaO	0.05
magnesium oxide	MgO	none
potassium oxide	K_2O	none
ash content (sum of inorganic material)		**98.81**
loss on ignition (sum of organic material)		**1.19**
Total (inorganic and organic material)		**100**

D.4.5 Results of Material Group 5 (brown powder)

This material showed a heavy formation of dust during the shredding process with the four-shaft shredder.

Also during the sieving analysis, the material was very dusty. The results of the humidified material remind on MG4, because the fine fraction of the humidified material is again bigger than the fine fraction of the dry sieved material (see Figure 56). In contrary to MG4, a separation of the aluminium form the core material could not be achieved (see Figure 57).

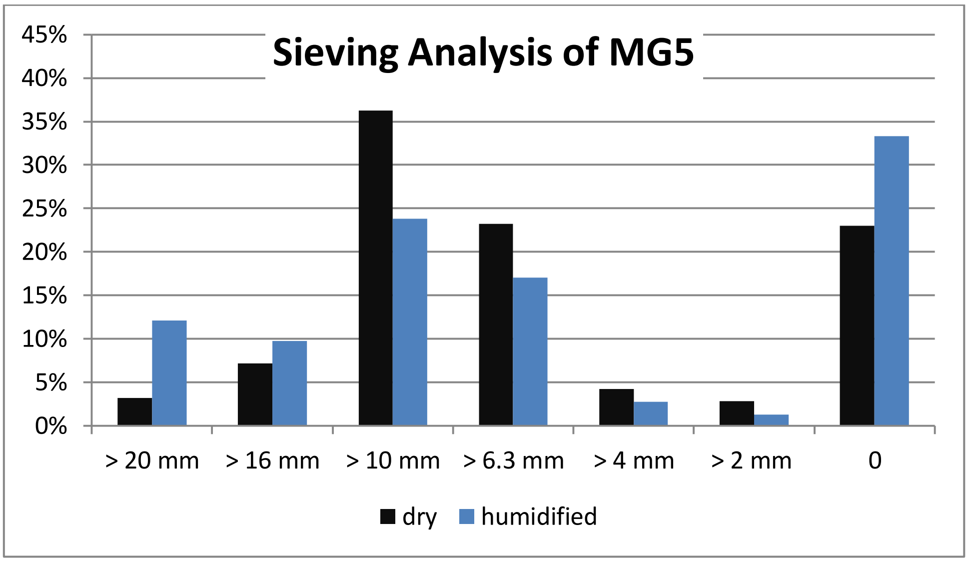

Figure 56: Comparison of dry and humidified MG5

In 2011 an X-ray fluorescence analysis was already accomplished within the report written by Renato Sarc and Josef Adam [Sarc]. According to this analysis (see Table 27) the main component of the core material is silicon dioxide with about 94%. The ash content of this material is compared to the previously described material groups relatively small with 94%. This means that about 6% organic material is contained.

Sieving Analysis of MG5

dry **humidified**

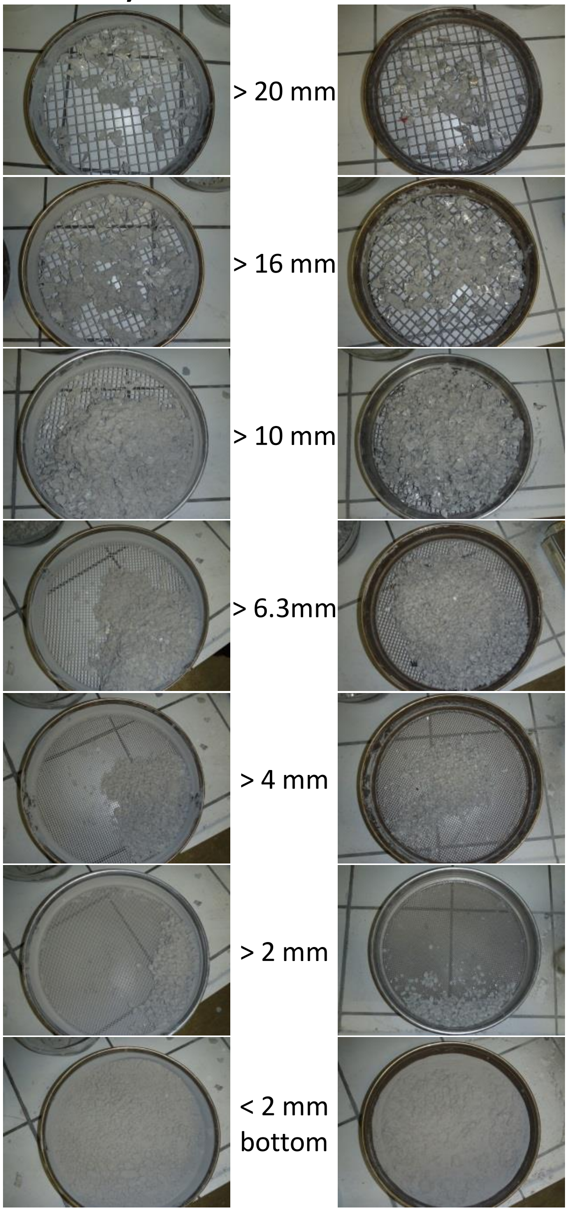

Figure 57: Series of Sieving Analysis of MG5

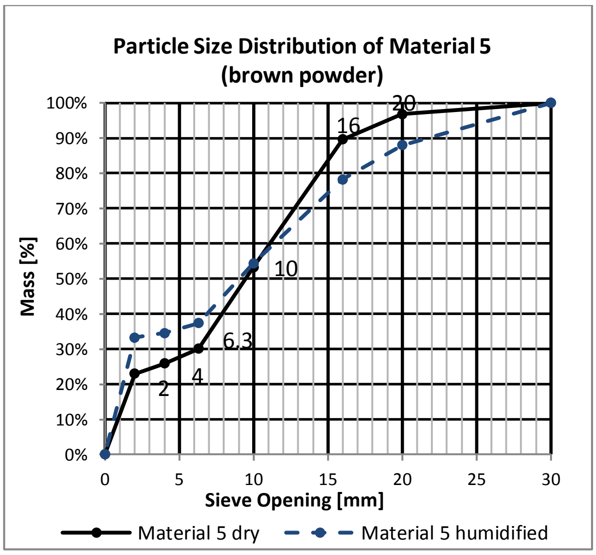

Figure 58: Particle Size Distribution of MG5

Figure 59: Core material of MG5 (brown powder)

Results of XRF Analysis (from 2011) of MG5

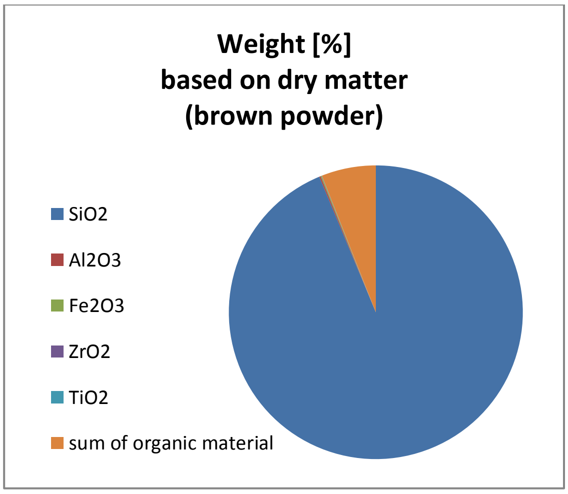

Figure 60: Mass balance of MG5 (brown powder)

Table 27: Results of XRF Analysis of MG5

Evaluation of XRF Analysis of Material 5 (brown powder) (Sample Number: 0172-11-00)		
Compound	**Chemical Formula**	**Weight [%]**
silicon dioxide	$\mathbf{SiO_2}$	**93.66**
aluminium oxide	Al_2O_3	0.14
iron(III) oxide	Fe_2O_3	0.11
zirconium dioxide	ZrO_2	0.03
titanium dioxide	TiO_2	0.02
ash content (sum of inorganic material)		**93.96**
loss on ignition (sum of organic material)		**5.98**
total organic carbon	TOC	1.79
other organic ingredients		4.19
water content (based on a ROI of 99.7%): H_2O		**0.30**
Total (inorganic material, organic material, water content)		**100.24**

D.4.6 Results of Material Group 6 (black powder)

Also this material caused a heavy formation of dust. With the material group 6 (black powder), no sieving analysis was realised.

The results of the XRF analysis show that the main components of the core material are silicon dioxide (74%) and iron(III) oxide (23%), which gives the characteristic black colour to the material. The ash content is with nearly 94% quite high.

Figure 61: Core material of MG6 (black powder)

Results of the XRF Analysis (from 2011)

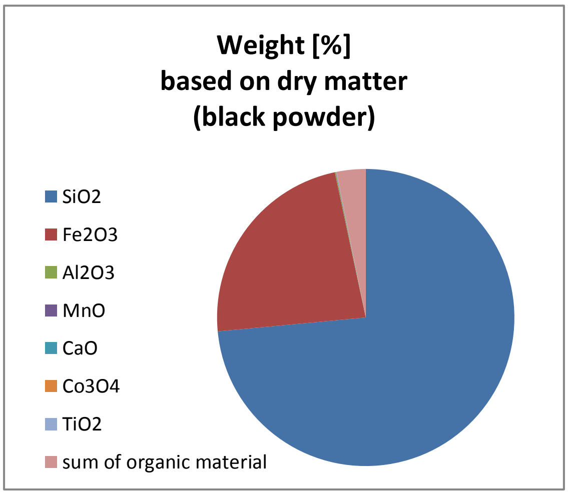

Figure 62: Mass balance of MG6 (black powder)

Table 28: Results of XRF Analysis of MG6

Evaluation of XRF Analysis of Material 6 (black powder) (Sample Number: 0174-11-00)		
Compound	**Chemical Formula**	**Weight [%]**
silicon dioxide	**SiO_2**	**73.47**
iron(III) oxide	**Fe_2O_3**	**23.15**
aluminium oxide	Al_2O_3	0.09
manganese(II) oxide	MnO	0.04
calcium oxide	CaO	0.03
cobalt(II,III) oxide	Co_3O_4	0.02
titanium dioxide	TiO_2	0.01
ash content (sum of inorganic material)		**96.8**
loss on ignition (sum of organic material)		**3.15**
total organic carbon	TOC	1.06
other organic ingredients		2.09
water content (based on a ROI of 99.7%): H_2O		**0.20**
Total (inorganic material, organic material, water content)		**100.15**

D.4.7 Summary of the Chemical Elements in VIPs

In Table 29 the main components of the analysed materials are listed. It is obvious that silicon dioxide is the most used material as core material for VIPs.

Table 29: Summary of the Chemical Main Components of the Material Groups

Compound/ Chemical Formula		Weight [%]					
		MG1 paperlike	**MG2** white fleece	**MG3** glass woollike	**MG4** grey powder	**MG5** brown powder	**MG6** black powder
silicon dioxide	**SiO_2**	69.08	54.08	51.03	98.01	93.66	73.47
calcium oxide	**CaO**	8.81	24.97	30.13	-	-	-
aluminium oxide	**Al_2O_3**	-	13.57	14.10	-	-	-
iron(III) oxide	**Fe_2O_3**	-		-	-	-	23.15
sodium oxide	**Na_2O**	14.09	-	-	-	-	-
sum of organic material		0.27	2.76	1.22	1.19	5.98	3.15

Regarding the main components of the VIPs' core materials, they are basically adapted for a recycling in cement industry (q.v. [Sarc]). It can be assumed, that the other core materials would also fulfil criteria for a recycling in the cement industry. Other possibilities for a recycling of the VIPs' core materials would be given in the glass industry as well as in the ceramics industry.

E. Large Scale Test – Phase 3

Within the framework of the large scale test, the previously mentioned six material groups and their impact in the recycling plants, when being treated together with cooling and freezing appliances, should be investigated. This chapter deals with the preparation and the results of the large scale tests. The first part describes the planning phase as well as the approach to the several plants, which were in line for the large scale test. The second part deals with the results of the performed tests in the chosen plants.

E.1 Planning Phase of Large Scale Test

Initially, contemplable recycling plants of C&F appliances in Europe had to be chosen. Ten different European recycling plants came into question for the large scale test. The task was to select three plants out of these ten possible plants (they are shown in Table 30, as well as a short description of their technology). Every plant received an info sheet about the VIP project, which is represented in appendix IV. The decision was based on the following criteria:

1. Willingness of the plant operator
2. Every state of the art technology in Europe should be represented
3. Nitrogen atmosphere in shredding unit
4. Monitoring available

STENA Lauingen in Germany and NOEX Grevenbroich in Germany did not meet criterion 1. SEVAL in Italy did not meet criterion 2, because they do not use a nitrogen atmosphere. Remondis Berlin in Germany only wanted to perform a small test (i.e. less than five appliances), because they have doubts concerning the dust emissions and equipment disturbances, which were confirmed in the past months. In the treatment plant Fricom/Corepa in France the same processing technology (SEG technology) is used as in the AVE plant in Austria. Because of easier logistics from Leoben to Timelkam, the Austrian plant was preferred. By comparing the still remaining two STENA plants in Italy and Sweden with logistical aspects, the Italian one is to prefer. To meet criterion 2, the Veolia plant in France was chosen over the Terecoval plant in France.

The selection of the plants for the large scale test finally led to the following three plants. Their flow sheets are shown in appendix II.

- AVE in Austria
- STENA in Italy
- VEOLIA in France

In July 2013 the German plant L+N Recycling also showed interest to join the large scale test. The problem is, that this plant has no permission to treat glass wool containing appliances. A realisation of the large scale test would be only possible, if the plant gets the permission by authority. That is why it will be kept in reserve, but no fix date is determined.

Table 30: Contemplable Plants for the Large Scale Test

Country	Firm	Technology
Austria	AVE Mühlfeld 2 4850 Timelkam	SEG technology: 4-shaft shredder, active carbon filter, desorption and liquefaction of CFC
France	FRICOM/COREPA 28 rue de Beaumont 95820 Bruyères-sur-Oise	SEG technology: 4-shaft shredder, active carbon filter, desorption and liquefaction of CFC
France	VEOLIA 16 Rue Maillé 49100 Angers	Cross flow crusher (QZ), cryogenic technology
France	TERECOVAL Z.I. Les Attignours 73130 La Chambre	Two 2-shaft shredders, two hammer mills, mono-rotor-crusher; activated carbon
Germany	L+N Recycling[1] An der Autobahn 7 89347 Bubesheim	4-shaft shredder and cross flow crusher (QZ)
Germany	REMONDIS Lahnstraße 31 12055 Berlin-Neukölln	Cross flow crusher (QZ), active carbon filter and cryogenic technology
Germany	NOEX Benzstraße 1 41515 Grevenbroich	Cross flow crusher (QZ), cryogenic technology
Germany	STENA Wittislinger Straße 7 89415 Lauingen (Donau)	2-shaft and 4-shaft shredders, granulator, pelletizer and cryogenic technology
Italy	SEVAL Via La Croce 14 23823 Colico (LC)	2-shaft and 4-shaft shredder, CFC directly burned (950°C)
Italy	STENA Via dell'Industria, 515/517 37050 Angiari (VR)	2-shaft and 4-shaft shredder, cryogenic technology
Sweden	STENA Kistinge Industriområde Box 1009; 30110 Halmstad	Two cutting units, active carbon units, direct treatment of gases

1) L+N Recycling is the additional 11th plant. They showed interest in July 2013.

Time Table for large scale test

The first test will be performed in Austria in AVE plant in Timelkam (planned is 1st, 2nd, 3rd or 4th October), the second test will be performed in Italy in STENA plant in Angiari (planned is 7th, 8th, 10th or 11th October) and the third test will be performed in France in Veolia plant in Angers (planned is 14th October.

E.1.1 Calculations for the needed amount of VIPs

For the selected plants the necessary amounts of VIPs were calculated based on the following points:

- Throughput of plants (according to each plant operator)
- Average weight of C&F appliances (according to each plant operator)
- 5 mass% VIPs in C&F appliances
- 5 hours working time for the test
- Equal amount of every material group

Calculations for AVE in Austria

The throughput of the AVE plant in Timelkam (Austria) is about 25 to 30 appliances per hour and the average weight of one appliance is 42 kg according to the information from Anton Niedermayr, factory manager of the selected plant [Niederm]. Referring to the points shown above, which represent the basis for the calculation, 60 kg of every VIP type is necessary for the large scale test in the AVE plant Timelkam (also see Table 31).

Table 31: Calculations of required VIPs for AVE in Austria

Calculation	Comment/Explanation
25 – 30 appliances/h * 42 kg = 1050 – 1260 kg/h	max. throughput: 1260 kg/h
1260 kg/h * 0.05 = 63 kg/h	5 mass% VIPs in C&F appliances (=0.05)
63 kg/h * 5 h = 315 kg VIPs in total	5 hours for the test
315 kg / 6 = 52.5 kg ≈ **60 kg of each material group**	6 different material groups
60 kg *6 = **360 kg VIPs in total**	…should be delivered to AVE

Calculations for STENA Italy

According to the information of Emanuele Bonaldi, the site manager of the selected STENA plant in Italy, the throughput is about 55 to 60 appliances per hour and the average weight for one appliance is 42 kg [Bonaldi]. Based on this information, the necessary amount of VIPs for the STENA plant in Italy is 105 kg of each material group of VIPs. The calculations who lead to this result are shown in Table 32.

Table 32: Calculations of required VIPs for STENA in Italy

Calculation	Comment/Explanation
55 – 60 appliances/h * 42 kg = 2300 – 2500 kg/h	max. throughput: 2500 kg/h
2500 kg/h * 0.05 = 125 kg/h	5 mass% VIPs in C&F appliances (=0.05)
125 kg/h * 5 h = 625 kg VIPs in total	5 hours for the test
625 kg / 6 = 104.2 kg ≈ **110 kg of each material group**	6 different material groups
110 kg * 6 = **660 kg VIPs in total**	…should be delivered to Italy

Calculations for Veolia France

In this plant approx. 50 appliances with an average weight of 45 kg are treated per hour, according to Frédéric Fournier, factory manager of the selected Veolia plant [Fournier]. Referring to this information a necessary amount of 94 kg of each material group of VIPs was calculated as shown in Table 33.

Table 33: Calculations of required VIPs for Veolia in France

Calculation	Comment/Explanation
50 appliances/h * 45 kg = 2250 kg/h	throughput: 2250 kg/h
2250 kg/h * 0.05 = 112.5 kg/h	5 mass% VIPs in C&F appliances (=0.05)
112.5 kg/h * 5 h = 562.5 kg VIPs in total	5 hours for the test
562.5 kg / 6 = 104.2 kg ≈ **94 kg of each material group**	6 different material groups
100 kg * 6 = **600 kg VIPs in total**	…should be delivered to France

E.1.2 Delivery of VIPs from VIP suppliers

For the large scale test the previously described six different material groups of VIPs are necessary in an equal amount. It was purposely refrained from reflecting the present market situation of the used VIP types to ensure comparability between all material types. Furthermore, the present market situation is not exactly known and if it was, it could change quickly. In Table 34 the required amounts of VIPs of each supplier are summarised.

Table 34: Required VIP Amounts for the Large Scale Test of each VIP Supplier

Company (Household appliance producer)	**Company** (VIP supplier)	**Material Group**	**Required VIP amount for test in**			**Total required VIP amount**
			Austria	**Italy**	**France**	
HHP-18	VIPS-6	MG1	30 kg	55 kg	50 kg	**135 kg**
HHP-9	VIPS-8		30 kg	55 kg	50 kg	**135 kg**
HHP-11	VIPS-4	MG2	60 kg	110 kg	100 kg	**270 kg**
HHP-15	VIPS-1	MG3	60 kg	110 kg	100 kg	**270 kg**
HHP-8	VIPS-2	MG4	60 kg	110 kg	100 kg	**270 kg**
HHP-12	VIPS-7	MG5	30 kg	ca. 55 kg	ca. 50 kg	**135 kg**
HHP-3	VIPS-7		30 kg	55 kg	50 kg	**135 kg**
HHP-10	VIPS-9	MG6	20 kg	ca.36.7 kg	ca. 33.3 kg	**90 kg**
HHP-7	VIPS-9		20 kg	ca.36.7 kg	ca. 33.3 kg	**90 kg**
HHP-3	VIPS-9		20 kg	ca.36.7 kg	ca. 33.3 kg	**90 kg**
Total:			360 kg	660 kg	600 kg	1620 kg

E.2 Realisation of the Large Scale Tests

E.2.1 Large Scale Test in Austria

E.2.2 Large Scale Test in Italy

E.2.3 Large Scale Test in France

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I. Appendix – Safety Data Sheet

1. Identification of the substance/preparation and company

1.1 Name of substance/preparation

Commercial product name: Vacuum Insulation Panels

1.2 Use of substance / preparation

Industrial

Thermal insulation

1.3 Company name/Manufacturer(s)

1.4 Emergency telephone number

Emergency Information (Austria):	
Office for Emergency Measures	+43/(0) 1/4000-75222
Emergency Information (German):	
plant fire brigade	+49/(0) 8677/83-2222
Emergency Information (internat.):	
National Response Center	+49/(0) 621/60-43333

2. Hazards identification

2.1 Classification

This product is a non-combustible, non-reactive solid material. Exposure to glass powder or dust released as a consequence of damage to the core materials of Vacuum Insulation Panels (VIPs) may cause mechanical irritation to eyes, skin or upper respiratory tract. Purely mechanical irritation, however, in Europe is not considered a health hazard in accordance with the European Directives 67/548/EEC. This is confirmed by the fact that EC Directive 97/69/EC for fibres does not stipulate the need to use an Xi (irritant) label nor a classification.

There are no known hazards associated with the handling or use of this insulation. Amorphous silica has a drying action on skin.

Dust produced from core insulation may, like any other dust, aggravate pre-existing upper respiratory and lung diseases.

Exposure of the panels to high temperatures, however, will result in the emission of smoke, and decomposition/combustion products.

2.2 Further Information

Owing to the length: diameter ratio, the fibres cannot enter the lungs (drawn continuous filament with diameter >6 µm according to Directive 67/548/EWG Note R & Directive 97/69/EC Note Q.

3. Composition/information on ingredients

3.1 Chemical characterization (substance)

Chemical Name	CAS-Number	EC Number	%
Amorphous silica	112945-52-5	31-545-4	50 to 100%
Calcium silicate	1344-95-2	235-336-9	

4. First-aid measures

4.1 General information:

In case of accident or if you feel unwell seek medical advice (show label or SDS where possible).

4.2 After inhalation

Provide fresh air.

4.3 After contact with the skin

Rinse affected areas with water, taking care not to scratch or rub. Seek medical attention if irritation persists.

4.4 After contact with the eyes

Flush immediately with copious amounts of water. Do not rub eyes. Seek medical attention if irritation persists.

4.5 After swallowing

In the event of suspected problems, seek medical attention.

5. Fire-fighting measures

Product does not burn. Use extinguishing measures appropriate to the source of the fire.

5.1 Suitable extinguishing media

not applicable

5.2 Extinguishing media which must not be used for safety reasons

not applicable

5.3 Special exposure hazards arising from the substance or preparation itself, combustion products, resulting gases

not applicable

5.4 Special protective equipment for fire fighting

not applicable

6. Accidental release measures

6.1 Personal precautions

Avoid dust formation. Do not breathe dust. Wear personal protection equipment

6.2 Environmental precautions

Cover any spilled material in accordance with regulations to prevent dispersal by wind.

6.3 Methods for cleaning up

Damp down dust and fill into containers.

7. Handling and storage

7.1 Handling

Avoid dust formation.

Electrostatic discharge is possible during transport and processing. Take precautionary measures against electrostatic charging. Ensure all parts of equipment are well earthed. Use inert gas when working with combustible and explosive liquids. Avoid dust deposit, remove dust regularly.

7.2 Storage

Should bed stored in dry conditions. Store in a cool, dry, ventilated area away from sources of heat, moisture and incompatibilities. Protect product from physical damage.

Protect from weather and prevent exposure to sustained moisture.

8. Exposure controls and personal protection equipment

8.1 Exposure limits

UK "EH 40/02 Occupational Exposure Limits 2002"

Published by the Health and Safety Executive

TOTAL INHALABLE DUST	RESPIRABLE DUST
(8-hour time weighted average reference period)	
Amorphous silica 6 mg/m^3 [OES]	Amorphous silica 2.4 mg/m^3 [OES]
Silicon carbide 10 mg/m^3 [OES]	Silicon carbide 4 mg/m^3 [OES]

[OES]….Occupational Exposure Standard

GERMANY: "List of MAK Values" for maximum concentrations at the Workplace.

TOTAL INHALABLE DUST	RESPIRABLE DUST
(8-hour time weighted average reference period)	
Amorphous silica 4 mg/m^3	Silicon carbide 1.5 mg/m^3
General dust limit 10 mg/m^3	General dust limit 3 mg/m^3

CAS-Nr. (Amorphous silica) 7631-86-9 and 112945-52-5
EG-Nr. (Amorphous silica) 231-545-4

8.2 Exposure limited and controlled

8.3 Exposure in the work place limited and controlled

General protection and hygiene

Measures: Do not breathe dust. Do not eat, drink or smoke when handling. Application of skin cream recommended to ensure optimum protection of skin.

Personal protection equipment Respiratory

Protection: In case of dust formation: fine dust mask without protection rating.

Hand protection Recommendation: rubber gloves

Eye protection Recommendation: protective goggles

Skin protection antistatic working shoes

9. Physical and chemical properties

9.1 General Information

Physical state / form:	solid – powder / white cloth covered panels / silvery film
Colour:	white / black powder (inside) / grey powder
Odour:	odourless / neutral

9.2 Important information about the protection of health, safety and the environment Method

Melting point / melting range:	core: 1700 °C / > 1200°C film: 150°C
Boiling point / boiling range:	not applicable
Flash point:	not applicable (on core) film: building material B3
Ignition temperature:	not applicable/ 350°C / > 150°C
Lower explosion limit (LEL):	not applicable
Vapour pressure:	not applicable
Density:	approx. 2,2 g/cm³ at 20 °C (DIN 51757)
Bulk density:	20 - 130 kg/m³ / 140 – 210 kg/m³
Water solubility/miscibility:	virtually insoluble at 20 °C
pH-Value:	3,6 - 4,5 (DIN EN ISO 787-9) / 4,2 – 4,3 at 20°C
Viscosity (dynamic):	not applicable

10. Stability and reactivity

10.1 General Information

If stored and handled in accordance with standard industrial practices no hazardous reactions are known.

10.2 Conditions to avoid

None known

10.3 Materials to avoid

None known

10.4 Hazardous decomposition products

If stored and handled in accordance with standard industrial practices and local regulations where applicable: none known.

The Barrier film used to encapsulate VIPs 'core material will begin to decompose at approximately 150. The thermal decomposition products will vary with temperature and oxygen availability, but could include carbon monoxide.

11. Toxicological information

11.1 General information

According to our present state of knowledge no damaging effect expected when treated in accordance with standard industrial practices and local regulations where applicable.

11.2 Toxicological tests

EXPOSITION	VALUE/VALUE RANGE	SPECIES	SOURCE
oral	5000 mg/kg rat	rat (Limit Test)	literature
dermal	> 5000	rabbit (Limit Test)	literature
by inhalation	> 0,139 mg/l/4h	rat (Limit Test)	literature

EXPOSITION	EFFECT	SPECIES/TESTSYSTEM	SOURCE
To skin	Not irritating	Rabbit	literature
To eyes	Not irritating	Rabbit	literature

11.3 Experience with man

By handling the product for many years no damage to health was observed.

12. Ecological information

12.1 Eco toxicity

SPECIES	TEST METHOD	EXP. TIME	RESULT	SOURCE
Daphnia magna	acute	24 h	> 10000 mg/l (EC50)	literature
zebra fish (Brachydanio rerio)	acute	96 h	> 10000 mg/l (LC50)	literature

No expected damaging effects to aquatic organisms.

According to current knowledge adverse effects on water purification plants are not expected.

It can remove mechanically from waste water.

12.2 Mobility

-

12.3 Persistence and degradability

Biodegradation / further information: Not applicable

Further information: Insoluble in water

12.4 Bio-accumulation potential

No adverse effects expected

12.5 Other harmful effects

-

12.6 Additional information

General information: Insoluble in water

13. Disposal considerations

13.1 Material

Can be disposed of with domestic waste, observe local/state/federal regulations

13.2 Uncleaned packing

Completely discharge containers (no tear drops, no powder rest, scraped carefully). Containers may be recycled or re-used. Observe local/state/federal regulations.

14. Transport information

14.1 Land transport ADR and RID

Road ADR: Not regulated for transport

Railway RID: Not regulated for transport

14.2 Transport by sea IMDG-Code

Not regulated for transport

14.3 Air transport ICAO-TI/IATA-DGR

Not regulated for transport

15. Regulatory information

15.1 Warning Label (EC)

The product is not dangerous, defined by the Chemical law or Hazardous Substances Ordinance.

15.2 National regulations

National and local regulations must be observed.

15.3 Other international regulations

15.4

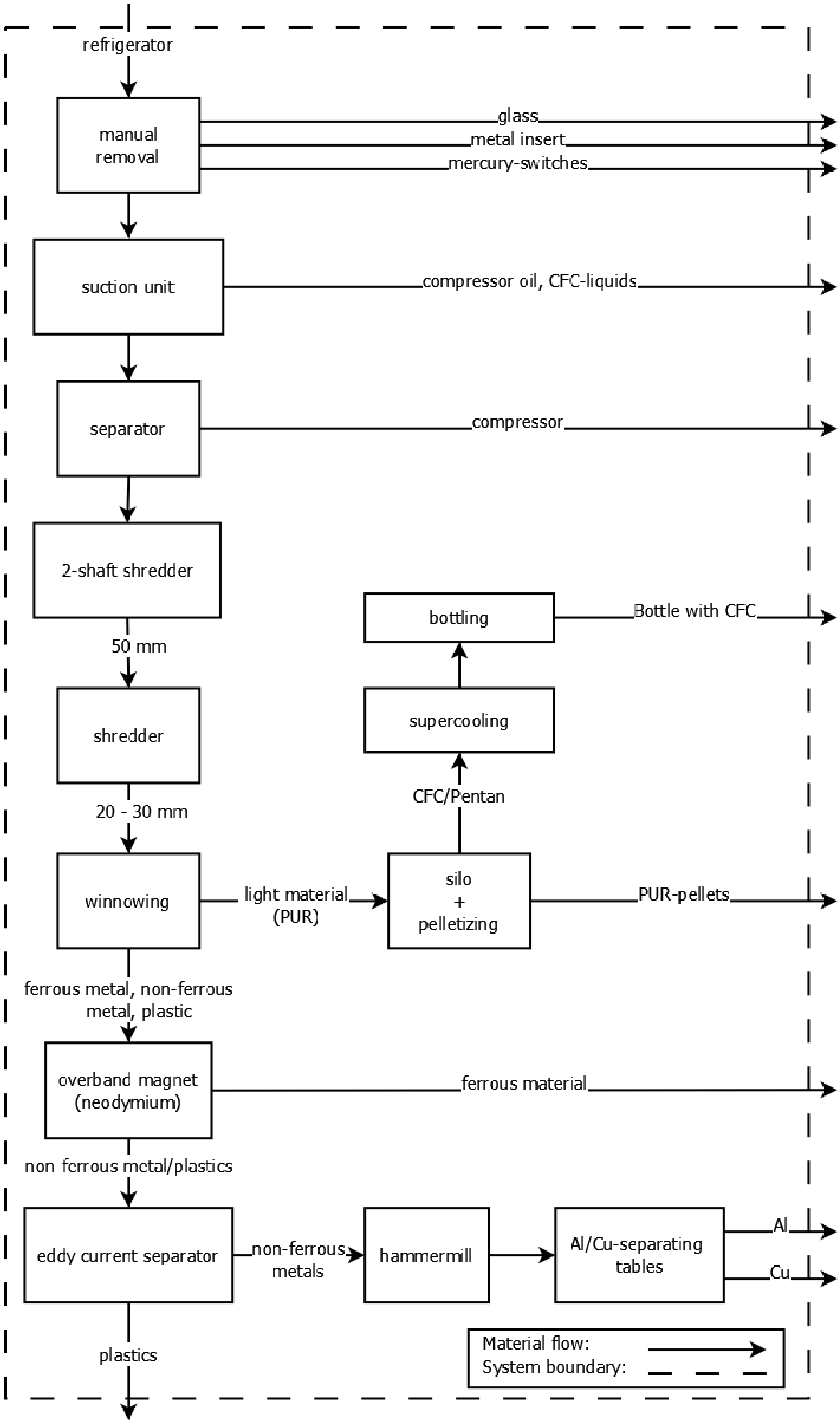
16. Other information

16.1 Material

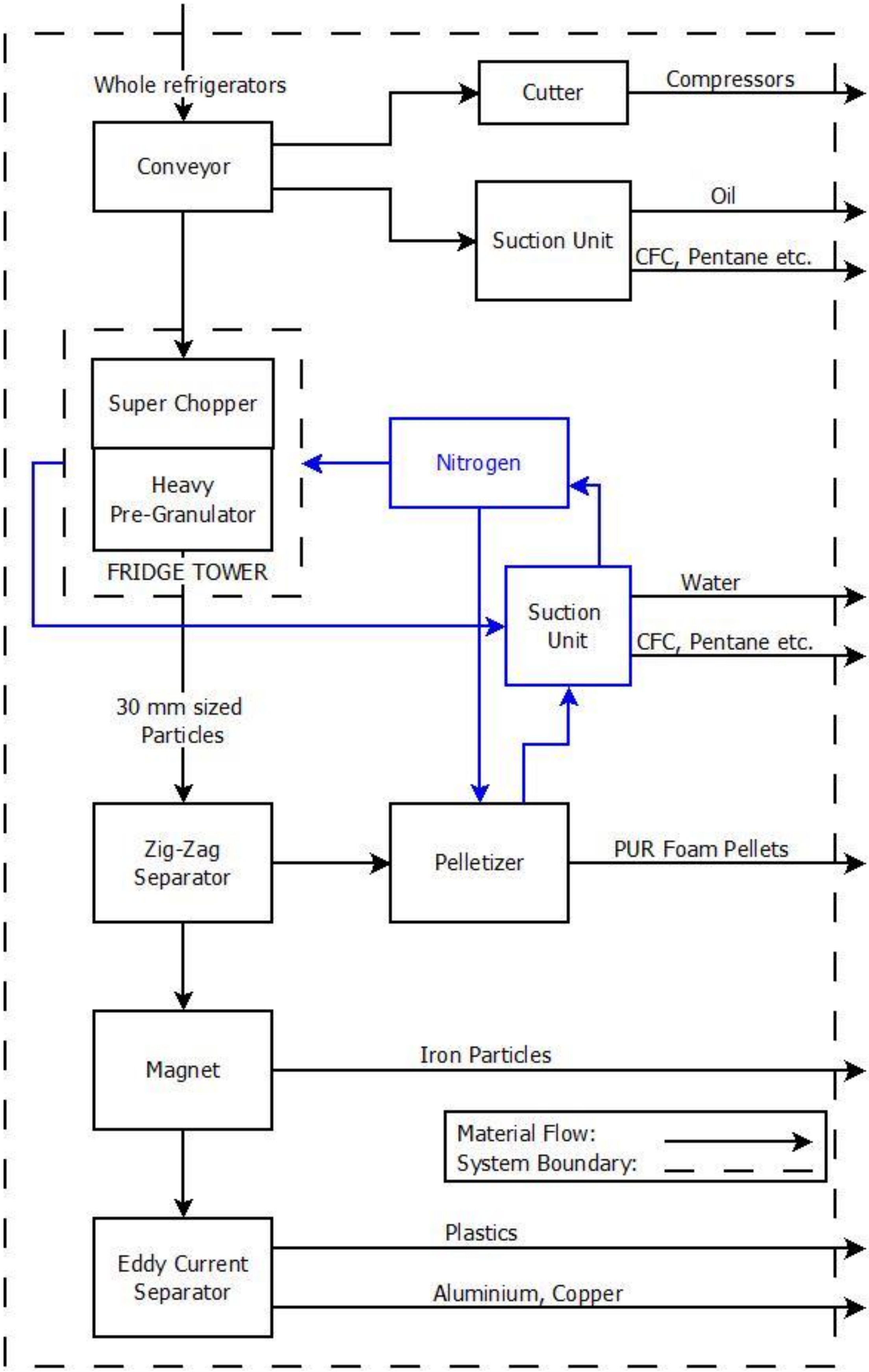
16.2 Further information

II. Appendix – Process Flow Sheets

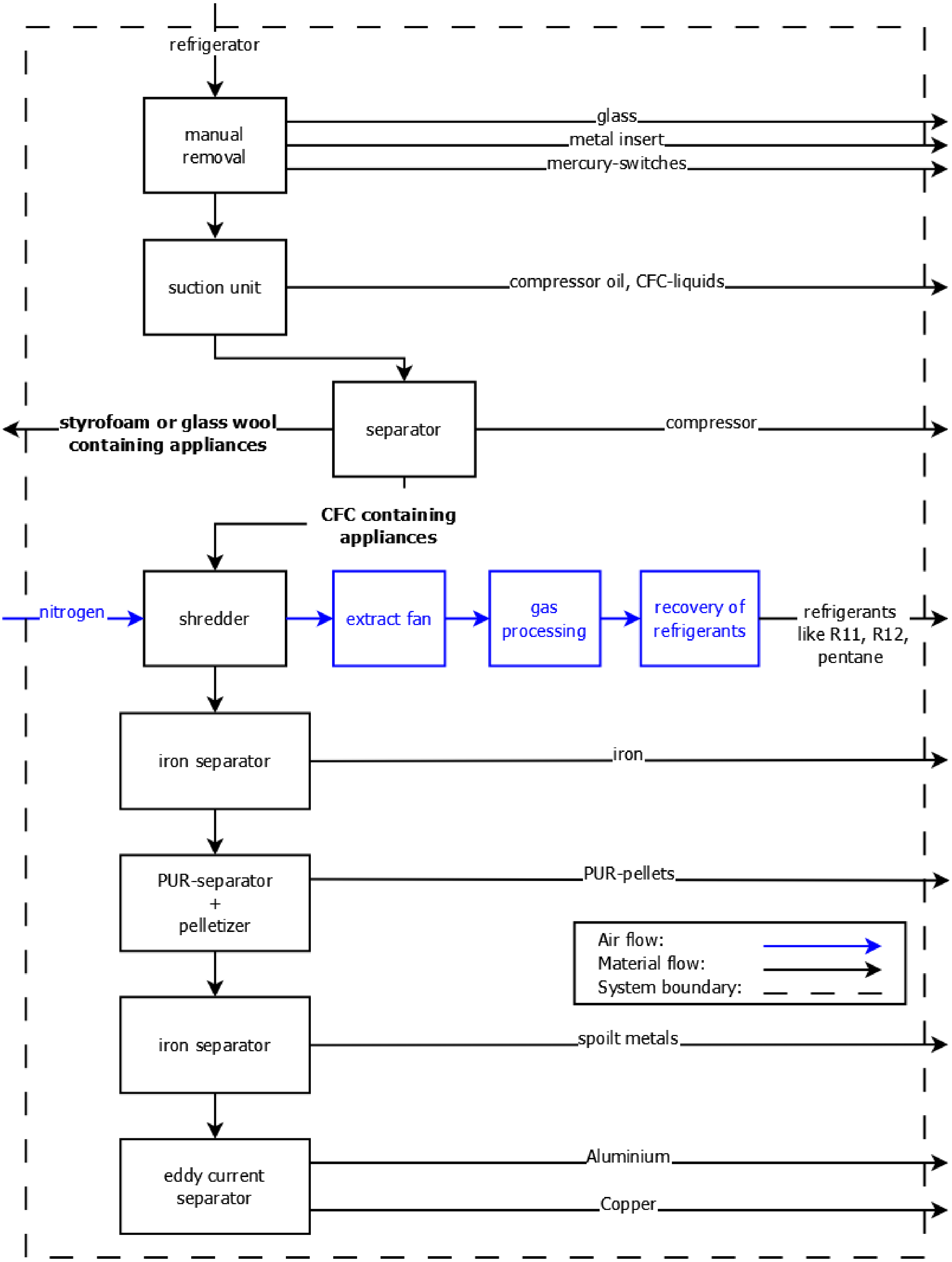
Factory 1



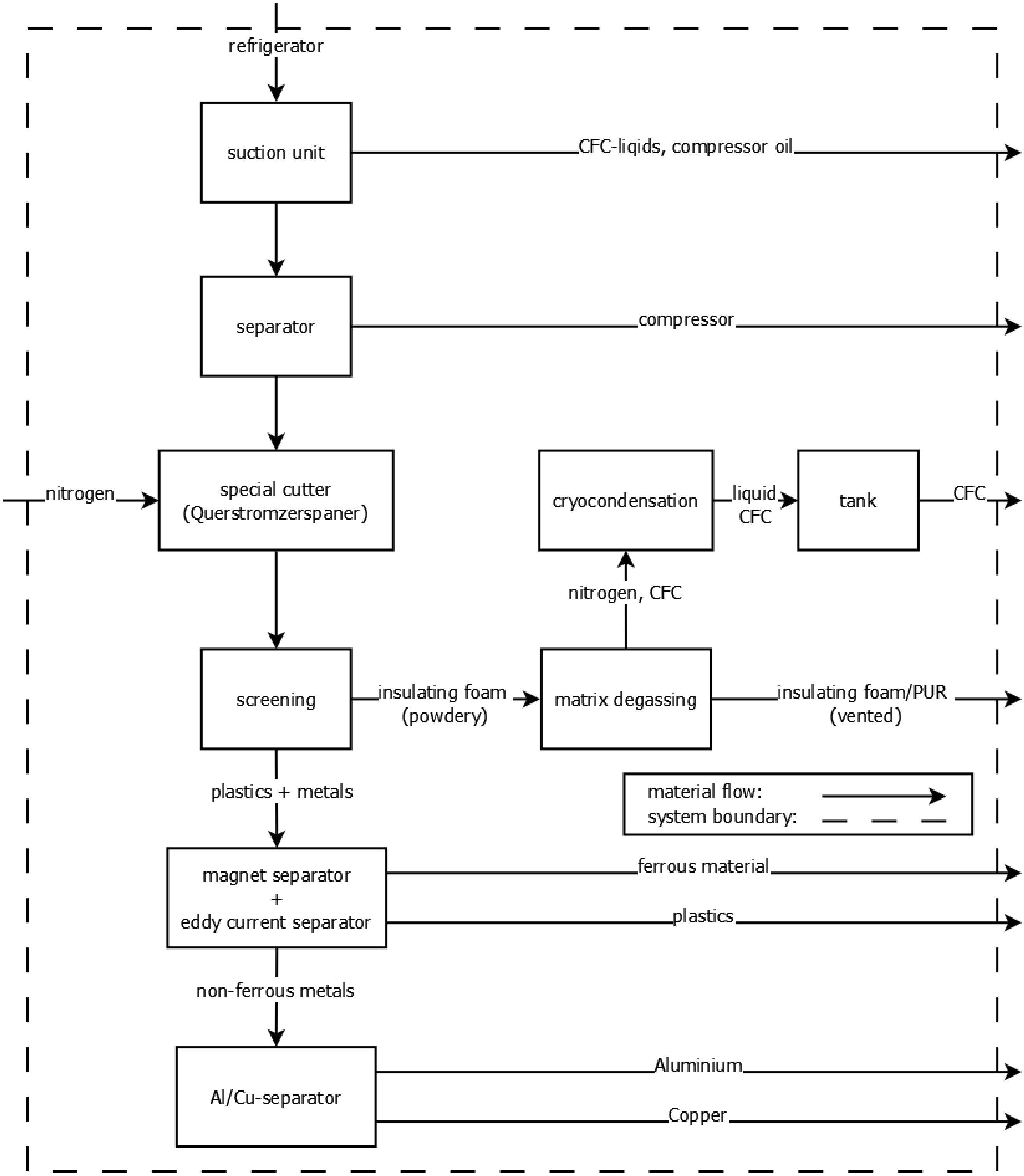
Factory 2


Whole refrigerators
Conveyor
Cutter
Compressors
Suction Unit
Oil
CFC, Pentane etc.
Super Chopper
Heavy Pre-Granulator
FRIDGE TOWER
Nitrogen
Suction Unit
Water
CFC, Pentane etc.
30 mm sized Particles
Zig-Zag Separator
Pelletizer
PUR Foam Pellets
Magnet
Iron Particles
Material Flow:
System Boundary:
Eddy Current Separator
Plastics
Aluminium, Copper

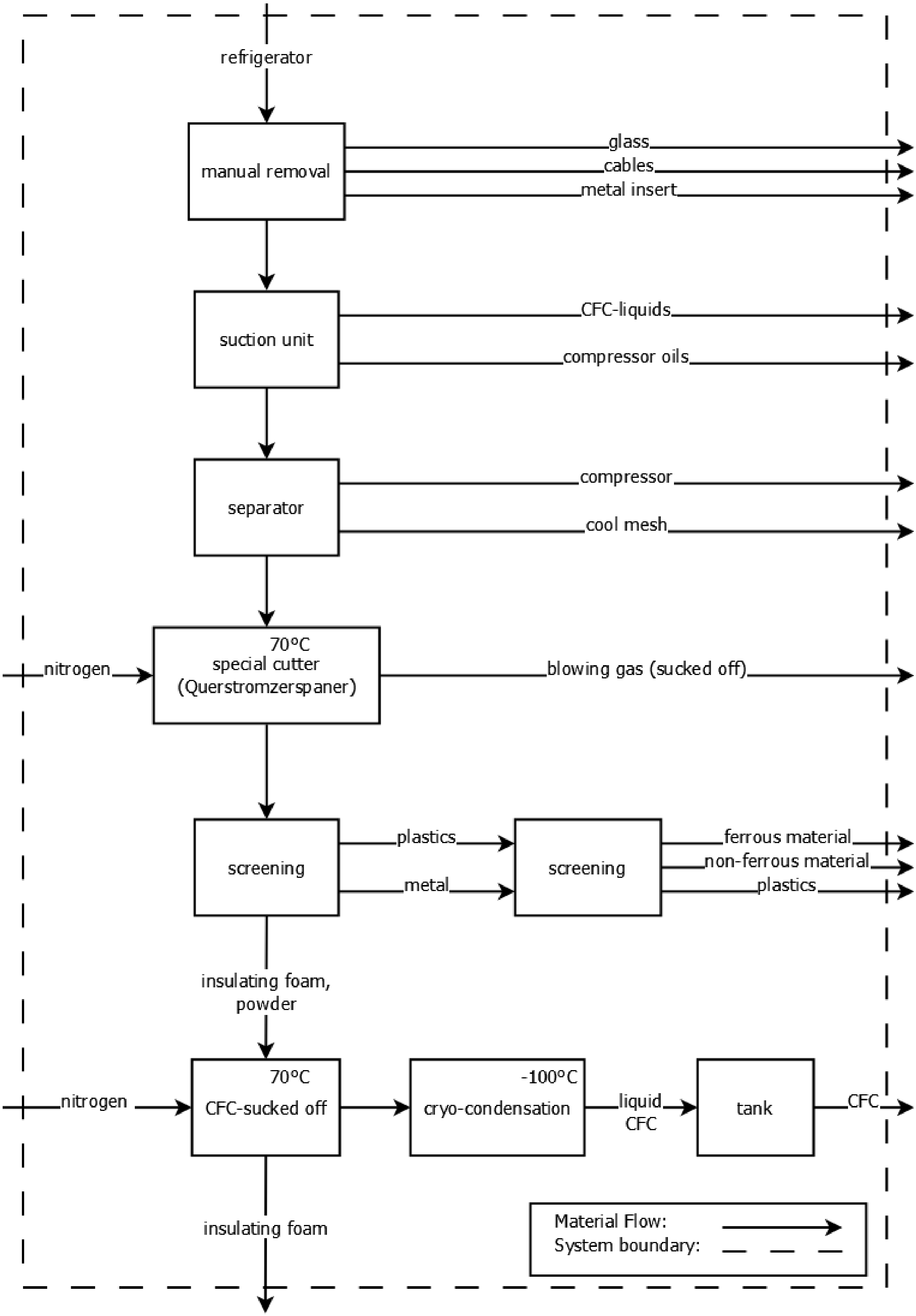
Factory 3


refrigerator
manual removal
glass
metal insert
mercury-switches
suction unit
compressor oil, CFC-liquids
separator
styrofoam or glass wool containing appliances
compressor
CFC containing appliances
nitrogen
shredder
extract fan
gas processing
recovery of refrigerants
refrigerants like R11, R12, pentane
iron separator
iron
PUR-separator + pelletizer
PUR-pellets
Air flow:
Material flow:
System boundary:
iron separator
spoilt metals
eddy current separator
Aluminium
Copper

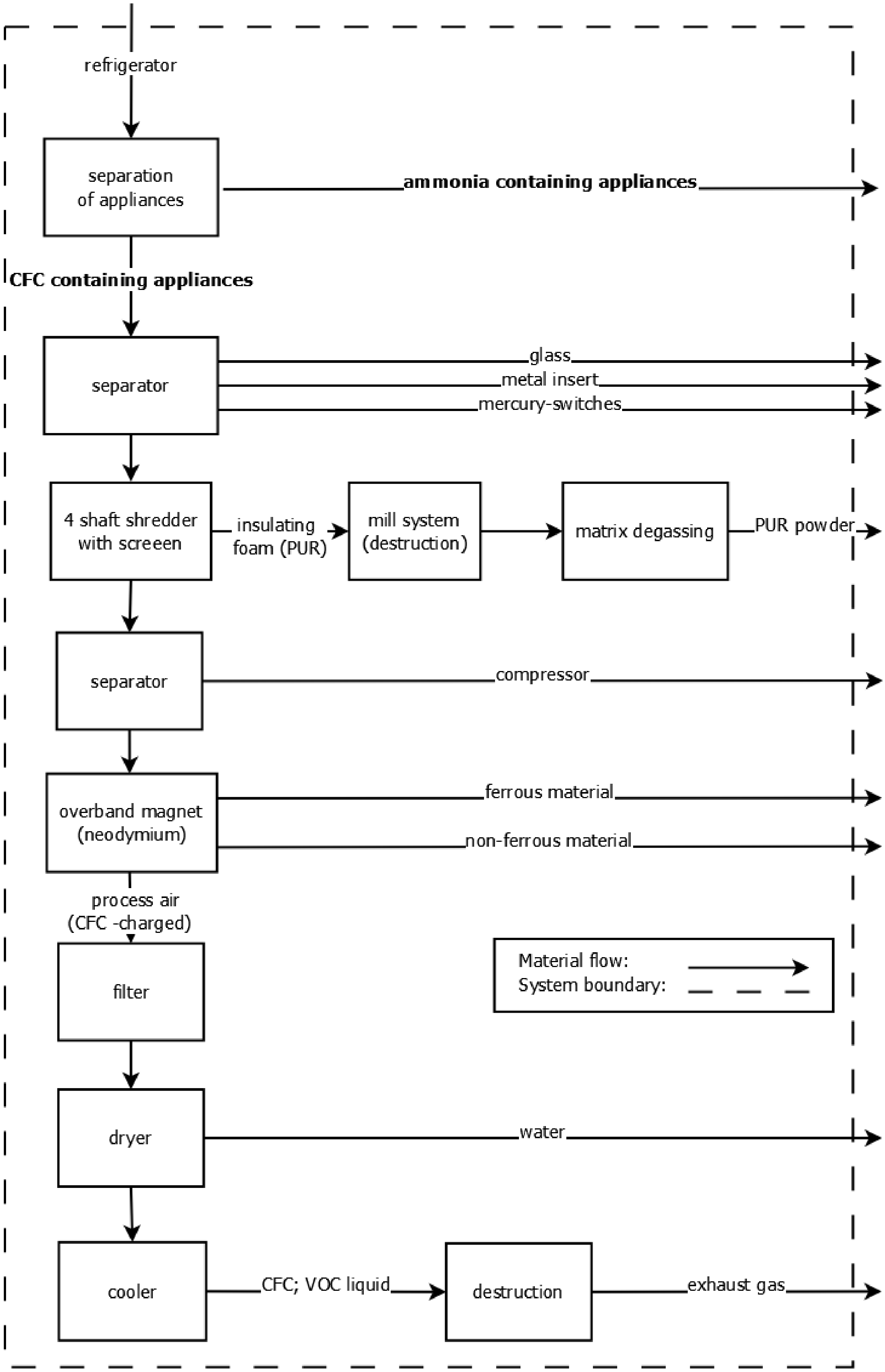
Factory 4


refrigerator
suction unit
CFC-liqids, compressor oil
separator
compressor
nitrogen
special cutter
(Querstromzerspaner)
cryocondensation
liquid
CFC
tank
CFC
nitrogen, CFC
screening
insulating foam
(powdery)
matrix degassing
insulating foam/PUR
(vented)
plastics + metals
material flow:
system boundary:
magnet separator
+
eddy current separator
ferrous material
plastics
non-ferrous metals
Al/Cu-separator
Aluminium
Copper

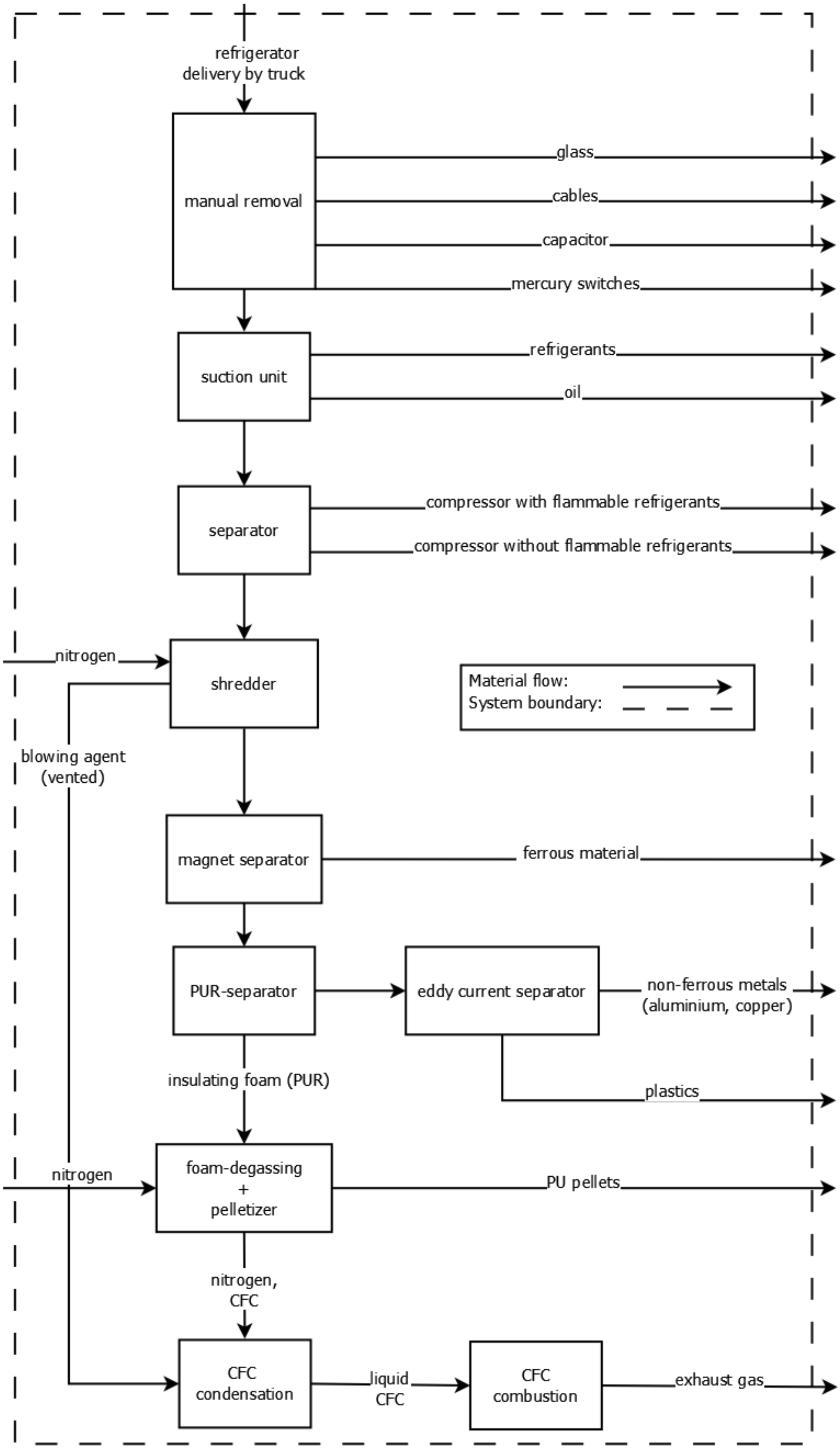
Factory 5


refrigerator
manual removal
glass
cables
metal insert
suction unit
CFC-liquids
compressor oils
separator
compressor
cool mesh
nitrogen
70°C
special cutter
(Querstromzerspaner)
blowing gas (sucked off)
screening
plastics
metal
screening
ferrous material
non-ferrous material
plastics
insulating foam,
powder
nitrogen
70°C
CFC-sucked off
-100°C
cryo-condensation
liquid
CFC
tank
CFC
insulating foam
Material Flow:
System boundary:

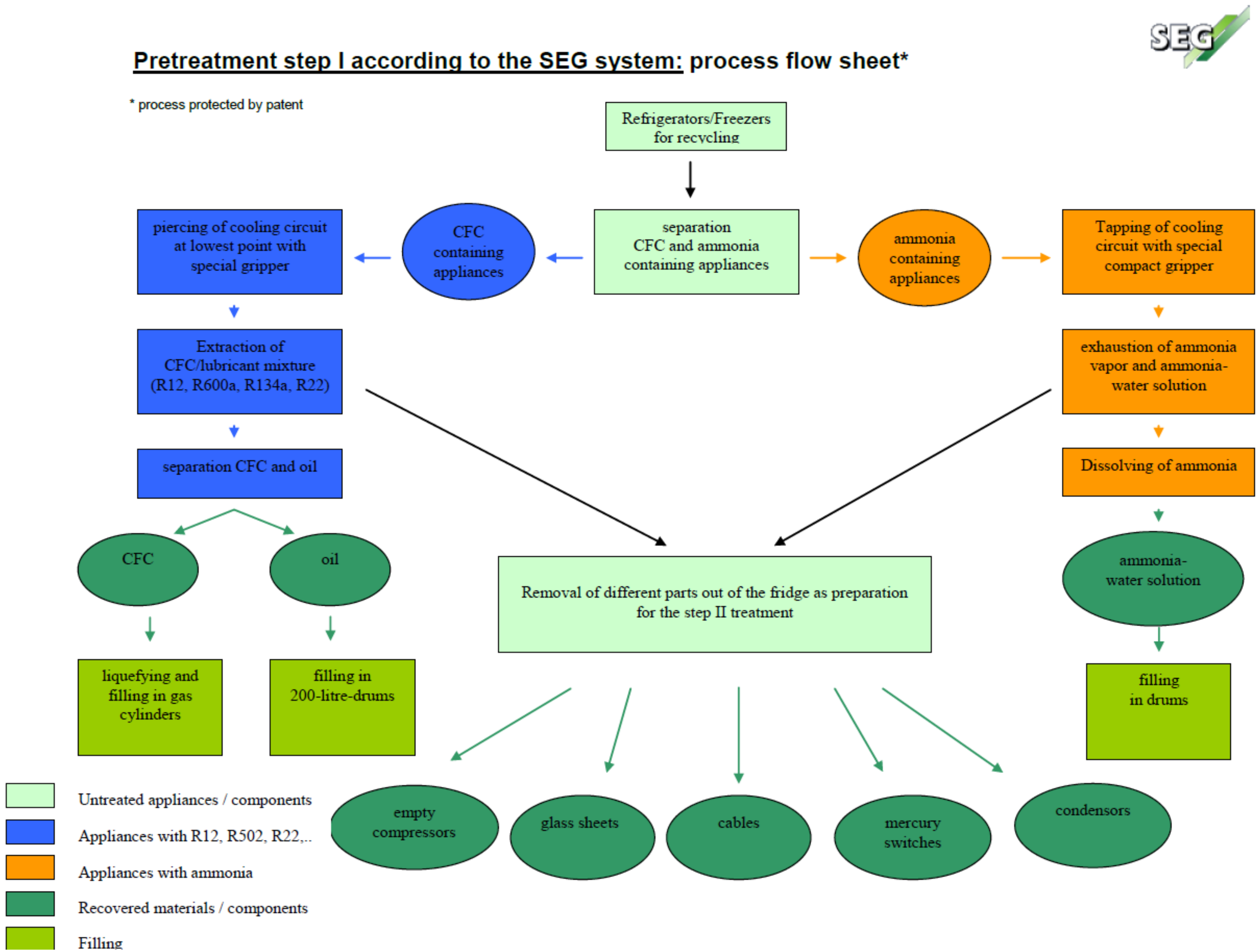
Factory 6


refrigerator
separation of appliances
ammonia containing appliances
CFC containing appliances
separator
glass
metal insert
mercury-switches
4 shaft shredder with screeen
insulating foam (PUR)
mill system (destruction)
matrix degassing
PUR powder
separator
compressor
overband magnet (neodymium)
ferrous material
non-ferrous material
process air (CFC -charged)
filter
Material flow:
System boundary:
dryer
water
cooler
CFC; VOC liquid
destruction
exhaust gas

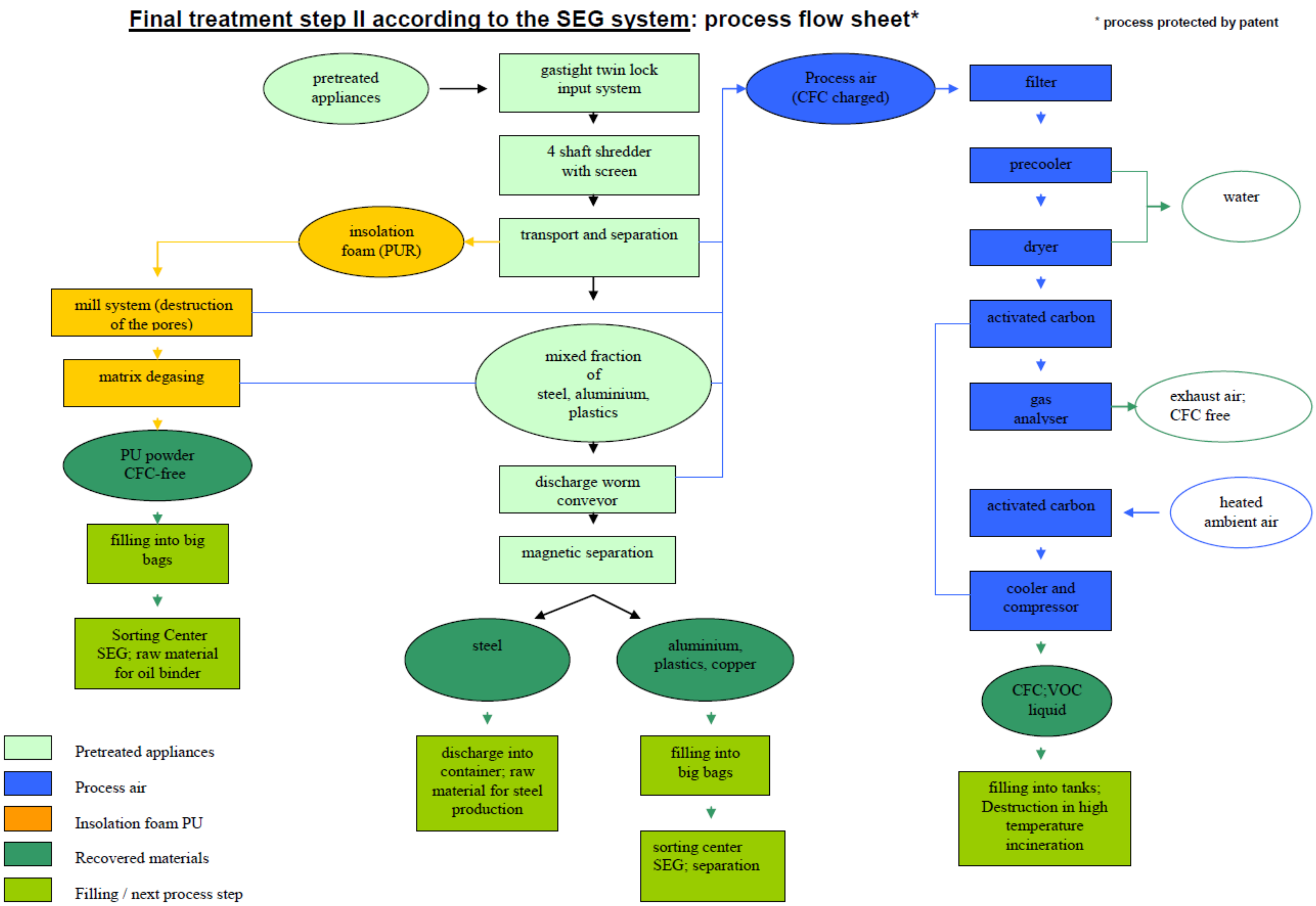
Factory 7


refrigerator delivery by truck
manual removal
glass
cables
capacitor
mercury switches
suction unit
refrigerants
oil
separator
compressor with flammable refrigerants
compressor without flammable refrigerants
nitrogen
shredder
Material flow:
System boundary:
blowing agent (vented)
magnet separator
ferrous material
PUR-separator
eddy current separator
non-ferrous metals (aluminium, copper)
insulating foam (PUR)
plastics
nitrogen
foam-degassing + pelletizer
PU pellets
nitrogen, CFC
CFC condensation
liquid CFC
CFC combustion
exhaust gas

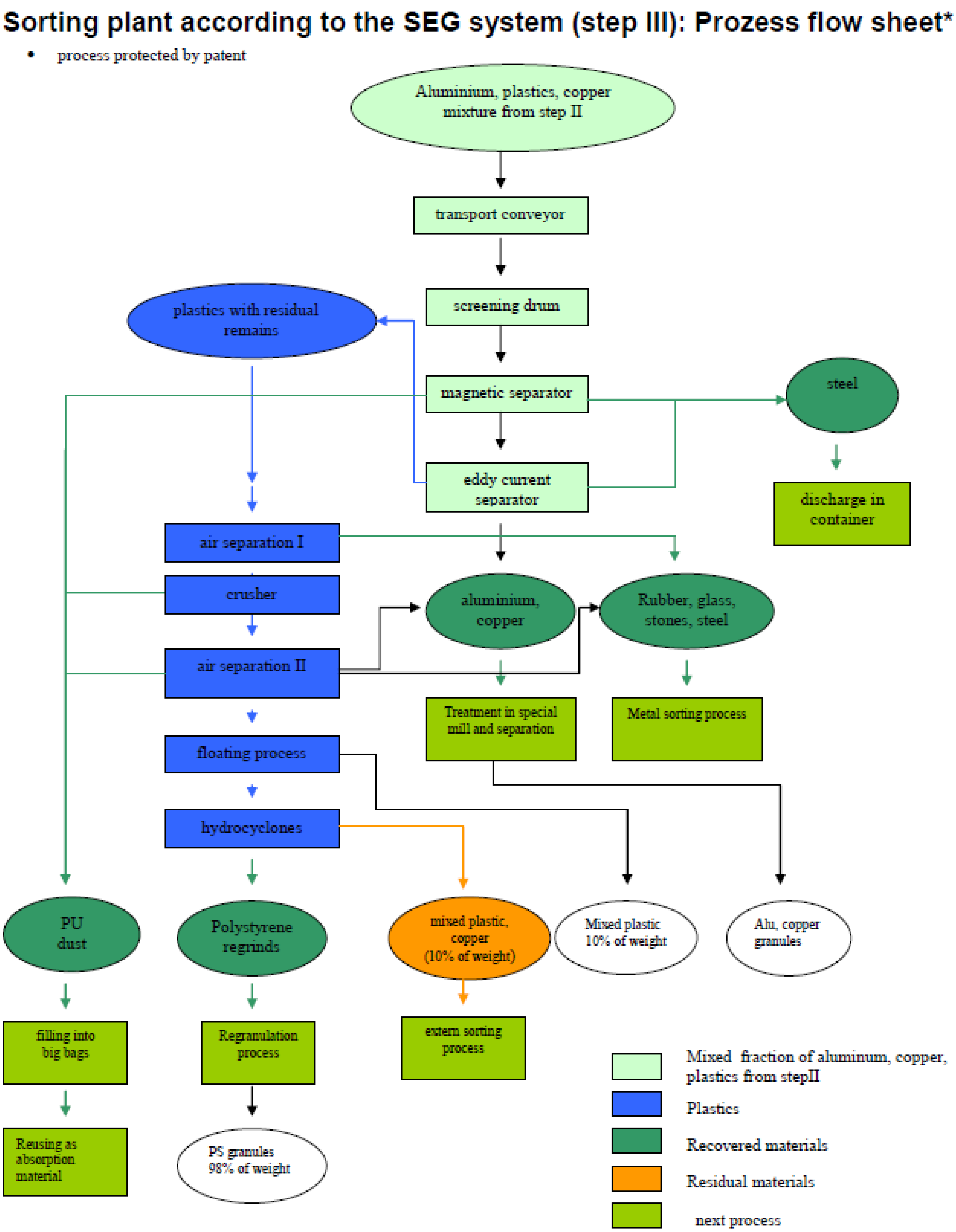
Flow Sheet of AVE Timelkam in Austria (SEG Technology, part 1)



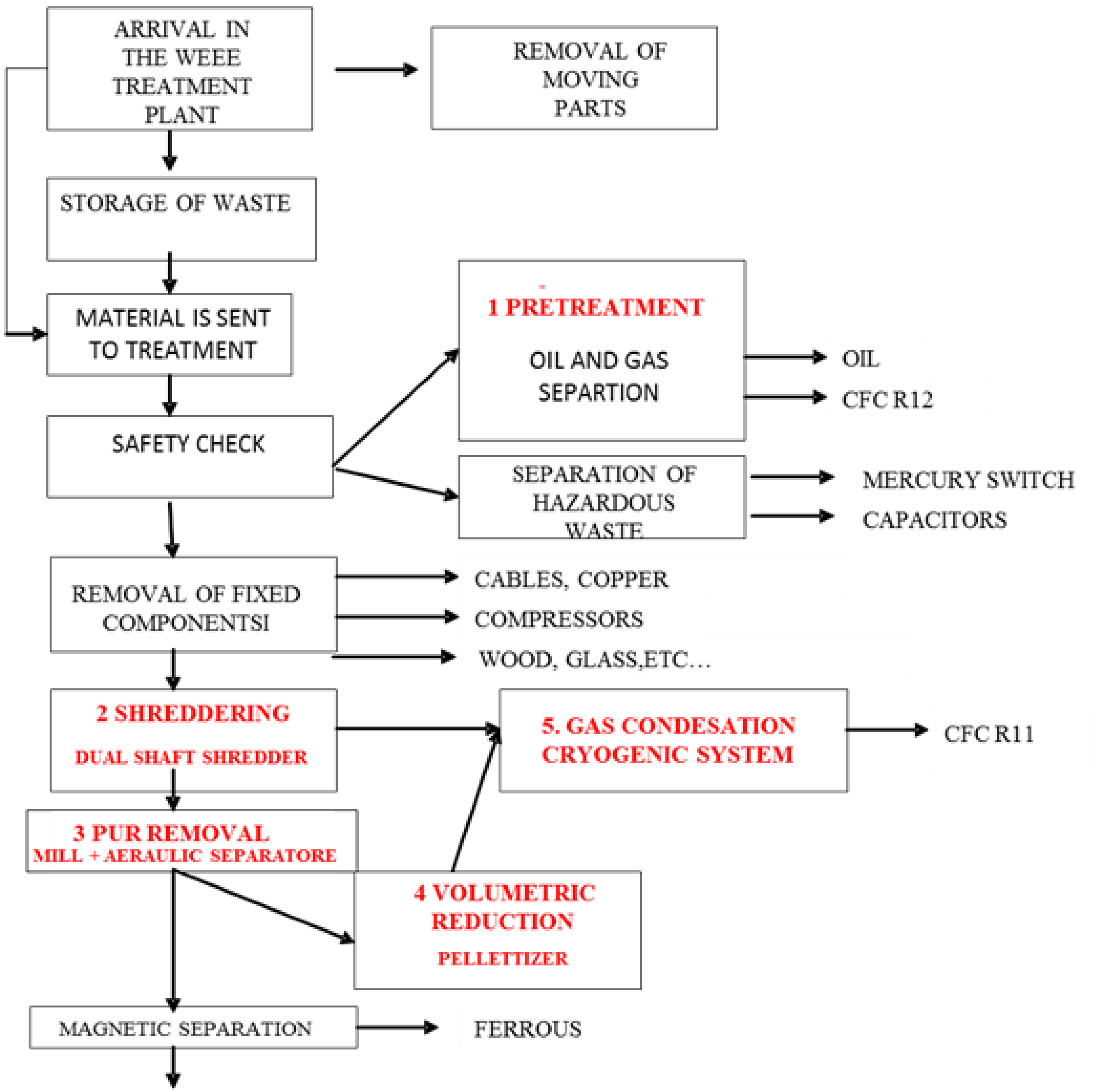
Flow Sheet of AVE Timelkam in Austria (SEG Technology, part 2)



Flow Sheet of AVE Timelkam in Austria (SEG Technology, part 3)



Flow Sheet of STENA in Italy



Flow Sheet of Veolia in France (part 1)

Treatment of Cooling and Freezing equipment

(Fridges, AC…)

1 2 3 **Phase I : « pretreatment »**

✓ Allows to extract cooling fluid from the cooling circuit:

- Extraction easy removable components (crispers, glass shelves ...);
- Draining of coolant with vacuum pump (recovery of oil and gas R12, R22, R502, R134 and R600 A);
- Separation of cooling (gas and oil) by ultrasound;
- Storage of oil and gas pressurization in tank for reprocessing;
- Dismantling of the fully depolluted compressor.

4 to 9 **Phase II : « treatment »**

✓ The automated unit is under inert nitrogen:

- Dissociates foams, plastics and metals using a disintegrator chain;
- Releases of most of the CFCs in foams through an initial rise in temperature (up to 70 °);
- Separates the foam from other residues;
- Extract residues CFCs in foams by a second temperature elevation (up to 140 °).

VEOLIA made the choice to invest in cutting-edge technologies

CFC recycling rate

99,4 %

Note

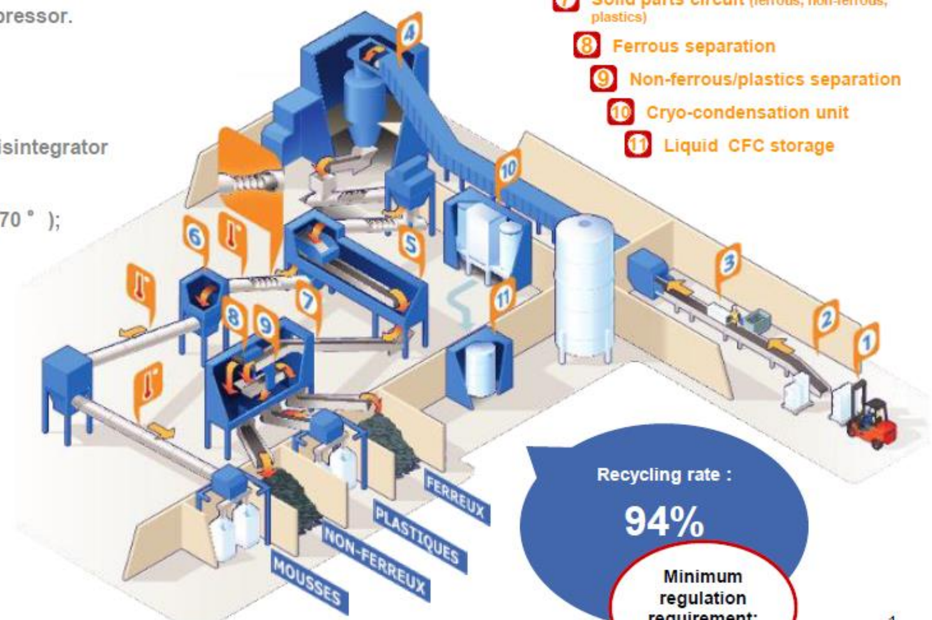
70 to 80% of the total amount of CFCs in Cooling and Freezing equipments are contained in the polyurethane foam used for insulation of the structure

10 11 **Phase III : « Packaging »**

✓ The automated unit:

- Cool down foams with nitrogen and store it in big bags;
- Sort reusable materials according to their category;
- Store CFCs in pressurized tanks after cryo-condensation at -160 °

1. Reception / weight /unloading
2. Feeding
3. Dismantling / manual depollution
4. Crusher (inerted zone)
5. Foam/solid parts separator
6. Foam circuit (CFC gas capture)
7. Solid parts circuit (ferrous, non-ferrous, plastics)
8. Ferrous separation
9. Non-ferrous/plastics separation
10. Cryo-condensation unit
11. Liquid CFC storage



Recycling rate :

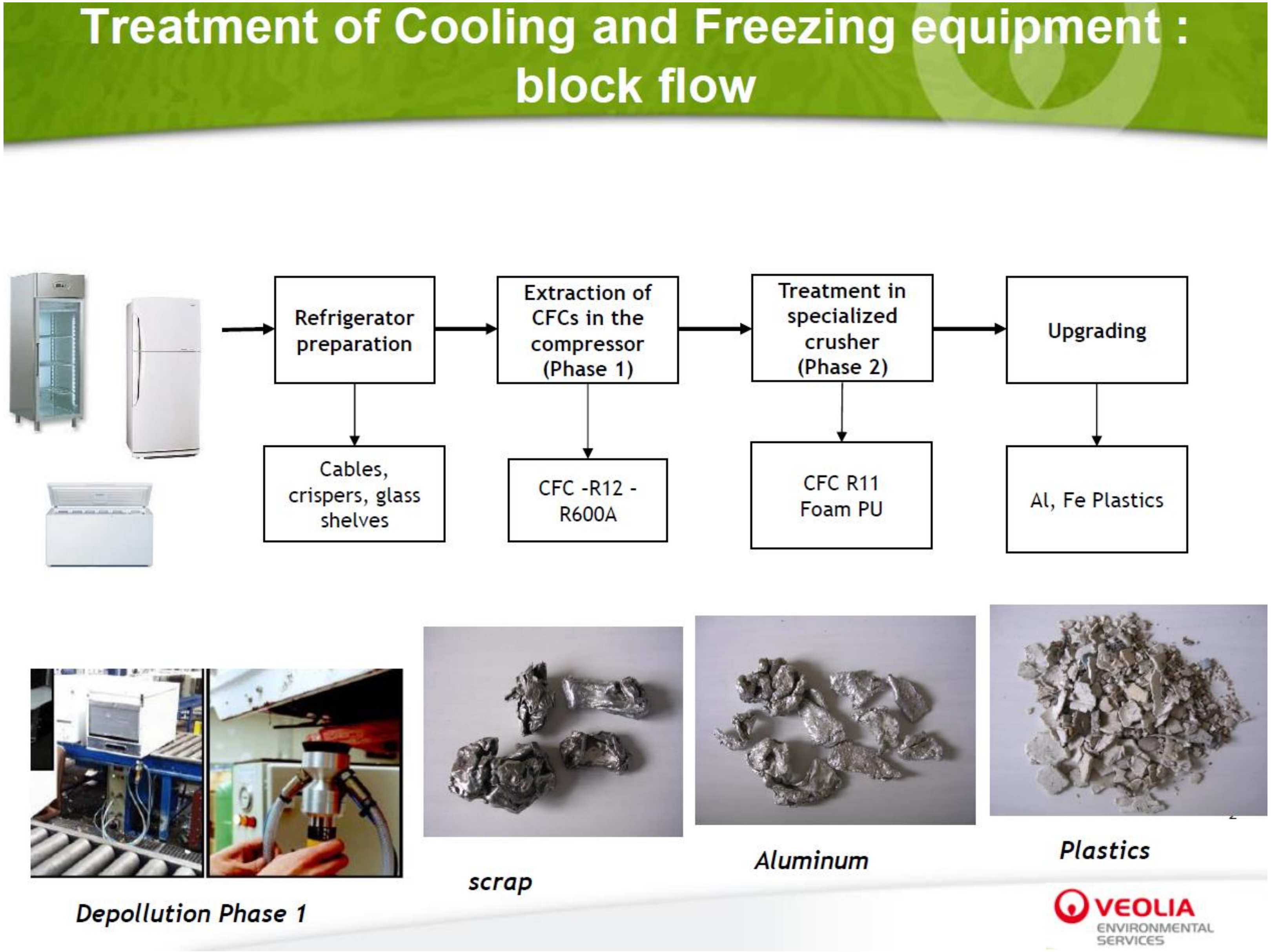
94%

Minimum regulation requirement: 80 %

1

VEOLIA ENVIRONMENTAL SERVICES

Flow Sheet of Veolia in France (part 2)



III. Appendix – Test Reports of Chemical Analyses

Department für Umwelt- und Energieverfahrenstechnik
Montanuniversität Leoben
Franz-Josef-Straße 18
http://iae.unileoben.ac.at/
A-8700 Leoben
Lehrstuhl für Abfallverwertungstechnik und Abfallwirtschaft / Lehrstuhl für Entsorgungs- und Deponietechnik
Akkreditiertes Labor nach ISO 17025

PSID:340

Prüfbericht

Probennummer: 0126-13-00

Auftraggeber: Montanuniverstität Leoben
LS für Entsorgungs- und Deponietechnik
Franz-Josef-Straße 18
8700 Leoben

Kundenbezeichnung: Probe1/ graues Pulver

Eingegangen von: DI Sarc

Probenzustand: Pulver <0,5 mm in der Kunststoffflasche

Bemerkung:

Probendatum: 20.03.2013

Probenkonservierung: keine

Probennahme: durch Kunden

Probenvorbereitung: keine

Probenaufbereitung: durch Kunden

Beurteilung nach: keine

Parameter	Kurzbez.	Messwert	Einheit	Analysendatum	Best. Grenze	Norm	
Röntgenfluoreszenzanalyse	RFA	siehe Anhang	-	21.03.2013	-	-	nicht akkreditiertes Verfahren Unterauftrag
Aschegehalt von festen Brennstoffen (815 °C)	AG	98,81	% TS	21.03.2013	0,1 %	DIN 51719:1997	akkreditiertes Verfahren

Univ.Prof.Dr.-Ing. Karl E. Lorber
Laborleiter

Carina Tauterer
Qualitätsleiter und Laborleiterstellvertreter

Der Prüfbericht darf ohne schriftliche Genehmigung des IAE nicht auszugsweise vervielfältigt, weitergegeben oder veröffentlicht werden.

Die im Prüfbericht angeführten Meßwerte beziehen sich ausschließlich auf das übergebene Prüfgut zum Zeitpunkt der Übergabe an das Labor, die Probenahme ist ausgeschlossen.

0126-13-00
22.03.2013

Seite 1 / 1

Customer name: .... Visit our website at:
address: .... http://www.uniquant.com

C:\UQ5\USER\2404Rh\Job\JOB.789
ProbenIdent = 1619/6617 0126-13
IAE, Tauterer
Mess Program : UniQuant

Compound	Wt%	StdErr	El	Weight%	StdErr
SiO2	99.19	0.05	Si	46.37	0.02
ZrO2	0.330	0.016	Zr	0.244	0.012
Al2O3	0.210	0.014	Al	0.111	0.008
Fe2O3	0.129	0.006	Fe	0.0900	0.0045
CaO	0.0543	0.0027	Ca	0.0388	0.0019
TiO2	0.0357	0.0040	Ti	0.0214	0.0024
V2O5	0.0165	0.0014	V	0.0092	0.0008
P2O5	0.0132	0.0013	Px	0.0058	0.0006

KnownConc= 0 REST= 0 D/S= 0.250Wachs
Sum Conc's before normalisation to 100% : 89.7%

Not significant:

F	0.038	0.031	F	0.038	0.031
Sm2O3	0.0044	0.0028	Sm	0.0038	0.0024
Tb4O7	0.0029	0.0020	Tb	0.0025	0.0017
MnO	0.0028	0.0010	Mn	0.0022	0.0008
WO3	0.0025	0.0015	W	0.0020	0.0012
Gd2O3	0.0021	0.0019	Gd	0.0018	0.0017
Pr6O11	0.0017	0.0031	Pr	0.0014	0.0025
RuO4	0.0015	0.0008	Ru	0.0011	0.0006
Y2O3	0.0015	0.0007	Y	0.0012	0.0006
Tl2O3	0.0015	0.0015	Tl	0.0013	0.0013
Ag2O	0.0012	0.0006	Ag	0.0011	0.0006
IrO2	0.0011	0.0012	Ir	0.00094	0.00100
In2O3	0.0011	0.0007	In	0.00091	0.00059
ZnO	0.0011	0.0007	Zn	0.00088	0.00052
Eu2O3	0.0008	0.0019	Eu	0.0006	0.0016
La2O3	0.0008	0.0016	La	0.0006	0.0014
Rh2O3	0.00077	0.00074	Rh	0.00062	0.00060
SO3	0.0007	0.0017	Sx	0.00028	0.00066
Tm2O3	0.0005	0.0015	Tm	0.0004	0.0013
Am2O3	0.00047	0.00085	Am	0.00043	0.00078
PtO2	0.0003	0.0012	Pt	0.0003	0.0010
CeO2	0.0003	0.0028	Ce	0.0002	0.0023
HgO	0.0002	0.0011	Hg	0.00016	0.00099
U3O8	0.00015	0.00091	U	0.00013	0.00078
SrO	0.00004	0.00062	Sr	0.00003	0.00052

=

DEPARTMENT FÜR UMWELT- UND ENERGIEVERFAHRENSTECHNIK
Montanuniversität Leoben
Franz-Josef-Straße 18
http://iae.unileoben.ac.at/
A-8700 Leoben
Lehrstuhl für Abfallverwertungstechnik und Abfallwirtschaft / Lehrstuhl für Entsorgungs- und Deponietechnik
Akkreditiertes Labor nach ISO 17025

PSID:340

Prüfbericht

Probennummer: **0127-13-00**

Auftraggeber: Montanuniverstität Leoben
LS für Entsorgungs- und Deponietechnik
Franz-Josef-Straße 18
8700 Leoben

Kundenbezeichnung: Probe2/ papierähnlich

Eingegangen von: DI Sarc

Probenzustand: papierähnliches Pulver <0,5 mm in der Kunststoffflasche

Bemerkung:

Probendatum: 20.03.2013

Probenkonservierung: keine

Probennahme: durch Kunden

Probenvorbereitung: keine

Probenaufbereitung: durch Kunden

Beurteilung nach: keine

Parameter	Kurzbez.	Messwert	Einheit	Analysendatum	Best. Grenze	Norm	
Röntgenfluoreszenzanalyse	RFA	siehe Anhang	-	21.03.2013	-	-	nicht akkreditiertes Verfahren,Unterauftrag
Aschegehalt von festen Brennstoffen (815 °C)	AG	99,73	% TS	21.03.2013	0,1 %	DIN 51719:1997	akkreditiertes Verfahren

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Der Prüfbericht darf ohne schriftliche Genehmigung des IAE nicht auszugsweise vervielfältigt, weitergegeben oder veröffentlicht werden.
Die im Prüfbericht angeführten Meßwerte beziehen sich ausschließlich auf das übergebene Prüfgut zum Zeitpunkt der Übergabe an das Labor, die Probenahme ist ausgeschlossen.

Customer name: .... Visit our website at:
address: .... http://www.uniquant.com

C:\UQ5\USER\2404Rh\Job\JOB.790
ProbenIdent = 1619/6618 0127-13
IAE, Tauterer
Mess Program : UniQuant

Compound	Wt%	StdErr	El	Weight%	StdErr
SiO2	69.27	0.23	Si	32.38	0.11
Na2O	14.13	0.26	Na	10.49	0.20
CaO	8.83	0.14	Ca	6.32	0.10
MgO	3.80	0.17	Mg	2.29	0.10
Al2O3	1.70	0.06	Al	0.902	0.034
K2O	0.617	0.031	K	0.512	0.026
Fe2O3	0.361	0.037	Fe	0.253	0.026
ZrO2	0.339	0.017	Zr	0.251	0.013
MnO	0.338	0.017	Mn	0.262	0.013
SO3	0.278	0.014	Sx	0.111	0.006
TiO2	0.152	0.008	Ti	0.0910	0.0045
CeO2	0.0902	0.0045	Ce	0.0734	0.0037
BaO	0.0203	0.0050	Ba	0.0182	0.0045
Cl	0.0137	0.0014	Cl	0.0137	0.0014
P2O5	0.0128	0.0011	Px	0.0056	0.0005

KnownConc= 0 REST= 0 D/S= 0.250Wachs
Sum Conc's before normalisation to 100% : 93.7%

Not significant:

Tb4O7	0.0047	0.0023	Tb	0.0040	0.0020
MoO3	0.0046	0.0016	Mo	0.0031	0.0010
As2O3	0.0033	0.0033	As	0.0025	0.0025
Rb2O	0.0016	0.0006	Rb	0.0015	0.0006
Co3O4	0.0011	0.0011	Co	0.00081	0.00084
PbO	0.0011	0.0015	Pb	0.0010	0.0014
I	0.0011	0.0020	I	0.0011	0.0020
CuO	0.00098	0.00080	Cu	0.00078	0.00064
Gd2O3	0.0006	0.0023	Gd	0.0005	0.0020
SeO2	0.00048	0.00070	Se	0.00034	0.00050
PdO	0.00047	0.00089	Pd	0.00041	0.00077
HgO	0.0004	0.0011	Hg	0.0004	0.0011
Nb2O5	0.0004	0.0011	Nb	0.00027	0.00074
WO3	0.0003	0.0016	W	0.0002	0.0013
Lu2O3	0.0003	0.0016	Lu	0.0003	0.0014
Br	0.00026	0.00052	Br	0.00026	0.00052
Rh2O3	0.00026	0.00095	Rh	0.00021	0.00077
CdO	0.00023	0.00080	Cd	0.00020	0.00070
Cs2O	0.0002	0.0035	Cs	0.0002	0.0033
Ga2O3	0.00011	0.00061	Ga	0.00008	0.00046
Tm2O3	0.0001	0.0018	Tm	0.0001	0.0016

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DEPARTMENT FÜR UMWELT- UND ENERGIEVERFAHRENSTECHNIK
Montanuniversität Leoben
Franz-Josef-Straße 18
http://iae.unileoben.ac.at/
A-8700 Leoben
Lehrstuhl für Abfallverwertungstechnik und Abfallwirtschaft / Lehrstuhl für Entsorgungs- und Deponietechnik
Akkreditiertes Labor nach ISO 17025

PSID:340

Prüfbericht

Probennummer:	**0128-13-00**	**Probendatum:**	20.03.2013
Auftraggeber:	Montanuniverstität Leoben LS für Entsorgungs- und Deponietechnik Franz-Josef-Straße 18 8700 Leoben	**Probenkonservierung:**	keine
		Probennahme:	durch Kunden
Kundenbezeichnung:	Probe3/ Vlies	**Probenvorbereitung:**	keine
Eingegangen von:	DI Sarc	**Probenaufbereitung:**	durch Kunden
Probenzustand:	pulvriges Vlies <0,5 mm in der Kunststoffflasche	**Beurteilung nach:**	keine
Bemerkung:			

Parameter	Kurzbez.	Messwert	Einheit	Analysendatum	Best. Grenze	Norm	
Röntgenfluoreszenzanalyse	RFA	siehe Anhang	-	21.03.2013	-	-	nicht akkreditiertes Verfahren,Unterauftrag
Aschegehalt von festen Brennstoffen (815 °C)	AG	97,24	% TS	21.03.2013	0,1 %	DIN 51719:1997	akkreditiertes Verfahren

Univ.Prof.Dr.-Ing. Karl E. Lorber
Laborleiter

Tauterer
Carina Tauterer
Qualitätsleiter und Laborleiterstellvertreter

Die im Prüfbericht angeführten Meßwerte beziehen sich ausschließlich auf das übergebene Prüfgut zum Zeitpunkt der Übergabe an das Labor, die Probenahme ist ausgeschlossen.

Customer name: .... Visit our website at:
address: .... http://www.uniquant.com

C:\UQ5\USER\2404Rh\Job\JOB.791
ProbenIdent = 1619/6619 0128-13
IAE, Tauterer
Mess Program : UniQuant

Compound	Wt%	StdErr	El	Weight%	StdErr
SiO2	55.62	0.25	Si	26.00	0.12
CaO	25.68	0.22	Ca	18.36	0.16
Al2O3	13.96	0.17	Al	7.39	0.09
ZrO2	1.95	0.07	Zr	1.44	0.05
MgO	0.692	0.061	Mg	0.417	0.037
Na2O	0.442	0.034	Na	0.328	0.025
F	0.435	0.059	F	0.435	0.059
TiO2	0.354	0.018	Ti	0.212	0.011
Fe2O3	0.338	0.034	Fe	0.236	0.024
SrO	0.226	0.011	Sr	0.191	0.010
K2O	0.180	0.009	K	0.149	0.007
P2O5	0.0388	0.0019	Px	0.0169	0.0008
HfO2	0.0385	0.0022	Hf	0.0326	0.0019
SO3	0.0240	0.0024	Sx	0.0096	0.0010
Cr2O3	0.0111	0.0020	Cr	0.0076	0.0014

KnownConc= 0 REST= 0 D/S= 0.250Wachs
Sum Conc's before normalisation to 100% : 93.8%

Not significant:

PuO2	0.0060	0.0021	Pu	0.0053	0.0019
WO3	0.0038	0.0019	W	0.0030	0.0015
V2O5	0.0032	0.0017	V	0.0018	0.0010
CeO2	0.0030	0.0041	Ce	0.0024	0.0034
MnO	0.0030	0.0015	Mn	0.0023	0.0012
NiO	0.0026	0.0012	Ni	0.0020	0.0009
CuO	0.0023	0.0010	Cu	0.0018	0.0008
Dy2O3	0.0022	0.0032	Dy	0.0019	0.0028
CdO	0.0021	0.0010	Cd	0.0018	0.0009
Gd2O3	0.0016	0.0027	Gd	0.0014	0.0023
Ho2O3	0.0016	0.0031	Ho	0.0014	0.0027
Rb2O	0.0016	0.0008	Rb	0.0015	0.0007
In2O3	0.0015	0.0010	In	0.0012	0.0009
Rh2O3	0.0013	0.0013	Rh	0.0011	0.0011
Er2O3	0.0013	0.0024	Er	0.0011	0.0021
HgO	0.0006	0.0012	Hg	0.0006	0.0012
PbO	0.0005	0.0018	Pb	0.0005	0.0017
U3O8	0.0005	0.0014	U	0.0005	0.0011
Yb2O3	0.0004	0.0020	Yb	0.0003	0.0017
Br	0.00030	0.00060	Br	0.00030	0.00060
IrO2	0.0002	0.0015	Ir	0.0002	0.0013

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Akkreditiertes Labor nach ISO 17025

PSID:340

Prüfbericht

Probennummer: **0129-13-00**

Auftraggeber: Montanuniverstität Leoben
LS für Entsorgungs- und Deponietechnik
Franz-Josef-Straße 18
8700 Leoben

Kundenbezeichnung: Probe4/ Glaswolle

Eingegangen von: DI Sarc

Probenzustand: Glaswolle <1cm in der Kunststofflasche

Bemerkung:

Probendatum: 20.03.2013

Probenkonservierung: keine

Probennahme: durch Kunden

Probenvorbereitung: keine

Probenaufbereitung: durch Kunden

Beurteilung nach: keine

Parameter	Kurzbez.	Messwert	Einheit	Analysendatum	Best. Grenze	Norm	
Röntgenfluoreszenzanalyse	RFA	siehe Anhang	-	21.03.2013	-	-	nicht akkreditiertes Verfahren,Unterauftrag
Aschegehalt von festen Brennstoffen (815 °C)	AG	98,78	% TS	21.03.2013	0,1 %	DIN 51719:1997	akkreditiertes Verfahren

Univ.Prof.Dr.-Ing. Karl E. Lorber
Laborleiter

Carina Tauterer
Qualitätsleiter und Laborleiterstellvertreter

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        Customer name: ........                    Visit our website at:
              address: ........                    http://www.uniquant.com
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C:\UQ5\USER\2404Rh\Job\JOB.792
ProbenIdent   = 1619/6620  0129-13
IAE, Tauterer
Mess Program  :  UniQuant
```

Compound	Wt%	StdErr	El	Weight%	StdErr
SiO2	51.66	0.25	Si	24.15	0.12
CaO	30.50	0.23	Ca	21.81	0.17
Al2O3	14.27	0.17	Al	7.55	0.09
Na2O	0.861	0.042	Na	0.639	0.031
TiO2	0.810	0.090	Ti	0.486	0.054
MgO	0.523	0.026	Mg	0.316	0.016
ZrO2	0.438	0.039	Zr	0.324	0.029
Fe2O3	0.423	0.024	Fe	0.296	0.017
SrO	0.151	0.013	Sr	0.127	0.011
K2O	0.135	0.007	K	0.112	0.006
SO3	0.131	0.006	Sx	0.0526	0.0026
P2O5	0.0329	0.0022	Px	0.0144	0.0009
V2O5	0.0153	0.0030	V	0.0086	0.0017
Cr2O3	0.0138	0.0028	Cr	0.0094	0.0019
MnO	0.0121	0.0024	Mn	0.0094	0.0018

```
KnownConc= 0                    REST= 0                  D/S= 0
Sum Conc's before normalisation to 100% :   51.3%


Not significant:
```

F	2.01	5.28	F	2.01	5.28
HfO2	0.0079	0.0031	Hf	0.0067	0.0026
Sm2O3	0.0069	0.0062	Sm	0.0059	0.0054
La2O3	0.0060	0.0040	La	0.0051	0.0034
NiO	0.0047	0.0019	Ni	0.0037	0.0015
Ho2O3	0.0045	0.0047	Ho	0.0039	0.0041
PuO2	0.0044	0.0023	Pu	0.0039	0.0020
CuO	0.0040	0.0017	Cu	0.0032	0.0013
Ga2O3	0.0036	0.0013	Ga	0.0027	0.0010
Yb2O3	0.0026	0.0031	Yb	0.0023	0.0028
WO3	0.0021	0.0030	W	0.0017	0.0024
In2O3	0.0016	0.0012	In	0.0013	0.0010
Y2O3	0.0015	0.0014	Y	0.0012	0.0011
HgO	0.0014	0.0017	Hg	0.0013	0.0016
Cl	0.0012	0.0024	Cl	0.0012	0.0024
TeO2	0.0010	0.0015	Te	0.0008	0.0012
Sb2O3	0.0010	0.0013	Sb	0.0008	0.0011
MoO3	0.0010	0.0024	Mo	0.0007	0.0016
Pr6O11	0.0006	0.0071	Pr	0.0005	0.0059
Bi2O3	0.0004	0.0017	Bi	0.0004	0.0015
SeO2	0.0004	0.0012	Se	0.00027	0.00086
Br	0.00034	0.00091	Br	0.00034	0.00091
Co3O4	0.0003	0.0021	Co	0.0002	0.0015
GeO2	0.0001	0.0012	Ge	0.00010	0.00086

IV. Appendix – Info Sheet

Recycling of Cooling and Freezing Appliances Containing Vacuum Insulation Panels (VIPs)

VIPs : **high performance thermal insulations** (high specific thermal resistivity)
new solutions for slim but still energy efficient insulations **used in A++ and A+++** appliances

Scope of the Project:

1) Phase 1: Identification of VIPs used by household appliance producers (done)
2) Phase 2: Realization of small technical tests (done)
3) Phase 3: **Large-scale tests in recycling plants** and evaluation (being planned)

Agents:

CECED - European Committee of Domestic Equipment Manufacturers
Blvd Brand Whitlock 114, 1200 Brussels contact person: **Kamila Slupek (kamila.slupek@ceced.eu)**

Montanuniversitaet Leoben, Department of Environmental and Energy Process Engineering, Chair of Waste Processing Technology and Waste Management
Franz-Josef-Straße 18, 8700 Leoben contact person: **Renato Sarc (Renato.sarc@unileoben.ac.at)**

Chemical Analyses of the Core Materials in Laboratory of Montanuniversitaet Leoben

Compound/ Chemical Formula		Weight [%]					
		MG1 paperlike	MG2 white fleece	MG3 glass woollike	MG4 grey powder	MG5 brown powder	MG6 black powder
silicon dioxide	SiO_2	69.08	54.08	51.03	98.01	93.66	73.47
calcium oxide	CaO	8.81	24.97	30.13	-	-	-
aluminium oxide	Al_2O_3	-	13.57	14.10	-	-	-
iron(III) oxide	Fe_2O_3	-		-	-	-	23.15
sodium oxide	Na_2O	14.09	-	-	-	-	-
sum of organic material		0.27	2.76	1.22	1.19	5.98	3.15

Within the framework of the first two phases, **six different VIP types** could be identified (material groups 1 - 6), which differ from each other in the core materials (see table). The mass percentage of VIPs is about 5% in an appliance.

NECESSARY INFORMATION FOR LARGE SCALE TESTS (FROM YOU):

Description of technology (cutting units etc.; if possible a flow sheet of your plant);

Infrastructure (delivery by trucks, train,...);

Possible date for test;

Input and output materials;

Throughput (appliances per hour or tonnes per hour);

Working time of shift operation;

Additionally technical details, which are important for the test