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Overcoming barriers to implementing recycling solutions: empirical analyses in the
German manufacturing sector

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Abstract

Based on the *German Manufacturing Survey 2009*, a large-scale dataset including data of 1,484 German manufacturing firms, we investigate the diffusion of recycling to reduce material consumption. Our findings suggest that firms using management tools such as environmental performance measurement systems or life cycle costing evaluation methods are more likely to invest in recycling solutions.

Keywords: material efficiency, recycling concepts, process innovations, manufacturing industry

Introduction

Material efficiency is becoming a top priority for German industry and academia due to growing scarcity for certain resources, volatile and increasing material costs and the import dependency of the German economy (Wied and Brüggemann 2009). It is particularly important for German companies to minimize these risks in order to remain competitive on the global level. Although material costs represent a share of 43 percent of the total production costs (Statistisches Bundesamt 2011), companies in the manufacturing sector still estimate their material saving potential to be seven percent on average (Schröter et al. 2011). Compared to the estimated energy saving potential of 15 percent this seems to be relatively low (Schröter et al. 2009). However, if the share of total production costs is taken into account as leverage, the possibilities for cost savings are significantly higher.

Different strategies and technologies exist to harness material saving potentials and exploit existing economic potentials such as recycling concepts which aim at using re-

cycled materials, or taking back end-of-life products. These concepts are further emphasized by the increasing product stewardship of companies following such political directives as the German directive on end-of-life vehicles (*German: Altfahrzeugverordnung*) or the WEEE Directive¹ (Bundesministerium der Justiz 2002; European Commission 2003). Despite these efforts, recycling concepts are still far from being fully exploited.

Therefore it is necessary to identify promising tools and solutions to overcome existing barriers and harness the material efficiency potentials. It can be assumed that there are firm-internal and -external influencing factors which stimulate the implementation of material-efficient solutions. For example, as part of an innovation system, each company interacts with and is dependent on different actors such as their stakeholders, e. g. (Carrillo-Hermosilla et al. 2009; Hekkert et al. 2007; Haddock-Fraser and Tourelle 2010). There are also strategic impulses, for instance, managerial attitudes and the firm's internationalization strategy, or whether environmental performance indicator systems or total cost of ownership concepts have been implemented which make internal material flows more transparent (González-Benito and González-Benito 2006; Schröter et al. 2011).

This paper analyzes the impact of different strategic tools and the influence of external actors in overcoming barriers and implementing recycling concepts in the German manufacturing industries.

The paper is structured as follows. Section one describes the data applied. We use a quantitative approach based on the *German Manufacturing Survey* 2009. To start with,

¹ WEEE = Waste Electrical and Electronic Equipment, Directive 2002/96/EC

we derive the distribution of different material recycling concepts in German manufacturing industries. The next section reviews different barriers which impede the diffusion of recycling concepts. Possible solutions to overcome existing barriers such as e. g. environmental performance indicator systems, total cost of ownership concepts, cooperation with different stakeholders and the use of different information sources are then discussed and tested by applying empirical results. The final section draws conclusions and summarizes the findings of the empirical results.

Empirical Research: Database

A quantitative approach was chosen for the empirical analyses. We used the database of the *German Manufacturing Survey 2009*, which provides a large set of data on companies in manufacturing industries including information on their process and organizational innovations in production amongst other things. Therefore, the survey enables detailed analyses to be made of firms in manufacturing industries and to derive the central drivers and levers of various successful innovation strategies. In particular, the firms have been asked whether they use certain recycling concepts or technologies for saving material consumption in their production such as “utilization of residues for energy generation”, “utilization of recycled material in production manufacturing”, “product take-back after end-of-product life cycle” and “utilization or delivery of industrial waste in an interplant context”.

This standardized, multi-topic mail survey of modernization trends in manufacturing industries in Germany has been carried out every two to three years since 1995. The 2009 survey covers 1,484 German firms and provides a representative database for all

manufacturing sectors. In total, 15,567 German manufacturing sites were contacted which have been selected randomly among all manufacturing establishments with more than 20 employees of the sectors 15 to 37 according to the “Nomenclature statistique des activités économiques dans la Communauté européenne” (NACE 2003). Thus, the rate of return is approximately 10 percent (Jäger and Maloca 2009).

Recycling concepts to increase material efficiency in the German manufacturing sector

An impression of the current relevance of material efficiency in manufacturing firms can be gained from analyzing the spread of key recycling concepts to reduce material consumption. The following sections examine the current state of use of these concepts in manufacturing.

Recycling concepts which increase material efficiency include taking back products at the end of their useful life, using recycled materials in product manufacturing as well as using residues for internal energy generation. For each of these three recycling concepts the *German Manufacturing Survey 2009* asked whether it is actually used or not in the production of the firm. Alongside these individual company approaches to saving materials, there are other options to improve material efficiency offered by approaches which span companies, so-called recycling networks. In recycling networks, companies supply other companies with by-products or production residues for further utilization, which would otherwise be dumped and not made use of in any way (Spengler 1998; Schwarz 1994). In order to analyze which production companies outside the recycling sector are active in these kinds of networks, as part of the survey firms were asked whether they

cooperate with other firms to recycle/supply production residues, which are not specialized recycling companies.

The state of use of different recycling concepts in manufacturing companies in Germany is plotted in Figure 1. Looking at the spread of recycling concepts throughout manufacturing as a whole, it is apparent that, depending on the concept, about 10 to 30 percent of companies are making use of recycling concepts. All in all, at least one of these analyzed concepts is used on average by 49 percent of the manufacturing firms.

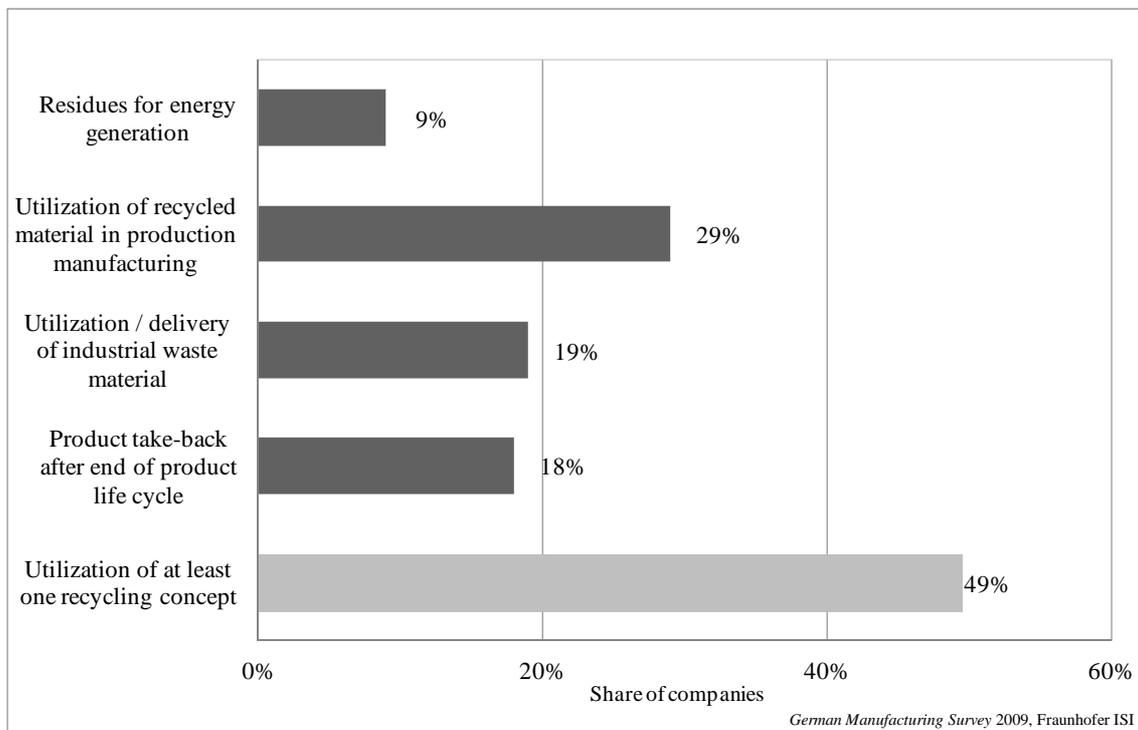


Figure 1: Implementation of recycling concepts

By examining the diffusion of the recycling concepts more thoroughly with regard to their diffusion in the different sectors, an even more heterogeneous picture emerges:

- Using **residues to generate energy** is very widespread, especially in the wood industry (69 percent of the companies). In this industry it makes sense to thermally use the large volumes of waste wood caused during production. This concept is much less relevant in other manufacturing industries. It is used comparatively often in the chemical industry, in printing and publishing and the rubber and plastics industry. Between 11 and 14 percent of the companies in these industries use residues to generate energy.
- Using **recycled materials** is mainly applied in the paper industry (62 percent of companies) and in rubber and plastics production (63 percent of the companies). This is not surprising because waste paper and recycled plastics are known to be used to manufacture goods in these sectors. In contrast, however, this concept is hardly applied at all in mechanical engineering, manufacturing metal products or the food industry (each between 11 and 16 percent of the companies).
- **Taking back products at the end of their useful life** is practiced by about 25 percent of the companies in the chemical industry, rubber and plastics production as well as metal production. About 20 percent of all the companies do this in automobile manufacturing, the electronics industry and mechanical engineering. In these sectors, product take-back should be understood as the used products actually arriving back at the companies. Even if legal guidelines have been passed regulating product take-back and recycling in these industries, this task is usually passed on to specialized companies from the recycling sector.

- The **supply and use of production residues** in recycling networks is widespread in textile, apparel and leather production, printing and publishing, rubber and plastics production, glass and ceramics industry and metal production (all between 30 and 38 percent of companies).

Barriers and drivers to resource efficiency

The diffusion of recycling concepts described above is influenced by various factors, both internal and external to the firm. In this section, barriers are described which impede the diffusion of existing recycling concepts. This was done via a literature search focusing on the barriers to resource efficiency concepts which include the sub-group of recycling concepts. Afterwards possible solutions to overcome those barriers are presented and tested empirically.

Technological lock-in and inertia can be seen as a typical barrier to recycling concepts due to perceived uncertainty in the decision making process to implement material-efficient solutions instead of applying familiar technologies (del Rio Gonzales 2005). These uncertainties can be caused by imperfect information such as missing knowledge about material saving potentials, existing technologies and their applicability due to a lack of competence, experience and qualified personnel (Ammenberg and Sundin 2005; Sorrell et al. 2004; Carrillo-Hermosilla et al. 2009). Changes in production processes and in organizational routines might be necessary to tap the existing saving potential and these can differ significantly to established corporate habits. Moreover they may require additional training of the employees (del Rio Gonzales 2005). The actual benefit of new recycling technologies is regarded as uncertain because there are risks associated

with their function and reliability (del Rio Gonzales 2005). Another barrier is the lack of awareness of material saving potentials because of insufficient information (Wied and Brüggemann 2009; Jochem et al. 2005). Technological lock-in can also occur because of the necessary high switching costs needed for adequate physical assets. This is especially the case if expensive, long-lasting equipment has been purchased recently which can only be applied with traditional technologies and would need to be replaced for more material-efficient solutions. Therefore investment cycles may hamper short-term investments in recycling technologies (del Rio Gonzales 2005).

The implementation of an environmental dimension in the corporate strategy also influences decisions about using recycling solutions as these may require the set up of a reverse logistic system or the purchase of recycling equipment. Due to uncertainties in regard to product returns and the yield of recycled material, this equipment may represent a higher financial risk for the company (Geyer and Jackson 2004). Investments in recycling solutions may also be more challenging if companies do not have access to sufficient capital or if the management's investment decisions are based only on short payback periods. The chosen innovation strategy may represent another barrier if the company is more risk-averse and prefers to be a late adopter in order to benefit from lower adoption costs and proved technologies (del Rio Gonzales 2005; Sorrell et al. 2004). Existing budgeting habits such as split incentives can also be a barrier to recycling solutions. If the cost savings achieved by material savings in a certain department within a company are assigned to a different cost center, the department's incentive for making these improvements vanishes (Sorrell et al. 2004).

Besides internal barriers, external factors such as regulatory uncertainties or the lack of pressure from the demand side can also influence the decision process (Schmid 2004; del Rio Gonzales 2005).

To overcome these existing barriers, we have to identify the determinants which stimulate the reduction of raw material consumption. These include specific tools or concepts to reduce the risk and uncertainty assessment, such as environmental management systems (Ammenberg and Sundin 2005; del Río et al. 2011; Horbach 2008). In order to achieve better cost transparency, total cost of ownership concepts can give a detailed cradle to grave cost overview and offer a standardized procedure. To improve and increase knowledge about new recycling technologies, cooperations with suppliers can be a profitable solution for shared technology development as can external stimuli e. g. input from research institutions (González-Benito and González-Benito 2006; Hofmann et al. 2012).

Data from the *German Manufacturing Survey 2009* will be used to test the relationship between the usage of recycling concepts and either internal, strategic tools such as environmental performance indicators and total cost of ownership concepts or external factors, such as external stimuli and innovation cooperations. The results are presented in the following section.

Results – facilitating the use of recycling concepts

Based on the *German Manufacturing Survey 2009* we analyze whether companies which use the above described concepts and tools that facilitate the decrease of the barriers also apply to a greater degree the different described recycling concepts. To simpli-

fy the description of the results, we only distinguish between companies which use at least one of the recycling concepts and companies which use none of them. The bivariate correlations are tested by using the t-test. Additionally, results were retested by analyzing subsamples defined by different firm size criteria.

Environmental performance indicators and the use of recycling concepts

The prerequisite for initiating measures to improve material efficiency is that corporate decision-makers know how high the saving potentials are in their production and where especially prominent weak spots can be found with regard to material consumption. The knowledge base required can be constructed by applying environmental performance indicators. The purpose of such indicators is to make data about material and energy use in the company accessible in a transparent form. This information helps companies with both the internal formulation of material efficiency targets and with deciding which measures to apply in order to achieve these targets.

A significant correlation was found when analyzing the relationship of applying environmental performance indicators and the use of the examined recycling concepts (cf. Figure 2). Out of all answering companies, at least one of these analyzed concepts is used on average by 49 % of the manufacturing firms. 64 percent of the companies using environmental performance indicators also use at least one of the examined recycling concepts. In contrast, only 43 percent of companies without environmental performance indicators apply at least one of these concepts for saving material.

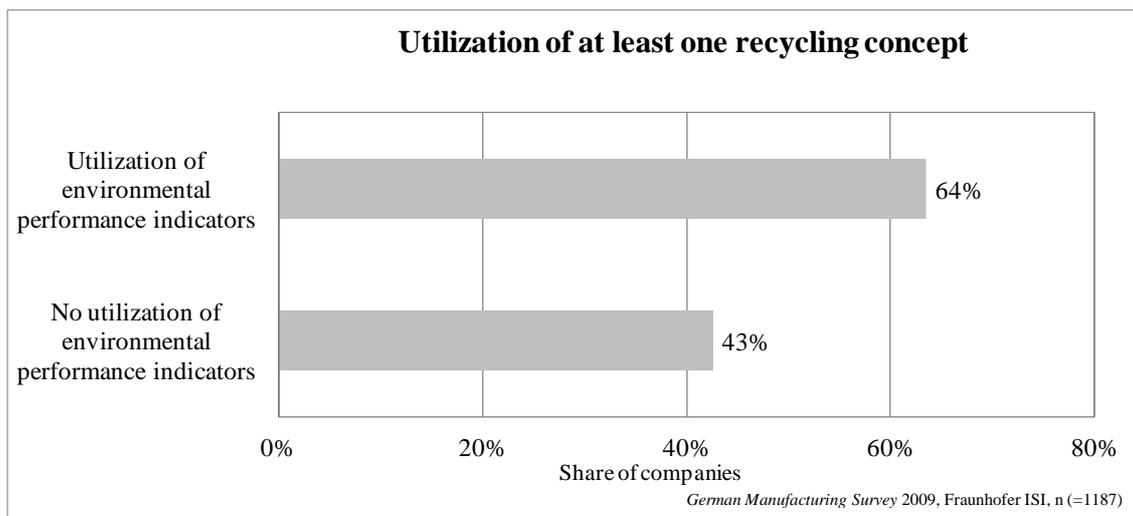


Figure 2: Use of environmental performance indicators and recycling concepts

More profound analyses show that this correlation also holds regardless of company size. Furthermore, it becomes apparent when examining each recycling concept separately that the overall result of the aggregated recycling concepts can be stated for each of these concepts. They are used much more frequently by companies with environmental performance indicators than by companies without them.

However, currently merely 17 percent of manufacturing companies use environmental performance indicators. Analyzing more profoundly the spread of use of environmental performance indicators in different industries shows the following picture: The industries in which these indicators are most often used by companies are metal production and processing (42 percent of companies) and vehicle manufacturing (34 percent of companies). In contrast, not even 10 percent of the companies use them in printing and publishing or in the food industry (Schröter et al. 2009). Therefore, by reinforcing the

implementation of environmental performance indicators, certain industries could pave the way for an increasing usage of recycling concepts.

Assessment based on life cycle costs and implementing recycling measures

From the viewpoint of the companies themselves, investments in recycling measures are often associated with a high risk. This can be explained, for instance, by the uncertainty concerning the development of material prices, changes in legal stipulations and technology development. This has the effect of preventing measures from being implemented such as the increasing use of recycled materials in products. Overcoming these obstacles requires that decision-makers have access to reliable information about the costs caused or the cost savings and that, as a result, the uncertainty and the associated risk are reduced. Apart from the already mentioned environmental performance indicators, suitable methods of calculation are also necessary. These include life-cycle costing (LCC) or the total cost of ownership (TCO) approach (Mattes and Schröter 2011).

Looking at the results based on the *German Manufacturing Survey 2009* reveals that companies which assess their investments by taking the entire life-cycle costs into account, use recycling concepts to increase material efficiency significantly more often (66 percent of companies) than companies which only consider the procurement costs for their investment decisions (34 percent of companies). The results are plotted in Figure 3.

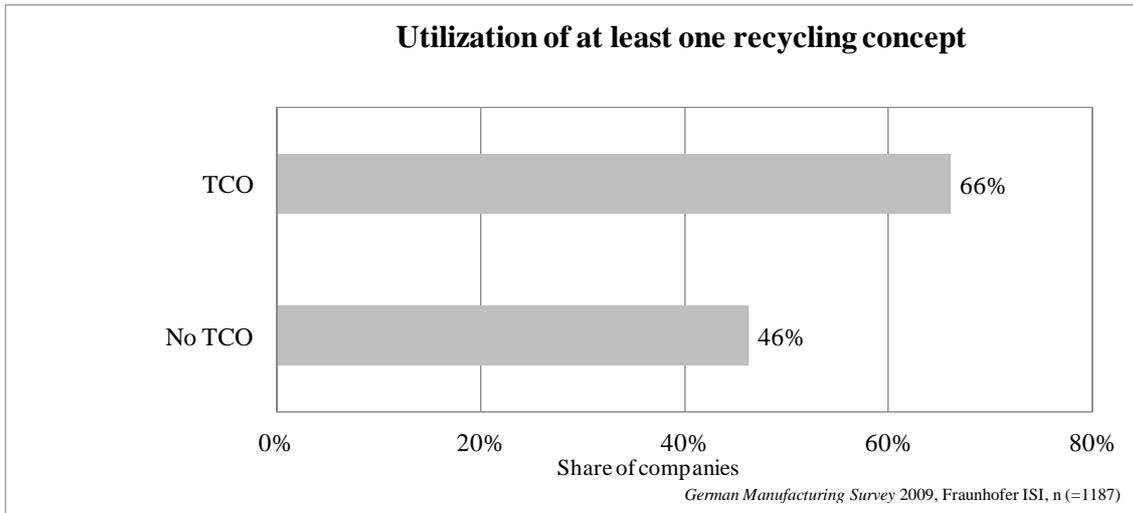


Figure 3: Use of recycling concepts and total cost of ownership (TCO) concepts

This correlation holds comparably for small, medium and large enterprises. More detailed analyses also reveal that the different analyzed measures were each more often implemented by companies which do life-cycle cost assessments. In general, it can be assumed that the economic advantages of the recycling concepts are made more transparent by the use of these assessment approaches and that this results in incentives to invest in such measures.

However, when looking at the diffusion of life-cycle cost approaches in manufacturing, it becomes clear that the absolute contribution of this instrument is nowhere near fully exploited. Only 14 percent of all companies use this approach to support their investment decisions. There are large differences in the frequency of use between the different sectors. Whereas more than one quarter of companies use this methodology in vehicle manufacturing and the electronics industry, this is the case in a maximum 7 percent of

all companies in the wood, printing and publishing and the paper industries (Schröter et al. 2009).

Using sources of information as impetus for the implementation of recycling concepts

Increased material efficiency in production results in the same amount of goods being able to be produced using fewer materials. These improvements are often attributed to technical or organizational process innovations such as recycling technologies (Rennings et al. 2005). One way to overcome the obstacle of a lack of information about existing methods for cutting material costs in production could be to make better use of different sources of information both within and outside a company. Possible internal sources of information are the company's own research and development department, for example, or employees from other departments. Outside the company, it is possible to obtain relevant information from customers, suppliers, competitors, research organizations and universities or at conferences, trade fairs and other events. Very specific information about alternative ways of saving material through recycling could come from these sources because of the variety of backgrounds and ways of accessing information. It can therefore be assumed that the company's own know-how about recycling concepts grows with the number of different information sources used, as does the probability that these concepts will be implemented to a greater extent.

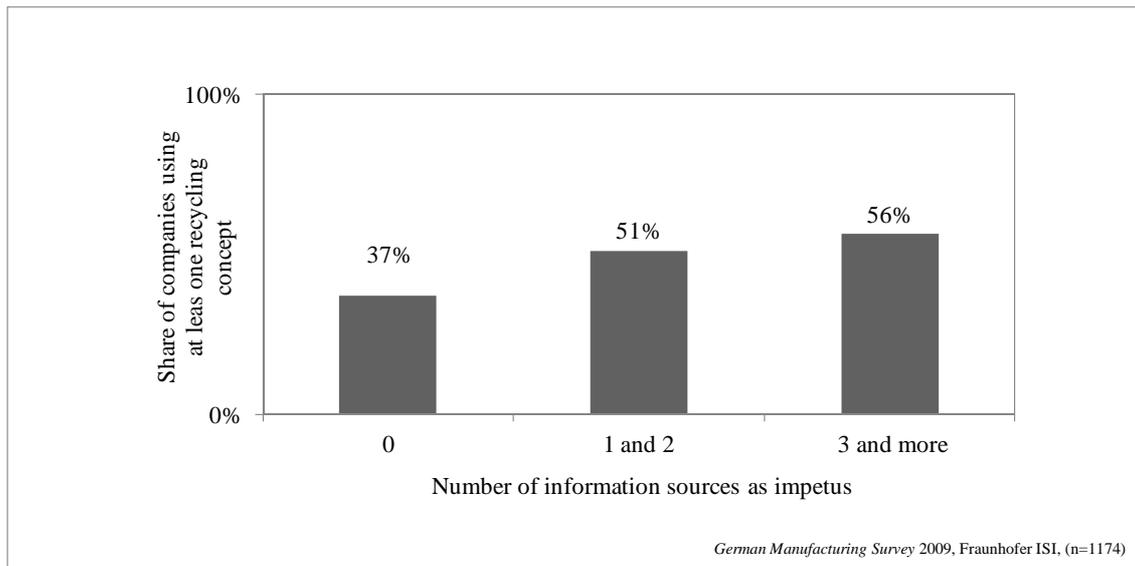


Figure 4: Usage of different impulses and recycling concepts

Analyzing the database shows an obvious corroboration of this assumption (cf. Figure 4). The share of companies which apply at least one recycling concept described above grows significantly with the number of information sources used as an impetus for technical and organizational process innovations.

Use of cooperation partners as a driving force for recycling innovations

Expanding the number of cooperation partners seems to be another way of overcoming the barriers to use recycling concepts in companies. These cooperation partners can, for instance, supply complementary knowledge, e.g. about the experiences gained with implementing recycling concepts. Cooperating with customers, for example, helps to judge whether customers will accept the use of recycled materials in new products. Because the implementation of recycling concepts is as a rule accompanied by improvements to technical or organizational processes (Rennings et al. 2005), it was therefore analyzed

whether companies which cooperate in these fields of innovation with at least one partner have implemented recycling concepts to a greater extent. Examples of possible cooperation partners who can influence improvements include customers, suppliers, competitors, service providers or research organizations and universities.

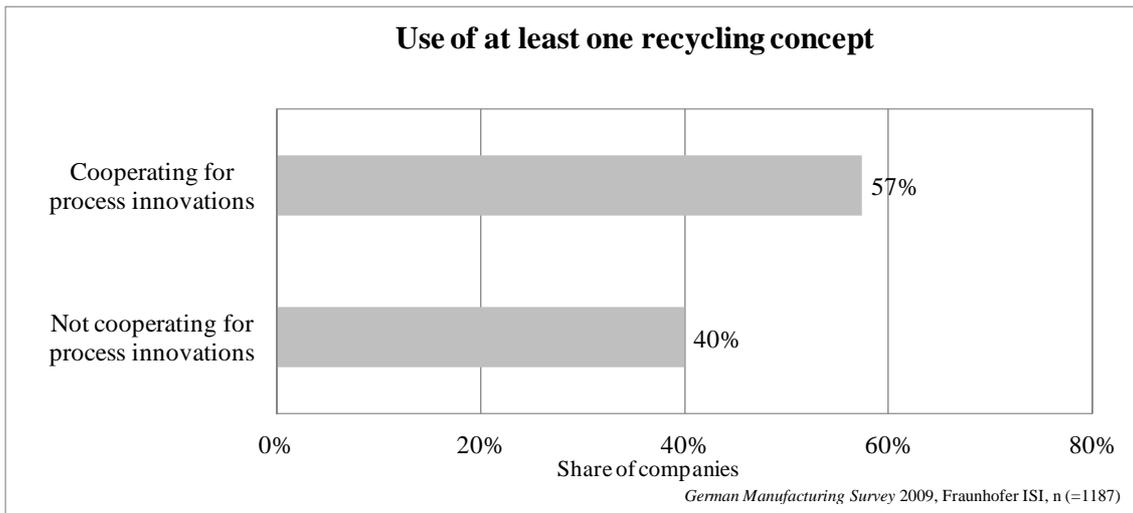


Figure 5: Cooperating for process innovations and usage of recycling concepts

As Figure 5 displays it can be shown that, on average, 57 percent of companies with at least one cooperation partner make use of recycling concepts². Only 43 percent of the companies which engage in innovation cooperations do not use any of the analyzed recycling concepts. An inverted picture emerges from comparing these shares with companies which do not cooperate for innovation purposes. Here, only 40 percent of the companies use at least one recycling concept to increase material efficiency. The bigger share of companies, 60 percent, does not use any of these concepts at all. The graph

² Out of all answering companies, at least one of these analyzed concepts is used on average by 49 % of the manufacturing firms.

shown here suggests that building up a network of cooperation partners has a positive effect on the use of material recycling concepts due to the additional information they provide.

Conclusions

Material efficiency is becoming a top priority for industry and academia. Actual and expected resource scarcities, increasing and volatile material costs and the fact that Germany is an import-dependent country with regard to various resources are some of the facts spurring this development. Therefore, the German Federal Government is using different political initiatives to address this topic such as the German Raw Materials Strategy (BMWi 2010).

Recycling concepts represent one way towards more resource-efficient production. Despite the existence of various solutions, barriers to material efficiency such as a lack of knowledge regarding the possible saving potentials are impeding the diffusion of these concepts. However, our findings show that the use of strategic tools, e. g. environmental performance indicators and total cost of ownership concepts, is making a significant contribution to overcoming existing barriers. In addition, it is vital for companies to cooperate with stakeholders to improve production technologies and to integrate different information sources in order to increase their knowledge about recycling solutions.

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