Vodafone Institute for Society and Communications

accenture

SEED Index 2023

Sustainable
Economic
Efficiency through
Digitalisation

seed

Digitalisation, decarbonisation and profitability in five sectors: buildings, industry, agriculture, logistics and electricity

Sustainable Economic Efficiency through Digitalisation

The newly created SEED Index measures the pulse of digitalisation efforts in the German economy. It links decarbonisation and profitability – two key effects of digitalisation – and assesses developments in five key sectors. In doing so, the Index shows how much progress German companies have made in the so-called “twin transition”. The study on which the Index is based determined the extent to which companies are already using digital technologies to reduce their CO_2 emissions and boost their profitability. It answers the question of how future-proof the German economy is.

Sustainable Economic Efficiency through Digitalisation

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Foreword

Dear readers,

The time when climate protection was considered a money-loser for companies is over. The Vodafone Institute's SEED Index study shows that, rather than being opposites, sustainability and profitability go hand in hand. This paradigm shift will be crucial for the future of Germany's economy and our planet.

Germany faces the challenge of achieving the ambitious climate targets set by its federal government. Our study shows that digitalisation will be the key not only to tackling this transition, but also to benefiting from it economically. With a SEED Index value of 53 out of 100, German companies are currently only leveraging half of the available potential. However, digitalisation offers a unique opportunity to boost efficiency, reduce emissions and increase competitiveness at the same time.

As a leading digitalisation company, Vodafone believes it has a responsibility to actively shape this transition. We are convinced that the future will be digital and sustainable.

Instead of being an additional cost factor, technologies are an investment in the future – a profitability booster that will also benefit the planet.

The SEED Index will serve as an indicator of the future viability of the German economy, and the study's findings are an appeal to all companies to view digitalisation as a promising prospect. By using artificial intelligence, augmented reality, IoT and the like, German companies can save 36% more CO_2 by 2030 and increase their EBIT growth by as much as 90%. This shows that there is no contradiction between ecological responsibility and economic success.

The future is starting now. Together, we can help to shape a sustainable and thriving digital economy. Let's ensure that Germany stays competitive.

Best regards,
Michael Jungwirth

Michael Jungwirth

Managing Director of Public Affairs, Regulatory, External Communications and Sustainability, Vodafone Deutschland

Foreword

Dear readers,

In a time that calls for ambitious climate-protection efforts and sustained competitiveness from our economy, the twin transition – the fusion of the digital and sustainable transitions – must no longer be merely a catchphrase. This study demonstrates that it can succeed. It shows how digitalisation and decarbonisation complement each other in order to achieve ambitious climate targets and boost the profitability of German companies at the same time. Although its findings give us hope, as things currently stand, the German economy still has a whole lot of catching up to do.

As an internationally active technology and strategy consultancy, we know how essential the increased use of digital technologies will be for the competitiveness of companies – and for the decarbonisation of the economy. This study sheds light on the interrelation of the two using specific use cases in five key economic sectors: From more precise fertilisation of agricultural land by using satellite data to energy savings in factories by using artificial intelligence and digital twins – the possibilities already exist, and the potential is huge.

The heart of the study is the new SEED Index, which links the decarbonisation and profitability effects of digitalisation. In addition to measuring the extent to which German companies are using digital technologies, it shows where the German economy stands and which potentials can still be leveraged: In 2030, digital technologies could reduce annual CO_2 emissions by around 42 million tonnes and increase EBIT in the five key sectors by around €53 billion in total.

The study is an urgent appeal to companies, associations, policymakers and researchers to recognise and actively promote digitalisation as a key factor for greater climate protection and profitability – for the future viability of the German economy.

Munich, 23 April 2024
Christina Raab

Christina Raab

Market Unit Lead for Accenture in Germany, Austria and Switzerland

Index and study at a glance
Innovative, comparable, practice-oriented

Innovative: The SEED Index is an indicator of how future-proof the German economy is

The SEED Index links two effects of digitalisation: decarbonisation and profitability.

A cross-sector SEED Index value was calculated for 2023. To calculate this value, the decarbonisation and profitability effects of digital technologies in German companies in 2023 were compared with those expected in 2030.[a]

The higher the SEED Index value, the more future-proof Germany's economy is in both fields. In this context, 0–59 points are considered "insufficient", 60–74 as "improvable", 75–89 as "good", and 90–100 as "excellent".[b]

Comparable: The sectors can be compared with each other on the basis of the same indicators

The study aims to show companies and policymakers how both decarbonisation and profitability can be increased.

To do so, the following figures were calculated:[a]

- Current and expected adoption rates[c] of use cases of digital technologies
- CO_2 savings in 2023 and potential savings in 2030
- Impact on profitability in 2023 and potential impact in 2030

Practice-oriented: A total of 26 use cases were analysed in five sectors

The study identifies a total of 26 use cases for digital solutions based on five sectors and 12 sub-sectors. These were selected on account of their major contribution to decarbonisation for companies.

To determine the key figures for the use cases, a total of 201 company surveys were conducted by the market research company Atheneum between 1 June and 15 September 2023.

Notes: a) Further explanations of the methodology can be found on p. 12 and in the Appendix, Chapter 5.1, p. 97 ff.; b) See also p. 13; c) See also definitions on p. 14.

Index and study at a glance

Figures, facts and arguments

31 megatonnes
of CO_2 were saved by German companies in 2023 thanks to digital technologies.

1.5
is the factor by which German companies must accelerate their digitalisation efforts if they are to catch up with global benchmarks.

€53 billion
is the estimated absolute increase in EBIT that can be achieved by the use cases of digital technologies in 2030 – or 90% more than today.

53 out of 100
is the SEED Index value for 2023: German companies are only leveraging half of the decarbonisation and profitability potential of digitalisation.

9%
is the EBIT increase in the five key sectors in 2023 that can be attributed to using the use cases of digital technologies described in this study.

A 100% increase
of the EBIT margin resulting from the use cases of digital technologies is possible by 2030.

10%
is the amount that companies can contribute to the German government's CO_2 emissions target in 2030 by using digital technologies.

Only 49 out of 100
is the value of the decarbonisation sub-index – which is proof that Germany's economy is far from exhausting its decarbonisation potential.

29%
was the adoption rate of digital technologies in German companies in 2023.

45%
is the adoption rate of digital technologies expected by German companies in 2030 – or only 16 percentage points more than today.

6–7
is the range of the enablement factor of digital technologies, meaning the ratio between the CO_2 savings and the CO_2 footprint of digital technologies.

26
use cases of digital technologies, which were selected owing to their high contribution to decarbonisation efforts, are presented in the study for 12 sub-sectors.

1 SEED Index

1.1 Introduction

Why this study? Why an index?
Spurring the transition

What challenges are German companies facing?

1. **Twofold transformation** – The challenge for German companies – to become more sustainable and more digital – is not only a big one; it must also happen at the same time. Linking the sustainability transition with the digital transition will be decisive for long-term success.[1,2]
2. **Growing competitive pressure** – Key sectors in Germany are struggling with rising costs and a rather limited presence in growth markets. They will need to confront strategic changes head-on and invest wisely if they are to remain among the leaders in their sectors.[3–8]
3. **Decarbonisation as a business case** – Using digital technologies for decarbonisation will need to make sense in both financial and ecological terms. If decarbonisation goes hand in hand with an increase in profitability thanks to digitalisation, the business case will be clear.[9]
4. **The digital gap** – Many companies do not know exactly how digital technologies can contribute to decarbonisation and boost profitability at the same time. Measuring, comparing and verifying these effects will help to close the gap.[10]

What key questions does this study address?

To what extent do digital technologies contribute to decarbonisation and increased profitability in German companies?

How high are the decarbonisation and profitability effects today, and how high will they be in 2030?

How can these effects be measured and compared simply and regularly (via monitoring) for Germany’s economy?

How wide will the gap between the adoption of digital technologies in German companies and global benchmarks be in 2030?

Note: a) Theoretically possible degrees of implementation of digital technologies, which are based on secondary data and expert assessments. As points of reference, we used (i) leading global companies or (ii) countries with extensive implementation of the use cases as well as (iii) growth rates for technological developments. See also p. 13. Sources: 1) Bertelsmann Stiftung, 2023; 2) Fraunhofer IAO, 2023; 3) Grömling, 2022; 4) Handelsblatt, 2019; 5) Olk, 2023; 6) Tagesschau, 2023; 7) WEF, 2022; 8) Wirtschaftsdienst, 2023; 9) WEF, 2024; 10) Nachtwey & Schmid, 2022.

What is analysed, and what is the target objective?

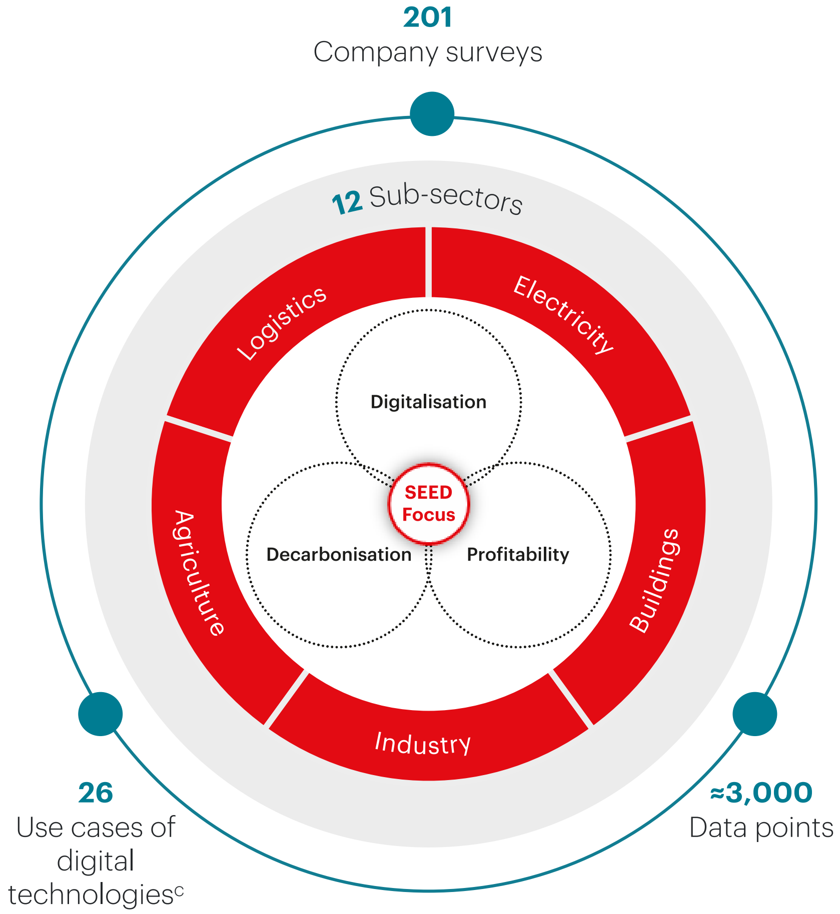
Facts for forecasting and decision-making

sustainable economic
efficiency through digitalization

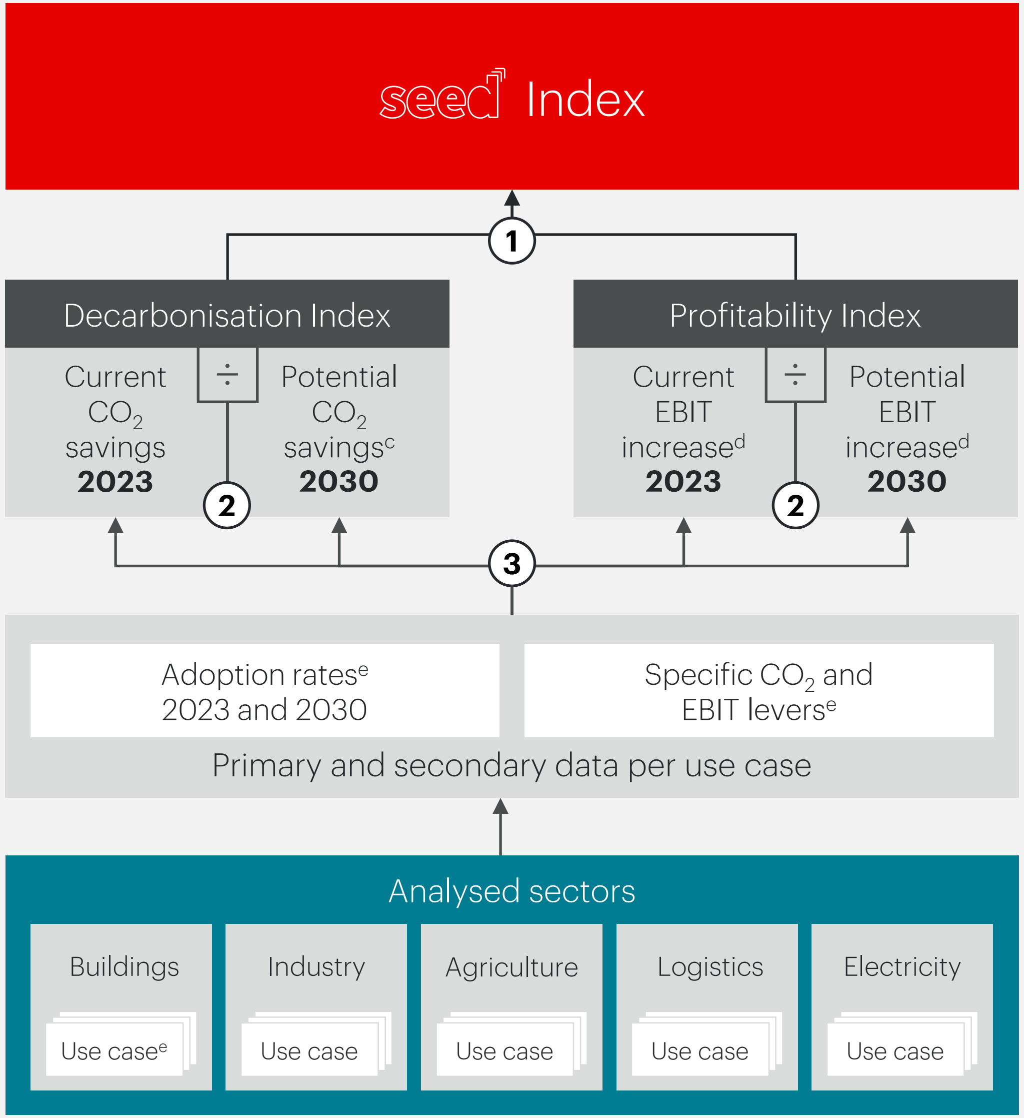
Focus – This study focuses on the overlapping of digitalisation, decarbonisation and profitability (see graphic) in order to address the aforementioned challenges and questions. The meta-analysis of over 300 publications carried out in advance shows: An in-depth investigation at this interface, especially for Germany and its most CO_2-intensive sectors[a,b] (see graphic), will provide a great deal of insight for corporate practice.

Idea and scope – Based on a survey of 201 companies and research efforts that yielded over 3,000 data points, the SEED Index summarises the status and development of two key indicators of the performance of the German economy in 2023 and 2030: (1) The adoption rate[c] of digital technologies in companies as a benchmark for utilisation and (2) the resulting CO_2 savings and profitability increases in companies – in 5 sectors, 12 sub-sectors and for 26 use cases[c] of digital technologies.

Objective – The SEED Index is a new indicator that measures how future-proof German companies are by analysing how they are reducing their CO_2 emissions and boosting their profitability by using digital technologies. Focusing on the current status (2023) and the year 2030 facilitates comparisons and forecasts, which will provide guidance for decision-makers in business, politics and civil society.



Notes: a) This refers to carbon dioxide equivalents, which serve as a unit of measurement to express the global warming potential of various greenhouse gases in relation to carbon dioxide (CO_2). In the study, this is abbreviated to CO_2 to improve readability. b) The five selected sectors (including energy) represent 99.4% of Germany's total emissions (745.7 megatonnes) in 2022, according to UBA, 2023m. The figures for 2023 were not yet available at the time of the study; c) See definitions on p. 14.



seed Index

1

Decarbonisation Index

Current CO_2 savings **2023** ÷ Potential CO_2 savings[c] **2030**

2

Profitability Index

Current EBIT increase[d] **2023** ÷ Potential EBIT increase[d] **2030**

2

3

Adoption rates[e] 2023 and 2030

Specific CO_2 and EBIT levers[e]

Primary and secondary data per use case

Analysed sectors

Buildings	Industry	Agriculture	Logistics	Electricity
Use case[e]	Use case	Use case	Use case	Use case

How is the SEED Index value calculated?
Combination of two sub-indices

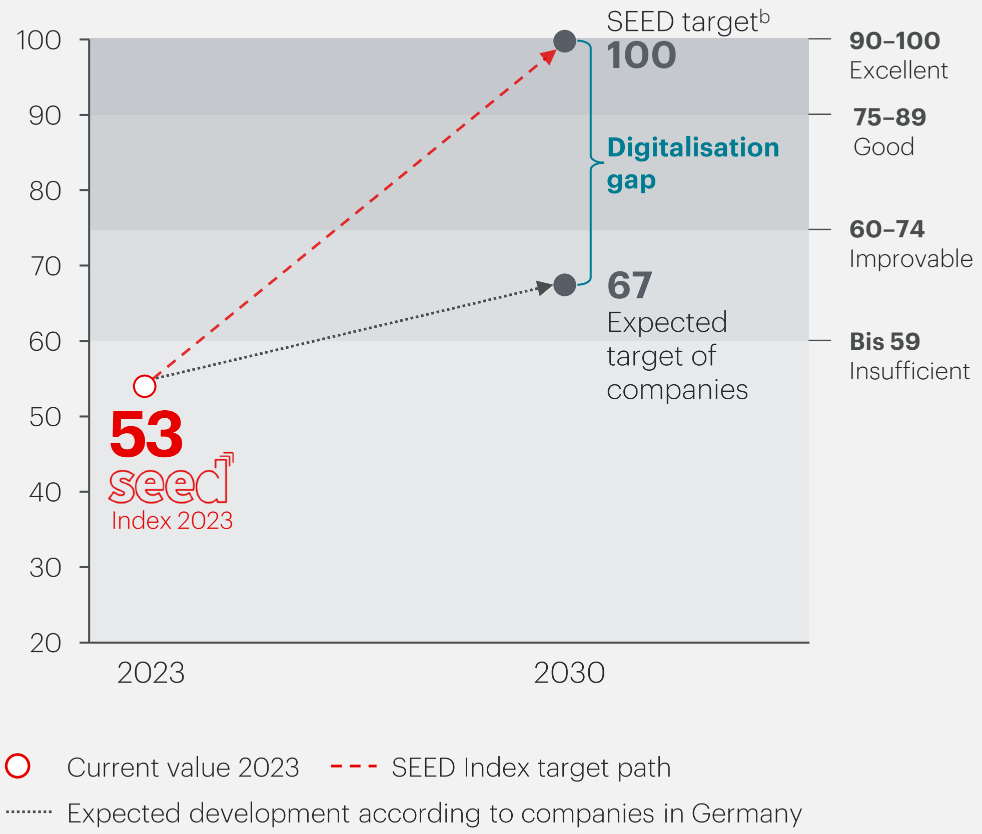
Proposition and composition[a] – The SEED Index shows the extent to which companies in Germany are already in a position to leverage their potential for decarbonisation and increased profitability.[b] It is therefore made up of two sub-indices (see graphic, point 1): the Decarbonisation Index, which quantifies the CO_2 savings effects of digital technologies, and the Profitability Index, which quantifies the corresponding EBIT effects. The linked, equally weighted consideration of ecological and economic effects is also expressed in the name of the index: Sustainable Economic Efficiency through Digitalisation (SEED). Both research and practice show that decarbonisation and profitability are often complementary or mutually reinforcing – particularly thanks to the increasing internalisation of CO_2 emissions through direct or indirect pricing.[1–4]

Calculation method[a] – The two sub-indices are calculated based on the ratio of the effects in 2023 to the potential effects in 2030 (see graphic, point 2). In other words, for the respective index value, the current CO_2 savings or EBIT increases are divided by the respective values forecast for 2030. Since it can be assumed that the adoption of digital technologies and technical improvements will intensify in the future, the potential for 2030 is estimated to be higher than for 2023.

Notes: a) See also Chapter 5.1 Methodology, p. 98 ff.; b) For this reason, their interpretation is also referred to in the text as “decarbonisation potential” or “profitability potential”; c) 2030 serves as a key reference year, mainly due to its importance in global climate agreements, such as the 2015 Paris Agreement; d) The EBIT effect is measured as an increase in the EBIT margin in percentage points, see Chapter 5.1 Calculations, p. 108 ff.; e) see definitions, p. 14. Sources: 1) Accenture, 2021; 2) Vigna et al., 2023; 3) Crispeels et al., 2023; 4) WEF, 2022.

At 53 out of 100 points, the current index value shows that German companies are only leveraging half of the potential of digital technologies.

SEED Index value



What does the SEED Index tell us?

The digitalisation gap is widening

Germany's economy will have to massively accelerate the adoption of digital technologies if it is to close the digitalisation gap by 2030.

A comparison of the SEED Index values for 2023 and 2030 reveals a widening digitalisation gap. This gap results from the discrepancy between the SEED target value of 100 (see definition) and the SEED Index value of 67 forecast for 2030, which is based on German companies' expectations regarding the adoption of digital technologies.

The higher the SEED Index value, the more future-proof Germany's economy is in terms of decarbonisation and profitability. In this context, 0–59 points are considered "insufficient", 60–74 as "improvable", 75–89 as "good", and 90–100 as "excellent". At 53 points, the SEED Index is currently insufficient.

Definitions

SEED target value: The SEED target value for 2030 is derived from companies' expected adoption rates and global benchmarks.[a]

Benchmarks: Theoretically possible degrees of implementation of digital technologies, which are based on secondary data and expert assessments. As points of reference, we used (i) leading global companies or (ii) countries with extensive implementation of the use cases and (iii) growth rates for technological developments.

Notes: a) See also SEED adoption path, p. 26; b) See definition in the definition box.

How are the sub-indices for the SEED Index calculated?

Sub-indices based on bottom-up calculation

Sector indices as a basis – The calculation of the two aforementioned sub-indices is based on sector-specific data. A separate decarbonisation index and a separate profitability index are calculated for each sector. Taken together and weighted, these sector indices then result in the cross-sector sub-indices.[a]

Calculation of CO_2 savings and EBIT increase – The two values are calculated separately for each year – 2023 and 2030 (see graphic, p. 12, point 3). The CO_2 savings mainly depend on the adoption rate of the use case and the specific CO_2 reduction level (see definitions). The same holds true for the increase in EBIT (see definitions). Both the assumed adoption rates and the levers are based on data from the company survey and secondary data.[b] A detailed explanation of the data basis, calculation methods and sources can be found in the Appendix in Chapter 5, p. 98 ff.

Selection of sectors and use cases – When selecting the sectors and use cases (see definition), the main focus was on effective decarbonisation. The key question was therefore: Which sectors, sub-sectors and use cases account for the largest share of company-related CO_2 emissions? Use cases that address the most emissions-intensive sectors and sub-sectors in Germany were accordingly selected.

The five selected sectors – buildings, industry, agriculture, logistics and electricity – represent 99.4%[1] of Germany's CO_2 emissions.[c] They are therefore considered key sectors for decarbonisation. The 26 use cases analysed in turn cover 94.5%[d] of the CO_2 emissions addressed by companies in Germany.

Definitions

Adoption rate: The adoption rate indicates the extent to which digital technologies are used in companies. It reflects the degree of implementation of specific use cases, which was calculated using the company survey for 2023 and as a forecast adoption rate for 2030. The adoption rate was quantified using a Likert scale (often referred to as a five-point scale) ranging from 0 to 100 percent.

CO_2 and EBIT levers: These key figures indicate the influence of a specific use case on the reduction of CO_2 emissions or the increase in EBIT per reference value (e.g. per building) as a percentage. They were determined based on specific impact levers (e.g. energy savings, reduction in personnel costs) using the company survey and analyses of secondary data.

Use Case: A use case represents the specific application of a digital solution in everyday business operations – whereby a variety of digital technologies are usually used in combination.

Notes : a) For the weighting logic, see Chapter 5.1 Methodology, p. 114; b) Detailed figures and sources can be found in the Appendix, Chapter 5.2, p. 117 ff.; c) The CO_2 emissions of the five sectors (incl. energy) amount to 741.4 Mt of CO_2 out of a total of 745.7 Mt of CO_2 in 2022, according to UBA, 2023m. The figures for 2023 were not yet available at the time of the study; d) See Chapter 5.1 Methodology p. 100. Source: 1) UBA, 2023n.

How are potentials calculated?

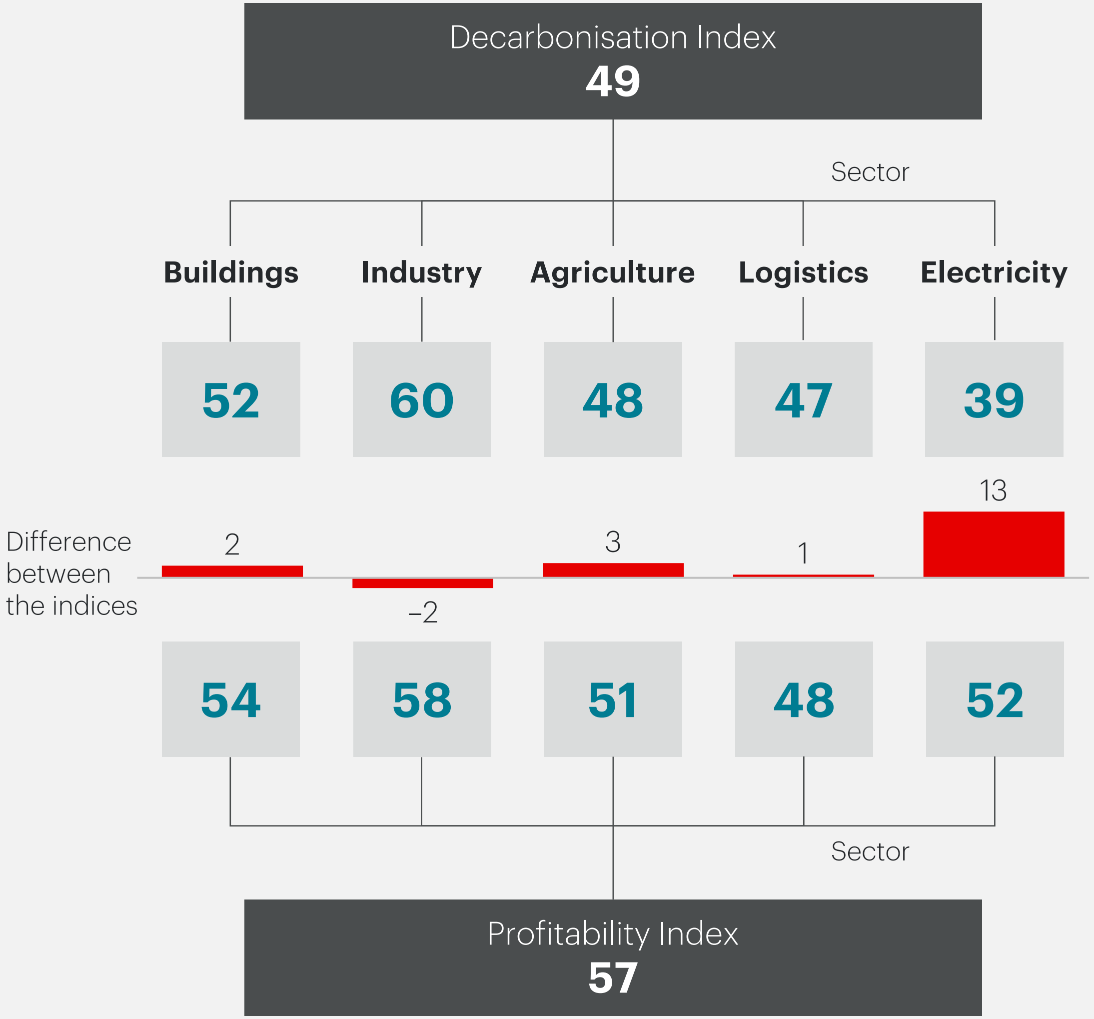
A comparison of the sub-indices by sector

There is still great potential for decarbonisation and profitability in all sectors.[a] The latter are exploited somewhat better on average.

The figure compares the sub-indices for decarbonisation and profitability – both across sectors and in relation to the five sectors. The comparison reveals that using digital technologies contributes more to an increase in profitability (index value 57) than in decarbonisation (index value 49).

On the other hand, a comparison of the sector-specific sub-indices shows the electricity sector exhibiting the largest difference (13 index points) between the two sub-indices. The profitability potential is much better leveraged in this case than the decarbonisation potential. The opposite is the case for the industry sector: In this case, the focus is more on decarbonisation (index value 60) than on profitability (index value 58).

The findings from the comparison of the Decarbonisation Index and the Profitability Index are presented in Chapters 1.2 and 1.3.


Decarbonisation Index
49

Sector

Buildings
Industry
Agriculture
Logistics
Electricity

52
60
48
47
39

Difference between the indices
2
–2
3
1
13

54
58
51
48
52

Sector

Profitability Index
57

Note: a) The sub-indices measure the extent to which companies in Germany are already able to leverage their potential to decarbonise and boost their profitability. For this reason, their interpretation is also referred to in the text as "decarbonisation potential" or "profitability potential" (see also p. 12 for details on the sub-indices). A low value signifies a high potential through digitalisation by 2030 or a relatively low leveraging of the potential today vis-à-vis 2030.

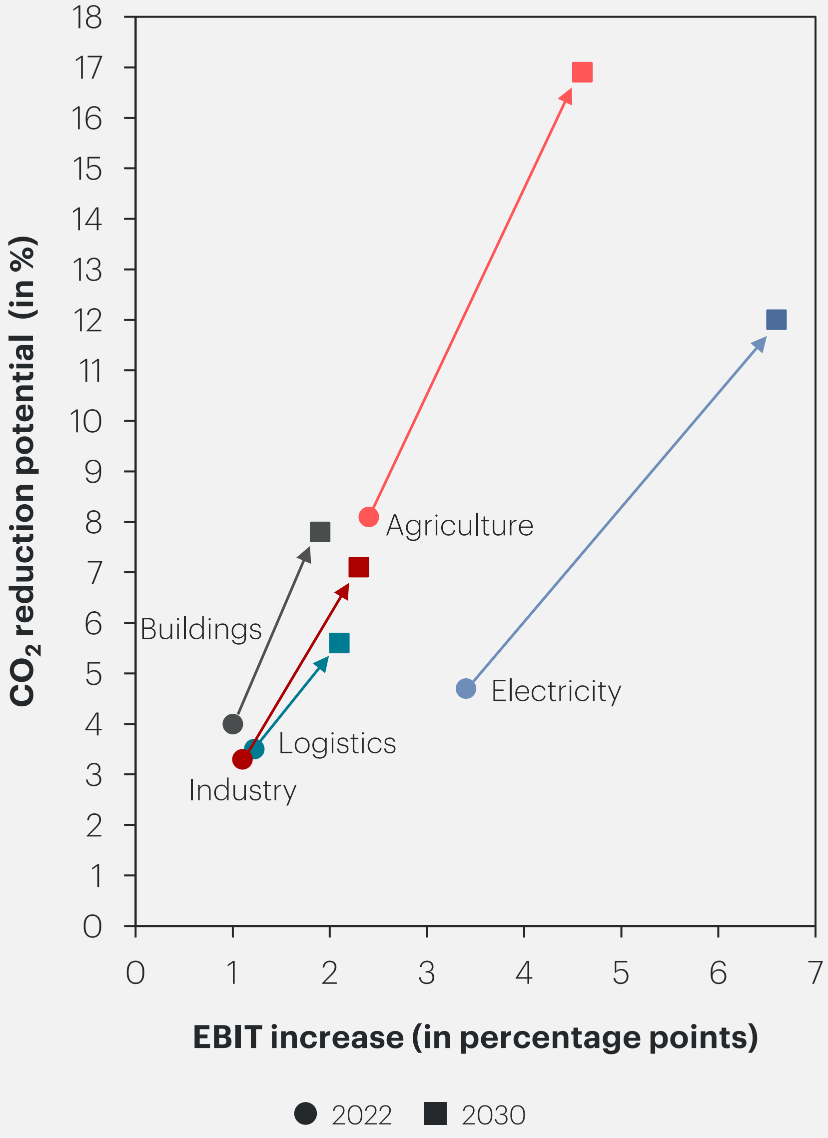
Why does the Index represent future viability?
Comparison of the CO_2 and EBIT effects

The adoption of digital technologies in companies has a major impact on CO_2 savings and EBIT increases. Both effects will be crucial for the future viability of companies.

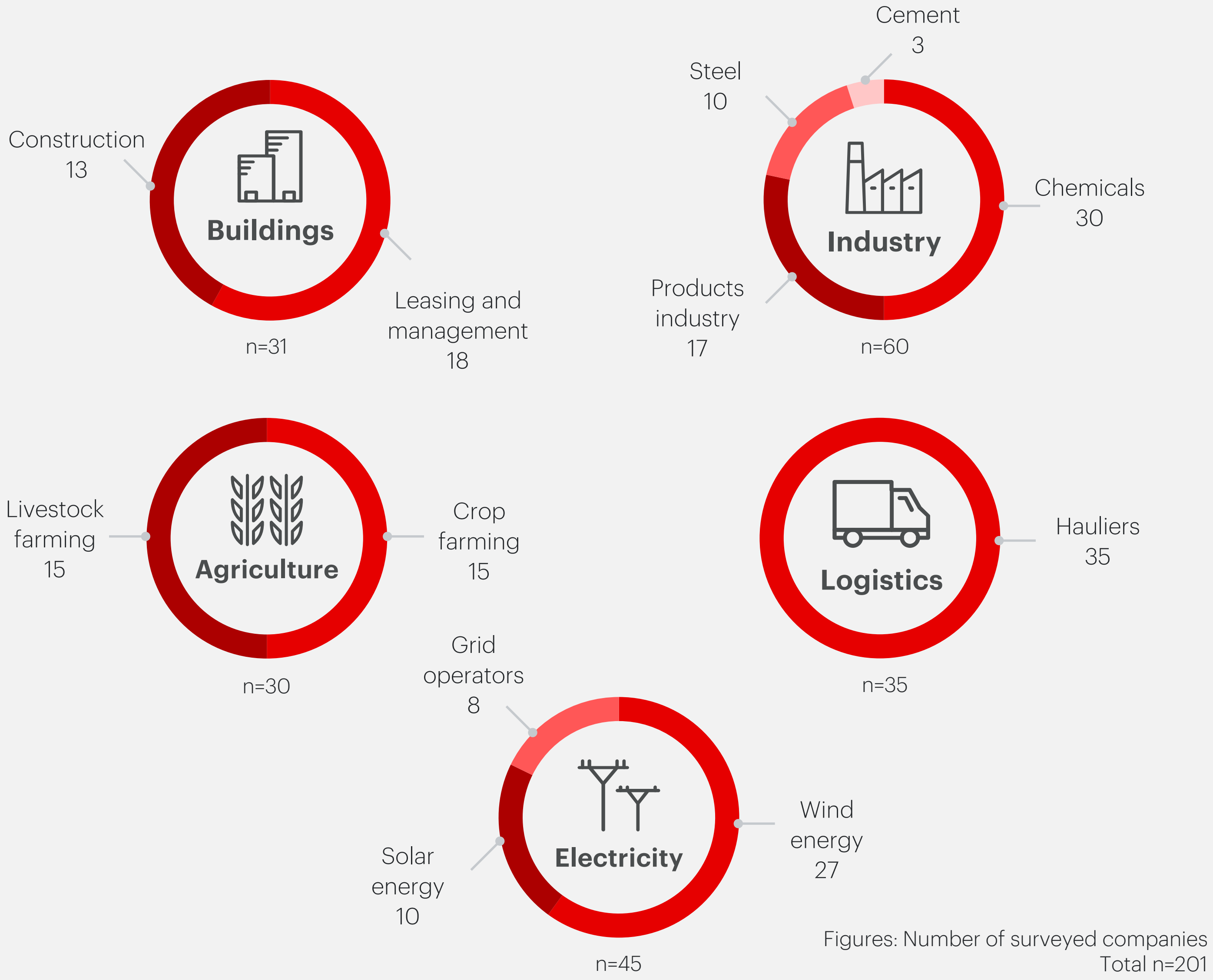
The sector comparison (see graphic) shows that using digital technologies will contribute to both CO_2 savings and EBIT increases in all five analysed sectors. Particularly noteworthy are the electricity and agriculture sectors, where digitalisation is expected to have the greatest decarbonisation- and profitability-related effects in percentage terms. There are two additive reasons for this.

First: Compared to the other sectors, a high adoption rate[a] of digital technologies is forecast for 2030 in the agriculture (63%) and electricity (60%) sectors. This forecast is based on the significant increase in adoption rates – by +31 percentage points in the agriculture sector and by +27 percentage points in the electricity sector – between 2023 and 2030. For the reasons, see also Chapter 1.4 Adoption Rates (p. 25 ff.).

Second: In both sectors, the CO_2 and EBIT levers are greater compared to the other sectors. Digital technologies will lead to a significant reduction in CO_2 emissions – up to 14% per hectare or livestock unit. In addition to cost savings, operators of wind and solar power systems will also see revenue increases of up to 8% as a result of efficiency improvements and the associated increase in capacity.[b]



Notes: a) See also definitions, p. 14; b) See also Chapter 5.1 Data Basis, p. 101, and Chapter 5.2 Figures in Detail, p. 117 ff.



Figures: Number of surveyed companies
Total n=201

What is the data based on?
The company survey

Companies from the key sectors were surveyed in order to determine current adoption rates as well as CO_2 and EBIT levers.

A total of 201 companies from five sectors and 12 sub-sectors provided answers on adoption rates, CO_2 and EBIT levers in 2023[a] (see also definitions on p. 14). These key figures were collected specifically for each individual use case.

The adoption rate was quantified in a scale ranging from 0 to 100 percent. The CO_2 and EBIT levers were calculated in the form of minimum and maximum values using a range of levers, such as energy consumption and personnel costs.

In addition to this primary data, secondary data was also used to supplement the recorded data points.[b]

Notes: a) In the period from 1 June to 15 September 2023; b) More information on the survey design can be found in Chapter 5.1, Methodology – Data Basis, p. 101.

1 SEED Index

1.2 Decarbonisation

Decarbonisation
A comparison of the sectors’ potentials

The potential for decarbonisation[a] is not being sufficiently leveraged in all sectors. The potential CO_2 savings by 2030 point to great opportunities.

As the factors[b] in the graphic illustrate, two sectors especially stand out.

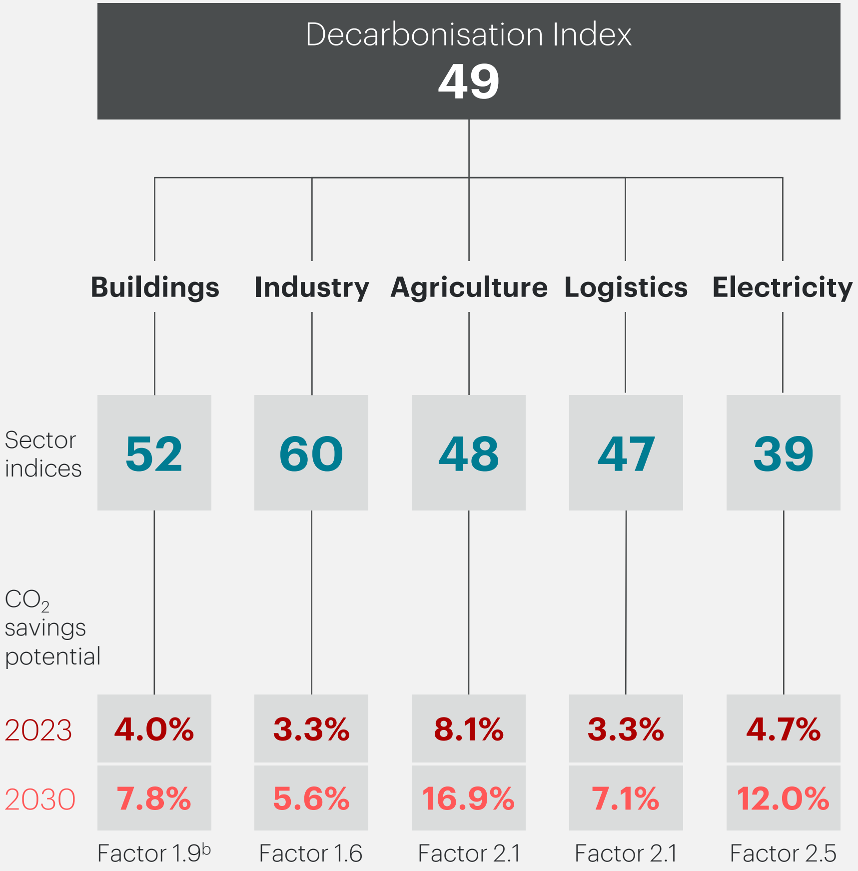
Companies in the electricity sector can leverage a 2.5-fold[c] decarbonisation potential by using digital technologies.

Efficiency-boosting digital technologies will offer wind and solar energy producers in particular an opportunity to increase CO_2 savings from 4.7% in 2023 to 12% in 2030 (see graphic). The planned expansion of regenerative electricity production in Germany[1] will facilitate this growth.

The industry sector will need to accelerate its adoption of digital technologies in order to increase its decarbonisation potential.

The industry sector has a lower decarbonisation potential (5.6%) for 2030 compared to the other sectors despite existing CO_2 reduction levers of 9% to 12%.[d] This is mainly due to the expected low adoption rate of digital technologies by 2030.[e] To increase this rate, incentives – especially financial support and funding programmes for SMEs in the industry sector – will be important.

With 49 out of 100 points, the Decarbonisation Index shows that the German economy can still double the current level of decarbonisation achieved using digitalisation.



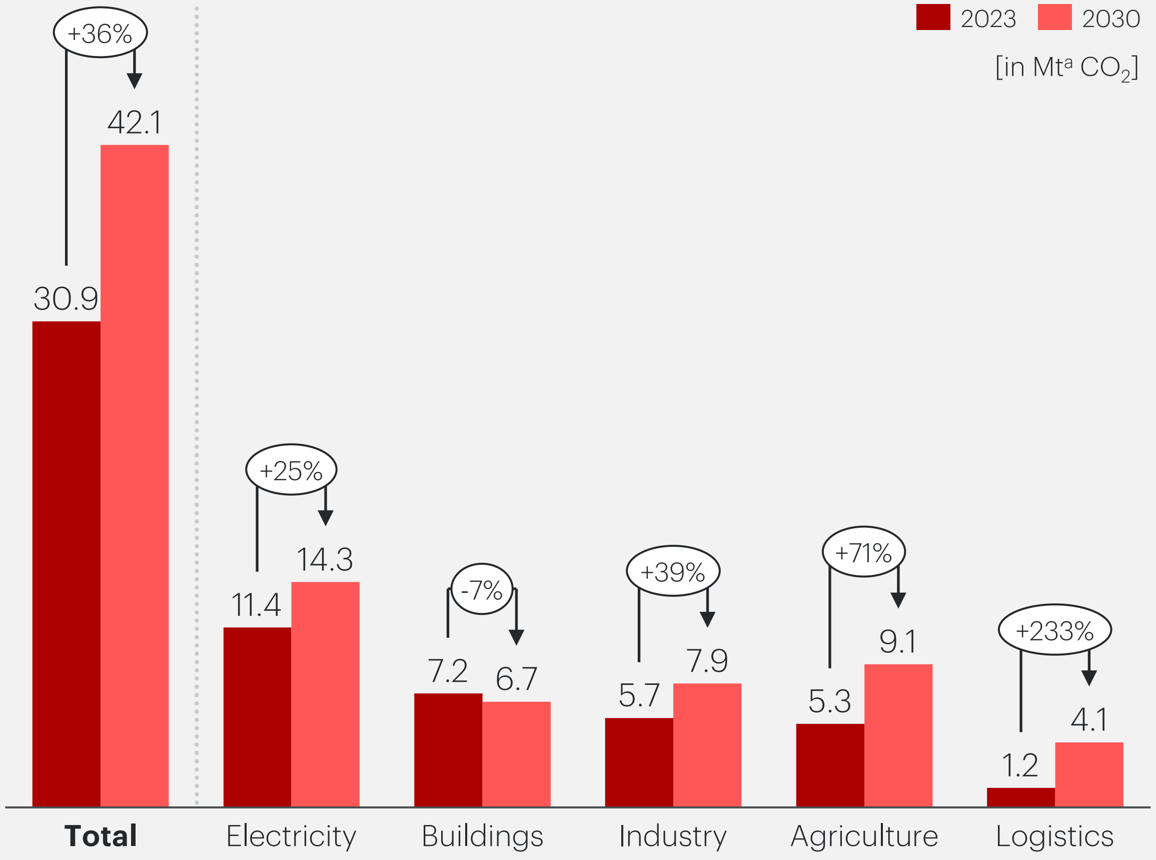
Decarbonisation Index
49

	Buildings	Industry	Agriculture	Logistics	Electricity
Sector indices	52	60	48	47	39
CO_2 savings potential					
2023	4.0%	3.3%	8.1%	3.3%	4.7%
2030	7.8%	5.6%	16.9%	7.1%	12.0%
	Factor 1.9[b]	Factor 1.6	Factor 2.1	Factor 2.1	Factor 2.5

Notes: Deviations in the divisions may result from rounding; a) See also p. 12 for an explanation; b) Factor = percentage 2030/percentage 2023; c) See graphic: 39/100=2.56 or =12.0%/4.7%; d) See also Chapter 5.2 Figures in Detail, p. 119; e) See also Chapter 1.4 Adoption Rates, p. 25 ff.; f) The value is calculated by weighting the sectors according to CO_2 intensity, i.e. how high the sector’s CO_2 emissions are (see also p. 112 and S. 114). Source: 1) UBA, 2023i.

Decarbonisation

Absolute CO_2 savings per sector in 2023 and 2030



Digital technologies enabled German companies to save around 31 megatonnes (Mt) of CO_2 in 2023.[a]

Digital technologies are already helping to reduce CO_2 emissions, with the greatest savings being realised in the electricity, buildings and industry sectors. The calculated savings add up to around 31 Mt of CO_2, which corresponds to around 4.7% of the total emissions addressed by this study (661 Mt) and 4.1% of Germany's total emissions (746 Mt)[1] in 2022. Although the logistics sector has the lowest CO_2 savings compared to the other sectors, it particularly stands out owing to another key figure.

The logistics sector is expected to see the largest percentage increase in CO_2 savings by 2030.[b]

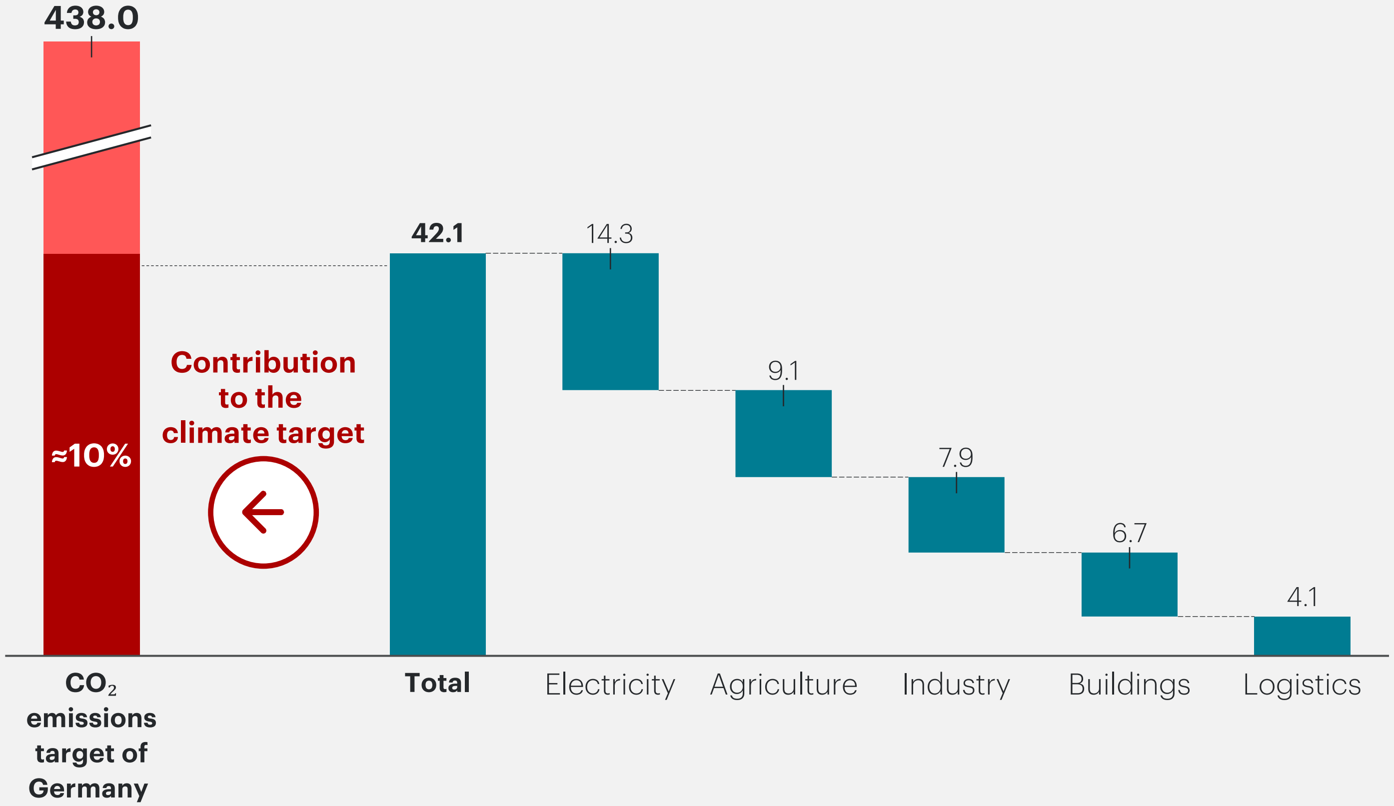
The CO_2 savings potential in the logistics sector could increase from 1.2 to 4.1 Mt of CO_2 – an increase of more than 200%. One reason for this is the expected growth in road haulage[c] – from 515 tkm (tonne-kilometres) in 2023 to 533 tkm[2] in 2030 – which will result in an increasing absolute reduction potential. On the other hand, the adoption rate in the logistics sector is expected to double by 2030.[d]

Notes : a) Mt = megatonnes or million tonnes; b) Road haulage (by truck) was examined; c) Measured on the basis of freight transport volume in tonne-kilometres (tkm); d) From an average of 17% in 2023 to an average of 34% in 2030, see Chapter 1.4 Adoption Rates, p. 25. Sources: 1) UBA, 2023n; 2) UBA, 2023l, in the with-measures scenario (MMS) of the projection.

Decarbonisation

Contribution to the German government's climate target for 2030

CO_2 savings in 2030 – by sector and in total
[in Mt CO_2]



By using digital technologies, German companies can save around 42 Mt of CO_2 emissions – or roughly the same amount as the residents of Rhineland-Palatinate produce each year – and thereby contribute to the German government's CO_2 emissions target for 2030.

In 2021, Germany's federal government set itself the goal of reducing greenhouse gas emissions by 65% by 2030 compared to 1990 levels by amending the Federal Climate Change Act of 2019. This corresponds to 438 Mt of CO_2 emissions in 2030.[1]

The savings forecast in the study for the key sectors in 2030 will total around 42 Mt CO_2.[a] This corresponds to 9.6% of the German government's CO_2 emissions target.[1]

Note: a) See also Chapter 5.2 Figures in Detail, p. 117 ff. Source: 1) UBA, 2023m.

1 SEED Index

1.3 Profitability

Profitability
A comparison of the sectors’ potentials

The profitability potential of digitalisation is already being leveraged slightly better. Nevertheless, possible EBIT effects up to 2030 show considerable opportunities to boost profitability by using digital technologies.

While two sectors stand out in particular for 2023, uniform results will be evident across all sectors by 2030:

The EBIT effects of digitalisation were greatest in the agriculture and electricity sectors in 2023, with respective margin increases of 2.4% to 3.4%.

In agriculture, digital technologies specifically helped to reduce increased costs in 2023, which were mainly due to higher expenditure on fertilisers and animal feed.[1,2] For wind and solar power producers, digital technologies served to boost efficiency of electricity production and thereby boost sales by up to 8%, as the data analyses show.[b]

By 2030, almost all sectors have a chance to double the EBIT margin they achieve through digitalisation.[c,d]

High or even rising costs are forecast for all sectors up to 2030, such as for maintenance personnel, fertilisers, animal feed, fuels and toll fees related to CO_2 emissions.[3,4] This is where digital technologies can have an impact through efficiency gains: An increase in the EBIT effect[d] to 4.6% in the agriculture sector and 6.6% in the electricity sector is possible.

With 57 out of 100 points, the Profitability Index shows that the German economy can boost the profitability currently achieved via digitalisation by a factor of 1.8.

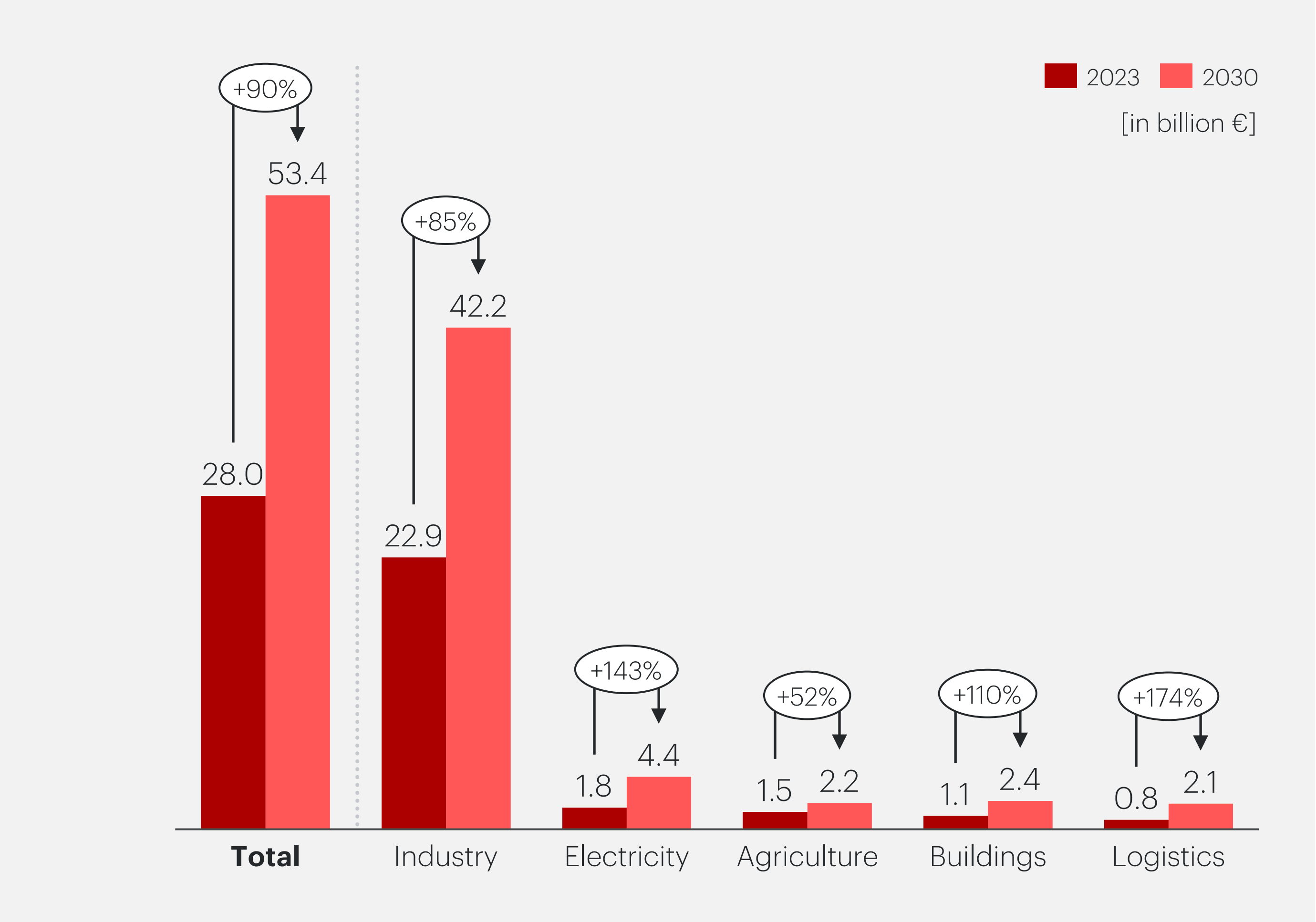
Profitability Index[f]
57

	Buildings	**Industry**	**Agriculture**	**Logistics**	**Electricity**
Sector Indices	**54**	**58**	**51**	**48**	**52**
EBIT effects[d] (in percentage points of the EBIT margin)					
2023	**1.0%**	**1.2%**	**2.4%**	**1.1%**	**3.4%**
2030	**1.9%**	**2.1%**	**4.6%**	**2.3%**	**6.6%**
	Factor[e] 1.9	Factor 1.7	Factor 2.0	Factor 2.1	Factor 1.9

Notes: Deviations in the divisions may result from rounding; a) See also p. 12 for explanation; b) See also Chapter 5.2 Figures in Detail, p. 117 ff.; c) See also factors at the bottom of the graphic; d) The EBIT effect is measured as an increase in the EBIT margin in percentage points (see also Chapter 5.1 Methodology p. 108 ff.); e) Factor = percentage 2030/percentage 2023; f) The value is determined by weighting the sectors by turnover (see Chapter 5.1 Calculations, p. 113 f.). Sources: 1) BMEL, 2024; 2) Deutscher Bundestag, 2022; 3) Michel, 2022; 4) Schlautmann, 2023.

Profitability

Absolute EBIT increase per sector in 2023 and 2030



Digital technologies increased EBIT in the five key sectors by an average of roughly 9% in 2023.[a] This corresponds to around €28 billion.

Digital technologies are already helping to increase EBIT in all five sectors. In absolute terms, the EBIT increase was concentrated in the industry sector, which was almost €23 billion (or 86% of the total).[b] This was by far the highest share of total turnover of the sectors analysed compared to the other sectors.

An absolute increase in EBIT to €53 billion is possible by 2030 via digitalisation. That would almost be twice as much.

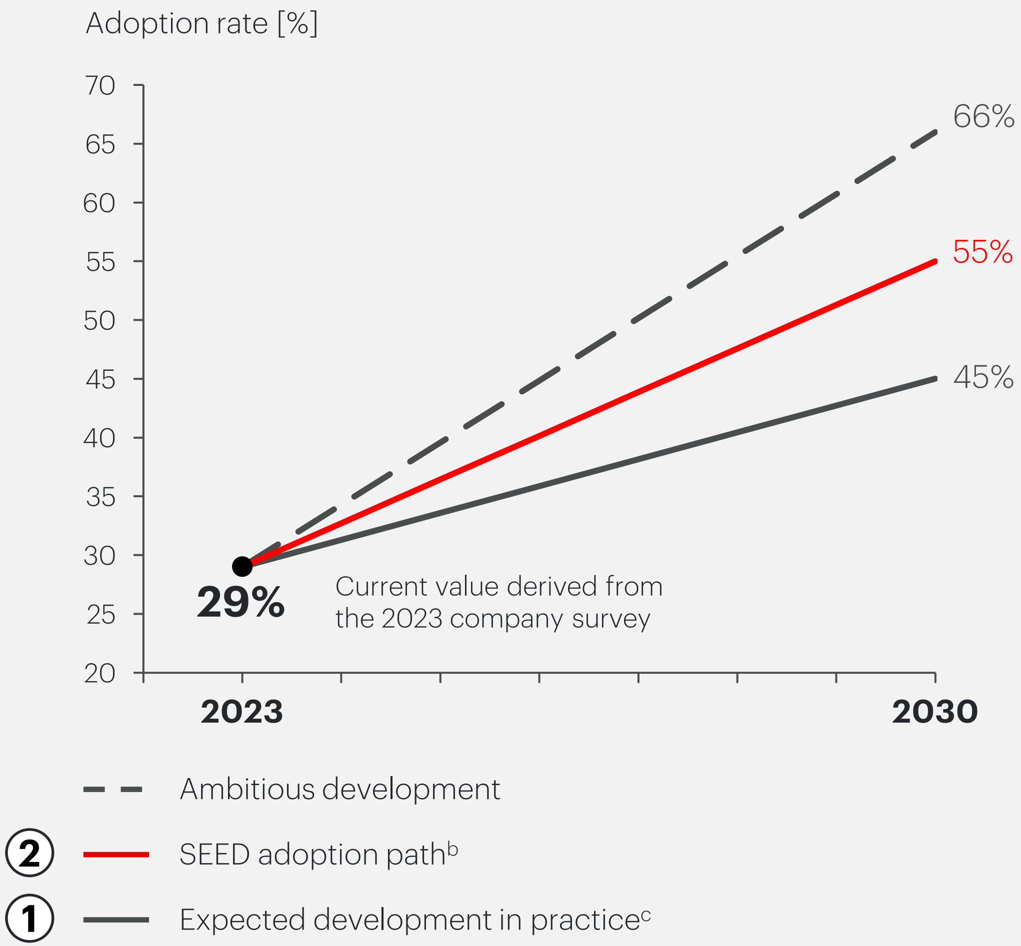
There are opportunities in all sectors to increase EBIT by 2030 by using digital technologies. The biggest EBIT effects will be seen in the logistics, electricity and buildings sectors (see graphic). However, in absolute terms, the increase in EBIT in the industry sector will be the highest in 2030, at around €42 billion (see graphic).

Notes: a) EBIT increase in 2023 in relation to total EBIT in 2023 for the analysed sectors: €28.1 billion/€308.1 billion; b) Turnover of the industry sector in 2023 in relation to total turnover in 2023 of the analysed sectors: €1,870 billion/€2,164 billion.

1 SEED Index

1.4 Adoption of digital technologies

With an average adoption rate of digital technologies of just 29%, German companies clearly have some catching up to do.



Adoption of digital technologies

55% by 2030 is possible!

The SEED adoption path outlines a possible development between ambitious digitalisation worldwide and expected hesitancy in Germany. It aims for a 55% adoption rate of digital technologies by 2030 instead of the 45% rate calculated on the basis of the company surveys.

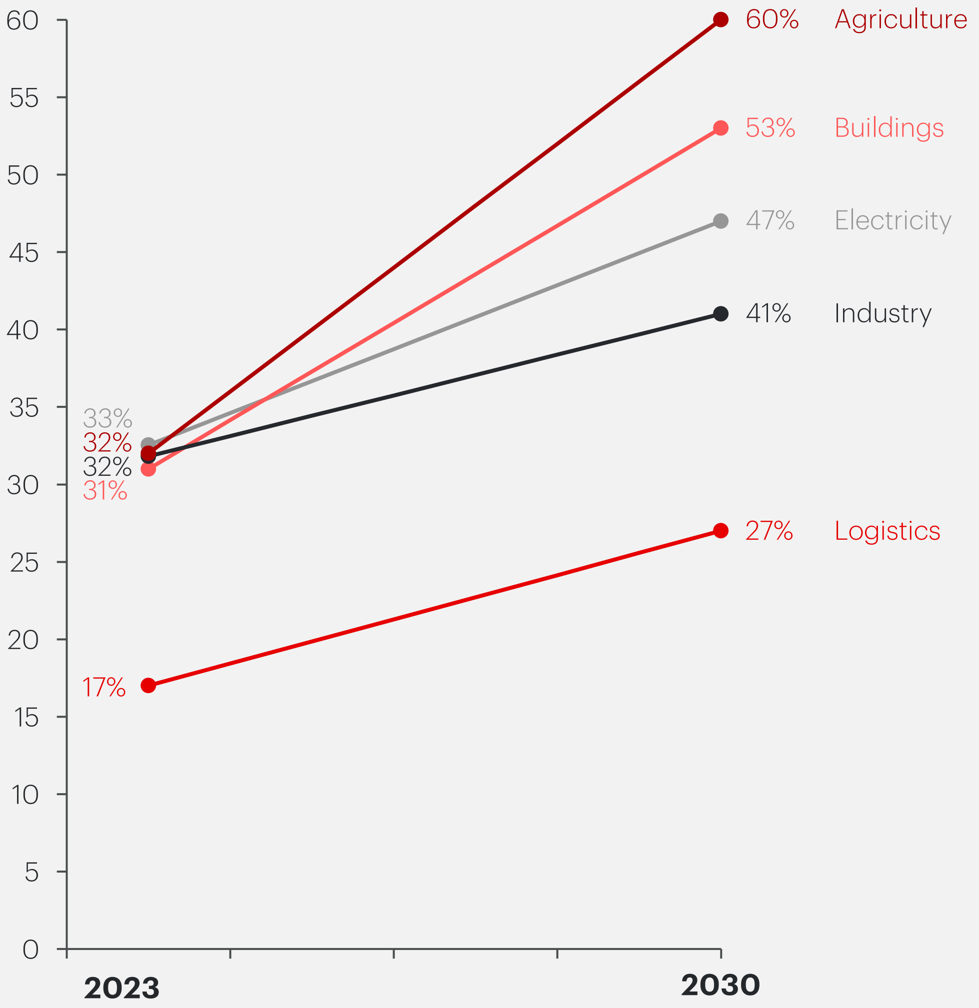
Based on the current value, the SEED adoption path represents a development path for the digitalisation of the German economy that sets both pragmatic and ambitious goals. In the coming years, it will make it possible to measure the progress of digitalisation in the context of this study. In doing so, it can and should also provide guidance as to what is possible for German companies in terms of decarbonisation and profitability via digital technologies if they exceed the adoption rate of 45% derived from the survey.

The target value of 55% results from two values: The first is the expected average adoption rate for 2030, which is derived from the company survey and is expected to be subdued based on past experience. The second value is the expected average adoption rate, which is derived from secondary data, forecasts for leading countries, companies and use cases. It is estimated to be 66% on average.

Notes: The numbers 1 and 2 in the key serve as a reference for the next three pages; a) For definition, see p. 14; b) Deviations in the mean values are due to rounding; c) Based on the company survey.

①

Adoption rate of German companies in 2030 based on company survey[a]
[in %]



Adoption of digital technologies

Into the future without ambition. Why?

In all five key sectors, the surveyed companies expressed little ambition to significantly accelerate their digitalisation efforts by 2030.

This trend can be explained by several factors:

1. **Regulatory challenges:** Data privacy and protection laws as well as regulations[1] in Germany, which are stricter than in other countries, force companies to undertake additional efforts, which in turn delays the introduction of technologies, especially those based on artificial intelligence and big data.
2. **Lack of digital infrastructure:** In some regions of Germany, especially in rural areas, there is a lack of sufficient digital infrastructure, particularly in terms of broadband coverage.[2] Introducing digital technologies that require large data bandwidths, such as cloud-based real-time data, will be difficult in these places.
3. **Shortage of skilled workers:** Many companies are struggling to find qualified specialists who have the necessary digital skills, including on peripheral topics such as data security and cybersecurity.

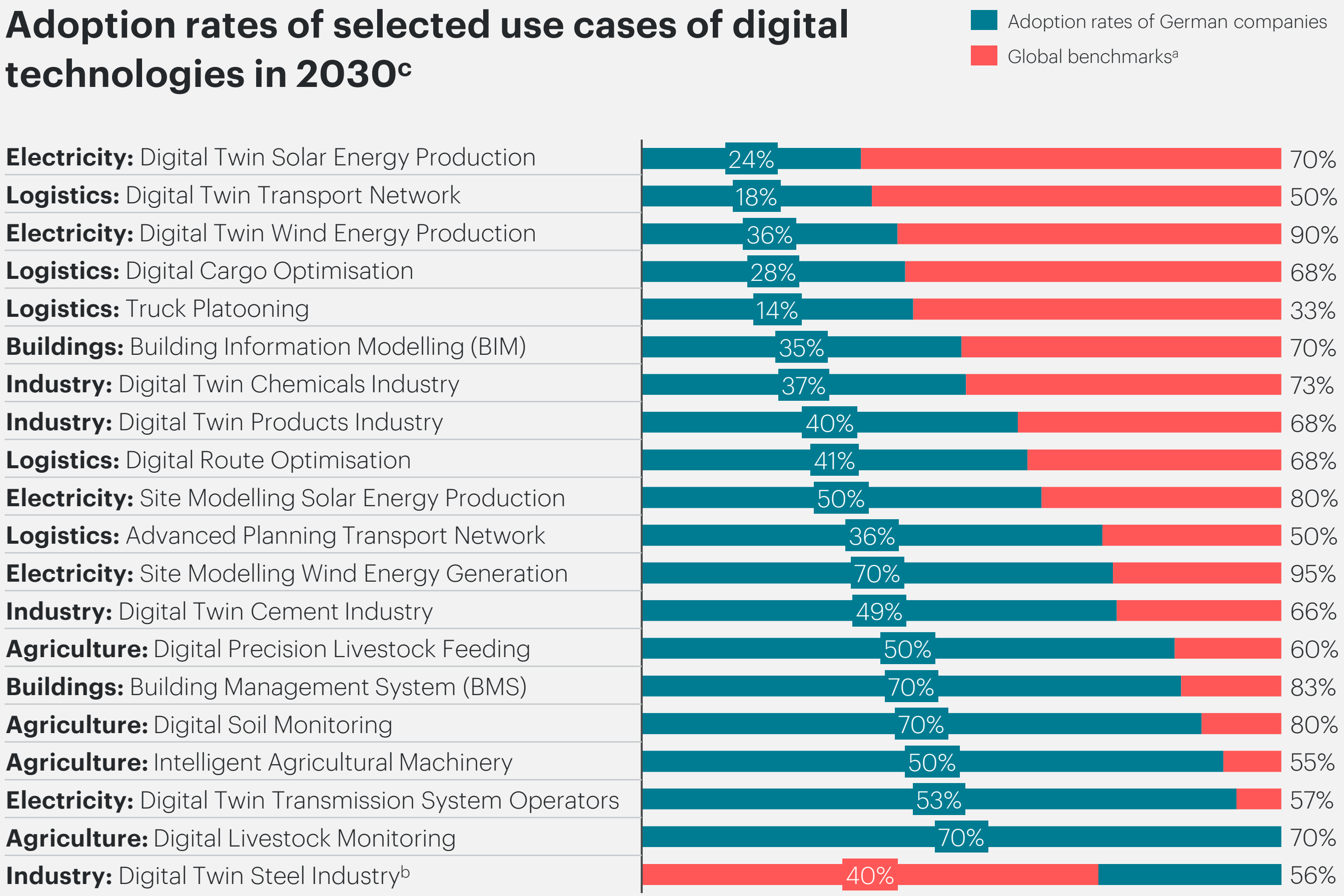
SMEs are more affected by these restrictions than large companies, as their ability to spread risks, recruit the right staff and make large investments is more limited.

Notes: Deviations in the mean values are due to rounding; a) The adoption rates for 2023 and 2030 are based on data from the company survey.
Sources: 1) Bitkom, 2022; Handelsblatt, 2022; 2) Handelsblatt, 2021.

①

Adoption of digital technologies
Comparison of the development of selected use cases until 2030

Adoption rates of selected use cases of digital technologies in 2030[c]



The adoption rates expected on the global level usually dwarf the ambitions of German companies.

A comparison of the adoption rates of digital technologies between German companies and global benchmarks shows that there are varying degrees of deviation from the target by 2030 across the different use cases. While there are major differences in some use cases (e.g. in the electricity, buildings and logistics sectors), the difference is much smaller in other sectors (e.g. agriculture). German companies are even considered leaders in the use of digital twins in the steel industry[b] with oxygen blast furnaces.

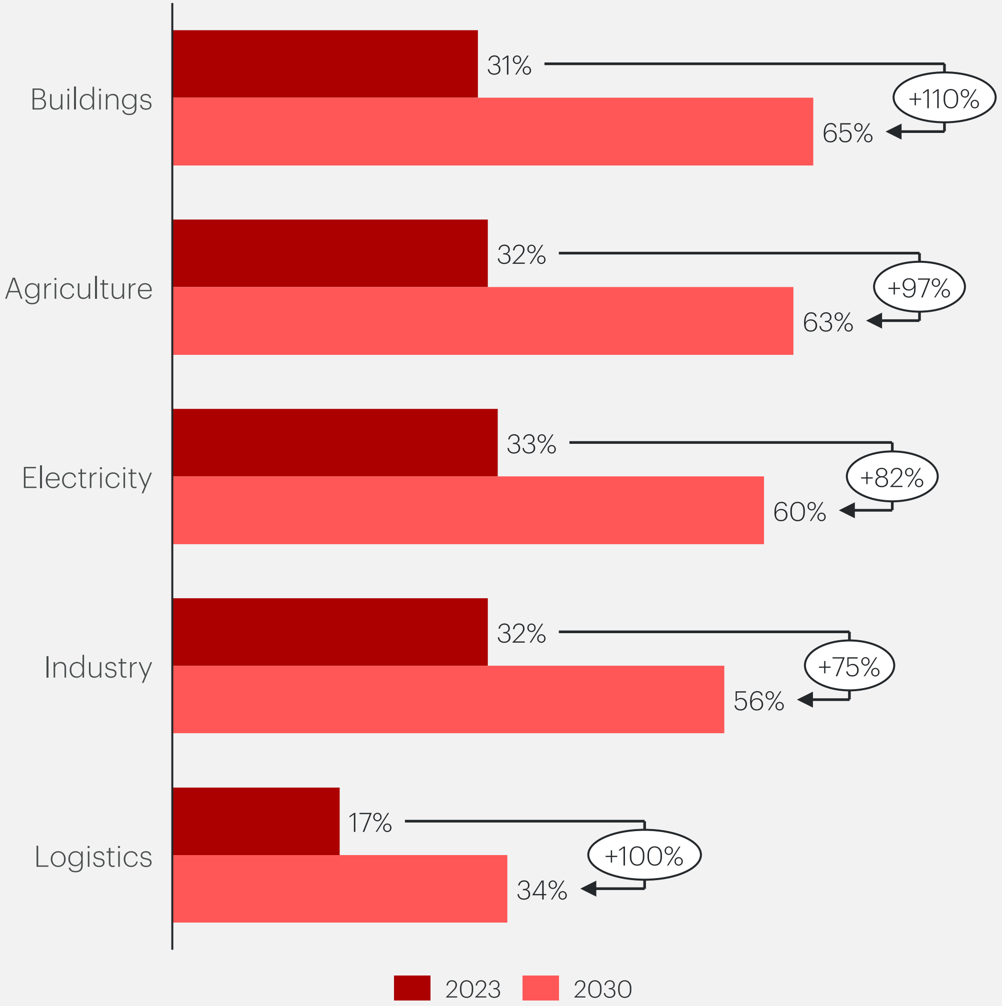
Sector	Average difference
Buildings	24%
Industry	16%
Agriculture	6%
Logistics	23%
Electricity	28%

Notes: a) For the definition, see definition box, p. 14; b) With an adoption rate of 56%, German companies are considered leaders in terms of global benchmarks when it comes to using digital twins in the steel industry with oxygen blast furnaces (see also Sector Chapter – Steel, p. 48; c) Some use cases, such as the digital twin in the cement industry, include additional sub-use cases. The values displayed in the graphic are average values for these sub-use cases. For reasons of clarity, the six additional sub-cases are not listed individually in the graphic.

②

Adoption rates according to the SEED adoption path[b]

[Adoption rate in %; Increase in percentage points]



Adoption of digital technologies
Doubling in almost all sectors by 2030

According to the entirely realistic SEED adoption path, the adoption of digital technologies will double in almost all sectors between 2023 and 2030.

The SEED target path logic (see p. 26) yields adoption rates for all sectors up to 2030 that are on average twice as high as they are today.

It predicts that the adoption of digital technologies will be highest in the buildings sector between 2023 and 2030. Here, the adoption rate will skyrocket from 31% to 65% in 2030, driven in particular by building management systems (BMS) in non-residential buildings.[a]

In contrast, the logistics sector – for which Germany has been a role model for many years[1] – will have a particularly hard time achieving high adoption rates across the board by 2030 due to the shortage of skilled workers and its largely SME-based[b] structure.

The following chapters on sector analysis show which use cases of digital technologies will be applied in the outlined adoption paths and what effects they will have on decarbonisation and profitability in the respective sector.

Notes: a) See also use case description, p. 40 f.; b) See SEED target path logic (see p. 26). Source: 1) Kümmerlen, 2023.

2 Sector analysis

Sector analysis
Structure of the chapters[b]

In the following sector analyses, the effects of digital technologies in terms of CO_2 reduction and EBIT increase are examined at the use-case level and aggregated at the sector and sub-sector levels.

In contrast, the organisation and documentation of the sector chapters is structured in a top-down manner, as shown on the left.

The chapters contain both qualitative descriptions of challenges and digital technologies as well as quantitative findings on the adoption rates of digital technologies and the associated CO_2 and EBIT effects.

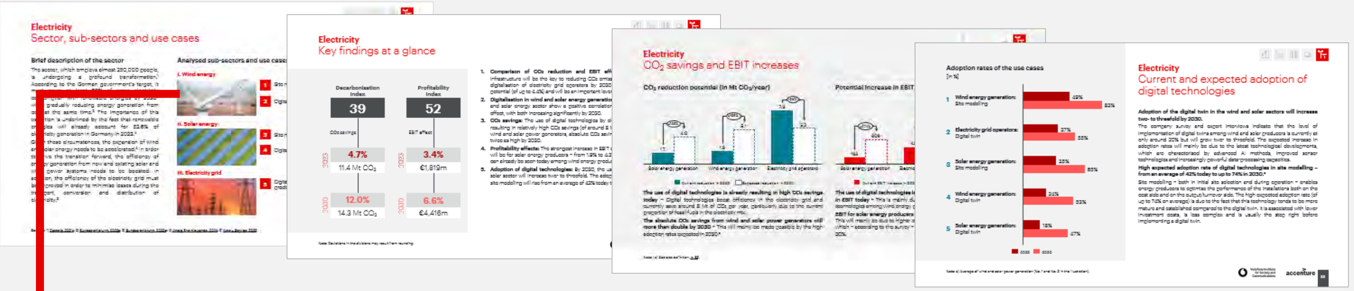
Sector

Brief description of the sector and scope

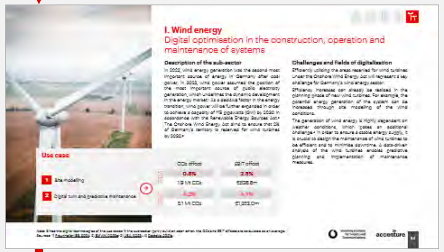
Key findings

Comparison of CO_2 reduction and EBIT effects[a]

Adoption of digital technologies

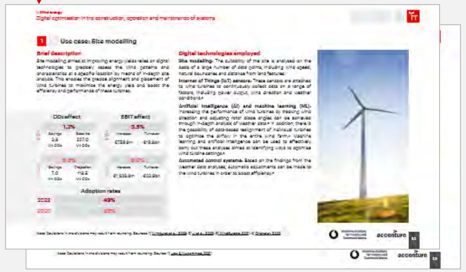


Sub-sector



Description, CO_2 and EBIT effects, challenges, digitalisation fields, use cases

Use case



Brief description, CO_2 and EBIT effects, digital technologies used

Notes: a) To improve readability, the illustrations here are either at the sub-sector or the use-case level, depending on the number of sub-sectors considered; b) The illustration uses the example of the electricity sector.

2 Sector analysis

2.1 Buildings

Buildings
Sector, sub-sectors and use cases

Brief description of the sector

The buildings sector comprises the planning, construction and management of buildings. With a share of around 41% of Germany's CO_2 emissions, it is one of the largest emitters and considered a key sector for achieving the German government's climate targets.[1]

The construction industry, which employs almost one million people,[2] is focused on the physical construction of buildings – public, commercial and industrial buildings as well as private houses and residential properties. In view of rising prices for materials, increasing labour shortages and growing demands regarding the energy efficiency of new buildings, sustainable and digitally supported construction is becoming increasingly important.

On its own, the use of buildings accounts for almost a third of CO_2 emissions and around 35% of final energy consumption in Germany.[3] In the building management sub-sector, the focus is therefore on efficiently managing existing buildings. Technical building management, as part of facility management, plays a key role in reducing energy and heat consumption.

Analysed sub-sectors and use cases

I. Construction industry

1 Building Information Modelling (BIM)

II. Building management

2 Building management systems (BMS) in non-residential buildings

Sources: 1) Vbw, 2021; 2) Destatis, 2024e; 3) UBA, 2023g.

Buildings
Key findings at a glance

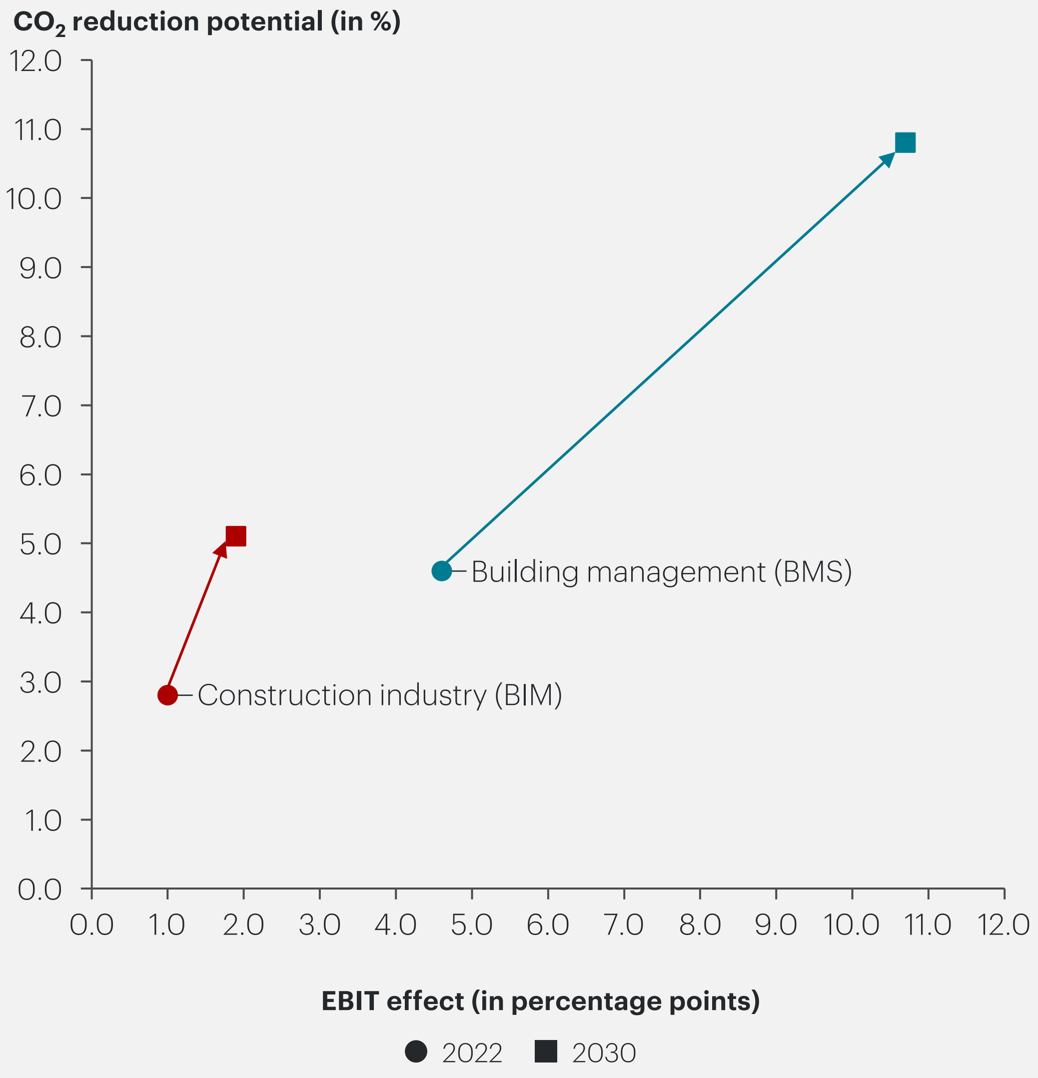
	Decarbonisation Index	Profitability Index[a]
	52	**54**
	CO_2 savings	EBIT effect
2023	**4.0%** 7.2 Mt CO_2	**1.0%** €1,130m
2030	**7.8%** 6.7 Mt CO_2[b]	**1.9%** €2,371m

1. **High CO_2 emissions:** With a share of around 40% of Germany's total CO_2 emissions, the building sector is one of the largest emitters and will play a key role in efforts to achieve the German government's climate targets.[1]
2. **Significant CO_2 savings:** Using digital technologies is already resulting in high absolute CO_2 savings, particularly in building management. In non-residential buildings alone, it will be possible to reduce around 11% of CO_2 emissions in 2030 by using building management systems (BMS). However, they will decrease in absolute terms by 2030 as electrification in the building sector progresses and fossil fuels are replaced by renewable energies.
3. **Positive EBIT effects:** Digital technologies are proving to be a driver of profitability in the building sector and will lead to an absolute increase in profitability of over €2.3 billion by 2030. In the construction industry, in particular, savings for materials (of up to 9%) and a reduction in construction time (of up to 18%) are expected to result in a further increase in profitability.
4. **High adoption rate of digital technologies:** The buildings sector is making good progress when it comes to introducing digital technologies. At 78%, the adoption rate expected in the building management sub-sector by 2030 is particularly high compared to that of the construction industry (53%). The positive EBIT effects – combined with new options for optimising efficiency offered by artificial intelligence – will increase the adoption rate in building management by a factor of 2.3 between 2023 and 2030.

Notes: Deviations in the divisions may result from rounding; a) The EBIT increases from the BMS use case are not included in the profitability index of the buildings sector, as the cost savings from using BMS are incorporated into the EBIT of the buildings' tenants; b) Despite higher percentage values, the absolute CO_2 savings may decrease by 2030, as the example shows, depending on the baseline; see also Chapter 5.1 Methodology – Calculations, p. 103 ff.
Source: 1) Vbw, 2021.

Buildings

Comparison of CO_2 reduction and EBIT effects



Approximately 11% of CO_2 emissions in the building sector can be reduced by 2030 via digitalisation.

The main source of these significant CO_2 savings will lie in the reduced energy consumption in building utilisation, which will be achieved by using digital technologies in building management systems (BMS). According to the results of the company survey, the intelligent and automated control of systems for heating, hot water, cooling, ventilation and lighting, in particular, will enable energy savings of between 10% and 19%. Since building management systems (BMS) are used throughout the entire service life of a building, they will also play a key role in the long-term reduction of energy consumption. The introduction of smart meters, which will be supported by national programmes (e.g. Germany's smart meter rollout plan[1]), and the promotion of renewable energies will play a key role in these efforts.[2]

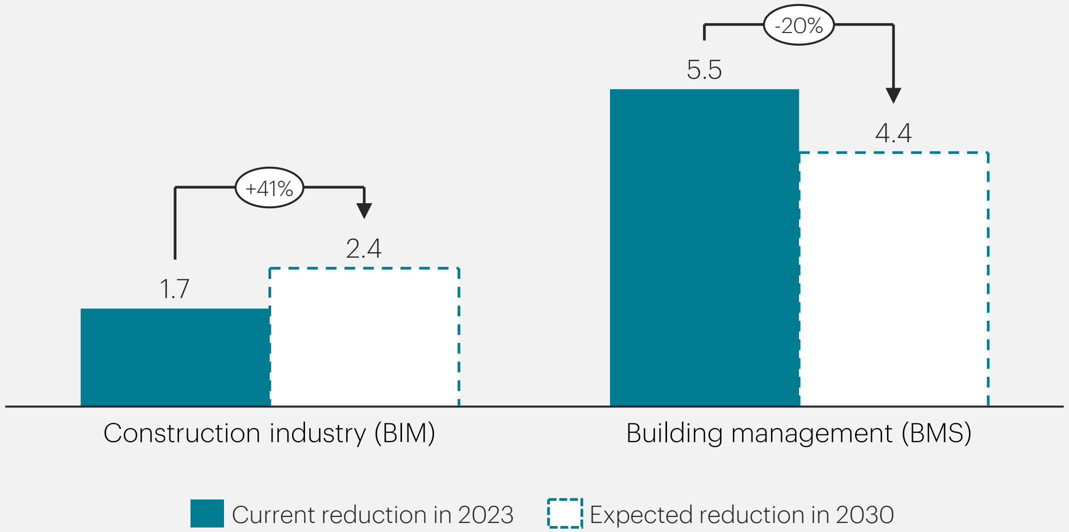
By comparison, the construction industry's contribution will be much smaller.

CO_2 emissions in the building management sub-sector for non-residential buildings (around 114 Mt of CO_2 in 2022) are higher than those of the construction industry (around 60 Mt of CO_2 in the same year).[a] Nevertheless, digital solutions, such as digital twins of construction sites (BIM[b]), will also contribute to significant CO_2 savings in the construction industry while simultaneously boosting profitability (see graphic).

Notes: a) See CO_2 emission projections in Chapter 5.2 Figures in Detail, p. 117; b) Building Information Modelling (BIM). Source: 1) BMWK, 2023d;
2) Hartmann, 2023

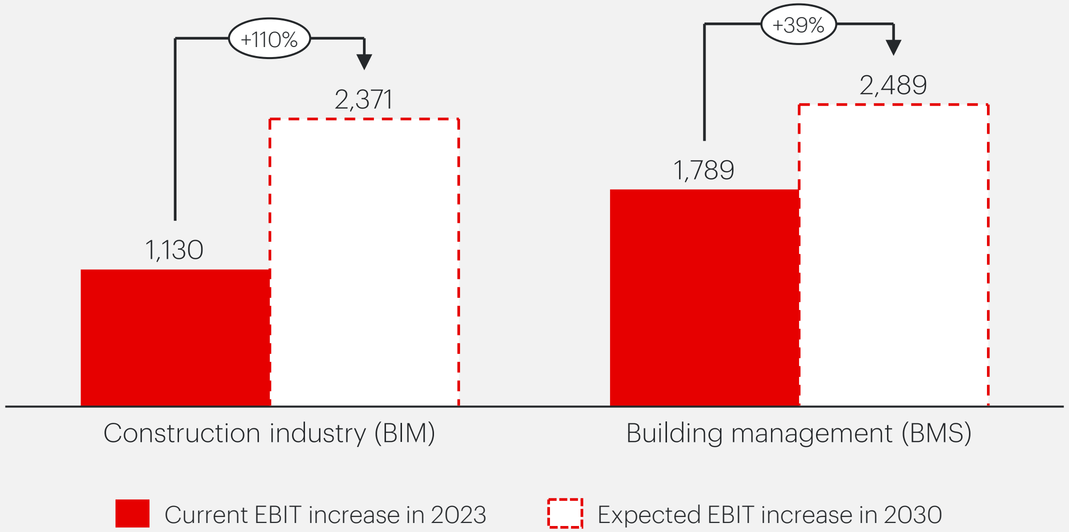
Buildings
CO_2 savings and EBIT increases

CO_2 reduction potential (in Mt CO_2/year)



Using digital technologies in building management is resulting in high absolute CO_2 savings today and will also do so in 2030 – However, with the ongoing electrification of building systems (e.g. with heat pumps[1]) and the replacement of fossil fuels with renewable energies, the absolute CO_2 reduction potential will decrease by 2030, as the total CO_2 emissions from building management will also decrease by 2030.[a]

Potential increase in EBIT (in € m)



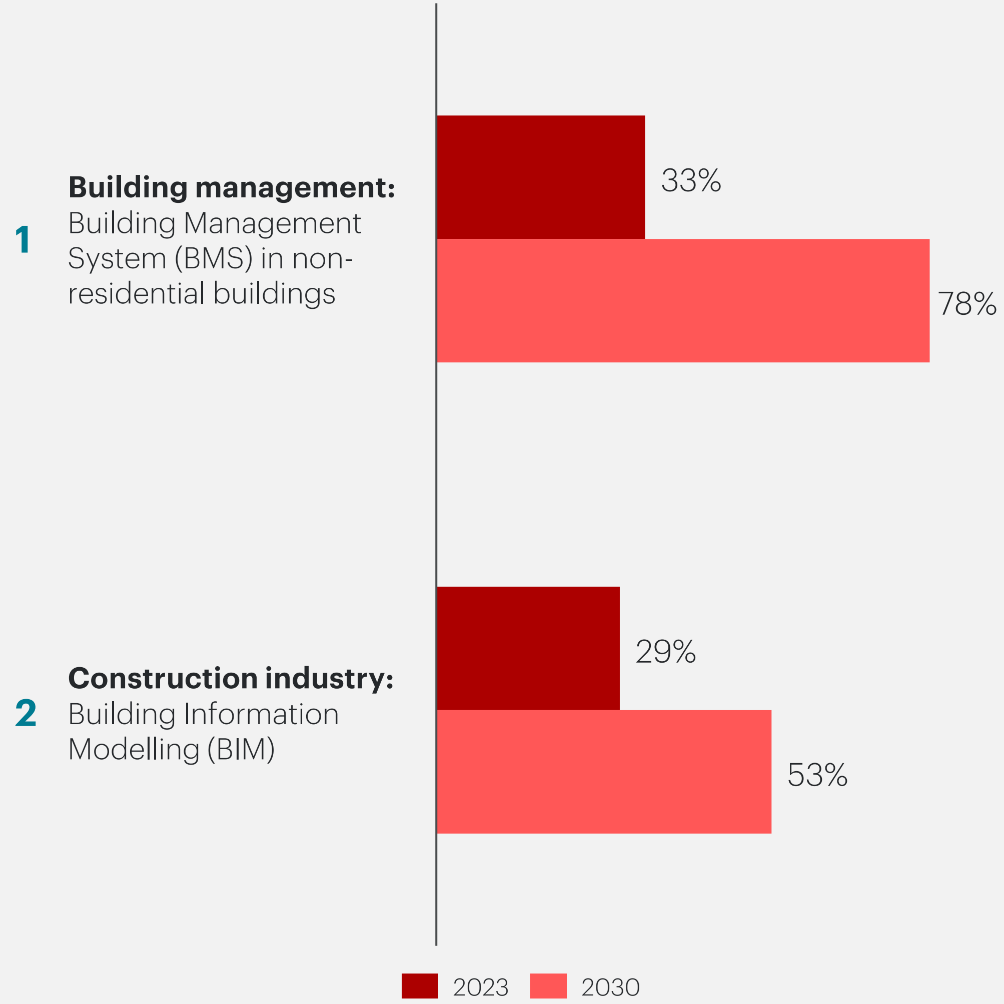
Similar profitability effects are expected in the construction industry and in building management in 2030 – Digital technologies are proving to be a driver of profitability in the buildings sector and will result in an absolute increase in profitability of over €2.3 billion.

In the construction industry, the EBIT effect is expected to double – Due to savings on materials (of up to 9%) and a reduction in construction time (of up to 18%), digital technologies will have a positive impact on profitability in the face of rising costs.[b]

Notes: a) See CO_2 emission projections in Chapter 5.2 Figures in Detail, p. 117; b) Based on data from the company survey. Source: 1) BWP, 2023; Krapp, 2023.

Adoption rates of the use cases

[in %]



Buildings
Current and expected adoption of digital technologies

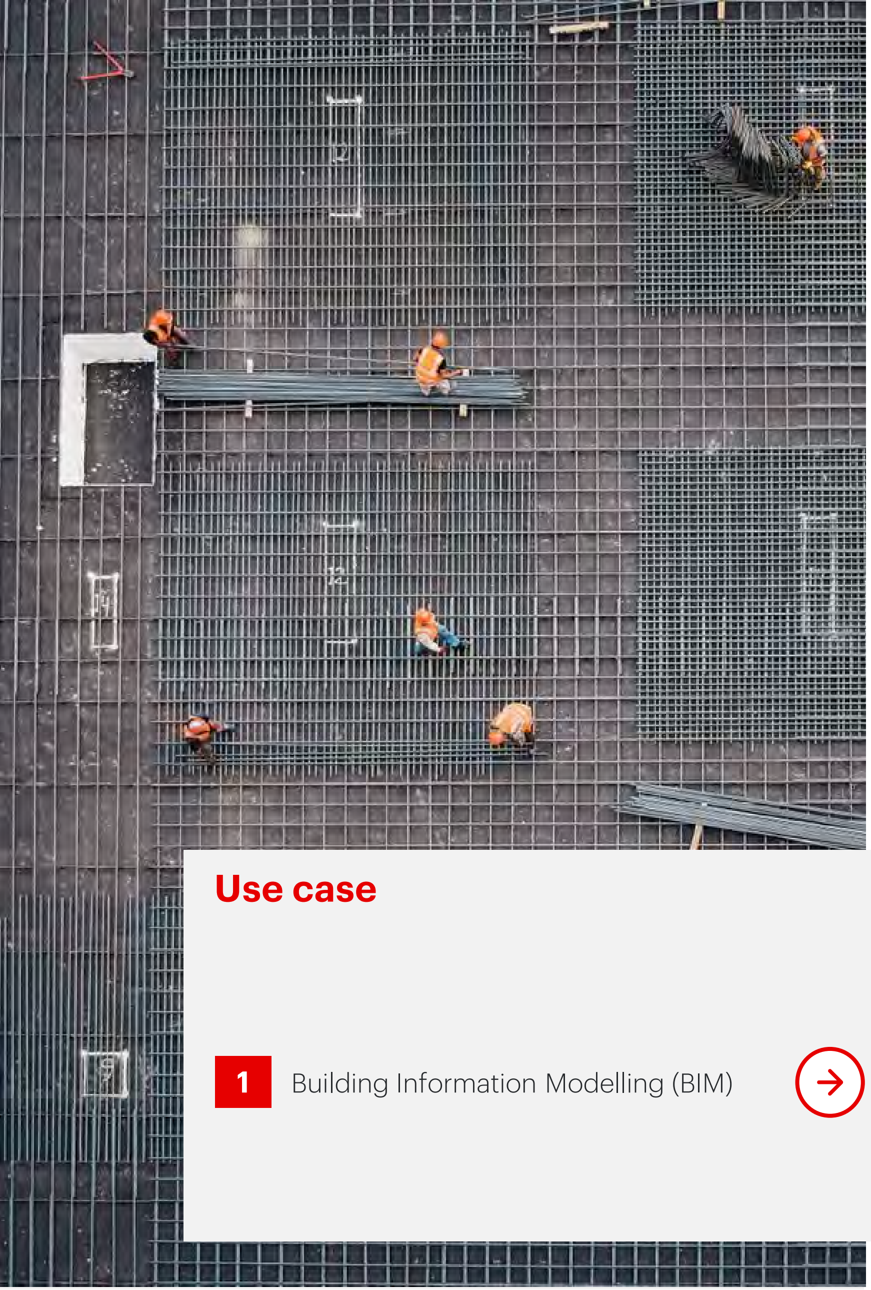
The adoption rate of building management systems (BMS) is expected to increase by a factor of 2.3 by 2030.

There are two trends behind this increase: First, the costs of purchasing a BMS are falling and the introduction of innovative technologies, such as artificial intelligence (AI) and analytics, is opening up new possibilities for optimisation.[1] Second, the high EBIT effects – of up to 11% (see p. 35) – represent a financial incentive for companies. These two trends will continue to spur market penetration and result in additional CO_2 savings and EBIT increases by 2030.

In contrast, the adoption rate of building information modelling (BIM) will only increase by a factor of 0.8.

At present, roughly 29% of construction companies in Germany use digital twins or BIM systems at various stages of digital collaboration and benefit from savings for costs and materials in the planning and construction phases.[a] Since these savings are higher the tighter the digital collaboration is, the average level of maturity is expected to be higher by 2030. The comparatively low increase in the adoption rate is due to the fact that smaller companies, in particular, are struggling to implement BIM due to the time-consuming training and additional costs involved. This is especially the case in the subcontractor ecosystem.

Note: a) Based on data from the company survey. Source: 1) Rieder, 2023.



I. Construction industry

Modelling, planning and execution of construction processes

Description of the sub-sector

As one of the key industries in Germany, the construction industry accounts for 6% of nominal gross value added. From a macroeconomic perspective, it is the most important industry after the services sector and the manufacturing industry.[1]

The construction industry is responsible for around 12%[2-4] of Germany's CO_2 emissions as a result of producing and transporting building materials as well as energy consumption. As a standard, DIN EN ISO 19650-1 | 2019-08 provides information on the organisation and digitalisation of building information, including building information modelling (BIM).[5]

Challenges and fields of digitalisation

In addition to the shortage of skilled workers[6], the effective and efficient coordination and integration of all parties involved is a key challenge in the construction industry. The suboptimal exchange of information in construction projects leads to difficulties in the delivery and storage of building materials, delays, construction errors and prolonged construction phases. Coordination and integration will therefore be crucial factors in enabling a cost-effective, precise, transparent and on-schedule construction process without construction errors.

Digitalisation offers a multitude of opportunities for the future of the construction industry. Fully leveraging these benefits will require a holistic and comprehensive approach that encompasses the planning, construction and operational phases of the building and ensures the exchange of information among the various parties involved.

As a response to these current challenges in the industry, BIM is paving the way for a digitalised, efficient and sustainable future for the construction industry.

Use case

Use case		CO_2 effect	EBIT effect
1 Building Information Modelling (BIM) →	2023	**2.8%** 1.7 Mt CO_2	**1.0 %** €1,130.1m
	2030	**5.1%** 2.4 Mt CO_2	**1.9 %** €2,371.4m

Sources: 1) Destatis, 2024c; 2) Vbw, 2021; 3) UBA, 2023g; 4) Dena, 2023; 5) Baunormlexikon, 2023; 6) Handelsblatt, 2023a.

1 Use case: Building Information Modelling (BIM)

Brief description

BIM is revolutionising construction and planning processes with 3D modelling[1] and continuous data exchange[2]. Collaboration is characterised by transparency and precise coordination. Modelling and collision checks allow inconsistencies to be detected at an early stage, manage costs during the design phase, and provide long-term advantages in terms of efficiency, maintenance and operation despite additional planning efforts.[3]

CO_2 effect

		Savings	Baseline / Projection
2023	2.8%	1.7 Mt CO_2	Baseline: 60.1 Mt CO_2
2030	5.1%	2.4 Mt CO_2	Projection: 46.4 Mt CO_2

EBIT effect

		Increase	Turnover
2023	1.0%	€1,130.1m	€108.4bn
2030	1.9%	€2,371.4m	€122.8bn

Adoption rates

2023	29%
2030	53%

Digital technologies employed

BIM management software, including:

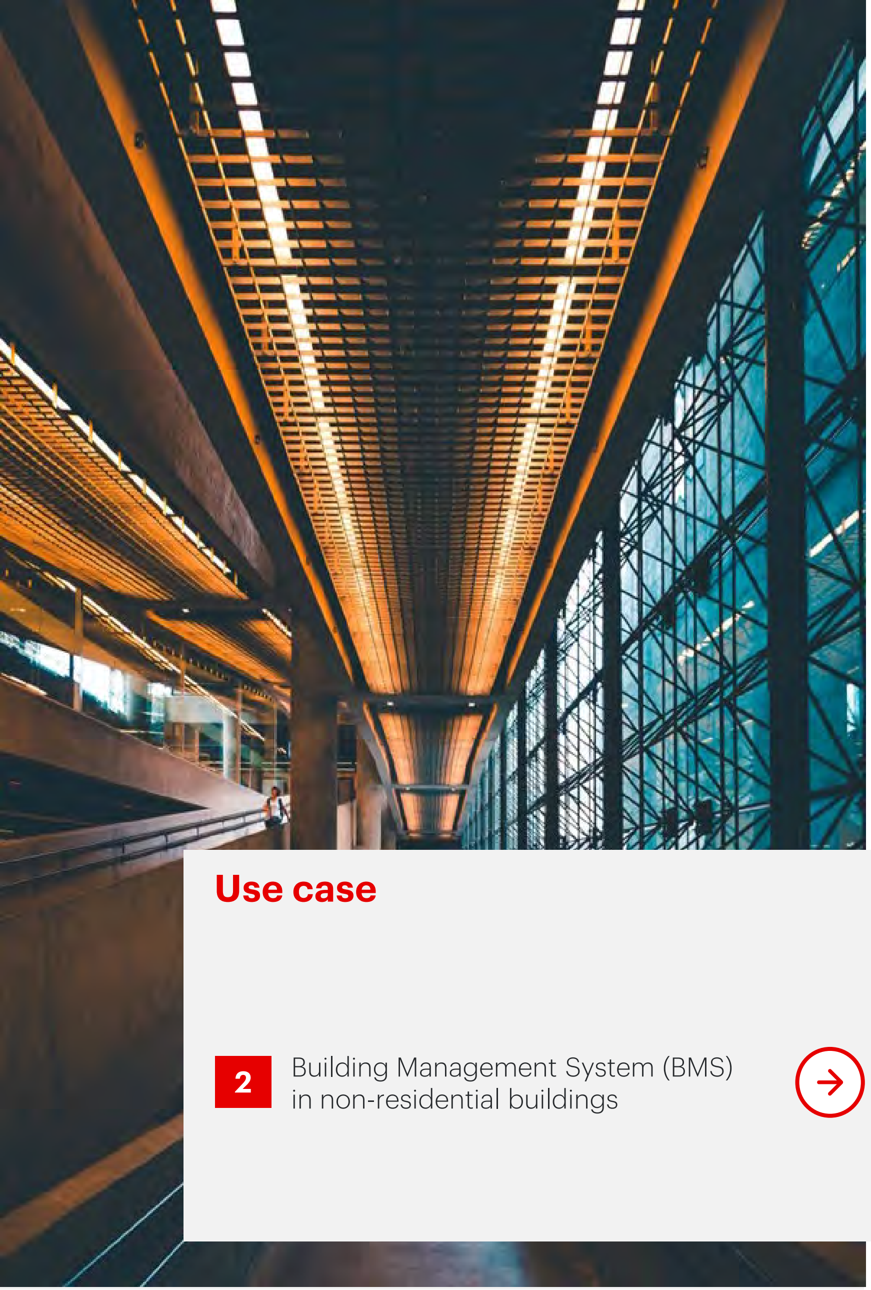
- **Simulation and modelling software (3D):** This software enables users to create and conduct simulations with detailed three-dimensional models of buildings in order to optimise the planning, design, construction and management of buildings and infrastructure.
- **(Cloud) platform/common data environment (CDE):** This centralised, cloud-based digital platform enables project stakeholders to share, manage and coordinate information and data in real time so as to enhance collaboration and efficiency in construction projects.

The various maturity levels of a BIM include:

- **Level 0 – No digital collaboration:** 2D technical drawings (e.g. CAD[a]) that are not shared in a digital format.
- **Level 1 –** Low level of digital collaboration: Concepts in 3D, but the designs and documentation are in 2D (BS 1192:2007 standard); each participant has their own isolated data.
- **Step 2 –** Advanced digital collaboration: Partly different 3D models, but information exchange via a common standard file format.
- **Level 3 –** Full digital collaboration: Common 3D model for all participants in an accessible, shared environment (Open BIM).

In the future, there will be additional levels, e.g. 4D (i.e. including the time dimension), 5D and 6D.[3]

Notes: Deviations in the divisions may result from rounding; a) Computer-aided design. Sources: 1) Bundesregierung, 2022; 2) BIM Deutschland, 2023; 3) Baldwin, 2018.



II. Building management
Efficient control and management of buildings

Description of the sub-sector

Building management encompasses the control, management, administration and monitoring of building infrastructure and is an important part of the buildings sector. The operation of buildings will account for around 30% of CO_2 emissions and around 35% of final energy consumption in Germany in 2023.[1] Non-residential buildings will in turn account for around 37% in the same year.[2] The approximately 21 million non-residential buildings across Germany comprise a variety of building types, including office, industrial and public buildings.[3,4] The efficient management of these buildings will play a major role in achieving the German government's climate targets.

Challenges and fields of digitalisation

Roughly €73 billion is spent each year in Germany on space heating, hot water, lighting and cooling in residential and non-residential buildings.[1] Non-residential buildings consumed around 330 terawatt hours (TWh) of energy in 2021 – as much as all the energy consumed by the city of Berlin. Of this, 70% was for space heating, around 17% for lighting, and 7% for air conditioning.[5] The lion's share of energy consumption is still based on fossil fuels, such as heating oil, natural gas and coal.[5,6]

In addition to building modernisation and the conversion of heating systems to renewable energy sources,[1] digital technologies will make a tangible contribution to reducing CO_2 emissions and costs.[7] For this reason, they will become increasingly important for efficient building management. This is because they visualise consumption, record external factors and – in tandem with building management systems (BMS) – automatically adjust heating, ventilation, air conditioning and lighting. In this way, digital building management will help to reduce CO_2 emissions and costs in non-residential buildings as well as boost profitability.

Use case

2 Building Management System (BMS) in non-residential buildings →

	CO_2 effect	EBIT effect
2023	**4.6%** 5.5 Mt CO_2	**4.6%**[a] €1,789.1m
2030	**10.8%** 4.4 Mt CO_2	**10.7%**[a] €2,488.5m

Note: a) Percentage share of cross-sector cost savings in Germany's total expenditures on heating, hot water, cooling, ventilation and lighting. Reason: The cost savings resulting from using BMS will have a cross-sector impact on the EBIT of building tenants rather than exclusively impacting companies in the buildings sector. Sources: 1) UBA, 2023g; 2) Dena, 2023c; 3) Energiewendebauen, 2021; 4) Dena, 2023c; 5) Dena, 2022; 6) UBA, 2023l; 7) Handelsblatt, 2023b.

2 Use case: Building management systems (BMS) in non-residential buildings

Brief description

A building management system (BMS) is a computer-based solution for the centralised control and monitoring of a range of building technologies, such as heating, ventilation, air conditioning, lighting and energy management. Digital technologies will optimise energy consumption, improve the regulation of temperature and air quality, and enable efficient lighting management.

CO$_2$ effect

2023	4.6%	
	Savings	Baseline
	5.5 Mt CO$_2$	113.5 Mt CO$_2$
2030	10.8%	
	Savings	Projection
	4.4 Mt CO$_2$	40.4 Mt CO$_2$

EBIT effect

2023	4.6%[a]	
	Increase	Expenses
	€1,789.1m	€38.7bn
2030	10.7%[a]	
	Increase	Expenses
	€2,488.5m	€23.2 bn

Adoption rates

2023	33%
2030	78%

Digital technologies employed

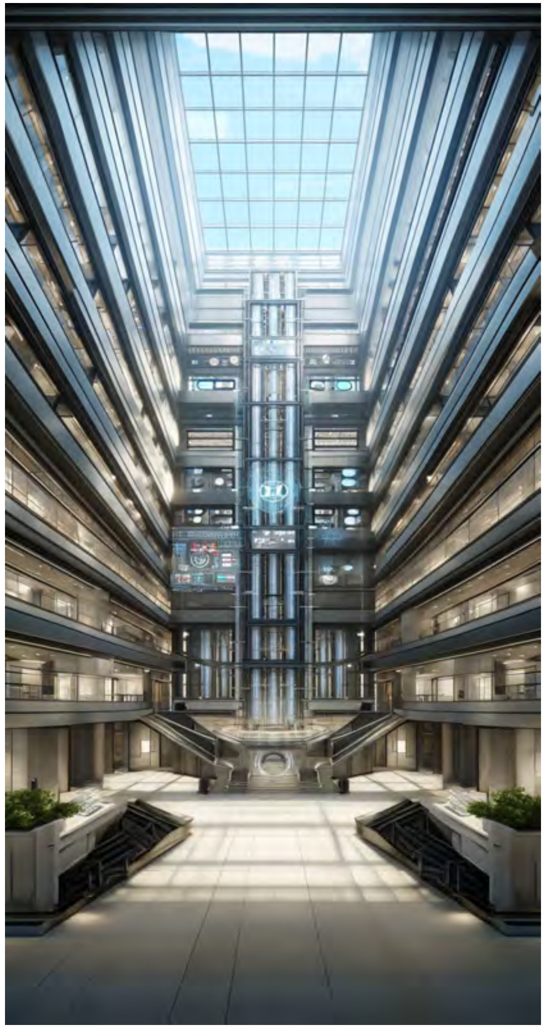
Sensor technology and IoT: The collection of real-time data on room temperatures, air quality, light levels and other environmental conditions in order to optimise energy consumption.

Automation and regulation: The use of automated systems to control heating, ventilation, air conditioning (HVAC), lighting and other building functions in order to maximise comfort and minimise energy consumption.

Energy management systems (EMS): The use of an EMS to continuously monitor, analyse and optimise energy consumption, including by integrating renewable energies.

Artificial intelligence (AI) and data analytics: The use of AI algorithms and data analysis in order to identify patterns in building behaviour, predict maintenance requirements and optimise operational processes.

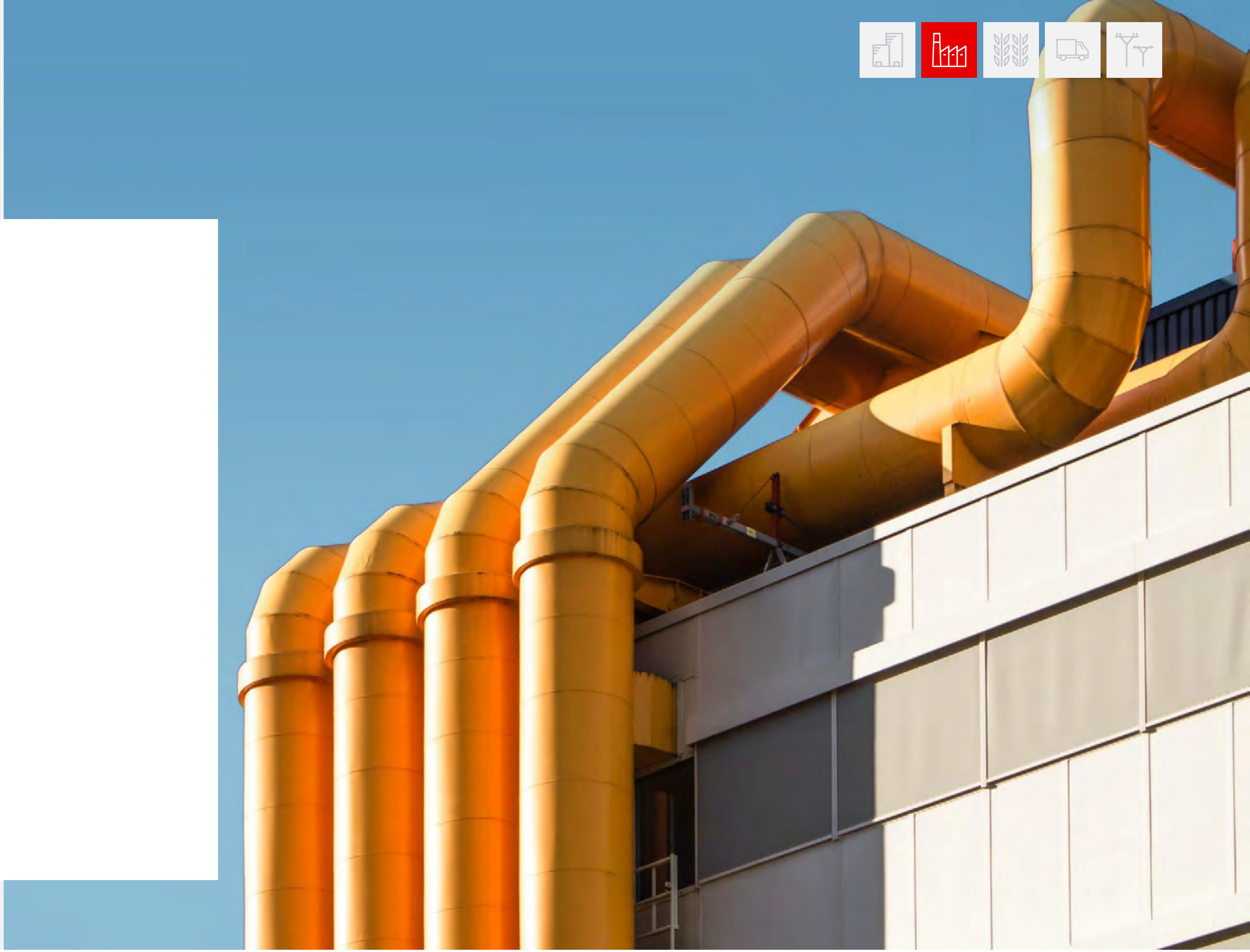
Mobile applications: The use of mobile applications that facility managers can use to remotely monitor and control building systems as well as to efficiently communicate in cases of emergency.



Notes: Deviations in the divisions may result from rounding; a) Percentage share of cross-sector cost savings (shown here as an EBIT increase of €1.8 billion and €2.5 billion) in Germany's total expenditures on heating, hot water, cooling, ventilation and lighting (€38.7 billion and €23.2 billion). Reason: The cost savings resulting from BMS have a cross-sector impact on the EBIT of building tenants ...and not just for companies in the buildings sector.

2 Sector analysis

2.2 Industry



Industry
Sector, sub-sectors and use cases

Brief description of the sector

Germany ranks among the world's leading industrialised nations and is renowned for developing and manufacturing complex goods. In 2023, 8 million people were employed in Germany's manufacturing industry,[1] and the sector contributed 24.5% to gross value added.[2] This makes the manufacturing industry a key factor for the growth of and prosperity in Germany – more so than for many other countries.

The innovative strength of Germany's economy, which is driven by intensive R&D efforts, will therefore play an important role in the country's development. In 2022, €121 billion was invested in R&D in Germany. This corresponds to more than 3% of GDP[3] and is well above the OECD average of 2.7%.[4]

Digital technologies are already playing a key role in the industry sector to ensure profitability and to boost innovative strength. To show how this is happening, this study analyses various sub-sectors and sub-industries, including the steel, products, cement and chemicals industries.

Analysed sub-sectors and use cases

I. Steel industry

1 Digital twin incl. digital modelling and optimisation of the smelting process

II. Products industry

2 Digital twin and virtual prototype development

III. Cement industry

3 Digital twin incl. digital modelling of the calcination process

IV. Chemicals industry

4 Digital twin incl. digital modelling for the reformulation of chemical products

Sources: 1) Destatis, 2024b; 2) Statista, 2024b; 3) Destatis, 2023a; 4) OECD, 2022.

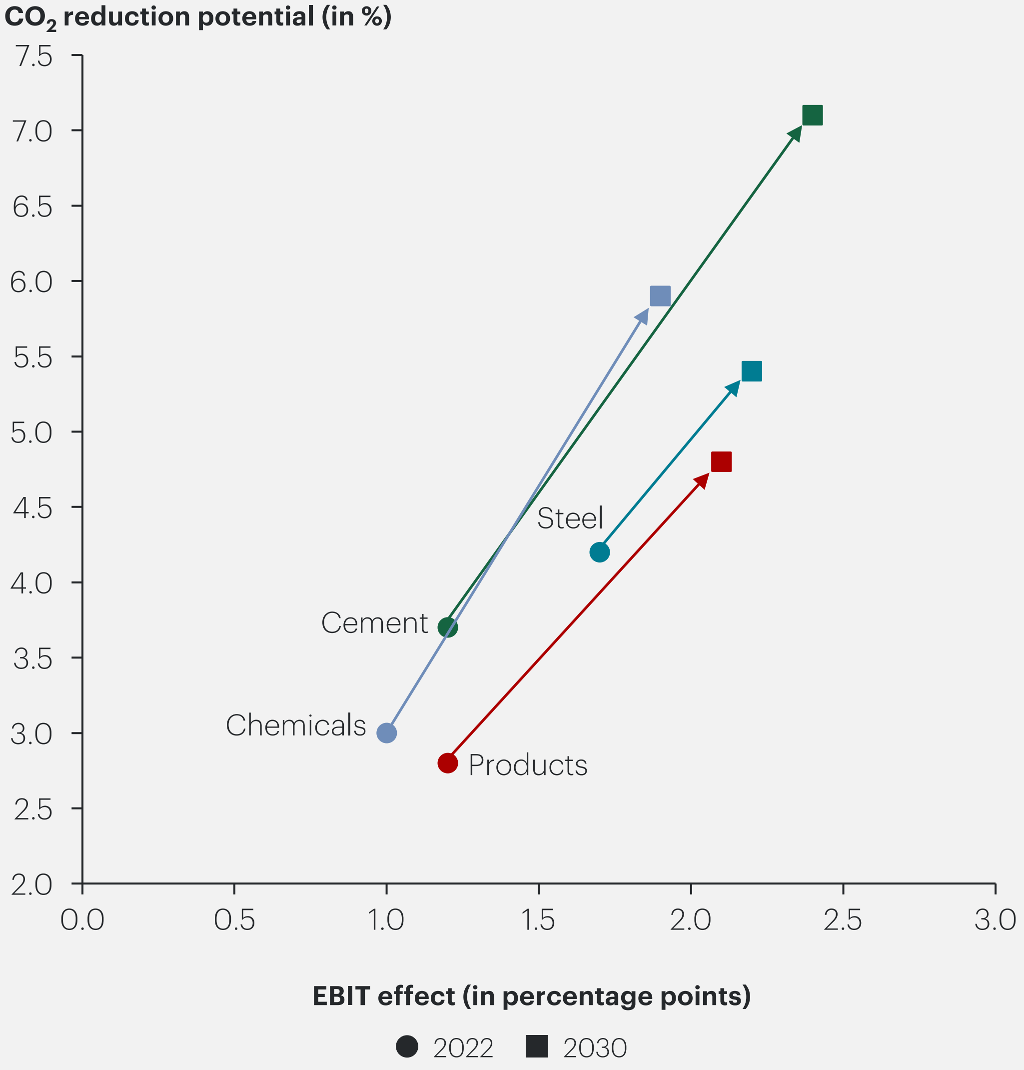
Industry
Key findings at a glance

	Decarbonisation Index	Profitability Index
	60	58
	CO_2 savings	EBIT effect
2023	3.3% 5.7 Mt CO_2	1.2% €22,861m
2030	5.6% 7.9 Mt CO_2	2.1% €42,215m

1. **Decarbonisation and EBIT effects will exhibit a parallel trend in all sub-sectors:** Since all four sub-sectors are energy-intensive, there is great potential for reducing the consumption of energy and raw materials by employing digital technologies.
2. **Cement and chemicals industry with highest growth in absolute CO_2 reduction by 2030:** Due to the expected strong increase in the adoption rate of digital technologies, absolute CO_2 savings are expected to increase by up to 70% in both sub-sectors.
3. **Highest CO_2 effect in 2030 in the cement industry**: Compared to the other sub-sectors, the highest CO_2 effect – 7% in 2030 – is expected to be in the cement industry.[a]
4. **Highest absolute CO_2 savings will be in the chemicals and steel industries:** In both sub-sectors, a reduction of well over 2 Mt of CO_2 is expected in 2030.
5. **The absolute EBIT effects in the cement and chemicals industries will double:** By 2030, both sub-sectors will have an opportunity to double the EBIT increase currently achieved via digitalisation.
6. **The largest absolute increase in profitability will be in the products industry:** By 2030, digital technologies will enable an additional EBIT of up to €17 billion in this sub-sector, which includes the automotive and mechanical engineering segments.
7. **The largest increase in the adoption rate will be in the cement and chemicals industries:** By 2030, the adoption rate of digital technologies is expected to increase by 100% in both sub-sectors.

Notes: Deviations in the divisions may result from rounding; a) Based on data from the survey of companies in the industry sector and the calculations (see also Chapter 5.1 Methodology, p. 103 ff.).

Industry
Comparison of CO_2 reduction and EBIT effects



Decarbonisation and EBIT effects from digital technologies will exhibit a similar trend in all sub-sectors.

All four industrial sub-sectors are traditionally energy-intensive[1] and show great potential for savings in energy and raw materials (up to ≈20%[a]) by using technologies such as digital twins. Since the reduction in energy and raw-material consumption is reflected in savings in both costs and CO_2 emissions, the CO_2 and EBIT lines of the four sub-sectors show similar proportional slopes.

In percentage terms, the highest potential CO_2 reduction (7%) in 2030 is expected in the cement industry.

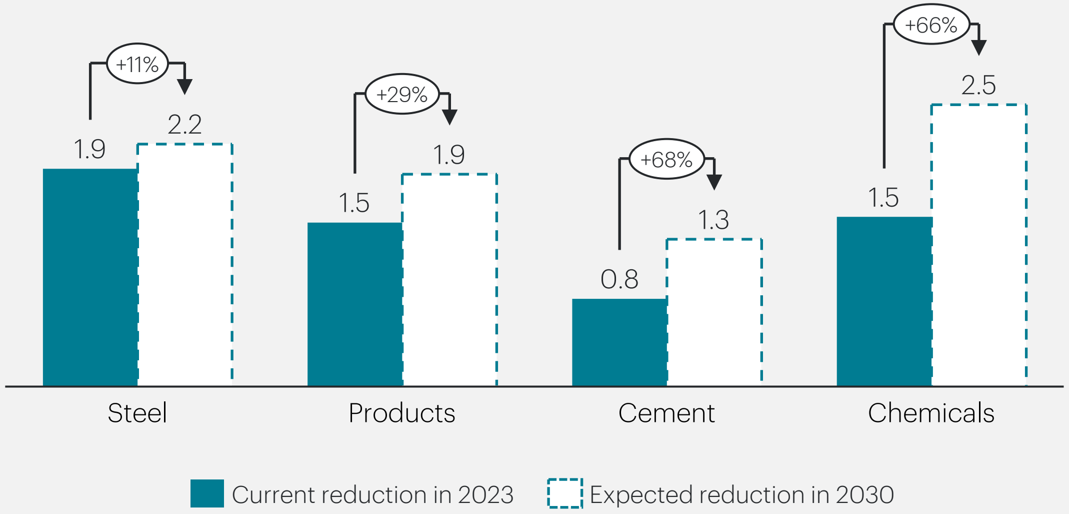
Germany's cement industry has set itself the goal of achieving climate neutrality by 2045 at the latest.[2] Since producing cement is a very energy-intensive process – mainly due to the calcination of limestone, a main component of cement – reducing CO_2 emissions in this sub-sector is considered particularly challenging. The cement industry will therefore have to make use of all available reduction levers, including digital technologies. The study shows that, compared to the other three sub-sectors, both the expected adoption rate of digital technologies (59%) and the specific CO_2 reduction lever (12%) are greatest in the cement industry.[a]

Note: a) Based on data from the survey of companies in the industry sector and the calculations (see also Chapter 5.2 Methodology, p. 119).
Sources: 1) Destatis, 2024a; 2) VDZ, 2023c.

Industry

CO_2 savings and EBIT increases

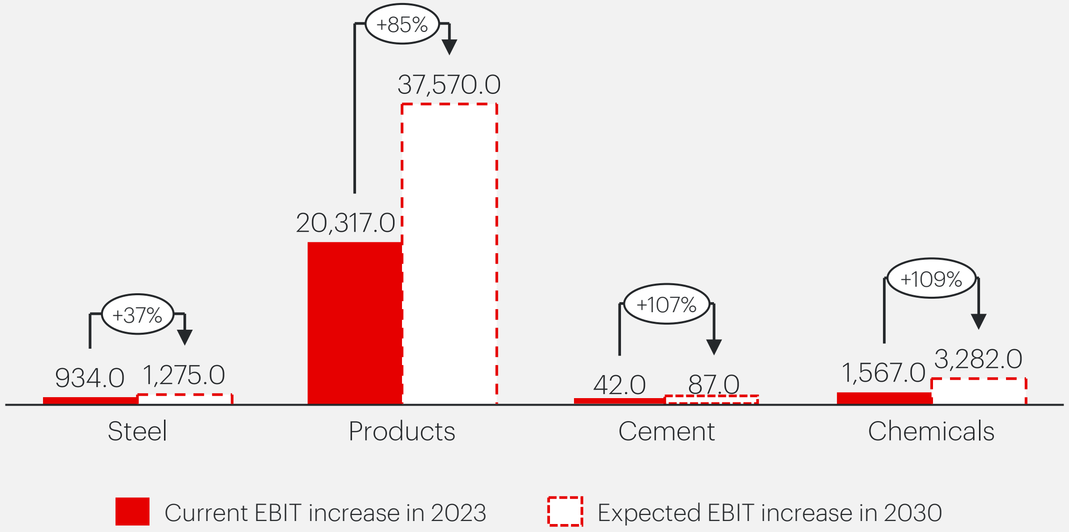
CO_2 reduction potential (in Mt CO_2/year)



The cement and chemicals sub-sectors will exhibit the highest rates of increase in CO_2 savings – One of the main reasons for this will be the significantly higher increase in the adoption rates of digital technologies (by around 100%) compared to the other sub-sectors.[a]

The chemicals and steel sub-sectors are expected to achieve the highest absolute CO_2 savings in 2030 – This is mainly due to having the highest CO_2 projections relative to other sub-sectors, which will collectively account for roughly 60% of expected industrial emissions in 2030.[b]

EBIT potential increase in EBIT (in € m)



The cement and chemicals sub-sectors have an opportunity to double the EBIT increases currently achieved via digitalisation – In this case, as with the CO_2 reduction potential, the significantly higher increase in the adoption rates of digital technologies will also be a contributing factor.[a]

The products sub-sector will achieve by far the highest absolute EBIT increases in 2030 – This will simply be due to the economic size of this sub-sector, which includes the automotive and mechanical engineering segments.[c]

Notes: a) See next page; b) See also Chapter 5.2 Figures in Detail, p. 119; c) This study forecasts that turnover from the products sub-sector (incl. the automotive and mechanical engineering segments) will contribute around €1,760 million of the industry sector's total turnover in 2030, or around 88% (see also section 5.2 Figures in detail, p. 119).

Industry
Current and expected adoption of digital technologies

Doubling of the adoption rate of digital twins in the cement and chemicals industry by 2030.

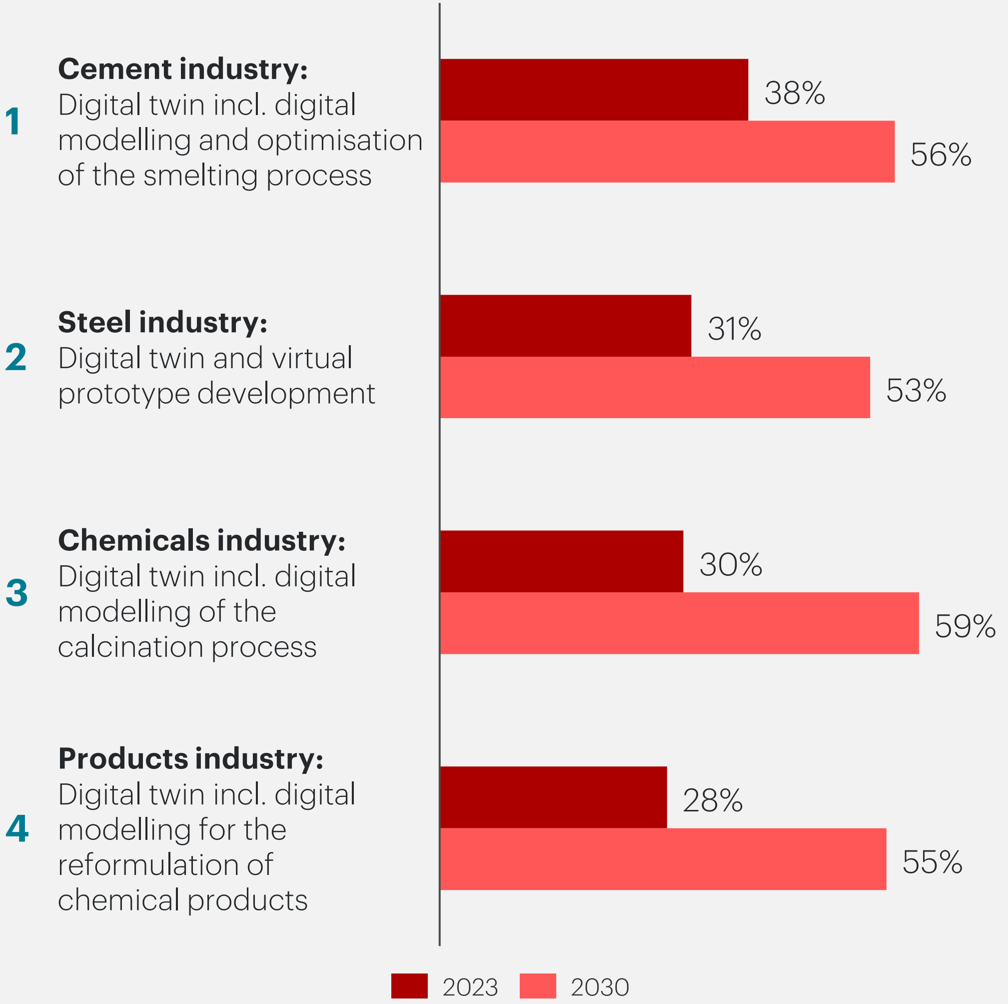
The level of implementation of digital technologies for the virtual depiction of physical objects and processes (digital twin) in the cement and chemicals industries currently stands at around 30% and will nearly double by 2030. Since both industries are under great pressure to reduce their carbon footprint, they will need to use every lever to decarbonise. The ambitious adoption of digital technologies is therefore considered indispensable. But it will not be a game changer on its own when it comes to tackling the net-zero challenge.

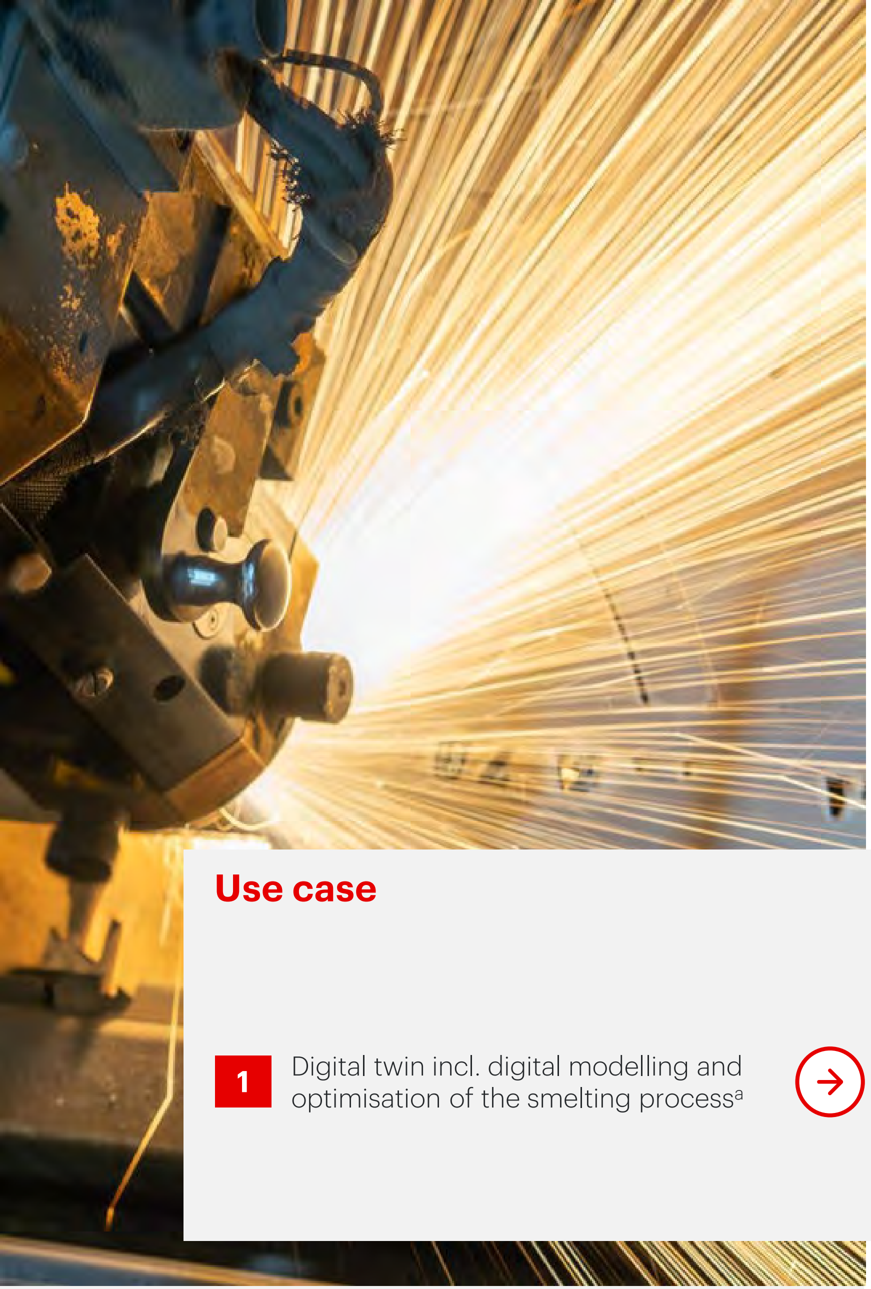
With an expected adoption rate of 56% in 2030, German steel companies are considered leaders.

When it comes to the use of digital twins in the steel industry with oxygen blast furnaces, German companies have more ambitious adoption rates compared to global benchmarks (see also Chapter 1.4 Adoption rates, p. 28 and next page).

Adoption rate of the use cases

[In %]





I. Steel industry
Digital optimisation of facilities and processes

Description of the sub-sector

In 2020, the German steel industry employed 81,000 people and generated €55.2 billion in turnover.[1] With a production volume of around 40 million tonnes of crude steel, Germany is the largest steel producer in the EU.[1] While around two-thirds of this involved the production of primary steel, one-third involved the processing of steel scrap.[1] As an important supplier to the automotive and construction industries as well as mechanical and plant engineering, the steel industry plays a key role in the German economy[2] and is responsible for around 30% of industrial CO_2 emissions.[3]

Challenges and fields of digitalisation

To meet the German government's climate target, ambitious decarbonisation will be required in the CO_2-intensive steel industry. In order for the transformation to climate-neutral steel production to succeed, existing plants and processes will have to be optimised or new ones designed. A large number of steel manufacturers already plan to build climate-neutral production facilities.[4] The analysis of adoption rates focuses on the use of oxygen blast furnaces, in which German companies hold a leading position. Nevertheless, one should not overlook the partial transition of the steel industry to electric arc furnaces. This advanced technology results in a significant reduction in the consumption of iron ore and therefore a significant reduction in CO_2 emissions – as does the utilisation of steel scrap in production.[5] Precise analysis, modelling and planning will be essential for the effective and cost-efficient implementation of these measures. The focus will particularly be on the energy-intensive smelting process, which causes substantial CO_2 emissions in primary steel production.[6]

Use case

1 Digital twin incl. digital modelling and optimisation of the smelting process[a]

	CO_2 effect	EBIT effect
2023	**4.2%** 1.9 Mt CO_2	**1.7%** €934.3m
2030	**5.4%** 2.2 Mt CO_2	**2.2%** €1,275.1m

Note: a) In the survey, adoption rates, CO_2 savings and EBIT increases were precisely differentiated for the sub-use cases (i) digital twin and (ii) virtual modelling and optimisation of the smelting process and then consolidated here. Sources: 1) Wirtschaftsvereinigung Stahl, 2022b; 2) Küster Simic et al., 2020; 3) Wirtschaftsvereinigung Stahl, 2022a; 4) Knitterscheidt, 2023; 5) Fraunhofer IMWS, 2019; 6) WOTech, 2023.

1 Use case: Digital twin incl. digital modelling and optimisation of the smelting process

Brief description

In steel production, the digital twin will enable the real-time monitoring of the status, performance and behaviour of a production facility. In doing so, it will facilitate predictive maintenance and minimise system downtimes by recording real-time data and performing pattern analyses. The precise design of the smelting process is an example of the resulting improvement in performance and efficiency in production.

CO_2 effect

2023	4.2%	
	Savings	Baseline
	1.9 Mt CO_2	44.1 Mt CO_2
2030	5.4%	
	Savings	Projection
	2.2 Mt CO_2	40.0 Mt CO_2

EBIT effect

2023	1.7%	
	Increase	Turnover
	€934.3m	€55.2bn
2030	2.2%	
	Increase	Turnover
	€1,275.1m	€58.9bn

Adoption rates[a]

2023	38%
2030	56%

Digital technologies employed

Sensors: Collect real-world data regarding a product or process in order to generate a fully detailed physical and functional description for a digital twin.[1]

Internet of Things (IoT) and machine-to-machine (M2M): IoT links machines with their digital twins, thereby enabling them to be monitored and controlled using real-time data. M2M communication in turn facilitates the automated exchange of information and thereby optimises maintenance processes and operating efficiency in the steel industry.[2]

Cloud computing: Data from IoT devices is analysed in the cloud to optimise the performance of physical assets. This enables the efficient use of resources and in-depth centralised analyses.[2]

Artificial intelligence (AI) and machine learning (ML): Advanced AI algorithms will use the data collected by digital twins to make predictions and optimise decision-making in the steel industry. ML will make it possible to recognise patterns and automatically react to new data, which in turn will result in continuous process improvement.[3,4]

Augmented reality (AR): AR links digital and real-world environments, enabling visualisations and interactions with digital twins and thereby offering innovative applications for training, inspections and maintenance work in the steel industry.[2]

Notes: Deviations in the divisions may result from rounding. a) In the survey, adaptation rates, CO_2 savings and EBIT increases were precisely differentiated for the sub-use cases (i) digital twin and (ii) digital modelling and optimisation of the smelting process and then consolidated here. Sources: 1) Ramschek, 2020; 2) AEA, 2022; 3) Altair, 2022; 4) Alajmi & Almeshal, 2020.

II. Products industry

Digital optimisation of production and product-development processes

Description of the sub-sector

The products industry, also known as the manufacturing industry, manufactures products (e.g. automobiles, machines, consumer goods) using specialised machinery and mass production techniques. In 2021, the sub-sector employed around 7.5 million people and generated €2,100 billion in turnover.[1]

The products industry is therefore of immense economic importance – as both a major employer and a driver of exports and innovation. Like all other industrial sub-sectors, it faces major challenges in reducing its CO_2 emissions and maintaining its profitability in the face of competitive markets.

Challenges and fields of digitalisation

Rising labour and energy costs will need to be managed in the products industry, particularly in the automotive and mechanical engineering segments. One key factor for ensuring competitiveness will be shortening development times in order to bring new products to market more quickly. At the same time, it will be necessary to boost efficiency, achieve additional growth and prioritise sustainability in all areas – but, most importantly, to advance decarbonisation.[2]

The digital solutions should concentrate on optimising production processes and reorganising product development. Two use cases are of particular importance here: A digital twin creates a virtual model of existing systems or products (e.g. production lines, motors) in order to carry out simulations for process optimisation. Virtual prototype development, on the other hand, makes it possible to analyse and improve the design and functionality as early as the design phase using digital models (e.g. vehicle bodies, machine parts). This improves cost efficiency and significantly shortens development times.

Use case

2 Digital twin and virtual prototype development[a] →

	CO_2 effect	EBIT effect
2023	**2.8%** 1.5 Mt CO_2	**1.2%** €20,317.3m
2030	**4.8%** 1.9 Mt CO_2	**2.1%** €37,570.5m

Note: a) In the survey, adoption rates, CO_2 savings and EBIT increases were precisely differentiated for the sub-use cases (i) digital twin and (ii) virtual prototype development and then consolidated here. Sources: 1) Destatis, 2023c; 2) Aras, 2023.

2 Use case: Digital twin and virtual prototype development

Brief description

In the products industry, the digital twin is a virtual replica of real-world physical products and production processes that enables both the monitoring and real-time control of real-world objects. Virtual prototype development involves creating a virtual replica of a product prototype to optimise its design, functionality and performance before a physical prototype is created.

CO_2 effect

		Savings	Baseline
2023	2.8%	1.5 Mt CO_2	50.9 Mt CO_2

		Savings	Projection
2030	4.8%	1.9 Mt CO_2	39.1 Mt CO_2

EBIT effect

		Increase	Turnover
2023	1.2%	€20,317.3m	€1,650.9bn
2030	2.1%	€37,570.5m	€1,760.3bn

Adoption rates[a]

2023	31%
2030	53%

Digital technologies employed

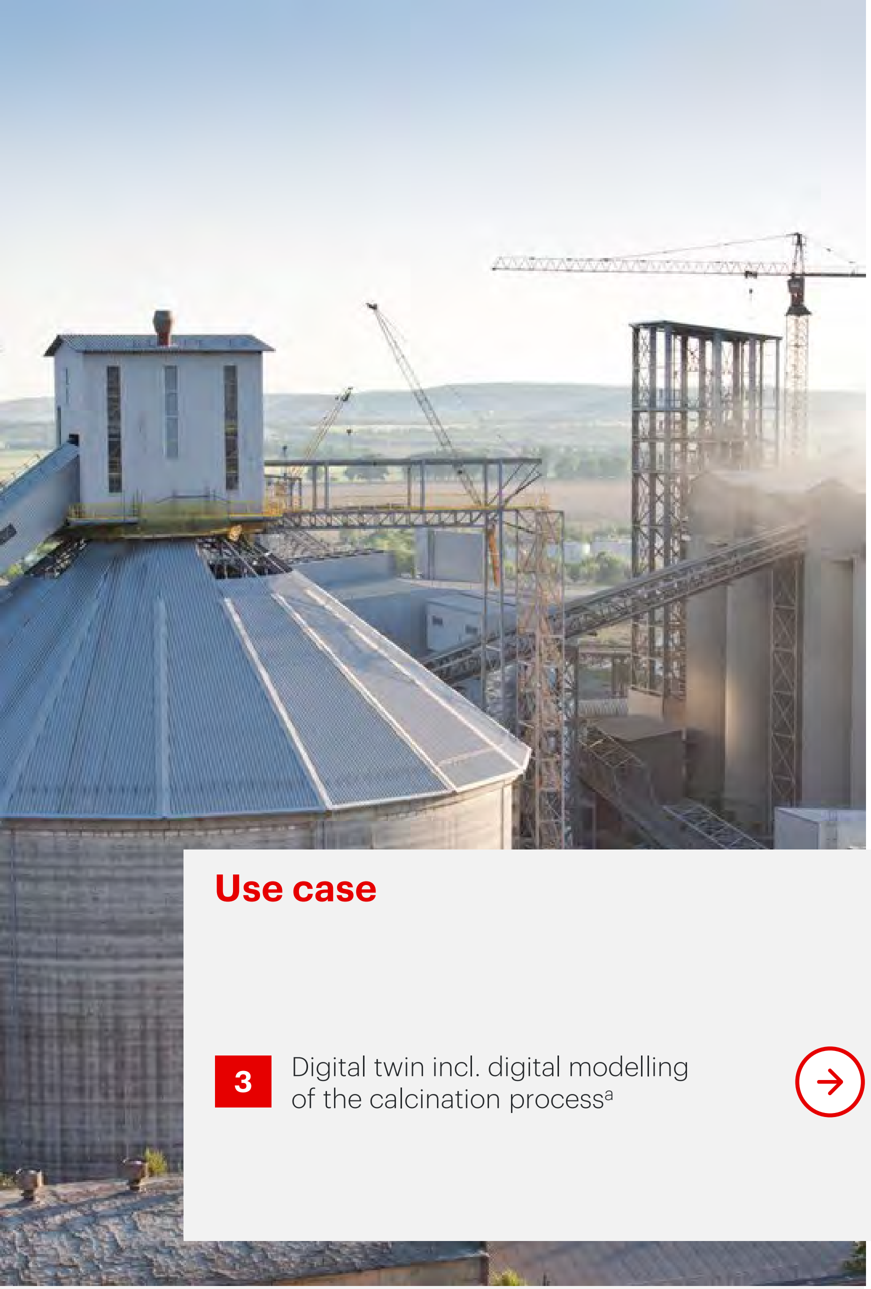
Sensors: In the automotive industry, for example, sensors record real-time data from vehicles and production facilities. They constitute the basis for creating or updating digital twins.

Internet of Things (IoT) and machine-to-machine (M2M): In sectors such as mechanical engineering, IoT and M2M communication enable networking and the automated exchange of information between production machines, which in turn allows for more efficient monitoring and control of production processes and maintenance procedures.[1]

Augmented reality (AR) and virtual reality (VR): AR and VR create interactive environments, e.g. for product design and prototype development or for interacting with a digital twin of a production line. While AR adds digital elements to the real world, VR immerses users in completely virtual worlds.[1,2]

Artificial intelligence (AI) and machine learning (ML): AI algorithms will use the data collected by the digital twin to create predictive models and optimise decision-making in production and product development. Machine learning will make it possible to identify patterns and automatically react to new data, which in turn will result in continuous process improvements.[3]

Notes: Deviations in the divisions may result from rounding. a) In the survey, adoption rates, CO_2 savings and EBIT increases were precisely differentiated for the sub-use cases (i) digital twin and (ii) virtual prototype development and then consolidated here. Sources: 1) AEA, 2022; 2) Stark et al., 2011; 3) Altair, 2022.



III. Cement industry
Digital optimisation of facilities and processes

Description of the sub-sector

The cement industry is one of the leading exporters within the German economy. In 2022, it employed around 8,000 people and generated €3.4 billion in turnover.[1]

Producing cement is a major contributor to global greenhouse gas emissions – 8% worldwide[2] and 2% in Germany.[3] In 2020 alone, 20 million tonnes of CO_2 were emitted.[4] This is because production is extremely energy-intensive, both in terms of the extraction and processing of raw materials. The commitment to climate-neutral production represents an enormous challenge to the cement industry.

Use case

3 Digital twin incl. digital modelling of the calcination process[a]

	CO_2 effect	EBIT effect
2023	**3.7%** 0.8 Mt CO_2	**1.2%** €42.3m
2030	**7.1%** 1.3 Mt CO_2	**2.4%** €87.2m

Challenges and fields of digitalisation

To counter rising energy consumption and material costs, the cement industry is increasingly relying on digitalisation, particularly in the production process.[5] Digital technologies enable more precise control and monitoring of production, which simultaneously improves product quality and reduces both energy consumption and CO_2 emissions.

Digital platforms for cement plants will enable effective monitoring and management of energy consumption, thereby reducing operating costs and environmental impacts. Digital modelling of the industry-specific calcination process (i.e. the process for deacidifying limestone at approx. 900 degrees Celsius) will enable precise control, lead to an increase in quality, and reduce both energy consumption and emissions. Using a digital twin in the cement industry will also enable real-time monitoring and optimisation of the entire production process.

These digital solutions offer promising opportunities for tackling the current challenges faced by this sub-sector.

Note: a) In the survey, adoption rates, CO_2 savings and EBIT increases were precisely differentiated for the sub-use cases (i) digital twin and (ii) digital modelling of the calcination process and then consolidated here. Sources: 1) VDZ, 2023, 2) Zajonz, 2023; 3) WWF, 2019; 4) VDZ, 2024; 5) VDZ, 2020.

3 Use case: Digital twin in the cement industry incl. calcination process

Brief description

In the cement industry, the digital twin will use a virtual replica of the production facility to record real-time data and minimise downtime with the help of IoT sensors and machine learning. Digital modelling of the calcination process will optimise efficiency and quality, improve operating processes and result in energy savings.

CO_2 effect

2023	3.7%	
	Savings	Baseline
	0.8 Mt CO_2	20.4 Mt CO_2
2030	7.1%	
	Savings	Projection
	1.3 Mt CO_2	18.5 Mt CO_2

EBIT effect

2023	1.2%	
	Increase	Turnover
	€42.3m	€3.4bn
2030	2.4%	
	Increase	Turnover
	€87.2m	€3.7bn

Adoption rates[a]

2023	30%
2030	59%

Digital technologies employed

Sensors: Collect real-world data on product components and processes in order to generate a fully detailed physical and functional description for a digital twin.

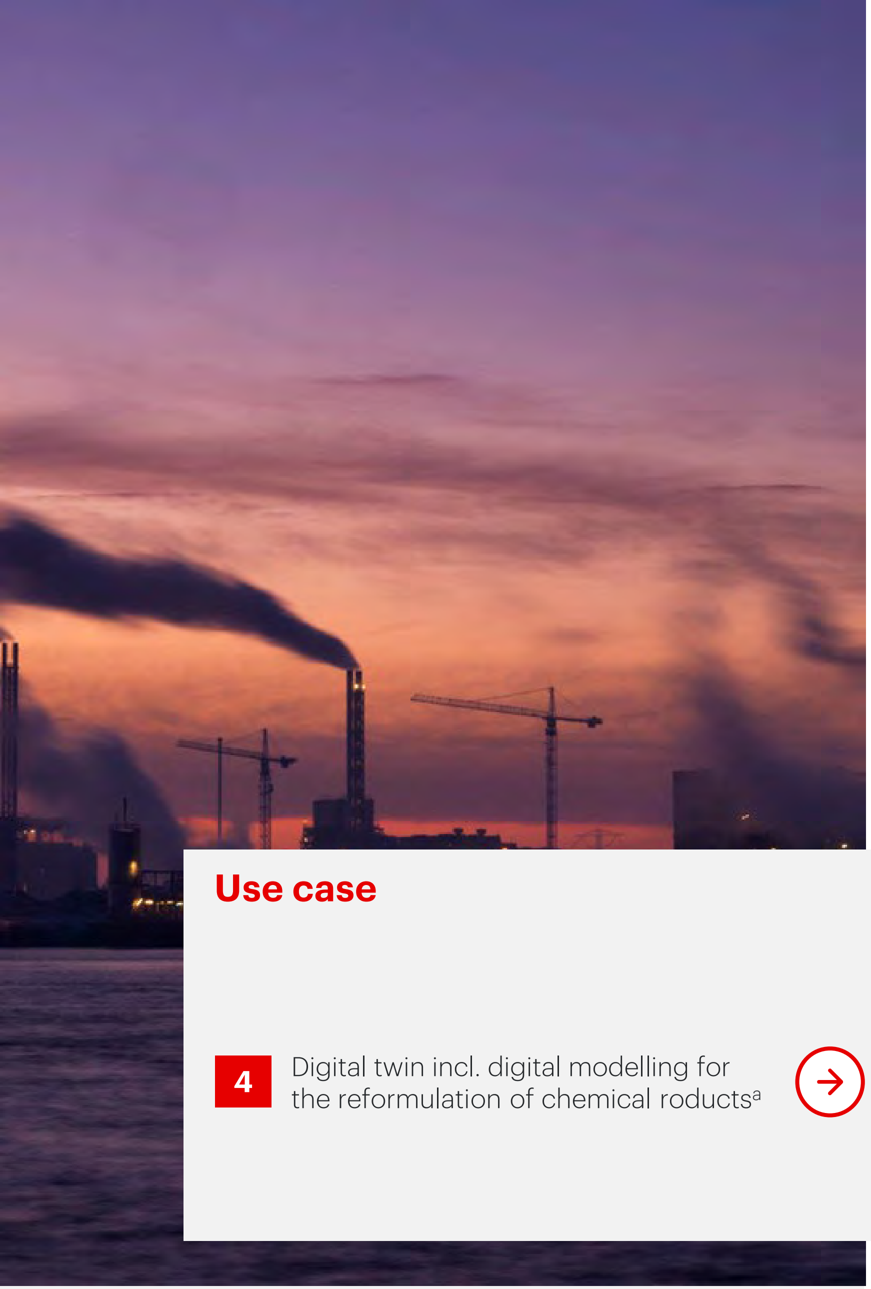
Internet of Things (IoT) and machine-to-machine (M2M): IoT links machines with their digital twins, thereby enabling them to be monitored and controlled using real-time data. M2M communication, in turn, facilitates the automated exchange of information in order to optimise the sometimes-parallel production steps and maintenance processes.[1]

Cloud computing: Storing large amounts of data from IoT devices and analysing them in the cloud results in improved data availability and transmission speeds among the various operating units (e.g. material replenishment and production). As a result, unnecessary transport operations can be avoided, for example.[2]

Artificial intelligence (AI) and machine learning (ML): Advanced AI algorithms use the data in the digital twin to make predictions and optimise decision-making. ML recognises patterns and automatically reacts to new data, resulting in continuous process improvement.[3]

Augmented reality (AR): AR links digital and real-world environments, enabling visualisations and interactions with digital twins and thereby offering innovative applications for training, inspections and maintenance work.[1]

Notes: Deviations in the divisions may result from rounding a) In the survey, adaptation rates, CO_2 savings and EBIT increases were precisely differentiated for the sub-use cases (i) digital twin and (ii) digital modelling of the calcination process and then consolidated here. Sources: 1) AEA, 2022; 2) Thyssenkrupp, 2022; 3) Altair, 2022.



IV. Chemicals industry
Digital optimisation of facilities and processes

Description of the sub-sector

The chemicals industry is one of Germany's major industrial sectors and has a long history. In 2022, it employed around 477,000 people and generated €261 billion in turnover. This puts it in third place among German industrial sectors.[1]

In addition to being of great economic importance, the chemicals industry is a driver of innovation and research. However, there is growing criticism of its production owing to its impact on air and water quality as well as its 49 million tonnes of CO_2 emissions in 2022.

Use case

4 Digital twin incl. digital modelling for the reformulation of chemical roducts[a]

	CO_2 effect	EBIT effect
2023	**3.0%** 1.5 Mt CO_2	**1.0%** €1,567.1m
2030	**5.9%** 2.5 Mt CO_2	**1.9%** €3,282.0m

Challenges and fields of digitalisation

The fact that rising energy costs pose a particularly great challenge to the chemicals industry is a result of the industry's high requirements in terms of temperatures and pressure energy, which are needed to manufacture chemicals and significantly influence energy requirements.[2]

Nevertheless, innovative technologies, such as digital modelling to reformulate chemical products and the use of digital twins to virtualise physical plants, offer promising solutions to reduce the carbon footprint and improve the profitability of the industry.

Digital modelling will make it possible to optimise the composition and properties of chemical products, which in turn will boost production efficiency. The digital twin will also help to boost efficiency and minimise environmental impacts by monitoring and optimising the production process in real time. Digital technologies can therefore make a major contribution to tackling the environmental challenges confronting the chemicals industry.

Note: a) In the survey, adoption rates, CO_2 savings and EBIT increases were precisely differentiated for the sub-use cases (i) digital twin and (ii) digital modelling for the reformulation of chemical products and then consolidated here. Sources: 1) VCI, 2023; 2) Nathusius, 2023.

4 Use case: Digital twin and virtual prototype development

Brief description

In the chemicals industry, the digital twin will depict the status, performance and behaviour of production facilities. IoT sensors, data analysis and machine learning will minimise downtime. This will boost efficiency, improve safety, and help to conserve resources and reduce CO_2 emissions.

CO_2 effect

2023	**3.0%**	
	Savings	Baseline
	1.5 Mt CO_2	48.6 Mt CO_2
2030	**5.9%**	
	Savings	Projection
	2.5 Mt CO_2	42.5 Mt CO_2

EBIT effect

2023	**1.0%**	
	Increase	Turnover
	€1,567.1m	€161.0bn
2030	**1.9%**	
	Increase	Turnover
	€3,282.0m	€171.7bn

Adoption rates[a]

2023	**28%**
2030	**55%**

Digital technologies employed

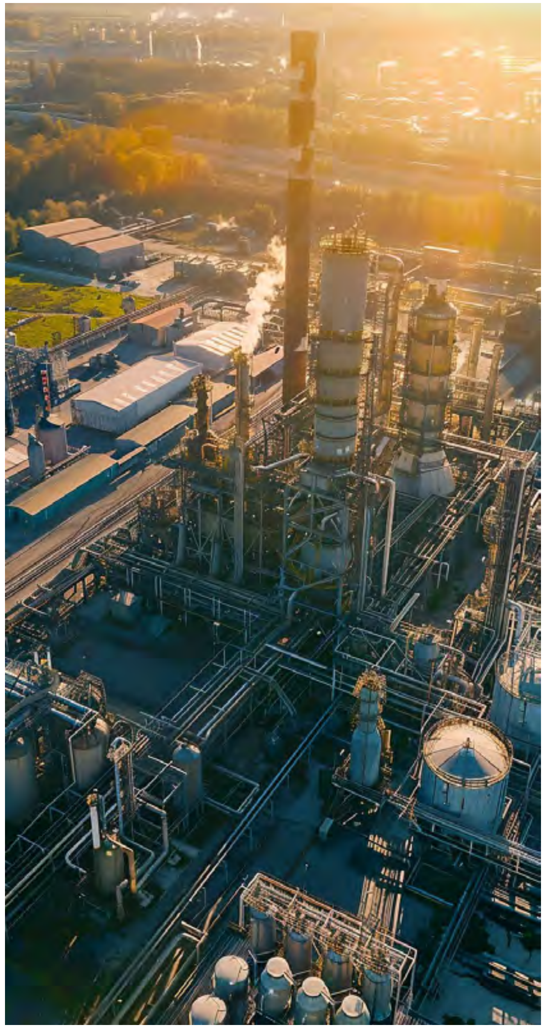
Sensors: Collect real-time data that will enable a fully detailed physical and functional description of production facilities and serve as the basis for generating the digital twin.

Internet of Things (IoT) and machine-to-machine (M2M): The IoT networks machines and devices with their digital twins, enabling real-time data monitoring and control. M2M communication facilitate the automated exchange of information between systems, which in turn boosts the efficiency of operating processes and optimises maintenance procedures.[1]

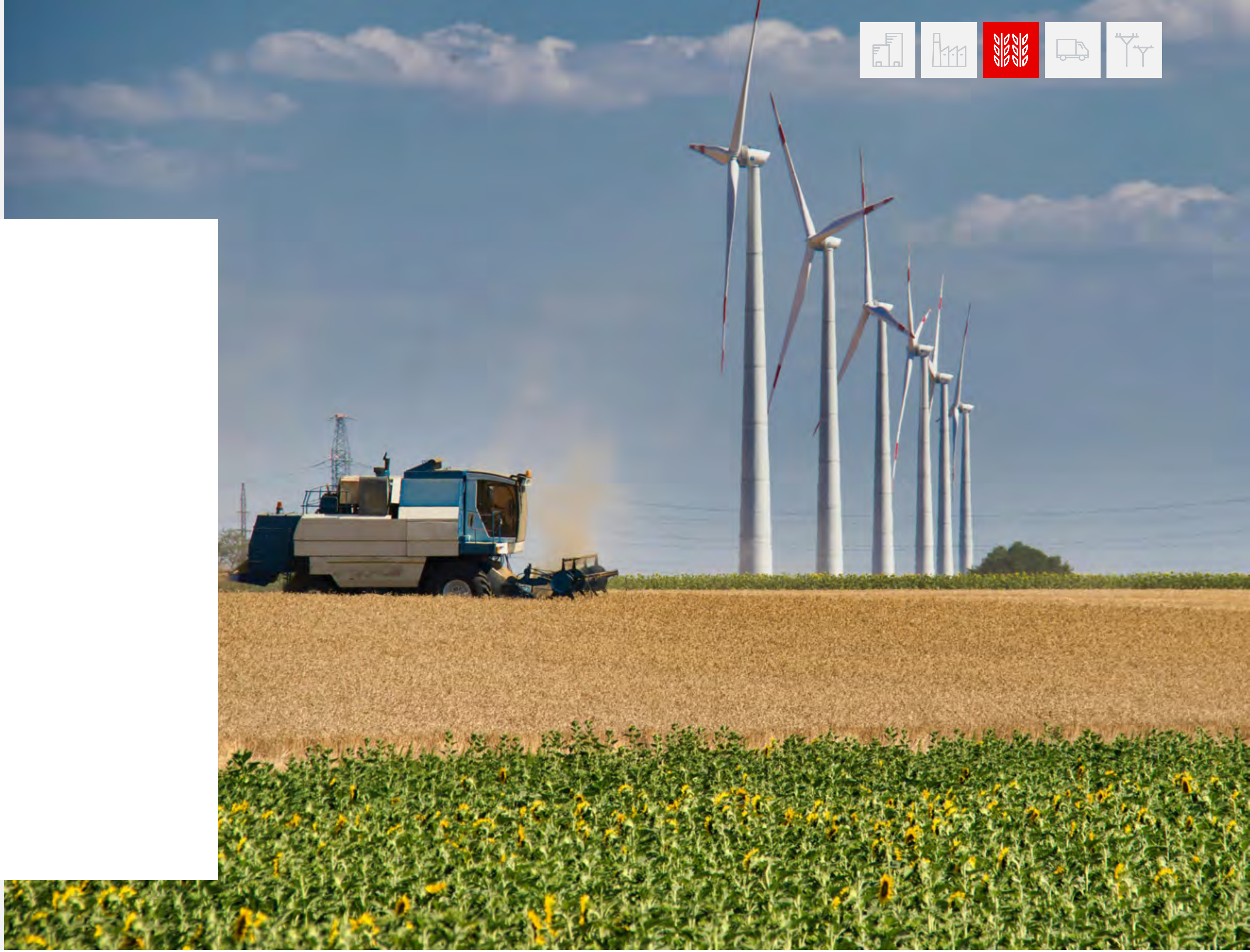
Cloud computing: IoT devices generate extensive data, which is stored and analysed in the cloud. Such data helps to optimise the performance of physical resources – represented by digital twins – and thereby enable the efficient use of resources.[1]

Artificial intelligence (AI) and machine learning (ML): Advanced AI algorithms use the data collected by digital twins to create predictive models and optimise decision-making. ML makes it possible to identify patterns and automatically react to new data, which in turn results in continuous process improvements.[2,3]

Augmented reality (AR): AR links the digital and physical worlds by enabling users to visualise digital twins in the real-world environment and thereby interact with them.[1]



Notes: Deviations in the divisions may result from rounding; a) In the survey, adaptation rates, CO_2 savings and EBIT increases were precisely differentiated for the sub-use cases (i) digital twin and (ii) digital modelling of the reformulation of chemical products and then consolidated here. Sources: 1) AEA, 2022; 2) Altair, 2022; 3) Fantke et al., 2021.



2 Sector analysis

2.3 Agriculture

Agriculture
Sector, sub-sectors and use cases

Brief description of the sector

Germany's agricultural sector is one of the four largest producers in the European Union.[1] In purely numerical terms, around 90% of Germany's food requirements are domestically sourced.[2] To produce these products, around 50% of Germany's land is used for agricultural purposes.[3] The sector, which employs around 1.2 million people[4] (including in the forestry and fishing segments), is divided into two sub-sectors: crop farming and livestock farming.

In crop farming, a structural change is taking place that is characterised by a steady reduction in the number of farms and a simultaneous increase in the average size (i.e. acreage) per farm.[3]

The livestock farming (i.e. animal husbandry) sector is also undergoing structural change, which is reflected in a decline in the number of farms[3] and the animal population itself.[5] In addition, farms engaged in animal husbandry are increasingly specialising in particular animal species.[3]

Analysed sub-sectors and use cases

I. Crop farming

1 Intelligent soil and crop monitoring

2 Intelligent farming machinery

II. Livestock farming

3 Digital livestock monitoring

4 Precision livestock feeding

Sources: 1) BMEL, 2023b; 2) BMEL, 2020; 3) BMEL, 2022; 4) Destatis, 2023b; 5) Destatis, 2023e.

Agriculture
Key findings at a glance

Decarbonisation Index

48

CO$_2$ savings

2023

8.1%

5.3 Mt CO$_2$

2030

16.9%

9.1 Mt CO$_2$

Profitability Index

51

EBIT effect

2023

2.4%

€1,454m

2030

4.6%

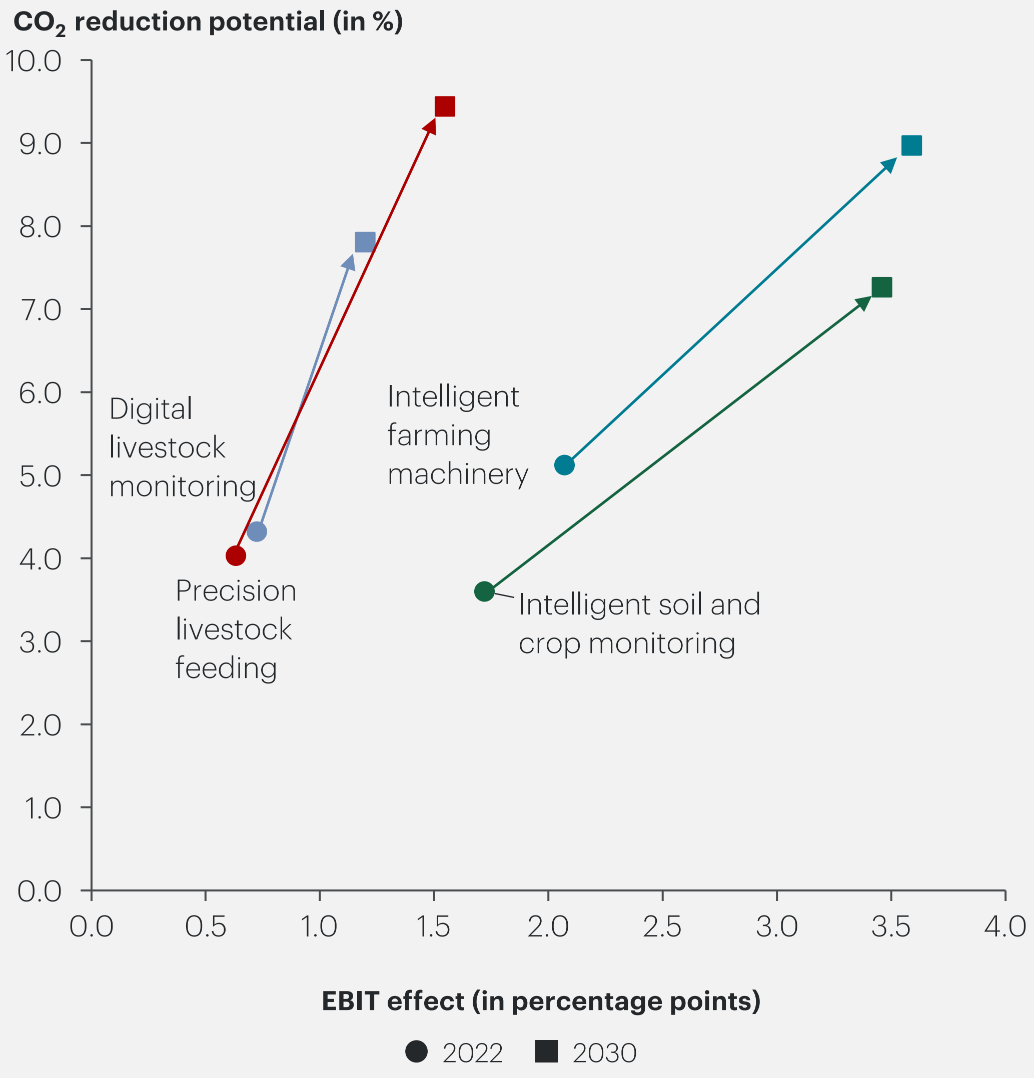
€2,212m

1. **CO$_2$ versus EBIT effects:** In livestock farming, the CO$_2$ effects of digitalisation will be higher than the EBIT effects; in crop farming, the effects on CO$_2$ reduction and EBIT will be almost the same.
2. **CO$_2$ reduction in livestock farming:** Livestock farming currently emits around twice as much CO$_2$ as crop farming. It already has higher absolute CO$_2$ savings today – an effect of digital technologies that will increase by 2030.
3. **EBIT increase in crop farming:** The cost-reduction levers will be greater in crop farming than in livestock farming, for example by 14% for fertiliser costs.
4. **Doubling of the adoption rate of digital technologies:** The adoption rate will increase from an average of 32% today to 63% by 2030.[a] The introduction and scaling of digital technologies – such as artificial intelligence (AI), the Internet of Things (IoT), sensors and drones – in agriculture is already in full swing.
5. **High scaling of monitoring use cases:** This primarily relates to digital technologies for monitoring soils, crops and livestock, which have a target adoption rate of up to 75%. This means that they will be widely used in Germany's agriculture industry by 2030.

Notes: Deviations in the divisions may result from rounding; a) See also Chapter 1.4 Adoption Rates, p. 29.

Agriculture

Comparison of CO_2 reduction and EBIT effects



Profitability and decarbonisation are closely linked in the agricultural sector[a] and will be significantly increased by digitalisation. The EBIT effects will be far greater in crop farming than in livestock farming.

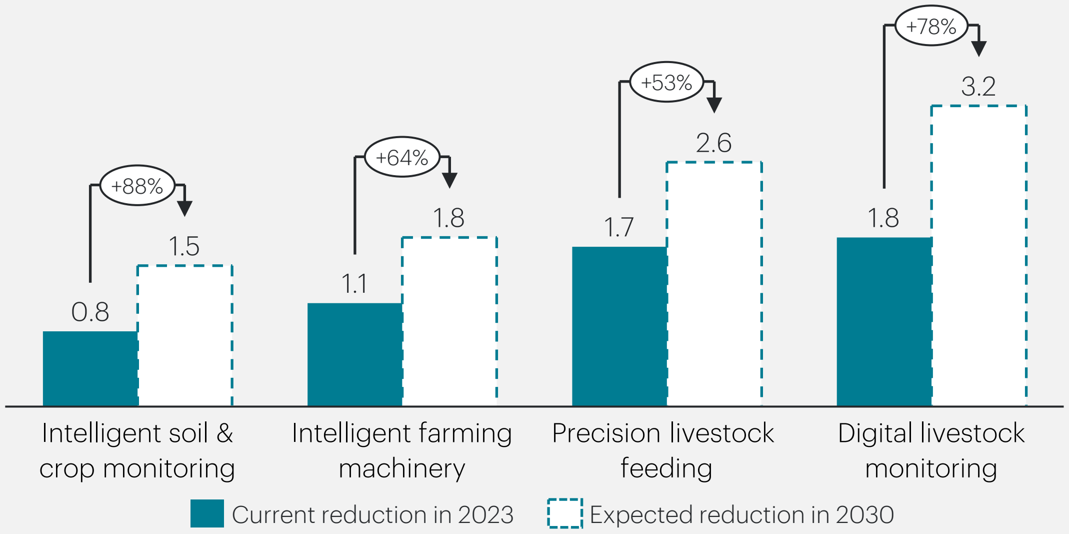
In crop farming, the two use cases "intelligent soil and crop monitoring" and "intelligent farming machinery" will address the two major cost drivers in farming operations: expenditures for fertilisers and for personnel.

Fertiliser costs can account for up to 40% of total operating costs. According to the company survey, it will be possible to reduce the consumption of fertilisers by between 6.0% and 13.5% with the help of digital technologies. Personnel costs, on the other hand, can account for up to 10% of total operating costs. In this case, digital solutions will make it possible to reduce the need for manual labour by between 6.3% and 14.3%.[a]

Note: a) Based on data from the survey of companies in the agricultural sector.

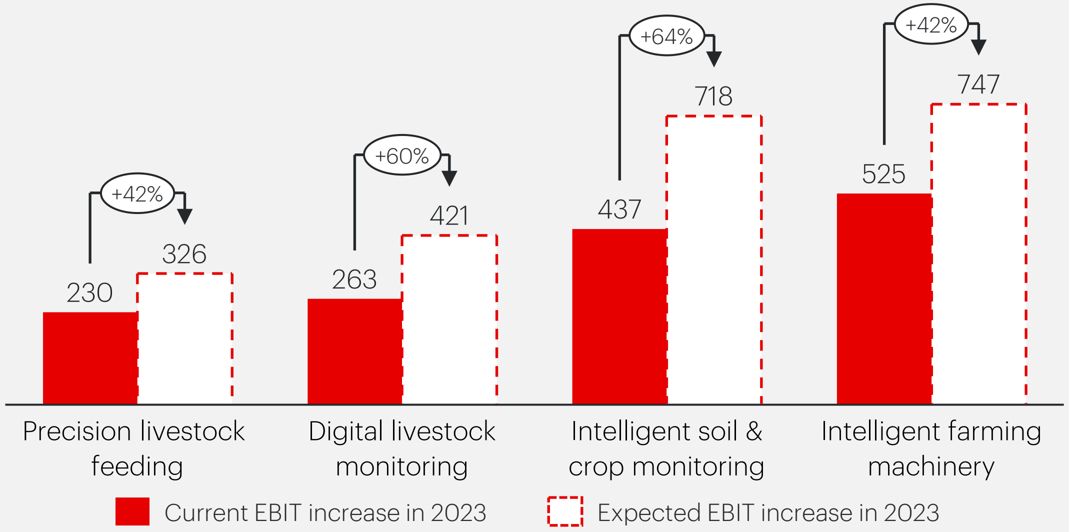
Agriculture
CO_2 savings and EBIT increases

CO_2 reduction potential (in Mt CO_2/year)



Digitalisation will result in higher absolute CO_2 savings in livestock farming compared to crop farming – both in 2023 and 2030 – This is due to the higher CO_2 emissions in livestock farming, which currently emits around twice as much CO_2 emissions as crop farming. The further adoption of digital technologies in this sub-sector will therefore play an important role in reducing emissions in the agricultural sector.

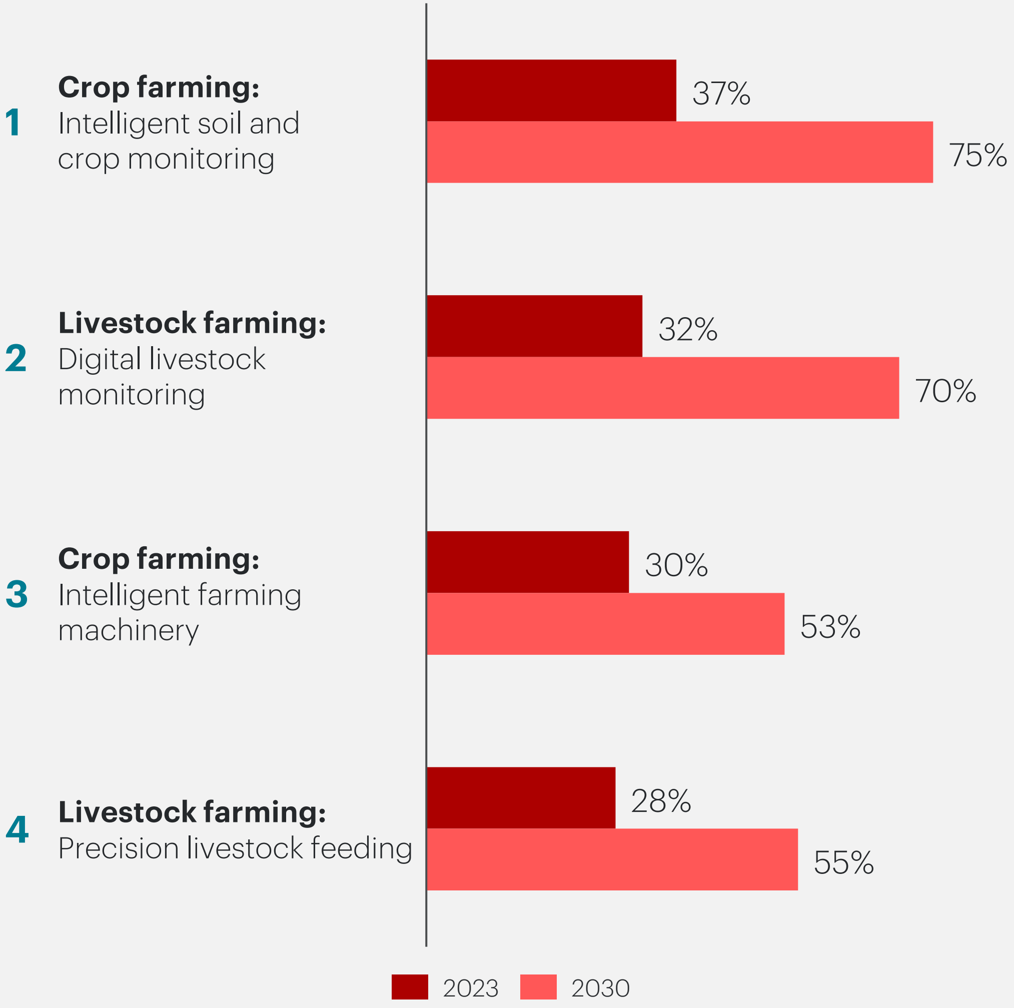
Potential increase in EBIT (in € m)



Digitalisation will result in greater profitability increases in crop farming compared to livestock farming – both in 2023 and 2030 – The company survey reveals that the cost-reduction levers in crop farming are significantly higher than in livestock farming, especially for fertilisers, personnel and fuel consumption (up to 12%).

Adoption rates of the use cases

[in %]



Agriculture

Current and expected adoption of digital technologies

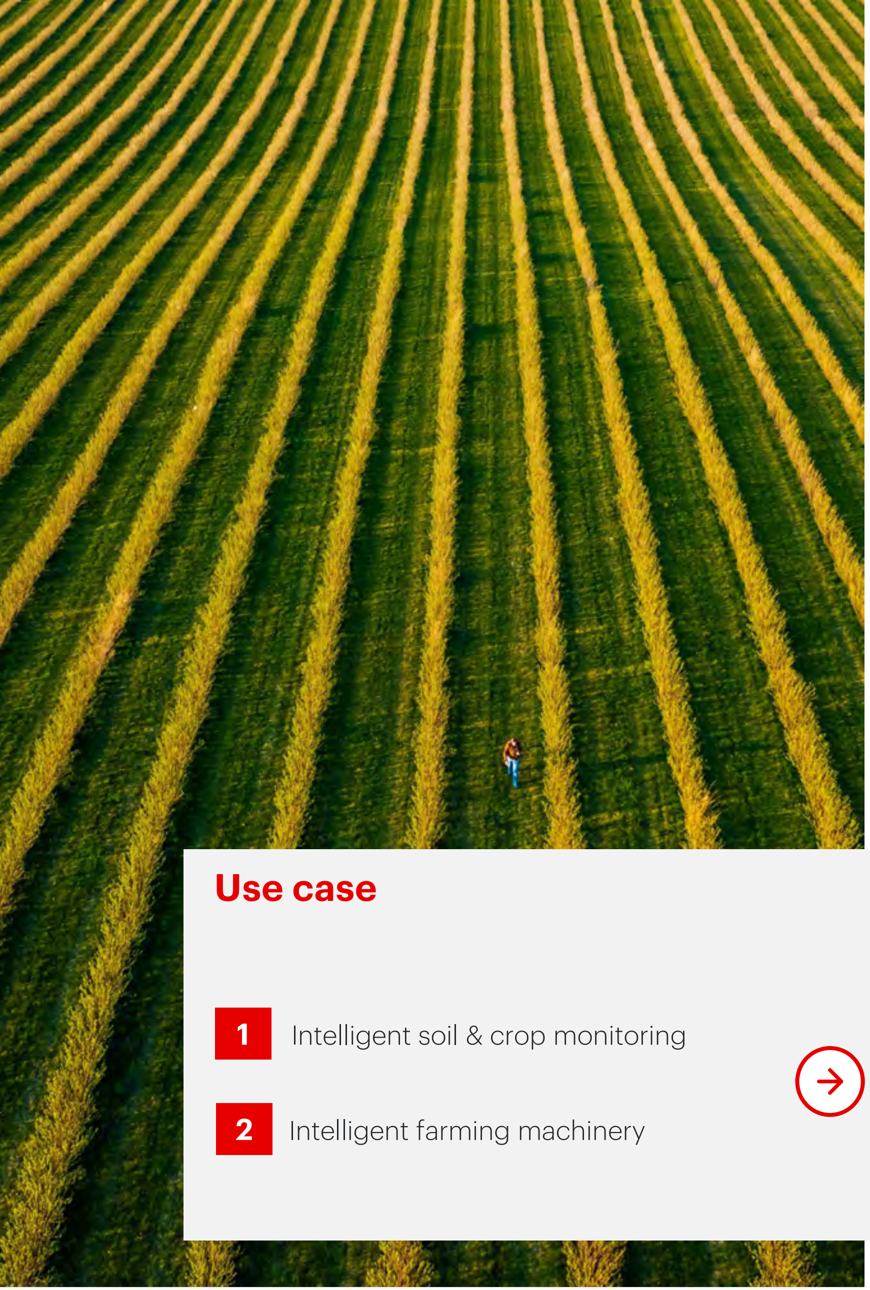
Doubling of the adoption rate of digital technologies expected in the agriculture sector, from an average of 32% today to 63% in 2030.[a]

One key reason for this is the fact that agricultural businesses will have the financial added value of digitalisation. Compared to other sectors, the EBIT effect of digital technologies in agriculture will be one of the highest by 2030 (see p. 16). The introduction and scaling of digital technologies – such as artificial intelligence (AI), the Internet of Things (IoT), sensors and drones – in agriculture will increase significantly.

Large scaling of digital technologies for monitoring and surveillance, which will enable more extensive and detailed data collection.

The company survey revealed that technologies for the intelligent monitoring of soils, crops and livestock have a target adoption rate of up to 75% (see points 1 and 2 in the graphic). Wide-scale implementation in the German agricultural sector is therefore to be expected. The adoption of these use cases is likely to be accelerated by the Deforestation Act, which obliges companies to review their supply chains and ensure that their products are not associated with deforestation. Since these technologies contribute to the verified traceability of raw materials pursuant to the law, their use is expected to increase.[1]

Note: a) See also Chapter 1.4 Adoption Rates, p. 29. Source: 1) BCLDE, 2023.



I. Crop farming
Digital crop monitoring and management

Description of the sub-sector

In 2022, around 50% of Germany's territory was used for agricultural purposes, with arable land accounting for 70% of this.[1] Agricultural products grown on this land are significant export goods and an important factor in Germany's foreign trade. In fact, roughly a third of all German agricultural production is exported.[2] This production, in turn, contributes to global warming. In 2022, a total of 15.8 Mt of CO_2 – or 30% of Germany's agricultural emissions – were attributable to the cultivation of arable land.[3]

Challenges and fields of digitalisation

Crop farming is currently facing numerous challenges that will require a greater focus on resource efficiency and sustainability.[4] In particular, crop farming is strongly affected by the consequences of climate change, as extreme weather events – such as droughts and floods – have a direct impact on crop yields.[5] In addition, the fertilisers and pesticides used in crop farming contribute to the pollution of ecosystems[4] and to climate change.[3] Agricultural businesses are also faced with a shortage of skilled workers[6] and rising prices for fertilisers and pesticides.[7]

These complex challenges will require innovative solutions that enable more precise crop monitoring, more efficient use of fertilisers and crop-protection products, and a reduction in the manual work required in crop farming.

Use case

1 Intelligent soil & crop monitoring

2 Intelligent farming machinery

	CO_2 effect	EBIT effect
2023	**9.4%** 1.9 Mt CO_2	**3.8%** €961.7m
2030	**14.4%** 3.3 Mt CO_2	**7.0%** €1,465.0m

Sources: 1) Destatis, 2023d; 2) BMEL, 2023a; 3) UBA, 2023; 4) UBA, 2023a; 5) BLE, 2023; 6) Deter, 2023; 7) Gabot.de, 2023.

1 2 Use case: Intelligent soil and crop monitoring

Brief description

Intelligent soil and crop monitoring provides real-time information on the condition of plants and farmland, helping to ensure their health and optimise the use of fertilisers, pesticides and lime. Thanks to remote monitoring using digital technologies, it is also possible to irrigate efficiently and detect pest infestations at an early stage.

CO$_2$ effect

2023	3.6%	
	Savings	Baseline
	0.8 Mt CO$_2$	20.8 Mt CO$_2$
2030	7.3%	
	Savings	Projection
	1.5 Mt CO$_2$	20.1 Mt CO$_2$

EBIT effect

2023	1.7%	
	Increase	Turnover
	€437.2m	€25.4bn
2030	3.5%	
	Increase	Turnover
	€718.3m	€20.8bn

Adoption rates

2023	37%
2030	75%

Digital technologies employed

Sensor technologies: Soil sensors measure the moisture level, pH value, nutrient content and temperature of soil. Leaf wetness sensors and plant growth sensors monitor the health and growth of crops.[1]

Satellite image analysis: Using satellite images enables the large-scale observation of growth patterns and thereby the identification of problem areas.[2]

Drones: Using drones enables detailed and flexible collection of data on plant height, vegetation density and soil moisture.[2]

Big data analytics: This allows users to process and analyse large amounts of data from multiple sources, which is crucial for precise planning and decision-making.[3]

Artificial intelligence (AI) and machine learning (ML): AI and ML process the collected data to recognise patterns and make predictions. AI can be used, for example, to detect diseases in plants or to optimise sowing and harvesting.[4]

Management software and mobile applications: Farm management systems make it possible to visualise data and trends. Planning and decision-making aids contribute to the optimised management of arable land.[5]

Note: Deviations in the divisions may result from rounding. Sources: 1) Bogue, 2017; 2) Inoue, 2020; 3) Sourav & Emanuel, 2021; 4) Joseph et al., 2020; 5) Karydas et al., 2023.

2 Use case: Intelligent farming machinery

Brief description

Intelligent agricultural machinery – such as automated and GPS-controlled fertiliser spreaders[1], agricultural drones[2] and robots[3] – are digitally controlled and enable remote interventions. A combination of intelligent crop monitoring and automatic or semi-automatic interventions means that site-specific fertilising, planting or weeding can be carried out more efficiently.

CO$_2$ effect

2023	5.1%	
	Savings	Baseline
	1.1 Mt CO$_2$	20.8 Mt CO$_2$

2030	9.0%	
	Savings	Projection
	1.8 Mt CO$_2$	20.1 Mt CO$_2$

EBIT effect

2023	2.1%	
	Increase	Turnover
	€524.5m	€25.3bn

2030	3.6%	
	Increase	Turnover
	€746.7m	€20.8bn

Adoption rates

2023	30%
2030	53%

Digital technologies employed

Sensor technologies: Include soil sensors, moisture/wetness sensors and weather stations. These sensors continuously collect data that is relevant for controlling the autonomous systems.[4]

GPS and geodata management: Enable precise navigation and mapping of agricultural areas, which are important for controlling autonomous vehicles and equipment.[5]

Networking and the Internet of Things (IoT): Enable communication between multiple devices and systems. With IoT, data can be exchanged and processed in real time to make adjustments and informed decisions quickly.[2]

Big data analytics: This allows users to process and analyse large amounts of data from multiple sources, which is crucial for accurate planning and decision-making.[6]

Drones: Are used for field monitoring, pest control and precise fertiliser distribution. Compared to ground-based devices, they enable faster recording of data from large areas.[2]

Robotics and automation: Include autonomously driving tractors, harvesting robots and automated irrigation systems.[3] These robots can work around the clock and thereby boost efficiency.

Note: Deviations in the divisions may result from rounding. Sources: 1) Göggerle, 2020; 2) Rejeb et al., 2022; 3) Ghafar et al., 2023; 4) Bogue, 2017; 5) Castrignano et al., 2020; 6) Misra et al., 2022.

II. Livestock farming
Precision livestock monitoring and feeding

Description of the sub-sector

According to the results of the 2023 Agricultural Structure Survey, there are around 161,700 livestock farms in Germany. This corresponds to 63% of all the farms in the country.[1]

In 2022, a total of 21 million pigs, 11 million cattle, 1.5 million sheep and 173 million poultry animals were counted in Germany.[2] Livestock farming is the largest emitter of methane in Germany.[3] The gas is produced during fermentation processes in the stomachs of ruminant animals and is around 28 times more harmful to the climate than CO_2.[4]

Challenges and fields of digitalisation

The livestock farming sector is facing growing demands from consumers in terms of animal welfare and animal health.[5]

The health of animals is the foundation of efficient agriculture[6] – and the fact that their resistance to antimicrobial agents has increased poses a major challenge, as the excessive use of antibiotics in livestock contributes to increased antibiotic resistance in both animals and humans.

As part of its Farm to Fork Strategy (F2F), the European Commission has set the goal of reducing the overall use of antibiotics in livestock farming and in aquaculture by 50% by 2030.[7]

Detailed monitoring and individually tailored feeding help to take into account the individual needs of the animals, promote animal welfare and health, and implement measures to reduce methane emissions.

Use case

3 Digital livestock

4 Precision livestock feeding

	CO_2 effect	EBIT effect
2023	**8.0%** 3.4 Mt CO_2	**1.4%** €492.2m
2030	**17.3%** 5.8 Mt CO_2	**2.7%** €746.8m

Sources: 1) Destatis, 2024f; 2) BMEL, 2023d; 3) Hahne & Clauß, 2022; 4) UBA, 2024d; 5) BfT, 2023b; 6) BMEL, 2023c; 7) European Commission, 2023.

3 4 Use case: Digital livestock monitoring

Brief description

Digital livestock monitoring refers to the use of portable or remote-controlled devices to monitor livestock. This technology allows the health, behaviour and location of animals to be determined and monitored in real time, which enables preventative or proactive measures to be taken and, if necessary, rapid treatment to be administered.

CO$_2$ effect

2023	4.3%	
	Savings	Baseline
	1.8 Mt CO$_2$	39.2 Mt CO$_2$
2030	9.4%	
	Savings	Projection
	3.2 Mt CO$_2$	33.8 Mt CO$_2$

EBIT effect

2023	0.7%	
	Increase	Turnover
	€262.6m	€36.3bn
2030	1.6 %	
	Increase	Turnover
	€420.8m	€27.2bn

Adoption rates

2023	32%
2030	70%

Digital technologies employed

Wearable sensors: Enable monitoring of individual animals by recording various health parameters, such as body temperature and movement.[1]

Stationary sensors: Can be used to monitor the climate in the stall or other enclosure housing as well as animal behaviour. To do this, they measure important environmental conditions – such as temperature, humidity and air quality – in the housing enclosure. They also record the feeding behaviour and radius of movement of the animals in order to be able to quickly react to deviations.[1]

Artificial intelligence (AI) and machine learning (ML): AI and ML process the collected data to recognise patterns and make predictions. AI can particularly be used to detect diseases in animals.

Management software and mobile applications: Farm management systems make it possible to visualise data and trends. They assist in planning and decision-making in order to optimise management.[2]

Note: Deviations in the divisions may result from rounding. Sources: 1) BfT, 2023a; 2) Karydas et al., 2023.

3 4 Use case: Precision livestock feeding

Brief description

Precision feeding refers to the targeted feeding of individual animals or groups of animals while taking into account the changes in nutrient requirements that occur over time. The method uses detailed data analyses and automation to adjust the feed composition and dispensing based on data regarding the individual animal.[1]

CO_2 effect

2023	4.0%	
	Savings	Baseline
	1.7 Mt CO_2	39.2 Mt CO_2
2030	7.8%	
	Savings	Projection
	2.6 Mt CO_2	33.8 Mt CO_2

EBIT effect

2023	0.6%	
	Increase	Turnover
	€229.6m	€36.3bn
2030	1.2%	
	Increase	Turnover
	€326.0m	€27.2bn

Adoption rates

2023	28%
2030	55%

Digital technologies employed

Real-time monitoring sensors: Wearable and stationary sensors monitor the feeding behaviour, health and movements of the animals at regular intervals or continuously. For example, cameras can be used in conjunction with image analysis to observe the animals' behaviour and estimate their body weight. In addition, real-time sound analysis enables the health and well-being of the animals to be monitored.[1]

Analysis software: Mathematical models help to generate individual analyses of the animals from the collected data. This allows the specific needs of each individual animal to be determined and its feed composition to be adjusted accordingly.[1]

Individualised feed dispensers: The system individually prepares and dispenses the feed for each animal. It selects from various pre-mixed feedstuffs to achieve a nutrient composition that meets the needs of the individual animals. Overfeeding is avoided by adjusting the feed on a daily basis.[2]

RFID tags: RFID stands for "radio-frequency identification".[a] An RFID system consists of a transponder, which is located on or in the object or creature and contains an identifying code, as well as a reader to read this identifier. This is used to identify animals and ensure that each animal receives its own individual mix of feed.[3]

Notes: Deviations in the divisions may result from rounding; a) Identification using electromagnetic waves. Sources: 1) Pomar et al., 2019; 2) Banhazi et al., 2012; 3) Schillings et al., 2021.

2 Sector analysis

2.4 Logistics

Logistics
Sector, sub-sectors and use cases

Brief description of the sector

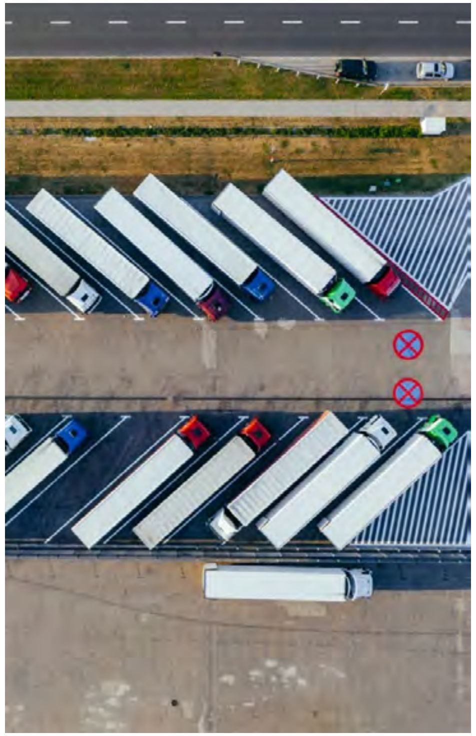
The logistics sector is Germany's third-largest economic sector and includes road and rail transport, domestic air transport and inland shipping.[1] It employs over three million people and generated roughly €330 billion in turnover in 2023.[2]

The sector benefits from its central location in the heart of Europe.[3] In fact, a quarter of the entire European logistics market is made up of German companies that generate their turnover in the fields of transport, handling/transshipment, warehousing, freight forwarding and packaging.[2]

CO_2-intensive road haulage (i.e. transport by truck) dominates the transport sector – and this trend is increasing as the demand for goods and transport capacity grows.[4,5] In 2022, trucks accounted for around 72.1% of total cargo haulage in Germany.[6] This study therefore focuses on road haulage.

Analysed sub-sectors and use cases

I. Road haulage



1 Digital twin and advanced planning[a]

2 Intelligent route and cargo optimisation

3 Truck platooning

Note: a) The term refers to the concept of "advanced planning systems" (APS), which is also used in German-speaking regions. Sources: 1) According to the German Environment Agency's definition of the transport sector, UBA, 2023l; excluding CO_2 emissions from international air transport and ocean shipping; 2) Statista, 2024f; 3) BVL, 2023; 4) Fraunhofer IML, 2024; 5) Statista, 2024e; 6) Statista, 2024a.

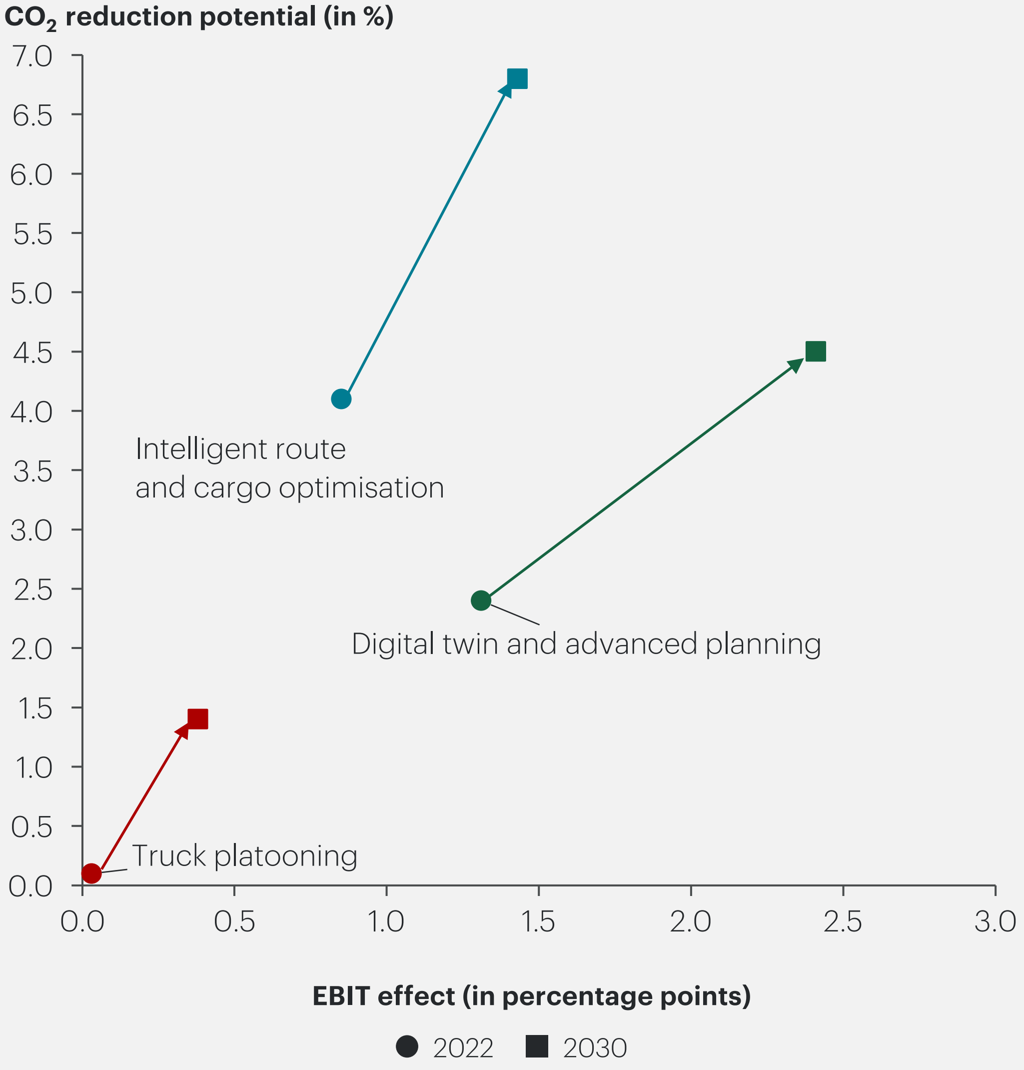
Logistics

Key findings at a glance

	Decarbonisation Index	Profitability Index
	47	**48**
	CO_2 savings	EBIT effect
2023	**3.3%** 1.2 Mt CO_2	**1.1%** €779m
2030	**7.1%** 4.1 Mt CO_2	**2.3%** €2,139m

1. **CO_2 versus EBIT effects:** Both effects show a strong mutual dependency in road haulage. This is because lower fuel consumption means lower CO_2 emissions and lower costs.
2. **Best use case:** Intelligent route and cargo optimisation, in particular, results in fuel savings through efficiency gains, which go hand in hand with direct CO_2 savings and EBIT effects.
3. **Tripling of both effects expected:** By 2030, digital technologies will triple both the CO_2 savings and the EBIT increase (in CO_2 and euros) in road haulage.
4. **No absolute CO_2 savings in 2030:** Since the logistics industry continues to grow rapidly, the absolute CO_2 emissions in this sector will significantly increase despite all the relative savings achieved by using digital technologies.
5. **Only a moderate increase in adoption rates**: Although there is a lot of potential for more decarbonisation and greater profitability in the sector, it is not yet being leveraged across the board. Many companies in the logistics sector do not yet have sufficient capacity to adequately harness digital technologies.

Note: Deviations in the divisions may result from rounding.



Logistics

Comparison of CO_2 reduction and EBIT effects

Profitability and decarbonisation are interdependent and will significantly increase. The digital twin will have the greatest impact on EBIT.

One reason for the high CO_2 reduction potential are the large CO_2 levers[a] of the three use cases, which range from 10% to 14%. Intelligent route and cargo optimisation, in particular, will result in fuel savings through efficiency gains, which will be accompanied by direct CO_2 savings.

The digital twin will allow logistics companies additional possibilities for optimisation at a higher planning level (e.g. in the scaling of truck fleets and personnel capacities to match actual transport demand), thereby making EBIT levers, such as personnel and maintenance costs, effective in addition to leading to fuel savings.

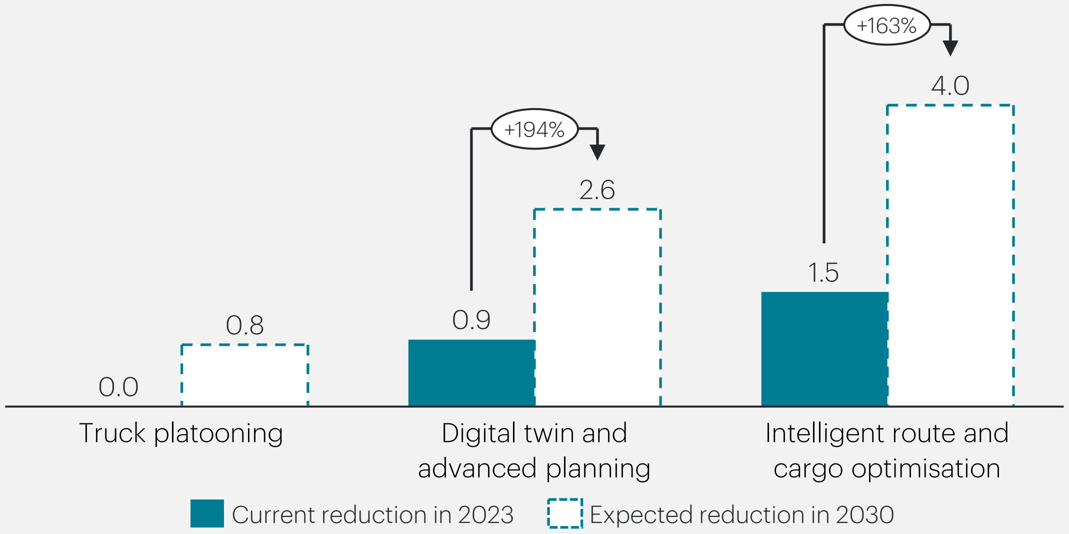
The potential of truck platooning is comparatively smaller and only being discovered at this time.

Automated convoy driving, known as truck platooning, is still in its early stages in Germany. After some initial pilot projects showed positive CO_2 and EBIT effects,[1,2] the company survey and current growth rates[3,4] point to a slight increase in adoption. Even if it can only be used on certain route sections and motorways, truck platooning promises up to 20% lower labour costs[b] and 14% lower fuel consumption.[c,5]

Notes: a) For definition see Chapter 1.1 Introduction, p. 14; b) For regulatory reasons, fully autonomous truck platooning (i.e. having driverless trucks) is not expected in Germany. For this reason, the labour-cost savings should not be estimated to average 15%; c) Taking into account the addressable runs, this results in an average cost saving of 2.8% and an EBIT margin effect of +0.38% for 2030. Sources: 1) Atasayar et al., 2022; 2) CAD, 2022; 3) MarketsandMarkets, 2023; 4) Market Research Future, 2024; 5) Pieringer, 2019.

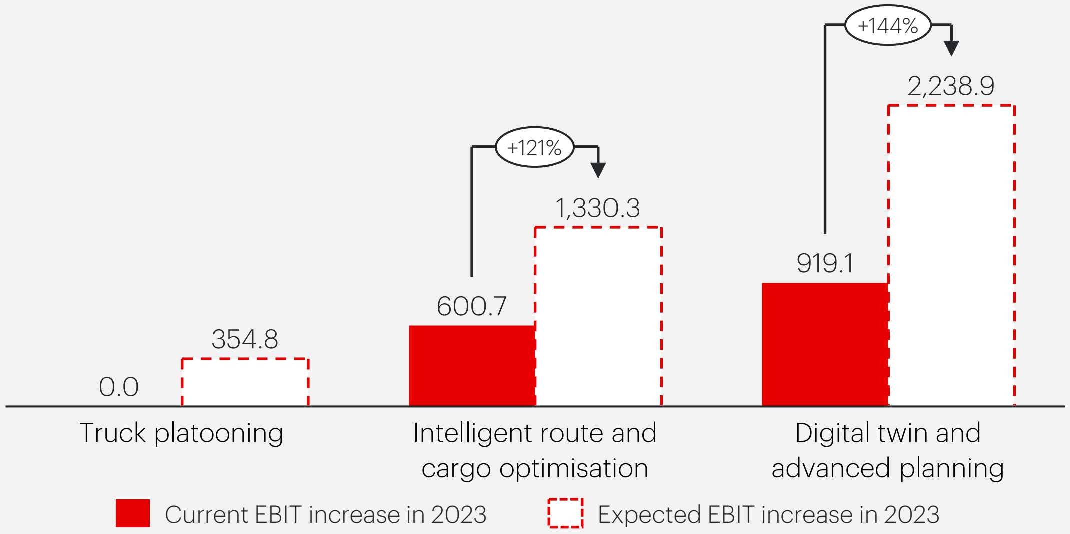
Logistics
CO_2 savings and EBIT increases

CO_2 reduction potential (in Mt CO_2/year)



CO_2 savings resulting from the use of digital technologies are expected to almost triple – Although the market penetration of the use cases (with an average increase in the adoption rate of around 17% by 2030) and the significant levers for CO_2 reduction (of 10% to 14%) will play a role, the high absolute CO_2 savings by 2030 will mainly be due to the strong growth in road haulage. This will also result in enormous savings.

Potential increase in EBIT (in € m)

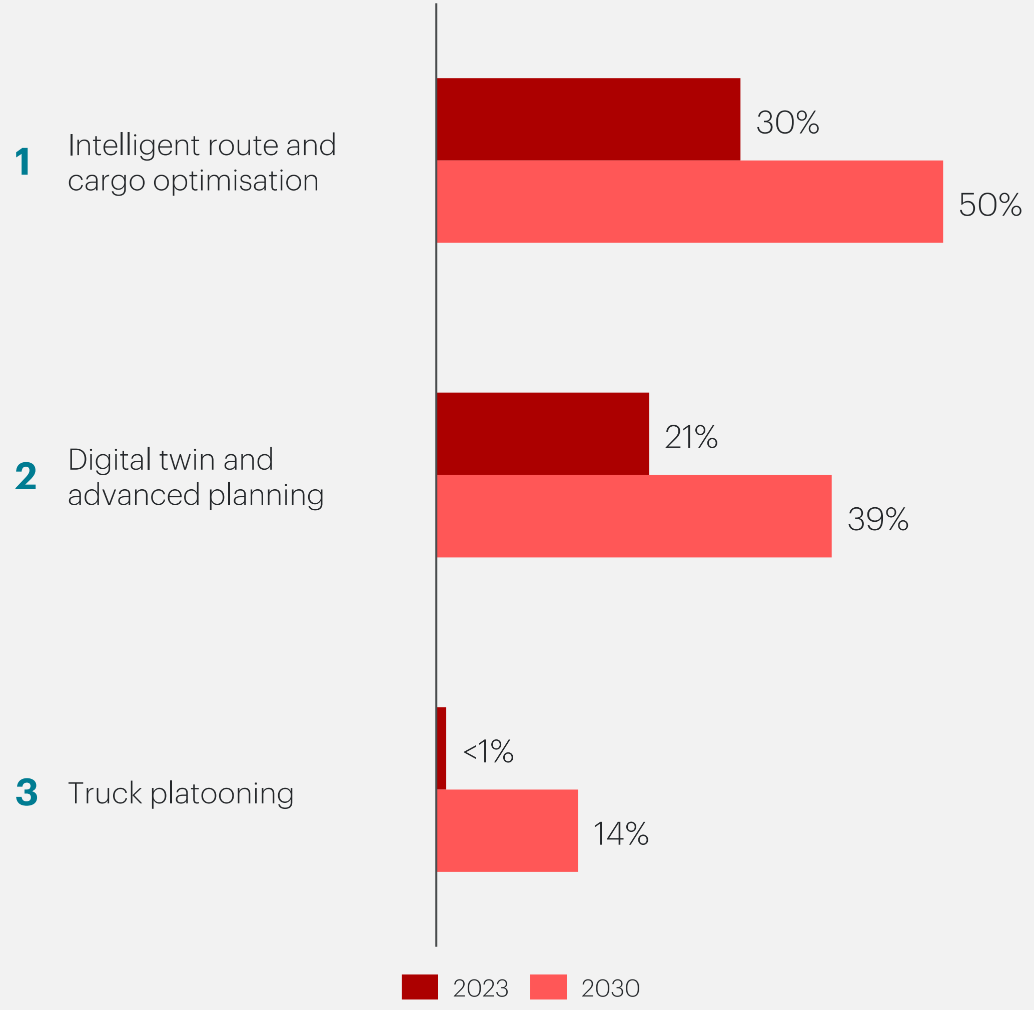


EBIT increases resulting from the use of digital technologies will triple, from around €0.8 billion today to around €2.1 billion in 2030[a] – While rising demand in the transport sector is increasing turnover, labour costs are rising disproportionately (partly due to a shortage of drivers). Together with the increasing use of digital technologies, such as "digital twin and advanced planning", which will have an impact on these labour costs, this will result in an increase in EBIT of up to 144%.

Note: a) To calculate the total EBIT savings, the mean value is calculated using the savings of the two use cases "intelligent route and cargo optimisation" and "digital twin & advanced planning". This step is necessary because the second use case also results in increased efficiency for routes and cargo.

Adoption rates of the use cases

[in %]



Source: 1) BALM, 2020.

Logistics

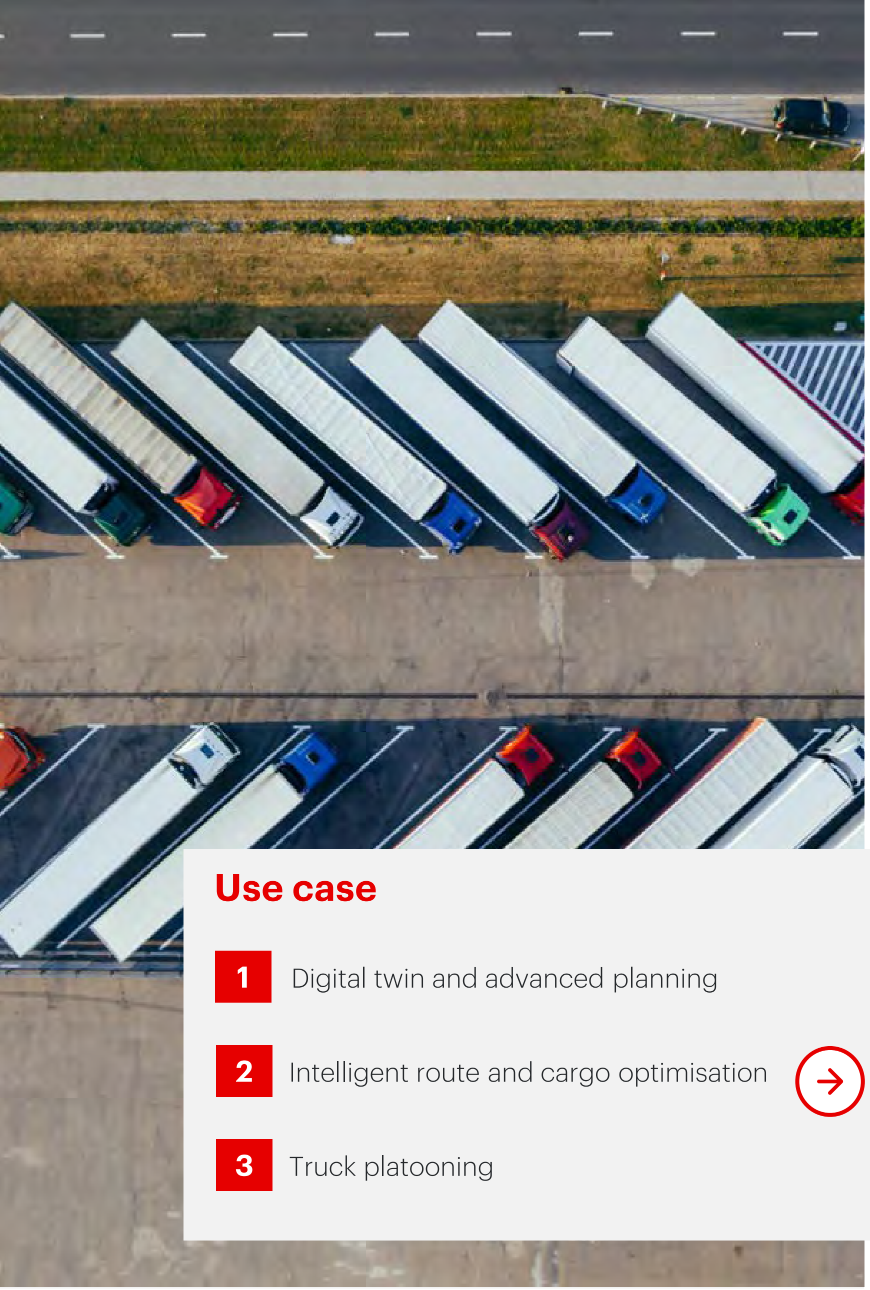
Current and expected adoption of digital technologies

Only moderate increase in the adoption rates of digital technologies by 2030, especially among SMEs.

Comparing the use cases for 2023 shows that digitalisation is particularly advanced in the field of intelligent route and cargo optimisation, while the use of digital twins for planning and real-time management of truck fleets is not yet very widespread.

The large logistics companies already have high adoption rates of digital technologies. However, the smaller the fleets are, the lower the level of digitalisation. The German market for commercial road haulage is very fragmented. Of the approximately 47,000 registered companies, around 51% are stand-alone businesses and 77% have fewer than 11 trucks.[1] For them, the barriers to entry and the scaling of digital technologies are disproportionately high. This is primarily due to the initial investment required to equip the fleet with telematics systems and (semi-)autonomous driving assistants. Added to this is the complexity of system integration when fleet systems are merged, as is the case with company acquisitions or mergers. Equally complicating is the lack of specialised personnel to deal with new digital technologies (e.g. such as AI or autonomous driving), to perform elaborate but necessary data-protection efforts, and to carry out training measures.

Bottom line: Given these circumstances, it is rather unlikely that the German logistics industry will fully adopt advanced digital technologies by 2030.



I. Road haulage
Intelligent fleets and transports

Description of the sub-sector

In 2021, road haulage accounted for just under 30% of CO_2 emissions from EU road traffic.[1] In Germany, it contributes 95% of emissions from the transport sector, and this figure is expected to rise even further as the number of kilometres travelled increases.[2]

Although specific emissions per kilometre have fallen since 1995 as a result of improved technologies, this decrease has been at least partially offset by a 34.5% increase in the number of kilometres travelled between 1995 and 2021.[3]

Challenges and fields of digitalisation

This steadily growing sector is facing immense challenges. For example, it is particularly called upon to contribute to Germany's climate-protection goals, has to contend with rising fuel costs and, despite growing labour costs, is experiencing a dire shortage of skilled personnel – in many cases due to the return of many drivers to their home countries as a result of the war in Ukraine. Added to this are disruptions caused by unforeseeable delays in the supply chains, which make the planning of road haulage much more difficult.[4]

In view of these challenges, digital technologies will prove to be indispensable for making road haulage more efficient and environmentally friendly. The use of digital technologies for route and freight optimisation is already making it possible to avoid unnecessary empty runs, which in turn results in considerable savings in fuel consumption and the associated CO_2 emissions.

Use case

1 Digital twin and advanced planning

2 Intelligent route and cargo optimisation

3 Truck platooning

	CO_2 effect	EBIT effect
2023	**3.3%** 1.2 Mt CO_2	**1.1%** €779.2m
2030	**7.1%** 4.1 Mt CO_2	**2.3%** €2,139.4m

Sources: 1) Destatis, 2023f; 2) UBA, 2021a; 3) UBA, 2023e; 4) BALM, 2023.

Use case: Digital twin and virtual prototype development

Brief description

A digital twin in the logistics sector will provide a virtual replica of the fleet and use real-time data on the trucks, their condition, their behaviour and their deployments (e.g. speeds, loads, delivery dates) to carry out real-time optimisations or enhanced planning interventions (e.g. deceleration). The digital twin will also enable strategic planning, for example with regard to the optimal sizing of fleets and personnel capacities.

CO_2 effect

		Savings	Baseline
2023	2.4%	0.9 Mt CO_2	35.9 Mt CO_2

		Savings	Projection
2030	4.5%	2.6 Mt CO_2	58.5 Mt CO_2

EBIT effect

		Increase	Turnover
2023	1.3%	€919.1m	€70.4bn
2030	2.4%	€2,238.9m	€92.7bn

Adoption rates

2023	21%
2030	39%

Note: Deviations in the divisions may result from rounding.

Digital technologies employed

Real-time data analysis: Utilises telematics and sensors to continuously collect data, such as on speed and vibrations. Edge computing devices and stream processing software enable the immediate processing of data for monitoring and rapid decision-making.

Geodata management: Utilises GPS tracking devices and geographic information systems (GIS) to monitor the exact location and movement of the fleet in real time. Route optimisation software helps to determine the most efficient routes and assist with fleet management.

Networking and the Internet of Things (IoT): Enables communication between vehicles, load sensors and control centres, allowing immediate data synchronisation and reactions to changes.

Cloud computing: Supplies the infrastructure for storing, processing and analysing large volumes of data in addition to enabling scalable access to resources.

Artificial intelligence (AI) and machine learning (ML): Analyses data streams to identify patterns, make predictions and support automated decision-making for route optimisation and load balancing.

Sensor technologies: Combines telecommunication with IT and sensor technology for remote monitoring and management of the means of transport.

Automated systems and autonomous driving: Integrates autonomous vehicles and systems into the fleet, enabling autonomous navigation and decision-making.

1 2 3

Use case: Intelligent route and cargo optimisation

Brief description

Intelligent route and cargo optimisation relies on real-time data, AI and networking among vehicles, loads and control centres to further optimise traditional route and cargo optimisation in real time. The benefits are manifold: more transparency, reliable alerts in case of critical events (e.g. traffic jams and blockages), and intelligent support[a] for dispatchers using AI-supported methods.

CO_2 effect

		Savings	Baseline
2023	4.1%	1.5 Mt CO_2	35.9 Mt CO_2
		Savings	**Projection**
2030	6.8%	4.0 Mt CO_2	58.5 Mt CO_2

EBIT effect

		Increase	Turnover
2023	0.9%	€600.7m	€70.4bn
2030	1.4%	€1,330.3m	€92.7bn

Adoption rates

2023	30%
2030	50%

Digital technologies employed

Telematics systems and AI: Enable comprehensive fleet monitoring using real-time data on location, vehicle and driving behaviour. Intelligent algorithms analyse historical and current speeds, forecast traffic flows and allow dynamic route adjustments. Advanced analytics and predictive modelling are incorporated into the AI to predict bottlenecks and plan more efficient routes and loads.

Internet of Things (IoT): Plays a key role in real-time monitoring and optimisation of vehicles and loads using integrated sensor networks to improve cargo monitoring and fuel efficiency.

Cargo space management systems: Use algorithms that are based on volume, weight and priority, among other things, to optimise the use of cargo space – and thereby help to reduce the number of runs and increase efficiency.

Driver assistance systems: Use data analyses to help drivers select routes and increase safety through warnings, such as in the event of severe weather.

Satellite communications: Provides reliable data communication even in remote areas to ensure route flexibility and accessibility.

Cloud-based cargo platforms: Improve transparency and minimise empty runs by means of efficient cargo allocation and optimised capacity utilisation.

Notes: Deviations in the divisions can result from rounding; a) For example, early deployment of subsequent deliveries if sensors on loading units detect faults (e.g. vibrations) in order to avoid CO_2-intensive express deliveries.

1 2 3

Use case: Truck platooning

Brief description

Truck platooning refers to convoys (platoons) of trucks that are controlled using automated driver-assistance systems and real-time communication. The vehicles can control their own speed and spacing as well as maintain a precise convoy formation with tight spacing on motorways. Platoons are monitored and assisted by control centres and boost efficiency, in particular by reducing air resistance, which in turn lowers fuel consumption and CO$_2$ emissions.

CO$_2$ effect

		Savings	Baseline
2023	0.0%	0.0 Mt CO$_2$	35.9 Mt CO$_2$
		Savings	Projection
2030	1.4%	0.8 Mt CO$_2$	58.5 Mt CO$_2$

EBIT effect

		Increase	Turnover
2023	0.0%	€0.0m	€70.4bn
2030	0.4%	€354.8m	€92.7bn

Adoption rates

2023	<1%
2030	14%

Digital technologies employed

Automated driver-assistance systems (ADAS): Offer functions such as adaptive cruise control and automatic braking, which are essential for spacing control and speed synchronisation among the trucks.

Vehicle-to-vehicle communication (V2V): Allows vehicles to communicate with each other in real time and exchange information on speed, spacing and route.

Vehicle-to-infrastructure communication (V2I): Integrates traffic infrastructure data, such as traffic status and road conditions, into the management of the platoons.

GPS and precise tracking systems: Ensure that the position of each truck in the platoon is accurately determined to optimise the formation and navigation.

Centralised control systems: Coordinate the platoons remotely, monitor the convoys and dynamically adapt the route planning.

AI-controlled algorithms: Continuously analyse data streams to maximise the efficiency of the platooning process and safely guide the vehicles.

Cloud and edge computing platforms: Store and process the huge amounts of data required to monitor and optimise the platoons.

Cybersecurity solutions: Protect the communication and control systems of the platoons from unauthorised interference and ensure the integrity of the system.

Note: Deviations in the divisions may result from rounding.

2 Sector analysis

2.5 Electricity

Electricity
Sector, sub-sectors and use cases

Brief description of the sector

The sector, which employs almost 250,000 people, is undergoing a profound transformation.[1] According to the German government's target, it must cover at least 80% of gross electricity consumption with renewable energies by 2030[2] while gradually reducing energy generation from coal at the same time.[3] The importance of this transition is underlined by the fact that renewable energies will already account for 52.6% of electricity generation in Germany in 2023.[4]

Given these circumstances, the expansion of wind and solar energy needs to be accelerated.[4] In order to drive the transition forward, the efficiency of energy generation from new and existing solar and wind power systems needs to be boosted. In addition, the efficiency of the electricity grid must be improved in order to minimise losses during the transport, conversion and distribution of electricity.[5]

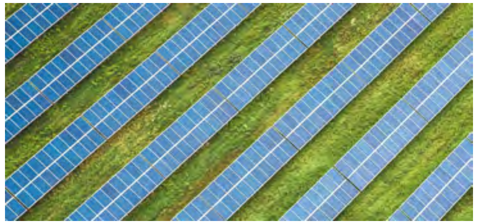
Analysed sub-sectors and use cases

I. Wind energy

1 Site modelling

2 Digital twin and predictive maintenance

II. Solar energy



3 Site modelling

4 Digital twin and predictive maintenance

III. Electricity grid

5 Digital twin including digital fault detection and predictive maintenance

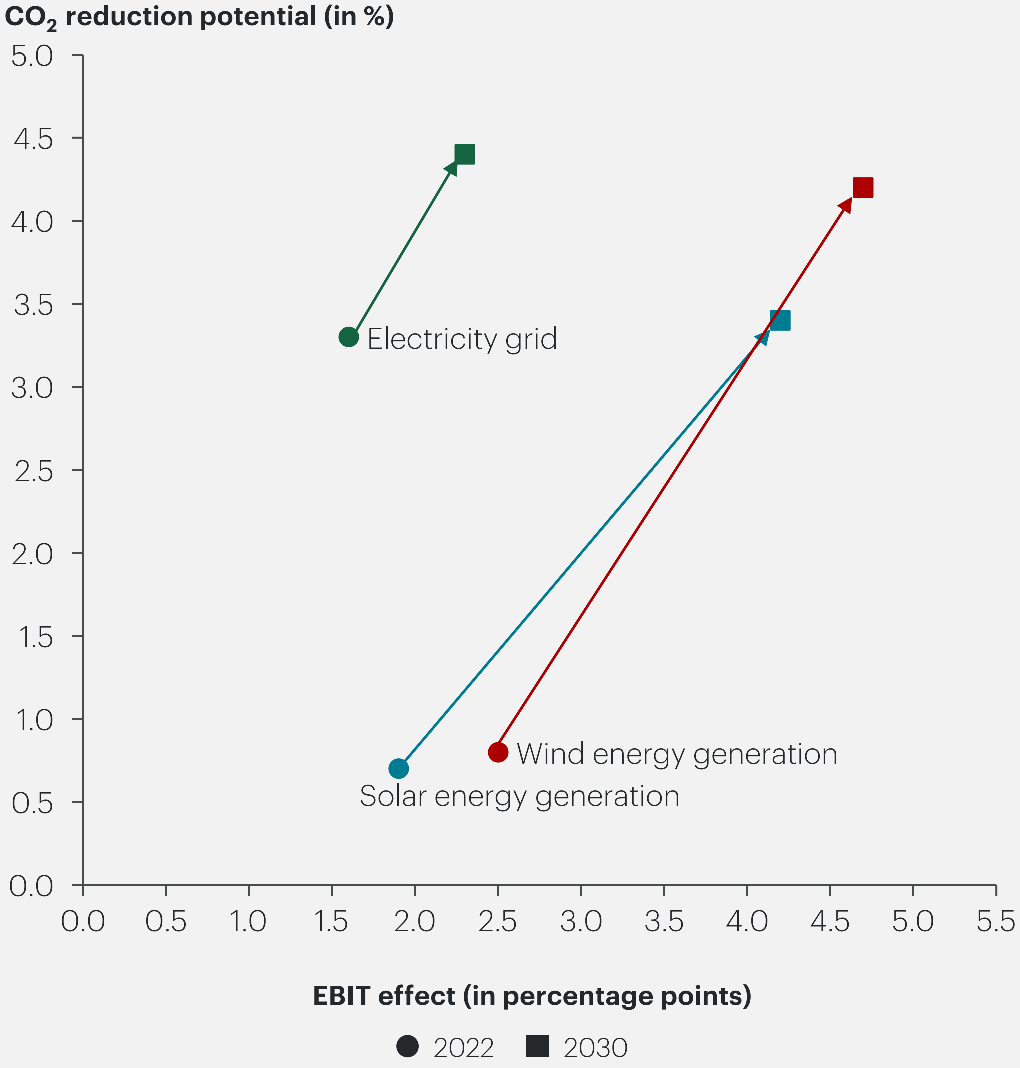
Sources: 1) Destatis, 2021a; 2) Bundesregierung, 2023a; 3) Bundesregierung, 2023b; 4) Agora Energiewende, 2024; 5) Netz + Service, 2023.

Electricity
Key findings at a glance

	Decarbonisation Index	Profitability Index
	39	52
	CO_2 savings	EBIT effect
2023	4.7%	3.4%
	11.4 Mt CO_2	€1,819m
2030	12.0%	6.6%
	14.3 Mt CO_2	€4,416m

1. **Comparison of CO_2 reduction and EBIT effects:** Digitalisation in the grid infrastructure will be the key to reducing CO_2 emissions in the electricity sector. The digitalisation of electricity grid operators by 2030 has the highest CO_2 reduction potential (of up to 4.4%) and will be an important lever for the energy transition.
2. **Digitalisation in wind and solar energy generation:** Digital technologies in the wind and solar energy sector show a positive correlation between CO_2 savings and EBIT effect, with both increasing significantly by 2030.
3. **CO_2 savings:** The use of digital technologies by electricity grid operators is already resulting in relatively high CO_2 savings (of around 8 Mt of CO_2 per year). In the case of wind and solar power generators, absolute CO_2 savings are expected to be more than twice as high by 2030.
4. **Profitability effects:** The strongest increase in EBIT effects resulting from digitalisation will be for solar energy producers – from 1.9% to 4.2% in 2030. An EBIT effect of 2.5% can already be seen today among wind energy producers.
5. **Adoption of digital technologies:** By 2030, the use of digital twins in the wind and solar sector will increase two- to threefold. The adoption rate of digital technologies in site modelling will rise from an average of 42% today to 72% in 2030.

Note: Deviations in the divisions may result from rounding.



Electricity

Comparison of CO_2 reduction and EBIT effects

Digitalisation in the grid infrastructure will be the key to reducing CO_2 in the electricity sector.

Digitalisation in grid operations is expected to make a significant contribution to CO_2 reduction by 2030, with a potential of up to 4.4%. Although the EBIT effect lags behind that of renewable energies, digitalisation will play a key role for electricity grid operators in Germany's energy transition. These efforts have been receiving support since 2018 as part of the grid expansion and renewal plan of Germany's Federal Ministry for Economic Affairs and Climate Action.[1]

Digitalisation in wind and solar energy generation – profitability and decarbonisation are closely linked and increasing significantly.

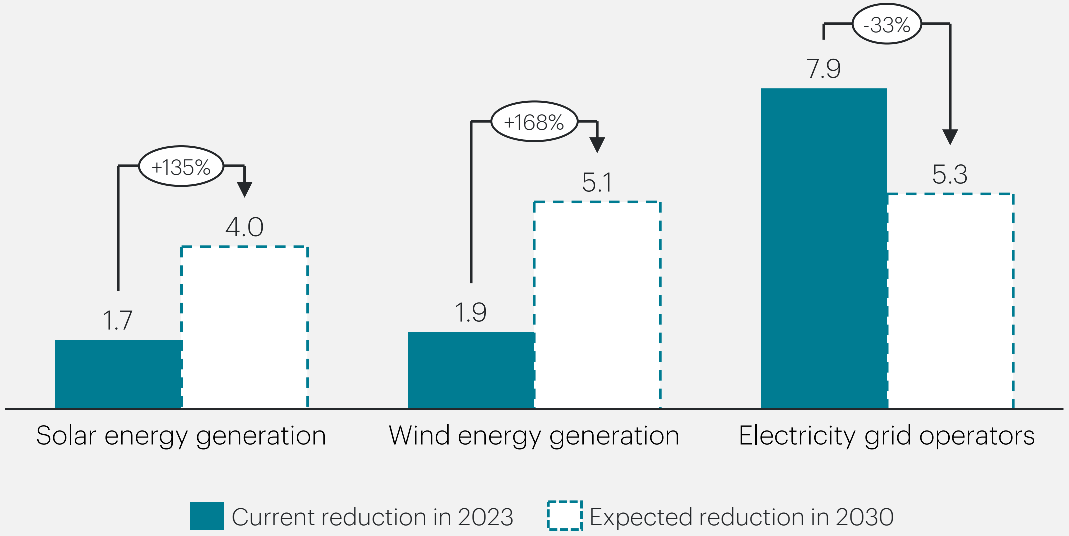
Digital technologies in the wind and solar energy sector show a positive correlation between CO_2 savings and EBIT effect, with both increasing significantly by 2030. This makes it clear that corporate investments in digital technologies will pay off in terms of both decarbonisation and profitability.

The expected increase in the EBIT effect by 2030 makes it clear that the energy transition is not only an ecological necessity, but also an economic opportunity for energy producers.

Source: 1) BMWK, 2023b.

Electricity
CO_2 savings and EBIT increases

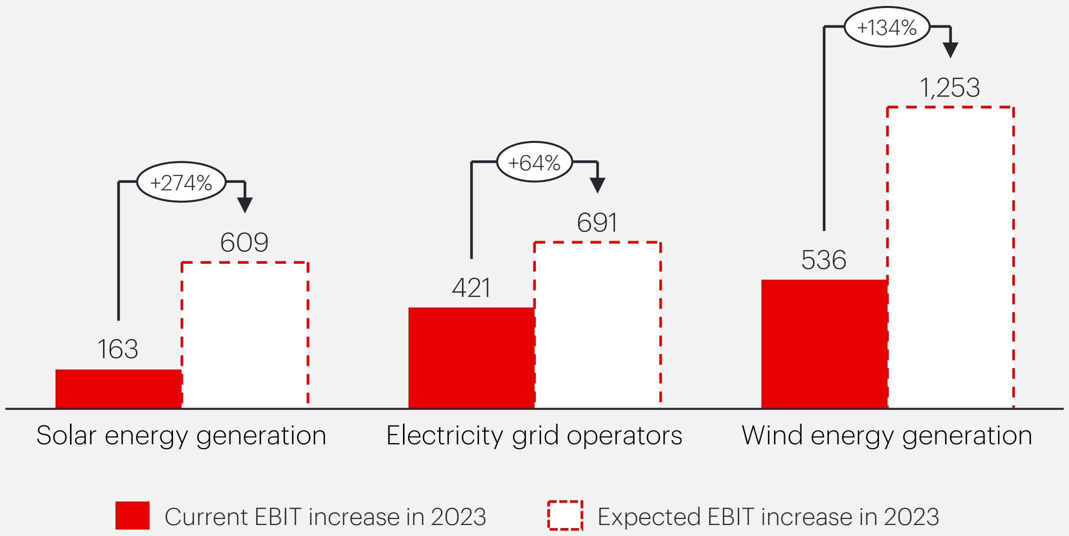
CO_2 reduction potential (in Mt CO_2/year)



The use of digital technologies is already resulting in high CO_2 savings today – Digital technologies boost efficiency in the electricity grid and currently save around 8 Mt of CO_2 per year, particularly due to the current proportion of fossil fuels in the electricity mix.

The absolute CO_2 savings from wind and solar power generators will more than double by 2030 – This will mainly be made possible by the high adoption rates expected in 2030.[a]

Potential increase in EBIT (in € m)



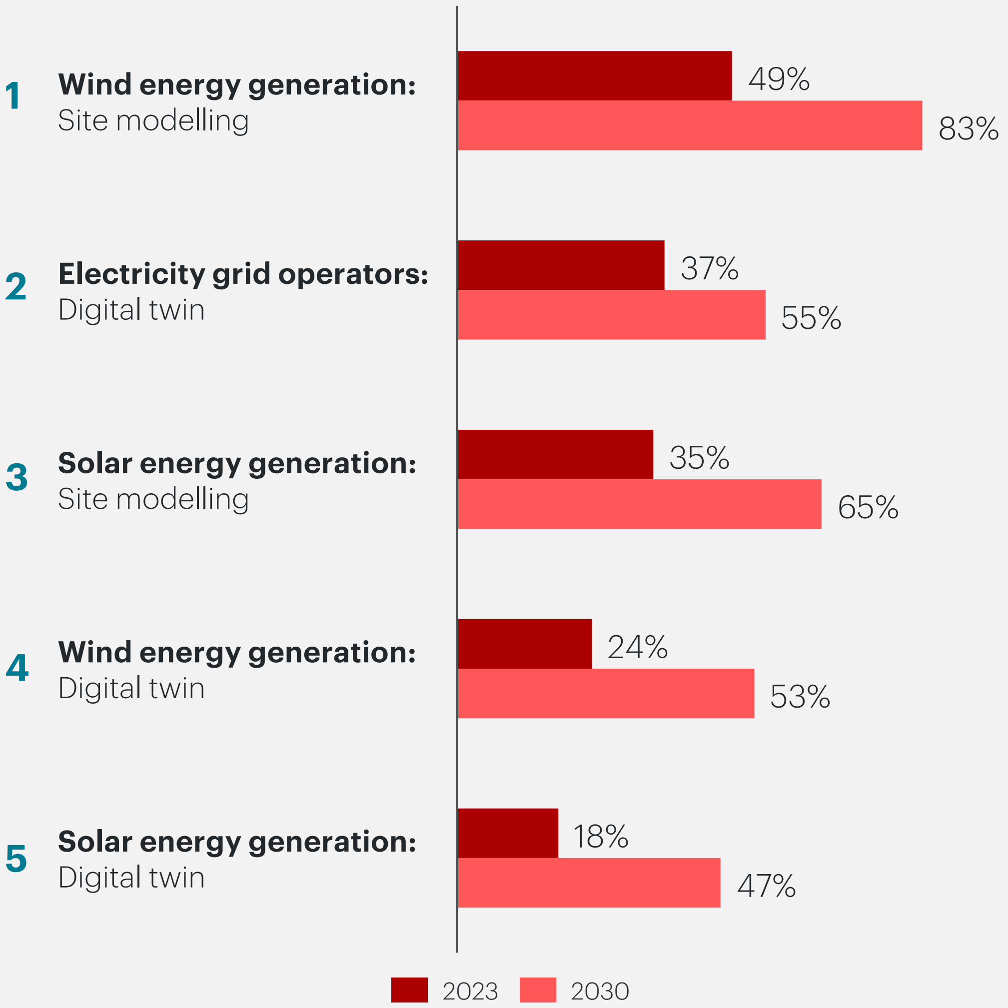
The use of digital technologies is already leading to a significant increase in EBIT today – This is mainly due to the already higher adoption of digital technologies among wind energy producers.[a]

EBIT for solar energy producers will increase by a factor of 2.7 by 2030 – This will mainly be due to higher energy output as a result of efficiency gains, which – according to the survey – will lead to an increase in turnover of up to 20%.

Note: : a) See also definition, p. 83.

Adoption rates of the use cases

[in %]



Electricity

Current and expected adoption of digital technologies

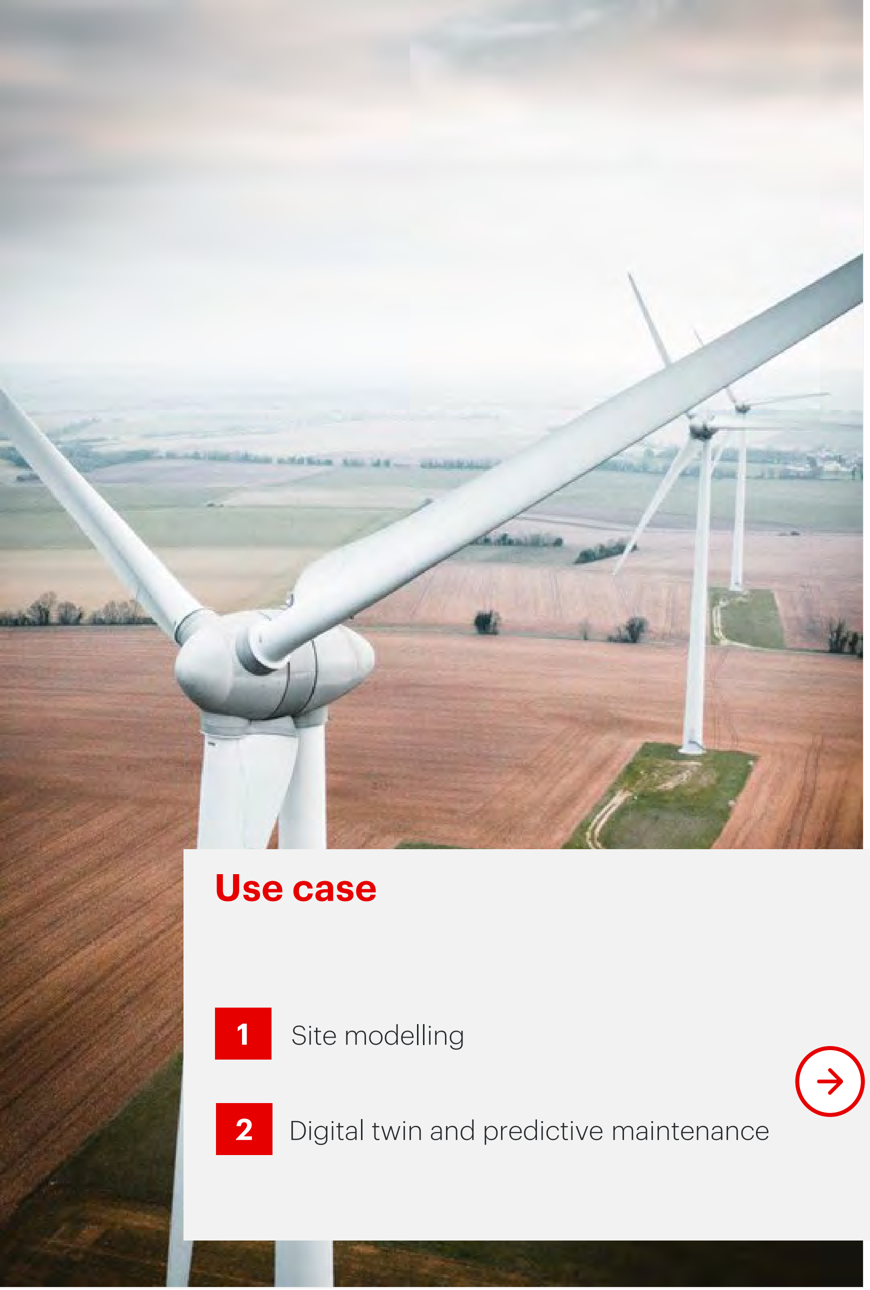
Adoption of the digital twin in the wind and solar sectors will increase two- to threefold by 2030.

The company survey and expert interviews indicate that the level of implementation of digital twins among wind and solar producers is currently at only around 20% but will grow two- to threefold. The expected increase in adoption rates will mainly be due to the latest technological developments, which are characterised by advanced AI methods, improved sensor technologies and increasingly powerful data-processing capacities.

High expected adoption rate of digital technologies in site modelling – from an average of 42% today to up to 74% in 2030.[a]

Site modelling – both in initial site selection and during operation – enables energy producers to optimise the performance of the installations both on the cost side and on the output/turnover side. The high expected adoption rate (of up to 74% on average) is due to the fact that this technology tends to be more mature and established compared to the digital twin. It is associated with lower investment costs, is less complex and is usually the step right before implementing a digital twin.

Note: a) Average of wind and solar power generation (No. 1 and No. 3 in the illustration).



I. Wind energy

Digital optimisation in the construction, operation and maintenance of systems

Description of the sub-sector

In 2022, wind energy generation was the second most important source of energy in Germany after coal power. In 2023, wind power assumed the position of the most important source of public electricity generation, which underlines the dynamic development in the energy market.[1] As a decisive factor in the energy transition, wind power will be further expanded in order to achieve a capacity of 115 gigawatts (GW) by 2030 in accordance with the Renewable Energy Sources Act.[2] The Onshore Wind Energy Act aims to ensure that 2% of Germany's territory is reserved for wind turbines by 2032.[3]

Challenges and fields of digitalisation

Efficiently utilising the areas reserved for wind turbines under the Onshore Wind Energy Act will represent a key challenge for Germany's wind energy sector.

Efficiency increases can already be realised in the planning phase of new wind turbines. For example, the potential energy generation of the system can be increased through site modelling of the wind conditions.

The generation of wind energy is highly dependent on weather conditions, which poses an additional challenge.[4] In order to ensure a stable energy supply, it is crucial to design the maintenance of wind turbines to be efficient and to minimise downtime. A data-driven analysis of the wind turbines enables predictive planning and implementation of maintenance measures.

Use case

1 Site modelling

2 Digital twin and predictive maintenance

→

	CO$_2$ effect	EBIT effect
2023	**0.8%** 1.9 Mt CO$_2$	**2.5%** €536.6m
2030	**4.2%** 5.1 Mt CO$_2$	**4.7%** €1,253.0m

Note: Since the digital technologies of the use cases in the sub-sector partly build on each other, the CO$_2$ and EBIT effects are calculated as an average.
Sources: 1) Fraunhofer ISE, 2024; 2) BMWK, 2023c; 3) UBA, 2023l; 4) Destatis, 2021d.

1 2 Use case: Site modelling

Brief description

Site modelling aimed at improving energy yields relies on digital technologies to precisely assess the wind patterns and characteristics at a specific location by means of in-depth site analysis. This enables the precise alignment and placement of wind turbines to maximise the energy yield and boost the efficiency and performance of these turbines.

CO_2 effect

2023	1.2%	
	Savings	Baseline
	2.8 Mt CO_2	227.0 Mt CO_2
2030	5.8%	
	Savings	Projection
	7.0 Mt CO_2	119.5 Mt CO_2

EBIT effect

2023	3.5%	
	Increase	Turnover
	€756.9m	€18.9bn
2030	6.0%	
	Increase	Turnover
	€1,628.6m	€23.9bn

Adoption rates

2023	49%
2030	83%

Digital technologies employed

Site modelling: The suitability of the site is analysed on the basis of a large number of data points, including wind speed, natural boundaries and distance from land features.[1]

Internet of Things (IoT) sensors: These sensors are attached to wind turbines to continuously collect data on a range of factors, including power output, wind direction and weather conditions.[2]

Artificial intelligence (AI) and machine learning (ML): Increasing the performance of wind turbines by tracking wind direction and adjusting rotor blade angles can be achieved through in-depth analysis of weather data.[3] In addition, there is the possibility of data-based realignment of individual turbines to optimise the airflow in the entire wind farm.[4] Machine learning and artificial intelligence can be used to effectively carry out these analyses aimed at identifying ways to optimise wind turbine settings.[3]

Automated control systems: Based on the findings from the weather data analyses, automatic adjustments can be made to the wind turbines in order to boost efficiency.[3]

Note: Deviations in the divisions may result from rounding. Sources: 1) Wimhurst et al., 2023; 2) Li et al., 2023; 3) WindEurope, 2021; 4) Chandler, 2022.

1 2 Use case: Digital twin and predictive maintenance

Brief description

In this use case, a virtual replica (digital twin) of the wind turbines is created. By using predictive analyses, real-time data is recorded, patterns are analysed, and system downtimes are predicted (predictive maintenance). This approach enables proactive maintenance and optimises wind energy generation. As a result, operational efficiency is boosted, downtimes are minimised, and costs are reduced.

CO$_2$ effect

2023	0.4%	
	Savings	Baseline
	1.0 Mt CO$_2$	227.0 Mt CO$_2$

2030	2.6%	
	Savings	Projection
	3.1 Mt CO$_2$	119.5 Mt CO$_2$

EBIT effect

2023	1.5%	
	Increase	Turnover
	€314.3m	€18.9bn

2030	3.3%	
	Increase	Turnover
	€877.4m	€23.9bn

Adoption rates

2023	24%
2030	53%

Digital technologies employed

Status monitoring and predictive maintenance: Vibration sensors and acoustic monitors (e.g. to detect gearbox damage caused by unusual vibration patterns) are used to predict wear and to plan maintenance work at an early stage.

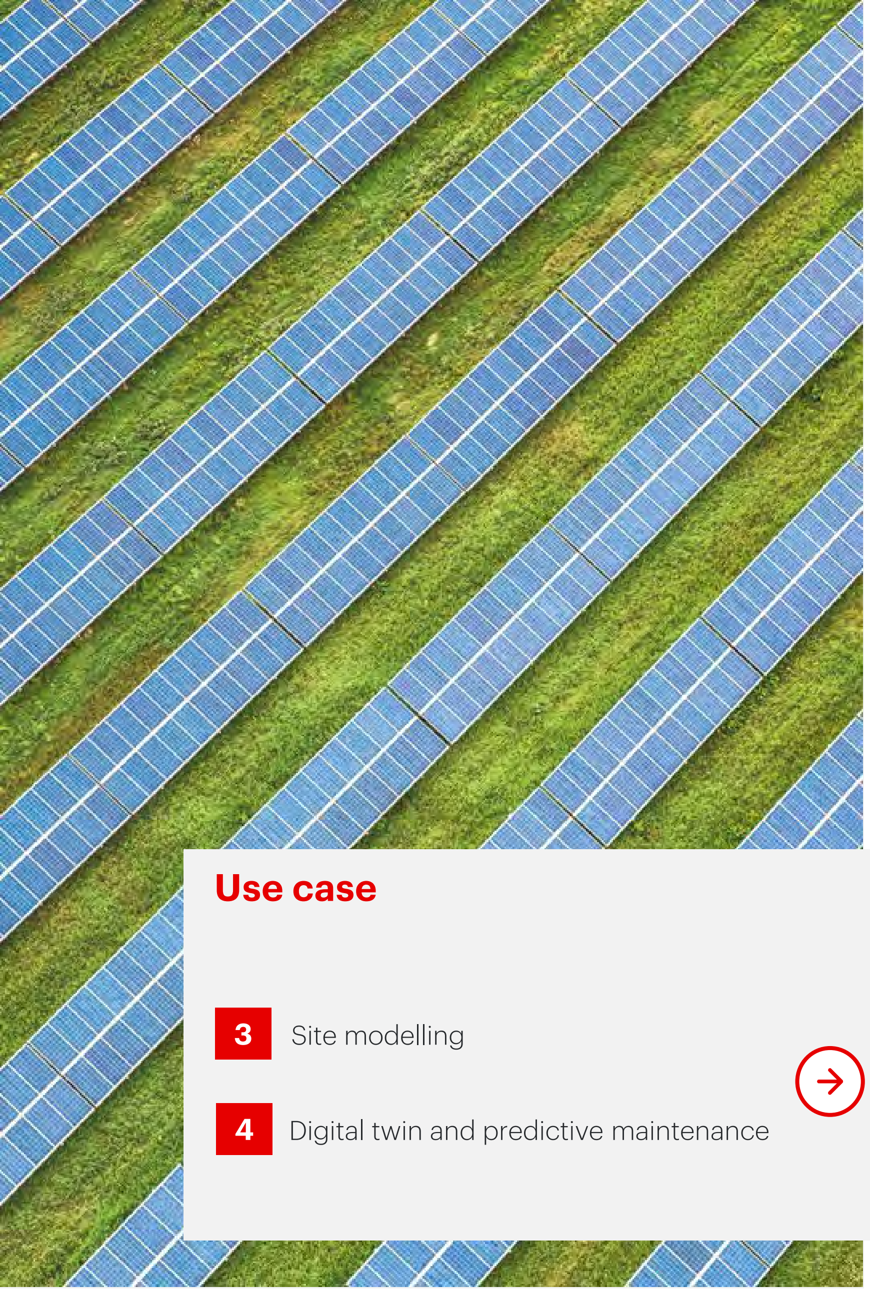
Internet of Things (IoT) and remote monitoring: Connects sensors and actuators on the wind turbine to centralised control systems in order to transmit operating data in real time.

Simulation and modelling: Physical and mathematical models are used to predict the behaviour of the wind turbine under various wind conditions and to control the blade pitch for optimum performance.

Data analysis and machine learning (ML): Algorithms are used to detect patterns (e.g. to predict downtimes based on historical operating data) in order to detect performance losses and optimise maintenance operations.[1]

3D visualisation: Virtual models of the system components (e.g. for the purpose of training maintenance personnel) are created in order to identify access points for repairs and simulate maintenance processes.

Note: Deviations in the divisions may result from rounding. Source: 1) Udo & Muhammad, 2021.



II. Solar energy
Digital optimisation in the construction, operation and maintenance of systems

Description of the sub-sector

In 2022, the German photovoltaic industry employed around 55,000 people and generated around €12 billion in turnover from the manufacture, installation and maintenance of solar cells.[1] In accordance with the requirements of the German Renewable Energy Sources Act (EEG 2023), Germany's Federal Ministry for Economic Affairs and Climate Action plans to triple the annual installed capacity within just a few years, from 7.4 gigawatts (GW) in 2022 to 22 GW in 2026.[2] Total installation capacity is set to increase from 67 GW[2] in 2022 to 202 GW[3] in 2030, which would correspond to a 57%[3] share of total renewable-energy output.

Use case

3 Site modelling

4 Digital twin and predictive maintenance

	CO_2 effect	EBIT effect
2023	**0.7%** 1.7 Mt CO_2	**1.9%** €163.1m
2030	**3.4%** 4.0 Mt CO_2	**4.2%** €609.3m

Challenges and fields of digitalisation

In order not to jeopardise the ambitious expansion targets of Germany's government despite the shortage of skilled workers and the tight schedule, it will be crucial to boost the efficiency and thereby the energy yield of photovoltaic modules. Such an increase in efficiency will make it possible to reduce the cost of solar modules while maintaining the same output.

One example of this is site modelling, which can be used as part of the planning process for photovoltaic systems to determine the optimal orientation and location of the solar modules.

The fluctuations inherent to renewable energies pose a major challenge for the energy transition. In order to ensure a stable grid, it is essential to intelligently control and predict supply and demand. It will therefore be crucial to minimise or even predict maintenance work by means of predictive analyses. This will also result in lower operating costs.

Note: Since the digital technologies of the use cases in the sub-sector partly build on each other, the CO_2 and EBIT effects are calculated as an average.
Sources: 1) BSW Solar, 2023; 2) BMWK, 2023e; 3) UBA, 2023l.

3 4

Use case: Site modelling

Brief description

Site modelling analyses the availability of solar energy at potential locations. Using advanced modelling software and data analysis, solar modules are precisely positioned and oriented. This enables decision-makers to maximise the energy yields while minimising the environmental impacts.

CO_2 effect

2023	1.2%	
	Savings	Baseline
	2.8 Mt CO_2	227.0 Mt CO_2
2030	3.8%	
	Savings	Projection
	4.5 Mt CO_2	119.5 Mt CO_2

EBIT effect

2023	2.2%	
	Increase	Turnover
	€188.5m	€7.3bn
2030	4.3%	
	Increase	Turnover
	€605.1m	€12.5bn

Adoption rates

2023	35%
2030	65%

Digital technologies employed

3D site modelling: Optimising the positioning of solar installations in locations with strong sunlight makes a significant contribution to boosting their efficiency. Satellite and drone imagery can provide some initial indications regarding the amount of sunlight at a location.

Geodata management: In addition, data from geographical information systems (GIS) can be used to assist in the selection of suitable locations for solar installations.[1]

Data analysis: The evaluation of weather data recorded by photo sensors enables the precise orientation of solar systems in the direction of the sun, using what is known as a solar tracking system.[2]

Note: Deviations in the divisions may result from rounding. Sources: 1) Heo et al., 2021; 2) Kuttybay et al. 2020.

3

4 Use case: Digital twin and predictive maintenance

Brief description

In this use case, a virtual replica (digital twin) of the solar installations is created and predictive analyses are carried out to optimise solar energy generation and early (i.e. predictive) maintenance. As part of this process, real-time data is recorded and analysed in order to optimise processes and proactively predict system downtimes. As a result, operational efficiency is boosted, downtimes are minimised, and costs are reduced.

CO_2 effect

	0.2%	
2023	Savings	Baseline
	0.6 Mt CO_2	227.0 Mt CO_2

	2.9%	
2030	Savings	Projection
	3.5 Mt CO_2	119.5 Mt CO_2

EBIT effect

	1.6%	
2023	Increase	Turnover
	€137.7m	€7.3bn

	4.2%	
2030	Increase	Turnover
	€613.6m	€12.5bn

Adoption rates

2023	18%
2030	47%

Digital technologies employed

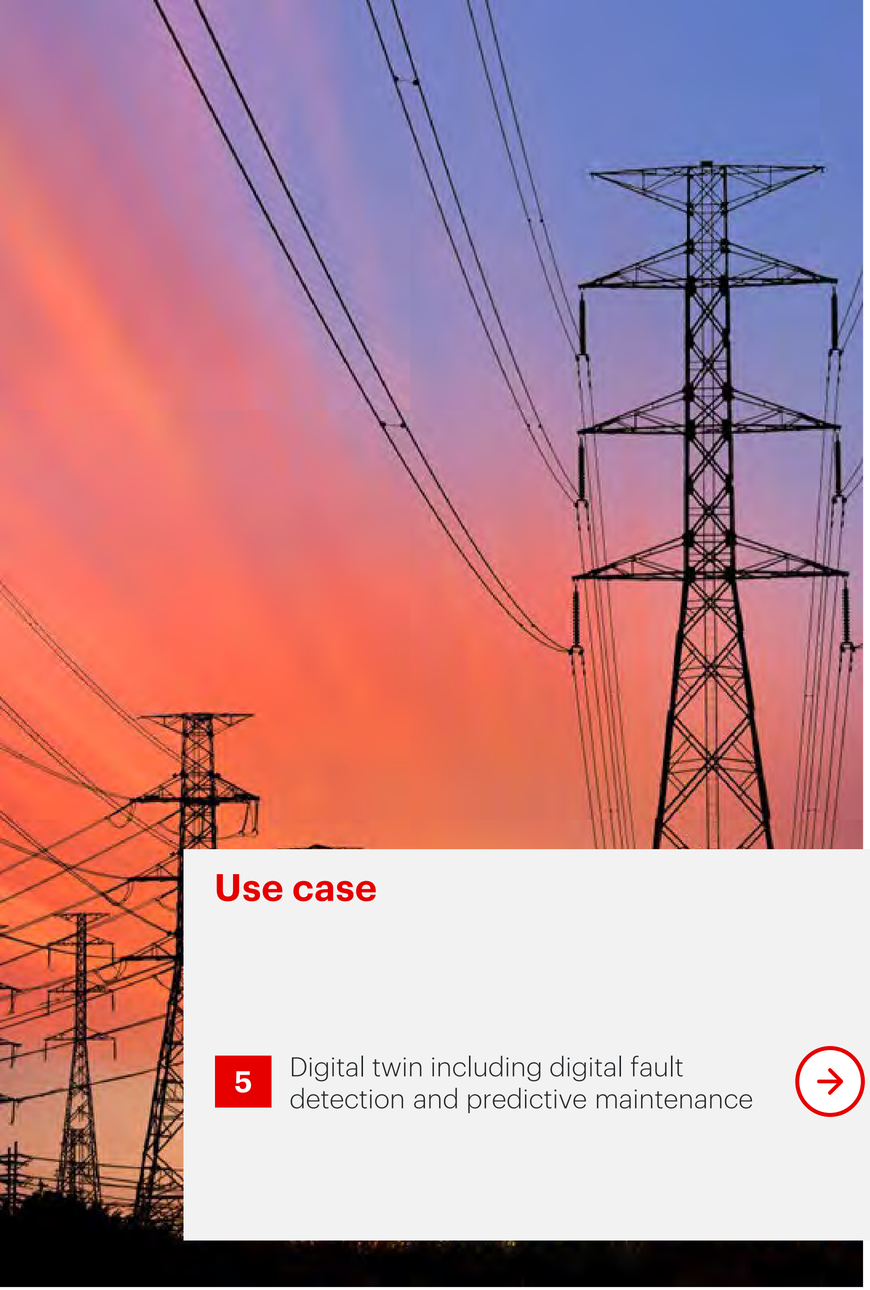
Internet of Things (IoT) and remote monitoring: Uses IoT devices to monitor the performance data (e.g. voltage and current) of the photovoltaic modules in order to monitor and adjust/optimise the overall efficiency of the system.[1]

Status monitoring and predictive maintenance: Uses thermography and electroluminescence imaging (e.g. to detect hot spots on photovoltaic modules) to monitor the efficiency of energy conversion and detect maintenance requirements at an early stage.

Data analysis and machine learning (ML): Uses pattern recognition algorithms (e.g. to analyse performance fluctuations caused by soiling) to optimise cleaning and maintenance intervals.[2]

Integration of renewable energies: Combines operating data from the solar installation with information from the energy management system to manage the storage or feed-in of solar power.

Note: Deviations in the divisions may result from rounding. Sources: 1) Sutaria, 2023; 2) Mohammad & Mahjabeen, 2023.



III. Electricity grid
Functionality and digital maintenance

Description of the sub-sector

Germany's electricity grid stretches over a length of 1.7 million kilometres and consists of a supra-regional transmission grid and regional distribution grids, which connect households and businesses.[1] In 2022, a total electricity generation of 509 billion kilowatt hours (kWh) was recorded, with coal-fired power plants accounting for 33.3% of this amount.[2] That same year, the increased use of electricity from coal resulting from the war in Ukraine led to an increase in emissions per kWh to 434 grams of CO$_2$.[3] With a total of 865 electricity grid operators,[4] Germany plays a key role in Europe's interconnected system.[5]

Challenges and fields of digitalisation

The nuclear power plants in Germany were decommissioned in 2023 and the coal-fired power plants are to be shut down by 2038 at the latest. A rapid expansion of the transmission grid will be needed to ensure a secure supply of electricity from renewable energies. This is because the geographical distance between electricity generation and consumption is considerable, and the existing grid is already reaching the limits of its capacity.[6]

The ageing infrastructure of Germany's electricity grid poses a significant challenge, as it is susceptible to outages. Digital technologies, such as predictive maintenance and digital fault detection, will play a crucial role in overcoming this problem. These technologies will enable continuous monitoring of the network and early detection of potential problems.

Use case

		CO$_2$ effect	EBIT effect
5 Digital twin including digital fault detection and predictive maintenance →	2023	**3.4%** 7.9 Mt CO$_2$	**1.6%** €421.4m
	2030	**4.4%** 5.2 Mt CO$_2$	**2.3%** €691.4m

Note: a) In EBIT margin percentage points; see also Chapter 5.1 Methodology, p. 99 ff. Sources: 1) VDE FNN, 2023; 2) Destatis, 2023g; 3) UBA, 2023b; 4) Statista, 2024d; 5) Heeke, 2021; 6) BMWK, 2023a.

5 Use case: Digital twin including digital fault detection and predictive maintenance

Brief description

The implementation of digital technologies – such as a digital twin of the electricity grid, digital fault detection and predictive maintenance – will optimise the efficiency of the electricity grid. Given the growing importance of renewable energies, this use case aims to reduce power losses without compromising the grid flexibility required when using sustainable energy sources.

CO$_2$ effect

2023	3.4%	
	Savings	Baseline
	7.9 Mt CO$_2$	227.0 Mt CO$_2$
2030	4.4%	
	Savings	Projection
	5.2 Mt CO$_2$	119.5 Mt CO$_2$

EBIT effect

2023	1.6%	
	Increase	Turnover
	€421.4m	€27.0bn
2030	2.3%	
	Increase	Turnover
	€691.4m	€30.1bn

Adoption rates[a]

2023	37%
2030	55%

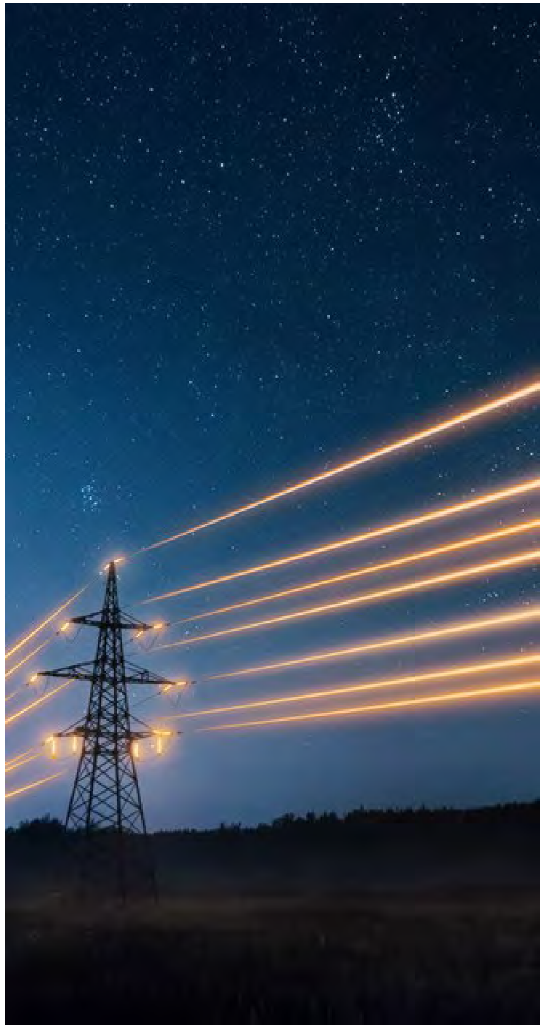
Digital technologies employed

Intelligent devices: Smart meters in the electricity grid enable real-time measurement and remote reading of energy consumption. At the same time, IoT devices and control units can be used to control decentralised energy sources.[1]

Data analysis and artificial intelligence (AI): Data analyses and AI enable important use cases such as network status estimates, scenario analyses and predictive maintenance. Given the increasing complexity of network planning, operation and maintenance, these digital technologies will become increasingly important in efforts to facilitate more efficient processes.[2]

Platforms/databases: IoT platforms make it possible to manage and analyse data from networked devices and enable data to be transmitted seamlessly between various platforms and components in the power grid.[3]

Visualisation software: Visualisation tools and digital 3D models are used to visualise complex network structures, identify faults and optimise network operation.[4]



Notes: Deviations in the divisions may result from rounding. a) In the survey, adaptation rates, CO$_2$ savings and EBIT increases were precisely differentiated for the sub-use cases (i) digital twin of the electricity grid and (ii) digital fault detection in the electricity grid and (iii) predictive maintenance in the electricity grid and then consolidated here. Sources: 1) Bundesnetzagentur, 2023a; 2) Dena, 2023b; 3) Sieverding & Schneidewindt, 2016; 4) ZfK, 2021.

3 Outlook and recommendations

Outlook and recommendations
Key stakeholders need to take action

This study confirms that using digital technologies will result in major decarbonisation and profitability effects. At the same time, it demonstrates that there will be a digitalisation gap in the German economy vis-à-vis global benchmarks.[a] But which stakeholders will be able to accelerate digitalisation, and which levers will help to disseminate the use cases more quickly?

Policymakers – Policy can have a major steering effect by employing a mix of instruments tailored to the specific sectors. More importantly, however, it will assist in surmounting the sometimes very specific hurdles to digitalisation. This includes projects to establish sovereign data ecosystems, such as GAIA-X, which facilitate the voluntary exchange of data between companies and the development of new digital business models.

Capital providers – The results of this study will help investors, banks and other lenders to enhance their financial and ESG-related risk analyses. They demonstrate that digitalisation will have a positive impact on EBIT and the decarbonisation of the economy. Capital providers must take the latter into account in their capital steering role within the framework of the EU Sustainable Finance Strategy.

Industry associations – As knowledge brokers for their member companies, they should focus even more strongly on accelerating digitalisation and the twin transition. As a link between national and industry-specific projects and data platforms, they can moderate conflicts and thereby guide them towards success. In addition, they should provide solutions to meet the growing need for expertise and training in companies, especially in SMEs.

Technology providers – They can facilitate scaling with standardised digitalisation solutions, especially for SMEs. At the same time, there is also a great opportunity here to advance digitalisation across the economy using innovative, bundled and easy-to-use solutions and to lay the foundations for additional data-driven business models.

Companies – They should align their digitalisation efforts more closely with the use cases that promote their business model. In doing so, they will be able to bolster mutual understanding between IT and business development as well as generate greater demand pressure from technology providers. Furthermore, intensifying collaboration with other players (e.g. technology- and data-driven start-ups), expanding innovative digital B2B platforms, and exchange initiated and facilitated by associations in the industry will play an important role in helping German companies to catch up with global technology leaders, to successfully achieve decarbonisation, and to operate profitably in the long term.

Note: a) See also definition, p. 13.

4 Participating institutes and project team

Participating institutes

Vodafone Institute for Society and Communications

The Vodafone Institute for Society and Communications is Vodafone's European think tank. Together with institutes, universities and organisations, we develop innovative visions for a digital and more sustainable future. In addition to encouraging reflection, clear recommendations for the transformation of the economy and society aim to spur concrete action.

Digital technologies and innovations will play an increasingly important role in tackling the challenges of climate change, in particular. The Vodafone Institute promotes scientific research on this topic and publishes the latest findings in comprehensive studies as well as strategy and research papers.

In this way, the content stimulates a broader debate on a political, economic and social level and is intended to promote dialogue among thought leaders in these disciplines, including in a European context.

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Project team
Close and constructive collaboration

Vodafone Institute for Society and Communications

Christina Arens

Director, Vodafone Institute for Society and Communications

Julia Ebert

Senior Researcher, Vodafone Institute for Society and Communications

Stephan Gesing

Senior Researcher, Vodafone Institute for Society and Communications

Olena Snidalova

Senior Researcher, Vodafone Institute for Society and Communications

Accenture

Balkan Cetinkaya

Director of Sustainability & Technology DACH, Accenture Strategy

Alexander Holst

Director of Sustainability Practice DACH, Accenture Strategy

Lea Schoppe

Sustainability Consultant Accenture Strategy

Jamie Sommer

Sustainability Consultant Accenture Strategy

Jonas Strunk

Sustainability Consultant Accenture Strategy

Subject experts

- Jürgen Bartz – Building sector
- Birte Buchwalde – Telecommunications
- Balkan Cetinkaya – Road haulage
- Ria Chopra – ICT footprint
- Eike Haas – Agriculture
- Christian Hoffmann – Telecommunications
- Sayali Karekar – ICT footprint
- Akshay Kasera – ICT footprint
- Yasar Mert – Road haulage
- Alisa Orlov – Agriculture
- Frank Rütten – Telecommunications
- Jonas Schwaben – Energy sector
- Michal Stachera – Energy sector
- Tomek Stec – Energy sector

Expanded team

- Anna-Laura Bonk
- Sabine Braun
- Laura Katryn Caspers
- Katharina Ent
- Maria Fitz
- Johannes Fuxjäger
- Jennifer Juch
- Jette Ohlert
- Magnus Petz
- Karolina Reichert
- Tilman Sauter
- Paula Schulze
- Manuel Simon
- Julia Tomaselli

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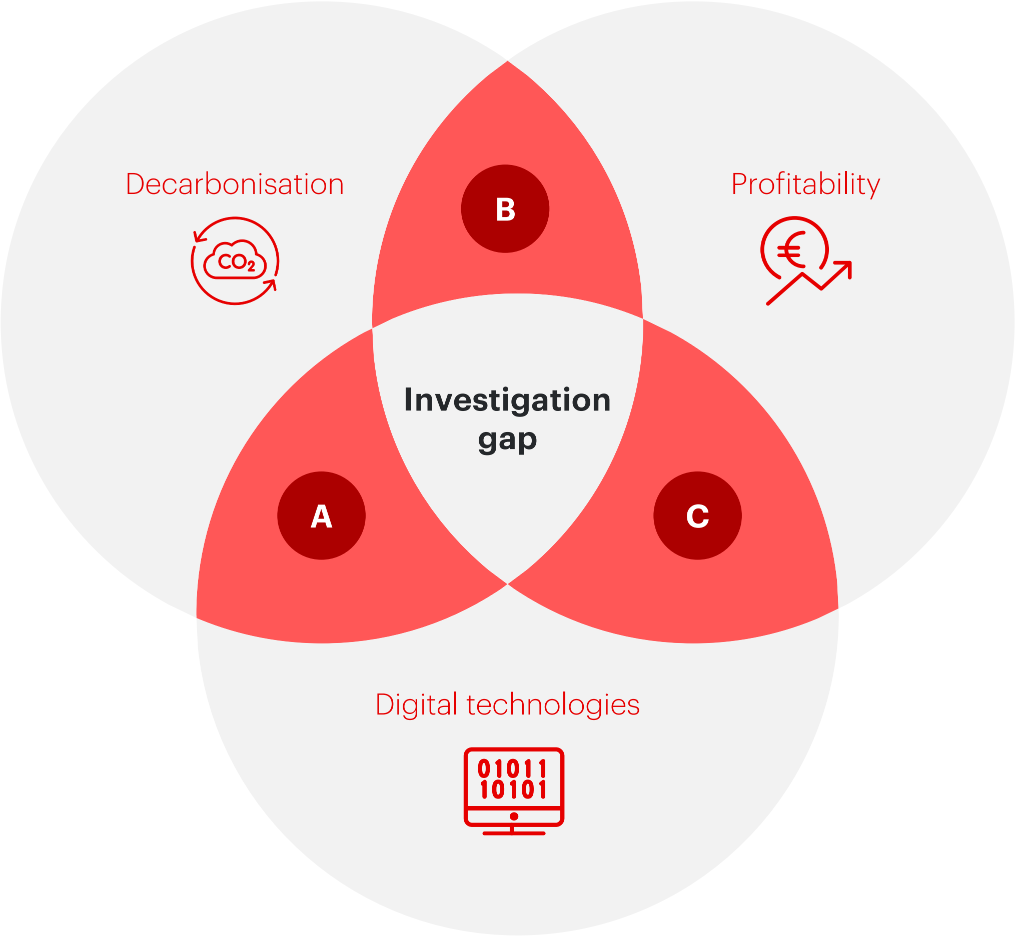
5 Appendix

5.1 Methodology

Investigation gap



Triad as a target image – Closely interlinking digitalisation, decarbonisation and profitability offers a great opportunity to companies, as the associated twin transition – i.e. the integration of digitalisation and decarbonisation strategies – will help them to secure their licence to operate, open up new fields of innovation and growth, and reduce costs. This will enable companies to boost their competitiveness while reducing their carbon footprint at the same time.

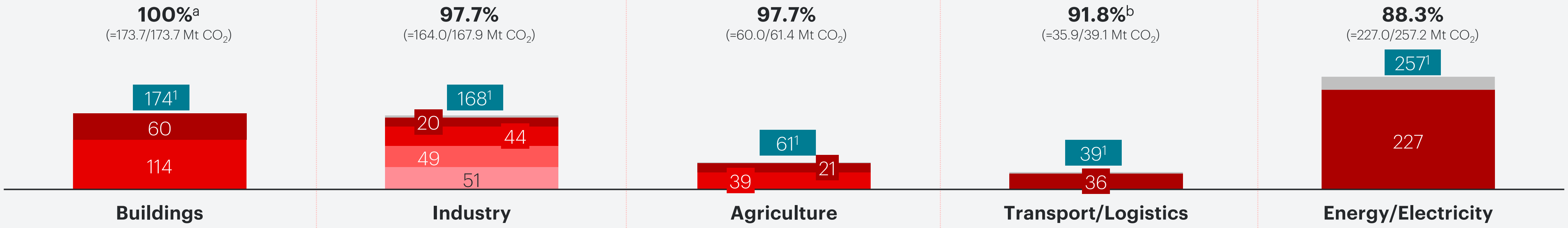
Need for knowledge – In order to make data-based decisions, business leaders will need to have a precise understanding of the interdependencies among these three dimensions. To date, however, in addition to the problem of implementation, applied science is still dealing with a problem of insufficient knowledge.

Research questions – In order to determine suitable research questions in the interest of the above-mentioned objectives and to concretise the need for knowledge, we collected and analysed 98 literature sources on the above-mentioned topics in the period between 01.03.2023 and 30.04.2024 as part of a preliminary study.

Investigation gap – Although the overlaps of digitalisation and decarbonisation or of profitability and decarbonisation (which are marked A, B and C in the illustration) are already being researched and are attracting great interest in both the academic and business spheres, there is still a noticeable investigation gap when it comes to examining these topics in an integrated manner. Studies that deal specifically with this core overlapping do exist, but they do not have the necessary degrees of quality and depth to answer our primary and secondary research questions.

Object of investigation – Selection of sub-sectors and use cases

Addressed CO_2 emissions in Germany in 2022 [Mt CO_2]



Buildings

I **Construction industry:**
1. Building Information Modelling (BIM)

II **Building management:**
2. Building Management System (BMS) in non-residential buildings

Industry

I **Steel industry:**
1. Digital twin
2. Digital modelling and optimisation of the smelting process

II **Products industry:**
3. Digital Twin
4. Virtual prototype development

III **Cement industry:**
5. Digital Twin
6. Digital modelling of the calcination process

IV **Chemicals industry:**
7. Digital Twin
8. Digital modelling for the reformulation of chemical products

Agriculture

I **Crop farming:**
1. Intelligent soil and crop monitoring
2. Intelligent farming machinery

II **Livestock farming:**
3. Digital livestock management
4. Precision livestock feeding

Transport/Logistics

I **Road haulage:**
1. Digital Twin
2. Advanced planning
3. Intelligent route optimisation
4. Intelligent cargo optimisation
5. Truck platooning

Energy/Electricity

I **Electricity:**[c]
1. Digital twin in wind energy generation
2. Site modelling in wind energy generation
3. Digital twin in solar energy production
4. Site modelling in solar energy generation
5. Digital twin of the electricity grid
6. Digital fault detection in the electricity grid
7. Predictive maintenance in the electricity grid

Key

🟥 X Sub-sector 1. Use case 2. Use case 3. ...	▨ Non-addressed CO_2 emissions 🟦 X CO_2 emissions of the sectors

When selecting the sectors and use cases (see definition), the main focus was on effective decarbonisation. The key question was therefore: Which sectors, sub-sectors and use cases account for the largest share of company-related CO_2 emissions? Use cases that address the most emissions-intensive sectors and sub-sectors in Germany were accordingly selected. The 12 sub-sectors analysed with a total of 26 use cases cover 94.5% of the CO_2 emissions generated by companies in Germany.

Notes: a) Excluding CO_2 emissions from residential buildings; b) Excluding CO_2 emissions from passenger transport; c) Includes three sub-sectors: wind energy producers, solar energy producers, electricity grid operators; d) 660.5 Mt of CO_2 of 699.2 Mt of CO_2. Sources: 1) UBA, 2024a; UBA, 2023l.

Basis of data basis – Literature analysis, interviews of experts, and company survey

Scientific publications

To triangulate the primary data, scientific studies were used that shed light on the status quo, growth rates and forecasts on the adoption rates of digital technologies and their effects on CO_2 emissions and profitability. To analyse the CO_2 and EBIT effects, published studies and statistics (e.g. from the German Environment Agency) were also used, which include a range of macroeconomic indicators, such as CO_2 emissions, turnover, expenditures and costs at the sector level.

Interviews of experts

Interviews of experts were conducted to validate the results of the survey and analyses. In particular, this involved a realistic assessment of the adoption rates of digital technologies as well as an assessment of regulatory and technological developments specific to the German context. For example, the transferability of global benchmarks to Germany was investigated and not taken into account where appropriate.

Company survey

The survey was used to determine the current adoption rate of use cases of digital technologies as well as companies' expectations regarding further adoption up to 2030. In addition, primary data on the impacts of the use cases on the companies' turnover, costs and CO_2 emissions was gathered. The telephone survey was conducted by the market research institute Atheneum in 2023 (1 July – 15 September).

Population – The population included all companies registered in Germany that can be assigned to the analysed sub-sectors. This enabled representative sampling and sub-sector-specific analysis.

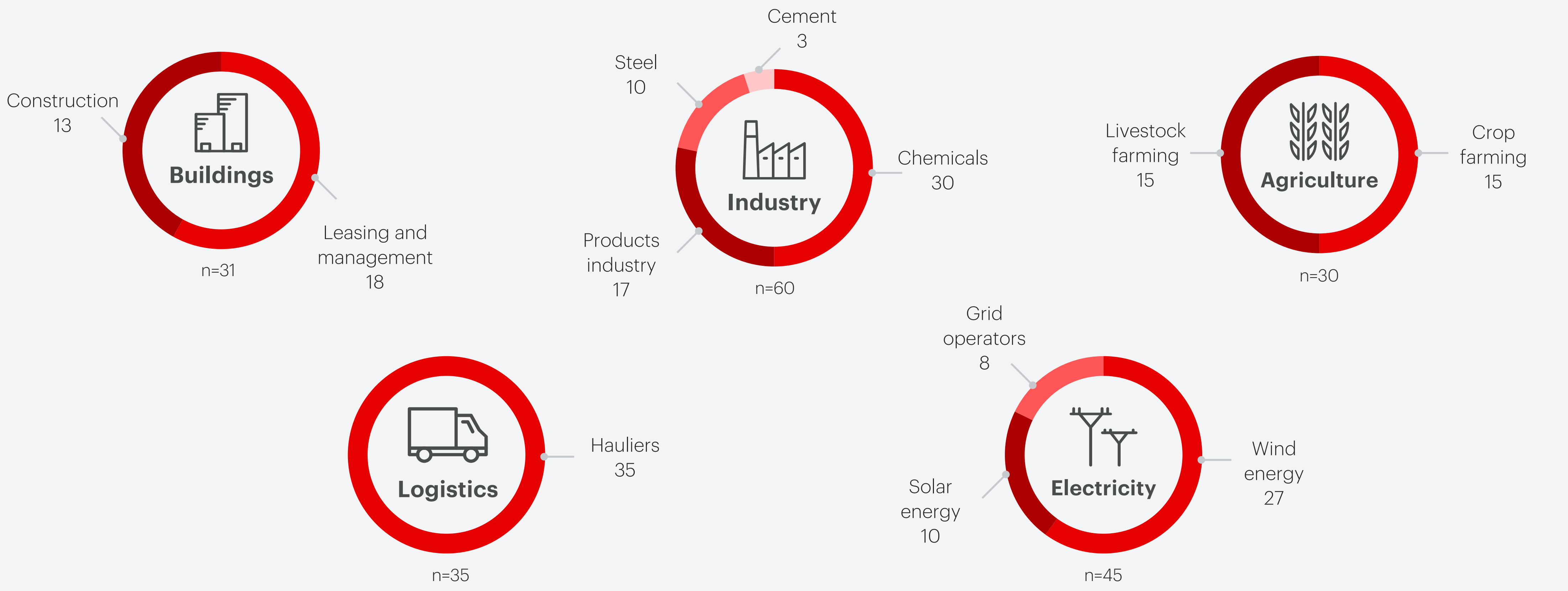
Number of interviews – 201 companies were surveyed. The samples were distributed across the five sectors as follows: Buildings (n=31), Industry (n=60), Agriculture (n=30), Logistics (n=31), Electricity (n=35). For details, see the next page.

Sample – The sample was based on a stratified random selection within the sub-sectors, taking into account both general company characteristics (e.g. number of employees, turnover) and specific criteria (e.g. number of livestock, size in hectares, fleet size). A minimum number of 30 companies per sector ensures the reliability of the statistics.

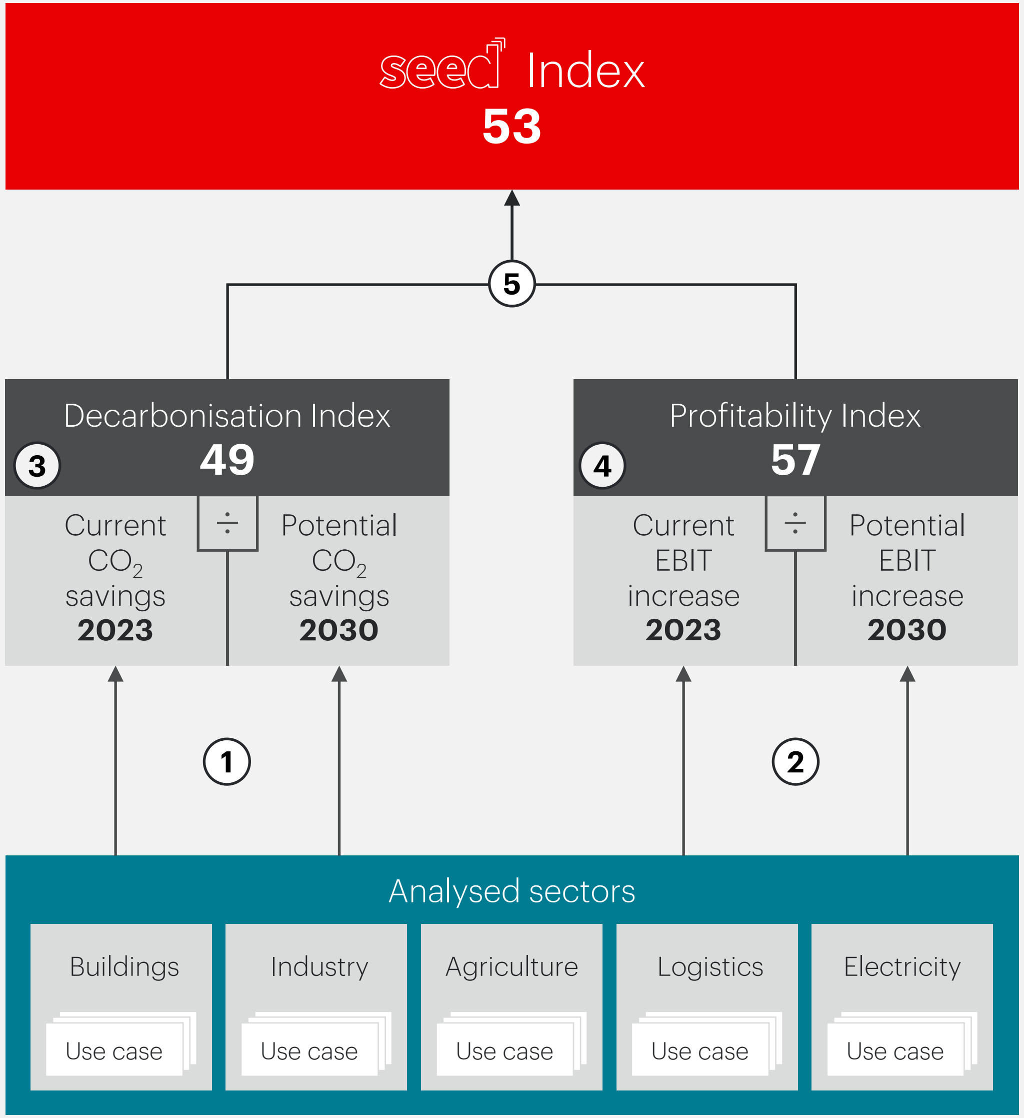
Surveying method – Telephone surveys with accompanying web access enabled participants to enter their answers interactively, and a member of the surveying staff was always available to answer questions during the process. On average, the interviews lasted one hour and asked questions on the following issues:

1. Company structure data
2. Current and expected adoption rates of the use cases of digital technologies
3. Effects of use-case adoption on CO_2 savings and EBIT increases at the level of individual CO_2 and cost drivers

Data basis – Number of surveys per sector and sub-sector



Figures: Number of surveyed companies
Total n=201



Calculations – Modules

The SEED Index is calculated in a bottom-up manner based on the use cases of digital technologies.

The following pages contain detailed descriptions of each of the following five calculation modules (see also the numbering in the figure).

1. Calculation of CO$_2$ savings per use case
2. Calculation of the EBIT increase per use case
3. Calculation of the decarbonisation index[1] per sector and consolidation into an overall Decarbonisation Index
4. Calculation of the profitability index per sector and consolidation into an overall Profitability Index
5. Calculation of the SEED Index

At the beginning of the descriptions, there is a table providing an overview of the calculation parameters used along with information on the unit, granularity/reference value, data basis and calculation method.

Note: When referring to the decarbonation or profitability indices of the individual sectors, we use lowercase. On the other hand, when "Decarbonisation Index" and "Profitability Index" are capitalised, the overall respective index is being referred to.

①

Calculations – Parameters for calculating CO_2 savings per use case (1/2)

Abbrev.	Parameter	Unit	Granularity/ reference value	Primary data	Secondary data	Expert opinion	Calculation (simplified)
CO%23	Current CO_2 savings in 2023 (CO_2 effect)	%	Sector-specific				=CO23/CBl23
CO%30	Potential CO_2 savings in 2030 (CO_2 effect)	%	Sector-specific				=CO30/CPr30
CO23	Actual CO_2 savings in 2023	Mt CO_2	Sector-specific, use case				=CBl23xCHbxAR23
CO30	Potential CO_2 savings in 2030	Mt CO_2	Sector-specific, use case				=CPr30xCHbxAR23
CBl23	CO_2 baseline 2023	Mt CO_2	Sector, sub-sector		x		
CPr30	CO_2 projection 2030	Mt CO_2	Sector, sub-sector		x		

①

Calculations – Parameters for calculating CO_2 savings per use case (2/2)

Abbrev.	Parameter	Unit	Granularity/ reference value	Primary data	Secondary data	Expert opinion	Calculation (simplified)
CHb	CO_2 reduction lever	%	Use case	x	x	x	Weighted averages
AR23	Adoption rate in 2023	%	Use case, sub-sector, sector	x			Median or arithmetic mean of all respondents
AR30	Adoption rate in 2030	%	Use case, sub-sector, sector				=ARU30/ART30
ARU30	Adoption rate of companies in Germany in 2030	%	Use case	x			Median or arithmetic mean of all respondents
ART30	Adoption-rate benchmarks in 2030	%	Use case		x	x	

①

Calculations – CO_2 reduction per use case

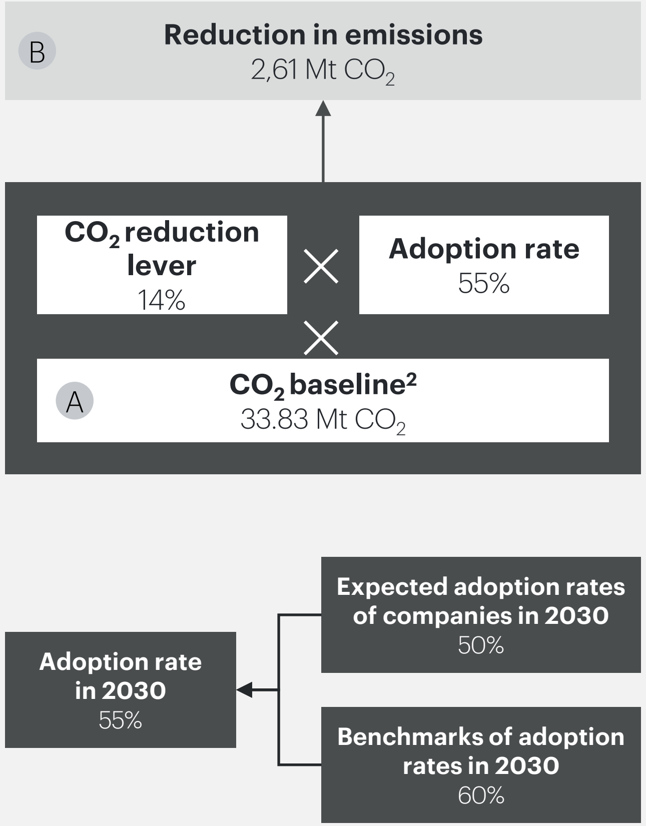
Step 1: For each use case, the reduction (B) in Mt of CO_2 resulting from the use of digital technologies is determined – for both 2023 and 2030. Use cases are defined as the combined use of various digital technologies, which particularly realise their potential when they are used in combination for a specific application in the sub-sector. The calculation logic for 2023 and 2030 is largely[a] identical and is illustrated using the sample calculation.[b]

The following parameters are multiplied together to calculate the reduction in emissions (B):

1. **CO_2 baseline 2023 or CO_2 projection 2030 of the (sub-) sector (A)** – CO_2 emissions of the sector or sub-sector that can be addressed by the use case in the respective year. Both values are based on secondary data.
2. **CO_2 reduction lever** – Average proportion of CO_2 emissions resulting from the use of digital technologies or their smart application in combination per use case. For example, site-specific fertilisation not only requires an intelligent drone (and therefore artificial intelligence and machine learning), but also access to granular data on soil conditions provided by sensors in the soil.
3. **Adoption rate** – Average utilisation of the use case in the sub-sector during the year under review. The adoption rate expected for 2023 was determined in the above-mentioned company survey using a Likert scale (5 levels from 0 to 100%, with 0% denoting no implementation and 100% denoting full implementation). The adoption rate for 2030 is derived from two values: (i) the expected average adoption rate for 2030 from the company survey and (ii) the expected average adoption rate resulting from forecast benchmarks or the theoretically possible degrees of implementation of digital technologies for the specific use case. The benchmarks are based on forecasts, which in turn are based on secondary data and expert assessments. The points of reference are (i) leading global companies or (ii) countries with extensive implementation of the use cases as well as (iii) growth rates for technological developments.

In simple terms, the multiplication of the three parameters can be formulated as follows: Which emissions can be reduced with a lever, and to what extent will (2023) or should (2030) this lever be utilised by companies in the respective year?

Step 1: Calculation of the reduction in emissions per use case in Mt of CO_2[b]



B **Reduction in emissions**
2,61 Mt CO_2

CO_2 reduction lever
14%

×

Adoption rate
55%

×

A **CO_2 baseline**[2]
33.83 Mt CO_2

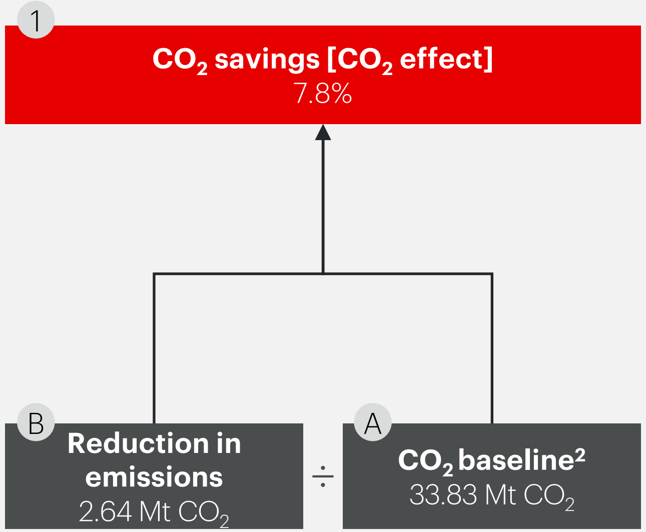
Adoption rate in 2030
55%

Expected adoption rates of companies in 2030
50%

Benchmarks of adoption rates in 2030
60%

Notes: a) There are two reasons for the discrepancy: first, the determination of the adoption rates for 2023 and 2030 (see continuous text on this and the next page); and second, the calculation of the 2023 CO_2 baseline and 2030 CO_2 projections. For the former, a baseline was calculated without adoption of the use case and used as (A). For the latter, the data from the UBA projection report (2023) was used; b) Sample calculation of CO_2 savings for 2030 using the example of the "precision livestock feeding" use case in the agricultural sector.

Step 2: Calculation of the reduction in emissions in %[a] per use case



1

CO_2 savings [CO_2 effect]
7.8%

B

Reduction in emissions
2.64 Mt CO_2

÷

A

CO_2 baseline[2]
33.83 Mt CO_2

①

Calculations – CO_2 effect per use case

Step 2: In the second step, the CO_2 savings are calculated as a percentage (1). In the study, this is also referred to as the CO_2 effect. For this purpose, the reduction in emissions (B) in Mt of CO_2 calculated in Step 1 is divided by the CO_2 baseline in Mt CO_2 calculated in Step 1.

As a result, the calculated percentage figure indicates the proportion of addressable emissions in the (sub-) sector that has been or will be saved by adopting the specific use case in the respective year.

Note: a) Sample calculation of CO_2 savings for 2030 using the example of the "precision livestock feeding" use case in the agricultural sector.

②

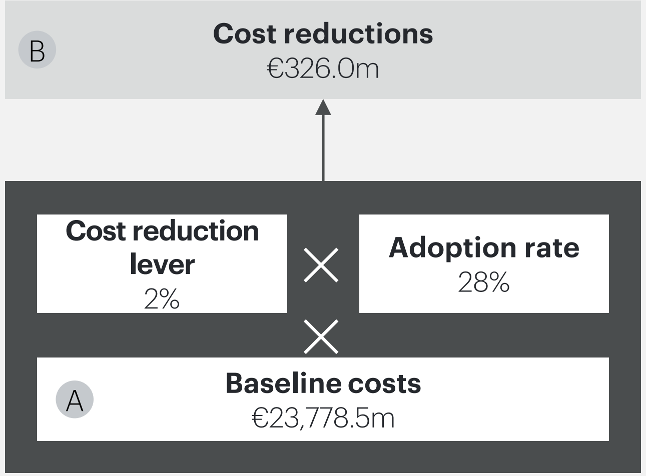
Calculations – Parameters for calculating the EBIT increase per use case

Abbrev.	Parameter	Unit	Granularity/ reference value	Primary data	Secondary data	Expert opinion	Calculation (simplified)
EB%23	Current increase in EBIT margin in 2023 (EBIT effect)	%	Sector-specific				=EB23/T23
EB%30	Potential increase in EBIT margin in 2030 (EBIT Effect)	%	Sector-specific				=EB30/T30
EB23	Current EBIT increase in 2023	€ m or bn.	Sector-specific, use case				=(T23xTIL)-(CBl23xCRL)
EB30	Potential EBIT increase in 2030	€ m or bn.	Sector-specific, use case				=(To30xTIL)-(CPr30xCRL)
CBl23	Baseline costs in 2023	€ bn	Sector, sub-sector		x		
CPr30	Projected costs in 2030	€ bn	Sector, sub-sector		x		
T23	Turnover in 2023	€ bn	Sector, sub-sector		x		
T30	Turnover in 2030	€ bn	Sector, sub-sector		x		
CRL	Cost-reduction lever	%	Use case	x	x	x	Weighted averages
TIL	Turnover increase lever	%	Use	x	x	x	Weighted averages

②

Calculation – EBIT increase per use case

Step 1: Calculation of the reduction in costs per use case (in €)


B **Cost reductions**
€326.0m

Cost reduction lever
2%

×

Adoption rate
28%

×

A **Baseline costs**
€23,778.5m

Step 1: For each use case per sub-sector, the first step is to determine the reduction in costs (B) in millions or billions of euros resulting from the use of digital technologies – for both 2023 and 2030. Use cases are defined as the combined use of various digital technologies, which particularly realise their potential when they are used in combination for a specific application in the sub-sector. The calculation logic for 2023 and 2030 is identical and is illustrated using the sample calculation.[a]

The following three parameters are multiplied together to calculate the cost reductions (B):

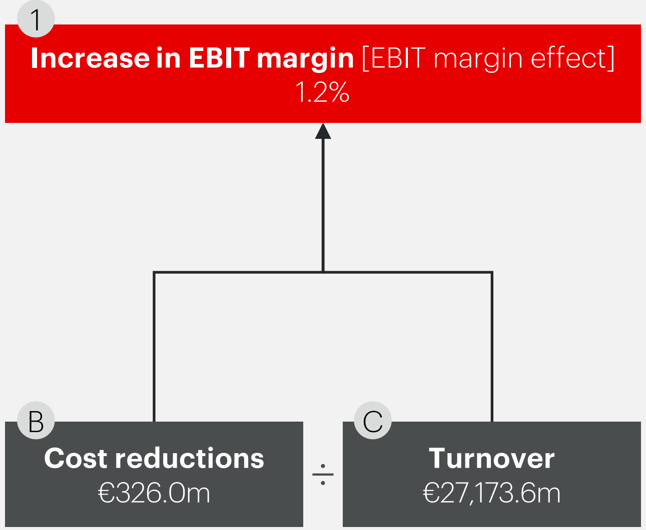
1. **Baseline costs in 2023 or projected costs in 2030 of the (sub-) sector (A) –** Costs of the sector or sub-sector that can be addressed by the use case in the respective year. Both values are based on secondary data.
2. **Cost-reduction lever –** Average percentage of cost savings that can be attributed to the use of digital technologies or their smart application in combination per use case – owing to their positive impact on cost drivers, such as energy consumption or personnel costs.
3. **Adoption rate –** Average utilisation of the use case in the sub-sector during the year under review. The calculation is independent of whether the CO_2 reduction or the EBIT effect is involved.

Note: a) Sample calculation for 2030 using the example of the "precision livestock feeding" use case in the agricultural sector.

②

Calculations – EBIT effect per use case

Step 2: Calculation of the increase in EBIT margin per use case in %[a]



1 **Increase in EBIT margin** [EBIT margin effect]
1.2%

B **Cost reductions**
€326.0m

÷

C **Turnover**
€27,173.6m

Step 2: In the second step, the increase in EBIT margin is calculated as a percentage (1). In the study, this is also referred to as the EBIT margin effect. For this purpose, the cost reduction (B) in euros calculated in Step 1 is divided by the turnover of the (sub-) sector in euros (C).

As a result, the percentage figure calculated indicates by how many percentage points the EBIT margin of the (sub-) sector in question increases as a result of adopting the use case.

If the use case also leads to an increase in turnover (e.g. in the electricity sector, where site modelling increases electricity production per wind turbine and reduces energy production costs), the EBIT margin *without* adoption of the use case was calculated and subtracted from the EBIT margin *with* adoption of the use case.

Note: a) Sample calculation for 2030 using the example of the "precision livestock feeding" use case in the agricultural sector.

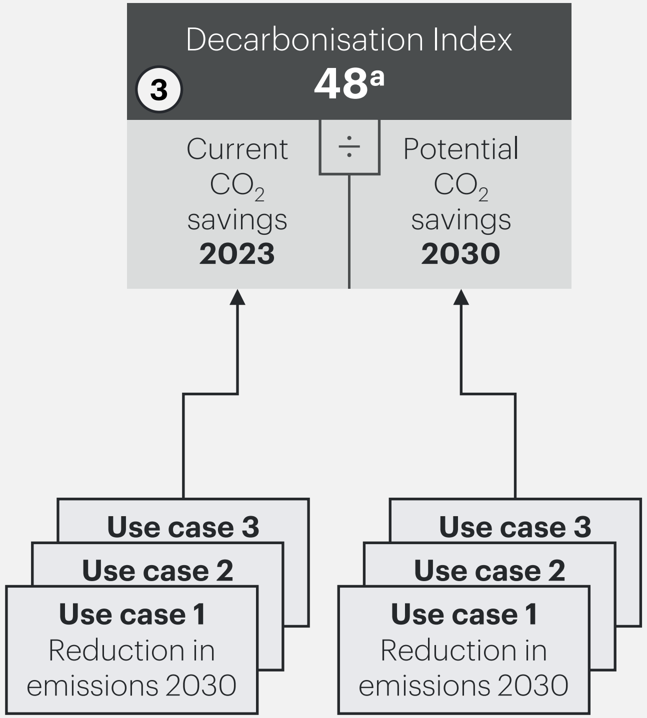
③④⑤

Calculations – Parameters for calculating the index

Abbrev.	Parameter	Unit	Granularity/ reference value	Primary data	Secondary data	Expert opinion	Calculation (simplified)
SI	SEED-Index	None	Cross-sectoral				=(DIgxPIg)/2
DIg	Decarbonisation Index (weighted)	None	Cross-sectoral				Weighted average of all DIs
PIg	Profitability Index (weighted)	None	Cross-sectoral				Weighted average of all PIs
DIs	Decarbonisation Index	None	Sector-specific				=CO%23/CO%30
PIs	Profitability Index	None	Sector-specific				=EB%23/EB%30

③

Calculations – Decarbonisation Index



Decarbonisation Index

③ **48**[a]

Current CO_2 savings **2023**

÷

Potential CO_2 savings **2030**

Use case 3

Use case 2

Use case 1
Reduction in emissions 2030

Use case 3

Use case 2

Use case 1
Reduction in emissions 2030

The decarbonisation index is first calculated per sector in order to arrive at the overall Decarbonisation Index via a weighted average. To do so, the following calculation steps are carried out:

Step 1: Total CO_2 savings in millions of tonnes (Mt) of CO_2 per sector

First, the CO_2 savings determined using calculation module 1 for each use case are added up in Mt of CO_2 for the sector in question. This is done for the savings in both 2023 [CO23] and 2030 [CO30].

Step 2: Total CO_2 savings per sector in %

For 2023, the total CO_2 savings for 2023 in Mt of CO_2 calculated in Step 1 are divided by the 2023 CO_2 baseline [CBl23] for the sector. [CO%23]

For 2030, the total CO_2 savings for 2030 in Mt of CO_2 calculated in Step 1 are divided by the 2030 CO_2 projection [CPr30] for the sector. [CO%23]

Step 3: Calculation of decarbonisation index per sector

For each sector, the total CO_2 savings in % [CO%23] determined in Step 2 for 2023 are divided by the total CO_2 savings in % for 2030 [CO%30].

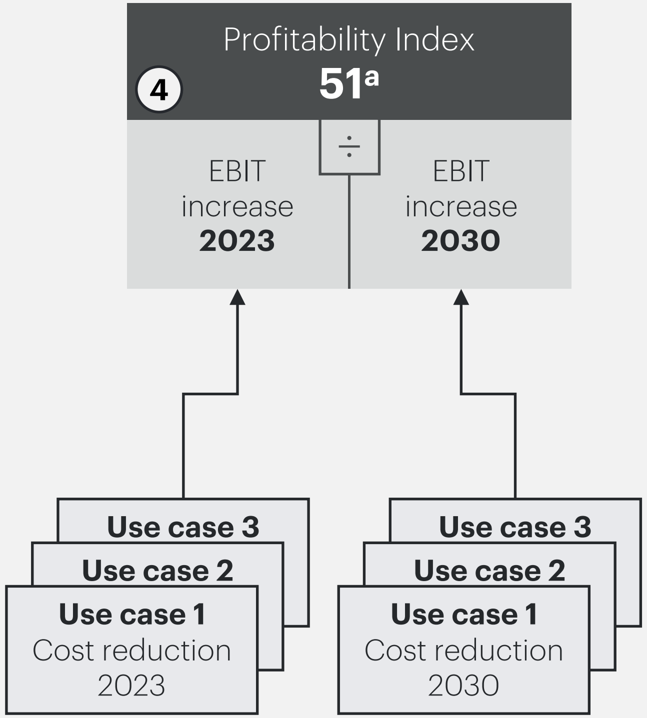
Step 4: Calculation of the overall Decarbonisation Index

The decarbonisation indices of the individual sectors calculated in Step 3 are combined into an overall Decarbonisation Index for the SEED study using a weighted average based on the CO_2 emission weightings (see table p. 114).

Note: a) Using the example of the agricultural sector.

④

Calculations – Profitability Index



The profitability index is first calculated for each sector, and then a weighted average is used to arrive at the overall Profitability Index. To do so, the following calculation steps are carried out:

Step 1: Total reduction in cost per sector in € m

First, for each sector in question, the cost reductions in millions of euros are calculated for each use case using Calculation Module 2. This is done for the reductions in both 2023 and 2030.

Step 2: EBIT increase per sector in %

For 2023, the total cost reductions for 2023 in millions of euros calculated in Step 1 are divided by the 2023 turnover [T23] of the sector.

For 2030, the total cost reductions for 2030 in millions of euros calculated in Step 1 are divided by the 2030 projected turnover [T30] of the sector.

Step 3: Calculation of Profitability Index per sector

For each sector, the total EBIT increase in % [EB%23] calculated in Step 2 for 2023 is divided by the EBIT increase in % for 2030 [EB%30].

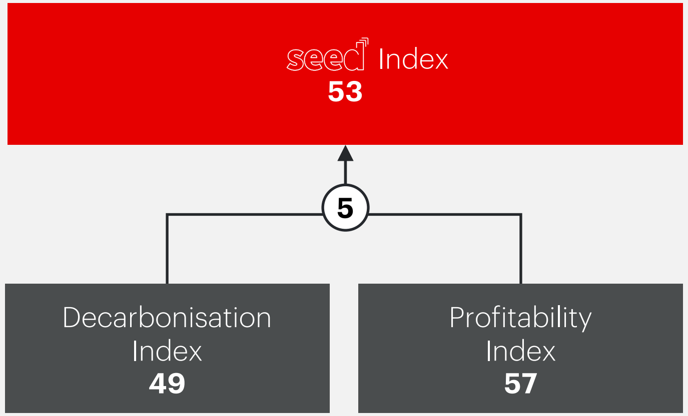
Step 4: Calculation of the overall Profitability Index

The profitability indices of the individual sectors calculated in Step 3 are combined into an overall Profitability Index for the SEED study using a weighted average based on the sectors' turnover (see table, p. 114).

Note: a) Using the example of the agricultural sector.

⑤

Calculations – SEED Index



Sector	Weighting (CO$_2$ emissions)
Buildings	23.2%
Industry	26.8%
Agriculture	10.3%
Logistics	8.4%
Electricity	31.3%

Sector	Weighting (Turnover)
Buildings	5.1%
Industry	86.1%
Agriculture	2.4%
Logistics	3.6%
Electricity	2.7%

The SEED Index is the arithmetic mean of the overall Decarbonisation Index and the overall Profitability Index. The linked, equally weighted consideration of ecological and economic impacts is also expressed in the name of the index: Sustainable Economic Efficiency through Digitalisation (SEED).

As already explained in the calculations for the sub-indices in Step 4, both the overall Decarbonisation Index and the overall Profitability Index are derived from a weighting of the sectors. The following weighting logic is based on two criteria: First, this is the depiction of the overall economy, which is generated using the weighting criteria of sector emissions and sector turnover. Second, this is the development over time, which is illustrated by analysing the values for 2023 and 2030.

The weighting is as described here in detail:

Weighting of the overall Decarbonisation Index: The decarbonisation indices of the individual sectors are weighted according to the CO$_2$ emissions of the sector in question, as these represent the importance of the sector for decarbonisation efforts in Germany. To determine the weightings per sector, the following quotient is calculated: (1) Average of sector CO$_2$ emissions in 2023 and sector CO$_2$ projected emissions for 2030 divided by (2) average total CO$_2$ emissions across all sectors. To determine the overall Decarbonisation Index, the weightings and the individual sector indices are then added up across all sectors using the “weighted average” method.

Weighting of the overall Profitability Index: The profitability indices of the individual sectors are weighted according to the turnover of the sector in question, as this represents the sector’s importance for gross value added in Germany. To determine the weightings per sector, the following quotient is calculated: (1) Average of sector turnover in 2023 and sector turnover in 2030 divided by (2) total turnover across all sectors. To determine the overall Profitability Index, the weightings and the individual sector indices are then added up across all sectors using the “weighted average” method.

Footprint of digital technologies
More CO_2 saving than emissions

The footprint of digital technologies results from the CO_2 emissions generated not only during the use, but also during the production of computing, storage and communication components as well as end devices.

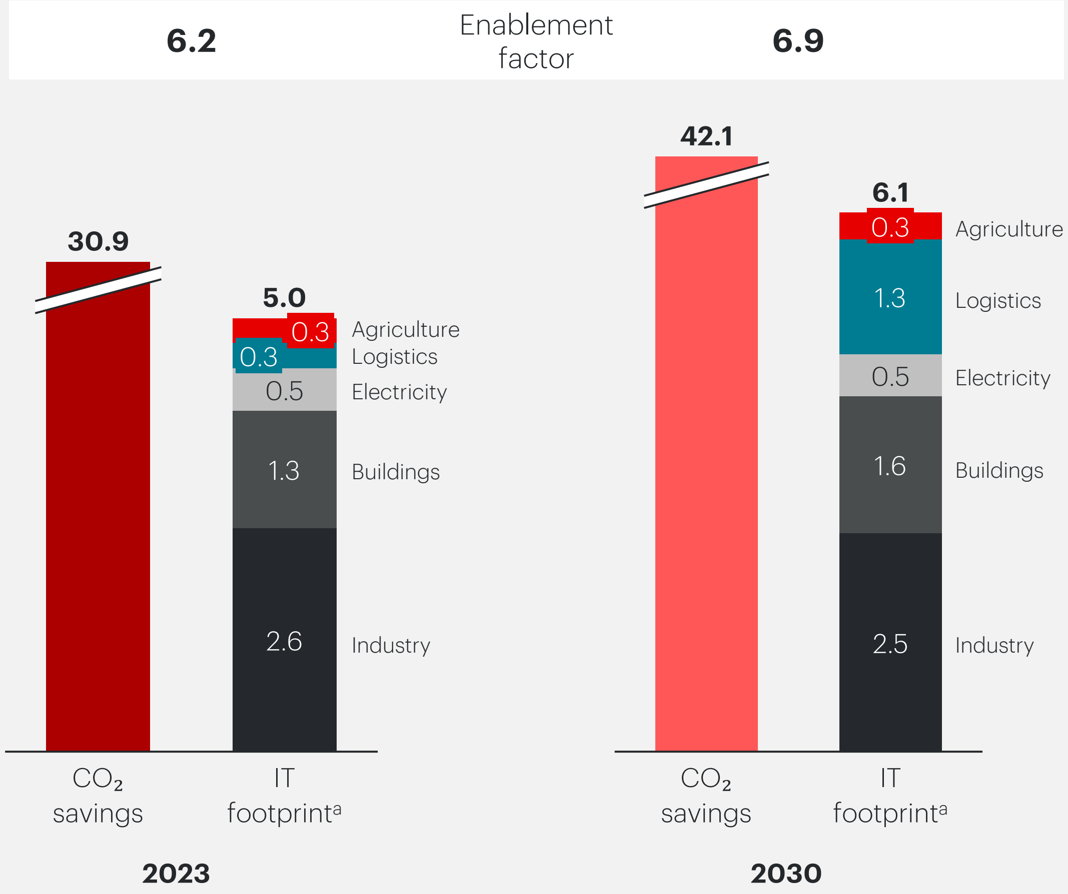
The digitalisation of the individual sectors is also reflected in their footprint: An increase in the carbon footprint[a] will be observed in all sectors, which will be due to digitalisation in the sector. The increase will be disproportionately low, as the energy transition is expected to improve electricity emission factors by 2030. The strong rise in logistics will primarily be due to the increase in demand for road haulage.[b]

The positive influence of digital technologies on carbonisation is confirmed by enablement factors of between 6 and 7: For 2023, the factor is 6.2. This means that digital technologies have saved 6.2 times as much CO_2 through their leverage effect as they have caused through energy consumption during production and use. For 2030, a slightly higher enablement factor of 6.9 is expected.

Definition

Enablement factor: The enablement factor measures the relationship between the induced CO_2 savings and the CO_2 footprint of a digital technology.

[All figures in the bars in Mt CO_2]



Note: a) This is the carbon footprint of the digital technologies in the use cases analysed; b) See also Chapter 2.4 Logistics, p. 69.

Limitations and assumptions

The study is subject to the following limitations and assumptions

Limitations

The lack of a causal model: The authors of the study assume that implementing digital technologies always leads to CO_2 savings and increases in profitability – even though there is no statistically significant causal model for this.

Representativeness of the data: Although the sample was logically derived (stratified) and the respondents were randomised, the data may show a certain bias owing to the different situational contexts of the telephone survey.

Latent factors: This study focuses on the main impacts of digital technologies – decarbonisation and profitability – and, in doing so, tends to ignore other possible factors for CO_2 savings and EBIT increases, such as changes in regulations or market dynamics.

Transferability of the results: The results are focused on German companies. They are not directly transferable to other countries or regions – particularly outside the EU – as the regulatory framework and market conditions are different there.

Assumptions

Reliability of the data: The authors of the study assume that the information provided by the companies in the surveys is reliable and correctly reflects the current and expected CO_2 savings and increases in profitability.

Comparison with global benchmarks: The comparison of the adoption rates of digital technologies at German companies with global benchmarks (countries, sectors, technology leaders) assumes that these could also be realised in Germany. This condition was checked for each use case and relativised if necessary, though without statistical validation. One example is truck platooning, which is expected to be subject to stricter regulation in Germany than elsewhere when it comes to fully autonomous driving.

Technological improvements: This study does not take into account the efficiency gains from the further development of digital technologies. Thus, it assumes the same leverage effects of digital technologies for reducing emissions as for reducing costs and increasing EBIT for 2023 and 2030.

5 Appendix

5.2 Figures in detail

Figures in detail – Buildings

Data points		Sector	Building Information Modelling	Building Management System in non-residential buildings
Decarbonisation	CO_2 effect in 2022 (in %)	**4.0%**	2.8%	4.6%
	CO_2 effect in 2030 (in %)	**7.8%**	5.1%	10.8%
	CO_2 savings 2022 (in Mt CO_2/year)	**7.2**	1.7	5.5
	CO_2 savings 2030 (in Mt CO_2/year)	**6.7**	2.4	4.4
	CO_2 reduction lever (in %)[a]	**n.a.**	9.7%	14.0%
	CO_2 baseline 2022 (in Mt CO_2/year)	**173.6**	60.1	113.5
	CO_2 projection 2030 (in Mt CO_2/year)	**86.7**	46.4	40.4
Profitability	EBIT effect 2022 (in %)	**1.0%**	1.0%	4.6%
	EBIT effect 2030 (in %)	**1.9%**	1.9%	10.7%
	EBIT increase in 2022 (in € m)	**€2,919.1**	€1,130.1	€1,789.1
	EBIT increase in 2030 (in € m)	**€4,859.9**	€2,371.4	€2,488.5
	Cost-reduction lever (in %)[a,b]	**n.a.**	3.9%	28.2%
	Turnover in 2022 (in € m)	**€108,353.7**	€108,353.7	[c]
	Projected turnover in 2030 (in € m)	**€122,766.0**	€122,766.0	[c]
Adoption	Adoption rate in 2022 (in %)	**31.1%**	29.2%	33.0%
	Adoption rate in 2030 (in %)	**65.0%**	52.5%	77.5%

Decarbonisation: Secondary sources for the calculations

1. BAFA, 2021
2. BDEW, 2022
3. DBFZ, 2023
4. Dena, 2022
5. PlanRadar, 2021
6. Statista, 2023a
7. UBA, 2021b
8. UBA, 2023c
9. UBA, 2023l
10. UBA, 2023k
11. vbw, 2021

Profitability: Secondary sources for the calculations

1. BAFA, 2024
2. BVMB, 2021
3. Destatis, 2019b
4. Destatis, 2024d
5. IBISWorld, 2023a
6. PlanRadar, 2021
7. vbw, 2023

Notes: a) Calculation based on specific impact levers. Figures shown represent weighted averages of the minimum and maximum impact levers; b) Weighting of the levers is based on the cost structure of the sub-sector. Impact levers: “building materials”, “planning and project management time”, “construction time”, “heating”, “hot water”, “air conditioning and ventilation systems” and “lighting”; c) Cost savings through BMS are realised across all sectors in the EBIT of building tenants and not just for companies in the buildings sector.

Figures in detail – Industry

	Data points	Sector	Steel: Digital twin[a]	Product: Digital twin and virtual prototype development	Cement: Digital twin[b]	Chemicals: Digital twin[c]
Decarbonisation	CO_2 effect in 2022 (in %)	**3.3%**	4.2%	2.8%	3.7%	3.0%
	CO_2 effect in 2030 (in %)	**5.6%**	5.4%	4.8%	7.1%	5.9%
	CO_2 savings 2022 (in Mt CO_2/year)	**5.7**	1.9	1.5	0.8	1.5
	CO_2 savings 2030 (in Mt CO_2/year)	**7.9**	2.2	1.9	1.3	2.5
	CO_2 reduction lever (in %)[d]	**n.a.**	11.2%	9.1%	12.0%	10.8%
	CO_2 baseline 2022 (in Mt CO_2/year)	**164.0**	44.1	50.9	20.4	48.6
	CO_2 projection 2030 (in Mt CO_2/year)	**140.1**	40.0	39.1	18.5	42.5
Profitability	EBIT effect 2022 (in %)	**1.2%**	1.7%	1.2%	1.2%	1.0%
	EBIT effect 2030 (in %)	**2.1%**	2.2%	2.1%	2.4%	1.9%
	EBIT increase in 2022 (in € m)	**€22,861.0**	€934.3	€20,317.3	€42.3	€1,567.1
	EBIT increase in 2030 (in € m)	**€42,214.7**	€1,275.1	€37,570.5	€87.2	€3,282.0
	Cost-reduction lever (in %)[d,e]	**n.a.**	4.8%	4.8%	4.5%	3.7%
	Turnover in 2022 (in € m)	**€1,870,621.1**	€55,200.0	€1,650,991.1	€3,430.0	€161,000.0
	Projected turnover in 2030 (in € m)	**€1,994,465.4**	€58,854.5	€1,760,294.8	€3,657.1	€171,659.0
Adoption	Adoption rate in 2022 (in %)	**31.6%**	37.5%	30.6%	30.3%	28.0%
	Adoption rate in 2030 (in %)	**55.8%**	56.0%	53.0%	58.7%	55.0%

Decarbonisation: Secondary sources for the calculations

1. DEHSt, 2023
2. Dena, 2023a
3. Global Energy Solutions e.V., 2022
4. UBA, 2023h
5. UBA, 2023l
6. UBA, 2023j
7. VCI, 2023
8. VDZ, 2023a
9. VDZ, 2023b
10. Wirtschaftsvereinigung Stahl, 2023

Profitability: Secondary sources for the calculations

1. BBS, 2023
2. Destatis, 2019b
3. Holcim, 2022
4. IBISWorld, 2023b
5. onvista, 2023
6. Salzgitter AG, 2023
7. Statista, 2023b
8. Thyssenkrupp, 2023a
9. VDZ, 2023b
10. VCI, 2024

Notes: a) Incl. digital modelling and optimisation of the smelting process; b) Incl. digital modelling of the calcination process; c) Incl. digital modelling for the reformulation of chemical products; d) Calculation based on specific impact levers. Figures shown represent weighted averages of the minimum and maximum impact levers; e) Weighting of the impact levers is based on the cost structure of the sub-sector. Impact levers: "energy consumption", "raw material consumption", "labour input", "raw material steel", "raw material combustion", "water consumption", "maintenance", "downtime" and "material consumption".

Figures in detail – Agriculture

	Data points	Sector	Crop farming: Intelligent soil and crop monitoring	Crop farming: Intelligent farming machinery	Livestock farming: Digital livestock management	Livestock farming: Precision livestock feeding
Decarbonisation	CO_2 effect in 2022 (in %)	**8.1%**	3.6%	5.1%	4.3%	4.0%
	CO_2 effect in 2030 (in %)	**16.9%**	7.3%	9.0%	9.4%	7.8%
	CO_2 savings 2022 (in Mt CO_2/year)	**5.3**	0.8	1.1	1.8	1.7
	CO_2 savings 2030 (in Mt CO_2/year)	**9.1**	1.5	1.8	3.2	2.6
	CO_2 reduction lever (in %)[a]	**n.a.**	9.7%	17.1%	13.5%	14.2%
	CO_2 baseline 2022 (in Mt CO_2/year)	**60.0**	20.8	20.8	39.2	39.2
	CO_2 projection 2030 (in Mt CO_2/year)	**53.9**	20.1	20.1	33.8	33.8
Profitability	EBIT effect 2022 (in %)	**2.4%**	1.7%	2.1%	0.7%	0.6%
	EBIT effect 2030 (in %)	**4.6%**	3.5%	3.6%	1.6%	1.2%
	EBIT increase in 2022 (in € m)	**€1,453.9**	€437.2	€524.5	€262.6	€229.6
	EBIT increase in 2030 (in € m)	**€2,211.8**	€718.3	€746.7	€420.8	€326.0
	Cost-reduction lever (in %)[a,b]	**n.a.**	5.0%	7.5%	2.5%	2.5%
	Turnover in 2022 (in € m)	**€61,648.7**	€25,352.6	€25,352.6	€36,296.1	€36,296.1
	Projected turnover in 2030 (in € m)	**€47,960.9**	€20,787.3	€20,787.3	€27,173.6	€27,173.6
Adoption	Adoption rate in 2022 (in %)	**31.9%**	37.1%	30.0%	32.0%	28.4%
	Adoption rate in 2030 (in %)	**63.1%**	75.0%	52.5%	70.0%	55.0%

Decarbonisation: Secondary sources for the calculations

1. Andeweg & Reisinger, 2015
2. Bartzanas et al., 2017
3. Bitkom e.V., 2023
4. Bosco et al., 2021
5. Chen et al., 2021
6. Corsini et al., 2015
7. Farooque et al., 2023
8. Gabriel & Gandorfer, 2022
9. Groher et al., 2020
10. Maloku, 2020
11. Masi et al., 2023
12. Mirzakhaninafchi, 2022
13. Pomar & Remus, 2019
14. Research and Markets, 2023
15. Shi et al., 2023
16. Späti, 2022
17. UBA, 2024e

Profitability: Secondary sources for the calculations

1. Bitkom e.V., 2023
2. BMEL, 2023e
3. Chen et al., 2021
4. Corsini et al., 2015
5. DBV, 2018
6. DBV, 2019
7. DBV, 2020
8. DBV, 2021b
9. DBV, 2022
10. DBV, 2023
11. Farooque et al., 2023
12. Gabriel & Gandorfer, 2022
13. Groher et al., 2020
14. Maloku, 2020
15. Masi et al., 2023
16. Mirzakhaninafchi, 2022
17. Research and Markets, 2023
18. Schimmelpfennig, 2016
19. Shi et al., 2023
20. Späti, 2022

Notes: a) Calculation based on specific impact levers. Figures shown represent weighted averages of the minimum and maximum impact levers; b) Weighting of the levers is based on the cost structure of the sub-sector. Impact levers: "fertiliser", "manual labour" and "fuel consumption".

Figures in detail – Logistics

	Data points	Sector	Road haulage: Digital twin and virtual prototype development	Road haulage: Intelligent route and cargo optimisation	Road haulage: Truck platooning
Decarbonisation	CO_2 effect in 2022 (in %)	**3.3%**	2.4%	4.1%	[a]
	CO_2 effect in 2030 (in %)	**7.1%**	4.5%	6.8%	1.4%
	CO_2 savings 2022 (in Mt CO_2/year)	**1.2**	0.9	1.5	[a]
	CO_2 savings 2030 (in Mt CO_2/year)	**4.1**	2.6	4.0	0.8
	CO_2 reduction lever (in %)[b]	**n.a.**	11.6%	13.6%	10.0%
	CO_2 baseline 2022 (in Mt CO_2/year)	**35.9**	35.9	35.9	35.9
	CO_2 projection 2030 (in Mt CO_2/year)	**58.5**	58.5	58.5	58.5
Profitability	EBIT effect 2022 (in %)	**1.1%**	1.3%	0.9%	[a]
	EBIT effect 2030 (in %)	**2.3%**	2.4%	1.4%	0.4%
	EBIT increase in 2022 (in € m)	**€779.2**	€919.1	€600.7	[a]
	EBIT increase in 2030 (in € m)	**€2,139.4**	€2,238.9	€1,330.3	€354.8
	Cost-reduction lever (in %)[b,c]	**n.a.**	6.4%	2.9%	2.8%
	Turnover in 2022 (in € m)	**€70,400.0**	€70,400.0	€70,400.0	€70,400.0
	Projected turnover in 2030 (in € m)	**€92,742.7**	€92,742.7	€92,742.7	€92,742.7
Adop-tion	Adoption rate in 2022 (in %)	**17.2%**	20.8%	29.9%	<1.0%
	Adoption rate in 2030 (in %)	**34.2%**	38.5%	50.2%	14.0%

Decarbonisation: Secondary sources for the calculations

1. Coherent Market Insights, 2023
2. Destatis, 2023c
3. Fraunhofer IIS, 2022
4. Fraunhofer IIS, 2020
5. GMI, 2022
6. HBEFA, 2024
7. KBA, 2023
8. Lehmann, 2020
9. MarketsandMarkets, 2023
10. Market Research Future, 2024
11. UBA, 2024c
12. UBA, 2024b

Profitability: Secondary sources for the calculations

1. BGL, 2023
2. Coherent Market Insights, 2023
3. Destatis, 2023c
4. GMI, 2022
5. HBEFA, 2024
6. KBA, 2023
7. Lehmann, 2020
8. MarketsandMarkets, 2023
9. Market Research Future, 2024
10. UBA, 2024c
11. UBA, 2024b

Notes: a) Currently in the pilot phase in Germany, which is why no significant effects can be identified for 2023; b) Calculation based on specific impact levers. Figures shown represent weighted averages of the minimum and maximum impact levers; c) Weighting of the levers is based on the cost structure of the sub-sector. Impact levers: “total fuel consumption”, “number of vehicles in the total fleet”, “maintenance costs”, “labour costs”, “average fuel consumption” and “total fuel consumption”.

Figures in detail – Electricity

	Data points	Sector	Wind: Site modelling	Wind: Digital twin and predictive maintenance	Solar: Site modelling	Solar: Digital twin and predictive maintenance	Electricity grid: Digital twin[a]
Decarbonisation	CO_2 effect in 2022 (in %)	**4.7%**	1.2%	0.4%	1.2%	0.2%	3.4%
	CO_2 effect in 2030 (in %)	**12.0%**	5.8%	2.6%	3.8%	2.9%	4.4%
	CO_2 savings 2022 (in Mt CO_2/year)	**11.4**	2.8	1.0	2.8	0.6	7.9
	CO_2 savings 2030 (in Mt CO_2/year)	**14.3**	7.0	3.1	4.5	3.5	5.2
	CO_2 reduction lever (in %)[b]	**n.a.**	5.4%	3.8%	4.8%	7.9%	8.0%
	CO_2 baseline 2022 (in Mt CO_2/year)	**227.0**	227.0	227.0	227.0	227.0	227.0
	CO_2 projection 2030 (in Mt CO_2/year)	**119.5**	119.5	119.5	119.5	119.5	119.5
Profitability	EBIT effect 2022 (in %)	**3.4%**	3.5%	1.5%	2.2%	1.6%	1.6%
	EBIT effect 2030 (in %)	**6.6%**	6.0%	3.3%	4.3%	4.2%	2.3%
	EBIT increase in 2022 (in € m)	**€1,818.9**	€756.9	€314.3	€188.5	€137.7	€421.4
	EBIT increase in 2030 (in € m)	**€4,416.0**	€1,628.6	€877.4	€605.1	€613.6	€691.4
	Cost-reduction lever (in %)[b,c]	**n.a.**	3.7%	4.1%	3.4%	3.3%	4.4%
	Turnover in 2022 (in € m)	**€53,170.5**	€18,903.2	€18,903.2	€7,286.2	€7,286.2	€26,981.1
	Projected turnover in 2030 (in € m)	**€66,569.7**	€23,946.0	€23,946.0	€12,519.0	€12,519.0	€30,104.6
Adoption	Adoption rate in 2022 (in %)	**32.5%**	48.6%	24.1%	34.8%	18.1%	37.1%
	Adoption rate in 2030 (in %)	**60.4%**	82.5%	53.1%	65.0%	46.9%	54.6%

Decarbonisation: Secondary sources for the calculations

1. AGEB, 2023
2. Betti et al., 2019
3. Chandler, 2022
4. DWD, 2023
5. Fraunhofer ISE, 2024
6. Klima- und Energiefonds, 2012
7. Kuttybay et al., 2020
8. Schlömer et al., 2014
9. Schmidt, 2022
10. UBA, 2023l
11. UBA, 2023h
12. WindEurope, 2021

Profitability: Secondary sources for the calculations

1. Amprion, 2022
2. BDEW, 2023a
3. BDEW, 2023c
4. BDEW, 2023a
5. BDEW, 2023b
6. Bundesnetzagentur, 2023b
7. Deutsche WindGuard, 2023
8. Encavis, 2022
9. Fraunhofer ISE, 2021
10. Honna et al., 2022
11. Lico & Barr, 2022
12. Research and Markets, 2022
13. Research and Markets, 2024
14. Scatec, 2022
15. Strom-Report, 2023
16. vbw, 2023
17. vbw, 2023
18. 50hertz, 2023

Notes: a) Including digital fault detection and predictive maintenance; b) Calculation based on specific impact levers. Figures shown represent weighted averages of the minimum and maximum impact levers; c) Weighting of the levers is based on the cost structure of the sub-sector. Impact levers: "costs of energy generation" and "costs of energy transmission".

5 Appendix

5.3 List of sources

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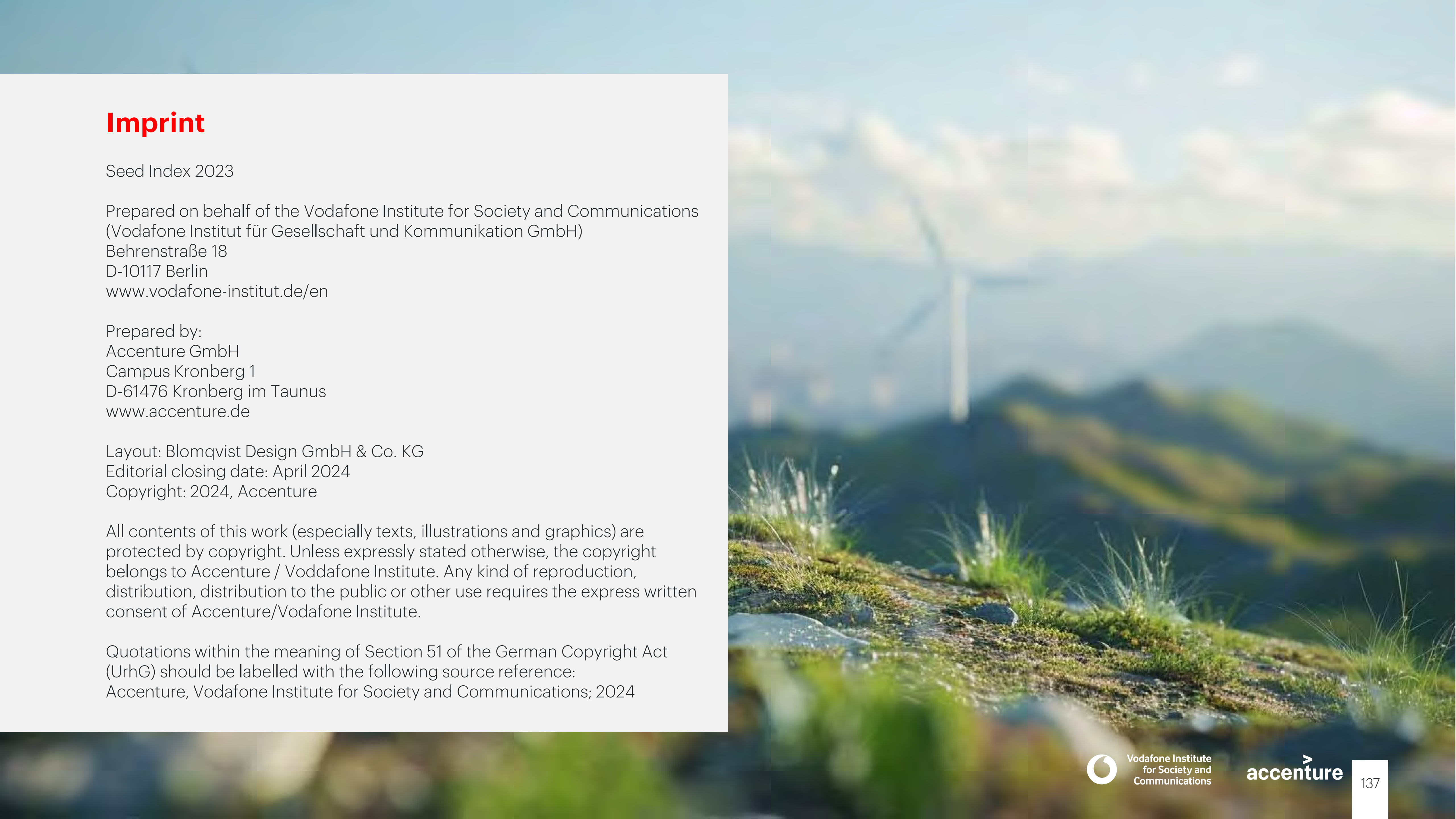

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Prepared by:
Accenture GmbH
Campus Kronberg 1
D-61476 Kronberg im Taunus
www.accenture.de

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