Digitalization as Enabler towards a Sustainable Circular Economy in Germany

Adriana Neligan, Senior Economist, Cologne Institute for Economic Research
neligan@iwkoeln.de
+49-30-27877-128
Georgenstrasse 22
10117 Berlin, Germany

Extended Abstract

Moving towards more sustainable patterns of production and consumption have been globally agreed in the Agenda 2030 with its Sustainable Development Goals (SDGs). A special focus is also given to retrofit industries for increased resource-use efficiency in particular in the goals 8, 9 and 12. The German economy also needs to modify further its current ways of production and consumption to save more resources and to avoid more waste. The increasing digital networking in complex industrial production and processes also opens up new potential for more sustainability. This paper delivers the first empirical findings on the relevance of digitalization to improving material efficiency in German industry. The analysis uses a unique dataset, for which survey data was specially and exclusively collected. It consists of responses from almost 600 German manufacturing firms taking part during the summer of 2016 in the representative survey 'IW-Zukunftspanel', which is carried out regularly.

There seem to be still barriers in German firms to digitalize their processes more. One main result is that efficiency-raising measures aimed at saving or circulating materials are only rarely heavily digitalized in the German manufacturing industry. Two main points of the analysis are:

1) To use less material: As a result of limited natural resources in the face of an increasing global demand for raw materials many German industrial firms are already taking measures to minimize their resource consumption as much as possible. Traditional efficiency-raising measures that optimize manufacturing processes are still predominant in the manufacturing sector, but new techniques and materials are also used. In many firms digitalization has already taken place, but very often only to a moderate extent. Furthermore, one in three companies is not yet digitalized.
2) To use resources more than once: In future thinking in complete cycles by looking at the entire life cycle/spectrum of a resource – from its preparation through its use up to its aftercare through recycling (circular economy) will be crucial to further increase resource efficiency. The basic course for a modern circular economy is not set yet in many manufacturing firms: saving materials on a broad scale as early as the product design stage, through materials cycle management or new business models are not very common yet. The results also show there is still more potential for more digitalization of these circular-economy relevant measures.

Keywords: Sustainable Development, Agenda 2030, Resource Efficiency, Circular Economy, Digitalization, Digital Transformation

JEL Classification: Q01, Q55, Q32, D21, P32

1. Background: Moving towards a Circular Economy

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 and consumption to waste management e.g. recycling. A circular economy aims to minimize both material input and waste generation by resource-saving product design (eco-design) and by recycling and re-using products and materials. Through recycling and reuse waste is turned into a resource again.[1]

Moving towards more sustainable patterns of production and consumption have been globally agreed in the Agenda 2030 with its Sustainable Development Goals (SDGs). An important impulse for moving from a linear to a circular economy is given with the Goals. With 12 out of the 17 Goals depending directly on the sustainable use of natural resources for their achievement increasing resource efficiency is an important strategy.[2] In particular with the targets 8.4, 9.4 and 12.2 a special focus is given to retrofit industries towards improved resource-use efficiency until 2030. With target 12.4 which aims at avoiding waste through prevention, reduction, recycling and reuse the idea of a circular economy is also being enhanced.[3]

To contribute to the implementation of the 2030 Agenda the G20 countries decided at the recent 2017 summit to launch the G20 Resource Efficiency Dialogue 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] The importance of resource efficiency had already been recognized by the G7 countries in 2015 by putting the issue as a fixture on the G7 agenda. Apart from the decision of launching the G7 Alliance on Resource Efficiency, the G7 requested two reports by UNEP's International Resource Panel and by the OECD to identify the most promising solutions and approaches for increasing resource efficiency.[5] In parallel, at European level the aim is to achieve greater resource efficiency through resource-saving product design, so-called eco-design, in the context of the EU Action Plan for the Circular Economy.

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[1] Adriana Neligan, Moving Towards a Circular Economy. Europe between Ambitions and Reality, IW Policy Paper No. 9. Cologne: Cologne Institute for Economic Research, 2016, 5-6. Accessed: March 9, 2017. https://www.iwkoeln.de/studien/iw-policy-papers/beitrag/adriana-neligan-moving-towards-a-circular-economy-europe-between-ambitions-and-reality-289257.

[2] Paul Ekins, Nick Hughes et al, Resource Efficiency: Potential and Economic Implications. A report of the International Resource Panel. United Nations Environment Programme: 2017, 265-266. Accessed July 20, 2017. http://www.resourcepanel.org/sites/default/files/documents/document/media/resource_efficiency_report_march_2017_web_res.pdf.

[3] United Nations, Transforming our World: The 2030 Agenda for Sustainable Development, A/RES/70/1, 2015. Accessed July 15, 2017. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf.

[4] European Commission, G20 Leaders' Declaration: Shaping an interconnected world, Statement, July 8, 2017. Accessed July 15, 2017. 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, last updated August 8, 2016. http://www.bmub.bund.de/en/topics/economy-products-resources-tourism/resource-efficiency/resource-efficiency-in-the-g7/#c33831.

Being highly integrated in global value chains industrialized countries, such as for example Germany, play a key role here as they can significantly influence production methods in industrialized, emerging and developing economies giving them a special responsibility towards a more sustainable global production.[6]

Being a highly industrialized economy Germany also needs to modify further its current ways of production and consumption to save resources and to avoid waste. Germany was one of the first European countries with a comprehensive political strategy on resource efficiency. At national level the political objective of decoupling the use of natural resources further from economic development and climate protection is anchored in the German Sustainability Strategy and the German Resource Efficiency Program. As early as 2002 the German Sustainability Strategy set a target of doubling raw material productivity by 2020 relative to 1994 to improve resource efficiency in domestic production. Raw material productivity expresses here how much gross domestic product is generated per ton of abiotic primary material consumed. To achieve this target the German Resource Efficiency Program was implemented in 2012. Every four years an evaluation of the current status and progress of the development of resource efficiency in Germany is undertaken and the program is refined. The first update was realized in 2016. The raw material productivity indicator from the German Sustainable Development Strategy is still a key point of reference for the German Resource Efficiency Program. However, it is supplemented with a new indicator, total raw material productivity, to be able to monitor improvements in resource efficiency, including biotic resources and making adequate allowance for imports. It prevents productivity gains to be reported just because resource-intensive processes are moved abroad. The target is here to sustain the trend from 2000 to 2010 until 2030.[7]

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

As an industrial nation, Germany has a high need for raw minerals. Germany 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

[6] The German Federal Government, Deutsche Nachhaltigkeitsstrategie. Neuauflage 2016, Berlin, 2017. Accessed May 15, 2017. https://www.bundesregierung.de/Content/Infomaterial/BPA/Bestellservice/Deutsche_Nachhaltigkeitsstrategie_Neuauflage_2016.pdf?__blob=publicationFile&v=7.

[7] Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, German Resource Efficiency Program II. Program for the sustainable use and conservation of natural resources. Berlin: 2016. Accessed July 7, 2017. http://www.bmub.bund.de/fileadmin/Daten_BMU/Pools/Broschueren/german_resource_efficiency_programme_ii_bf.pdf.

[8] Peter Bakker, The private sector's role in promoting sustainable development. Accessed July 25, 2017, http://www.wbcsd.org/Overview/News-Insights/Insights-from-the-President/The-private-sector-s-role-in-promoting-sustainable-development.

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 end products such as castings and forgings as well as machine parts.[9] A thriftier use of materials could therefore not only save costs also reduce the dependence on imports.

Hence, many German companies are already taking measures to minimize their resource consumption as much as possible. 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. In order to counter the over-consumption of valuable resources, there are two significant approaches open to businesses:

- To use less material: increasing resource efficiency and preventing waste by better eco-design of products
- To use 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 sustainable productions methods. Digitally integrated and cooperating networks within and along value chains make it possible to observe, follow up on and optimize 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. The growing intertwining of modern information and communications technologies with traditional industrial processes offers new potential for both a thriftier and more efficient use and reuse/recycling of resources. In addition, new business fields can be opened up, for example the sale of a service instead of a product.

2. Aim and Research Question

The aim of this study is to see if the digital transformation in German industry is already an important enabler for more sustainable production methods and for moving towards a circular economy according to the Agenda 2030 and other policies at national, European and international level. In the context of these policies a focus is given to the usage and the level of digitalization of material efficiency measures in German manufacturing firms. 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 (2017).[10]

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[9] Umweltökonomische Gesamtrechnungen, Umweltnutzung und Wirtschaft, Teil 4: Rohstoffe, Wassereinsatz, Abwasser, Abfall, Ausgabe 2015, Wiesbaden: Federal Statistics Office, 2016.

[10] Adriana Neligan and Edgar Schmitz, Digitale Strategien für mehr Materialeffizienz in der Industrie – Ergebnisse aus dem IW-Zukunftspanel, IW-Report No. 3, Cologne: Cologne Institute for Economic Research, 2017. Accessed February 22, 2017, http://www.iwkoeln.de/studien/iw-reports/beitrag/adriana-neligan-edgar-schmitz-digitale-strategien-fuer-mehr-materialeffizienz-in-der-industrie-325155?highlight=materialeffiziznz.

There are four main research questions this paper aims to address:

- How and to what extent do German manufacturing firms improve their material efficiency?
- Is there still further potential for material savings in manufacturing firms?
- What role plays digital networking of material efficiency approaches in manufacturing firms?
- Is digitalization an enabler for more material efficiency in Germany industry?

3. Data set and Method

This analysis provides the first representative empirical findings on digital strategies for improving material efficiency in the German manufacturing sector. It makes use of a unique dataset, for which survey data was specially and exclusively collected to answer the above questions.

The data set contains responses from 589 manufacturing companies taking part in the 27nd survey of the German company survey 'IW-Zukunftspanel' during June to August 2016. 'IW-Zukunftspanel' is a regular representative survey of business leaders in industry, construction and industry-related services in Germany. One asset of the survey is that it not only collects general firm data e.g. turnover, sector, management structure but also indicators on all aspects regarding all relevant aspects of structural change e.g. innovation, research and development, internationalization, market environment and success. In addition, the 27nd survey had a special focus on digitalization. In this context the companies also gave answers on the role of digital networking for increasing material efficiency. The results deliver qualitative descriptive answers both on the prevalence and the degree of digital networking of different material efficiency measures. Furthermore, it is possible to quantify the share of material costs and the realized and further potential material savings with the provided data.

The sample for this analysis is limited to firms in the German manufacturing sector. 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). 85 firms have more than 250 employees (large). Nonetheless, large companies are over-represented in the sample in comparison to the total population of German companies. As a result, the responses are weighed 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 volumina a different weighting is used. In this case larger companies weigh more heavily due to their higher turnover.

4. Empirical results

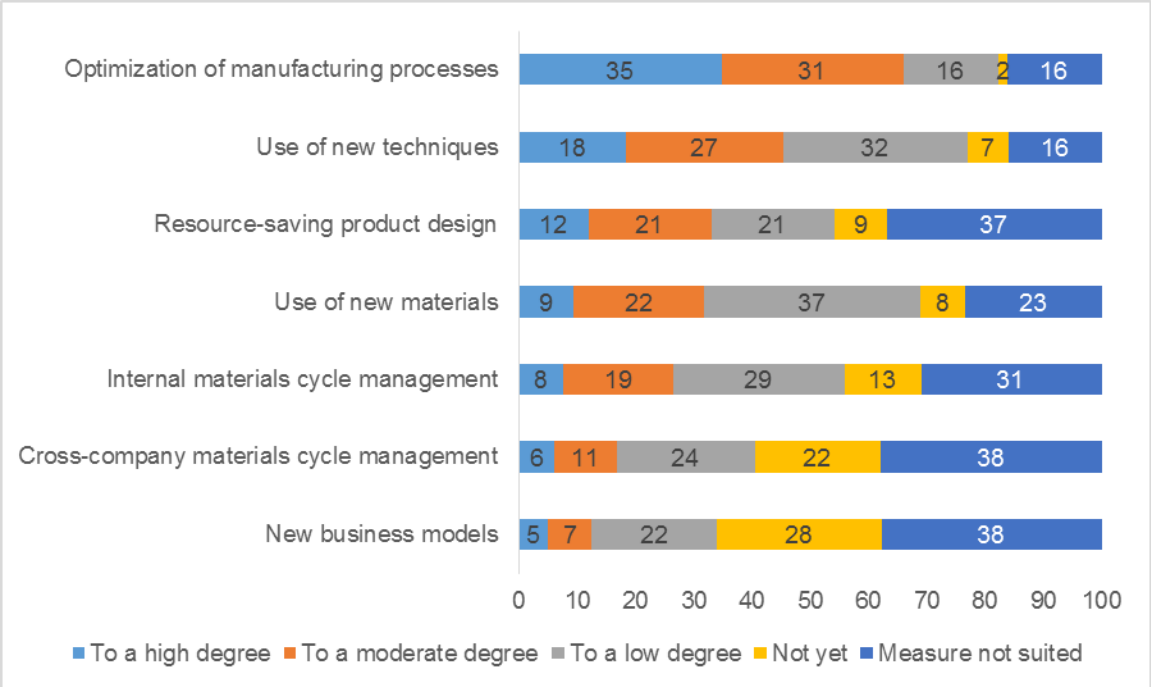
4.1 Business strategies and material savings potential

There are several possibilities for optimizing the deployment of materials at the various levels 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 focusses on traditional efficiency-increasing measures that optimize manufacturing processes. Examples are to prevent waste and rejects or to achieve a better utilization of machinery (Diagram 1). In one third of the cases, this approach is applied to a high degree. However, new techniques and materials are also used, albeit to a lesser degree.

In future, however, thinking in complete cycles by looking at the entire life cycle/spectrum of a resource - from its preparation (extraction/processing) through its use (production/consumption) up to its aftercare through recycling (circular economy) will be crucial to further increase resource efficiency. In many manufacturing firms the basic course for a modern circular economy is not set yet: saving materials on a broad scale as early as the product design stage, through materials cycle management or new business models are not very common yet. These measures are applied considerably less frequently, 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.

Diagram 1: Measures used to increase material efficiency[11]
Shares as a percentage of companies in the manufacturing sector



Depending on their size, industrial companies act differently in some cases in applying different material efficiency measures. With some measures, medium-sized manufacturing companies (20-249 employees) adopt a somewhat diverse strategy from other companies in their sector. Nearly half of the medium-sized companies optimize their manufacturing processes to a high degree and use resource-saving product design

[11] Neligan and Schmitz, Digitale Strategien für mehr Materialeffizienz in der Industrie.

at least to a medium degree to increase efficiency. Large companies (over 250 employees) prefer to use new materials, such as, for example, new material types. Almost half of the large companies use new materials to a minor extent, while a further third makes moderate use of them.

According to the survey, German manufacturing companies – taking account of the varying levels in their material requirements – have been able to save 8 per cent of the materials originally required through material efficiency measures in the past five years. The material savings potential in industry has not been exhausted yet.[12][13] In the companies' view, they could save a further 3 to 4 per cent if they made optimum use of all technical possibilities. With reference to the 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) totaling 48 billion euros, the absolute savings potential comes to 2 billion euros. This is significantly smaller than indicated in previous studies for Germany.[14][15] Often, the recalculation of the materials saving potential is related to the cost of materials indicated in the German cost structure survey (20 employees and more) for the manufacturing industry.[16] In that case, the savings potential of 3.6 per cent (20 employees and more), based on the survey results, would correspond to almost 30 billion euros. However, the savings potential would be considerably overestimated in this calculation. This is mainly to the fact that material expenditure in the German cost structure survey does not only include raw, auxiliary and working materials but also bought-in intermediate products, such as building components. In particular, in the case of finished goods that solely need to be built into the products, German companies have no or hardly any possibilities for increasing material efficiency themselves. Theoretically, additional savings of a similar magnitude would be possible. Main reason is that 40 per cent of Germany's accumulated imports of mineral raw materials are finished goods alone. In the case of ores, it is even 50 per cent. A key requirement would be that international suppliers raise material efficiency to the same extent and pass on the resulting cost advantage fully. However, this is very unlikely to

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[12] Zentrum Ressourceneffizienz GmbH, Status quo der Ressourceneffizienz im Mittelstand Befragung von Unternehmensentscheidern im verarbeitenden Gewerbe 2015, Berlin: 2015, Accessed December 12, 2016. http://www.ressource-deutschland.de/fileadmin/user_upload/downloads/studien/Studie_VDI_ZRE_Status_quo_Ressourceneffizienz_2015.pdf.

[13] Marcus Schröter and Christian, Lerch and Angela, Jäger, Materialeffizienz in der Produktion und Verbreitung von Konzepten zur Materialeinsparung im Verarbeitenden Gewerbe, 2011, Accessed on September 1, 2016.
http://www.deutsche-rohstoffagentur.de/DERA/DE/Downloads/frauenhofer_materialeffizienz_2014.pdf?__blob=publicationFile&v=3.

[14] Arthur D. Little GmbH, Wuppertal Institut, Fraunhofer Institut für System- und Innovationsforschung, Studie zur Konzeption eines Programms für die Steigerung der Materialeffizienz in Mittelständischen Unternehmen. Final Report, 2005. Accessed November 1, 2016.
www.materialeffizienz.de/dateien/fachartikel/studie.pdf.

[15] Schröter and Lerch and Jäger, Materialeffizienz in der Produktion und Verbreitung von Konzepten zur Materialeinsparung im Verarbeitenden Gewerbe.

[16] German Federal Statistics Office, 2016, Kostenstrukturerhebung, Kostenstruktur der Unternehmen des Verarbeitenden Gewerbes sowie des Bergbaus und der Gewinnung von Steinen und Erden, Wiesbaden: 2016. Accessed October 7, 2016,
https://www.destatis.de/DE/Publikationen/Thematisch/IndustrieVerarbeitendesGewerbe/Strukturdaten/Kostenstruktur2040430147004.pdf?__blob=publicationFile.

happen.

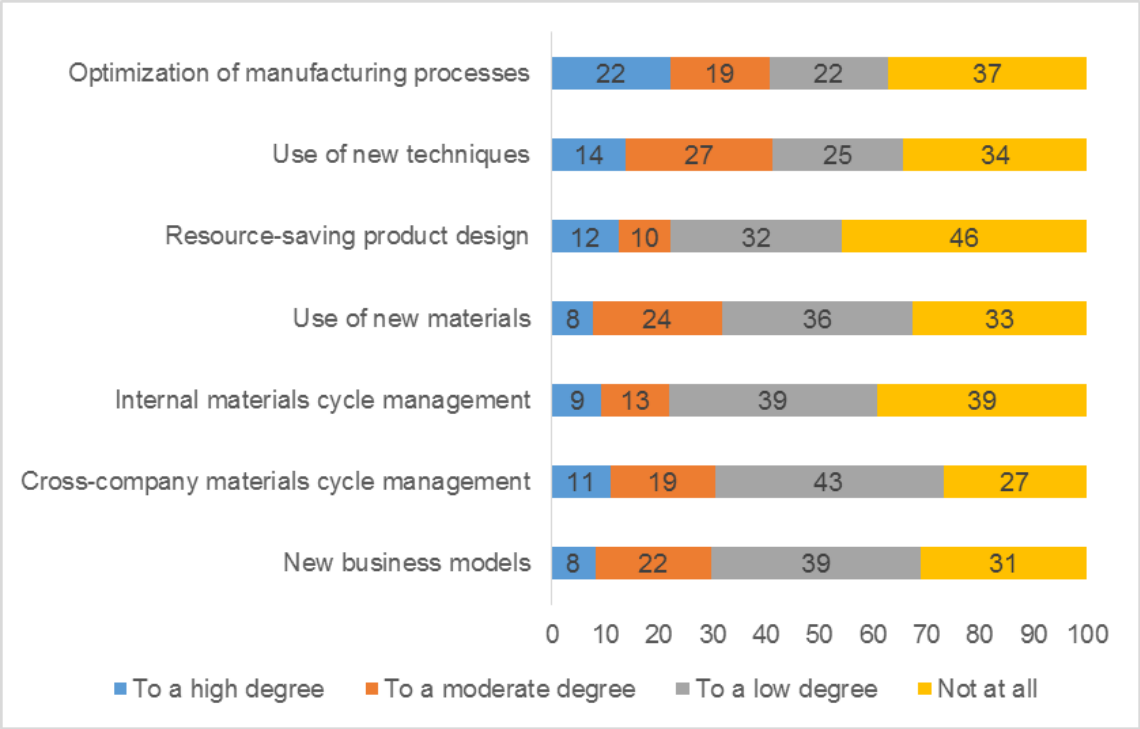
4.2 Digital strategies for increasing material efficiency

The possibilities of digital networking of material efficiency measures have only been exploited to a limited extent so far (Diagram 2). Today, digitalization - particularly in the case of large companies - is taking on an important role, most often in combination with the optimization of manufacturing processes and the use of new techniques, the most prevalent industrial efficiency-raising measures. Companies have most frequently digitalized cross-company materials cycles, but this instrument is only applied by two fifths of industrial companies.

There is still potential for more digitalization of measures relating to product design, materials cycle management and new business models. At least every second processing company reuses residue and waste materials via internal circulation systems. Nonetheless, for two fifths of these companies digital networks do not play any part and in the case of a further two fifths, the part they play is minor. Only one in ten companies is heavily digitalized. 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. One third of the industrial companies up to now have considered new business models as a way of increasing efficiency. Of these, three out of ten have not been digitalized yet with a further two fifths having only a minor level of digitalization.

Diagram 2: Digitalization of material efficiency measures[17]
Shares as a percentage of companies applying the respective measure in the manufacturing sector

[17] Neligan and Schmitz, Digitale Strategien für mehr Materialeffizienz in der Industrie.

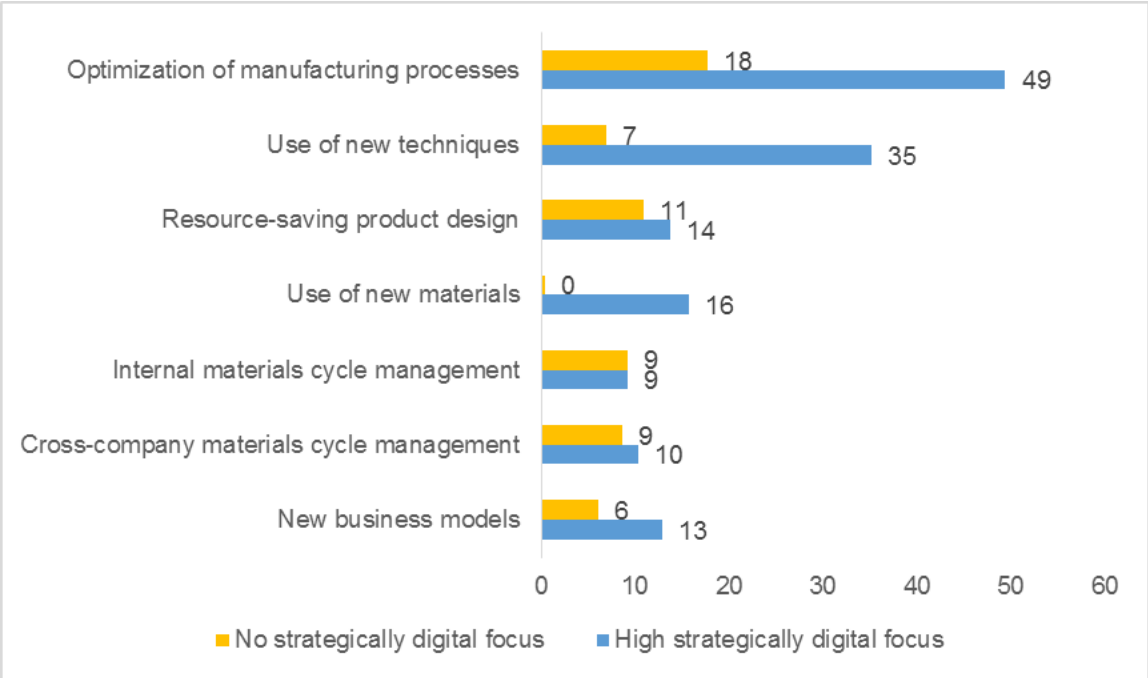


4.3 Forerunners in material efficiency: companies with a digital strategy

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 frontrunners on the road to improved material efficiency. These companies more frequently use material efficiency measures intensively, are more likely to recognize further potential savings and their efficiency-saving approaches are also clearly more often highly digitalized. Industrial companies with a highly developed digitalization strategy make considerably more intensive use of new techniques and optimization approaches in manufacturing processes and also rather avail of new materials or new business models than companies without a digitalization strategy (Diagram 3).

The material savings potential is also assessed differently depending on the degree of digitalization in the company. While only one in four manufacturing companies without a digitalization strategy will see additional savings potential, a third of the companies with a highly developed digitalization strategy recognize here further potential. However, companies that up to now have only integrated digitalization into their strategy to a small or moderate degree expect more often further savings potentials. Almost half of the companies with a moderately developed digitalization strategy see still additional savings potential if they make the optimum use of all technical possibilities. This also applies to over a third of the companies with a minor strategic focus on digitalization.

Diagram 3: Important measures according to digitalization strategy[18]
Shares as a percentage of companies in the manufacturing sector applying the respective measure to a high degree according to strategic focus on digitalization[19]

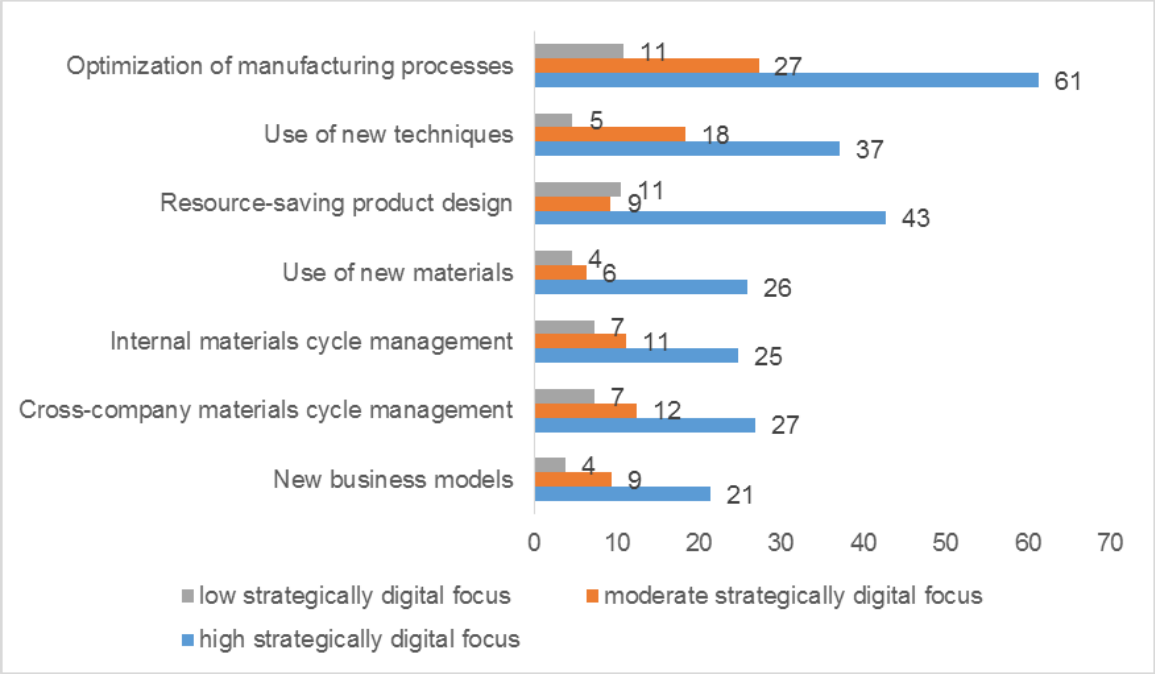


Companies that already have a strong focus on digital transformation in their strategy also tend to have a considerably greater digital emphasis in their material efficiency measures (Diagram 4). Differences in the intensity of using digital networks in material efficiency measures can be seen in particular in the optimization of manufacturing processes. Roughly two in five industrial companies with a clear digitalization strategy are also highly digitally networked in the areas of resource-saving product design and the use of new technologies, while the digitalization level in other companies is considerably lower. As an overall average, it is somewhat more than one in ten companies. With the other measures too, one out of four companies with a highly

[18] Neligan and Schmitz, Digitale Strategien für mehr Materialeffizienz in der Industrie.
[19] All possible indications of the level of usage: to a high, moderate, low degree, not yet, measure not suited. All possible indications of strategic focus on digitalization: to high, moderate, low, no focus.

developed digitalization strategy is already well digitally networked concerning material efficiency measures, while this is far less often the case for companies with a minor or moderate strategic focus on digitalization.

Diagram 4: Highly digitalized measures according to digitalization strategy[20]
Shares as a percentage of companies in the manufacturing sector having the respective measures highly digitalized according to their strategic focus on digitalization[21]



5. Conclusions

Moving towards more sustainable patterns of production and consumption have been globally agreed in the Agenda 2030 with its Sustainable Development Goals (SDGs). Being a highly-industrialized country and a G20 and G7 member Germany has a special responsibility in achieving these targets. This also implies a step towards a circular economy which is only possible if the private sector participates in this transformation. Thus, the private sector plays a pivotal role towards moving Germany towards a sustainable circular economy. As a result of limited natural resources in the face of an increasing global demand for raw materials saving natural resources is a central challenge for the German economy to secure raw materials supplies. At the same time material consumption is also a considerable cost factor. Therefore, German industry has a self-interest to increase material efficiency.

[20] Neligan and Schmitz, Digitale Strategien für mehr Materialeffizienz in der Industrie.
[21] All possible indications of the level of digitalization: to a high, moderate, low degree, not at all. All possible indications of strategic focus on digitalization: to high, moderate, low, no focus.

Traditional efficiency-raising measures that optimize 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: saving materials on a grand scale as early as the product design stage, through materials cycle management or new business models are not very common so far. Latter approaches, however, are central for a strategic readjustment towards a circular economy.

The opportunities of digital networking for increasing material efficiency are only used to a limited extent to date. If they are - particularly in large companies - they tend to be used for process optimization. Companies have most frequently digitalized cross-company materials cycles, but this instrument is only applied by two fifths of industrial companies. There seem to be still barriers in German firms to digitalize their processes more. As a result, the reasons for a lack of digitalization should be investigated further to be able to achieve more sustainable production via digital networking.

In future, more material can be saved in German industry. The available saving potential in the German manufacturing sector is estimated to be 3 to 4 per cent. With reference to the value of Germany's purchases of mineral raw materials from both domestic and foreign sources, this translates into a realizable savings potential of 2 billion euros. Yet, a future task is to determine the specific digitalization-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 striking finding is that firms that are already prepared for digital transformation today are also frontrunners on the road to improved material efficiency. Assuming that primarily innovative companies have already placed digitalization at the core of their strategy, then innovations could be relevant drivers for greater material efficiency. Hence, questions that remain unanswered are whether less innovative companies up to now have underestimated their possibilities for greater material efficiency and whether innovations lead to improved material efficiency.