R'02

Geneve, 12-15 februari 2002

-Reserapport-

Karin Strömberg
CIT Ekologik

1 Introduktion

World Congress on Integrated Resources Management är en återkommande internationell konferens, som ursprungligen initierades för att skapa ett diskussionsforum för hållbar utveckling.

Den 12-15 februari 2001 hölls konferensen för 6: e gången. Konferensen hölls denna gång i Genève och samlade omkring 600 deltagare från hela världen. Över 400 bidrag granskades av den internationella expertpanelen. Under konferensen hölls totalt 160 presentationer i fyra parallella sessioner. Konferensen arrangerades av EMPA (Swiss Federal Laboratories for Materials Testing (St. Gallen), PEAK Ltd. (Zurich) och Orgexpo-Palexpo (Geneva) tillsammans med ett antal nationella och utländska organisationer.

CPM representerades vid konferensen av Karin Strömberg från CIT Ekologik, som presenterade en modell för värdering av återvunnet material vid LCA sessionen.

2 Konferensupplägg

Följande sessioner hölls:

- IRM (Integrated Resource Management)
- Biological Processes
- Energy Recovery
- Product Design & Eco Design
- Chemical and Biochemical Processes
- Thermal: General Schemes
- Mechanical Recycling
- Socio-Economic Issues
- Integrated Waste Management
- Chemical Processes
- Metallurgy
- Identification & Separation Technologies
- Life Cycle Assessment
- Logistics

För mer information om konferensupplägget, se www.r02.org. På samma webbsida kan man beställa en CD med samtliga proceedings.

3 CPM presentation: Valuation of Recycled Material in LCA/DfE applied to Aluminium

Inför konferensen skrev Karin Strömberg, David Weiner och Tomas Rydberg en artikel om en metod för värdering av recirkulerat material (VARM-modellen), se bilaga 1 och 2. Artikeln baserade sig på det examensarbete[1] Karin Strömberg utförde på Volvo Teknisk Utveckling inom CPMs projekt ”Recycling” under etapp 2. I examensarbetet togs VARM-modellen fram och presenterades, som ett första steg, avseende värdering av aluminium i återvinningssystem.

VARM-modellen kombinerar materialpoolskonceptet med en ekonomisk allokering. Modellen är lämpad för material med en väletablerad marknad för återvunnet material. Modellens styrka verifierades genom en fallstudie, i vilken modellen tillämpades på tre fogningsmetoder. Syftet med studien var att studera hur valet av fogningsmetod påverkar en aluminiumprodukts återvinningsbarhet. Fallstudien visar på att VARM-modellen har förmåga att särskilja olika aluminiumprodukters återvinningspotential.

På konferensen presenterades VARM-modellen och den fallstudie som genomfördes inom projektet. Vidare förmedlades att CPM har för avsikt att utveckla VARM-modellen till att omfatta ytterligare material.

Efter presentationen blev det en del frågor. Frågorna rörde sig om varför man hade använt sig av en ekonomisk allokering och inte allokerat med avseende på massa. Svaret på den frågan är att man med massallokering inte skulle kunna få samma klara klassindelning av materialet. Vidare är det inte massan som driver återvinningen av exempelvis aluminium, utan de ekonomiska aspekterna. Sessionens moderator, Dr. Klaus Richter från EMPA, var mycket intresserad av modellens upplägg och tillämpning. Han var själv helt insatt i användbarheten, eftersom man på EMPA har en doktorand som tittar på något liknande. Richters har förmedlat kontakten med nämnda doktorand, vars artikel beskriver ett liknande tillvägagångssätt men som ej beskriver exakt vad den ekonomiska allokeringen baserar sig på.

4 Reflektioner från konferensen

Konferensen besöktes av både representanter från företag, forskningsinstitut och universitet och högskolor. Bland de svenska deltagarna fanns representanter från CIT Ekologik, IFP Research, Kungliga Tekniska Högskola (KTH), MEFOS, MISTRA och SP.

4.1 Återvinning

4.1.1 Återvinning av plast – optimering av återvinningsgrad

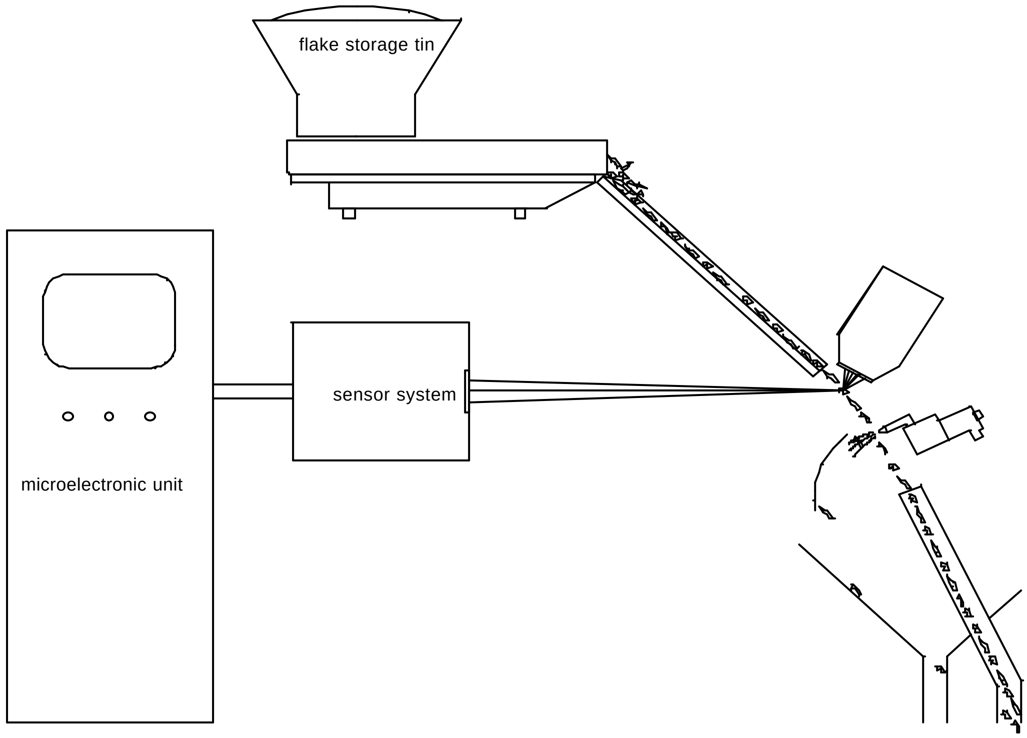
Dr Neil Mayne och Dr Herbert Fisch har på uppdrag av APME gjort en studie där olika europeiska återvinningsscenarion (mekanisk återvinning, kemisk återvinning, energiåtervinning och deponering) för plastförpackningar studerades. Metodiken man använde baserade sig på LCI data samt kostnader för återvinningen.

[1] Värdering av aluminium i återvinningssystem – Metodutveckling - Modellering - Programutveckling

Studien visar att kostnaderna för insamling och materialbehandling ökade snabbt med ökad återvinningsgrad. Genom att öka den mekaniska återvinningsgraden från 15 % till 50 % (resterande mängd energiåtervinns) ökar återvinningskostnaderna med en faktor 3 medan miljövinsten påverkas väldigt lite eller inte alls.

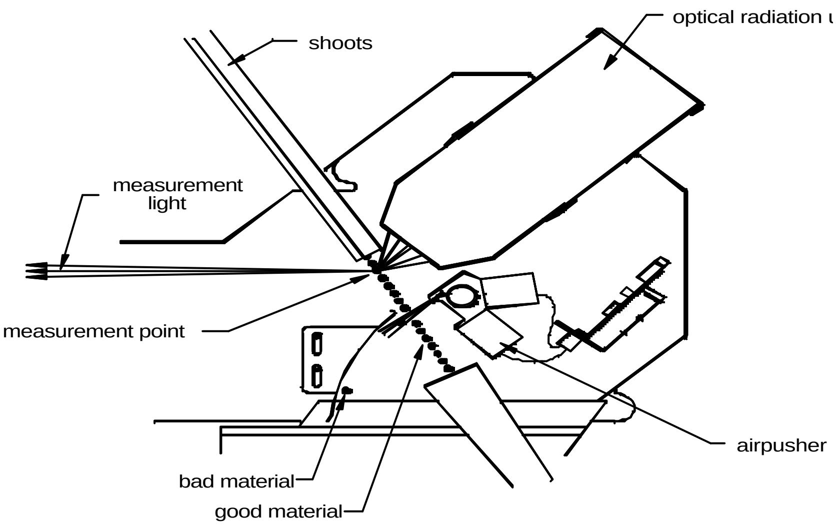
4.1.2 Sortering vid återvinning av PET-flaskor

Forrest L. Bayer från The Coca-Cola Company i Atlanta höll ett mycket uppmärksammat föredrag[2] om en studie av bortsortering av främmande material vid återvinning av PET-flaskor. Studien var genomförd tillsammans med Gunther Krieg (Polytechnical University, Karlsruhe), Manfred Dausch, Dirk Fey, Jurgen Bohleber, Alfred Schmidt (Unisensor Sensorsysteme GmbH, Karlsruhe), och Karel Wendl (Coca-Cola Greater Europe and Eurasia, Bryssel).



Figur 1: Schematisk bild över sorteringsanläggningen.

[2] Purification of Post Consumer PET Feedstreams for Food Applications via Sophisticated Flake Sortation for Material Types, Colors and Contaminants



Figur 2: Detaljerad bild av utsorteringen.

Utsorteringssystemet har kapacitet att från PET:

- Detektera och sortera ut olika plasttyper
- Urskilja olika färger på plast
- Detektera och sortera ut främmande material (papper/glas/metall)
- Detektera och sortera ut föroreningar som har absorberats i PET materialet.

4.1.3 Avfallsbörs

Det italienska företaget Ecosquare har etablerat en avfallsbörs på nätet (www.ecosquare.com).

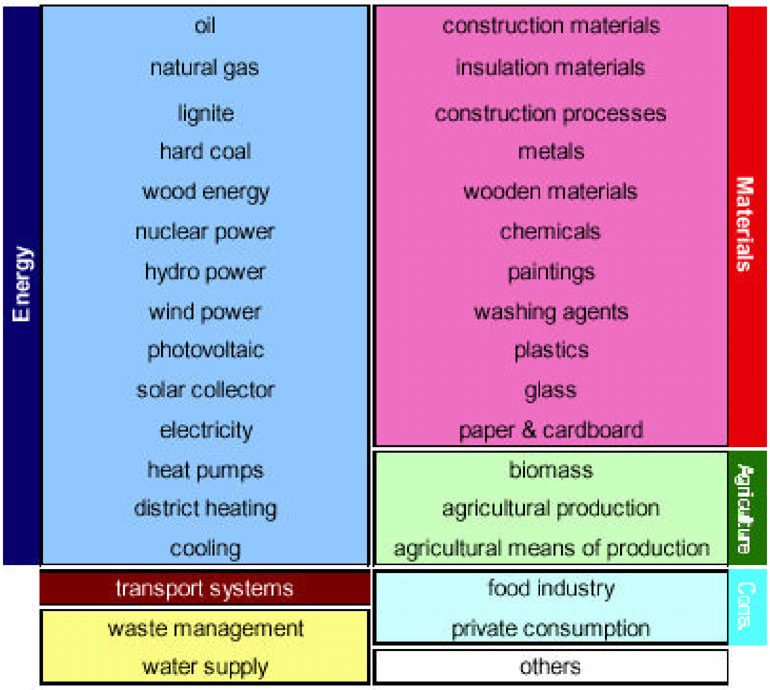
Marknader:

- aluminium and non ferrous scrap metals
- construction and demolition
- durables
- energy
- glass
- hazardous
- land reclaiming
- organic waste
- paper and cardboard
- plastics
- precious metals
- steel and ferrous scrap metals
- textiles
- tyres
- transports
- used oil
- wood

4.2 LCA

4.2.1 Samordnad Schweizisk databas – Ecoinvent 2000

Paul Gilgen från EMPA presenterade den Schweiziska satsningen på att samordna olika nationella databaser. Ett flertal institut i ETH-domänen ligger bakom satningen: the Swiss Federal Institutes of Technology (ETH), the Swiss Federal Laboratories for Materials Testing and Research (EMPA), the Paul Scherrer Institute (PSI) och the Swiss Federal Institute for Environmental Science and Technology (EAWAG). Även LCA-avdelningen vid the Swiss Federal Research Station for Agroecology and agriculture (FAL) och the Swiss Agency for the Environment, Forests and Landscape (BUWAL) är involverade. Rolf Frischknecht kommer att vara den centrala administratorn. I figuren nedan presenteras de områden som Ecoinvent 2000 avser att täcka.



Figur 3: De områden som Ecoinvent 2000 avser att täcka.

För att dokumentera data har man gjort ändringar och kompletteringar i SPOLD-formatet utifrån kommittéutkastet för ISO 14048 och kallar detta ”nya” format för EcoSpold. Databasen kommer att kunna köpas fr.o.m. våren 2003.

4.2.2 Cost Benefit Analys av hantering av förpackningsavfall i Tyskland

Volrad Wollny, från University of Applied Science Mainz, presenterade en studie som gjorts tillsammans med Oeko-Institute i Tyskland. 1997/1998 fick Oeko-Institutet i uppdrag av Dual System Deutschland (DSD), den tyska motsvarigheten till svenska REPA, att utreda om DSD bidrog till en hållbar utveckling eller inte.

Studien omfattade bland annat:

- En systemanalys
- Identifiering av vad som i huvudsak bidrog till en hållbar utveckling eller inte samt val av lämpliga indikatorer
- En relativ utvärdering som tog hänsyn till alternativa produkter och tjänster
- Identifiering av de faktorer som främst påverkar produktsystemet eller tjänstesystemet.

Följande metoder för avfallshantering har omfattats:

- Förbränning med energiåtervinning
- Produktion av avfallsbaserat bränsle och deras användning vid cementproduktion
- Separat insamling (BRING system) endast av större förpackningar av plast och dryckeskartong
- ”Trottoarinsamling” av PMD samt avancerad separationsteknik
- Separering av det kommunala avfallet efter insamling. Separering med hjälp av avancerad teknik.

Relationen mellan miljövinsterna och kostnaderna för de olika återvinningsalternativen identifierades som ett av nyckelproblemen. En separat återvinning av papper och kartong samt glas gav både ekonomiska och miljömässiga fördelar, medan en separat insamling, separering och återvinning av plast, metall och dryckesförpackningar (PMD) gav begränsade miljöfördelar men höga kostnader.

5 Referenser

Bayer F L. et al, *Purification of Post Consumer PET Feedstreams for Food Applications via Sophisticated Flake Sorting for Material Types, Colors and Contaminants.* R'02 Conference Geneva, Abstract No. 392, The Coca Cola Company, Atlanta, Unisensor, Karlsruhe, Polytechnical University, Karlsruhe, 2002

Coletti S., *The Net Trading as Integration Tool to Enhance the Recycling and Waste Market*. R'02 Conference Geneva, Abstract No. 316, Ecosquare S.p.a., Pavia, 2002

Gilgen P. et al, *Life Cycle Inventories – The Swiss Approach* «*Ecoinvent 2000*». R'02 Conference Geneva, Abstract No. 394, EMPA, St. Gallen, ETHZ Zürich, Zürich, 2002

Mayne N., Fisch H., *The Use of Eco-Efficiency Assessments to Determine the Optimum Recovery Options for Different Plastics Waste Streams.* R'02 Conference Geneva, Abstract No. 320, APME, Brussels, 2002

Strömberg, K., *Valuation of Aluminium in the Recycling system – Method development - Modelling -Software development*, Master Thesis (report written in Swedish), Department of Experimental Physics, Chalmers University of Technology, Göteborg University, Göteborg, Sweden, 2000

Strömberg K. et al, *Valuation of Recycled Material in LCA/DFE Applied to Aluminium*. R'02 Conference Geneva, Abstract No. 145, CIT Ekologik AB, Göteborg, CPM, Göteborg, Volvo Car Corporation, Göteborg, 2002

Wollny V., Dehoust G., *Analysis and Assessment of Packaging Waste Management Options.* R'02 Conference Geneva, Abstract No. 153, Oeko-Institute e.V. , Darmstadt, 2002

Bilaga 1: VARM-modellen

VALUATION OF RECYCLED MATERIAL IN LCA/DFE

APPLIED TO ALUMINIUM

Karin Strömberg[1], Tomas Rydberg[1, 3], and David Weiner[2, 3]
[1] CIT Ekologik AB, Chalmers Science Park, S-412 88 Göteborg
[2] Volvo Car Corporation, S-405 08 Göteborg
[3] Centre for the Assessment of Product and Material Systems,
Chalmers University of Technology, S-412 96 Göteborg

Abstract

The Valuation of Recycled Material (VARM) model combines a material pool concept with an economic allocation procedure. The economic allocation procedure follows the price trend on the commodity market. Each material has two specific material pools, one for virgin material and one for recycled material. The materials in the pool for recycled material are divided into different classes, which are based on the properties (chemical composition) of the material. The classes are given environmental values by the economic allocation. The VARM model is suited for materials with a well-established second hand market. The strength of the model was verified by a case study, where the model was applied to three aluminium joints.

Background

The background for deriving the VARM model was the need for a practical way to define and calculate the credit for recycling in generic LCA end-of-life scenarios. Within life cycle assessment (LCA), there are several suggestions on how to account for the environmental impact of a single product in open loop recycling (allocation). According to ISO 14 041, the basic rules for allocation are: avoid allocation (e.g. system expansion), allocation based on physical relations (e.g. mass), and allocation based on other relations (e.g. economic value) (ISO 14 041). The reasons for which method to choose, and the consequences of these choices, have been discussed elsewhere (e.g. Rydberg 1995a, Ekvall 1999).

Allocation is a fairly complicated issue that hardly can be investigated in detail in a design process. One way to help the designer is to provide generic credit factors for different materials going to recycling.

In the Swedish Product Ecology Project (Rydberg 1995b) the material pool concept was introduced to represent any system receiving the material going to recycling. The concept was chosen, as it gives incentive to "design-for recycling". It was believed, that the potential effects of recycling would be most effectively communicated to designers by using this model. As an interim solution, the recycling credits as in table 1 were developed (Steen, 1999). The credits are based on rough estimates of how the quality of the material decreases when it is recycled (Ryding et al, 1995; Strömberg[3], 2000).

Table 1: Technical value of recycled material compared to virgin material in LCA perspective. By recycling the material at the end-of-life, x % of the environmental load of virgin material can be reduced from the total. *Source: Ryding et al 1995*

[3] Includes information obtained from one of the inventors of the quality degradation factors, Gunnar Westerlund.

Material Group	Material Recycling - production scrap -	Material Recycling - end of life -
Precious metals	99 %	98 %
Other metals	90 %	80 %
Glass	90 %	80 %
Thermoplastics	80 %	50 %
Other plastics	30 %	

The VARM model

The VARM model (Valuation of Recycled Material) was developed as a refinement of the credit factors developed in table 1. The rough grouping of materials, where e.g. alloy content or impurities in metal scrap are not taken into account, limits the usability of the credit factors (Ryding et al 1995) in e.g. complex designs.

Since the recycling industry is driven by economical factors, their classification of scrap reflects technical and economical values of the materials. In the VARM model, these economical values are used as a measure of the recyclability of the materials.

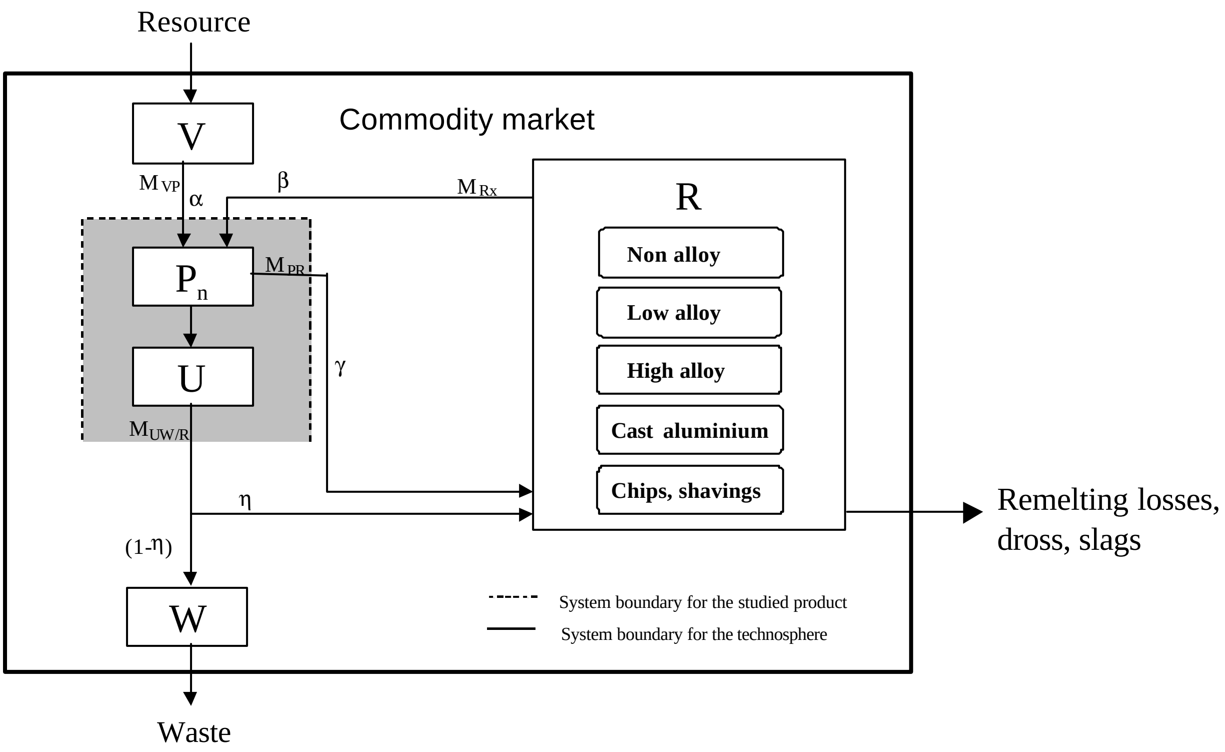


Figure 1: *Flow chart with material pools for aluminium, V and R, which are placed outside the system boundary for the studied product. The R-pool represents the recycling industry. The shaded area represents the production and the use phase. When remelting aluminium the metal exchange varies with the presence of surface treatments etc. that affects the remelting losses. Source: Strömberg, 2000.*

The material pool concept has been used in the VARM model to illustrate the commodity market, see figure 1. On the commodity market you will find two different kinds of material pools, one for virgin material and one for recycled material. Each material has its own material pools. The pool for recycled material represents the recycling industry, and here the material is divided into different classes based on the properties (chemical composition) of the material. By classifying the material in this way, the model follows the procedure of the recycling industry. In table 2, the allowed composition of the different classes is listed. The classes are given recycling values by an economic allocation. The classification aims at providing an incentive to design for recycling.

The recycling value represents the quotients between the scrap material price and the virgin material price on the commodity market for metals in London (London Metal Exchange), see table 3. For aluminium, as for other materials that are circulating in well-established markets for recycled materials, these quotients are fairly stable. The strength of the VARM-model was verified using differently designed T-joints in aluminium as a case study.

Table 2: The allowed chemical compositions of alloys for the different R-classes for aluminium. Source: Strömberg, 2000

R - class	Weight percent	Si	Fe	Cu	Mn	Mg	Ni	Zn	Sn	Pb	Ti
Non alloyed	max	0,50	0,50	0,05	0,10	0,05	0,05	0,10	0,05	0,05	0,05
	min	0	0	0	0	0	0	0	0	0	0
Low alloyed	max	1,3	0,40	0,10	1,0	0,80	0,05	0,10	0,05	0,05	0,05
	min	0,30	0,40	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
High alloyed	max	1,3	1,0	6,0	1,5	5,0	0,30	5,0	0,20	1,2	0,20
	min	0,35	0,40	0,10	0,50	0,30	0,01	0,20	0,01	0,01	0,05
Casted Al	max	13,5	1,2	5,0	0,50	1,0	0,30	2,0	0,20	0,30	0,20
	min	0,25	0,25	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05

Values of second hand material

By combining the recycling value for different R-classes with the metal exchange at the remelting, a DFR-index (Design for Recycling) is obtained. The DFR-index is suitable for the designers and LCA practitioners to use as generic credit factors for aluminium going to recycling. Table 3 shows the DFR-index for different R-classes of aluminium according to the VARM model.

Tabell 3: *DFR-index for aluminium going to recycling. The classes are based on Gotthard Aluminium, 1997 and the values have been developed together with Gotthard Aluminium AB and Sapa Recycling and Technology (Karlsson 1999, Clevesson 1999, Knutsson 1999).* A clean and undyed product represents a product that is free from oil and other material such as e.g. plastic, paint and steel screws. *Source: Strömberg, 2000.*

R-class	Recycling Value	Metal Exchange	DFR-index
Non alloyed aluminium			
- clean and undyed	0,88	0,95	0,84
- general	0,88	0,85	0,75
Low alloyed aluminium			
- clean and undyed	0,80	0,95	0,76
- general	0,80	0,85	0,68
High alloyed aluminium (unsorted)			
- clean and undyed	0,70	0,95	0,67
- general	0,70	0,85	0,60
High alloyed aluminium (sorted by type of alloy)			
- clean and undyed	0,80	0,95	0,76
- general	0,80	0,85	0,68
Casted aluminium			
- old/used product	0,75	0,90	0,68
- new process scrap	0,75	0,94	0,71
- originally non/low/ high alloyed Al classified as casted Al due to its chemical composition	0,75	0,85	0,64
Chips - bricletes	0,50	0,87	0,44

The Case Study

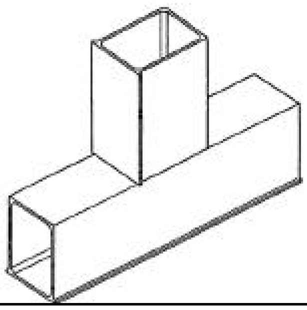
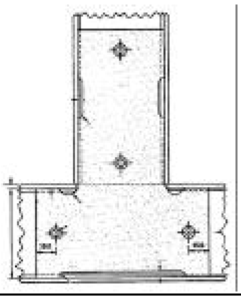
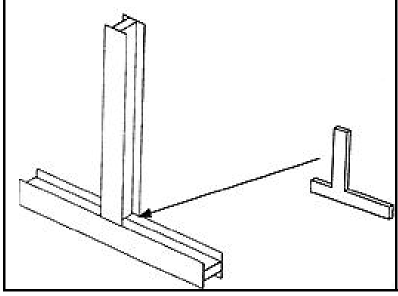
Three different T-joints were studied. T-joints are typical structure elements in space frames that are used in e.g. the automotive industry. The aluminium profiles used in the study were all constructed to sustain a specific minimum load.

The objective of the case study was to study if the choice of jointing method would affect the recyclability of the aluminium. The aluminium profiles used are classified as low alloyed aluminium and are dominating the total weights of the T-joints. To affect the recyclability, the T-joints must in this case therefore be classified to a lower R-class according to the VARM-model.

Recyclability of T-joints in different designs

The joining methods studied were MIG-welding, rivets, and screws as shown in table 4. The aluminium profiles and plates, which are classed as low alloyed, used for the T-joints represent over 90 % of the weight of the joints. Therefore, to affect the recyclability of the aluminium negatively, the T-joints must be classified to a lower R-class than low alloyed aluminium.

Table 4: *Description and results of the case study where the VARM model has been used.*

T-joint	**Description**	**Results**
MIG-welded 	A MIG-electrode of aluminium (AlSi12) was used to join the two profiles. Since a welded joint is difficult to disassembly, the whole T-joint is assumed to be remelted at recycling.	For the MIG-welded T-joint, the electrode adds such a small amount of alloys, to the chemical composition of the T-joint, that it does not affect the recyclability at all. A MIG-welded T-joint of aluminium can therefore be given the same recycling value as the aluminium profiles used, since it is classified as low alloyed aluminium, see figure 2.
Screws 	To joint the profiles with screws, two plates were needed, see figure 2. The same aluminium alloy was used for the plates as for the profiles. The profiles were jointed with 8 screws made of steel.	When the entire T-joint is remelted at recycling, the steel screws will increase the iron content. To be classified as low alloyed aluminium, 85 % of the screws need to be removed at the disassembly, see figure 2.
Rivets 	To join the profiles with rivets, four L-shaped plates were used. The same aluminium alloy was used for the plates as for the profiles. The profiles were joined with 16 rivets made of steel.	When the entire T-joint is remelted at recycling, the steel rivets will increase the iron content. To be classified as low alloyed aluminium, 50 % of the rivets need to be removed at the disassembly, see figure 2.

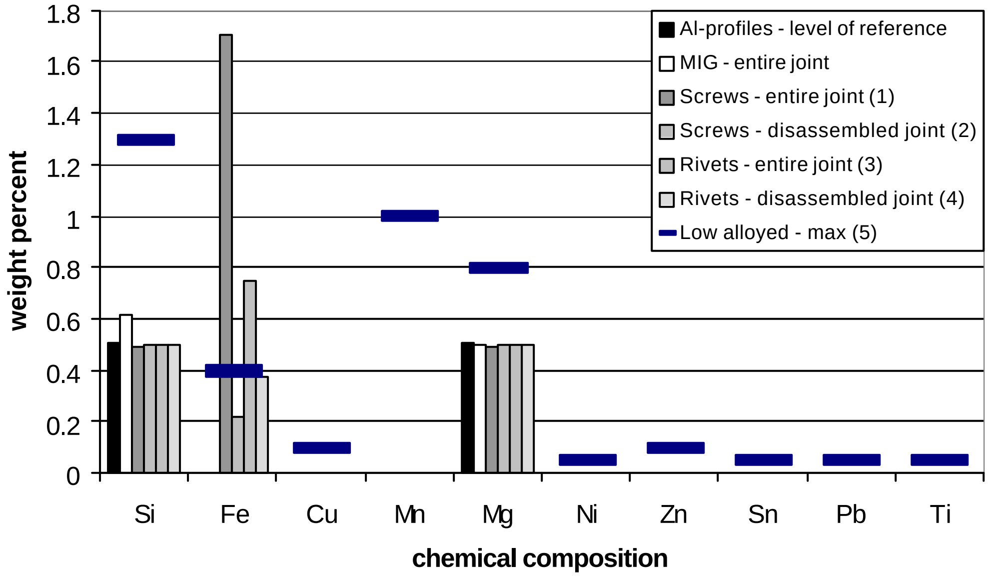


Figure 2: *Comparison between the chemical composition of the different T-joints and the aluminium profiles used.*
(1) When the entire joint with screws is remelted, the maximum tolerance level for iron is exceeded by more than four times. (2) To classify the joint as low alloyed, over 85 % of the screws need to be removed at the disassembly.(3) When the entire joint with rivets is remelted, the maximum tolerance level for iron is exceeded by 1.9 times. (4) To classify the joint as low alloyed, over 50 % of the screws need to be removed at the disassembly. (5) The maximum tolerance level of the chemical composition of low alloyed aluminium.

Both joining with screws and joining with rivets shows that steel screws/steel rivets affects the recyclability of the T-joint negatively, see figure 2. This is due to that the classification is sensitive to the iron content.

The result of this case study shows that it is important to think about the disassembly of products from the recycling point of view. The smaller product the more important the choice of joining method becomes, since the recyclability is strongly related to the weight percent of metallic material. Iron is a problem for the aluminium recycling industry, since it is present in the technosphere in large amounts and therefore easily slips with the material flows of aluminium e.g. as bolts. There is no demand for alloys with a high content of iron, since the presence of iron makes the aluminium harder and more difficult to work with. To lower the iron content in the furnace you need to mix it with non or low alloyed aluminium.

Results and vision

The case study shows that the VARM model is suitable for aluminium. It can be assumed that the same kinds of results can merge from studies with other metals. The properties of metals are well known and how their properties change with the mixing with different alloys are also well known. Furthermore, there is a well-established and commercial second hand market for metals. The extensive knowledge of metals makes it possible to divide them into different recycling classes that depend on the alloy content.

One advantage of the VARM model is that it can separate the recycling potential of different aluminium products. Another advantage is that it can be used together with any characterisation and valuation method. The recycling value can be adjusted to changes in price of e.g. the recycling class and/or better technology for recycling. ISO 14 041 supports the economic allocation procedure, which is applied in the model.

By dividing the material into different classes the model gives the designer an incentive to design recyclable products, but to some extent the model also gives incentive to use recycled material.

A further development of the VARM model would be to adapt it for other metals than aluminium, but also for other materials. When it comes to other materials, the model is preferably suitable for material with a well established and commercial second hand market. This includes degradable materials, such as e.g. paper, as well. Decisions during the design process, regarding the recyclability and environmental load of products, can be done more easily with the information from the VARM model.

References

Ekvall, T., *System Expansion and Allocation in Life Cycle Assessment, with Implications for Wastepaper Management*, PhD dissertation, Chalmers University of Technology, Göteborg, Sweden, 1999.

Gotthard Aluminium, *Skrotboken*, Internal guidance for classification of recyclable aluminium, Gotthard Aluminium AB, Älmhult, Sweden, 1997

ISO 14 041, *Environmental management – Life cycle assessment – Goal and scope definition and inventory analysis (ISO 14041:1998)*, International Organisation for Standardisation, 1998

Karlsson R, *Recycling in Life Cycle Assessments*, Licentiate thesis, Technical Environmental Planning, Chalmers University of Technology, report 1995:6, Göteborg, 1995

Rydberg, T., *Cascade accounting in Life Cycle Assessment applied to Polymer Recycling*, *Polymer Recycling,* Vol 1(4), pp. 1-9, 1995a.

Rydberg, T., Cleaner products in the Nordic Countries based on the Life Cycle Assessment approach - the Product Ecology Project and the Nordic Project for Sustainable Product Development, *J. Cleaner Prod.*, Vol 3, pp. 101-105, 1995b.

Ryding S-O., Ekvall T., Karlsson I., Karlsson R., Nevén C-O., Tillman A-M, Steen B., Westerlund G., *Miljöanpassad produktutveckling*, pp 504-505, Industriförbundet, Förlags AB Industrilitteratur, 1995

Ryding, S.-O., B. Steen, A. Wenblad and R. Karlsson, '*The EPS system - a life cycle assessment approach for cleaner technology and product development strategies, and design for the environment*', paper presented at The EPA Workshop on Identifying a framework for Human Health and Environmental Risk Ranking, Washington DC, June 30 - July 1, 1993.

Steen, B., CPM Report 1999:5, *A Systematic Approach to Environmental Priority Strategies in Product Development (EPS), Version 2000 - Models and data of the default method*, 1999.

Strömberg, K., *Valuation of Aluminium in the Recycling system – Method development -Modelling - Software development*, Master Thesis (report written in Swedish), Department of Experimental Physics, Chalmers University of Technology, Göteborg University, Göteborg, Sweden, 2000

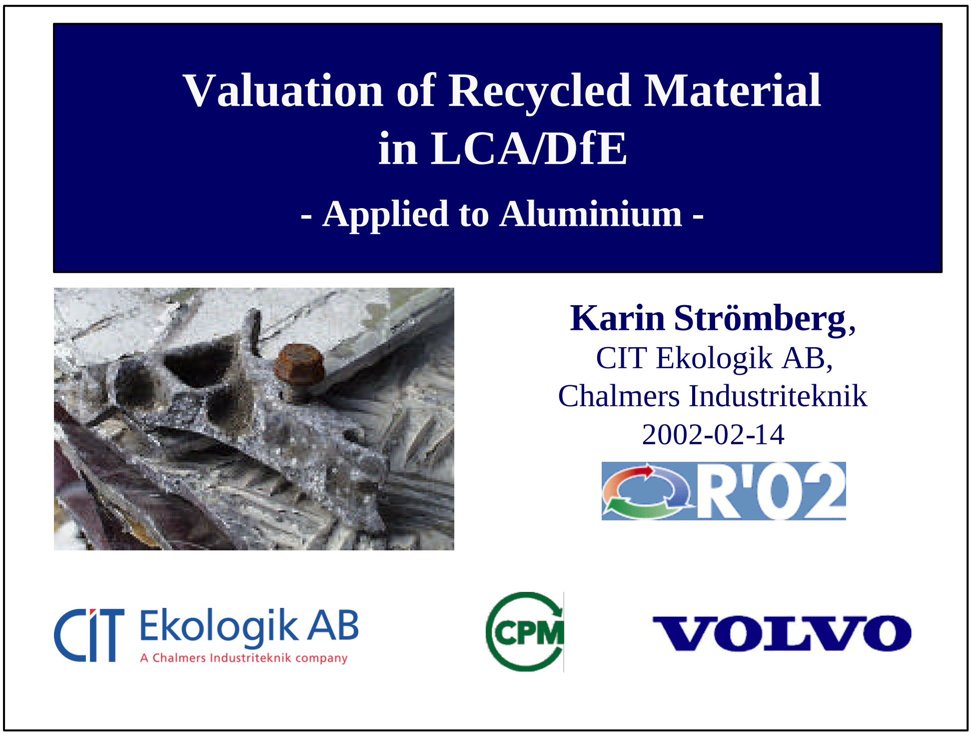
Personal Contacts

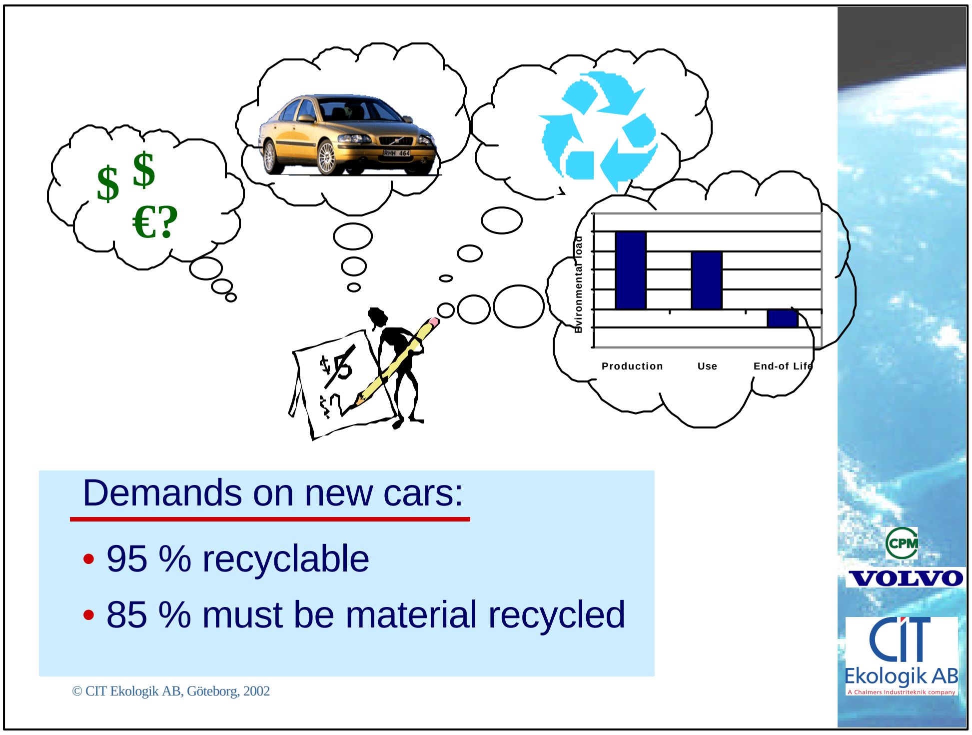
Clevesson Örjan, 1999; Sapa Recycling, Finspång, Sweden

Karlsson Ricky, 1999; Gotthard Aluminium, Älmhult, Sweden

Knutsson Lage, 1999; Sapa Technology, Finspång, Sweden

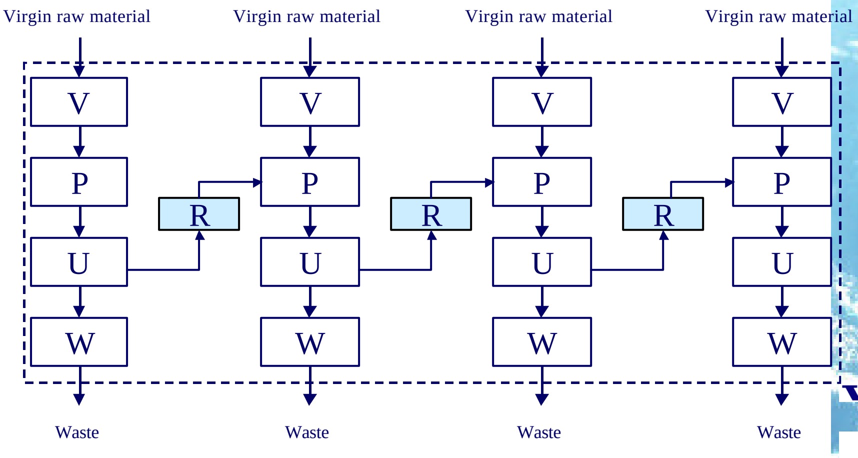
Bilaga 2: VARM-modellen: presentation





Product systems analysis

Open-loop recycling

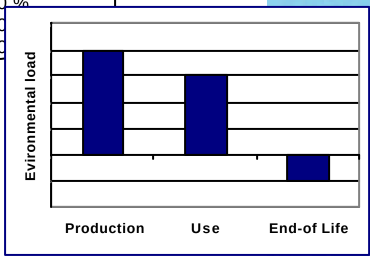


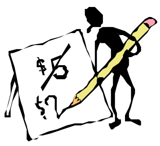
Credit factors

Example

Material Group	Material Recycling - production scrap -	Material Recycling - end of life -
Precious metals	99 %	98 %
Other metals	90 %	80 %
Glass	90 %	80
Thermoplastics	80 %	50
Other plastics	30 %	

- Rough grouping of materials
- Alloy content or impurities are not taken into account
- Limited usability in complex designs



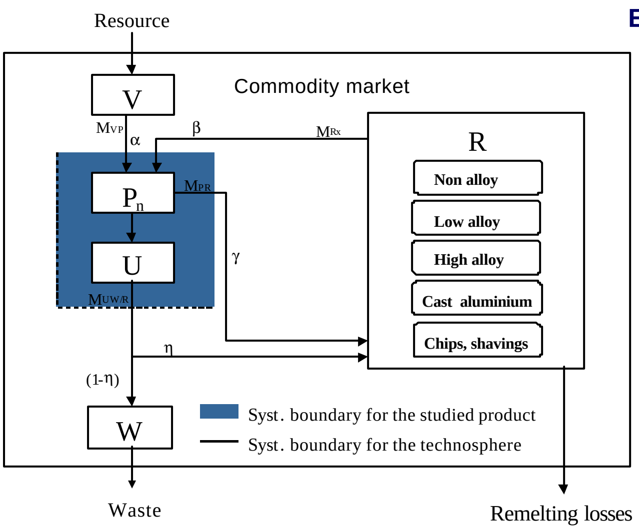


The VARM-model

Valuation of **R**ecycled **M**aterial

- **Material pools**
  - Separates product systems in an open loop
  - Pool for virgin material, pool for recycled material
- **Economic allocation**
  - Follows the LME-index
  - The economic value of the material measures the recyclability
  - Follows changes in supply and demand
  - Supported by ISO 14041
- **Accounts for:**
  - The properties/chemical composition of the material
  - The purity of the material and the efficiency of the recycling process
- **Simulates realistic recycling process**

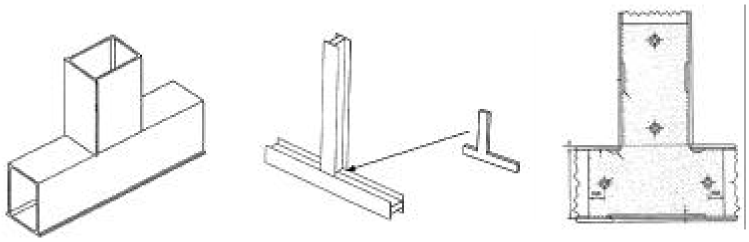
VARM: applied to Aluminium



Economic allocation

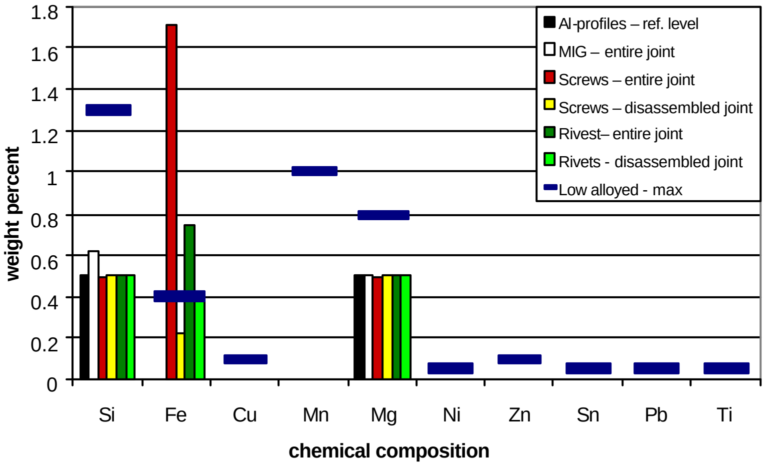
Case study

Does the choice of joint affect the recyclability?



MIG-welding	Rivets	Screws
AlSi12 MIG-electrode	16 steel rivets	8 steel screws
	4 Al plates	2 Al plates

Case study: Results



Result and vision

- Separates different aluminium products
- Economic allocation is recommended by ISO 14041
- The modell is suited for metallic materials
- The VARM-model can be used as a design tool in product development
- Further development:
  – Other metalls and materials