Including the product-specific recyclability into the environmental assessment with Environmental Product Declarations (EPDs)

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Abstract (Heading)

This methodological paper addresses shortcomings of actual practise in considering recyclability of products in environmental assessment. Most environmental assessment tools consider recycling in terms of a material-specific input ratio of recycled material. This view is not able to account for all relevant environmental pressures in a product-specific way and therefore does not discriminate between good and poor recyclability.

In order to include product-specific recyclability into the assessment, a Swiss eco-label was analysed focusing on construction parts containing aluminium. The system-boundaries were extended by a value corrected substitution of primary materials. The recycling potential of each individual aluminium part was determined and the Cumulative Energy Demand (CED) was computed.

The results indicate an improved rating for components that are recovered in large amounts with a high material quality.

If EPDs are to be used for comparing different products, they need to base on a consistent product-specific modelling, including the product-specific recyclability.

Keywords

Building materials, Environmental Product Declarations (EPD), Cumulative Energy Demand (CED), Value Corrected Substitution, Recycling.

1 Introduction

Recycling activities in Switzerland are mainly motivated with arguments of environmental sound behaviour and great efforts have been undertaken to raise the collection rate and recycling of End-Of-Life (EOL) products. However, the recycling rate is not only determined by the consumer but to a large extent by the design of the product and the materials deployed. When assessing the environmental performance of a product to be designed, the assessment methods – rules and concepts – indicate the direction where the journey towards sustainability should go. The methods applied translate the object under study into an abstract representation in the form of a model that can be valued. This valuation step has to reflect the values underlying the idea behind the assessment. The values themselves are manifest in policies, whereas the methods are subject to the state of the art that is at best agreed on in international standards (Werner, 2002a).

2 Recycling and the Policy Framework

Regarding the policy framework, the 6th Environmental Action Plan (European Communities, 2002) with the relating Thematic strategies on sustainable use of natural resources COM(2005) 670, the prevention and recycling of waste COM(2005) 666 and Urban Environment COM(2005) 718 together with the overarching IPP toolbox (COM (2001) 68) can be considered as guiding documents. This policy framework gives clear indications for the underlying values and thereof derived actions. Recycling is recognised as major approach to reduce the relevant environmental pressures. The pressures have to be assessed from a life-cycle perspective, whereas the assessment results are to be taken up in the information of the market participants and enable voluntary actions assisted by tools such as Environmental Product Declarations.

3 Recycling and Environmental Pressures

Recycling of materials contained in EOL-products play a crucial role, since this activity influences a multitude of drivers responsible for environmental pressures.

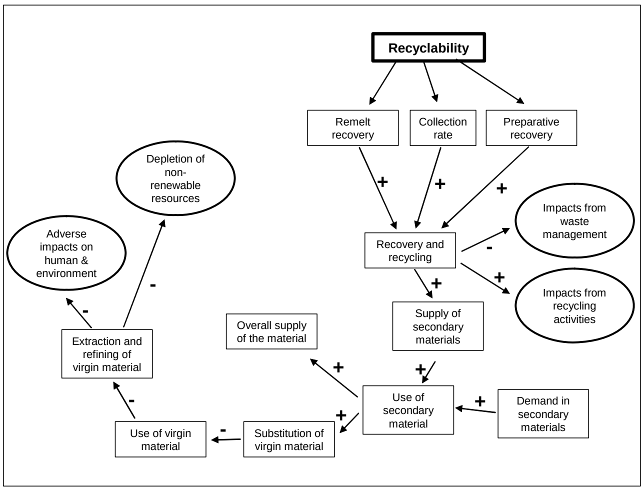

Figure 1 Interrelations of the recyclability of a product with the relevant environmental pressures. The ease for technical recovery and also the available market for secondary materials play a key role.

Figure 1 shows a causal chain how pressures are linked to product-specific recyclability. A fair recyclability assured will lower the efforts to recover the materials in terms of costs and of related impact, whereas the main impacts are of indirect nature by avoiding primary production. Therefore EPDs have to reflect the product's recyclability in order to succeed in implementing the policies claims.

4 Recycling in Environmental Assessment Tools

Most impact indicators base on Life Cycle Inventory (LCI)-data, be it as physical flows (e.g. kg SO_2), characterised flows (e.g. CO_2-eq) or aggregated endpoints of valuations (e.g. Eco-indicator points). The representation of recycling in the LCI-model becomes an issue for allocation because of the multiple functionality of product reuse (Werner, 2002b). First, the recycling is bi-functional in the way that it represents both waste treatment and secondary material production. Second, the production chain has to be considered as joint processes with subsequent functions that are shared by more than one product system (ISO/EN14041:1998, chap. 6.5.4) and consequently have to be allocated to the different product systems. This "open-loop" recycling is the case for goods whose constituents are recycled into other products than the EOL-good itself.

4.1 Open-loop allocation in ISO/EN

The situation of "open-loop" recycling has been specially treated within the international standards. ISO/EN14041:1998 and ISO/TR14049:2000 regulate this issue with a series of rules. Generally allocation has to be based on causal relationships and wherever possible have to be avoided by system expansion or subdivision of unit-processes. For the "open-loop" recycling situation LCI-modelling knows a set of different approaches to solve the allocation problem, see e.g. Ekvall (2001, 2004), Azapagic (1999) and Weidema (2001).

The **"closed-loop"** situation refers to a recycling of material within the product system itself to replace virgin material directly, i.e. it addresses rather a re-use. In reality the assumption of a complete substitution is not valid since most recycling processes change some inherent qualities of the material. As pointed out by Fletcher (1996) increased recycling does not necessarily mean that the market will absorb the surplus.

The most prevalent perception of how to reflect "open-loop" recycling is the **"cut-off"-**procedure relating to the "sunk-effects" concept that is inspired by economic theory of sunk cost (Frischknecht, 1998). As shown in Figure 2a the material in the product under consideration is considered as a blend of recycled (secondary) and virgin (primary) material, reflecting the global or regional split. The material leaves the system burden free, the subsequent recycling is accounted at the cost of the next (hypothetical) product system. This approach therefore is only sensitive at material-level but not on product-level, i.e. it does not discriminate between applications of the material in products that are fair recyclable and others that aren't. Aluminium as a foil – for example a vapour barrier – is modelled in the same way as Aluminium in a massive façade.

This shortcoming can be addressed by the modelling approach of **"value corrected substitution"**, which is based on the concept of material pools as conceptualised in ISO/TR14049:2000. Virgin material is substituted by recovered material in exchange with a hypothetical global material pool. A value correction (see Figure 2b) reflects the possible degree of constrained applicability of the recycled material compared to the virgin one, corresponding to the different economic values of secondary and primary materials of different qualities (Werner 1999, Werner, 2000 and Werner, 2003). This LCI-model considers product-specific recycling rates and is able to discriminate between good and poor recyclability of a material in a specific product.

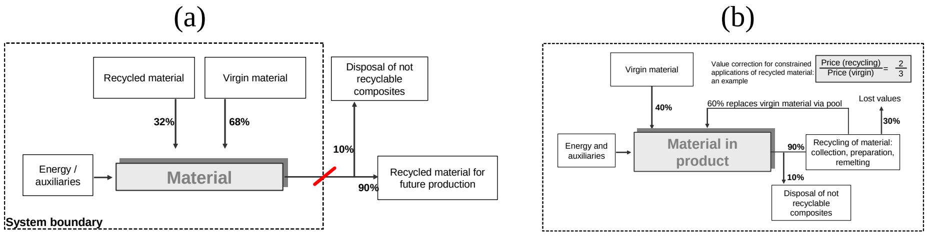

Figure 2 Representation of the (a) “cut-off” situation and (b) “value corrected substitution. (a) For the production a material specific blend of virgin and recycled material is assumed. Additional functions like the recycling leave the system burden free. (b) Value corrected substitution of virgin material via a hypothetical material pool. Depending on the price-ratio of the virgin and recycled material a part of the value of the recycled material is lost to reflect the constrained field of applications.

4.2 Open-Loop Recycling of metals in EPDs

According to the standards (ISO/EN14020:2000 and ISO/TR14025:2000) EPDs publish performance indicators that base on LCI-Data as defined in ISO/EN14041:1998. The standards do not prescribe specific allocation procedures. They are to be described within “product category rules” (PCR). The Swedish Environmental Management Council (MSR, 1999) recommends a “cut-off” approach.

4.2.1 PCR Steel – MSR, Sweden

The Swedish Environmental Management Council (MSR) issues a number of PCRs. In the considered PCRs for Steel products (MSR, 2002) and building products (MSR, 2006) the rules prescribe a “cut-off” at the system boundaries according to the willingness to pay principle. This may lead to a somewhat different boundaries than in Figure 5a including some additional preparation and transport processes to the point where the recycled fractions may be sold.

4.2.2 PCR Baumetalle – AUB, Germany

The “Arbeitsgemeinschaft Umweltverträgliches Bauprodukt E.V. (AUB)” issues PCRs for construction materials. One deals specifically with metals used in construction work (AUB, 2004). In this PCR the recyclability of the material is considered by complementing the basic indicators with a negative “recycling potential”. The basic indicators are modelled in a “cut-off” approach. The recycling potential is the avoided future production of virgin material that can be substituted with the secondary material from the product. This approach allows in principle a product-specific view but at the cost of a bipartite indicator.

5 The Swiss eco-label eco-devis

The Swiss labelling system eco-devis (Vogel, 2003) rates construction materials based on different criteria, the most important being "Graue Energie" according to Kasser (1999), i.e. the sum of the Cumulative Energy Demand (CED) of non-renewable primary energy and hydropower. The indicator “Graue Energie” used in eco-devis is calculated based on a LCI-model with “cut-off” allocation. The indicator does not account for pressures from resource depletion, toxic effects and land degradation. Furthermore the product-specific recyclability is not reflected due to the “cut-off” approach resulting in the impossibility of eco-devis to reward enhanced product recyclability. In this way the scheme gives little emphasis to recycling. These conditions affect especially the assessment of metals as Aluminium, for which the primary production is very energy consuming but the products are easily recyclable. Therefore the valuation scheme was expanded methodically in Classen (2004) and applied to construction parts made from Aluminium to study the differences in the valuation.

5.1 Adaptation of the “eco-invent” LCI-model

To achieve this, the model was expanded by a Value Corrected Substitution of the virgin Aluminium. An explicit modelling of the whole product’s lifecycles was needed, which has been done with a parameterised LCI-model. The parameters determine the product specific recycling process. The recovery rate corresponds to the resource orientated recycling quota RQ_r according to Quinkertz (2002). The recycling process has been diversified after Wolf (2000) into the sub-processes collection, scrap preparation and remelting (Figure 3).

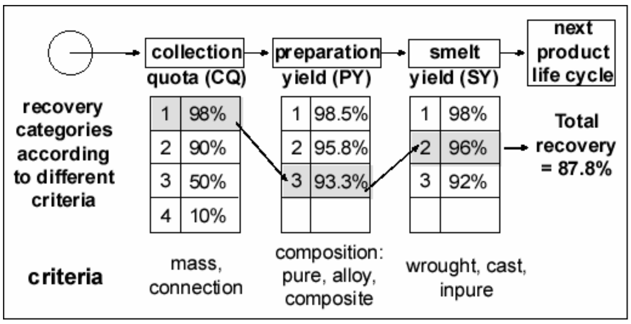

Figure 3 Method used to assess the product-specific recycling quota for construction parts that are made from Aluminium.

The resource orientated recycling quota (RQ_r) equals the product of collection quota (CQ) and the technical recycling quota (RQ_t) which again is the product of preparation yield (PY) and effective smelting yield (SY) including salt slag and dross recovery (Equation 1).

$$RQ_r = CQ * RQ_t = CQ * PY * SY \qquad (1)$$

RQ_r = resource orientated recycling quota
CQ = collection quota
RQ_t = technical recycling quota
PY = preparation yield
SY = smelting yield

The assessment of each parameter has been conduced depending on product specific material properties that influence the recovery quota, metallurgical composition, format, impurities as proposed in Gerke (1999) and mass as found in Boin (2004) and Rubli (2004).

The collection quota (CQ) is defined as the extent to which the material is recovered, the rest being disposed of to be lost in the waste incineration or to landfill. The mass of the part was indicated by Boin (2004) and Rubli (2004) to be the property determining collection. Another important factor is the degree of how the part is attached to the building.

The estimate of the preparation yield (PY) bases partly on literature (Gerke, 1999, Rubli, 2004) and on evaluations of a Swiss recycler. Material composition and purity influence fractionation efficiency. The metal losses occur during scrap-handling and shredding during the fractionation step and in the flotation step.

The smelting yield (SY) is chiefly determined by the technology used. Aluminium contaminated with organic material has to be processed in reverberatory furnaces with the lowest yield (Rombach, 2002, Werner, 2003). Clean and pure material can be processed in induction furnaces with high smelting yield (EAA, 2000). Average smelting processes are assumed to yield 96% recovery. Small cast products and thin parts are subject to enhanced losses (Gerke, 1999).

According to Werner (2003) the degree of the value correction can be expressed by the ratio of the contracts for unalloyed primary and alloyed (secondary) aluminium traded at London Metal Exchange (LME). A statistical analysis indicates a stable long-term ratio of 0.9 between the quotations of the two

Aluminium commodities. For parts like wrought façade tiles which accrue in highest quality in terms of being low alloyed (1xxx series), cleanness and quantity no correction has been applied, as such parts can replace virgin aluminium directly.

5.2 Results

The mass of aluminium element mainly determines the overall degree of recovery RQ_r. The bigger the element, the better is the collection recovery and the recycling potential (Figure 4a). Smaller elements are more easily lost during the recycling process and occur often in a mixed fraction with an additionally smaller total recovery. The modelling approach leads to a substantial reduction of "Graue Energie" (GE) score for those parts with a high recycling potential (Figure 4b). For parts with low or no recycling potential the result is not significantly altered compared to the original assessment in eco-devis.

(a) (b)

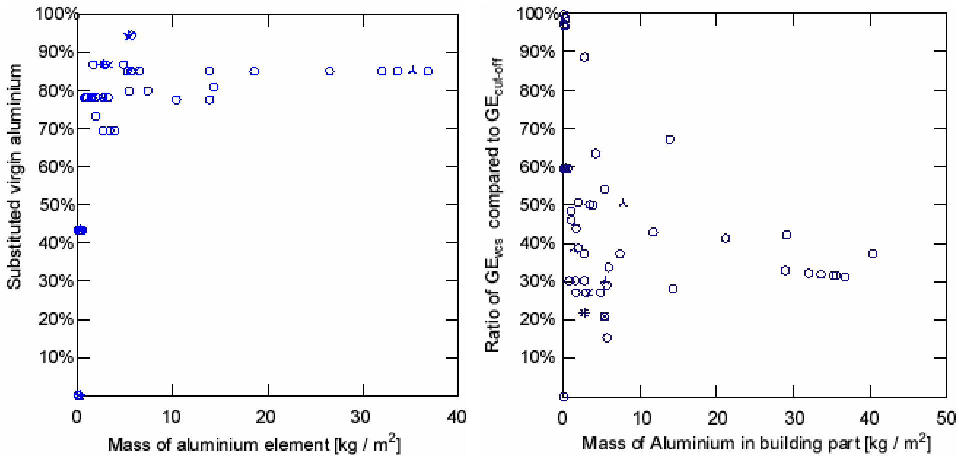

Figure 4 Results showing the influence of the mass of the construction part on the overall results of (a) substitution and (b) the indicator “Graue Energie”. Small parts are merely not collected and lost. Overlaying data points are represented with a symbol with more strokes (cross, star, etc.).

6 Conclusions

The work shows that the value corrected substitution in combination with a parameterised LCI-model is suitable to include the recycling potential of construction parts from Aluminium into the scope of the valuation. It is able to give incentives towards a Design for Recycling that is supported by the implications derived from societal values. The Author recognises in this approach a more suitable way to achieve the aims imposed by the European

Policy than the “cut-off” or “closed-loop” approach implemented by various EPDs. The application of a value corrected substitution should be examined for the products made of metals.

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Materials Science & Technology

Including the product-specific recyclability into the environmental assessment with Environmental Product Declarations (EPDs)

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Overview

- **Recyclability matters!**
  - The policy context of product recycling
  - Influence of recyclability on the valuation
- **How conventional schemes fail**
  - Material specific view: cut-off, recycling input rate
  - Incomplete assertions
- **How recyclability can be included**
  - Value corrected substitution
  - Parameterised LCIs for product-specific view

Policy context of Recycling: 6th EAP

- 2002: 6th European Environmental Action Plan (EAP)
- Resource efficiency and resource/waste management recognised as major aim to reduce environmental impacts
- “encouraging re-use and (...) preference should be given to recovery and especially to recycling” (Art. 8)
- Waste prevention inter alia by
  - encouraging ecologically sound and sustainable product design
  - the formulation of operational measures to stimulate re-use and recovery
- Initiate thematic strategies

Policy context of Recycling: Strategies

- Thematic strategies on
  - Sustainable use of Natural Resources *COM(2005) 670*
  - the Prevention and Recycling of Waste *COM(2005) 666*
  - Urban Environment *COM(2005) 718*

- “Maintaining the resource base” (strategic)
- Long-term goal „recycling society“
- „Impacts minimised throughout whole life cycle“
- „New ways to foster recycling: Producer responsability?“

Policy context of Recycling: Implementation

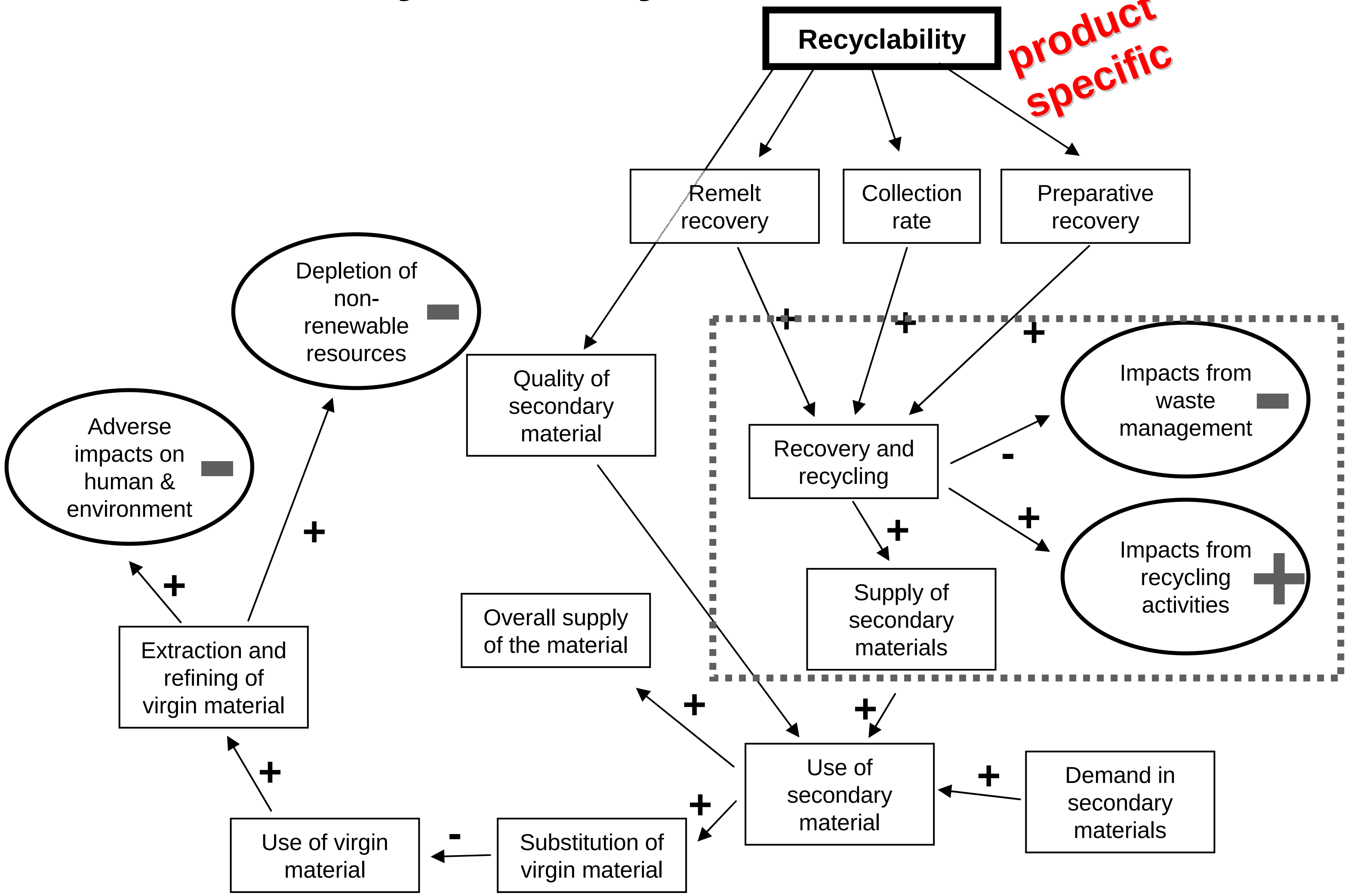
- Application through existing and emerging policies
  - Overarching IPP toolbox *COM (2001) 68*
  - Voluntary initiatives to ensure efficiency

→ Environmental Product Declarations (LCI-based)

→ Harmonised valuation Framework
(PCR, CEN/TC 350)

→ Encouraging Recyclability

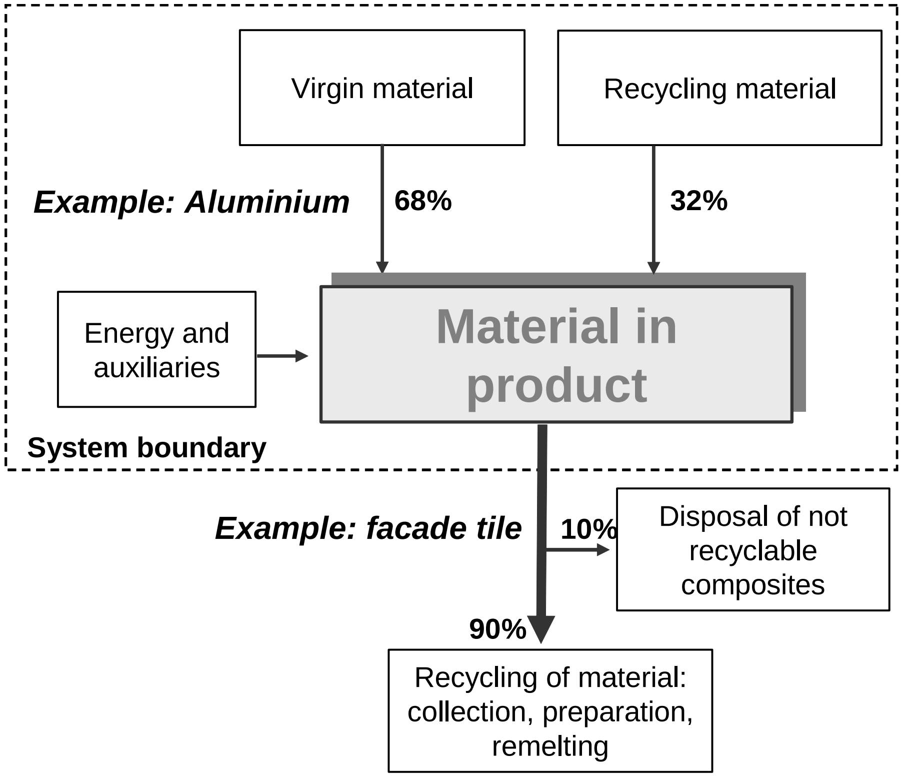
The role of recyclability in valuation



Recyclability matters!

- Material recovery is a cornerstone in environmental policy
- Recyclability reduce environmental impacts chiefly by preventing additional virgin production
- Recyclability is determined by product design.
- Recycling objectives are to be implemented with voluntary initiatives, such as EPDs

Conventional schemes: “cut-off” with RIR



- Recycling Input Rate (RIR): material specific blend of recycling / virgin material
- End of life product leaves without burden

Not the whole picture

- **Facade-tile 10 kg**
- **loose**
- Wrought alloy
  - Collection ~100%
  - Preparation 98.5%
  - Re-melting 98%
- CED = 1800 MJ / part *
- Total recovery ~90%

- **Facade-tile 10 kg**
- **<u>fix riveted</u>**
- Wrought alloy
  - Collection <u>~50%</u>
  - Preparation 98.5%
  - Re-melting 98%
- CED = 1800 MJ / part *
- Total recovery ~45%

* **aluminium, production mix, wrought alloy, at plant (RER), ecoinvent v1.1**

→ Same CED, but different recycling potential

→ No incentive to use better recyclable part

Shortcomings of RIR on product decisions

- Two aspects for decision:
  Recycling vs. valuation score
- RIR is material specific → No product specific view to support product specific decision.
- Use with EPDs: no incentives for better recyclable products
- Not the direction intended by European policy

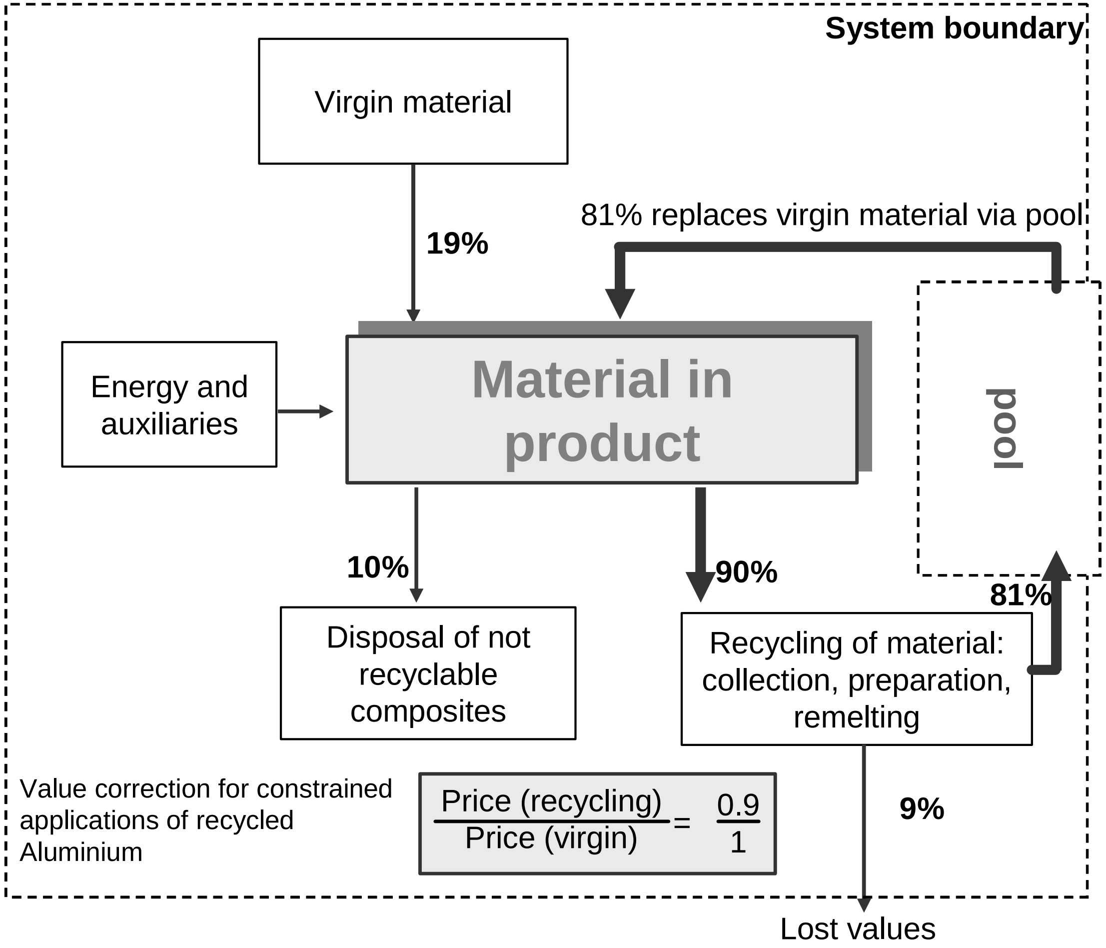
How recyclability can be included

- Inclusion of product specific recyclability within the inventory model.
  - Value Corrected Substitution
  - Parameterised Model

- Mental model is able to reflect product specific recyclability

- Extension of a Swiss Eco-Label for Construction Parts from Aluminium

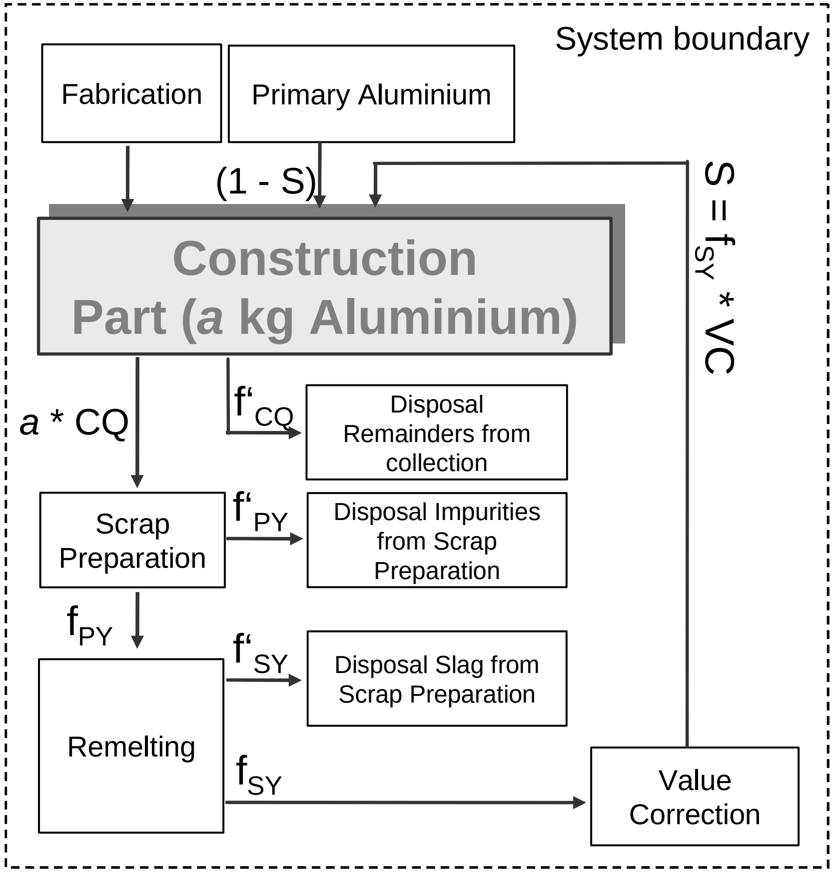
Value Corrected Substitution* of Aluminium



- End of Life material replaces virgin material
- Exchange over a metal value pool
- Value correction of recycled material (price)
- Lost metal values have to be recharged with virgin material

* Werner F (2005): Ambiguities in Decision-oriented Life Cycle Inventories. The Role of Mental Models and Values. Eco-Efficiency in Industry and Science, 17, Hardcover, Springer Verlag.

Parameterised Inventory Model



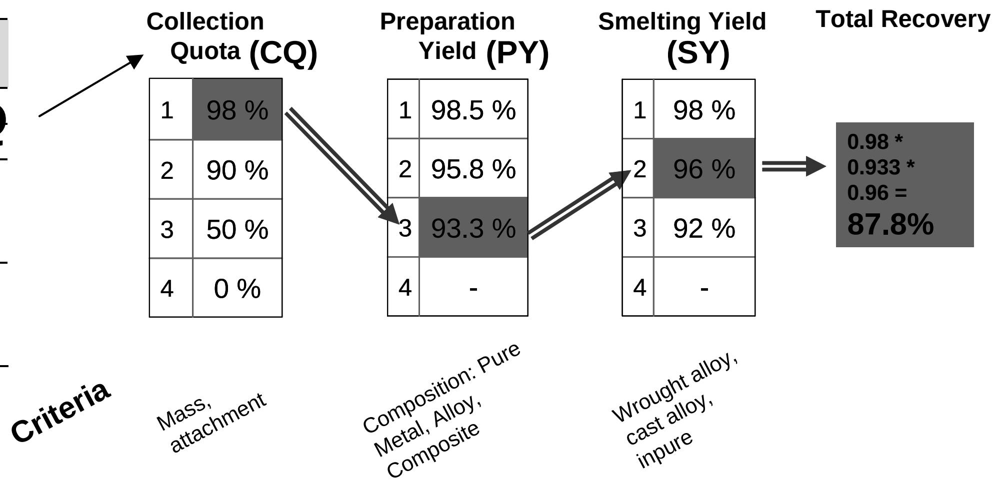
- Each construction part has individual set of parameters
- System reflects actual market structures
- CQ = Collection Quota
- PY = Preparation Yield
- SY = Smelting Yield
- VC = Value Correction

Parameterised Inventory Model

- Parameters are classified with product specific characteristics: Mass, Composition, Alloy type
- Characteristics easily visible and describable.
- A value is <u>assigned</u> to each class

Product characteristics:	Collection quota
1 big (over 5 kg per m^2)	98 %
2 considerable (over 0.5 kg per m^2)	90 %
3 small and loose (under 0.5 kg per m^2 and loosely attached to the building)	50 %
4 small and fixed (under 0.5 kg per m^2 and tightly attached to the building, glued, riveted, etc.)	0 %

CQ



Outlook

- Value corrected substitution is a viable option for EPDs (product specific, single score)
- Parameterised models may be negotiated by stakeholders for materials (i.e. Associations)
- EPDs for comparative assertions
  → same models for other (compared) products
- Harmonisation of generic LCI-Data AND LCI models within PCR!

Thank you!

Questions?

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