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Digitalisation as Enabler Towards a Sustainable Circular Economy in Germany

The increasing use of digital networking in complex industrial processes opens up new potential for more sustainability. This paper delivers the first empirical findings on the relevance of digitalisation for improving material efficiency in German industry based on a unique dataset including nearly 600 manufacturing firms. The survey results indicate that the opportunities of digital networking for increasing material efficiency are only being used to a limited extent thus far, primarily for traditional efficiency-raising measures optimising manufacturing processes.

Moving towards more sustainable patterns of production and consumption was globally agreed upon as an essential part of the United Nations' Agenda 2030 and its Sustainable Development Goals (SDGs). The SDGs provide an important impulse for progressing from a linear to a circular economy. With 12 of the 17 SDGs depending directly on the sustainable use of natural resources, increasing resource efficiency is a key strategy.[1] Targets 8.4, 9.4 and 12.2 place a special emphasis on retrofitting industries to improve resource-use efficiency by 2030. Target 12.4, which aims at avoiding waste through prevention, reduction, recycling and reuse, enhances the idea of a circular economy.[2] The rationale behind a circular economy is to keep resources in use for as long as possible. The approach is to look at the complete life cycle of a resource – from extraction to product design, production, consumption and ultimately waste management, e.g. recycling. A circular economy aims to minimise both material input and waste generation by resource-saving product design (eco-design) and by recycling and reusing products and materials. Through recycling and reuse, waste is turned back into a resource.[3]

With the recent launch of the G20 Resource Efficiency Dialogue, the G20 countries aim to contribute to the implementation of the 2030 Agenda. The purpose is to exchange good practices and national experiences to improve the efficiency and sustainability of natural resource use across the entire life cycle, and to promote sustainable consumption and production patterns.[4] Prior to this, the G7 countries recognised the importance of resource efficiency in 2015, placing the issue as a fixture on the G7 agenda. In addition to the creation of the G7 Alliance on Resource Efficiency, the G7 requested two reports by UN Environment Programme's International Resource Panel and by the OECD to identify the most promising solutions and approaches for increasing resource efficiency.[5] In parallel, the European Union instituted the EU Action Plan for the Circular Economy, whose aim is to achieve greater resource efficiency through eco-design.

Germany was one of the first European countries to formulate a comprehensive political strategy on resource efficiency. At the national level, the political objective of

1 P. Ekins et al.: Resource Efficiency – Potential and Economic Implications – A report of the International Resource Panel, United Nations Environment Programme, 2017, available at http://www.resourcepanel.org/sites/default/files/documents/document/media/resource_efficiency_report_march_2017_web_res.pdf.

2 United Nations: Transforming our World: The 2030 Agenda for Sustainable Development, A/RES/70/1, 2015, available at https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf.

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3 A. Neligan: Moving Towards a Circular Economy – Europe between Ambitions and Reality, IW Policy Paper No. 9, 2016, available at https://www.iwkoeln.de/studien/iw-policy-papers/beitrag/adriana-neligan-moving-towards-a-circular-economy-europe-between-ambitions-and-reality-289257.html.

4 European Commission: G20 Leaders' Declaration: Shaping an interconnected world, Statement/17/1960, 8 July 2017, available at http://europa.eu/rapid/press-release_STATEMENT-17-1960_en.htm.

5 Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety: Resource Efficiency in the G7, 2016, available at http://www.bmub.bund.de/en/topics/economy-products-resources-tourism/resource-efficiency/resource-efficiency-in-the-g7/.

decoupling the use of natural resources from economic development is anchored in the German Sustainable Development Strategy (GSDS) and the German Resource Efficiency Programme (GREP). As early as 2002, the GSDS set a target of doubling raw material productivity relative to 1994 by 2020 in order to advance resource efficiency in domestic production.[6] To achieve this target, the GREP was implemented in 2012. Every four years, an evaluation of the current status and progress with regard to resource efficiency in Germany is undertaken, and the programme is subsequently refined accordingly. The first update was realised in 2016. The raw material productivity indicator from the GSDS is still a key point of reference for the GREP. However, it is now supplemented with a new indicator, total raw material productivity, to be able to monitor improvements in resource efficiency, e.g. through the inclusion of biotic resources and by making adequate allowance for imports. This prevents the reporting of productivity gains that were based solely on moving resource-intensive processes abroad. The target is here to sustain the 2000-2010 trend through 2030.[7]

Businesses: Resource efficiency as a key strategy

A more circular and resource-efficient economy can only be realised with the involvement of all state and non-state parties alike, in particular in the private sector. The industrial sector plays a key role as a source of investments and as a driver of technological development and innovation that make better and more careful use of natural resources.[8]

As a highly industrialised economy, Germany also needs to further modify its current patterns of production and consumption to save resources and to avoid waste. Being highly integrated in global value chains, industrialised countries like Germany play a key role here, as they can significantly influence production methods in industrialised, emerging and developing economies, giving them a special responsibility for advancing more sustainable global production.[9]

Germany has a high need for raw minerals. The country can fully or at least partly meet its own needs from domestic sources with non-renewable (abiotic) raw materials, in particular raw materials from quarrying. Although the greater part of Germany's raw materials in terms of volume are domestic, a significant portion – particularly in terms of metal raw materials, many high-tech raw materials and most energy raw materials – come from abroad. Germany's metal ore requirements, for example, are almost entirely imported. In the case of metals, a large number of ores arrive in Germany not in the form of raw materials but already as metals or semi-finished products in the form of intermediate products such as pipes, sheet metal and wires, or as end products such as castings, forgings and machine parts.[10] A thriftier use of materials could therefore not only save costs but also reduce the dependence on imports.

Hence, many German companies are already taking measures to minimise their resource consumption. In addition, material consumption constitutes a considerable cost factor. In order to safeguard the future supply of raw materials, the German economy faces the challenge of dealing sparingly with available resources. To counter the overconsumption of valuable resources, there are two significant approaches available to businesses:

- Using less material: increasing resource efficiency and preventing waste through the better eco-design of products;
- Using resources more than once: increasing the use of secondary raw materials via improved reuse and recyclability (circular economy).

The increasing digital networking in complex industrial production and processes also raises high expectations in terms of more resource-efficient productions methods. The growing intertwining of modern information and communications technologies with traditional industrial processes offers new potential for both the thriftier and more efficient use and reuse (i.e. recycling) of resources. In addition, new business fields can be opened, for example the sale of a service instead of a product.

Empirical analysis: Role of digitalisation for greater material efficiency

This paper analyses whether the digital transformation is already a key enabler for more resource-efficient produc-

6 Raw material productivity expresses how much GDP is generated per tonne of abiotic primary material consumed.

7 Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety: German Resource Efficiency Programme II – Programme for the sustainable use and conservation of natural resources, 2016, available at http://www.bmub.bund.de/fileadmin/Daten_BMU/Pools/Broschueren/german_resource_efficiency_programme_ii_bf.pdf.

8 P. Bakker: The private sector's role in promoting sustainable development, WBCSD Insight, 29 November 2016, available at http://www.wbcsd.org/Overview/News-Insights/Insights-from-the-President/The-private-sector-s-role-in-promoting-sustainable-development.

9 The German Federal Government: Deutsche Nachhaltigkeitsstrategie – Neuauflage 2016, available at https://www.bundesregierung.de/Content/Infomaterial/BPA/Bestellservice/Deutsche_Nachhaltigkeitsstrategie_Neuauflage_2016.pdf?__blob=publicationFile&v=7.

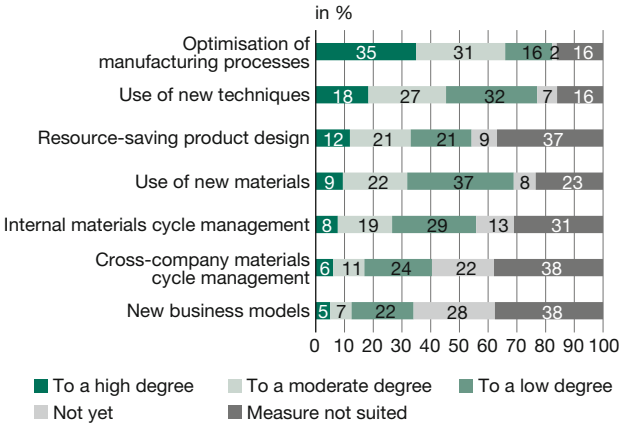
10 Umweltökonomische Gesamtrechnungen: Umweltnutzung und Wirtschaft – Teil 4: Rohstoffe, Wassereinsatz, Abwasser, Abfall - Ausgabe 2015, Wiesbaden 2016, Statistisches Bundesamt.

tion methods and for moving towards a circular economy in German industry. A more detailed discussion of underlying business strategies for raising material efficiency, including a first analysis of the data, is given in Neligan and Schmitz.[11] By making use of a unique dataset, for which survey data was specially and exclusively collected, this paper offers the first representative empirical findings on digital strategies for improving material efficiency in the German manufacturing sector. The dataset contains responses from 589 manufacturing companies that took part in the 27th *IW-Zukunftspanel*, a regular representative survey of business leaders in industry, construction and industry-related services in Germany, from June to August 2016.[12] The results deliver qualitative descriptive answers both on the prevalence and the degree of digital networking of different material efficiency measures. Furthermore, the data allow us to quantify the share of material costs as well as the realised and additional potential material savings.[13]

German industry: Prevalent efficiency-raising strategies

There are several possibilities for optimising the deployment of materials at the various stages of the value chain: saving on materials (efficiency in a narrow sense), recycling and substitution. The survey results show that the German manufacturing sector still focuses on traditional efficiency-increasing measures that optimise manufacturing processes (Figure 1). Examples include preventing waste and rejects or achieving the better utilisation of machinery. In a third of the cases, this approach is applied to a high degree. Additionally, new techniques and materials are also used, albeit to a lesser degree.

Figure 1
Measures adopted by German firms in the manufacturing sector to increase material efficiency



Source: IW-Zukunftspanel, German Economic Institute (IW).

In the future, however, thinking in terms of the entire life cycle of a resource – from its preparation (extraction/processing) through its use (production/consumption) to its aftercare through recycling (circular economy) – will be crucial to further improve resource efficiency. In many manufacturing firms, the basic course for a modern circular economy is not yet set: strategies such as saving materials on a broad scale as early as the product design stage, material cycle management or the adoption of new business models aimed at raising material efficiency are not very common yet. These measures are applied relatively infrequently, and where they are, their application is at a low to medium level. However, closed-loop circulation approaches are considerably more common among large companies.

Depending on their size, industrial companies act differently in applying various material efficiency measures. Medium-sized manufacturing companies (20-249 employees) adopt a strategy for certain measures that is somewhat distinct from other companies in their sector. Nearly half of the medium-sized companies optimise their manufacturing processes to a high degree and use resource-saving product design at least to a medium degree to increase efficiency. Large companies (over 250 employees) generally regard the use of new materials as a suitable approach, but only a few use this measure intensively. Almost half of the large companies use new materials to a minor extent, while a further third makes moderate use of them.

German manufacturing firms see further potential material savings

According to the survey, German manufacturing companies – taking into account their varying levels of material

11 A. Neligan, E. Schmitz: Digitale Strategien für mehr Materialeffizienz in der Industrie – Ergebnisse aus dem IW-Zukunftspanel, IW-Report No. 3, 2017, available at http://www.iwkoeln.de/studien/iw-reports/beitrag/adriana-neligan-edgar-schmitz-digitale-strategien-fuer-mehr-materialeffizienz-in-der-industrie-325155?highlight=materialeffiziznz.

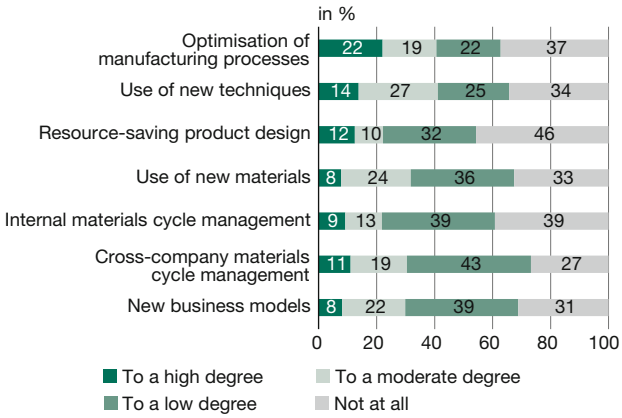
12 One asset of the *IW-Zukunftspanel* survey is that it not only collects general firm data, e.g. turnover, sector and management structure, but also indicators on all relevant aspects of structural change, e.g. innovation, research and development, internationalisation, market environment, and success.

13 In accordance with the German company structure, the majority of surveyed companies are small and medium-sized enterprises, with 231 firms having up to 19 employees (small) and 273 companies between 20 and 249 employees (medium-sized). The remaining 85 firms have more than 250 employees (large). Nonetheless, large companies are overrepresented in the sample in comparison to the total population of German companies. As a result, the responses are weighted representatively on the basis of the German business register to account for possible size effects. Similarly, the weighting also considers that certain industrial sectors might be overrepresented. To compute the past and potential savings volumes, a different weighting is used. In this case, larger companies weigh more heavily due to their higher business volumes.

requirements – have been able to save eight per cent of the materials through material efficiency measures in the past five years. The potential for industrial material savings has not been exhausted yet.[14] In the companies' view, they could save a further three to four per cent if they made optimum use of all technical possibilities. With reference to the €48 billion value of Germany's purchases of mineral raw materials from both domestic and foreign sources (including the indirect import of metals in the form of semi-finished products), the absolute savings potential comes to €2 billion.

This is significantly smaller than indicated in previous studies of Germany.[15] Often, the recalculation of the material saving potential is related to the cost of materials as indicated in the German cost structure survey of the manufacturing industry (of firms with 20 or more employees).[16] Based on those survey results, the savings potential of 3.6% would correspond to almost €30 billion. However, this calculation considerably overestimates the savings potential. This is mainly due to the fact that material expenditure in the German cost structure survey includes not only raw, auxiliary and working materials but also bought-in intermediate products, such as building components. In particular, in the case of finished goods that only need to be built into the products, German companies do not have any realistic ability to increase the material efficiency. Theoretically, additional savings of a similar magnitude would be possible. The main reason is that 40% of Germany's accumulated imports of mineral raw materials are finished goods. In the case of ores, it is as high as 50%. A key requirement would be that international suppliers raise material efficiency to the same extent and fully pass on the resulting cost advantage. However, this is very unlikely to happen.

Figure 2
Level of digitalisation of material efficiency measures in the German manufacturing sector



Note: Percentage of companies applying the respective measures.

Source: IW-Zukunftspanel, German Economic Institute (IW).

Digital strategies for increasing material efficiency

Digitally integrated and cooperating networks within and along value chains make it possible to observe and optimise the use of resources. The availability of all relevant information in real time and the bringing together of different players through intelligent automation technology in industrial manufacturing processes provides consistently high quality and planning security in production. According to the survey results, the possibilities offered by the digital networking of material efficiency measures have only been exploited to a limited extent so far (Figure 2). Today, digitalisation – particularly in the case of large companies – is taking on an important role, most often in combination with the optimisation of manufacturing processes and the use of new techniques, the most prevalent industrial efficiency-raising measures. Companies have most frequently digitalised cross-company material cycles, but this instrument is only applied by two-fifths of industrial companies.

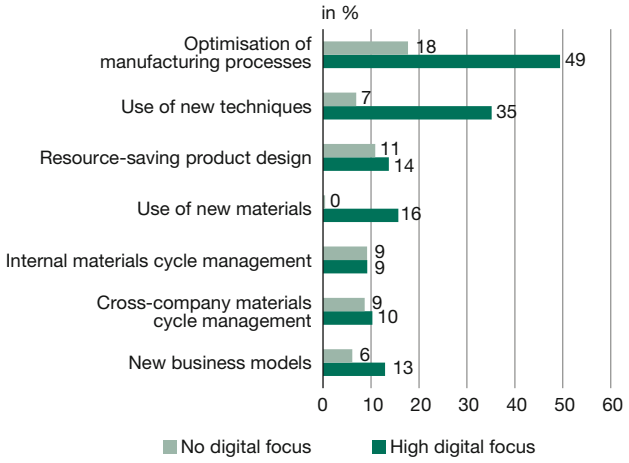
There is still potential for more digitalisation of measures related to product design, material cycle management and new business models. At least every second processing company in Germany reuses residue and waste materials via internal circulation systems. Nonetheless, for two-fifths of these companies, digital networks do not play any role, and in the case of a further two-fifths, the part they play is minor. Only one in ten companies is heavily digitalised. More than half of industrial companies use resource-saving measures that begin at the product design stage. To date, almost half of these companies are not digitally networked, or if they are, it is only to a small extent. Only a third of industrial companies have considered new business models as a way of increasing efficiency. Of these,

14 Zentrum Ressourceneffizienz GmbH: Status quo der Ressourceneffizienz im Mittelstand – Befragung von Unternehmensentscheidern im Verarbeitenden Gewerbe, 2015, available at http://www.ressource-deutschland.de/fileadmin/user_upload/downloads/studien/Studie_VDI_ZRE_Status_quo_Ressourceneffizienz_2015.pdf; M. Schröter, C. Lerch, A. Jäger: Materialeffizienz in der Produktion und Verbreitung von Konzepten zur Materialeinsparung im Verarbeitenden Gewerbe, 2011, available at http://www.deutsche-rohstoffagentur.de/DERA/DE/Downloads/frauenhofer_materialeffizienz_2014.pdf?__blob=publicationFile&v=3.

15 Arthur D. Little GmbH, Wuppertal Institut, Fraunhofer ISI: Studie zur Konzeption eines Programms für die Steigerung der Materialeffizienz in Mittelständischen Unternehmen – Final Report, 2005; M. Schröter, C. Lerch, A. Jäger, op. cit.

16 Statistisches Bundesamt: Kostenstrukturerhebung – Kostenstruktur der Unternehmen des Verarbeitenden Gewerbes sowie des Bergbaus und der Gewinnung von Steinen und Erden, 2016, available at https://www.destatis.de/DE/Publikationen/Thematisch/IndustrieVerarbeitendesGewerbe/Strukturdaten/Kostenstruktur2040430147004.pdf?__blob=publicationFile.

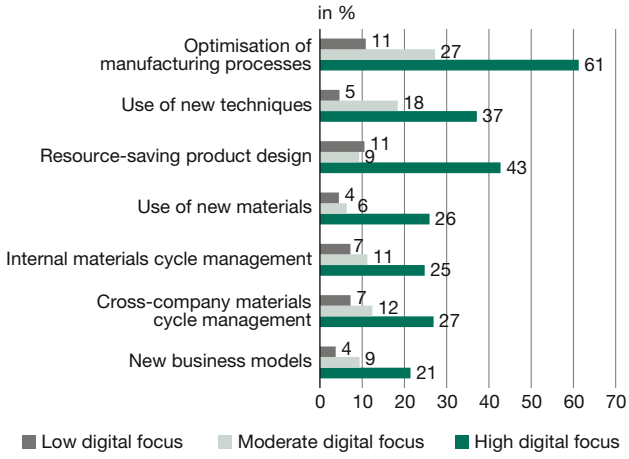
Figure 3
Highly used measures in the German manufacturing sector according to digitalisation strategy



Note: Percentage of companies applying the respective measure to a high degree. All possible indications of the level of usage: high, moderate, low degree, not yet, measure not suited. All possible indications of a company's digital focus: high, moderate, low, no focus.

Source: IW-Zukunftspanel, German Economic Institute (IW).

Figure 4
Highly digitalised measures in German manufacturing firms according to digitalisation strategy



Note: All possible indications of the level of digitalisation: high, moderate, low degree, not at all. All possible indications of a company's digital focus: high, moderate, low, no focus.

Source: IW-Zukunftspanel, German Economic Institute (IW).

three out of ten have not been digitalised yet, with a further two-fifths having only a minor level of digitalisation.

Forerunners in material efficiency: Companies with a digital strategy

German industrial firms currently face the challenge of making digital networking a core component of their business strategy. One striking finding of the analysis is that firms that are already prepared for digital transformation today are also forerunners on the road to improved material efficiency. These companies more frequently use material efficiency measures intensively, they are more likely to recognise further potential savings and their efficiency-saving approaches are also more often highly digitalised. Industrial companies with highly developed digitalisation strategies make considerably more intensive use of new techniques and optimisation approaches in manufacturing processes. They are also more likely to utilise new materials or new business models than companies without a digitalisation strategy (Figure 3).

The material savings potential is also assessed differently depending on the strategic focus on digitalisation in the company. While only one in four manufacturing companies without a digitalisation strategy sees additional savings potential, a third of the companies with a highly developed digitalisation strategy recognise further potential. However, companies that have so far integrated digitalisation into their strategy only to a small or moderate degree are more likely to expect further savings potential. Almost half of the companies with a moderately developed digitalisation strategy see additional savings potential if they make optimum use of all technical possibilities. This also applies to over a third of the companies with a minor strategic focus on digitalisation.

Companies that already have a strong focus on digital transformation in their strategy also tend to have a considerably greater digital emphasis in their material efficiency measures (Figure 4). Differences in the intensity of using digital networks in material efficiency measures can be seen in particular in the optimisation of manufacturing processes. Roughly two in five industrial companies with a clear digitalisation strategy are also highly digitally networked in the areas of resource-saving product design and the use of new techniques, while the digitalisation level in other companies is considerably lower. On average for the entire sector, the figure is somewhat more than one in ten companies. With the other measures, one out of four companies with a highly developed digitalisation strategy are already quite digitally networked with regard to material efficiency measures. This is far less often the case for companies with a minor or moderate strategic focus on digitalisation.

Conclusions

As a highly industrialised country and a G20 and G7 member, Germany has a special responsibility to help achieve

the Sustainable Development Goals. This also implies taking steps towards a sustainable circular economy, which is only possible if the private sector participates in this transformation. As a result of the combination of limited natural resources and increasing global demand for raw materials, using natural resources efficiently is a central challenge for the German economy. At the same time, material consumption is also a considerable cost factor, and therefore, German industry has a self-interest in increasing material efficiency.

Traditional efficiency-raising measures that optimise manufacturing processes are still predominant in the manufacturing sector, but new techniques and materials are also used. In many companies, the basic course for a modern circular economy is not yet set. Strategies for saving materials on a large scale as early as the product design stage, through material cycle management or new business models, are not very common so far. Such approaches, however, are central for a strategic readjustment towards a circular economy.

The opportunities offered by digital networking for increasing material efficiency are only used to a limited extent to date. When they are – particularly in large companies – they tend to be used for process optimisation. Companies have most frequently digitalised cross-company material cycles, but this instrument is only utilised in two-fifths of industrial companies. There seem to be barriers preventing German firms from digitalising their processes more. As a result, the reasons for a lack of digitalisation should be investigated further in order to achieve more sustainable production via digital networking.

Estimates indicate that the German manufacturing sector could save an additional three to four per cent of material. With reference to the value of Germany's purchases of mineral raw materials from both domestic and foreign sources, this translates into a realisable savings potential of €2 billion. A topic for future research is to determine the specific digitalisation-related savings potential and compare it with the associated costs.

In addition, it is still necessary to identify the significant drivers for increasing material efficiency in businesses. One important finding is that firms that are already prepared for digital transformation are also leaders on the road to improved material efficiency. Assuming that primarily innovative companies have already placed digitalisation at the core of their strategies, then innovations could be relevant drivers for greater material efficiency. Hence, questions that remain unanswered include whether less innovative companies have thus far underestimated their possibilities for greater material efficiency and whether innovations lead to improved material efficiency.