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THE INFLUENCE OF ALTERNATIVE RECYCLING PROCESSES ON EMPLOYEE NUMBERS

M. Ćorić, N. Lommatzsch, H. Kloberdanz and H. Birkhofer

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1. Introduction

The development of sustainable products requires equal implementation of economic, ecological and social goals. Commonly, the achievement of these goals is hindered by contradictions and ambivalence. One way to improve products at an ecological level is to optimize resource consumption during material production. A measure of this strategy is to increase the amount of secondary resources during production [Albas et al. 2008]. Optimization of resource usage has effects on the other two dimensions of sustainability. Aside from reducing negative ecological impacts, the efficient use of resources promises competitive advantages and the enhancement of company image. Additionally, optimized resource use results in higher job security, which leads to strengthening of the overall economic and social situation [Arthur D. Little GmbH et al. 2005], [Westkämper et al. 2010].
During production of metal products, for example, car body parts, as much as 50 % of the material becomes offcuts [Maurer et al. 2001], [Vollmer et al. 2009]. Generally, these offcuts are melted down to produce new parts [Wells et al. 2005], [Klug 2010], [Achatz 2012]. This method of offcut recycling consumes a lot of energy. The offcut recycling process by master shaping processes is questionable, because the offcuts are pure substances with properties that are barely changed compared to the raw workpiece. Analysis of the ecologic impact of different recycling processes with the ReCiPe Method, which was created by the Institute of Environmental Sciences (Rijksinstituut voor Volksgezondheid en Milieu) at Leiden University, PRé Consultants and Radboud Universiteit Nijmegen for Life Cycle Impact Assessment, has proven the ecologic advantages of using offcuts as wrought material. For example, producing 1 kg of technical washers from offcuts had an 80 % lower ecological impact than the same amount made from primary wrought material.
Using offcuts for ecological optimization of sheet metal products will have an impact on economic and social dimensions as well. Rerouting the offcuts as a mass flow from the iron works to the production industry will have inevitable effects on the stakeholders in the value chain. It changes the input and therefore the mass flow of stakeholders, which affects the number of employees. The preservation of jobs and permanent employment are a criteria for social sustainability [Hanusch 2011]. The influence of the fluctuating mass flow on the number of employees can be seen in the introduction of container deposit legislation in Germany in 2003. The legislative authority had economic and ecologic goals in introducing this measure. Through the harmonization of packaging and packaging waste management, trade barriers and anti-competitive practices within the EU should have been eliminated [Directive 94/62/EC]. The aim of introducing a deposit was to motivate consumers to reduce waste by promoting the use of reusable packaging. Additionally, a return system for disposable single-use containers was established.
The mass flow of disposable single-use containers for drinks was diverted from general waste towards direct material utilization, resulting in workers being made redundant due to a lower mass flow in

municipal waste removal and the recycling industry [Lehrke 2013]. Enforced redundancy also occurred in other areas of the value chain. Bottlers, producers and distributors of disposable single-use beverage containers experienced a drop in orders [Mitteldeutsches Druck- und Verlagshaus GmbH & Co. KG 2003]. The effect of the introduction on the industry of processed sorted material flow for the production of PET flakes has not been researched. However, increasing mass flow and direct labour can be expected.
This example illustrates that optimization of one dimension of sustainability affects the other two dimensions. Therefore, recycling of metal offcuts, without melting, changes the material flow of other stakeholders in the value chain.
This paper highlights opportunities to recycle metal offcuts without primary shaping processes. Starting with these recycling processes, a basic model to illustrate the relation between mass flows and the number of employees within a value chain is described. The effects of implementation of the described recycling processes on the number of employees are discussed. To make a decision for or against implementation of alternative recycling processes for holistic sustainability the method makes it possible to estimate the impact of changed mass flows on the number of employees as a cost driver during manufacturing and as an indicator of the social dimension of sustainability as well.

2. Foundations

In the following, the basis for understanding the proposed processes for alternative recycling of metal offcuts and their interdependencies are discussed. Waste legislation need to be considered. The applicable processes are dependent on the offcut properties induced during the production process and are also influenced and anticipated by the designer. The motivation for developing a new model for quantifying the influences of different recycling processes will be elaborated.

2.1 Waste legislation of offcut recycling

The European Waste Framework Directive 2008/98/EG contains measures to protect the environment and human health, by preventing or reducing the adverse impacts of the current generation and from the management of waste, and by reducing the overall impact of resource use and improving the efficiency of resource use [Directive 2008/98/EC]. Explicitly, § 4 KRWG (Act for promoting closed cycle substance waste management and ensuring environmentally compatible waste disposal) defines waste and by-products separately; a substance needs to fulfil four requirements to be considered a by-product of a production process [BT-Drs 17/6052], [Directive 2008/98/EC]:

1. further use of the substance or object is certain
2. the substance or object can be used directly without any further processing other than normal industrial practice
3. the substance or object is produced as an integral part of a production process
4. further use is lawful, i.e. the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.

Guaranteeing further use requires a positive prognosis of the by-product's planned use [BT-Drs 17/6052 2011]; a market with positive prices for the by-product is necessary.
Criteria 2, further processing, is fulfilled if normal industrial practice is comparable to common processing of primary products [BT-Drs 17/6052 2011] however primary products or common industrial practice is not defined. Instead, common industrial practice is differentiated from typical recycling processes. In the context of offcut recycling, a typical recycling process is melting. The requirement that the substance and object is an integral and therefore inevitable part of the production process ensures preparation and later use [BT-Drs 17/6052 2011]. Lastly, the use has to be lawful. According to § 7 para. 3 KrWG, the use has to be orderly and harmless [BT-Drs 17/6052 2011] by fulfilling protective standards for product, ecology and health rights. As a result, quality management during by-product production is necessary.
If the four requirements listed above are fulfilled and verified, the offcut counts as a by-product and waste law is no longer applicable. Therefore, the bureaucratic and legal obligations are reduced, and by-products can be regarded as products within the EU. The key benefit is the possibility of realising

alternative recycling processes for metal offcuts without expensive and time-consuming bureaucratic burdens (Figure 2).

2.2 Design methodological foundations

"The predominant part of the product properties and effects are defined by the designer with his design decisions in the course of the product development process" [VDI 2243 2002]. In the development of sustainable products, the effects of property selection on the realization of a product's function and its environmental and societal impacts during all sub-processes of product life need to be considered. The concept of holistic product and process development describes the relation between the process chain of product development and the process chain of the product life-cycle [Birkhofer et al. 2012].
With each sub-process of product development, the designer anticipates and influences individual product life processes. The information content is dependent on the sub-process. Generally, the designer anticipates the processes of the product life during an early stage of the design process to deduce requirements: anticipation is a key factor in the fulfilment of the four requirements (Section 2.1) and the classification of offcuts as a by-product. By anticipating usage scenarios and required target properties in the form of requirements, the use of the product is secured. There are two parallel processes in the design of recycling: the by-product is developed alongside the main product, a car door as a car body part. The complexity of the offcut design depends on anticipated offcut use (Section 3).
Only in later phases of the design process does the increasing detail of the design affect product life. With the selection of material or geometry, the designer controls the available production processes as well as the waste generated, e.g. offcut, and its properties.

2.3 Methods for forecast for the labour market

There are some methods for forecasting the labour market in relevant literature. The two main methods are the time series model and the macroeconomic simulation model [Brunow et al. 2012]. The time series method is based on econometric or iterative-analytic models. The indicators used are demographic trends, the GDP growth and the difference between the labour supply and labour demand [Bach et al. 2009]. The macroeconomic simulation model is based on economic relationships. Economic relationships are consumer behaviour in relation to economic income or company investment in relation to interest rates applied by credit institutions [Bach et al. 2009]. The literature does not contain a model for the forecast of the labour market, using mass-flows as a primary indicator of the knock-on effect of engineering or legislation. Using mass-flow as an indicator is useful in examples like the introduction of single-use container deposit and its influence as a fluctuating mass flow on the number of employees in single value-added steps. A new model with specific indicators is needed to show the relationship and dependencies between the number of employees and mass-flow and to develop a new method for forecasting the labour market.

3. Realization of alternative processes for recycling metal offcuts

A car door is used as an example product to describe the recycling processes mentioned above. One possible manufacturing process chain for a car door is shown in Figure 1.

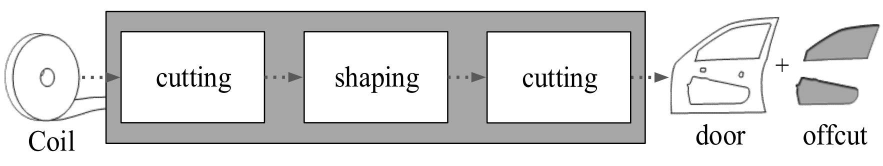

Figure 1. Process chain of the production of a car door (origin process of the offcuts)

The process chain of the production of a car door starts with the cutting of blanks from a coil for the forming processes that follow. In the machine press chain, the blanks are incrementally formed into the final geometry. Unnecessary material is then cut off for creating the car door and offcuts. The offcuts are an integral part of the process. The offcuts can be described by their almost completely

known properties. The chemical and physical properties of the work piece are not modified during this production process; its technological, geometric and mechanical structural properties are. For example, technology-dependant plastic deformation and internal stress, which leads to anisotropic material behaviour, are induced [Groche et al. 2012].
Because offcuts are a by-product (Section 2.1) and their properties are changeable during the process chain of product development, new possibilities for alternative recycling processes arise. Figure 2 shows examples of using the offcut as a by-product during alternative recycling processes [Ćorić et al. 2013].

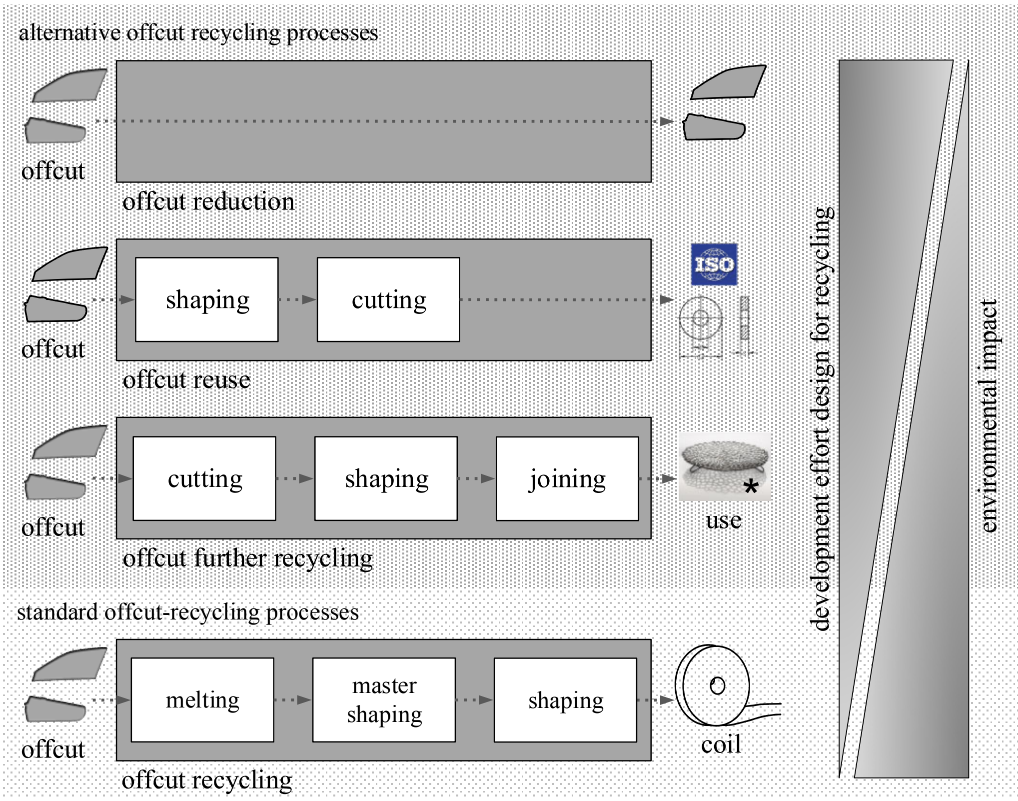

Figure 2. Possible recycling processes for metal offcuts * [Brown 2013]

Offcut reduction does not require additional processes for the manufacturing of an offcut product. The designer has fixed the decisive properties of the offcut. Dependency between the properties of the offcut and the product is the greatest of all the examples. The development effort required for designing for reduction is the biggest. Accordingly, no offcut is created to recycle. Possible products are reinforcement sheets for car bodies or simple raw workpieces. Offcut reduction is preventative rather than a recycling process.
Offcut reuse describes the production of new products, e.g. standard parts or raw workpieces. The additional sub-processes induce technology-dependent properties. Offcut properties need to meet the requirements of additional processes, for example, requirements of surface properties, cambers or limiting sizes. Hence, a large volume of the offcut material is reused without being melted down.
Offcut further recycling is the recycling of the offcut by, for example, granulating. Dependencies between the properties of the offcut and the recycling product are detached. Accordingly, the effort required for offcut further recycling is lower than for offcut reduction and offcut reuse. Example products are art or bulk material as filling, ballast or production resources, such as spheres for polishing.
Offcut recycling is the standard process. The entire mass-flow is directed to the steel industry, melted down and processed further into raw workpieces or components. During this process chain, the material's cohesion is dissolved. As a result, offcut properties are almost independent of the recycling product's properties. In this process, the offcut is not classified as a by-product.

In investigating the influence of the alternative processes of recycling, as shown in Figure 2, this proposed model assumes the following simplifications:

- During offcut reduction, the whole offcut mass-flow stays within the metalworking industry.
- During offcut recycling, the whole mass-flow is directed from the metalworking industry to the steel industry. In offcut reuse and further recycling, these processes require that the mass-flow is partially used or melted down.

All of the proposed processes can be implemented within a company or a company network, which is referred to as the offcut network in the following sections.

4. A basic model

The mass-flow is used as an indicator to create a basic model to quantify the influences of different recycling processes on the number of employees. The mass-flow is the connection between the actors in a value chain, who represent different value-added steps (Figure 3). The offcut network represents the companies of the metalworking industry, where the offcut is produced and processed according to the first three processes (Figure 2). The mass-flow $\dot{m}_1$ represents the offcut output that company A adds to the value chain. The mass-flow $\dot{m}_{31}$ describes the mass-flow that leaves the offcut network. The difference between $\dot{m}_1$ and $\dot{m}_{31}$ corresponds to the mass-flow towards company B ($\dot{m}_2$).

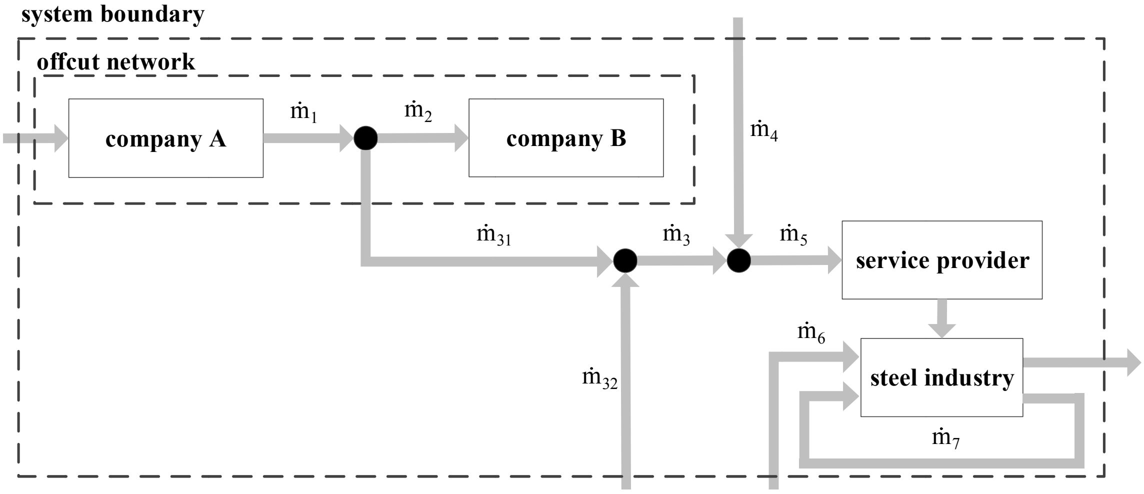

Figure 3. A basic model for analysis

The steel industry produces crude steel from a mixture of different components. Therefore, 42 % scrap is used ($\dot{m}_5$+$\dot{m}_7$) while the remaining mixture is iron ore ($\dot{m}_6$) [Jochem 2004]. The scrap steel consists of different scrap forms (Figure 4). Based on the breakdown of different types of scrap, the relations between the different mass flows in Figure 3 are known.

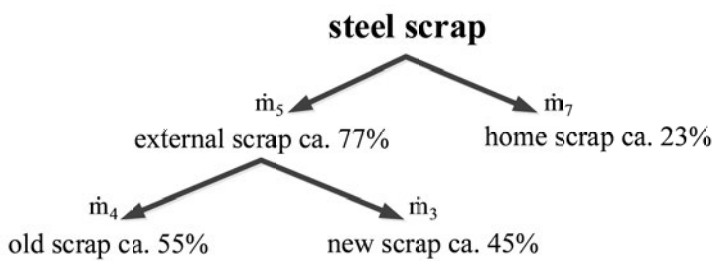

Figure 4. Scrap forms [Becker 2009]

Besides the 23% self-produced home scrap of the steel industry ($\dot{m}_7$), 77 % of the scrap for crude steel production is bought (external scrap $\dot{m}_5$). The bought scrap is composed of old ($\dot{m}_4$) and new ($\dot{m}_3 = \dot{m}_{31} + \dot{m}_{32}$) scrap. The old scrap consists of metal scrap from industry, e.g. demolitions and consumer goods. The new scrap consists of production scrap, chipping flakes, reworks, offcuts and

stamping scrap. To simplify the calculation, it is assumed that new scrap consists of one third chipping flakes, one third reworks ($\dot{m}_{32}$) and one third offcuts ($\dot{m}_{31}$). The disposal of iron material in landfill or thermal recycling is not considered. As a boundary condition, the scrap composition in Figure 4 is independent of changing mass-flows. Therefore, a decrease in the mass-flow of new scrap results in a decrease in crude steel produced. This is assumed since offcuts as a high quality scrap with a known chemical composition is reduced in the steel industry.
Based on this mass-flow specific model, stakeholders within the value chain are examined more closely. They are allotted numbers that quantitatively characterise their productivity, reflecting the mass-turnover per employee [Becker 2009]. The basis for the identification of these employment-specific characteristic numbers is explained in Equation (1).

$$B_{ij} = \dot{m}_{ij} \cdot \frac{1}{kB_{ij}} \cdot V_{ij} \tag{1}$$

The number of employees in each industry, of each actor of a value-added step (B_{ij}) is calculated with the scrap-mass per year and value-added step j ($\dot{m}_{ij}$) multiplied with the inverse of the employment-specific characteristic number kB_{ij} and multiplied with the employment index V_{ij} for each mass-flow and value-added step. The work productivity ($1/kB_{ij}$) describes how much time a worker of a value-added step j requires to process one ton of material i. The employment index determines the ratio of employees of a value-added step j that solely provide their work force to this value-added step. For the recycling of steel in the steel industry, the employment index varies between 0.02 and 0.05 [Becker 2009].

4.1 The stakeholders of the basic model

The value chain shown in Figure 3 describes the relations between the stakeholders in offcut recycling. Each stakeholder carries certain functions within the value chain and represents a value-added step.
Company A is the manufacturer of the car door and the by-product offcut. Its sphere of action is the development and production of products. Depending on the recycling process, additional processes are carried out. In the case of relaying the offcut to company B, organizational tasks occur, such as the provision of information about the offcut. The development of products, as well as the provision of information, requires a workforce. The responsibility for fulfilling the first two criteria for the offcut to be considered as a by-product is on company A (Section 21).
Company B within the recycling network uses the offcuts from company A. For the corresponding processes, employees are necessary. It is assumed that new offcut-adapted products, described in Sections 2.1 and 2.2, are produced instead of substituting material through offcuts. Additionally, new data handling processes are required. Transportation of the offcut from company A requires a workforce for general logistics, collecting and transporting of the mass flow.
The recycling of scrap by the steel industry requires pre-treatment of the old scrap. A service provider sorts and pre-treats the mass-flow $\dot{m}_4$ and trades the old and new scrap (Figure 5). The service provider is responsible for logistics.

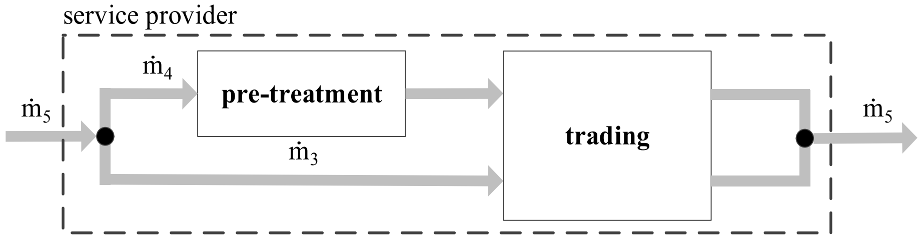

Figure 5. Process chain of a service provider

The steel industry processes the flows of steel scrap, iron ore and home scrap into new parts and raw workpieces.

4.2 The employment-specific characteristic number

The employment-specific characteristic number kB_{ij} (from Equation (1)) for the mass-flow of iron materials in the value-added steps of logistics, pre-treatment, trade and steel industry is listed in the 2009 study on the economic importance of recycling in Germany by the Federal Ministry of Research and Technology. For the development and manufacturing of sheet metal parts, values are estimated and other sources are considered. The employment-specific characteristic numbers from Equation (1) for the mass-flow of iron materials are summarized in Table 1.

Table 1. Employment-specific characteristic number of all stakeholders of the value chain

j / char. number	Logistic*	Pre-treatment*	Trading*	Steel industry*	Development**	Manufacturing***
$kB_{iron,j}$ [t/a]	1,750	2,500	15,000	6,000	8,255	257
* [Becker 2009] ** self-estimated *** [Rujoub 2007]						

The entire scrap use of steelworks adds up to approximately 21.2 x 10^6 t/a [Becker 2009]. The entire weight of steel used in Germany is about 36.0x10^6 t/a [Bundesanstalt für Geowissenschaften und Rohstoffe 2007]. Overall, 43,600 engineers work in metal production and processing, and the manufacturing of metal product from this steel [Koppel et al. 2010]. It can be assumed that about 10% of engineers are responsible for the development of sheet metal products. That corresponds to 8,255 t/a for the employment-specific characteristic number for development activity.
Additionally, it can be assumed that the offcut is designed completely by engineers ($V_{steel,\ company\ A} = 1$).

5. Influence of the recycling processes on the number of employees

Based on the quantification of employee productivity in different value-added steps (Table 1) and the quantitative survey of material flow (Figure 3), the impact of the recycling processes (Figure 2) is evaluated. As a standard process, offcut recycling is considered.
As in Section 4.2, the entire scrap input of the steel industry is used for the calculation of employment numbers for the typical recycling of offcut. No mass exchange occurs within the offcut network and $\dot{m}_1=\dot{m}_{31}$ applies. Table 2 summarizes the number of employees in offcut recycling.

Table 2. Number of employees in offcut recycling as standard recycling process for offcuts

j / char. number	Logistic	Pre-treatment	Trading	Steel industry	Development	Manufacturing
$B_{iron,j,rec}$	9,328	3,591	490	4,852	0	0
$B_{iron,total,rec}$	18,261					

This calculation indicates that about 18,000 employees are necessary to process offcuts into a usable product, such as parts or raw workpieces with forming processes.
Offcut reuse incorporates additional steps for the recycling process. Due to the need for anticipation of these processes, additional effort from company A is required. The development workload correlates with mass-flow transferred to company B. A high degree of anticipation during offcut development results in a high recycling rate within the offcut network. However, company B requires additional employees to process the offcut. Figure 6 illustrates the connection between the recycling rate and the change in number of employees for each value-added step for offcut reuse. With an increasing recycling rate, the material-flow shrinks the boundaries of the offcut network. Hence, the number of employees of the service provider and of the steel industry is reduced as well. In contrast, the number

of employees within the offcut network rises. Overall, the number of employees of the value chain is increased by about 4,000 positions, which is a 20 % increase. Mainly, the low employment-specific characteristic number of company B, as a processor of the offcut, leads to the increase in available jobs.
Offcut further recycling paints a similar picture. Due to the lower development effort, the number of developers in company A will increase slower than the recycling rate, which leads to a lower incline for the number of employees in connection to the recycling rate.

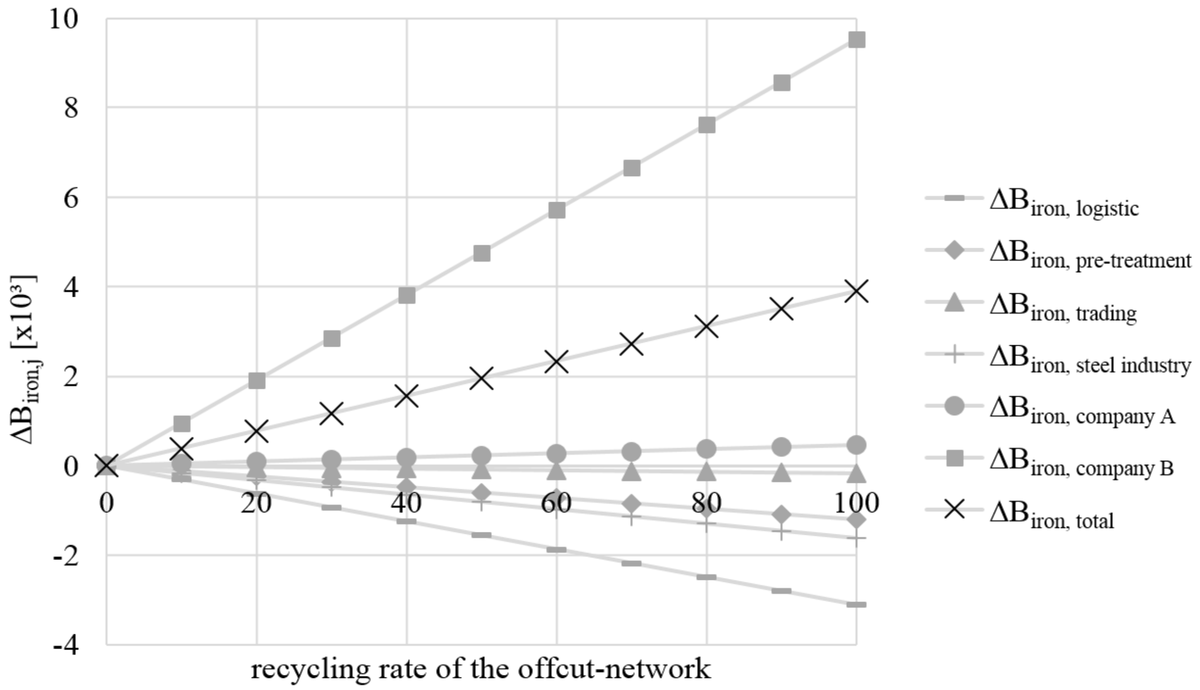

Figure 6. Change in the number of employees dependent on the recycling rate for offcut reuse

Offcut reduction does not require additional processes. The offcut can be used directly as another product. As a result, the recycling rate reaches 100 %. However, no mass-flow is transferred to company B. As in the introductory example, the calculation underlines the disparity of sustainability: Offcut reduction as the process with the lowest environmental impact is not the optimum solution if number of employees is considered. The number of employees of the value chain is decreased by about 5,500 positions, which is a 30 % decrease. Table 3 summarizes the results.

Table 3. Number of employees for offcut reduction

j / Char number	Logistic	Pre-treatment	Trade	Steel industry	Development	Manufacturing
$\Delta B_{iron,j,red}$	-3,109	-1,197	-163	-1,617	460	0
$\Delta B_{iron,total,red}$	-5,627					

6. Conclusion

The method, based on the mass-flow specific model, is able to estimate the influence of recycling processes with fluctuating mass-flows on employee numbers. It does not aim to evaluate or review recycling processes for the social dimension of sustainability. This method mainly aims to estimate the impact of changing mass-flows to support decision-making, regardless of alternative recycling processes. The example of container deposit legislation in Germany proves the connection between mass-flows and number of employees.

With defined characteristic numbers adaption to specific value chains is possible. The values used for the example shown are based on a statistic survey conducted in Germany. The conclusion only serves as a representative calculation rather than a general result. For practical use, the necessary mass-flows and characteristic numbers need to be determined. Due to different degrees of production process automation and different production technologies, the characteristic numbers vary according to the specific circumstances.

Another advantage of the mass-flow specific approach is the analogy to ecological balancing methods by describing a reference-flow. Therefore, the basic model can be used to determine the ecological impact of different processes in offcut processing within a value chain. Economic considerations, e.g. estimations of stakeholder revenue, are possible as well. The number of employees is a cost driver in manufacturing and an indicator of the social dimension of sustainability.

Further research will aim to develop a uniform model at the level of processes and their realization using procedures for holistic assessment of the impact of changing material flows on the economic, ecological and social dimensions of sustainability.

References

Achatz, D., "Umwelterklärung 2012. Audi Stort Ingolstadt", 2012, available at: http://www.audi.de/etc/medialib/ngw/company/sustainability.Par.0030.File.pdf/audi_umwelterklaerung.pdf, accessed 30.10.2012.

Albus, J.-J., Rubach, C., Stroese, R., "Recycling für den Klimaschutz: Ergebnisse der Studie von Fraunhofer UMSICHT und INTERSEROH zur C02-Einsparung durch den Einsatz von Sekundärrohstoffen", Köln, 2008.

Arthur D., Little GmbH, Fraunhofer-Institut für System- und Innovationsforschung Fh-ISI, Wuppertal Institut für Klima, Umwelt, Energie, "Studie zur Konzeption eines Programms für die Steigerung der Materialeffizienz in mittelständischen Unternehmen", Abschlussbericht, Wiesbaden, 2005.

Bach, H.-U., Gartner, H., Klinger, S., Rothe, T., Spitznagel, E., "Die IAB-Prognose der kurzfristigen Entwicklung auf dem deutschen Arbeitsmarkt", IAB-Forschungsbericht, Nürnberg, 2009.

Becker, C., "Die wirtschaftliche Bedeutung der Recycling- und Entsorgungsbranche in Deutschland: Stand, Hemmnisse, Herausforderungen; Endbericht", 2009, available at: http://www.argus-statistik.de/dokumente/Recycling_und_Entsorgungsbranche_lang.pdf, accessed 30.08. 2013.

Birkhofer, H., Rath, K., Zhao, S., "Umweltgerechtes Konstruieren", Handbuch Konstruktion, Steinhilper, R., Rieg, F. (Eds.), Carl Hanser Verlag, 2012, pp. 561–582.

Brown, S., "Tasmanian artist Sally Brown creates unique, hmade, functional art objects from metal salvaged materials", 2013, available at: http://www.sallybrown.com.au/wp-content/uploads/2012/07/SallyBrown_LichenPlatter1-1024x765.jpg, accessed 28 August 2013.

Brunow, S., Garloff, A., Wapler, R.,; Zika, G., "Wie wird sich der Arbeitsmarkt langfristig entwickeln? - Methoden und Validitäten von Prognosen zur Vorhersage von Fachkräfteangebot und –bedarf", IAB-Stellungnahme, Nürnberg, 2012.

BT-Drs 17/6052, "Drucksache des Deutschen Bundestages 17/6052 vom 06.06.2011: Entwurf eines Gesetzes zur Neuordnung des Kreislaufwirtschafts- und Abfallrechts", 2011.

Bundesanstalt für Geowissenschaften und Rohstoffe, "Rohstoffwirtschaftliche Steckbriefe für Metall- und Nichtmetallrohstoffe", 2007, available at: http://www.bmwi.de/BMWi/Redaktion/PDF/P-R/rohstoffwirtschaftliche-steckbriefe,property=pdf,bereich=bmwi,sprache=de,rwb=true.pdf, accessed 4.09.2013.

Ćorić, M., Birkhofer, H., Kloberdanz, H., "Recycling Methods – Developing a uniform terminology using the process model and the properties theory", Proceedings of the 8th international symposium on Environmentally Conscious Design and Inverse Manufacturing - EcoDesign 2013, Jeju, 2013.

Directive 2008/98/EC, "European Parliament and Council Directive 2008/98/EC of 19 November 2008 on waste and repealing certain Directives".

Directive 94/62/EC, "European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste".

Groche, P., Birkhofer, H., Bauer, O., Göllner, T., Gramlich, S., Kaune, V., Rullmann, F., Weitzmann, O., "Potenziale einer durchgängigen Produktentstehung - Nutzung technologieinduzierter Eigenschaften zur Entwicklung von Blechstrukturen", Konstruktion, Vol 11, No. 12, 2012, pp. 11–12.

Hanusch, D., "Die Entwicklung nachhaltiger Produkte : theoretischer Anspruch und Möglichkeiten zur praktischen Umsetzung in der sozialen Dimension", VDI-Verlag, Düsseldorf, 2011.

Jochem, E., "Werkstoffeffizienz: Einsparpotenziale bei Herstellung und Verwendung energieintensiver Grundstoffe, Innovationspotenziale", Fraunhofer-IRB-Verl, Stuttgart, 2004.

Klug, F., "Logistikmanagement in der Automobilindustrie: Grundlagen der Logistik im Automobilbau", Springer-Verlag, Berlin, 2010.

Koppel, O., Schumann, T., "Ingenieurarbeitsmarkt 2009/10: Berufs- und Branchenflexibilität, demografischer Ersatzbedarf und Fachkräftelücke", VDI und Institut der deutschen Wirtschaft Köln, Köln, 2010.

Lehrke, G., "Streiks nach Meassenkündigung, Betriebsrat wird ausgesperrt. Alba-Arbeiter: Man behelt uns wie Müll",2013, available at: http://www.berliner-kurier.de/archiv/streiks-nach-massenkuendigung--betriebsrat-wird-ausgesperrt-alba-arbeiter--man-behelt-uns-wie-muell,8259702,4213314.html, accessed 31.07.2013.

Maurer, A., Stark, W. A., "Steering Carmaking into the 21st Century: From Today's Best Practices to the Transformed Plants of 2020", Boston Consulting Group, Boston, 2001.

Mitteldeutsches Druck- und Verlagshaus GmbH & Co. KG, "Dosenpfand kostet Jobs in Getränkeindustrie", 2003, available at: http://www.mz-web.de/wirtschaft/umweltschutz-dosenpf-kostet-jobs-in-getraenkeindustrie, 20642182,19671752.html, accessed 31.06.2013.

Rujoub, G., "Modernste Stanztechnologie im Brose-Presswerk installiert", 2007, available at: http://www.brose.de/ww/de/pub/presse/pressemitteilungen/textarchiv/content8715.htm, accessed 3 September 2013.

VDI 2243, "Recycling-oriented product development", Beuth Verlag, Düsseldorf, 2002.

Vollmer, T., Cirulies, N., Meyer, H., "Sektorstudie Industrielle Produktion: Automobilindustrie", Vol. 2, Books on Demand GmbH, Norderstedt, 2009.

Wells, P., Seitz, M., "Business models closed-loop supply chains: a typology", Supply Chain Management: An International Journal, Vol. 10, No. 4, 2005, pp. 249–251.

Westkämper, E., Warnecke, H.-J., "Recycling", Westkämper, E., Warnecke, H.-J. (Eds.), Einführung in die Fertigungstechnik, 8th ed., Vieweg + Teubner, Wiesbaden, 2010, pp. 267–283.

M. Ćorić, M.Sc., Research Associate
Technische Universität Darmstadt, Institute for Product Development and Machine Elements (pmd)
Magdalenenstraße 4, D-64289 Darmstadt, Germany
Telephone: +49 (0) 6151/163053
Telefax: +49 (0) 6151/163055
Email: coric@pmd.tu-darmstadt.de
URL: http://www.pmd.tu-darmstadt.de