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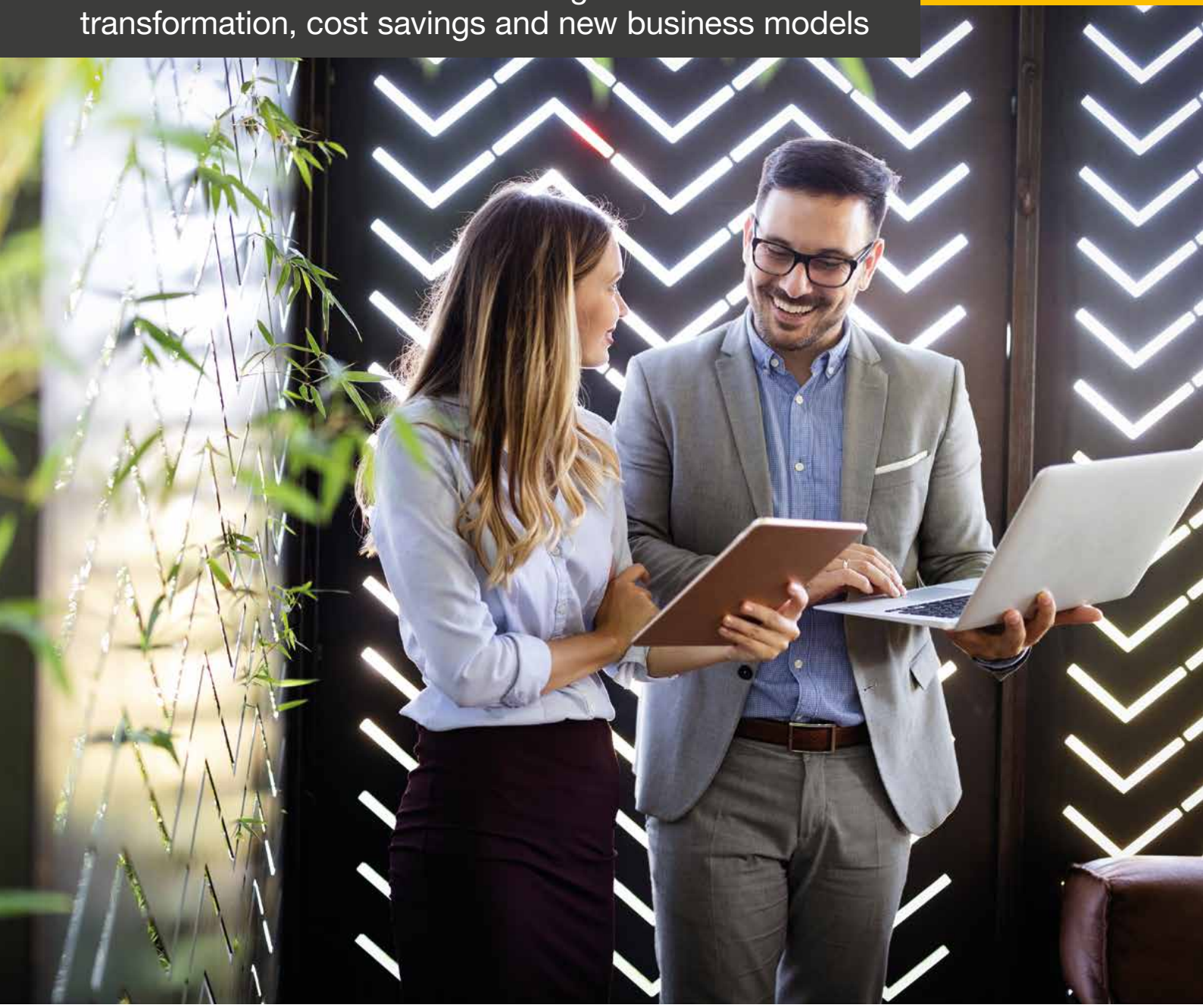
The Longevity Key for Business

The role of data and AI in unlocking sustainable business transformation, cost savings and new business models



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About

This research paper is a result of a joint effort and collaboration between PwC, Microsoft and The University of Oxford's Environmental Change Institute and Smith School of Enterprise and the Environment. Please find more information on the authors below.

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Microsoft creates platforms and tools powered by AI to deliver innovative solutions to meet the evolving needs of our customers. Our technologies are designed to benefit everyone, at every level, in every organization. Together with our customers, partners and communities, we are committed to making AI available broadly and doing so responsibly, with a mission to empower every person and every organization on the planet to achieve more.

This whitepaper is the work of the Microsoft Commercial and Partner team and is intended to highlight new business opportunities created by the advancement of AI for commercial customers and partners. It is not an extension of or additional to Microsoft's corporate environmental sustainability policies or goals, which focuses on AI as an essential tool for accelerating sustainability. More information on Microsoft's policies on AI and Sustainability may be found in Accelerating Sustainability with AI: A Playbook and in the 2024 Environmental Sustainability Report by Microsoft's Vice Chair and President, Brad Smith and Chief Sustainability Officer, Melanie Nakagawa.

Smith School of Enterprise and the Environment
Our vision is a net-zero emissions future supported by a sustainable global economic and financial system – a healthy planet and a more prosperous, fairer world. We help to achieve that vision through our world-leading research, teaching and partnerships.

- Our research delivers business-focused solutions to stabilise the climate and protect our natural world, by shifting the global economic and financial system to sustainability.
- Education is at the heart of our mission – we equip the next generation through undergraduate and graduate teaching and empower business leaders through executive education.
- We host public lectures and academic conferences, and convene business, finance and enterprise partners from around the world.

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Our mission is to organise and promote interdisciplinary research on the nature, causes and impact of environmental change and to contribute to the development of management strategies for coping with future environmental change.

Foreword by Microsoft

Business leaders everywhere now recognize that sustainability is not just an environmental imperative; it is a critical component for business success. Embracing sustainable practices can unlock efficiencies, drive innovation and open new markets, positioning companies as leaders in the transition to a greener and competitive economy.

And in the era of AI, there are more opportunities for forward-looking leaders to leverage their ESG data as strategic asset to not only drive sustainable business transformation, but to also futureproof their organization's business model.

The success of these leaders lies in how they are rethinking sustainability and business impact not as two separate "pockets", but rather as mutually enhancing. They are not focused solely on regulatory compliance. Instead, they are thinking about green value creation which creates business growth, increased efficiency and enhanced resiliency. Such efforts are delivering rapid payback both for business and the planet, something that is particularly important at a time of economic headwinds in Europe.

Take for example Outokumpu, a Finnish stainless-steel producer. Their team are actively utilizing advanced analytics and AI to reduce their energy use and increase factory output, as well as reducing CO_2 emissions. Then there is Alfa Laval, who manufacture plate heat exchangers. Their team developed with Microsoft a thermal detection camera with AI that can be used to monitor the performance of their products, identify any discrepancies in heat transfer and automatically suggest appropriate measures. Another example is Stena Line, a Swedish shipping company which is using AI to enable their crews with optimised fuel savings while reducing CO_2 emissions.

All of these organizations have shown that sustainability and business strategy are two sides to the same coin: there is no business without sustainable business. In this paper, we will explore these examples in more detail, as well as many other examples of organizations, industries and sectors which are successfully enabling green value creation with the help of digital technology.

And at Microsoft, we know we have a part to play too. We're driving progress toward a more sustainable future by reducing our environmental footprint, accelerating research and innovation, and advocating for policies that benefit the environment. We're also continuing to invest in purchasing renewable energy and other efforts to meet our sustainability goals of being carbon negative, water positive and zero waste by 2030. We're building sustainability into everything we do – including our operations, products, solutions, and beyond our four walls. Because we believe that companies that can do more, should.

As we report in our 2024 Sustainability Report, we are on track in several areas and mobilizing to accelerate progress in areas where we're not yet on track.

As a global technology provider, we have a role to play in supporting our partners, customers and stakeholders around the world. We believe our most important contribution to carbon reduction will be by helping them reduce their environmental footprint with the power of data science, artificial intelligence, and digital technology. From managing data relevant to environmental footprints with Microsoft Cloud for Sustainability to accelerating innovation for new climate technologies, we're working to empower our customers and partners across industries.

Aligning your sustainability and business strategy doesn't have to be daunting. Regardless of where you are in your journey, data analytics and AI can help you get started with your most pressing sustainability use cases: be that optimizing resource use, identifying environmental impacts or unlocking new green business models, all powered by the Microsoft Cloud for scalable, energy-efficient infrastructure. Regardless of where your organization may be, we're committed to helping you achieve more.

So, the real bottom line? There is no "two-pocket" thinking here. Sustainability and business strategy are two sides to the same coin: digitization is the turnkey for both.

Dr. Laura-Marie Töpfer

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A Impact and business – a symbiotic relationship

> "Companies with higher sustainability awareness ensure shareholder value creation via improved financial performance, management quality as well as reduced risk metrics."[1]

In recent years, a lot of academic research has been published showing how sustainability can make a positive financial impact on a company.[2,3] But at the same time, there have been compelling voices arguing that companies must choose to either maximise their positive impact on society and the environment, or maximise their financial returns – because it's allegedly impossible to do both. These conflicting pieces of information have arrived against a backdrop of increasingly strict regulations and reporting requirements related to sustainability that are placing big demands on time and money for businesses.[4]

In this context, sustainability programmes without a clear and positive business case can sometimes be viewed as "nice-to-have" activities for boosting brand positioning, rather than "must-have" activities to optimise and grow the core business.[5] For leaders, it's difficult to gain clarity about whether the positive impact of sustainability programmes can outweigh the overall cost.

Recent evidence shows that leaders may consider shrinking or scrapping sustainability programmes that do not deliver commercial benefits for their company – especially when the external business environment becomes challenging.[6] This suggests that the future of sustainability programmes will depend on value creation.

On the other hand, CEOs and CFOs also need to balance the fact that sustainability is a big focus topic for shareholders, investors and customers. Nowadays, investors are willing to pay a premium for companies that can offer genuine transparency about the impact of their sustainability programmes.[7] This is because investors now also need to meet increasingly strict regulations and reporting requirements. One example is the EU's Sustainable Finance Disclosure Regulation (SFDR), which requires asset owners to prove the sustainability profile of their financial products.

In addition, modern customers and consumers value products and services with a strong sustainability profile – and they also favour businesses that can demonstrate their commitment to sustainability in a credible and transparent manner.[8] This creates a set of clear imperatives for businesses. If they don't transform their products to meet these changing customer demands, they won't grow. If they don't take action to address their impact on society and the environment, the cost of capital will rise.

Data and artificial intelligence (AI) have the potential to make sure sustainability programmes are backed up by a strong positive business case. Unlocking that potential begins with collecting, aggregating and analysing vast amounts of operational, financial and sustainability data – and bringing it all together into one unified data estate. Many organisations have already started that process as part of their efforts to meet increasingly strict regulations and reporting requirements. However, very few businesses have tapped into the full potential of this data.

Leaders have a huge opportunity to leverage data that has been gathered for sustainability compliance by using it to create business value – by establishing the necessary foundation for AI to help cut costs or open up new, more sustainable revenue streams. In a world where shareholders and investors are making both sustainability performance and business performance a key focus, investments in data and AI capabilities for sustainability are now also investments in ensuring future access to capital.[9]

Those companies that are doing good by having a positive impact on the environment while at the same time improving business performance are testament to the fact that sustainability and business are entering a symbiotic relationship.

[1] Zumente & Bistrova, 2021.
[2] Wong et al., 2017.
[3] Clark et al., 2015.
[4] Harvard Business Review, 2021.
[5] edie, 2022.
[6] Harvard Business Review, 2022.
[7] McKinsey, 2023(b).
[8] NielsenIQ & McKinsey, 2023.
[9] PwC, 2023(b).

B A big opportunity for sustainability and business

"AI has the potential to reduce gigatonnes of global carbon emissions and to generate savings worth hundreds of billions of dollars annually." See Table 1 for details

CO_2 emissions are directly linked to costs on the balance sheet – because every tonne of CO_2 emitted by businesses is part of the global value chain for producing goods and services.[10] But despite the rise in corporate net zero commitments[11], total global CO_2 emissions have increased[12] in recent years.

CO_2 emissions are also directly linked to revenue on the balance sheet – because customers and consumers are increasingly interested in products that generate a lower carbon footprint when they are manufactured (e.g. bio-based rather than fossil-based plastic), used (e.g. electric cars) or disposed of (e.g. biodegradable packaging).[13] Leaders who steer their businesses towards offering products that meet these shifting expectations can grab a first-mover advantage by proactively driving the switch to low-carbon products before competitors do.

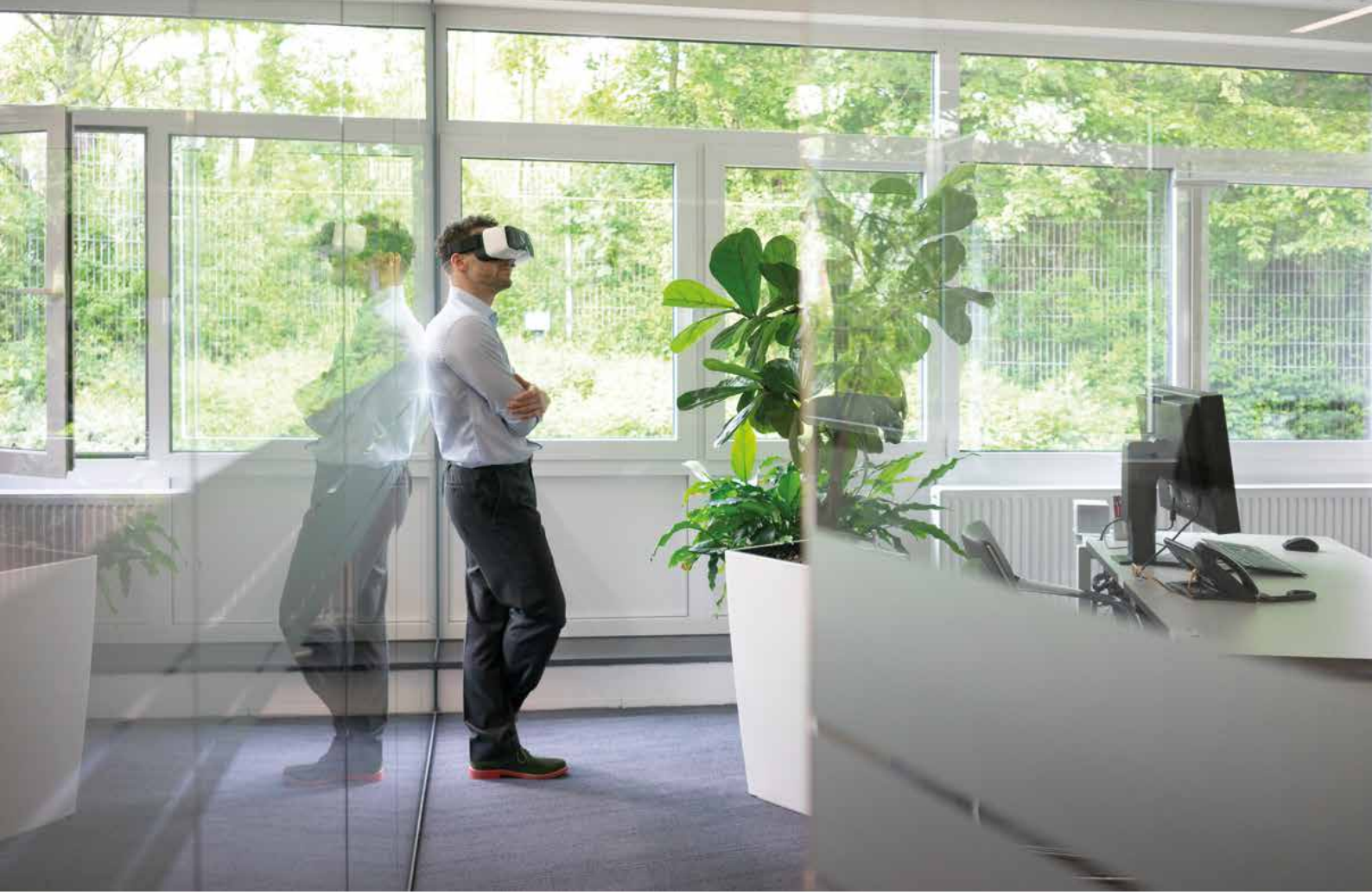
Recent advances in AI give companies a new toolbox to cut costs related to CO_2 emissions[14],[15] and generate new, low-emission revenue streams.[16] This report shows that these technologies have the potential to reduce global carbon footprints by gigatonnes (Gt) of CO_2 equivalent (CO_2e) annually. Our analysis provides indicative figures that suggest reductions on the order of 2Gt are possible, which is in line with our previous analysis that suggested AI could reduce emissions in the agriculture, transport, energy and water sectors by 0.9–2.4Gt – or 1.5–4% of global emissions – by 2030.[17]

On top of this, our research shows that using data and AI to reduce emissions has the potential to save companies hundreds of billions of dollars each year.

The methodology used for these calculations is explained in more detail in the appendix to this report. Of course, these figures are only an approximation to indicate the order of magnitude of the potential impact of data and AI, rather than a precise calculation. One limitation of this study is that the costs associated with AI were not considered. This report should be read as showing the general direction of travel for business leaders and decision-makers, rather than as a fully exhaustive or conclusive statement.

This report limits its focus to CO_2 emissions from the five most carbon-intensive sectors as defined by the World Resources Institute (WRI).[18] In addition, the report mainly focuses on European companies because the pressure from increasingly strict regulations and reporting requirements (e.g. the CSRD) is highest in this region. It is reasonable to assume that the impact across all industries worldwide would be larger than the impact within these five industries.

[10] Espinosa-Gracia et al., 2023.
[11] Economist Impact, 2023.
[12] World Resources Institute, 2020.
[13] PwC, 2023(c).
[14] McKinsey, 2023(a).
[15] Hatzius et al., 2023.
[16] Sjödin et al., 2021.
[17] Joppa & Herweijer, 2019.
[18] World Resources Institute, 2020.



Resource implications of data and AI

While this is not the focus of this paper, we nevertheless want to draw attention to the resource implications of data and AI, and to raise awareness for a holistic approach. This report presents evidence of the potential for data and AI to support sustainable and profitable business growth. However, AI requires significant computing power, which in turn requires electricity and water. The IEA has forecasted that the energy demand of AI will increase exponentially in the next few years.[19]

Without proactive action, the growth of AI could stress local electric grids and water resources in some regions where data centre development is expanding to meet the needs of AI computing. It is important to establish and adhere to best practices, ensuring optimal resource utilisation in AI infrastructure and algorithm design and operations. This might involve emphasising the design of software that is optimised to use the least carbon-intensive electricity source available. It is also key to support research and development that targets innovative approaches for improving energy and water efficiency in data centres.

There are also concerns about the rebound effect of AI, which can be explained in terms of the Jevons Paradox.[20] This states that improvements in resource efficiency, such as those facilitated by AI, may paradoxically lead to increased resource consumption. For example, if autonomous vehicles using AI succeed in reducing emissions intensity per mile travelled, this could lead to driving becoming more affordable, ultimately increasing vehicle usage. If the electricity system is not fully decarbonised, the reduction in emissions per mile could paradoxically lead to higher total emissions. An effective response to this paradox requires a holistic approach that considers the broader impacts of AI. Policymakers, businesses and researchers must collaborate to develop strategies that align AI advancements with sustainability goals.

[19] IEA, 2024.
[20] Munyon et al., 2018.

This report was created based on more than 50 interviews with C-Level and senior executives at leading corporations, as well as innovators at the forefront of unlocking the potential of data and AI for sustainable business transformation. The findings and learnings from this research are presented in two chapters.

Chapter 1 examines companies that are unifying data from various fragmented sources to create a consolidated foundation that supports their efforts to unlock the potential of AI. It presents examples of businesses that are applying advanced analytics to generate cost savings and identify new, more sustainable revenue streams. It also spotlights the most promising use cases via a series of two-page interviews that showcase each company's unique approach.

The report then extrapolates the contributions from these companies and estimates the potential impact if every relevant company worldwide took the same approach.

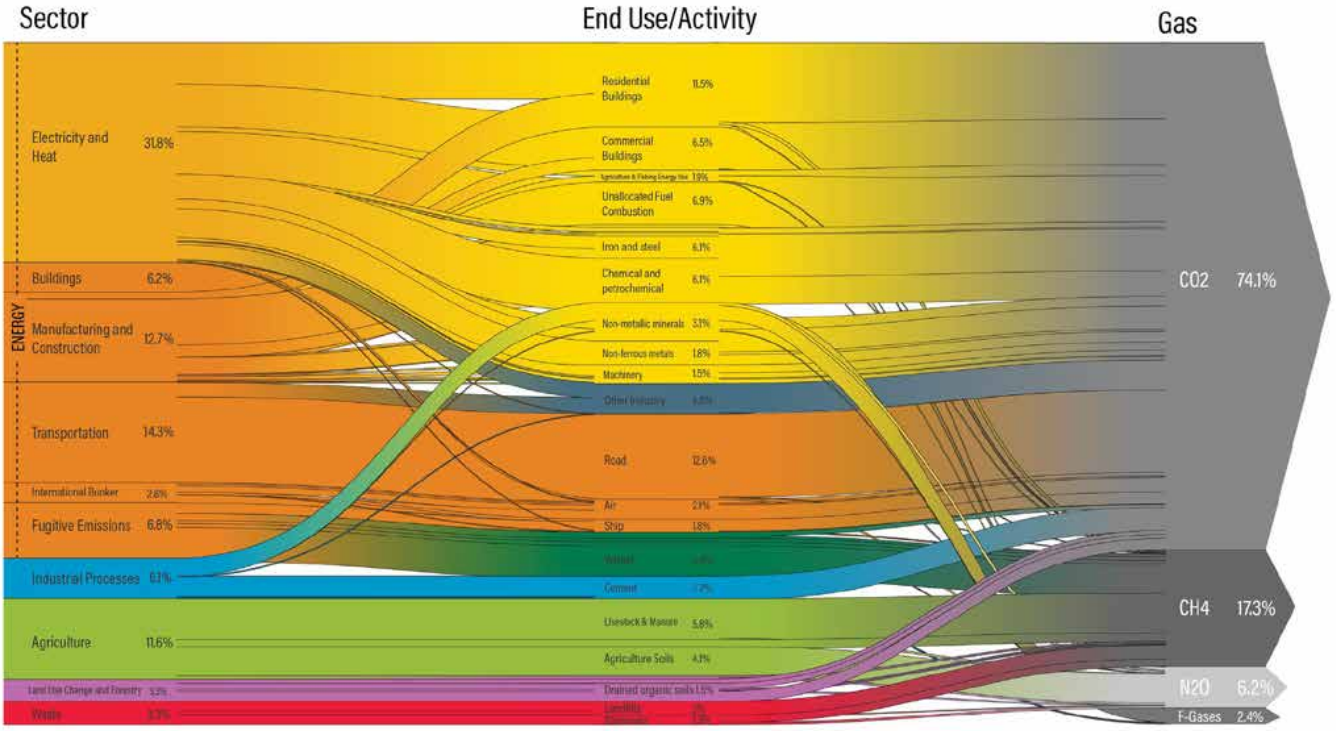
Of course, the report has not identified all potential use cases – and it is not realistic to assume that all companies would adopt the same approach. However, this report aims to provide indicative figures that may help business leaders to gain an overview of what is possible.

This extrapolation focuses on the five most carbon-intensive sectors as defined by the World Resources Institute.[21] They are:

- Energy (37.5Gt CO_2e, or 75% of total emissions)
- Agriculture (5.5Gt CO_2e, or 11% of total emissions)
- Industrial Processes (3Gt CO_2e, or 6% of total emissions)
- Waste (1.5Gt CO_2e, or 3% of total emissions)
- Land Use Change (1.5Gt CO_2e, or 3% of total emissions)

These five sectors can be broken down into further sub-sectors, as shown in the illustration below. This approach reflects the data currently available rather than an exact representation of reality.[22]

Fig. 1 Global greenhouse gas emissions in 2019



Source: Climat Watch, based on raw data from IEA (2021), GHG Emissions from Fuel Combustion, www.iea.org/statistics; modified by WRI.

[21] World Resources Institute, 2020.
[22] World Resources Institute, 2020.

A multibillion-dollar opportunity

The table below provides a summary of the findings of this report. The following numbers are indicative. They have been extrapolated from interviews and secondary literature, and illustrate the art of the possible.

Tab. 1 Overview of financial and sustainability impact opportunities by WRI sector, with example use cases

WRI sector	Indicative size of emissions reduction based on company use cases[1]	Indicative value of savings[1]
Energy in Electricity andHeat	(A) 200 million t CO_2e (B) 300 million t CO_2e	(A) €60 billion (B) €90 billion
Energy in Transportation	(A) 44 million t CO_2e (B) 6 million t CO_2e	(A) €20 billion (B) €2 billion
Energy in Manufacturing and Construction	1 Gt CO_2e	€330 billion
Agriculture	120 million t CO_2	€19 billion
Industrial Processes	160 million t CO_2	€7 billion
Land Use Change and Forestry	100 million t CO_2e	€35 billion
Waste	120 million t CO_2e	€40 billion
Sum	**2 Gt CO_2e**	**€600 billion**

[1] The sources for the numbers, along with the calculations, can be found in the "Turbocharging sustainability" section. A summary of the calculations can be found in the appendix. (A)(B) indicates that two separate use cases have been identified.

Chapter 2 provides an outlook for the future of how AI might support the sustainable transformation of industries and economies. Based on an analysis of current research grants, experts from the University of Oxford share their prognoses for how the use cases identified in this report will evolve and scale in the years ahead.

Overall, this report provides a preliminary snapshot of these first examples of how data and AI can cut emissions, reduce costs and enable new and more sustainable revenue streams across industries. This technology is evolving rapidly and there is a steady flow of additional applications. By highlighting trailblazing businesses, this report aims to inspire leaders to tap into the opportunities of data and AI to unlock growth opportunities – and drive sustainability in a way that is also financially worthwhile.

C Sustainability – the longevity key for business

"The time to do sustainability reporting with a spreadsheet is over. Sustainability is a cross-functional discipline, and an opportunity to save costs and generate new revenue streams."[23]

The Corporate Sustainability Reporting Directive (CSRD) is elevating the nature of sustainability reports to make them increasingly comparable to financial reports. The world's largest and most comprehensive sustainability reporting standard, the CSRD is now mandatory for about 50,000 companies in Europe – as well as for global companies that conduct business in Europe.[24] Companies covered by the CSRD must significantly expand their sustainability reporting efforts to increase transparency and accountability. And that will increase costs, place extra demands on resources and require special expertise for reporting.[25]

The CSRD runs to more than 1,000 pages and requires more than 1,000 different data points, and is likely to change and evolve continuously.[26] Companies must also comply with further regulations such as the EU Taxonomy[27], the Sustainable Finance Disclosures Regulation (SFDR)[28], the German Act on Corporate Due Diligence Obligations in Supply Chains (Lieferkettensorgfaltspflichtengesetz, or LkSG)[29], the Corporate Sustainability Due Diligence Directive (CSDDD)[30] and the EU Regulation on Deforestation-Free Products (EUDR).[31]

Collecting such a vast range of data points from across a company and presenting them in line with so many regulations brings a high risk of human error. That risk is problematic because the CSRD is also audit-relevant.[32] Companies are liable for any errors in their sustainability reporting in the same way as they are liable for errors in financial reporting. That liability is accompanied by legal consequences that are determined locally in each member state.[33] Relevant companies that do not comply may be fined[34] by the regulator. In France, failure to comply with the CSRD can lead to up to five years in prison for executives. As outlined in the previous section of this report, businesses that fail to report in line with relevant standards may also face challenges with raising capital, and with gaining and retaining customers.[35]

Taken together, all this means that the time for doing sustainability reporting on an Excel spreadsheet is over. A better method is needed in order to move towards more reliable, audit-grade reporting. Business leaders face a clear choice: either they can decide to spend money doing the absolute minimum to avoid fines and risks related to allegations of greenwashing, or they can decide to view sustainability regulations as an opportunity to future-proof their organisations by becoming leaders in sustainable business transformation. This will strengthen their business operations and make them more resilient[36], while also increasing brand value[37] and making their business more attractive to talent.[38]

Data and AI offer opportunities to ensure reporting in line with increasingly strict regulations and reporting requirements, and can also help businesses to seize a leading role in sustainable business transformation. Essentially, sustainability is a cross-business function that touches every area of business – from Human Resource (HR) and Finance to Operations and Supply Chain Management. Those areas all generate data. Consolidating all of that data into a single source opens up possibilities to use AI as a powerful tool to boost efficiency, cut costs and explore profitable, sustainable new revenue streams that can future-proof the business.

Solid data is the foundation of AI. That foundation can be the key lever that connects risk management with business opportunities to enable a substantial synergetic impact. An organisation's data for sustainability compliance can become a tool for business growth by establishing the foundation to unlock AI-driven cost savings and business models that were previously impossible. In other words, data is the active ingredient that turns sustainability into a sustainable superpower for future-proofing businesses.

[23] Andreas Feiner, Partner at PwC Germany.
[24] European Parliament, 2022.
[25] Baumüller & Grbenic, 2021.
[26] Supplementing Directive 2013/34/EU (ESRS).
[27] EU Taxonomy.
[28] Sustainable Finance Disclosure Regulation (SFDR).
[29] Lieferkettensorgfaltspflichtengesetz (LkSG).
[30] Corporate Sustainability Due Diligence Directive (CSDDD).
[31] European Union Regulation on Deforestation-Free Products (EUDR).
[32] Directive (EU) 2022/2464.
[33] PwC, 2023(a).
[34] European Parliament, 2023(a).
[35] PwC, 2021(a).
[36] Eggert & Hartmann, 2022.
[37] El Zein et al., 2019.
[38] Handelsblatt, 2023.

D AI – the enabler

"AI won't replace humans – but humans who use AI will replace humans who are not using AI."[39]

Prominent computer scientist Dr Andrew Ng argues that AI represents a breakthrough for humanity comparable to the invention of electricity.[40] AI is able to mimic human intelligence based on inputs from data and can perform tasks that have always been in the exclusive domain of humans. Put simply, data and AI are fundamentally changing the way people live, work and interact with the world.

This technology is also capable of making a significant positive impact on environmental, social and governance (ESG) topics. AI has the potential to positively impact 93% of the United Nations Sustainable Development Goals (SDGs) that focus on the environment, as well as 82% of the SDGs that focus on social considerations. It achieves this by enhancing resource management, economic prosperity, societal well-being and sustainability.[41],[42]

Leaders who want to tap into the potential for AI to future-proof or turbo-boost their businesses[43] – even in today's challenging economic environment[44] – are taking a close look at this technology. There is never a perfect time to get started with a transformation journey led by data and AI. But companies that never get started will miss out on the lasting benefits for managing risk and unlocking profitable, sustainable business growth.

In this report, the term "AI" is used in a broad sense that covers three key applications: machine learning, deep learning and generative AI. This simplification aims to establish a helpful common language. Readers who are interested in definitions of the three specific technologies behind this simplified term can find them here:

- Machine learning (ML) involves training AI models to learn from data. ML can analyse large amounts of data and identify patterns that can then be used to make predictions or decisions. For instance, ML is used in agriculture to analyse data from satellite imagery to help farmers optimise crop yields while minimising the use of resources such as water and fertilisers.[45]
- Deep learning (DL) is a subset of ML that uses complex data and requires more data to train. In the energy sector, DL algorithms help maintain the performance of renewable power systems.[46] For example, DL is used to optimise the productivity of wind turbines by learning the air movement patterns in a specific location and adjusting the angle of the turbine blades to maximise power generation from every turbine – even in crowded wind farms where oncoming wind streams do not reach all turbines equally.[47]
- Generative AI (GenAI) is a subset of DL that analyses data and recognises patterns, and then generates new output such as text, photos, videos, code and data.[48]

  GenAI may also be able to offer faster and more accurate insights[49] or prompts than typical data analytics. Technology companies such as Microsoft are using GenAI to power solutions such as Copilot[50] that assist humans to enable more efficient, productive ways of working – such as drafting an offer to a customer and then prompting users with possible improvements. Outputs from GenAI need to be validated and reviewed by humans.

[39] Harvard Business Review, 2023.
[40] Lynch, 2017.
[41] The 17 Goals.
[42] Vinuesa et al., 2020.
[43] Sipola et al., 2023.
[44] World Economic Forum, 2023.
[45] Stridely Solutions, [no date].
[46] Fan et al., 2023.
[47] Microsoft, 2021.
[48] Microsoft, 2023(a).

The graphic below illustrates some of the various uses of these three AI applications. In practice, these uses often combine a variety of AI technologies to gain the best possible outcome. However, all uses of AI require unified data as a foundation – as well as humans to verify and check all outputs – in order to unlock the full potential of AI to support profitable and sustainable business growth.

Fig. 2 Types of AI and their areas of application

[49] Datascience Central, 2023.
[50] Microsoft, 2023(c).

E Solid foundations: there is no AI without data

"Data is the foundation on which AI operates, shaping its insights, predictions and decision-making capabilities."[51]

Research shows that sustainability measures not only have a positive impact on effective risk management; they can also be a significant driver of new value creation, reducing operating costs[52],[53] and lowering the cost of equity capital.[54] However, most research focuses on the financial benefits of sustainability in isolation, without considering the additional financial benefits of integrating data from other areas such as HR, Finance, Supply Chain, Sales or R&D into sustainability management. These areas often operate their own separate data systems and sources. Bringing together data from every area of an organisation establishes a powerful foundation that can make it easier to comply with increasingly strict regulations and reporting requirements for sustainability – while also opening up opportunities to cut costs and unlock profitable, sustainable new revenue streams.

In this context, business leaders can seize a valuable competitive advantage by rethinking their company's data estate. Fragmented data is a major obstacle that disrupts efforts to achieve sustainability compliance and leverage business growth opportunities related to sustainability. Leaders can remove that obstacle by driving efforts to break down data silos, unify various data sources and combine existing data systems across an organisation. This can turn data into a valuable strategic asset for organisations seeking to boost risk management and business growth.

Transforming a business's data estate requires skills and processes such as data literacy and a data-driven mindset among employees, as well as aligned organisational structures that support effective data management.[55] To successfully establish solid data foundations to enable AI-driven growth from sustainable new business models, organisations need to address several topics and considerations.

Research by Microsoft and insights from PwC's Enterprise Data Management Framework[56] point to five key aspects that must be mastered to achieve this data-centric business transformation.

[51] Luers et al., 2023.
[52] Bello, 2020.
[53] Javaid et al., 2022.
[54] Chen et al., 2023.
[55] PwC, 2022.
[56] PwC, 2021(b).

1 Data and AI operating models

Companies need well-defined operating models that embed sustainability governance across different business functions and their respective data domains. This might involve a decentralised governance structure that emphasises data collection and analysis in each area of the organisation, such as a data mesh[57] paradigm. This approach distributes data engineers and analysts across the organisation, then empowers them to make self-service use of the data platform. This decentralised setup promotes a culture of data democratisation and fosters agility, scalability and collaboration across the organisation. International furniture company IKEA, for example, has collaborated with PwC to introduce a data mesh concept that is moving the company towards its goal of achieving democratised data and analytics. This approach is a good fit for IKEA because it operates a franchise business that gives rise to a highly federated structure, with deep-set entrepreneurial spirit across the organisation.[58]

Overall, businesses that want to maximise the positive impact of AI for profitable and sustainable business growth must focus on unlocking the potential of all data within the organisation – starting with the data that has the widest range of possible uses and reuses, such as energy consumption data.

2 Data and AI tech architecture

It is essential to replace on-site storage of data with cloud storage in order to unlock the power of AI. Cloud-based data platforms create a strong foundation for integrating data from various sources and systems. They also facilitate the exchange of data, which helps to make data available for analytics and AI. Cloud-based solutions offer scalability, flexibility and cost-effectiveness. This enables organisations to process and analyse vast amounts of data.[59]

One report from Microsoft found that migrating data to the cloud can decrease power consumption and related CO_2 emissions by up to 98%.[60] In addition, adopting industry-standard data models makes it possible to integrate data feeds from third parties by ensuring a common approach to data exchange, interpretation and collaboration across organisations. This is a key success factor in assessing a company's overall sustainability performance based on metrics such as CO_2 emissions. It also ensures a comprehensive and up-to-date understanding of the factors that influence sustainability.

3 Data and AI governance

Establishing a robust data foundation is a critical success factor for achieving high quality and reliability that enables the effective use of sustainability data for analytics or AI. Solid policies and processes for data governance can ensure the integrity, accuracy and transparency of that data.

4 Data security and privacy

Organisations use data that is subject to data protection regulations such as the EU's General Data Protection Regulation (GDPR).[61] For this reason, it is essential to maintain public trust by ensuring responsible use of data. Effective data security and privacy mechanisms rely on robust security measures and encryption protocols that protect sensitive information.

5 People and culture

Individuals, teams and organisational cultures play a crucial role in establishing a data-centric organisation. People must be given necessary skills as their jobs evolve. Campaigns to raise awareness can emphasise the importance of data for driving sustainability and business growth, while also promoting the effective use of available data and tools.

[57] Github, [no date].
[58] PwC, 2022.
[59] Microsoft, 2023(b).
[60] Microsoft, 2018.
[61] General Data Protection Regulation (GDPR).

Overall, the five key aspects described above are key to enabling data-driven, sustainable and profitable business transformation. In particular, they can help businesses to overcome the obstacle of “garbage in, garbage out”. This is a common challenge experienced by companies across industries. It refers to the difficulty of consolidating data from various sources and systems while still ensuring accuracy.[62] This is especially important in the context of the increasingly strict regulations and reporting requirements discussed earlier in this report.

Solid data foundations and AI can help support the collection, unification and analysis of vast amounts of data in one place – and they can provide that support in real time. This might involve automatic prompts that flag gaps or anomalies. It could also include turning data into actionable forecasts that empower sustainability professionals to make better decisions in the light of growing and increasingly complex reporting demands by streamlining the administrative workload generated by the CSRD, the TCFD and the EU Taxonomy. This empowers businesses to strengthen their brand reputation and protect share prices in the light of growing sustainability-related demands made by stakeholders including shareholders, investors, customers and consumers.

Constructing an effective data strategy is not necessarily a daunting task. Companies can start by taking small steps. This might involve selecting the most urgent or material sustainability use case, and then cleaning the relevant data for that specific topic. Companies can then use the experience gained from this process to shape their broader data strategy and scale it more quickly.[63]

In this way, businesses can gain a first-mover advantage by embracing the power of data and AI to streamline their sustainability reporting activities. And they can also leverage that same data from within a consolidated setup to tap into new opportunities to drive progress in sustainability that is truly worthwhile in terms of profitable business growth.

[62] Saxena et al., 2022.
[63] English, 2023.

F Turbocharging sustainability

"AI and its offshoot, machine learning, will be a foundational tool for creating social good as well as business success."[64]

This report opened with the observation that, within a challenging economic environment, sustainability programmes risk being scrapped if they do not offer a positive business case. The research in this report demonstrates that data and AI have the potential to enable programmes to meet those two expectations. With AI, it is possible to find new business models that contribute to sustainability goals and also have a positive commercial impact by unlocking cost savings and profitable growth. Asstated, this two-pronged positive impact of AI requires a solid data foundation.

The following chapter will present sections that focus on each of the five most carbon-intensive industry sectors. Each section will begin with a short summary of the industry's key challenges and opportunities. It will then feature three or more examples of businesses that are using data and AI to achieve profitable and sustainable outcomes, with at least one direct interview with a leading figure from one of these trailblazing businesses.

Our analysis of the energy sector is divided into the three sub-units that make up the bulk of emissions: electricity and heat, transportation, and manufacturing and construction. This is because the energy sector is the largest emitter, generating more than 75% of global CO_2 emissions (37.5Gt per year).

1 Energy in Electricity and Heat

"The energy transition must be swift and coordinated; digitalisation is needed as an enabler."[65]

Sector overview: what do leaders need to know?
Energy in Electricity and Heat generates more than 30% of global CO_2e emissions every year (15Gt).[66] The substantial carbon footprint of this sector means it is essential to transition to renewable energy sources for electricity and heat if the world is going to achieve global targets for net zero.[67] Currently, wind and solar make up 12% of the global energy mix.[68] However, the IEA states that the proportion of solar and wind energy must increase to nearly 70% by 2050 in order to achieve net zero.[69]

AI is already used in a wide range of applications in this sector and is delivering benefits in various areas[70,71], including supporting energy forecasts.[72] One recent case study showed that using AI to analyse real-time wind data and turbine performance enabled a 20% increase in energy output from wind farms.[73] This is equivalent to an additional 425 terawatt-hours (TWh) of renewable energy[74] (based on figures for generation in 2022).

A multibillion-dollar opportunity

- Using data and AI for renewable energy could create an additional 425 TWh of energy.[75]
- This would replace traditional energy sources that generate 475g of CO_2 per kilowatt-hour (kWh).[76]
- 425TWh x 475g of CO_2 per kWh would save around 200 million tonnes of CO_2 emissions.
- Selling 425TWh of renewable energy at €0.15 per kWh[77] (European average) could generate approximately €60 billion of additional revenue.

64 Mark V. Hurd (former CEO of Oracle).
65 World Economic Forum, 2021(b).
66 World Resources Institute, 2020.
67 World Economic Forum, 2021(a).
68 Enerdata, 2023.
69 IEA, 2021.
70 Stanford Report, 2018.
71 IEA, 2023(a).
72 Enel, 2023.
73 Data Dynamics, 2023.
74 IEA, 2023(b).
75 Data Dynamics, 2023.
76 IEA, 2019.
77 Eurostat, 2023.

Sector examples: how are companies using AI for sustainability and business success?

Vestas, a company that manufactures and manages wind turbines, is successfully using AI to maximise energy yield. Data is used to run simulations and generate insights. Those insights train AI to make the best possible use of wind conditions and capture more energy.[78] This helps to mitigate challenges related to variations in weather conditions. Wind turbines also face challenges connected to the "shadow effect", which occurs when turbines at the front of a wind farm block or slow down the flow of air to the turbines at the back of the wind farm. In this way, data and AI are supporting energy companies with maximising the amount of power they generate and can sell for revenue, while also supporting the transition to renewable energy and a net-zero future.[79]

Alfa Laval, a company that manufactures plate heat exchangers, is developing AI solutions to reduce CO_2 emissions while also cutting costs. Its products play a key role in cooling and heating within industrial processes – and in people's homes. The company has partnered with Microsoft to create a thermal detection function that can be added to the camera app on a typical mobile phone. Service engineers or customers can upload a photograph of a heat exchanger. The AI is then able to calculate the optimal performance of the heat exchanger based on that image by identifying discrepancies in heat transfer. It then suggests appropriate measures[80] that save costs and resources by eliminating replacements of components that are still delivering optimal performance. This also boosts energy efficiency and cuts related emissions by increasing the performance of the heat exchanger throughout its working life.

Northvolt, a company that manufactures batteries, is using AI to optimise its profitability and sustainability around energy storage for electric cars. The company collects more than 10,000 data points from its supply chain and uses that data to fuel its AI tools. Specifically, it uses AI to create digital blueprints and digital twins of its manufacturing sites. This saves considerable amounts of resources in the company's process control and quality control activities. Initial estimates show potential to cut a 22-day production cycle down to less than one day thanks to AI. In addition, this use of data and AI allows Northvolt to optimise yields, predict failures and accurately predict the quality of its batteries. This reduces production costs by saving energy and decreasing the need for employee involvement. As a result, the company is able to produce batteries that support the transition to carbon-free mobility while also saving money and boosting the quality of its products.

Beyond these specific cases, there are several further opportunities for data and AI to help save power, reduce CO_2 emissions and open up attractive business opportunities for Energy in Electricity and Heat. Cooling in buildings is one energy-intensive example where power consumption is continuing to rise.[81] AI can be used to create thermal models that predict room temperatures and initiate pre-cooling measures to decrease energy consumption by up to 30%.[82]

A multibillion-dollar opportunity

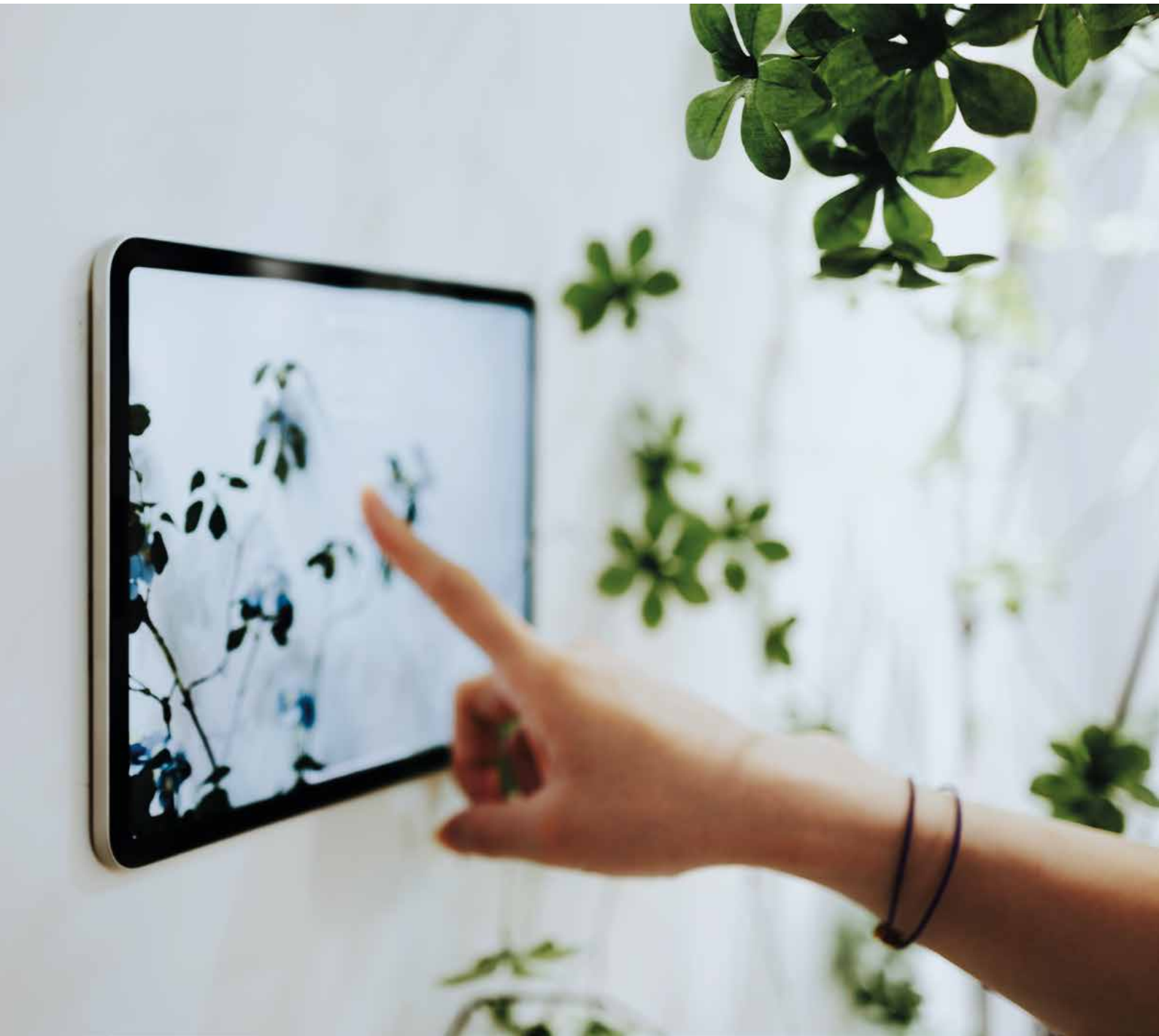
- Using data and AI for cooling buildings could reduce energy consumption by 30%.[83]
- Globally, cooling buildings generates 1Gt of CO_2 emissions per year.[84]
- 30% of 1Gt would be a saving of around 300 million tonnes of CO_2 emissions per year.
- Globally, cooling buildings is predicted to require 7 exajoules (EJ) of energy per year by 2030.[85]
- 30% of 7EJ would be a saving of around 600 billion kWh per year.
- At a unit cost of €0.15 per kWh[86], this would save around €90 billion.

[78] Microsoft, 2022(a).
[79] Microsoft, 2023(d).
[80] Microsoft & Alfa Laval, 2022.
[81] Andreou et al., 2020.
[82] Lee & Lee, 2023.
[83] Andreou et al., 2020.
[84] IEA, 2023(f).
[85] Lee & Lee, 2023.
[86] Eurostat, 2023.

Sector summary: what are the key takeaways?
The Energy in Electricity and Heat sector makes a significant contribution to global CO_2 emissions. There is a clear need for a transition to renewable energy and AI can play a vital role in that transition. Vestas is already successfully applying AI to optimise yields from wind turbines, Alfa Laval is collaborating with Microsoft to leverage AI for reducing emissions from cooling buildings, and Northvolt is taking advantage of AI to boost resource efficiency and quality for electric vehicle batteries. These examples demonstrate the potential for data and AI to accelerate the transition to sustainable energy practices – while at the same time opening up attractive opportunities for business growth.

Tab. 2 Summary of data and AI applications for Energy in Electricity and Heat

Use case	Data used	Applications of AI
Energy in Electricity and Heat	• Energy generation data (wind and solar) • Weather data • Real-time operational data from production sites • Electricity market data • Measurement data from buildings	• Energy forecasts using ML in the area of energy prices, energy supply and demand • Increased efficiency through optimisation of energy production • Optimisation of processes and data analyses in the production of energy systems, intelligent power grids, demand response management, predictive maintenance, energy storage, smart homes and buildings, monitoring of production facilities and exploration energy resources



Alfa Laval | WRI segment: Energy in Electricity and Heat

Alfa Laval is a Swedish company that is a global leader in providing heat transfer, separation and fluid handling products. It has more than 20,000 employees worldwide, with subsidiaries in over 100 countries.

Interviewee

Anna Celsing
Chief Sustainability Officer, Alfa Laval

> "Through the power of data and AI, we unlock higher and longer quality of service for our products – which saves money for our customers and reduces carbon emissions."

What products does Alfa Laval offer to its customers?
Anna: Our product portfolio ranges from heat exchangers through to pumps. We're able to serve a wide variety of our customers' needs and wishes. As an example is heat transfer very relevant for customers today. By recycling heat, our heat exchangers can optimise a customer's energy consumption and ensure the right temperature for each individual step in their production process.

What problem does your company solve?
Anna: Heat exchangers are a vital part of most heating and cooling processes, especially in industrial applications. Our customers need heat exchangers that offer optimal levels of consistency and efficiency because that enables them to plan more effectively and reduce unexpected costs. By constantly improving our technologies, we're able to produce heat exchangers that are 50% more efficient than conventional shell-and-tube exchangers. This efficiency boost gives our customers cheaper and more stable heating solutions. And it also saves enough power to heat 10 million homes in Europe each year.

What role does AI play in your products?
Anna: It's very important to achieve steady and reliable performance from our heat exchangers over many years – because our products have a long life span. AI helps us make that happen. In cooperation with Microsoft, we have partnered to develop tools that enable customers to make self-assessments and to identify any necessary maintenance services. Special software that works on a typical mobile phone adds a thermal recognition function to the device's camera. Our customers or service engineers simply upload a picture of the heat exchanger. Our AI is then able to calculate the optimal performance based on the image. That eliminates replacements of components that are still delivering optimal performance, while also increasing functionality and performance in general. That makes it possible to maximise the efficiency of the heat exchanger throughout its extended lifespan.

So you are basically solving two problems at the same time, right?
Anna: Yes! Through the power of data and AI, we unlock higher and longer quality of service for our products – which saves money for our customers and reduces carbon emissions. It also increases profits for us and our customers. The reduction in carbon emissions is related to using less energy. Approximately 2.5% of total CO_2e emissions worldwide are due to non-optimal heat exchanger maintenance (1.245 Gt CO_2e). So using AI has massive potential to cut emissions, while also increasing product performance, extending optimal functionality for longer and reducing costs.

What's your outlook for the future within the context of data and AI for sustainable business success?
Anna: Our AI-augmented digital maintenance approach is only the first of many data and AI applications that will boost sustainability and open up new business opportunities. This technology is evolving rapidly, so it's essential to learn how to utilise its potential and take action right now. Our first experiences of using AI applications have shown that we can generate value from seemingly basic data sources. Compiling maintenance data directly gives us unique insights into how our products perform after initial installation. This helps our product development teams to remain at the technological cutting-edge. And it also provides a solid foundation for a smart approach to data, which will help us find applications for AI that support sustainability and business success in the future.

2 Energy in Transportation

> "The answer to global transportation challenges is not less transport – it is sustainable transport."[87]

Sector overview: what do leaders need to know?
Energy in Transportation generates 14% of global CO_2e emissions per year (around 7Gt CO_2e).[88] The main cause of emissions in transport is burning fossil fuels.[89] However, it is not realistic to reduce emissions by simply transporting fewer people and less goods – especially in today's interconnected world of global trade. Instead, transitioning to cleaner sources of energy and reducing energy consumption are the way forward.[90],[91]

Sector examples: how are companies using AI for sustainability and business success?
Stena Line, a shipping company, uses AI to empower its crews to save fuel and reduce CO_2 emissions. The company achieves this by combining nautical expertise from its staff with data about currents, waves, ocean depth and wind conditions, as well as the ship's characteristics and route schedule. This AI assistance makes it possible to reduce fuel consumption by between 2% and 5%.[92]

A multibillion-dollar opportunity

- Using data and AI in shipping can reduce fuel consumption by up to 5%.
- Globally, shipping generates 890 million tonnes of CO_2 emissions per year.[93]
- 5% of 890 million tonnes would be a saving of around 44 million tonnes of CO_2 emissions per year.
- Globally, shipping required 9EJ of energy in 2022.[94]
- At a unit cost of €0.15 per kWh[95], this would cost €400 billion.
- 5% of €400 billion would be a cost saving of €20 billion.

AI also has the potential to reduce emissions and increase economic value in air transport, which is particularly challenging to decarbonise.[96],[97] SITA, a company that provides IT and telecommunications services to the air transport industry, has launched AI-powered software called OptiFlight[98], which is able to optimise route navigation and flight patterns in commercial flights.[99] OptiFlight enabled Air Asia to reduce fuel consumption by 0.75%.[100]

A multibillion-dollar opportunity

- Using data and AI for air transport can reduce fuel consumption by 0.75%.
- Globally, the air transport industry uses 356 billion litres[101] of kerosene per year.
- Consuming 1 litre of kerosene generates 2.5kg of CO_2 emissions.[102]
- 356 billion litres of kerosene x 2.5kg of emissions = 890 billion kg of CO_2 emissions.
- 0.75% of 890 billion kg would be a saving of around 6 million tonnes of CO_2 emissions per year.
- At a unit cost of €0.95 per litre of kerosene, this would save €2 billion per year.

Charging infrastructure for electric vehicles (EVs) is another application where AI is helping to analyse charging station load and enable dynamic pricing models.[103] ABB has developed an AI-based dynamic pricing model for EV charging that flexibly responds to changing grid conditions. Charging prices adapt based on grid conditions to balance supply and load, thereby enhancing grid stability. In simulated trials, the AI was able to reduce grid variations while lowering charging costs for EV users. ABB now plans to implement this in demos for further testing.[104] By enabling progress towards a power grid that is capable of handling increasing demand from EVs, this optimisation of charging infrastructure would support the transition to EVs as an emissions-free alternative to vehicles with combustion engines, while also cutting costs and boosting profitability for businesses in this growing sector.

87 Ban Ki-moon, former Secretary-General of the United Nations.
88 World Resources Institute, 2020.
89 Solaymani, 2021.
90 Anable et al., 2012.
91 Li & Loo, 2014.
92 Stena Line, 2019.
93 World Resources Institute, 2020.
94 IEA, 2023(c).
95 IEA, 2023(f).
96 ICCT, 2023.
97 Filmanovic, 2023.
98 United Nations, [no date].
99 Voit, 2021.
100 AirAsia, 2022.
101 BAZL, 2020.
102 AirAsia, 2022.
103 Elmelin, 2023.
104 Suryanarayana et al., 2023.

Sector summary: what are the key takeaways?
AI can play a substantial positive role in cutting CO_2 emissions and opening up opportunities for business growth in the Energy in Transportation sector. Stena Line uses AI to achieve significant fuel savings in shipping, SITA is providing AI-based software that optimises route navigation in commercial flights to cut fuel consumption and related emissions, and ABB is exploring the potential for AI to support the future stability of the power grid as EVs gain popularity. These examples show how data and AI can cut the environmental impact of the transport industry – while creating pathways to profitable and sustainable new business models.

Tab. 3 Summary of data and AI applications for Energy in Transportation

Use case	Data used	Applications of AI
Energy in Transportation	• Real-time traffic data • Machine data, e.g. power and energy consumption data • Nautical data in the shipping sector • General logistics data	• ML algorithms analyse real-time data and dynamically optimise freight routes. • Analysis enables efficient decision-making in the air transport sector. • Analysing and adapting charging infrastructure locations and implementing dynamic pricing models for charging stations.

3 Energy in Manufacturing and Construction

> "Energy is essential for development, and sustainable energy is essential for sustainable development."[105]

Sector overview: what do leaders need to know?
Energy in Manufacturing and Construction accounts for 12% of global CO_2e emissions (around 6Gt CO_2e).[106] Such a carbon-intensive industry presents challenges related to balancing innovation for decarbonisation with the need to ensure profitability and competitiveness.[107],[108]

Data and AI offer opportunities to achieve this delicate balancing act. These technologies can optimise manufacturing and construction operations by helping to implement data-driven, smart processes at every stage in the value chain. They can also support efforts to streamline data collection and analysis with suppliers across complex global supply chains to enable compliance with increasingly strict regulations and reporting requirements related to sustainability, while also combining that data with various other data from across the business – and then leveraging it to drive cost-cutting, boost profitability and enable more sustainable new business models.

Sector examples: how are companies using AI for sustainability and business success?
Outokumpu, a stainless steel producer, uses data from the machines in its largest factory in Finland to drive AI tools that optimise its manufacturing processes. These tools have reduced the company's energy use by 10% and increased factory output by 4%. Alongside those cost savings and productivity improvements, AI has also reduced the related CO_2 emissions by saving energy and speeding up operations.[109]

These sustainable and profitable successes in the stainless steel industry are notable because the production of iron and steel accounts for 6% of global emissions.[110] Businesses at every stage in the value chain for iron and steel are pursuing ambitious sustainability goals, while customer demand for "green steel" is rising. Against this backdrop, companies in this sector that successfully transition to more sustainable manufacturing processes can gain a valuable competitive advantage. Data and AI can assist with optimising raw material needs and energy consumption, as well as by shortening processes. It is estimated that AI could save 40 million tonnes of CO_2e globally[111],[112]; for example, from the production of steel with electric arc furnaces (EAFs).

In other industries, smart factories are using data and AI to boost the efficiency, flexibility and resilience of manufacturing processes. ZF Friedrichshafen, an automotive supplier, has implemented a high-tech smart factory that is now leveraging data and AI to increase planning efficiency, while also coordinating maintenance work and enabling more resource-efficient manufacturing processes.[113] This use of AI enables the company to reduce costs, cut waste, boost process efficiency and decrease CO_2 emissions.

Predictive maintenance is one key element of this smart factory. Maintaining machinery is time-consuming and expensive. Using data and AI makes it possible to forecast when machinery is likely to fail, while also detecting signs of potential failures before they happen. This reduces downtime and makes production processes more reliable. It can also increase productivity and decrease costs, which makes a valuable positive contribution to profitability. A report by PwC states that predictive maintenance can help improve machine uptime by 9%, reduce costs by 12% and extend the life of ageing equipment by 20%.[114]

Augury, a technology company, uses AI-supported hardware – such as sensors and cameras – to monitor manufacturing processes and machinery. In some use cases, its AI solutions have reduced waste from defects and downtime by up to 37%, while decreasing emissions from rotating machinery by 12%. This supports progress on sustainability and on the company's production targets.[115]

A multibillion-dollar opportunity

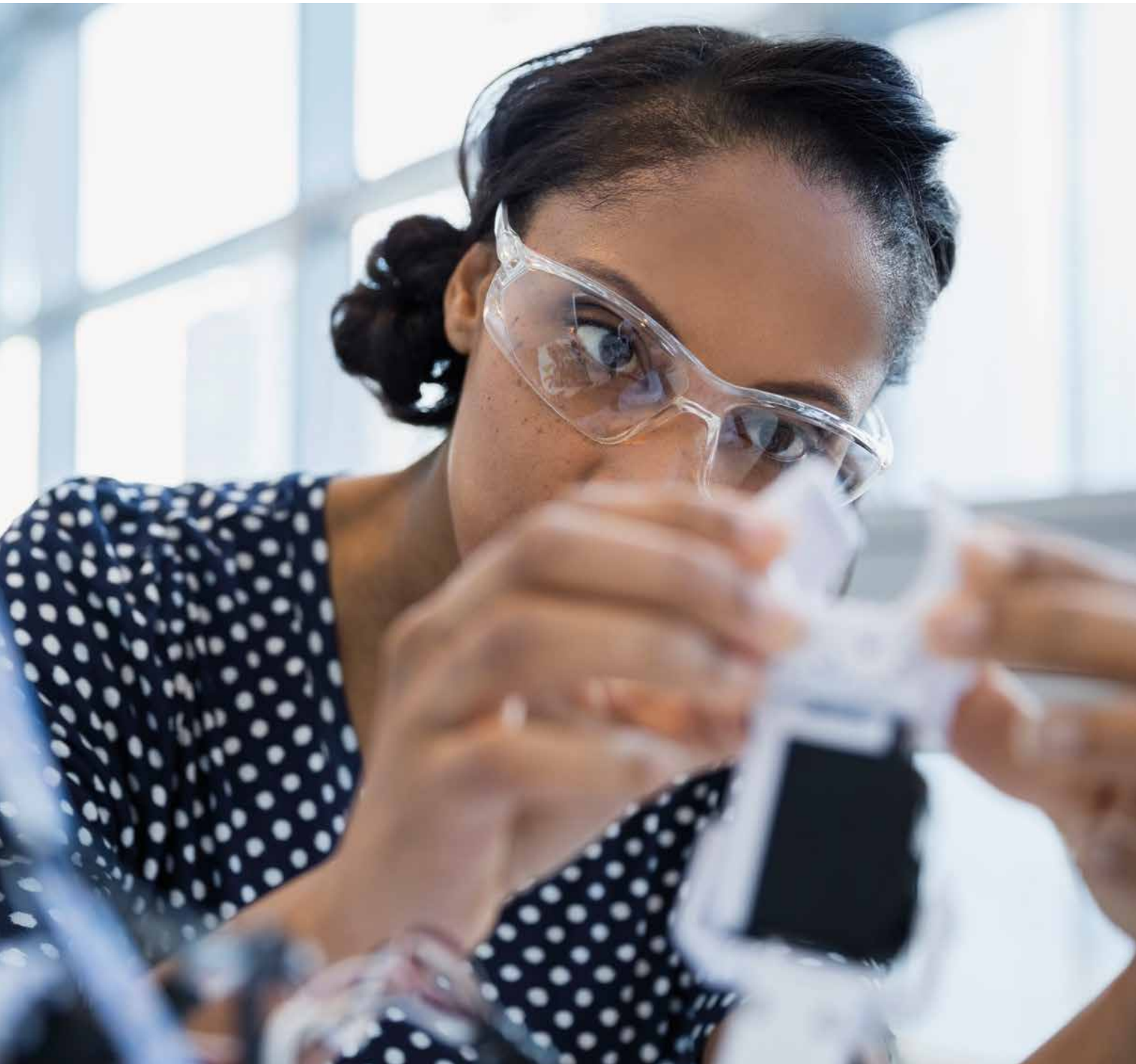
- Using data and AI in factories has the potential to reduce power consumption by 20%.[116]
- Globally, energy for manufacturing (excluding construction) generates 6Gt CO_2e emissions per year.
- 20% of 6Gt would be a saving of around 1Gt of CO_2e emissions per year.
- Globally, manufacturing required 37EJ of electricity in 2022[117].
- 20% of 37EJ would be a saving of around 7.4EJ of electricity per year.
- At a unit cost of €0.15 per kWh[118], this would save €330 billion.

[105] Tim Wirth, former US Senator.
[106] World Resources Institute, 2020.
[107] Lin & Wang, 2015.
[108] Dechezleprêtre & Sato, 2017.
[109] Peltonen, 2023.
[110] World Resources Institute, 2020.
[111] Smart Steel, 2023.
[112] Fero Labs, 2023.
[113] ZF, 2021.
[114] PwC, 2018.
[115] Augury, 2023.
[116] Lee et al., 2022.
[117] IEA, 2023(g).
[118] Eurostat, 2023.

Sector summary: what are the key takeaways?
Data and AI can make a valuable contribution to decreasing CO_2 emissions in the Energy in Manufacturing and Construction sector while also cutting costs and enabling profitable new business models. Stainless steel producer Outokumpu has successfully reduced its energy consumption and emissions with the help of AI, ZF Friedrichshafen is using data-driven solutions to achieve cost savings and increased efficiency in its smart factory, and Augury is demonstrating how AI tools can reduce waste, downtime and emissions while also improving production efficiency. Beyond these three examples, there is substantial further potential to achieve progress in sustainability and business growth along the entire value chain for these sectors – from product design and raw material sourcing through to logistics, use and disposal.

Tab. 4 Summary of data and AI applications for Energy in Manufacturing and Construction

Use case	Data used	Applications of AI
Energy in Manufacturing and Construction	• Operational data • IoT data from processes • Product demand data • Energy demand data	• Predictive maintenance • Process optimisation • Optimisation of resource utilisation • Smart factory applications • Process analysis using ML to optimise production processes



Outokumpu | WRI segment: Energy in Manufacturing

Outokumpu is the global leader in sustainable stainless steel. With approximately 8,500 employees in almost 30 countries around the world, the Finnish company is a force for positive impact to accelerate the green transition across industries.

Interviewee

Heidi Peltonen
Vice President, Sustainability, Outokumpu

> "At Outokumpu, we have taken transparency in sustainability to the next level by becoming the first stainless steel producer to provide a product-specific carbon footprint. This data, based on continuous production data and accurate emission factors including the value chain emissions, is part of our commitment to helping our customers to reduce their climate emissions."[119]

Interviewee

Kristiina Tiilas
Vice President, IT Europe, Outokumpu

> "No AI will magically solve fundamental business problems. But where data, operations and strategy are already good, AI stands to make them better."[120]

There's a lot of pressure in the market related to sustainability topics and demand for greener products. How is Outokumpu addressing this?
Heidi: We have a dual role – on one hand, steel industry accounts to 7–9 % of global greenhouse gas emissions. At the same time, our role in the value chain means we are able to support customers to reduce carbon emissions by over 12 million tonnes annually with the lowest carbon footprint in the industry. This has motivated us to set even more ambitious climate targets. Our Science-Based Targets initiative SBTi-approved target across the value chain is aligned with the 1.5°C scenario. We are joining forces with suppliers and science to innovate on the path towards reaching net zero. Of course, this goes hand-in-hand with strategic investments and a transformation of our business.

How exactly are you pursuing this business opportunity?
Heidi: We have taken various measures to reach our ambitious climate target – with data and AI playing a key role in the journey. The starting point is tracking material data. This enables a deeper understanding of the carbon footprint across our value chain. We then use these insights to optimise our production, and to report the impact of our products all the way to the customers. In addition, we are integrating various operational data from factories and supply chains into a standardised data platforms. Providing access to all data from centralized platforms creates an important basis for data analytics and further actions, including the use of AI. Our production processes are now more efficient and generate less waste, which enables cost savings and reduces CO_2 emissions.

How can data and AI accelerate sustainability and drive business growth?
Kristiina: AI has been used within stainless-steel production processes for many years. It provides substantial value through applications such as predictive maintenance and prevention of equipment failure. At Outokumpu, we also use various ML applications for time-series forecasting and streaming analytics. Through AI-supported analysis of machine operating data, we were able to reduce energy consumption by 10% and increase efficiency by 4% in our factories.

[119] Business Finland, 2023.
[120] Kristiina Tiilas, Vice President, IT Europe, Outokumpu

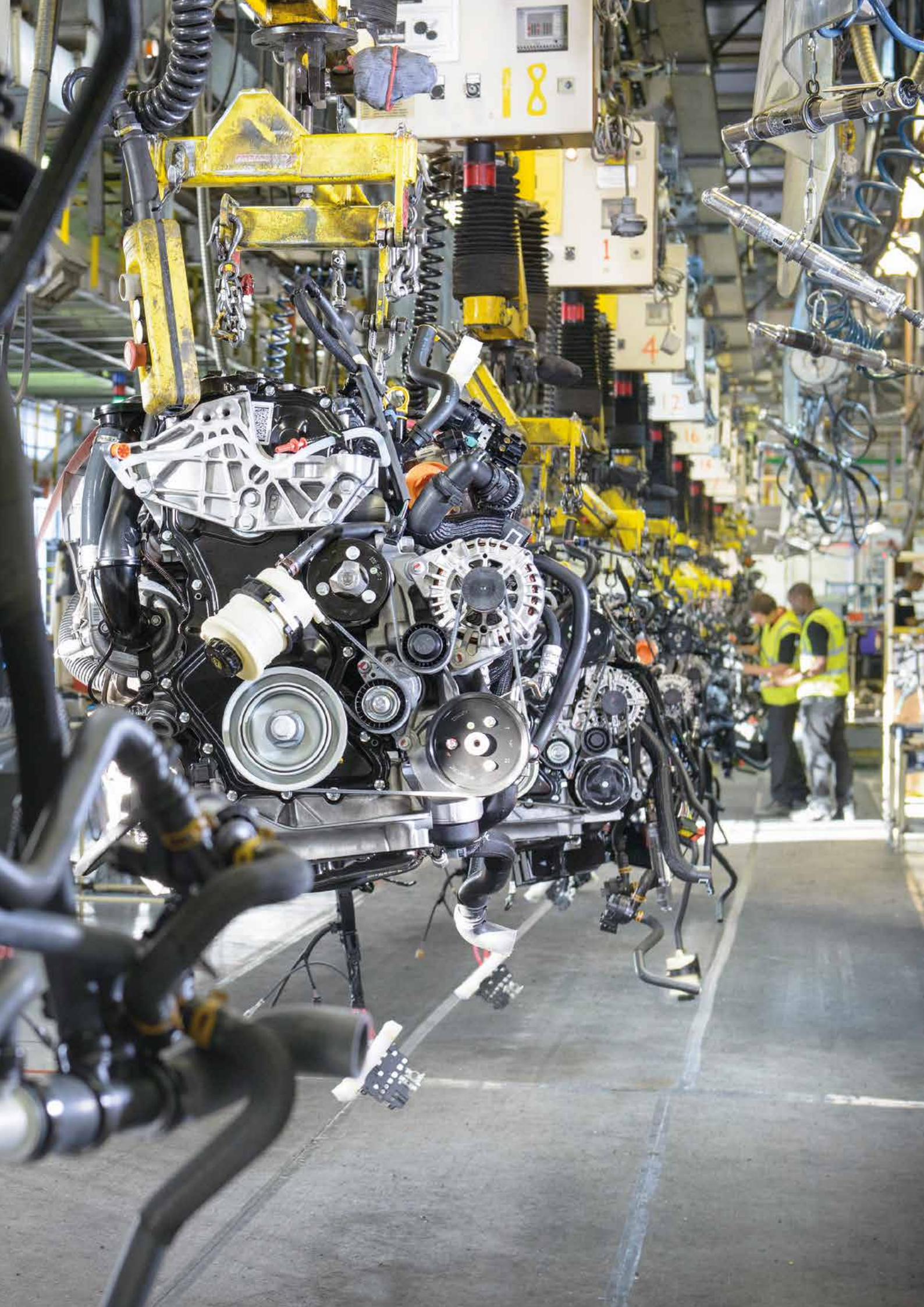
Is Outokumpu also using data and AI in other areas?
Kristiina: We have found that a robust data foundation and the use of AI algorithms can optimise the material mix of our steel. This helps us enable more sustainable production processes, while also improving financial performance and strengthening our competitive advantage. AI also enables us to optimise heating times in walking beam furnaces, shortening the heating times by up to 4% and increasing capacity by 17%. These enhancements have been reducing our carbon emissions by approximately 6,000 tonnes. Other types of AI, including computer vision, also play a part. But today, GenAI is leading to a fundamental paradigm shift.

How exactly is GenAI leading to a paradigm shift for Outokumpu?
Kristiina: As a stainlesssteel producer, we are responsible for creating a great product – while also reducing its climate impact, ensuring long-term business excellence, continuously engaging with stakeholders and maintaining a maximised competitive advantage. GenAI is creating countless new possibilities for all these responsibilities. We are now testing GenAI in many fields, like building internal chatbots for sales persons or operators enabling them to improve the efficiency with new AI capabilities. On top of this, we are using AI for topics like workplace safety, training and skill development, recruitment and employee wellbeing, marketing, customer service, communications and more. Of course, we always consider the ethical and legal aspects of using GenAI. Our teams maintain up-to-date awareness about shifting industry and regulatory standards.

What will be important in stainless steel production going forward?
Heidi: The surge in the global population will lead to rising energy demand and urbanisation, with a direct effect on the need for steel. This is a very energy-intensive and resource-intensive industry. And the future of the green transition – from renewable energy to hydrogen or electric vehicles – is all dependent on sustainable stainless steel.

What's the future for data and AI at your company?
Heidi: We are already halfway towards our target of reducing emission intensity by 42% by 2030. We use over 95% renewable electricity, while more than 90% of the materials used in our production processes are recycled. By embracing circularity, we have minimised the use of virgin materials – which reduces carbon emissions and mitigates biodiversity loss. Now, Outokumpu is committed to continuing its journey.

Kristiina: No AI will magically solve fundamental business problems. But where data, operations and strategy are already good, AI stands to make them better. There are almost no limits to how AI can be used in R&D, for example. AI has the potential to support us with identifying new ways of creating and combining materials, while reducing the carbon footprint or revolutionising processes. As these possibilities emerge, however, we have to be mindful of AI's own footprint and use it responsibly.



ZF | WRI segment: Energy in Manufacturing

ZF is a global technology company supplying advanced mobility products and systems for passenger cars, commercial vehicles, and industrial technology. Its comprehensive product range is primarily aimed at vehicle manufacturers, mobility providers, and startup companies in the fields of transportation and mobility. ZF electrifies a wide range of vehicle types. With its products, the company contributes to reducing emissions, protecting the climate, as well as enhancing safe mobility. Alongside the automotive sector – passenger cars and commercial vehicles – ZF also serves market segments such as construction and agricultural machinery, wind power, marine propulsion, rail drives, and test systems.

With some 168,700 employees worldwide, ZF reported sales of €46.6 billion in fiscal 2023. The company operates 162 production locations in 31 countries.

Interviewee

Dr René Deist
Chief Digital Officer

> "Achieving sustainability goals is both, an important and a tough task. Especially the complexity in our network of connected Supply Chains needs to be well understood. Generative AI offers a promising approach."

What does ZF offer that its competitors cannot match?
René: We're able to provide solutions for each customer's unique needs – because of our experience and our comprehensive product portfolio for mobility providers and manufacturers. Over time, we've perfected our products for each sector. The German automotive sector is highly competitive, and this has driven our company's development. Today, we're in a unique position to create mobility solutions for the ongoing transformation in the transportation industry. In other words, ZF is right in the center of the mobility transformation.

What role does AI play in this process?
René: ZF is always driven to improve. We see AI as a way to reduce the complex interplay in our industry – such as modern, industry 4.0 based production processes, the push for sustainability and the rise of electric vehicles. We evaluated data-driven and AI-based applications for our business before most other players in our market. From our first deep dive project into Generative AI in, we have discovered that AI has and will play a key role in our future and the future of all mobility manufacturers.

What exactly did your teams discover when they first examined Generative AI?
René: Of course, we recognised the potential of data and AI to improve product development, predictive monitoring, quality control, inventory management, … All closely related to our digital manufacturing platform. In addition to these typical applications, we also found a wide range of other applications where we can use AI. For example, all our Generative AI pilots have successfully led to direct quality and efficiency improvements in our product creation and manufacturing processes.

How will ZF's use of AI make an impact on its customers?
René: We use AI in two ways: First, we enhance the value of our products by AI driven Software features. This means we map our customers' expectations into modern solutions of the new mobility world. Second, we use AI in all its forms effectively to increase speed and improve processes. This ultimately leads to faster reaction times and yet again in improvements in our supply chain. Finally, our customers have like us a clear goal to reduce carbon footprint. So, here we are teaming up to improve the overall conditions for our climate and we help to achieve our common climate goals.

What's your view about the future of data and AI related to sustainability and business success?
René: AI is already very valuable to ZF. It gives us a competitive advantage in our industry, while also enabling us to increase efficiency – for example, by using AI to create software solutions faster.

I believe the potential of AI will only increase in the future. Sustainability is a very complex issue. That is why AI is ideal because it can help to solve complex challenges. Developing the right AI tools and setting the right constraints have the potential to put sustainability at the heart of any profitable market strategy.

Last, but not least we use AI technology to improve our associate's work environment. Starting from improved learning and continuing with new easy to use automated processes we believe that AI – and here especially generative AI – will play a major role in creating the best work environment for us.

4 Agriculture

> “Artificial intelligence in agriculture has brought an agriculture revolution.”[121]

Sector overview: what do leaders need to know?
The WRI estimates that agriculture is responsible for 11% of total global CO_2e emissions (5.5Gt).[122] The largest two contributing factors are manure from livestock, and enteric fermentation, which refers to the digestive process in farm animals such as cattle, sheep and goats.

Sector examples: how are companies using AI for sustainability and business success?
Dairy farming presents a unique set of challenges for cutting greenhouse gas emissions while remaining competitive and tapping into profitable growth. Data-driven technologies and AI are now being used to help solve these challenges[123] by supporting emissions reduction via processes for genetic selection, diet management and feed additives. Sensor technologies also play a key role. Companies that combine these various strategies can open up pathways towards a more environmentally responsible and efficient future.[124]

SEGES, a company that develops innovations for sustainable farming, has created an AI-powered data platform to monitor cameras in cowsheds. This makes it possible to detect signs of disease or injury in cows up to 90% earlier.[125] Ever.Ag, a software company, also installs cameras in dairy farms. Its solution uses tools that are similar to facial recognition software. This helps dairy farmers to optimise feeding, milking and animal welfare.[126] As a result, farmers can reduce CO_2 emissions using precision feeding, manure treatment technology and more[127], while also increasing financial returns.[128]

Cultivated meat that is grown in a laboratory using synthetic biology has a significantly lower carbon footprint than conventional meat from livestock farming.[129] It generates 92% less CO_2 emissions than beef and 44% less CO_2 emissions than pork. Growing food in laboratories also means less land is required to host animals and grow feedstock – using about 95% less space than beef, for example.[130] It is estimated that the global meat market will be worth €1.3 trillion by 2030, and that cultivated meat could account for 10% of the market by then.[131] Cultivated meat could thus achieve revenues of €128 billion by 2023.

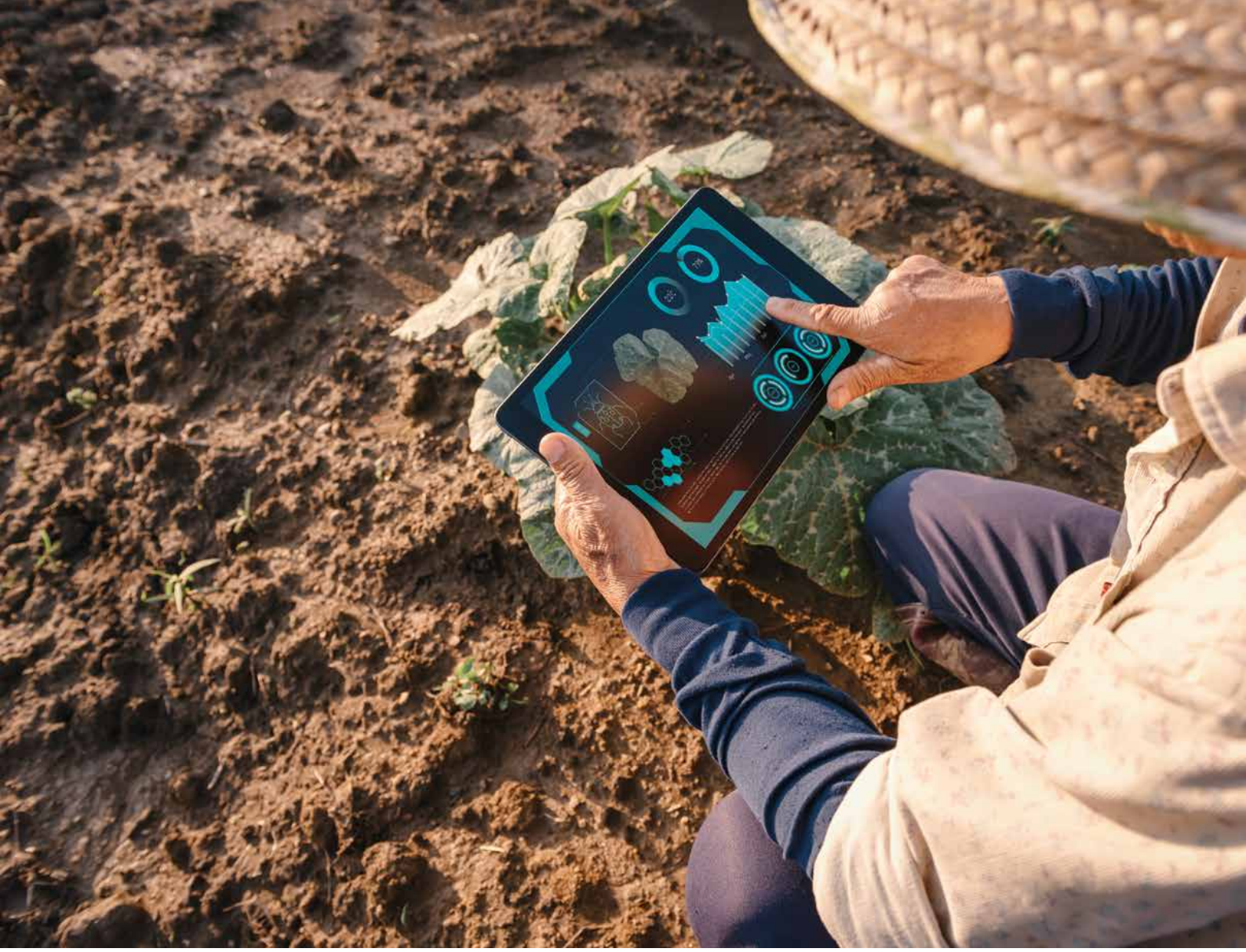
NotCo[132], a food tech company, has spotted this potential for sustainable and profitable business growth. The company has built an AI-powered platform called Guiseppe that supports customers in creating new recipes[133] more efficiently. This supports its efforts to engage with consumers and grab an advantage in this growing market for lab-grown and low-carbon meat products.

Synthetic fertilisers are a key driver of emissions from agriculture. xarvio®, a digital farming company, is collaborating with engineering and technology company Bosch to develop AI-supported solutions that reduce the use of fertilisers and expand precision agriculture.[134] AI-based predictions and recommendations make it possible to control the fertilisation of fields more efficiently, while reducing over-fertilisation.[135] Images from drone cameras and analysis by AI can show where fertiliser is required in a field and reduce fertiliser use by 20%.[136] This is possible for all types of crops.

A multibillion-dollar opportunity

- Using data and AI in farming could reduce consumption of fertiliser by 20% per year.
- Globally, 195 million tonnes of fertiliser[137] are used each year.
- 20% of 195 million tonnes would be a saving of around 39 million tonnes of fertiliser per year.
- Synthetic fertilisers generate around 0.6Gt of CO_2e emissions per year[138].
- Reducing fertiliser consumption by 20% would save 120 million tonnes of CO_2e emissions per year.
- At a unit cost of €500 per tonne of fertiliser[139], this would save €19 billion per year.

121 Talaviya et al., 2020.
122 World Resources Institute, 2020.
123 Bloomberg Quicktake, 2022(b).
124 Neethirajan, 2023.
125 Microsoft & SEGES, 2023.
126 DIGI, 2022.
127 Liu et al., 2023.
128 Bloomberg Quicktake, 2022(a).
129 McKinsey, 2021.
130 GFI, 2021.
131 A. T .Kearney, 2019.
132 Bloomberg Quicktake, 2022(a).
133 NotCo AI, 2022.
134 XARVIO, 2019.
135 Grell et al., 2021.
136 super.AI, 2023.
137 International Fertilizer Industry Association, 2023.
138 FAO, 2022.
139 World Bank, 2023.



Sector summary: what are the key takeaways?
The Agriculture sector creates a diverse, complex and interconnected range of challenges when it comes to cutting CO_2 emissions and ensuring opportunities for business success. SEGES and Ever.Ag are using data and AI to optimise dairy farming and reduce CO_2 emissions, NotCo is leveraging AI tools to engage with consumers in the growing market for cultivated meat, and xarvio® and Bosch are working together on AI solutions that reduce the use of fertilisers through precision farming. These real-world examples indicate the broader possibilities for data and AI to enable emissions reduction in agricultural practices – and lead the way forwards to new business models with attractive growth potential.

Tab. 5 Summary of data and AI applications for Agriculture

Use case	Data used	Applications of AI
Agriculture	• Natural production data • Machine data • Plant-specific cultivation data • Weather data	• AI algorithms for agricultural natural production models • AI optimisation in sensor recognition • Weather forecasting • Analysis of natural data and optimisation of plant production and breeding

xarvio® Digital Farming Solutions | WRI segment: Agriculture

xarvio® Digital Farming Solutions, a BASF brand with roots stretching back to 2014 and entering the market in 2017, is driving the digital transformation of agriculture. With a foundation bolstered by over 25 years of experience and growth through three key acquisitions, xarvio® is redefining global farming practices.

Interviewee

Clemens Graf von Hardenberg
Global Business Development Manager – Sustainability, xarvio®

> "Our AI-driven technologies can help customers to reduce the carbon footprint of their production by up to 30% while increasing the return on investment (ROI) by up to 25%."

Why is xarvio® using AI to increase efficiency and sustainability in the agriculture industry?
Clemens: We believe AI is the key to transforming agriculture with cutting-edge Agronomic Decision Engines (ADEs). It offers potential to make farming more efficient, while helping reduce its impact on nature and the climate. We aim to enhance the efficiency of agricultural practices and make measurable contributions to sustainability. We are fully aligned with industry-wide goals for increased productivity, reduced environmental impact and long-term profitability.

We built the robust foundation for our AI-enabled, outcome-based solutions using tools tailored for complex farming data analysis and management. This includes predictive analytics and ML. Our agile, interdisciplinary team of data scientists and experienced agronomists have developed technologically advanced AI digital farming applications that are combined with agricultural science – and comply with local and international data management regulations. In doing so, we emphasise the responsible use of AI in line with the objectives of the European Union's proposed regulatory framework for AI.

How has xarvio® implemented AI to benefit its customers?
Clemens: Our AI journey in agriculture involves co-creation, scalability, connectivity, and customisation. That's how we aim to increase the use of precision farming technologies. We have developed a unique ADE that combines ML with predictable models for timely and precise plant growth, pest, and disease detection and management. It also considers current data from sources including weather station devices, farm machinery, farm management information systems, drones, and satellites. Based on this, the ADE provides timely, field, and sub-field-specific recommendations to optimize crop production. Our core product, xarvio® FIELD MANAGER, is a holistic crop optimization platform. It supports every job step during the entire growing season, from seeding to harvest. It is proven to enhance financial and environmental performance. This leads to cost savings, greater input efficiency, and higher yields – while also improving sustainability and reducing farming's environmental footprint.

What are the key features of xarvio®'s technology?
Clemens: Our technology is scalable and adaptable at the same time, and suitable for any climate zone and its prevailing agronomic conditions. Adaptability is vital for sustainable agriculture because it ensures that our solutions are relevant and effective in diverse climatic conditions, especially under the pressure of climate change. Tailoring our solutions in response to different target markets' needs also enables us to address the challenges affecting consumers, the agriculture sector, and the food production supply chain: These include the need for enhanced traceability, increased food production, superior nutritional quality, and reduction in the environmental and ecological footprint, thereby positively impacting climate, and nature.

Our AI-driven solutions have consistently demonstrated their capacity to improve yield efficiency, soil health, biodiversity, pesticide use, mineral fertiliser input, CO_2 emissions, water consumption, and fuel consumption. The technology also reduces input costs. These outcomes are a big step towards more sustainable and environmentally conscious agriculture, which supports global efforts to mitigate climate change and protect nature. Our solutions further support the input reduction targets detailed in policies such as the European Union's Green Deal and Japan's Midori strategy for sustainable food systems.

Can you describe an example of a specific application that uses xarvio®'s FIELD MANAGER?
Clemens: Malting barley production for beer is a strong example of our impact. We worked with German brewer Weldebräu to utilise xarvio® FIELD MANAGER's precise field-specific recommendations. This included using xarvio®'s variable application maps for fertiliser, in combination with BASF's advanced nitrification inhibitors and comprehensive agronomic support from our team of expert agronomists. In the first analysis, one field already showed a 14.9% decrease in CO_2e emissions and a remarkable 24.7% increase in ROI, primarily through more efficient fertiliser use. Variable application maps ensure targeted crop treatment, optimising product use while maximising yield and protein quality. Across all our projects worldwide, we have seen CO_2e reductions of up to 34%. This outcome shows the potential of solutions customised for each field, geographic location, crop, and agronomic condition.

How does xarvio® FIELD MANAGER save resources while improving yield and positively impacting the environment?
Clemens: Farmers have consistently reported reduced input use and increased yield quality and quantity when using xarvio® FIELD MANAGER. This leads to improved ROI and helps reduce environmental impacts. For example, extensive field trials at 98 European locations from 2019 to 2021 showed positive outcomes, particularly in winter wheat. These trials encompassed diverse weather conditions and reported a €27 per hectare gross margin gain. There was an average 15% reduction in fungicide use, while maintaining yield (+1% in some cases).

What additional opportunities are being made possible by AI and FIELD MANAGER?
Clemens: xarvio® FIELD MANAGER uses AI in various agricultural applications, such as processing remote sensing satellite data with enhanced cloud and shadow detection capabilities. This technology assists with accurately analysing weed patches using drone imagery to facilitate the creation of precise on/off spray application maps. The AI can automatically detect field boundaries and buffer zones, streamlining the planning process for farmers. It calibrates and implements plant growth and disease risk models while improving crop health and yield predictions. The use of an AI driven phenology model allows the remote monitoring of crop development giving the farmer a huge benefit in his daily logistics. Drone imagery offers detailed insights into crop conditions and weed growth. These applications showcase the comprehensive nature of AI integration and the value for customers that use xarvio® FIELD MANAGER.

What is xarvio®'s goal and which topics do you expect to shape the future?
Clemens: This transformation, driven by AI and data, requires a systematic approach considering technologies, co-creation, and practical application. There is a clear need for a new food production model that prioritises climate, nature, and consumer needs. We are dedicated to transforming agricultural practices through enhanced education and collaborative innovation. We engage with partners, including agricultural consultants, distribution, cooperatives, value chain partners, machinery producers, information management systems, IoT technology, educational institutions, governments, NGOs, and farmers. Our approach centres around leveraging digital tools for Monitoring, Reporting, Verification, and Validation (MRVV). We offer tailored, data-driven, field-specific guidance to empower farmers to adopt more pragmatic and environmentally sustainable practices. Our holistic solutions also help supply chain companies adapt to new regulations and rising consumer demand for sustainable more resilient food production. These solutions benefit companies that strive to meet ambitious goals like those approved by the SBTi or similar. Our efforts aim to foster a sustainable, prosperous future for global agriculture and food systems.

5 Industrial Processes

> "Artificial intelligence will digitally disrupt all industries. Don't be left behind."[140]

Sector overview: what do leaders need to know?
Industrial processes contributed 6% of global CO_2e emissions (3Gt) in 2019.[141] According to the WRI, around half of those emissions came from cement production.[142] The chemical industry is also a significant contributor, generating around 2% of total global CO_2e emissions.[143] Business leaders in these two specific sub-sectors are now exploring applications of AI to combat high levels of emissions, while maintaining or strengthening profitability. Example technologies include digital twinning approaches that develop a digital model of a factory to enable production staff to test the implications of various hypothetical changes in the manufacturing process, as well as predictive maintenance methods that avoid equipment downtime and extend the lifetime of machinery.

Sector examples: how are companies using AI for sustainability and business success?
There are three key possible ways of reducing CO_2 emissions from cement production. The first option is by using biomass for heating[144], the second is carbon capture and storage[145], and the third is to embrace innovations for efficiency.[146] Data and AI have the potential to make the most significant positive impact in this third area.

Heidelberg Materials, a building materials company, has introduced AI tools that leverage large volumes of data. By analysing the compositions of its products and the steps in its cement production processes, the company has been able to reduce energy consumption by 5% and decrease the related CO_2 emissions.[147] In collaboration with Giatec, a technology company, Heidelberg Materials is now training special software that can optimise the composition of its concrete products to reduce costs, decrease the use of concrete and cut its carbon footprint.[148] The company is also exploring the potential for AI to have a positive impact on the development of new concrete mixes.

Carbon Re, a software company, has developed AI tools that can optimise the preheating and kiln stages during the cement production process. This can reduce emissions by 10% and generate attractive cost savings.[149] The company uses a digital twin model for cement works. This digital twin is created from available production data, as well as data from sensors and product samples. It then uses AI to simulate and test various combinations of possible inputs, such as different types of raw material or alternative forms of fuel. The AI enables accurate predictions that can be used to recognise, adapt or shut down inefficient processes – saving energy and other resources, while also cutting emissions and ensuring required levels of product quality.[150]

The 10% emissions reduction achieved by Carbon Re would have the potential to save 160 million tonnes of CO_2 if it was applied across the entire cement production sector worldwide. On average, 116kWh of energy is required to produce a tonne of cement in Europe.[151] With annual production of 4 billion tonnes[152] and an average energy cost of 0.15€ per kWh[153], this amounts to energy costs of around €77 billion. Cutting 10% of that energy consumption would save €7 billion.

SLB Capturi, the joint venture between SLB and Aker Carbon Capture, uses data and AI to enable optimization of carbon capture deliveries throughout the project phases and specially in operational phase of its carbon capture plants. SLB Capturi estimates that its solutions can capture up to 95% of the emission from industrial processes such as cement and waste-to-energy facilities. In this way, SLB Capturi's customers are able to manufacture products with drastically reduced CO_2 emissions, with data that can be used to transparently meet increasingly strict regulations and reporting requirements, as well as the expectations by procurers of low carbon materials and services.

[140] Dave Waters, Emeritus Fellow of St Cross College – University of Oxford.
[141] World Resources Institute, 2020.
[142] Please note that there are several ways to calculate these numbers. This report is based on WRI numbers and calculations.
[143] World Resources Institute, 2020.
[144] UNECE, 2021.
[145] Oxford Institute for Energy Studies, 2023.
[146] Fennell et al., 2021.
[147] Microsoft, 2022(b).
[148] Giatec, 2023.
[149] Carbon Re, 2023(a).
[150] Carbon Re, 2023(b).
[151] IEA, 2018.
[152] IEA, 2023(e).
[153] Eurostat, 2023.

Sector summary: what are the key takeaways?
The range and scope of potential applications of data and AI within the Industrial Processes sector is vast. For cement production, these technologies are saving energy and related costs for Heidelberg Materials, while also opening up potential new product compositions that are optimised for sustainability and profitability. Carbon Re is leveraging data and AI by creating digital twins of its cement works that then simulate a range of possible scenarios to suggest the most efficient, sustainable and economical production parameters. Finally, SLB Capturi is developing and providing advanced carbon capture solutions that use data and AI to maximise the volume of CO_2 emissions from industrial processes that is captured and stored. Data and AI can make a significant contribution to the reduction of carbon emissions in hard-to-abate sectors such as steel and cement, while offering a big opportunity for businesses to differentiate themselves from their peers.

Tab. 6 Summary of data and AI applications in Industrial Processes

Use case	Data used	Applications of AI
Industrial Processes	• Operational data, such as extraction rates or sensor data from machines	• Building complex models, such as the digital twin (cement works) • Process analysis using ML to optimise production processes

SLB Capturi (the joint venture between SLB and Aker Carbon Capture) | WRI segment: Industrial Processes

SLB Capturi is a company headquartered in Norway that operates across Europe and North America. Its purpose is to reduce and remove carbon from industry and energy solutions with carbon capture technologies.

Interviewee

Hanne Rolén
Head of Sustainability, SLB Capturi

> "SLB Capturi is a pioneer in developing scalable and cost-effective solutions for capturing carbon dioxide from industrial sources, contributing to the global efforts to combat climate change. We leverage the power of artificial intelligence to accelerate the deployment of our solutions."

What do you offer your customers?
Hanne: Some industries, such as cement and waste to energy, are hard-to-abate sectors. This means that their emissions are inherent to their production process and cannot be fully eliminated by using renewables or changing fuels. These industries need carbon capture and storage to achieve net zero. Our technology takes the flue gas from the industrial processes to our process plant, where we can separate the CO_2 content in a different stream, reducing emissions by up to 95%. The CO_2 is then compressed to liquid, making it easier to transport to either utilization or to permanent storage, typically in saline aquifers.

By taking action on their emissions now, emitters can achieve their climate goals and prepare their business for the future, meeting the requirements and expectations of their stakeholders.

How are you connecting carbon capture technologies with data and AI?
Hanne: AI has exciting potential to make a positive impact when combined with carbon capture. AI can support the management of on-site carbon capture systems in a dynamic manner. AI can support and accelerate the insights of the carbon capture processes as increasingly more plants across various industry segments are being deployed. Continuous data streams from all of our capture sites will enable us to react to changing needs quickly, in real time.

What might this mean for consumers?
Hanne: As carbon capture, utilization, and storage (CCUS) is a required solution towards net zero, enabling both carbon reduction and carbon removal, it is adamant for fast feedback loops to increase the speed of deployment. Core to this is to further improve the energy efficiency of the carbon capture plants, directly impacting the cost of operations as well as the embedded footprint of the operations.

AI provides the necessary insights to subject matter experts of carbon capture process, without needing any specific coding skills. With the increasing availability of large data sets, AI is essential for evaluating opportunities across sites, enabling faster application of knowledge and continuous improvement initiatives across our solutions.

Have your experiences changed the way you view data and AI in terms of sustainable business success in the future?
Hanne: Yes. Data and actionable insights enhanced by AI are key for a successful deployment of carbon capture for our customers. From the product design, throughout project execution, and specially during operations. We already knew that carbon capture offers an immediate solution for many processes that are difficult to decarbonise. Data-driven tools and AI applications can make carbon capture more efficient, generating multiplicative impact along value chains. As we continue to combine AI and carbon capture, the power of their joint impact will grow.

6 Land Use Change and Forestry

> "Forests are the lungs of our land, purifying the air and giving fresh strength to our people."[154]

Sector overview: what do leaders need to know?
Land Use Change and Forestry is responsible for about 3% of global CO_2 emissions (1Gt).[155] Between 1960 and 2019, almost a third of the world's land area underwent a change of use.[156] Around 85% of the world's usable land has now been heavily harvested for wood or converted for agriculture. This significant land-use change affects CO_2 emissions, because forests absorb a volume of CO_2 equivalent to 1.5 times the annual emissions of the US[157] – about 7Gt per year.

Agriculture is by far the largest human land use. Food systems are a central factor in rising pressures on land, with 38% of the Earth's landmass currently used for food production.[158] The WRI estimates that the increase in demand for food between 2010 and 2050 will require an additional 600 million hectares (Mha) of agricultural land, and harvesting of 800Mha of forests.[159] In this context, "efforts to transform food systems need to be redoubled".[160]

Sector examples: how are companies using AI for sustainability and business success?
17% of food produced globally is wasted.[161] Alongside concerns about the amount of land that is used to produce that food, there are further concerns about the impact on water and the consumption of pesticides, fertilisers and energy.[162] Retailers that operate multiple shops supplied by a complex supply chain are responsible for 18% of total food waste.[163] They are exposed to regular supply chain disruption and the unpredictability of customer demand, resulting in significant financial losses due to shortages and overstocking.[164]

Data and AI can address some of these challenges. For example, AI can be used to identify risks in the supply chain, which can lead to cost savings for companies.[165] In addition, AI can leverage demand and supply data to enable more efficient trade processes that consider sustainability aspects such as food waste.[166] Sharing data to increase transparency within the supply chain also enables companies to meet increasingly strict regulations and reporting requirements, and protect the reputation of their brand among shareholders, investors and consumers.

SPAR, an Austrian retail company, uses data and AI to reduce food waste. Based on AI forecasts that are customised for each store, the company is able to predict consumer behaviour with a high level of accuracy. This enables SPAR to reduce unnecessary stock purchases[167] and connect local food waste apps with regional stores – selling products before they become inedible.[168] This enables the company to save money and reduce its environmental impact by decreasing food waste.[169]

Ahold Delhaize, another retail company, has used AI to reduce food waste in its Belgian operations by 21%. The company developed an algorithm that includes product promotions, time of day and weather conditions. This made it possible to predict customer demand more accurately. These data-driven predictions have enabled Ahold Delhaize to react to trends quickly, manage stock levels efficiently and avoid unnecessary overproduction – and reduce food waste.[170]

A multibillion-dollar opportunity

- Globally, 1.3 billion tonnes of food waste[171] generate 3 billion tonnes of CO_2[172] emissions, and the retail industry accounts for 18% of food waste.
- 18% of 3 billion tonnes means that approximately 500 million tonnes of CO_2 emissions are generated by food waste in the retail industry.
- Using data and AI in the retail industry could reduce food waste by 21%.
- This would save approximately 100 million tonnes of CO_2 emissions (21% of 500 million tonnes of CO_2 emissions) per year.
- At a unit cost of €720[173] of lost revenue per tonne of unsold food, this would unlock global savings in the retail industry of more than €35 billion.

154 Franklin D. Rosevelt, 32nd US President.
155 World Resources Institute, 2020.
156 Winkler et al., 2021.
157 World Resources Institute, 2021.
158 FAO, 2020.
159 Searchinger et al., 2023.
160 King et al., 2023.
161 United Nations, 2023.
162 EPA, 2021.
163 Fraunhofer, 2021.
164 Ovezmyradov, 2022.
165 Wong et al., 2022.
166 Tsolakis et al., 2023.
167 SPAR, 2022.
168 SPAR, 2023.
169 Microsoft, [no date].
170 Ahold Delhaize, 2022.
171 World Food Programme, 2020.
172 Amicarelli et al., 2021.
173 Ahold Delhaize, 2022.

Timber is another important topic in the context of Land Use Change and Forestry. 1.6m^3 of timber is required to produce 1m^3 of sawn wood.[174] Data and AI can bring these two numbers closer together – and reduce the amount of waste timber generated when making sawn wood.

AI can scan a set of logs and help saw them into boards, before identifying the optimal sequence for joining them together. This reduces the amount of waste by up to 30%[175] by using the minimum possible proportion of the tree.[176]

Sector summary: what are the key takeaways?
The world's land faces significant challenges, with food systems contributing to environmental issues such as biodiversity loss, deforestation and CO_2 emissions. Data and AI are enabling reductions in food waste from the retail sector, enhancing sustainability and improving financial outcomes for SPAR and Ahold Delhaize. Leveraging AI in the timber industry is also making it possible to decrease waste from wood processing and optimise the methods used, which has the potential to reduce the amount of land subject to logging or deforestation. These examples demonstrate potential ways for data and AI to relieve pressures on the planet's land, while also cutting costs associated with waste and supporting more profitable business operations.

Tab. 7 Summary of data and AI applications for Land Use Change and Forestry

Use case	Data used	Applications of AI
Land Use Change and Forestry	• Sales and demand data • Inventory data • Logistics and supply chain data • Sensor and IoT data	• Optimisation of supply and demand models • Analysis of supply chains • Optimisation to increase efficiency in wood processing • Intelligent recording of products in quality control

[174] proHolz Austria, 2019.
[175] Carlo Ratti Associati, 2023(a).
[176] Carlo Ratti Associati, 2023(b).

7 Waste

> “Waste is a resource that we’re wasting.”[177]

Sector overview: what do leaders need to know?
Waste is responsible for 3% of total CO_2 emissions per year (1.5Gt). The World Bank estimates that global waste will increase by 70% between 2020 and 2050.[178] Countermeasures are clearly needed. The European Union is taking a leading role with its Waste Framework Directive[179], which aims to contribute to the European Green Deal ambition of reducing waste generation and transitioning to a circular economy.[180] Data and AI can support that transition to circularity by optimising every step in the value chain – from product design and raw material selection through to use and reuse or recycling.

Sector examples: how are companies using AI for sustainability and business success?
In the fashion industry, data and AI are enabling innovative approaches that reduce waste. Fashable, a digital technology provider, has developed an AI tool that generates very realistic visualisations for designers. This helps its customers to accelerate the design process for fashion products by up to 75% – unlocking valuable cost savings to boost profitability, while also supporting more sustainable practices by reducing the amount of fabric used during this process.

ZEGNA, a luxury apparel brand, is leveraging data and AI via a digital platform for achieving traceability of the raw materials it uses. This enables its brands to make credible, data-supported claims about the ethical and sustainable origins of its fabrics – appealing to shifting consumer demand regarding these topics. The company is also using AI to strengthen its demand forecasting and make its production processes more flexible, which helps to reduce waste by more accurately matching production volumes to order volumes.

Alongside these examples of cutting waste during design and manufacturing, data and AI are also supporting waste reduction via remanufacturing. This involves rebuilding or recovering products that have already been sold or used. IKEA, a furniture company, states that 10% of all products purchased in its stores get returned and that 15% of those returned products go to waste. An AI tool is now tackling this problem. It predicts the best possible destination for returned merchandise – whether it goes back to the shop floor, is listed on the website, gets donated to charity or is sold to a third-party wholesaler. The algorithm determines this based on what makes most sense for IKEA’s profits.[181]

Data and AI can also make waste management processes more resource-efficient. Combining AI with image recognition, for example, enables more precise and efficient waste separation.[182] This method identifies opportunities for recycling and composting, while also reducing landfill waste by improving the separation of recyclable materials.[183] FCC Environment, a waste and resource management company, used AI-powered robotics to sort waste in collaboration with Recycleye. This increased its capacity to identify and separate key materials by 12%[184], with that waste being reused or recycled instead of going to landfill.

A multibillion-dollar opportunity

- Using data and AI in waste management AI can increase reuse and recycling by 12%.
- Globally, landfill sites generate 990 million tonnes of CO_2e[185] per year.
- 12% of 990 million tonnes would be a saving of around 120 million tonnes of CO_2e emissions per year.
- Globally, the cost of waste disposal is predicted to reach €340 billion in 2025.[186]
- 12% of €340 billion would be a saving of around €40 billion per year.

[177] Rose George, British journalist and author.
[178] Kaza et al., 2021.
[179] Waste Framework Directive.
[180] European Parliament, 2023(b).
[181] Fast Company, 2020.
[182] Alonso et al., 2021.
[183] Fang et al., 2023.
[184] Recycleye, 2023.
[185] World Resources Institute, 2020.
[186] World Bank, 2012.

Sector summary: what are the key takeaways?
Waste generates a lot of emissions – and the global volume of waste is expected to keep growing in the years ahead. In the fashion industry, Fashable and Zegna are using data and AI to cut waste during design processes, and to optimise processes related to supply chain transparency. This supports credible brand claims about sustainability, which appeals to shifting consumer expectations. IKEA uses AI to predict optimal destinations for returned furniture, which helps to reduce waste while also targeting the most profitable course of action. Finally, in waste management, FCC Environment is using AI-powered robotics to maximise the efficiency of waste-sorting processes – turning waste into a valuable raw material that can re-enter the economic cycle. Data and AI have the potential to help businesses to reduce their environmental footprint, while at the same time opening up business opportunities. This symbiotic relationship will help companies to accelerate the transition to a more sustainable economy.

Tab. 8 Summary of data and AI applications for Waste

Use case	Data used	Applications of AI
Waste	• Sensor and IoT data • Waste and product-specific data	• Simulation-based product design • Analysing and forecasting demand in the supply chain • Efficient design of recycling processes • Automated image processing for waste identification and classification • AI-powered robotics for optimised waste separation

Fashable | WRI segment: Waste

Fashable is a Portuguese company focused on digital content creation. It aims to build powerful visual technology to solve real problems and make a positive impact in fashion and industry.

Interviewee

Orlando Ribas Fernandes
CEO and Founder, Fashable

> "Our GenAI-driven technology allows customers to shorten the design process for clothes by 75% while also using considerably less material. This saves time, resources and money."

What does Fashable provide for its customers?
Orlando: Our GenAI technology can reduce the design times for clothing brands by creating very realistic visualisations for designers. This helps our customers to accelerate the design process for a product by up to 75%. Of course, this unlocks valuable cost savings. On top of this, embracing a virtual design process helps our customers to reduce the amount of material that is used.

Could your technology enable consumers to design their own products?
Orlando: Right now, we're focused on B2B applications. However, we can envisage this technology empowering consumers to design their own clothes in partnership with a brand that uses our tools. That could achieve another positive effect for the environment because the production of such small batches would probably take place nearshore, more close to the customer – since the economies of scale related to producing clothes in Asia would not apply. Of course, that would have a massive effect on supply chains and would lead to significantly lower emissions generated when transporting clothes. And since is on-demand production will eliminate the current returns rate, which is 30% in the e-commerce space.

It would also decrease the risk of products failing to sell if consumers designed their own clothes. Today, 150 billion pieces of clothing are produced annually but only around 25% of those clothes are sold at full price – and 30% goes unsold.

Does your technology also offer further advantages for business success and sustainability?
Orlando: Yes! Customers also use our platform for marketing purposes. The very photo-realistic images created by our GenAI technology give customers the possibility to customise their marketing approach for each market worldwide without the need to hire models and conduct expensive photo shoots. For example, brands that want to sell a collection in Asia need to work with images that are appealing to Asian consumers. Selling the same collection in Europe would require different images that appeal to European consumers. Our AI models enables our customers to create those images without expensive photo shoots. This saves a lot of time and money.

Some customers have even used our technologies to sell collections that failed to achieve their initial sales targets. Often, companies destroy unsold collections. That is not a sustainable or profitable approach. Now, our solution makes it possible to market those collections to a wider audience without needing to conduct expensive photo shoots. And that allows customers to increase sales and reduce their environmental footprint.

The same concept can be applied to second marketplaces to feature more inspiring images, which can lead to faster sales conversion.

What's your view on the future of data and AI in terms of sustainability and business success?
Orlando: We believe in customised clothing for everybody. In the future, consumers will have the power to upload their photos and see an AI-generated projection of how they'd look wearing a new piece of clothing. In addition, consumer want to design their own products in partnership with their favourite brands and labels. That means everybody will have the chance to wear truly unique fashion items. As a result, we expect product returns to decrease by up to 80%. That's because a customer is less likely to return a product that doesn't fit or doesn't look good if they have already taken time to personalise the design or check out how it looks on an AI version of their body. That will require a transformation of supply chains for this market, but we believe this change is coming very soon – starting in the luxury segment and gradually reaching price-competitive segments of the market too.

G This is just the beginning

"I believe AI is going to change the world more than anything in the history of humanity. More than electricity."[187]

Introduction

This report has shown that data and AI can make a positive contribution to sustainability while also generating economic value for companies. Not everyone will win. However, AI is likely to have a positive influence on average overall living standards, while increasing productivity and creating new jobs.[188] Goldman Sachs predicts that Generative AI has the potential to raise global GDP by 7%.[189] Interest in AI from corporations is increasing exponentially, with around 16% of companies mentioning AI in their 2023 earnings calls – in comparison to the 1% of Russell 3000 companies highlighting AI in 2016.[190]

The following sections of this report explore the future of data and AI, before making predictions for the five most carbon-intensive sectors as defined by the WRI.

Data explosion

The global data sphere has grown tremendously over the past decade.[191] The internet of things (IoT) and sensors are key drivers of this expansion.[192] The number of satellites in use is also rising exponentially, with a six-fold increase over the past decade.[193] All of these sensors and satellites generate data. And that data is the foundation for AI applications that have already been implemented – and that will revolutionise daily lives and economies soon.

Ubiquitous AI

AI has become ubiquitous. It is now doing things that were once the sole domain of humans, such as composing music, creating illustrations, writing texts and designing products.[194] Algorithms that create these ideas might soon be available open-source and at a high readiness level.[195] Everyone will be able to use them. Data is expected to be available online, and processing power is set to become cheaper and more widely accessible.[196] Intelligent business analytics are expected to be universally available within the next three to five years.

Investments in AI are also growing. The market for AI is projected to grow from €221 billion to €676 billion by 2030. The International Data Corporation expects investments in GenAI alone to double in 2024 and grow to €138 billion by 2027.[197]

The future of AI is limited only by human imagination. So far, popular AI has focused mainly on vision and text, with Unreal Engine and ChatGPT being the most prominent examples – but it has the potential for much more. AI can exploit all of the senses (e.g. natural language processing[198], electronic nose[199] and electronic tongue[200] technology). Consumers could cyber-taste coffee before buying it[201], which would cut emissions from returns and waste. AI could also make it possible to digitally twin entire supply chains to support optimisation[202] and increase efficiency. This would include performing stress tests, subjecting the twin to external shocks or shifts in large-scale consumer preferences – making long-term planning easier and more resilient. In this way, companies would gain insights that can help reduce CO_2 emissions by decreasing reliance on traditional resources and energy sources.

The future of data and AI in the five most carbon-intensive sectors

In view of this growth in the global AI market, investments are already delivering on their potential. This report will now take a look at the potential distribution of investment across the WRI sectors, giving examples of the amount of research funding and financing for startups that is already available.

Overall, we are seeing an increase in global funding for scientific projects in the field of AI. Researchers from Imperial College London have been awarded €1.6 million to lead an AI project focused on helping the UK's energy and transport sectors achieve carbon neutrality.[203]

187 Kai-Fu Lee, Taiwanese businessman, computer scientist, investor and writer.
188 The White House, 2022.
189 Goldman Sachs, 2023(b).
190 Goldman Sachs, 2023(a).
191 Own calculations based on IDC & Statista, 2021.
192 Businesswire, 2019.
193 JSR, 2023.
194 Stanford Business, 2023.
195 Martínez-Plumed et al., 2021.
196 Epoch AI, 2022.
197 International Data Corporation, 2023.
198 Khurana et al., 2023.
199 Fang et al., 2022.
200 Gabrieli et al., 2022.
201 PR Newswire, 2021.
202 MIT Sloan, 2022.
203 Imperial College London, 2023.

In the field of manufacturing and industrial processes, a project at the University of Trento has received €8 million of funding.[204] This project aims to investigate how robots can remove and dismantle batteries automatically, without an operator. It is also exploring efficient and intelligent interaction and control of automated, heavy-duty cranes in production plants.[205]

Various projects are being funded in the agricultural sector. This includes the HOPLA project (€4.4 million), in which the University of Hohenheim and its partners are investigating the development of camera sensors for field sprayers to optimise the targeted treatment of unwanted plants with herbicides.[206] The University of Aberdeen has received a €12.4 million grant to support young scientists in acquiring skills for using AI to research sustainable practices in agriculture.[207]

Funding is also available in the area of Land Use Change and Forestry. As part of the Forest 4.0 project, a centre of excellence is being set up with €20 million of funding to optimise the monitoring of forest ecosystems with the help of AI.[208]

The WRI sectors also overlap in research projects, with the University of Toronto receiving around €135 million of funding to expand research into materials for biodegradable plastics, low-carbon cement and renewable energy.[209] Another overarching research project in Europe, ELIAS, is receiving around €11 million of funding to research various sustainable innovations and economic developments, such as optimisation of energy consumption in buildings.[210] Furthermore, the University of Minnesota has received initial funding of €18.3 million to establish an AI research institute – with the goal of creating the next generation of AI for forestry and agriculture.[211]

Startups are also receiving strong financial support. In 2022, AI startup funding totalled €47.3 billion.[212]

In the energy sector, Tibber (€92 million) offers optimisation of household electricity consumption based on AI forecasts[213], Stem (€533 million) uses AI for energy storage to automate energy cost savings and protect customers from tariff changes[214], and Octopus Energy (€732 million) has developed an innovative AI platform for load balancing in smart grids.[215]

Startups in other WRI sectors are also receiving financial support. One example is ZenRobotics (€15.6 million[216]) in the waste sector, which uses AI to identify waste in recycling processes.[217]

Based on these highlighted examples, it is clear that financial support for startups is advancing AI solutions in the area of sustainability.

Data and AI: making sustainability worth it

This report illustrates the immense financial potential and significant impact on sustainability that AI is already having. Investments into research and startups from companies and government funding bodies, as well as the expected market volume of AI, show that it is logical to expect that previously unimaginable technological solutions for sustainability will be developed in the future.

It is foreseeable that measures will also be taken to make AI more climate-friendly. Some operators of data centres are already changing how their facilities are designed, built and operated. Steps can be taken to reduce the consumption of energy and water, while also increasing efficiency. It is possible to counter the high energy consumption of AI by switching to renewable energy sources, for example. Some data centres are also exploring ways of recycling or repurposing the water used for cooling, or using air instead of water for cooling. Further advances are possible for data centres that are built using low-carbon materials as an alternative to carbon-intensive materials such as steel and concrete. There is also potential to reduce the energy requirements of AI and cloud services by optimising models and code. At the same time, AI is helping to drive further innovative energy efficiency solutions, including energy recovery in data centres.

There are still bumps in the road to sustainability, but the move towards greater sustainability is clearly visible. Companies are making rational economic decisions and the attractiveness of sustainability will be further strengthened by the positive economic impact of AI, which is likely to influence corporate behaviour. In the global context, where tackling climate change is dependent on political decisions by industrialised nations, technologies such as AI can contribute to the decarbonisation of our economies – particularly if political action is delayed or ideologically restricted.

The rise of AI is not the beginning of something new. Instead, it is the latest part of a long-term digital transformation. The future is likely to bring many more sustainable and economic benefits. As the world moves towards a more sustainable economy, it is crucial to seize opportunities – and for companies to embrace data and AI to drive sustainability programmes that are financially worthwhile.

[204] RockingRobots, 2024.
[205] AZO Robotics, 2024.
[206] BMBF, 2022.
[207] University of Aberdeen, 2023.
[208] Forest 4.0, 2023.
[209] University of Toronto, 2023.
[210] ELIAS, 2023.
[211] University of Minnesota, 2023.
[212] Statista, 2024.
[213] ArcticStartup, 2022.
[214] Growjo, 2023.
[215] ESG Today, 2023.
[216] Tracxn, 2024.
[217] ZenRobotics, 2024.

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Appendix

1 Methodology

This report tackles a complex question with the aim of providing an indicative set of findings. As such, we have developed a methodology that gives us confidence in the approximate scale of these findings. However, it is not designed to be highly precise. We proceeded as follows:

1. We used data from the World Resources Institute to identify energy use and emissions by sector, based on figures from 2022. We then chose to focus on the seven sectors with the highest emissions:
   a. Energy in Electricity and Heat
   b. Energy in Transport
   c. Energy in Manufacturing and Construction
   d. Agriculture
   e. Industrial Processes
   f. Land Use and Forestry
   g. Waste
2. For each sector, we interviewed companies that are using innovative approaches to data and AI to reduce CO_2 emissions, save costs or generate new revenue streams. From these interviews, we identified specific case studies with quantified emissions reductions by means such as optimised fertilizer usage, waste prevention or energy intensity reduction as a proportion of total energy used. This gives us an energy efficiency coefficient: the percentage increase in energy efficiency that is delivered by this use of data and/or AI.
3. We extrapolated from the cases of individual companies to create a picture at sector level. To do this, we assumed that the whole sector could make an energy intensity reduction similar to that observed in a particular use case. We then multiplied the energy efficiency coefficient by the total energy use of the sector. This gave us the sector-level energy reduction potential.

   For the case studies, we aimed to focus on Microsoft clients in Europe. In cases where this was not possible, we searched for international use cases.
4. Finally, we ascribed a carbon value and an economic value to these reductions.
   a. We calculated the potential sector-level emissions reduction by applying the energy intensity reduction coefficient to the total emissions of the sector (in one year). If an intervention delivers a 5% reduction in energy intensity, for example, we calculated that it would deliver a 5% reduction in emissions. This assumes that both total output and the energy supply mix remain constant.
   b. We calculated the sector-level economic value by taking the average global energy price of €0.16 per kWh (Eurostat, 2023) and calculating the savings that would theoretically be made in one year.
5. By adding together the carbon effects, we were able to quantify the total potential emissions reduction. By doing the same for energy savings, we were able to quantify total potential economic savings.

Considerations

This methodology is designed to deliver an indicative estimate of the approximate total emissions reduction potential of deploying innovative data and AI technologies at scale. However, as noted in the introduction to this report, this approach has limitations and is not a prediction. In particular, it is important to consider the following points:

- Extrapolating from particular cases to a sector-wide picture assumes that all organisations and activities within a sector have the same potential to improve efficiency and cut emissions as the examples chosen (on average). This assumption allows some level of projection based on real-world experience, but clearly it is a significant simplification, with the potential for both larger and smaller impacts.
- The report focuses on the potential of AI and data to drive efficiency. This assumes that other enabling factors are in place. No data processing algorithm or large language model will cut emissions on its own. It will need to be supplemented with operational change that delivers improvement.
- We have used the 2023 price per kWh to calculate financial savings. The financial projections are therefore sensitive to the actual energy price. If it goes up, savings will also increase. If it falls, the savings will fall.
- All financial figures stated within the main body of the text are presented in euros, converted at the European Central Bank's standard rate for 11 March 2024. They have been rounded.

2 Calculations of potential from the use cases

The following numbers are indicative. They have been extrapolated from interviews and secondary literature and illustrate the art of the possible.

Tab. 9 Calculation details for each use case

WRI segment	Indicative size of emissions reduction (CO_2e)	Indicative value of cost savings	Calculation
Energy in Electricity and Heat	200 million t CO_2 300 million t CO_2	€60 billion €90 billion	$X1_{CS}$: 425TWh × 475g CO_2/kWh ≈ 200,000Gg CO_2 200,000Gg CO_2 × 1,000,000kg/Gg = **200 million t CO_2** $X1_{NR}$: 425TWh × €0.15/kWh ≈ **€60 billion** $X2_{CS}$: 1Gt CO_2 × 30% = **300 million t CO_2** $X2_{NR}$: 7EJ ≈ 2.000 000 × 10^{12}kWh 2.000 000 × 10^{12}kWh × 30% × €0.15/kWh ≈ **€90 billion**
Energy in Transportation	44 million t CO_2 6 million t CO_2	€20 billion €2 billion	$X1_{CS}$: 890 million t CO_2 × 5% ≈ **€44 million t CO_2** $X1_{NR}$: 9EJ ≈ 2.5 × 10^{12}kWh 2.5 × 10^{12}kWh × €0.15/kWh ≈ €400 billion €400 billion × 5% ≈ **€20 billion** $X2_{CS}$: 2.5kg CO_2/l × 350 billion l × 0.75% ≈ **6 million t of CO_2** $X2_{NR}$: $1/l × 0.9 EUR/USD × 350 billion l × 0.75% ≈ **€2 billion**
Energy in Manufacturing and Construction	1 Gt CO_2e	€330 billion	X_{CS}: 6Gt CO_2e × 20% ≈ **1 Gt CO_2e** X_{NR}: 37EJ ≈ 1 × 10^{13}kWh 1×10^{13}kWh × €0.15/kWh × 20% ≈ **€330 billion**
Agriculture	120 million t CO_2	€19 billion	X_{CS}: 0.6Gt CO_2 × 20% ≈ **120 million t CO_2** XNR: 195 million t × 20% × €500/t ≈ **€19 billion**
Industrial Processes	160 million t CO_2	€7 billion	X_{CS}: 1.60Gt CO_2 × 10% ≈ **160 million t CO_2** X_{NR}: 116kWh/t × 4.16 billion t × €0.15/kWh ≈ €71 billion €71 billion × 10% ≈ **€7 billion**
Land Use Change and Forestry	100 million t CO_2e	€35 billion	X_{CS}: 3Gt CO_2 × 21% × 18% ≈ **100 million t CO_2e** X_{NR}: 1.3 billion t × 21% × 18% ≈ 49 million t 49 million t × €720/t ≈ **€35 billion**
Waste	120 million t CO_2e	€40 billion	X_{CS}: 990 million t CO_2e × 12% ≈ **120 million t CO_2e** X_{NR}: $375 billion × 0.91 EUR/USD × 12% ≈ **€40 billion**
Sum	**2 Gt CO_2e**	**€600 billion**	

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