IMPLEMENT
CONSULTING GROUP_

REPORT
OCTOBER 2023

A greener and more digital Germany

The impacts of Google's digital infrastructure investment

An Implement Consulting Group study commissioned by Google

A greener and more digital Germany

Google has invested approximately 1 billion euro in digital infrastructure and clean energy in Germany between 2017 and 2022.[1]

Implement Consulting Group (Implement) has been asked by Google to assess the social, environmental, and economic impacts for the German society of this investment.

Google

Disclaimer

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SUMMARY

A greener and more digital Germany

Google's approximately 1 billion euros investment in Germany's digital infrastructure since 2017, including the 182 MW operational renewable energy portfolio in 2022, is accelerating the journey to a net-zero digitised German economy.[2]

The twin transformation of sustainable digitalisation fuels productivity, prosperity, and decarbonisation in Germany.

Digitalisation is a vital driver of Germany's competitiveness, prosperity, and well-being, and needs support of a strong policy framework. The German Council of Economic Experts (GCEE) emphasises the significance of investing in digital infrastructure, skills training, and technology transfer to foster growth and resilience across all economic sectors.[3] Moreover, Germany's digital infrastructure plays a pivotal role in the thriving cloud computing industry, valued at about 20 billion euros in 2022.[4] Notably, cloud adoption by German firms has surged from 16 percent in 2016 to 42 percent in 2021.[5]

Google's investment helps drive this progress by expanding its digital infrastructure while conscientiously prioritising environmental, economic, and social aspects throughout the entire supply chain. This report examines the impacts of Google's investments on the planet, its people, and the economic prosperity in Germany.

The impact assessment relies on a broad set of indicators from the Organization for Economic Co-operation and Development's (OECD) *Better Life Index.* The index assesses well-being across a range of indicators that are essential for material living conditions and overall quality of life. This includes indicators such as GDP and the underlying drivers of economic prosperity such as productivity and employment.

Our key findings include:

Planet: Operating in Germany while advancing carbon-free energy[6]

- Globally, Google showcases environmental stewardship by operating computing facilities that are 1.5 times more energy-efficient than traditional data centres and promoting the use of sustainable resources.
- Google is collaborating with ENGIE on a first-of-its-kind CFE Manager Agreement to assemble and develop a carbon-free energy portfolio structured to align with Google's clean energy needs and carbon free energy goals in Germany throughout each hour of the year.
- In 2022, the CFE agreement enabled Google and ENGIE to match electricity demand with renewable energy sources resulting in a very high carbon-free energy usage in Germany. The goal is to reach 100 percent carbon-free operations by 2030 and to achieve this will require that more carbon-free capacity is added to the portofolio.[7]
- Google's digital infrastructure in Germany uses air cooling instead of water helping conserve water resources in data centre operations in their respective locations.

People: Providing 5,200 stable jobs and fostering new digital skills for people in Germany

- In 2022, Google's digital infrastructure investment and operations in Germany supported approximately 2,100 direct jobs, 1,350 indirect jobs, and 1,800 induced jobs, generating around 290 million euros in labour income. The number of total supported jobs has been growing at a remarkable rate of 65 percent annually since 2020.

- Google's investment in Germany contributes to the quality of life through its digital skills training initiatives. Around 1.9 million people in Germany have been trained through the initiative of the Google Zukunftswerkstatt (a Grow with Google program), while over 250,000 individuals have benefited from grants to schools and learning institutions.

Prosperity: Contributing approximately 1.2 billion euro to German GDP in 2022

- From 2017 to 2022, Google invested around 1 billion euros in digital infrastructure[8] in Germany and significantly contributed to the German economy through its infrastructure investments and operational expenses.

- The total impact on Germany's GDP in 2022 is estimated at almost 1.2 billion euros, comprising of:

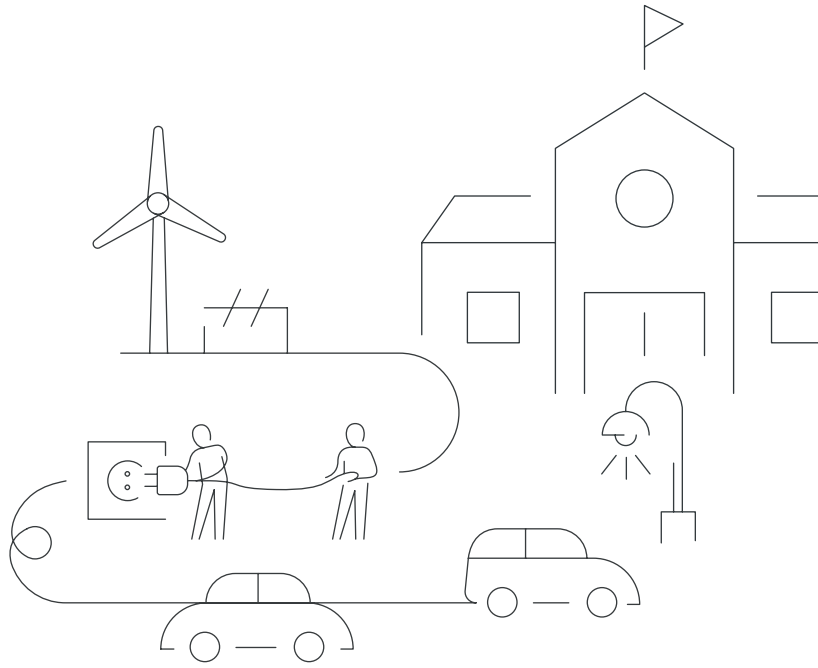
- 110 million euro from operating the infrastructure

- 90 million euro from investing in the infrastructure

- 1,000 million euro from increased productivity for German user firms

Google's investment in Germany's digital infrastructure delivers valuable social returns while promoting sustainable resource utilisation. This report finds that Google's digital infrastructure has a positive impact on both the social and economic well-being in Germany. A significant social return on investment (SROI) of about 2.1 euros for every euro invested in 2022 demonstrates Google's positive contributions. Additionally, the company's highly efficient data centre operations and carbon-free energy achievements in 2022 show that these positive societal outcomes can be achieved while minimising its environmental footprint.[9]

As the digital economy grows in Germany and beyond, so will Google's operations. This will require more employees and entail more opportunities for local suppliers. Higher load will also require Google to source additional carbon-free energy supply to keep up with demand for its products and services. In turn, and with more renewable energy projects, this will help other businesses, people and governments to reduce their own emissions, too.



DIGITAL INFRASTRUCTURE

Google has **invested about 1 billion euro in digital infrastructure** from 2017-2022

Computing facilities

Facility security

Data storage

Data processing

Fit out anda construction

Maintenance

Air cooling

Power purchasing agreement with ENGIE

Network
Fibre cables
Sub-sea cables
Edge computing facilities

PEOPLE

5,200 jobs
supported at Google, their suppliers and local businesses in 2022.

290 million euro
in labour income sustaining secure livelihoods of German families and individuals in times of uncertainty.

1.9 million people trained
improving their digital skills which are essential for reaping the benefits of digitalization.

PLANET

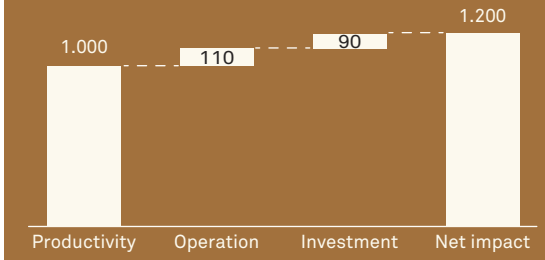
Google's **hourly matching with carbon-free energy**

>80%
carbon free energy

Approx. 0 impact
Water Air

PROSPERITY

1.2 billion euro
in GDP contribution mainly from productivity gains generated at German firms using Google's cloud solutions.



CHAPTER 1
Introduction

Digital infrastructure is essential in our digitally-driven society, driving economic activity and job opportunities throughout Germany. Google's investment in digital infrastructure in Germany has significant economic, social, and environmental impacts. To evaluate the impacts of this investment, Google engaged Implement Consulting Group, conducting an impact assessment with three dimensions: Planet, People, and Prosperity.

This report evaluates Google's digital infrastructure investments from 2017 to 2022 in Germany, providing stakeholders a clear understanding of their impact. It examines various aspects, including Frankfurt and Berlin-Brandenburg cloud regions, digital networks, technical equipment, and the power purchase and CFE Manager agreements with ENGIE. The assessment considers both positive and negative effects using comprehensive primary and secondary data.[10] Indicators from the OECD's Better Life Index[11] are used to measure the effects, contributing to Germany's digital transformation and sustainability. Additionally, it employs a robust approach to stakeholder engagement to prioritise topics most critical to both stakeholders and Google.

The report is structured accordingly: Chapter 2 presents an overview of Google's digital infrastructure footprint in Germany. Chapter 3 analyses Google's activities in the context of the external business environment in Germany. Chapter 4 conducts a materiality assessment to identify key topics for stakeholders. These topics are then explored in Chapter 5, which examines Google's positive and negative impacts on Planet, People, and Prosperity in Germany. Finally, Chapter 6 concludes the report by discussing the existing challenges and opportunities for the future.

CHAPTER 2
Google's digital infrastructure in Germany

Google's digital infrastructure in Germany encompasses:

- A data centre in Hanau[12], near Frankfurt, and additional operations in Frankfurt and Berlin-Brandenburg.
- Proprietary hardware and networks linking these facilities and technology such as Google Cloud to users.

The digital infrastructure is backed by a state-of-the-art power agreement which empowers ENGIE to assemble and develop a carbon-free energy portfolio in Germany (see section 5.1 for details).

Between 2017 and 2022, Google contributed to Germany's digital infrastructure through:

Investments in digital setup: Upgrades to facilities, electrical equipment, servers, and land, particularly around Frankfurt, to meet the rising demand for dependable cloud services and advanced computing.

Skilled workforce development: Local hiring of engineers and administrators, boosting expertise in managing the digital infrastructure.

Vendor collaborations: Partnering with external experts to ensure seamless digital infrastructure operation.

Clean energy procurement: Utilising renewable energy from ENGIE in Germany to substantially reduce the carbon footprint of operations.[13]

Figure 1.

Map of Google's locations in Germany

Community support: Backing community projects like workforce development, computer science education, small businesses, and local food banks.

These actions underscore Google's commitment to expanding digital infrastructure in Germany while emphasising sustainability, local talent, and community welfare.

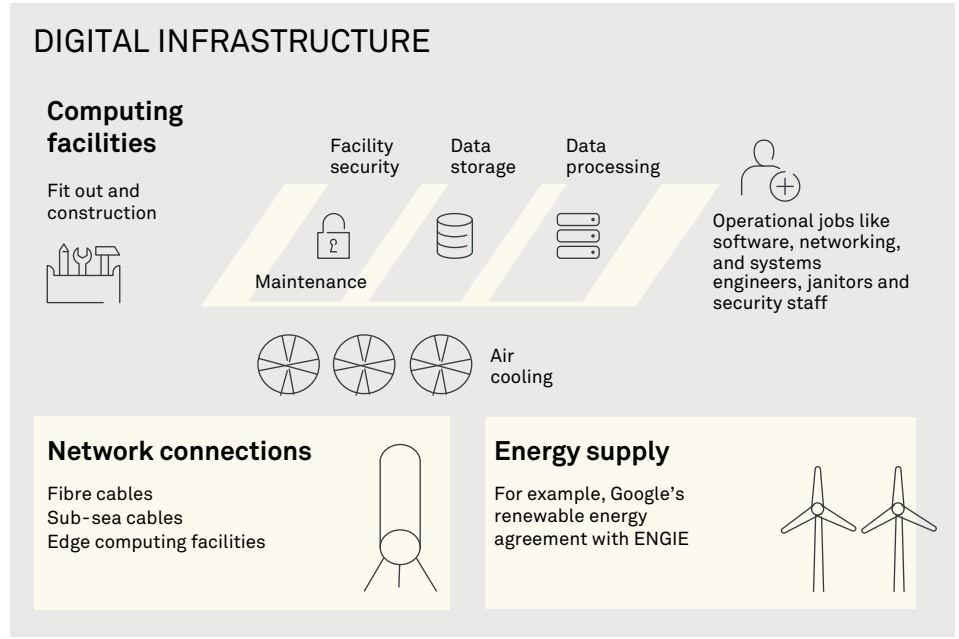
Box 1

The digital infrastructure is an integrated system of computing facilities, networks and renewable energy supply

WHAT IS DIGITAL INFRASTRUCTURE?

A computing facility, also known as a data centre, houses high-powered computers known as servers and related equipment such as networking devices, storage systems and communication links. Its primary objective is to facilitate large-scale and efficient computing operations. Digital infrastructure plays a vital role to support the use of digital services by individuals and companies. The digital infrastructure handles extensive computational tasks, ensuring smooth and uninterrupted delivery of services.

Google's digital infrastructure in Germany offers secure cloud, AI, and advanced computing services vital to sectors like manufacturing and finance that drive the German economy. For a detailed breakdown of the cloud market by sector, please refer to the table 1 below. Google is helping local and global clients in Germany innovate, including startups, in retail, telecommunications, media, and health tech (see Box 2).



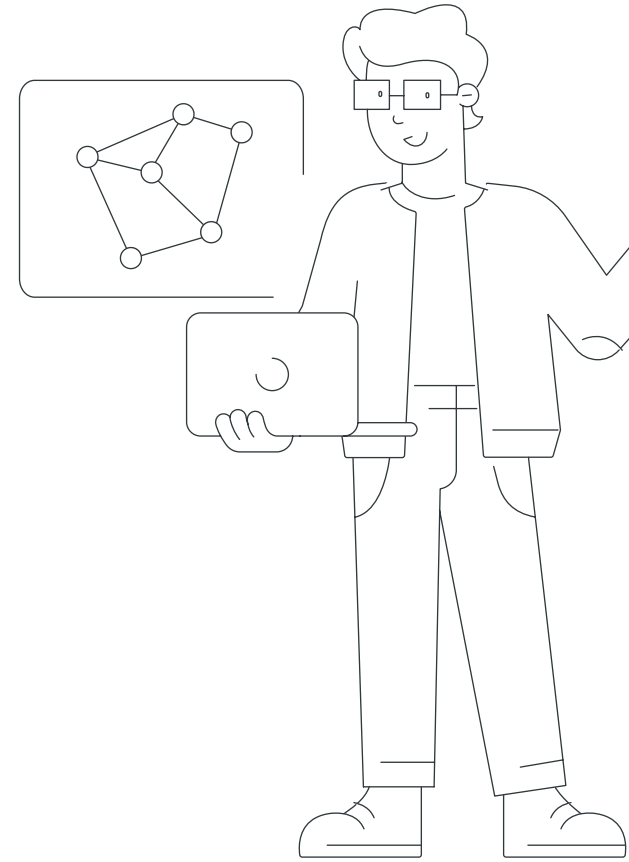


Table 1.

Share of total cloud market by industry in Germany
Percent share of total value in 2022

	Percent
Manufacturing	28%
Finance and insurance	16%
Business services	14%
Public sector, education and health	14%
Trade and transport	14%
Information and communication	8%
Utilities	4%
Consumer services	1%
Construction	1%
Other	0%
Total	100%

Source: Implement Economics based IDC data.

Box 2

Google is aiming to simplify access to technology and make it easy to use

- **Manufacturing**: Volkswagen is collaborating with Google Cloud to design more energy efficient cars.
- **Finance:** Deutsche Bank and Google Cloud are co-innovating the next generation of cloud-based financial services.
- **Retail:** Otto Group, a leading online-retailer and service group in Germany and one of the world's largest ecommerce companies, migrated their SAP workloads to Google Cloud in order to modernise their SAP landscape and build a more agile environment that would enable them to quickly scale up or down according to business needs.
- **Media:** BMG, a global music company, helps artists and songwriters navigate the complicated royalties landscape of the digital music industry using Google Cloud.
- **Healthtech:** Using the Google Cloud Platform, FORMEL skin, a healthtech startup, is innovating digital healthcare by developing a platform for tackling chronic skin conditions.

Source: Implement Economics based on Google blog posts.

"Our vision for cloud computing is to simplify access to technology for businesses and to make it so easy that anybody can get access to it and use it extraordinarily easily."

– Thomas Kurian, Google Cloud CEO[14]

CHAPTER 3
External business environment analysis

This chapter serves to put Google's digital infrastructure investments into the perspective of the external business environment in Germany.

Germany is the largest economy in Europe and the fourth largest globally.[15] A significant proportion of the German economy can be attributed to its strong focus on international trade and the integration of its manufacturing sector into global value chains. Germany's total foreign trade as a share of its GDP is particularly high at about 80 percent.[16]

Germany's economy grappled with challenges from Russia's invasion of Ukraine, energy uncertainty, and pandemic-related trade disruptions. To address these issues, the nation is intensifying efforts to cultivate renewable energy sources to both diversify the energy supply and align decarbonisation with economic expansion. Meanwhile, businesses across sectors are embracing cloud and AI technologies, catalysing investments in energy-efficient infrastructure.

3.1. Germany's digital performance

Germany's future competitiveness hinges on its ability to enhance productivity and maintain high employment levels through innovation and new technology, as the German Council of Economic Experts emphasises.[17]

Digital technology has become a foundational element for all industries (a so-called general-purpose technology), and digitalisation and new AI solutions are becoming an ever more important determinant of modern age competitiveness.

3.1.1. Germany's digital infrastructure is lagging behind

The quality of the digital infrastructure is a key factor that directly impacts the successful diffusion of digital technologies. According to the OECD, Germany faces shortcomings in infrastructure investment, particularly in digital infrastructures such as mobile and fixed broadband connections. Insufficient fibre connections and slow performance in small and rural municipalities contribute to the country's digital infrastructure lagging behind leading nations. Furthermore, under-investment in knowledge-based capital has undermined German firms' innovation potential over time.[18]

3.1.2. German cloud adoption is behind EU digital frontrunners

Cloud adoption, although accelerated during the pandemic, remains relatively low in Germany compared to EU digital frontrunners.[19] While overall cloud adoption in Germany of 42 percent is on par with the EU average of 41 percent, the manufacturing sector, which is a vital component of the German economy, lags with a 38 percent adoption rate compared to the EU average of 40 percent and the frontrunner average of 62 percent.[20]

3.1.3. Germany has a digital skill gap

As the digital transformation continues to reshape the job market, it is crucial for German workers to acquire new skills to remain competitive.

The current digital skills within the German workforce are inadequate for the future, as evident by the shortage of 96,000 skilled IT workers.[21] Only 49 percent of Germans possess basic digital skills, below the EU average of 54 percent and significantly lower than the average of frontrunner countries at 67 percent.[22] Given these circumstances, enhancing digital skills is a top priority for the German Government.[23]

This highlights the need for substantial investments in training and education, making Google's digital training programs and knowledge sharing initiatives increasingly pertinent.

3.1.4. Digitalisation is crucial for competitiveness

An advanced digital infrastructure has become a fundamental aspect for competitiveness across all industries, and digital solutions such as AI are increasingly crucial for maintaining competitiveness. Unlocking the digital potential of the German economy has become a primary imperative. This is particularly crucial in light of the economic slowdown in Germany and the weakened export demand resulting from the current global economic outlook.[24] The significance of digitally-enabled competitiveness is now more critical than ever.

CHAPTER 4
Topics that matter most to stakeholders

This chapter outlines the essential environmental, social, and economic concerns that are significant for stakeholders in Germany, including the public sector, industry, services and not-for-profits. Our report is structured around these areas, analysing how Google's digital infrastructure impacts these dimensions. To gain a more comprehensive understanding of stakeholder types, engagement and topic prioritisation, please refer to the report's annex.

Based on input from internal and external stakeholders, we have identified 14 key topics. Among these, six primary topics emerged as the top priorities for stakeholders:

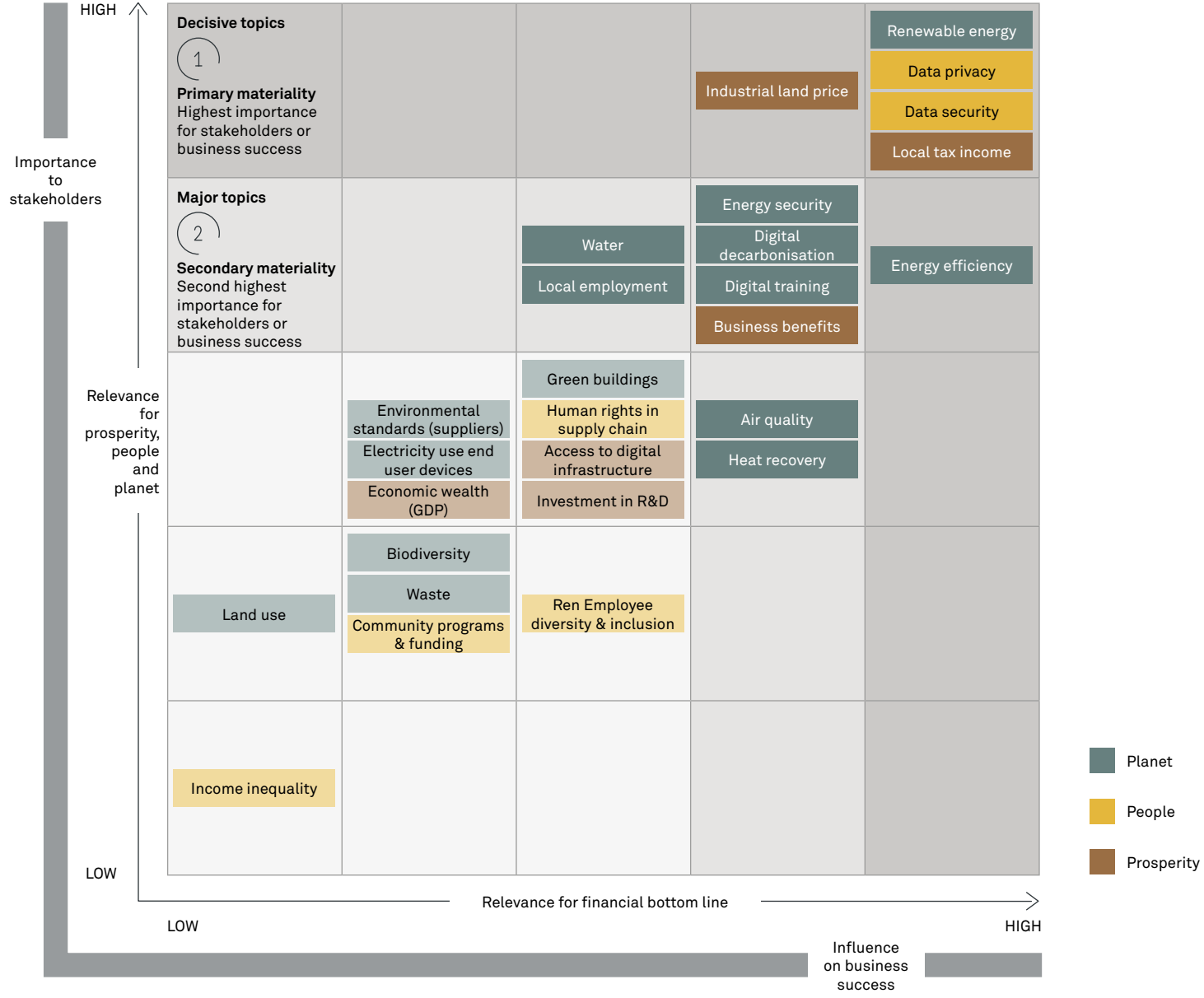
- Renewable energy
- Energy efficiency
- Local tax income
- Data privacy
- Data security
- Industrial land prices

Furthermore, we identified an additional eight themes that ranked secondary in importance for both stakeholders and business success:

- Cloud computing benefits
- Digital skills
- Digital decarbonization
- Energy security
- Local employment
- Water resources
- Air quality
- Heat recovery

Figure 2.

Mapping of the importance of topics for German stakeholders



RENEWABLE ENERGY

Renewable energy is a must, but supply is scarce

Renewable energy is important to cloud users due to their own climate commitments in their operations and supply chains.

State and administrative stakeholders are concerned about local contribution to climate change.

DATA PRIVACY

Data privacy is a public concern

Individuals are more concerned about how their data is used rather than more "macro" issues like the climate and productivity gains.

Public entities require strict GDPR compliance, and private companies are also firm in stating their requirements in this area. However, due to EU regulation, confidence is high.

LOCAL TAX INCOME

Scepticism about local tax contribution from data centres

Stakeholders consistently place high importance on data centres paying local tax income, including corporate tax, taxes for suppliers and employees, and thereby contributing to the prosperity of local communities.

INDUSTRIAL LAND PRICES

Industrial land price increases is a concern for local businesses in metro areas

In Germany, Google data centres are mainly located in metro areas. Land in industrial zones in proximity to larger cities is scarce, and data centres can put in higher bids than most smaller businesses with lower margins.

There is a public perception that this drives up prices and can potentially displace local business owners.

ENERGY EFFICIENCY

Energy efficiency is key from a climate, cost and resilience perspective

With reference to Russia's invasion of Ukraine and the energy crisis, energy efficiency is stated as a main concern by most stakeholders.

They are concerned about meeting their carbon reduction targets and about costs of production.

DATA SECURITY

Data security is a fundamental hygiene factor

Data security is highly relevant and an absolute prerequisite for customers. The confidence that data centre providers can deliver on this is generally high.

Businesses emphasise the importance of their data being stored within the EU.

These topics influence Google's actions in Germany, contributing to their decision-making on infrastructure development. Google aligns with these priorities through energy-efficient digital infrastructure, renewable energy investments, fostering local business innovation, and enhancing digital skills among Germans. In the next chapter, we will evaluate the impact of Google's infrastructure based on these priorities.

CHAPTER 5
Impact assessment

Google is creating social value in Germany with a sustainable use of natural resources

This chapter examines the impact of Google's technical infrastructure investment and operations on key stakeholder concerns. We assess the effects on three important dimensions: *Planet* (environmental dimension), *People* (social impact) and *Prosperity* (economic impact). Throughout this assessment, we aim to quantify the impact using relevant indicators from the OECD's *Better Life Framework*. By evaluating both the positive and negative outcomes, we provide a comprehensive analysis of how Google's infrastructure investment in Germany influences the topics that are of utmost importance to stakeholders.

5.1. Planet

Google's digital infrastructure in Germany operated on locally sourced carbon-free energy almost every hour of the day throughout the year in 2022, as Google continued to advance its ambitious goal to operate entirely on carbon-free energy by 2030.[25] The digital infrastructure is energy efficient. Google's digital infrastructure uses air cooling instead of water cooling systems, which helps conserve water resources. Also, local air pollution impact is negligible.

In this section of the report, we first discuss the efficiency of Google's digital infrastructure with respect to energy management and resource utilisation and address the choice to use air cooling and its implications for energy consumption. Secondly, we assess Google's contribution to the net-supply of renewable energy, highlighting how Google achieves a high hourly carbon-free energy score.

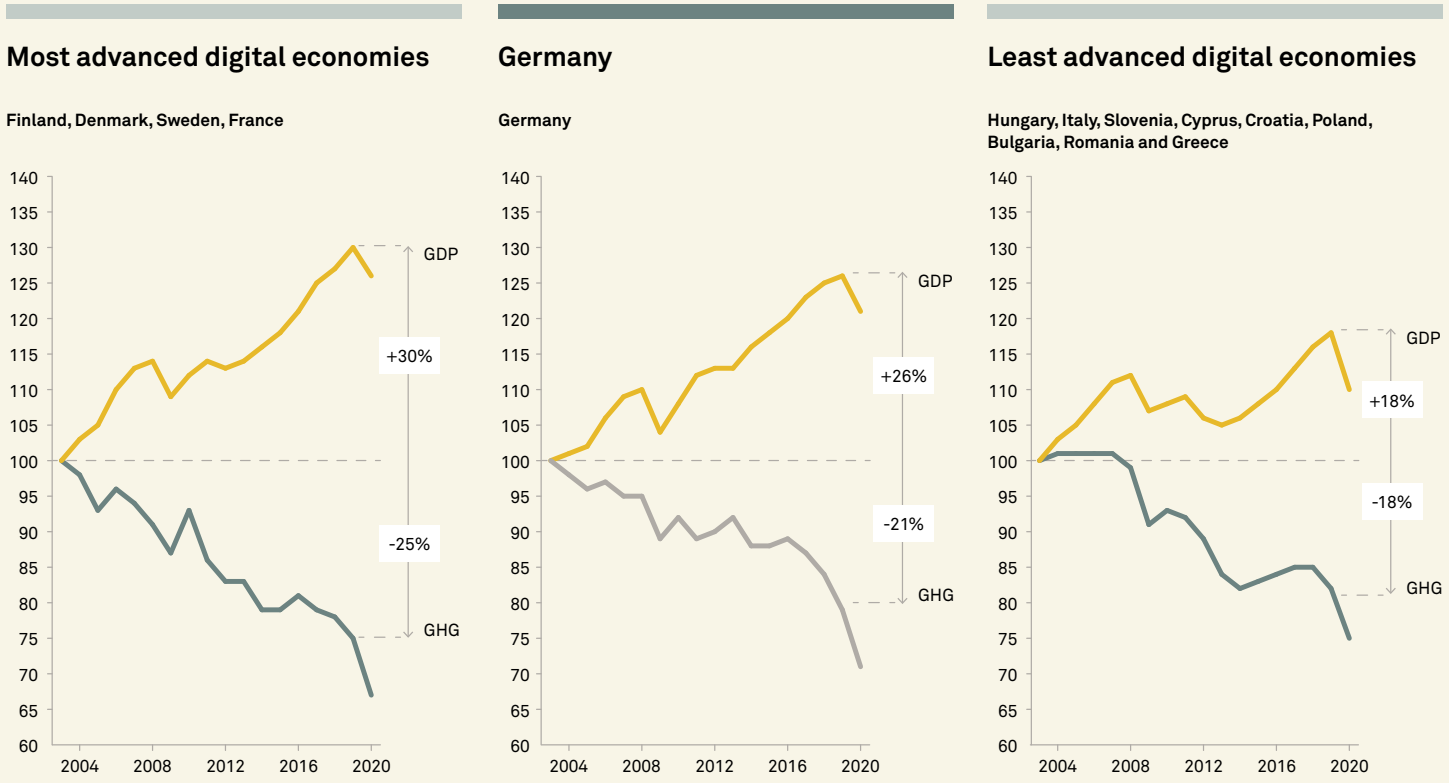
In assessing the environmental impact, we also explore how Google's digital solutions enable the emissions reductions and decarbonisation efforts in other sectors of the German economy.

Box 3

Decarbonisation happens faster in the most digitalised economies

The level of digitalisation varies across the EU countries as measured by the European Commission's DESI-index. The most digitalised economies have achieved a strong decoupling of greenhouse gas emissions (-25% since 2003) from economic activity (+30%). Germany is in the mid-field of Europe's digital economies and has seen slightly slower growth (+26%) and slightly slower decarbonisation (-21%). Germany's digitalisation and carbon efficiency would need to accelerate to be among the frontrunners in Europe to experience robust growth aligned with increased decarbonisation.

GDP and greenhouse gas
Index 2003 = 100



Source: Implement analysis, Digital Decarbonisation report for Germany.

Material topic
Energy efficiency

5.1.1. Efficient use of resources for the digital infrastructure

With Germany's rising electricity demand and a deepening dependence on digital solutions, the efficiency of the digital infrastructure gains paramount importance for stakeholders. This concern is accentuated by Germany's recent energy crisis and the disrupted imports of Russian gas. Achieving sustainable digital solutions for German users hinges significantly on an energy efficient digital infrastructure.[26] In contrast to conventional data centres, including small enterprise setups, large efficient cloud facilities like Google's show significant advantages.

Google's digital infrastructure is more energy efficient than the industry average

Google has world-class standardised practices for operating its digital infrastructure and is introducing the world's most energy efficient servers to Germany with their investments in digital infrastructure.[27] At global scale, Google's cooling system boasts an industry-leading power usage effectiveness (PUE) of 1.1, minimising energy consumption.[28] In Germany, Google uses air cooling which uses slightly more power but conserves water.[29] In 2021, German data centres across the industry had an average PUE of 1.56.[30]

The government's updated draft Energy Efficiency Act from July 2023 will require a PUE value of 1.2 or lower for new data centres going into operation after July 1, 2026.[31] Google will need to meet this requirement for its new data centres in Germany.[32]

Optimising resource use with large-scale digital infrastructure

Google's digital infrastructure and other hyperscale data centres are more energy efficient than smaller enterprise data centres.[33] Large data centres allow for economies of scale as the overhead energy for cooling etc. can be distributed across more machines. Moreover, they have the advantage of hosting multiple digital solutions simultaneously. This enables efficient resource allocation among numerous users. A small company with its own e-mail server may need to purchase more servers than needed to accommodate their needs, which ultimately consumes more energy and results in a less efficient solution. Google's digital infrastructure and cloud solutions offer scalability, ensuring applications align with actual needs.

As a result, large-scale cloud infrastructure can accomplish more with less energy and in the case of Google's facilities they globally exhibit 1.5 times the energy efficiency of typical enterprise data centres.[34]

Box 4

Examples of how Google's cloud solutions save energy

65-90% REDUCTION

A study from the US public sector showed that by switching to Google Apps such as email, calendaring, spreadsheets, documents, and other applications, users were able to reduce office computing costs, energy use and carbon emissions by 65-90 percent.[35]

98% REDUCTION

Another study has shown that businesses that use Gmail have decreased the environmental impact of their email service by up to 98 percent compared to those that run email on local servers.[36]

Source: Implement Economics based on a case study of the U.S. General Services Administration (GSA) and Google study.

German companies have yet to fully embrace cloud solutions compared to other leading European countries.[37] Transitioning to cloud computing can result in significant energy savings. Consider the hypothetical scenario of migrating all current capacity from non-cloud data centres to large-scale cloud infrastructure. This shift to the cloud alone could reduce energy consumption in Germany by 3-4 terawatt-hours (TWh), which is equivalent to a 20 percent reduction of energy use by data centres. This energy efficiency potential corresponds to the electricity use of more than a million German households or 3 percent of German households.[38]

Material topic **Water**

Minimising water usage and supporting water security

Google's overall cooling approach aims to minimise the net climate impact today and in the future.[39] As part of this approach, Google evaluates local factors such as responsible water use and the availability of carbon-free energy to determine the best cooling solution.

Google's cooling solution in Germany is an air-cooled technology, reducing the need to consume water for data centre cooling. Compared to water cooling, this implies a slightly higher energy use[40], which is nearly carbon-free (see section 5.1.2).

5.1.2. Supporting renewable energy in Germany

Material topic **Renewable energy**

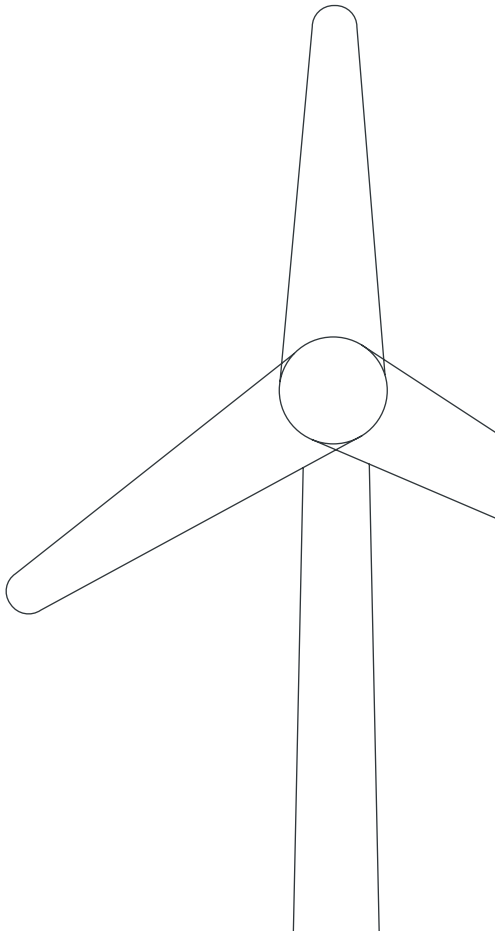
Material topic **Energy security**

Not only should the digital infrastructure be as energy efficient as possible, it should also run on as much carbon-free energy as possible. Renewable energy is a key element in achieving the German government's net-zero goal for 2045.[41] Renewable energy capacity in Germany will need to increase by a factor five to achieve the net-zero goal by 2045 and the share of power production from renewable energy will need to increase to 100 percent from the current level of 46 percent in 2022.[42]

The energy efficiency act affirms this course and establishes targets for energy efficiency including for data centres.[43] From January 2024, data centre operators will be required to purchase renewable energy equivalent to 50 percent of their electricity demand, rising to 100 percent from January 2027.

Google has already supported 182 MW of renewable energy projects in Germany in 2022 through a unique *CFE Manager agreement* with ENGIE which supports Germany's national renewable energy goals and demonstrates Google's commitment to operating on carbon free energy at all times (see Box 5).[44]

Google has also signed renewable energy deals to expand supply further. In 2021, Google signed a 50 MW PPA with Orsted for the Bokram Riffgrund 3 offshore wind farm,[45] which will be operational in 2025. In July 2023, around 20 MW of solar capacity was added to the ENGIE portfolio.



Box 5

Investing in renewable energy in partnership with ENGIE

Google signed a **CFE Manager agreement** with ENGIE in 2021 to supply renewable energy to Google's operations.[46] With the CFE Manager agreement, Google has tasked ENGIE with assembling a portfolio of carbon-free energy projects designed to better match its demand with clean electricity in every hour of the year. Compared to an energy user like Google signing its own PPAs, the CFE Manager model reduces the transaction costs, shifts PPA risks to the entity best suited to manage them (the energy service provider), and can lead to greater decarbonisation of hourly electricity consumption and a competitive price. The model is also scalable since contracts can be designed so that the portfolio of clean energy projects keeps pace with Google's growing electricity demand.

The agreement is a **24/7 carbon-free** arrangement, which means that ENGIE keeps track of the actual renewable energy production from the agreement hour-by-hour all year round and tracks how this matches Google's electricity consumption in each hour. 24/7 carbon-free energy deals are the new gold standard and there is an important difference between 24/7 hourly matching of demand with clean energy supply, and the current industry approach of operators sourcing an equivalent volume of renewable energy to match their *annual electricity demand* (which is not as impactful on emissions).

The ultimate goal is to ensure that Google has a supply of carbon-free energy at all times and the ENGIE CFE Manager agreement is a key element in actually eliminating the operational greenhouse gas emissions from Google's digital infrastructure.

A recent study from the Technical University of Berlin (TU Berlin) shows that 24/7 carbon-free energy (CFE) procurement leads to lower emissions for both the buyer and the system, as well as reducing the needs for flexibility in the rest of the system. Based on detailed cost modelling, the researchers from TU Berlin find that reaching a CFE score of 90-95 percent can be done with only a small cost premium compared to annually matching 100 percent renewable energy. 90-95 percent CFE can be met by supplementing wind and solar with battery storage. Reaching 100 percent CFE target is possible but costly with existing renewable and storage technologies, with costs increasing rapidly above 95 percent. These costs come down significantly if a broader portfolio of next generation technologies is introduced.

Source: Implement Economics based on Riepin and Brown (2022), System-level impacts of 24/7 carbon-free electricity procurement in Europe, TU Berlin, Xu and Jenkins (2022), System-level Impacts of 24/7 Carbon-free Electricity Procurement, Princeton University, IEA (2022), Advancing Decarbonisation through Clean Electricity Procurement, Oman (2021), A blueprint for Clean Energy in Europe, and Implement Consulting Group (2023), Digital Decarbonisation report for Germany.

Box 6

The CFE Score

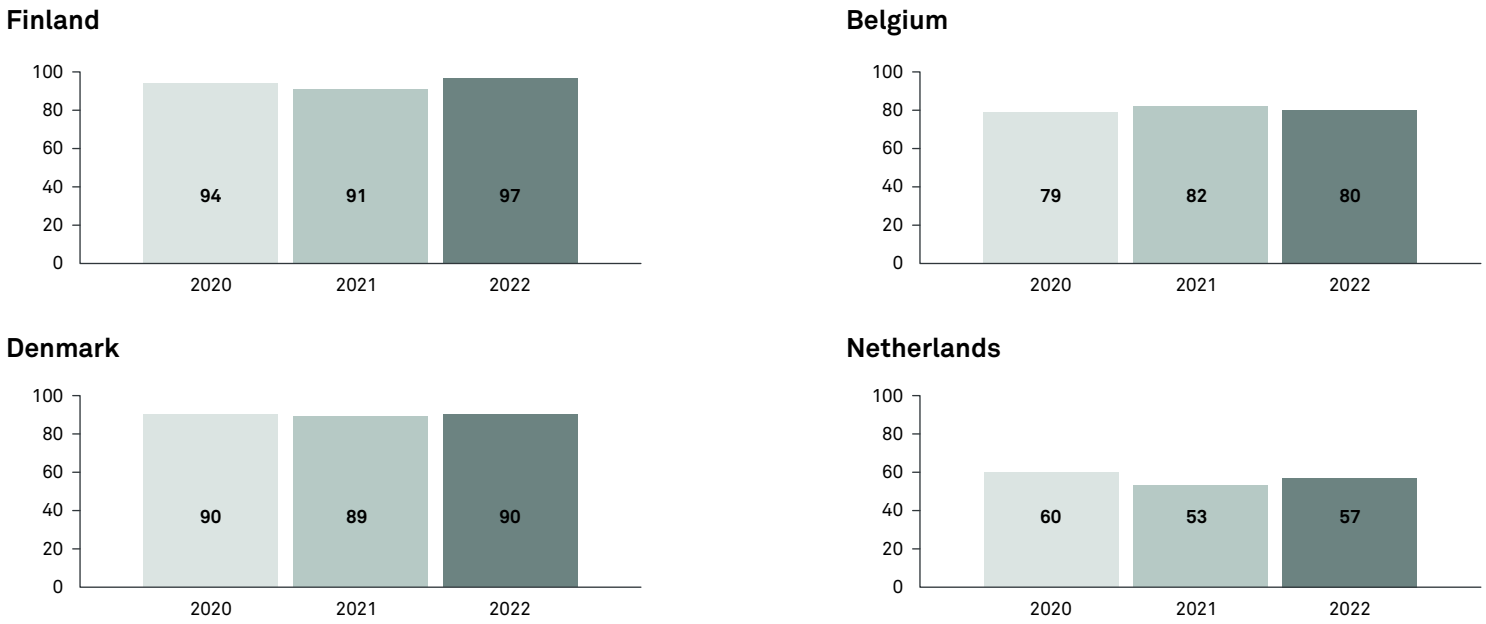
The **carbon-free energy score** (CFE Score) measures the degree to which each hour of electricity consumption on a given regional grid is matched with carbon-free energy on an hourly basis.[47]

When assessing the CFE performance, it is important to acknowledge that CFE scores can vary from location to location and from year to year. Google's CFE score depends on a range of factors such as the amount of renewable energy from its power deals on the same grid, the local grid mix in the given year and how well the supply of carbon free energy matches hour-by-hour with Google's power demand (see figure 3).

Source: Google CFE methodology.

Figure 3.

Google carbon-free energy (CFE score)
Percent



Source: Implement Economics based on published Google data.[48]

Assessing the impact of the Google's CFE Manager agreement with ENGIE in Germany for 2022 we find:

- Google's renewable energy portfolio with ENGIE consisted of 182 MW land-based wind farms in 2022. In 2022, the portfolio consisted of out-of-subsidy wind farms, i.e. wind farms that are no longer eligible for the German renewable subsidy scheme.[49] This means that a proportion of the capacity may have been retired and taken out of production without ENGIE's agreement with Google.[50]

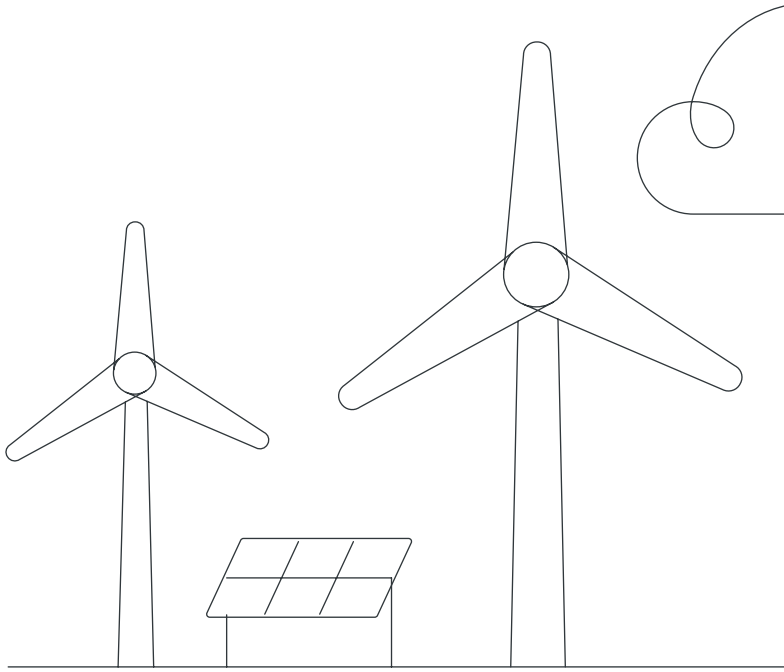
- Thanks to the CFE agreement with ENGIE, Google's power use is more carbon-free than the grid average. Google's German infrastructure had a CFE score[51] of 60 percent in 2021 and with the ENGIE CFE agreement it increased to 96 percent in 2022.[52] This is significantly higher than the average grid mix in Germany of 56 percent in 2022.[53] Google has set a target of 100 percent hourly carbon-free energy by 2030.[54]

In this report, we assess Google's impact in Germany against the indicators in the OECD's Better Life framework. The relevant indicator in the OECD framework in this context is the *greenhouse gas emissions from domestic production*.

Given that Google's operations were nearly carbon-free in the year 2022, we assess that Google's operations are currently close to the maximum of what is attainable within the existing energy system and associated costs (see Box 5). As a result of the high energy efficiency and the CFE Manager agreement with ENGIE, the domestic carbon emissions in 2022 stemming from Google's operations in Germany were minimal. These emissions are stemming from electricity use in hours during 2022 where the electricity was not 100 percent carbon-free.[55] This is typically in hours with high demand and lack of wind. As a result, Google's operations had a very small negative impact on the Better Life indicator of *domestic* greenhouse gas emissions from production in that year.

However, the small amount of domestic emissions in Germany were fully matched by clean energy elsewhere in Google's global renewable energy portfolio ensuring Google achieves a 100 percent renewable energy match on an annual basis for its global operational emissions, which it has done since 2017.[56]

To put this into perspective, it is important to note that Google's operations are much more carbon-free than the average of the data centre industry in Germany. A recent report from the German tech industry association, Bitkom, estimated that data centres in Germany are associated with emissions of around 8 million tons of carbon-dioxide equivalents (MtCO2e) in 2022.[57] If all digital infrastructure in Germany pursued the best practices of the leading operators in terms of energy efficiency and hourly carbon-free energy purchases, emissions from Germany's digital infrastructure could be lowered to around 1 MtCO2e, when factoring in CFE purchases as above.[58] This would be beneficial towards the German government's net-zero goal for 2045.[59]



5.1.3. Helping German companies and consumers decarbonise through digitalisation

Material topic
Digital decarbonisation

Google is playing a role in Germany's cloud adoption and supporting broader decarbonisation efforts. A conservative estimate suggests that Google's involvement leads to yearly reductions of 0.1 MtCO2e in Germany.[60] This reduction is significantly larger than the emissions from its own digital infrastructure operations, demonstrating that Google helps reduce more emissions in Germany than it generates. Box 7 demonstrates how Google's solutions can help achieve digital decarbonisation.

Box 7

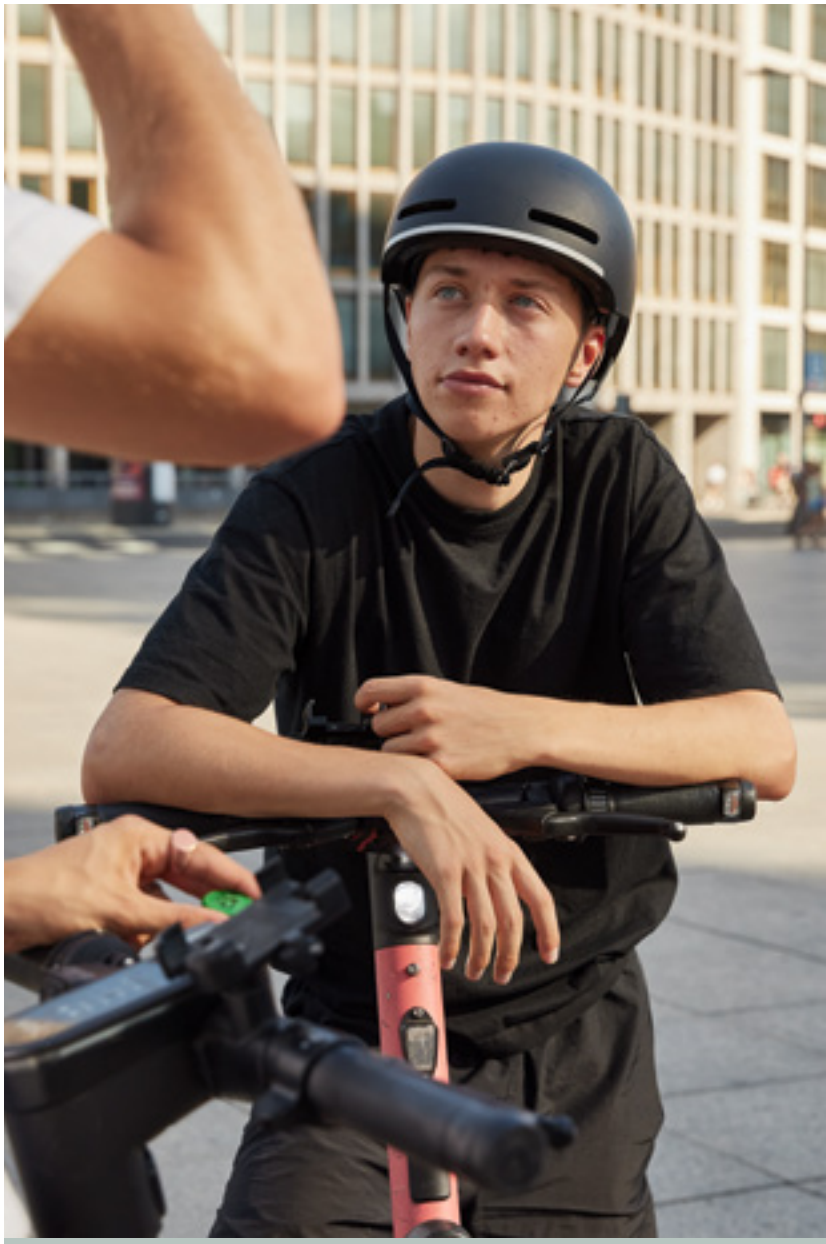
Digital solutions reducing carbon emission in Germany

German railway company **Deutsche Bahn (DB)** and Berlin's public transport company **Berliner Verkehrsbetriebe (BVG)** are digitalising public transport using Google Maps (an advanced AI solution) to enhance the passenger experience and ease the transition toward low emission options.

Mercedes-Benz, the German car manufacturer, has partnered with Google to create the next-generation navigation system that utilises Google Maps to provide drivers with access to real-time and predictive traffic information, alternative route suggestions to reduce congestion and emissions. Eco-friendly routing can save nearly 30 percent of expected fuel consumption.

Google's AI tool **Green Light** uses AI to optimise traffic lights at intersections with the aim to minimise congestion and related pollution.

Source: Implement Economics based on Google blog article from Tagesspiegel.



5.1.4. Heat recovery

Material topic
Heat recovery

Google is actively assessing onsite and offsite heat recovery opportunities at various locations across Europe. Google has already implemented on-site heat recovery in some of its European data centres (e.g. in Belgium, Ireland and Finland for heating office buildings, technical buildings, and logistic buildings). Capturing data centre heat represents an important opportunity for energy conservation and can contribute to the German energy transition. These opportunities should be enabled where it is technically feasible and environmentally sound. Offsite heat recovery opportunities should be assessed with local authorities and off-take partners. This is in fact happening in multiple locations across Europe.[61] It is important to note that the availability of an offtaker is a prerequisite for the offsite heat recovery at a local level.

5.1.5. Air quality

Material topic
Air quality

Digital infrastructure must be designed and built for resilience, efficiency and security. To ensure security of power, Google has onsite emergency power capacity using the best available technology meeting all permit emissions limits. The onsite power equipment is only for emergency use and is only in use for rare and very brief mandatory testing. Google is also starting to use low carbon fuels to help further reduce the very limited emissions from the backup generators. The local air emissions are thus negligible.

Furthermore, Google is piloting batteries at their data centres, storing solar energy to replace part of the onsite power equipment.[62]

5.1.6. Conclusion on environmental impacts

Globally, Google's data centres are 1.5 times as energy efficient as traditional data centres, thanks to smart energy practices. Combined with its clean-energy use, this makes Google's cloud solutions environmentally preferable, benefiting businesses that use them. Google's German digital infrastructure operates efficiently, utilising air cooling to avoid water consumption and minimise local air pollution and noise.[63]

Our assessment shows that Google's digital infrastructure in Germany not only exemplifies responsible resource usage but also adheres to Better Life indicators for environmental well-being. This alignment with the Better Life Indicators signifies that the evaluated aspects meet the standards established by the Better Life Index for overall well-being and sustainable progress.

Better Life indicator	Google's current impact (2022)
Renewable energy	**Neutral impact** because the ENGIE portfolio of 182 MW carbon-free energy projects in 2022 closely paralleled Google's energy consumption for the same period.
Greenhouse gas emissions from domestic production	**A combined positive impact on decarbonisation in Germany** when contrasting the small operational greenhouse gas emissions with the decarbonisation impact when enabling greenhouse gas reductions in other sectors of the economy.
Water stress	**Negligible impact** on water stress because Google's digital infrastructure in Germany is air cooled.
Air quality	**Negligible impact** on local air quality from the digital infrastructure.

5.2. People

Google's digital infrastructure is strategically positioned in the greater Frankfurt area, a significant European data centre hub, and recently expanded near Berlin. These locations create a demand for tech workers and serve as centres for Germany's skilled workforce.

In Germany, Google's digital infrastructure generates stable employment directly and within proximity to its main facilities. It also fuels job growth at user companies benefiting from Google's cloud solutions. Moreover, Google's commitment includes training and grants, empowering individuals with essential digital skills for improved employability and a more promising future.

5.2.1. Impact on jobs: Supporting stable, export independent and future proof jobs

Material topic
Local employment

Good jobs and income are vital for people's well-being as reflected in the Better Life Index indicators like employment rate and personal earnings. Google's digital infrastructure investment in Germany improves these indicators. It creates stable jobs around its locations and ensures secure employment at firms using its cloud solutions.

Direct, indirect and induced impacts: Jobs supported at and around the main facilities

We find that Google's investment and operation of digital infrastructure have supported more than 5,200 jobs and around 290 million euro in labour income in Germany in 2022. These are jobs at and around the facilities and cover:

- **Direct jobs** needed to run the infrastructure like highly skilled technical workers, administrative workers, security personnel, kitchen and cleaning staff. Some of these are direct Google employees, others are external contractors.
- **Indirect jobs** supported at suppliers outside Google's site, such as power suppliers, suppliers of technical equipment and other suppliers to the facility.
- **Induced jobs** supported at local businesses like retailers and cafes from the wage expenditure of Google's employees and suppliers.

The number of jobs supported has grown by **65 percent annually since 2020** compared to a national average annual employment growth in Germany below 1 percent in the same period.

Table 2

Jobs and labour income supported by Google in Germany, 2022

	Employment (number of persons)	**Labour income** (mEUR)
Direct jobs needed to run and build the computing facilities	2,090	125
Indirect jobs supported at suppliers outside the computing facilities	1,360	80
Induced jobs supported at local businesses from wage expenditures	1,790	85
Total	**5,240**	**290**

Source: Implement Economics based on OECD Input-Output tables and client data

The jobs and labour income supported by Google's investment and operations in Germany bring prosperity and upskill workers through experience. In addition, jobs associated with the digital infrastructure are uncorrelated with business cycles and independent of export market swings. These jobs can thereby cushion local economic slowdowns and bring stability to local employment.

Figure 4 illustrates the employment effects across industries. The construction sector experiences the highest impact, supporting around 1,200 workers due to Google's infrastructure investments. Meanwhile, Google's digital infrastructure operations support about 1,100 highly skilled workers in the information and communication industry. Key roles include ICT professionals (34 percent), ICT technicians (11 percent), and office associate professionals (9 percent).[64]

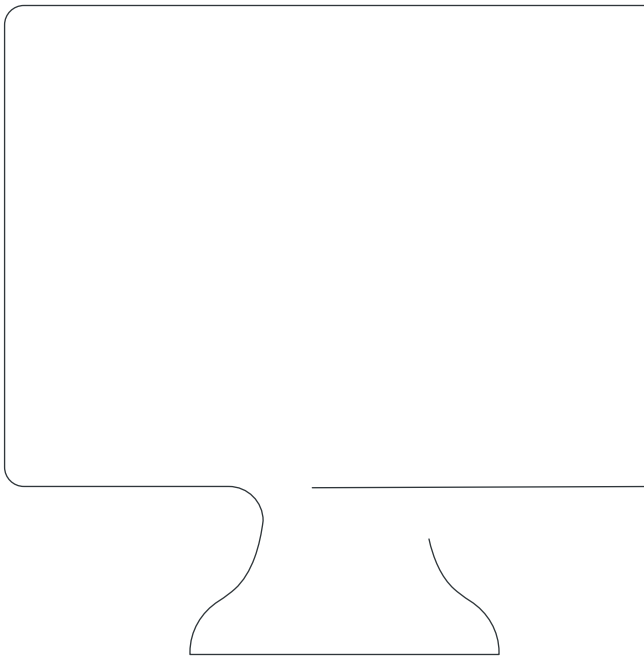
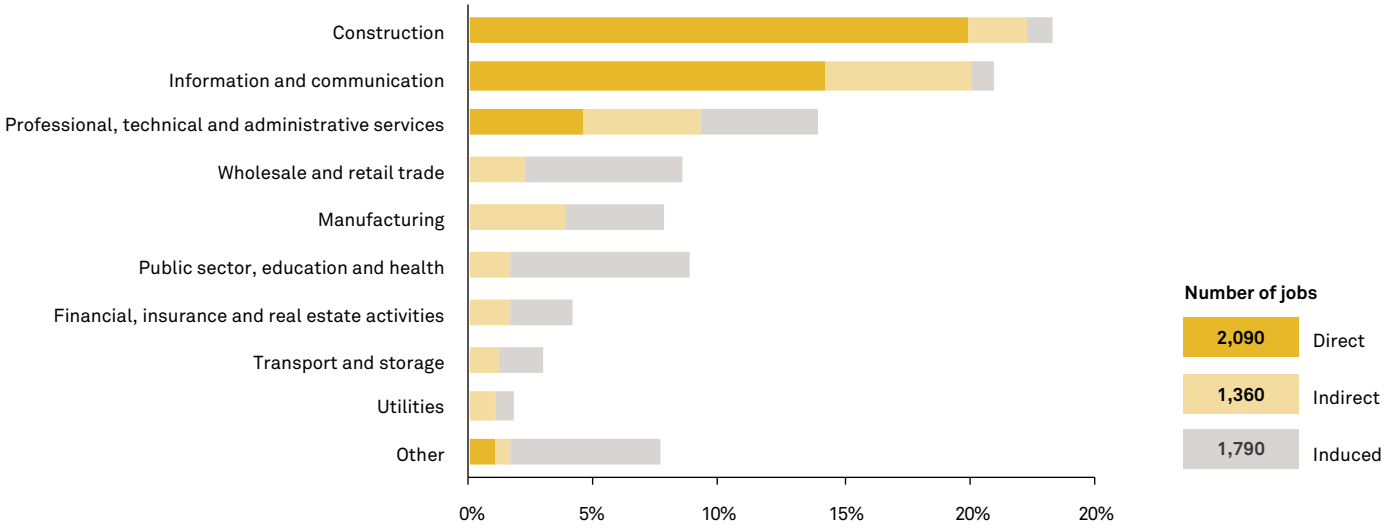


Figure 4.

Industry distribution of jobs supported by Google in Germany, 2022
Percent



Source: Implement Economics based OECD Input-Output tables and client data.

The jobs supported by Google provide a high quality of living for the employees because of good wages[65] and employee development.[66] These skilled employees could have likely found jobs elsewhere because their expertise is in high demand, even without Google's investment.[67]

In the Frankfurt region, which hosts the majority of Google's operations, the Information and Communication Technology (ICT) sector is experiencing rapid expansion. Nearly half of the tech companies in the area face the challenge of a skilled workforce shortage.[68] To address this, Google is playing an important role by providing training programs that cover essential soft skills and technical expertise.

Impact on jobs for cloud user firms

Studies by MIT and the OECD highlight the benefits of using cloud solutions, such as Google Cloud, for German businesses and public institutions, driving higher productivity and performance.[69] This increased competitiveness translates into improved job prospects and growth within Germany.

Google's cloud services to German companies helps them to increase activity due to innovation and operational efficiency. This enhanced competitiveness is assessed to support approximately 7,500 to 8,000 jobs across Germany and contribute to an added labour income of about 560-600 million euros in 2022. These jobs are primarily in productive and digitally-focused companies, which will contribute to the sustained economic growth of the German economy in the long term.

5.2.2. Helping improve digital skills of the German population

Material topic
Digital training

In today's digital world, strong digital skills are vital for success and active engagement in a society where digital platforms drive communication, community interaction, and government engagement. Unfortunately, there's a significant shortfall of these skills in Germany's workforce. For instance, the absence of 96,000 skilled IT workers makes up 5 percent of the country's current IT specialists.[70] The Digital Economy and Society Index (DESI) reveals that only 49 percent of Germans possess basic digital skills, which falls behind both the EU average of 54 percent and the leading European countries at 67 percent.[71] The European target for 2030 is to achieve an 80 percent proficiency in digital skills.[72]

To address this challenge, Google is playing a role in digital upskilling in Germany. Their efforts encompass substantial investments in *Grow with Google* digital training programs (Google Zukunftswerkstatt), forging partnerships and providing grants to German universities, as well as offering support for computer science and digital responsibility education. These investments yield a positive impact on three crucial Better Life indicators: digital skills, the wage premium linked to digital skills, and the digital competence of educators.

Google's training efforts help to reduce the digital divide and help to increase equitable access to digital skills.

Knowledge sharing with *Grow with Google*

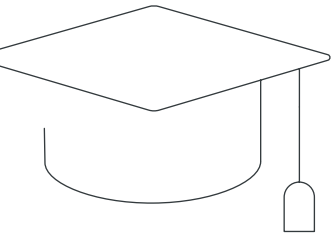
The Grow with Google program has empowered approximately 1.9 million Germans via the Google Zukunftswerkstatt with new digital skills from a broad training portfolio including computational thinking, AI, and machine learning. This has had a direct and positive impact on individuals, businesses, and the broader German economy.

For example, with the help of the Google Zukunftswerkstatt Grow with Google trainings, three young entrepreneurs successfully developed the sharing economy platform 'ShareSpace' by leveraging their Google Analytics training. This training significantly enhanced their data analysis skills and platform development.[73]

> "The insights from the Google Analytics training helped us tremendously in properly evaluating data and improving our platform".[74]

Investing in IT and technical skills training programs

Google's grants for digital training have enabled over 500 Germans to acquire certified IT courses, and more than 2,800 small business employees have enhanced their technical skills. The 2022 Skillsoft report underscores that better digital skills amplify work engagement and quality. Among employees who completed a certified course, 56 percent noted an increase in work quality, and 41 percent reported heightened engagement. Beyond these benefits, academic research reveals that digital skill training can boost employment chances by 5 percent and raise wages by 3 percent.[75] We estimate that Google's training initiatives contributed to a wage premium of at least 5 million euros in 2022.



Investing in computer science education

A recent Vodafone survey reveals that schools lack sufficient digital skills education. Over half of students find school digital equipment inadequate, and 70 percent of new workforce entrants feel unprepared for the digital world.[76] Google has boosted German digital education, training over 250,000 students and 370 teachers in computer science. Impressively, 90 percent of Google-trained students expressed strong interest in further computer science learning.

"Young people are optimistic about the digital future and recognise the importance of digital skills. Unfortunately, schools are not yet imparting these skills adequately, as our study has shown. In particular, young adults who have just started their careers do not feel sufficiently prepared for life and work in the digital world. This should be a wake-up call for us."

– Matthias Graf von Kielmansegg, Managing Director of the Vodafone Foundation Germany

Investing in digital responsibility

Almost half of Germany's youth lack clarity on internet data protection and responsibility and about 30 percent are uncertain about identifying fake news. Google's online teacher training fosters responsible digital use, covering ethics, safety, and misconduct consequences, aiming to amplify digital citizenship, positive behaviour, and community engagement.[77] Google supports German digital literacy and has trained about 4,500 individuals in digital responsibility.[78]

Following effective pilot efforts in Central and Eastern Europe, in June 2023, Google ran a campaign for several weeks to fight online misinformation in Germany.[79] The campaign used short videos to help audiences spot and reject future attempts to manipulate them online through "prebunking".[80]

This is part of Google's global effort to combat online misinformation. Another example is the *Debunk EU*, which is an initiative in the Baltic countries to tackle fake news online using a combination of artificial intelligence-based analytics and a dedicated community of volunteers, known as 'elves'.[81]

Google grants in Germany	Outcome	Impact
IT and technical skills training program	More than 500 people in Germany completed the certified IT support professional course.	Enhancing engagement and work quality. Supporting about 5 million euros in labour income through improved employment prospects and wage growth resulting from training.
	More than 2,800 employees from small businesses improved their digital skills.	
Computer science education	250,000 students and 370 teachers completed training in computer science.	90 percent of children are interested in computer science education, and almost all teachers feel more confident teaching it.
Digital responsibility	4,500 people were trained in online safety or media literacy.	2,000 participants improved their digital responsibility skills.

Material topic
Data security
Data privacy

5.2.3. Providing a secure digital transition in Germany

Trust in digital tools and applications is vital for maximising the benefits of the digital transformation, with data security being a crucial concern for both stakeholders and the German Government.[82]

Google places a strong emphasis on data security and privacy, ensuring universal access via innovative technical solutions.[83] For example, Google introduced Assured Open Source Software, provided free of cost.[84] Additionally, Google demonstrated its commitment to scientific research in privacy, safety and security by awarding 1.1 million euro in a grant to the Technical University of Munich (TUM), a long standing collaborator.[85]

Google ensures robust digital security through multiple layers of protection:

- **Network:** Communications to Google's public cloud services are encrypted during transit, with a fortified network that guards against denial-of-service attacks.
- **Facilities:** Google's sites feature tight security layers, employing secure perimeters, advanced cameras, biometric authentication, and round-the-clock guards. A strict access policy and continuous security training for staff are enforced. Data is dispersed across locations, divided into encrypted segments with randomised names for added safety.[86]
- **Hardware:** Proprietary servers are used exclusively within Google's secure infrastructure to safeguard design confidentiality and ensure security.[87]
- **Software:** Google develops user-friendly security technologies, such as the Google Cloud Security AI Workbench, which leverages AI and large language models(LLM) to tackle security challenges effectively.[88]

Google's robust security measures protect against harmful breaches that could harm businesses and users. On average, firms incur a cost of 4.6 million euros for a breach, but users of AI and automation, such as Google's solutions, identify and contain breaches 28 days sooner, resulting in a saving of 2.7 million euros.[89] Google Cloud's enhanced security monitors and accesses real-time log data for quick issue resolution, preventing major security problems.

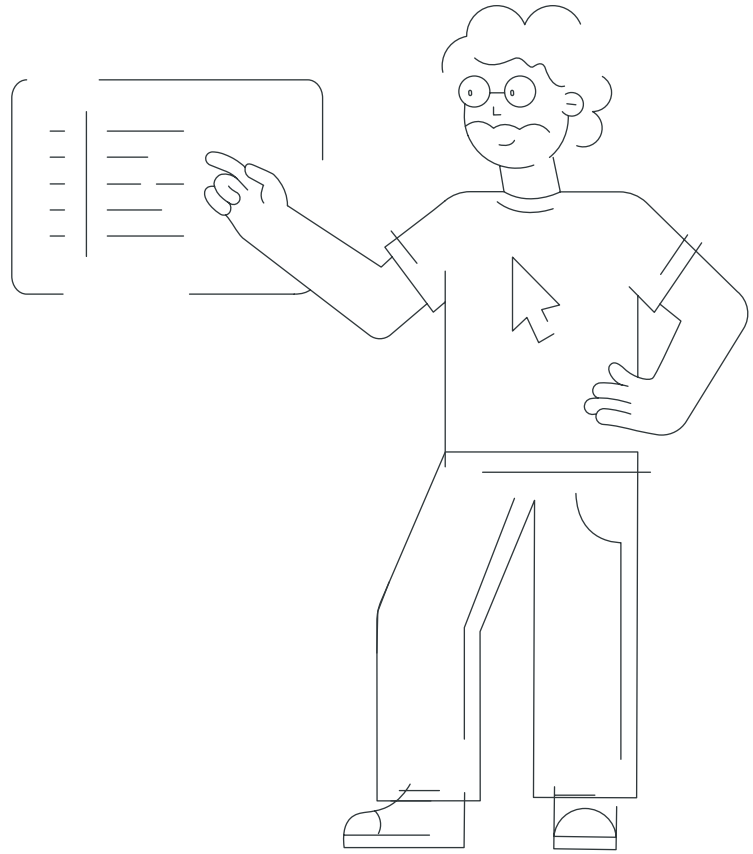
As one of Google's customers phrases it:

> We now have a single view with a dashboard to see the data. And it's easier to access. I don't need to look into multiple tools or random containers when I need to find data to resolve performance issues."[90]

5.2.4. Conclusion on social impacts

Google's presence in Germany supports over 5,200 stable jobs and fosters a self-reliant job market. Its digital infrastructure fuels cloud solutions that help support 7,500-8,000 jobs at user companies. Moreover, Google's grants and free online courses bridge digital skill gaps, preparing the next generation for the future. These efforts significantly improve social conditions in Germany, as indicated by relevant Better Life indicators.

Better Life indicator	Google's impact
Employment rate	**Positive impact** on employment in Germany due to 5,240 direct, indirect and induced jobs supported from investment and operations. Additionally, 7,500-8,000 jobs are secured at German cloud user firms.
Personal earnings	**Positive impact** on personal earnings in Germany due to 290 million euro in labour income from investment and operations. Additionally, 560-600 million euro in labour income secured at German cloud user firms.
Digital skills	**Positive impact** on digital skills due to more than half a million people improving their digital skill through Grow with Google and grants, and 235,000 students say they are interested in learning more about computer science because of training supported by Google.
Wage premium with digital skills	**Positive impact** on wage premium with digital skills due to wage bump and enhanced employment opportunities valued at 5 million euro annually.
Teacher ICT skills	**Positive impact** due to 360 teachers reported increased confidence to teach computer science because of training supported by Google.



5.3. Prosperity

To ensure lasting well-being for people and the planet, it's essential to invest in factors like economic prosperity and measure other factors including GDP growth, local business activity, and global competitiveness, which also contribute tax revenue to governments to support local services.

5.3.1. Impact on GDP: Local business activity and long-term competitiveness

Material topic
Business benefits

Google's investments and operations, involving digital infrastructure and cloud services, have significant effects both locally and nationally. Cloud user firms boost productivity and global competitiveness with these solutions. Our assessment finds a combined net impact of about 1.2 billion euros added to Germany's GDP in 2022.[91]

Google's digital infrastructure in Germany contributed to Germany's GDP and the assessment is accounting for the following direct, indirect, and induced effects:

- **Operating** Google's digital infrastructure in Germany contributed approximately 310 million euro to GDP in 2022 (net impact of 110 million euro), considering direct, indirect and induced effects
- **Investing** in Google's digital infrastructure in Germany added around 240 million euros to GDP in 2022 (net impact of 90 million euro), factoring in direct, indirect, and induced effects.

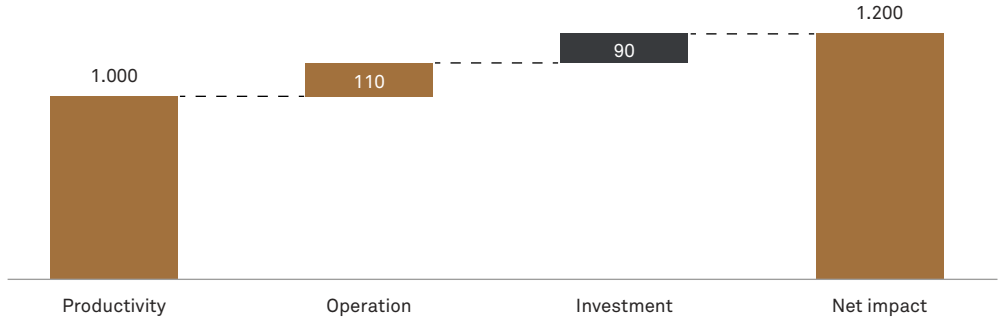
In addition

- **Using** Google's digital infrastructure in Germany contributed around 1 billion euros to the GDP in 2022 by boosting productivity among German user firms.

The impacts from operating the digital infrastructure and investing in its expansion are gross impacts. We assess that around two-thirds of these impacts would occur anyway (-350 million euro), and only one-third, or around 200 million euro, being the net impact.[92] This means that the combined net impact is around 1.2 billion euro in 2022.

Figure 5.

GDP impacts from Google's digital infrastructure in Germany, 2022
mEUR



Source: Implement Economics based on OECD estimates and client data.

Direct, indirect and induced impacts: Prosperity at and around the facilities

Google's digital infrastructure involves substantial investments, spanning land, buildings, machinery, equipment, and servers. Google has invested about 1 billion euros between 2017 and 2022 in digital infrastructure in Germany.[93]

In 2022, Google's investment in German digital infrastructure contributed around 240 million euros to the country's GDP. The ongoing operation of this infrastructure, encompassing staffing, power, maintenance, and administration, further boosted the country's GDP by around 310 million euros. Together, these investments and operations generated a substantial 550 million euros impact on Germany's GDP.

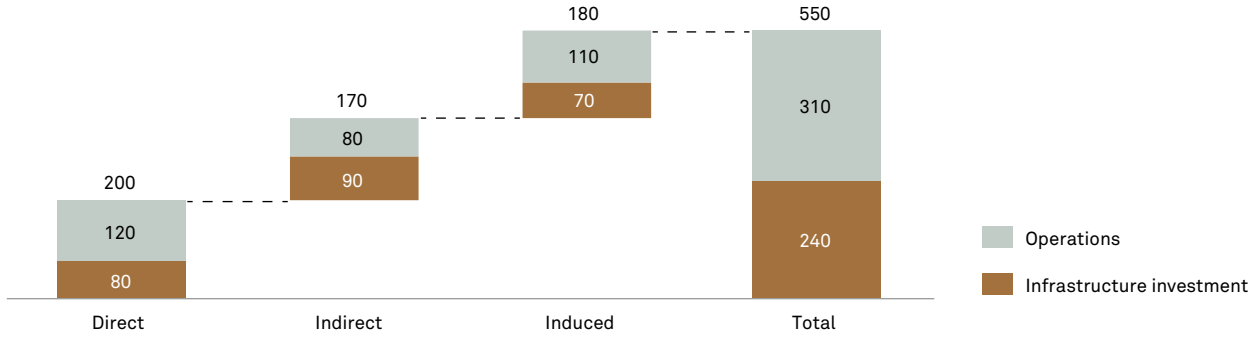
Direct impacts on the economy stem from on-site operational activities, maintenance, and infrastructure investments. Meanwhile, spending on suppliers, subcontractors, power providers, and various services results in indirect impacts. The spending of wages from Google's employees and suppliers on private consumption, including retail and services, triggers induced effects that resonate throughout the German economy.[94]

The sectors with the highest indirect and induced impacts are the information and communication industry, finance, real estate, and construction.

The reported GDP contributions are total gross estimated impacts. To evaluate the net impact, the assessment considers that a portion of the jobs and the associated GDP-impact would have naturally occurred even without Google's investment. We assess that about one third of the 550 million euros, around 200 million euros, are net impacts that would not have occurred otherwise. This is because digital infrastructure creates stable, well-paying jobs, less affected by economic changes or export dependency (more details in the Annex).

Figure 6.

GDP impacts from Google's digital infrastructure investment and operations in Germany, 2022
mEUR



Source: Implement Economics based on OECD Input-Output tables and client data.

Impact on productivity:
Benefits from cloud computing at user firms

The key impact is the increased productivity for German firms using Google's cloud services, estimated at around 1 billion euros in 2022. A strong economy thrives on competitiveness, which is rooted in the productivity of companies and organisations.

"(...) the future competitiveness of the German economy depends to a large extent on its ability to raise its productivity and maintain high levels of employment with the help of innovation and new technology."

– German Council of Economic Experts[95]

Cloud computing can improve firm's productivity[96] through IT cost optimisation, risk reduction, optimisation of operations and innovation through data analytics, scalability, and accelerated and innovative product development.

Cloud computing enhances business productivity by optimising IT costs, reducing risks, streamlining operations, and fostering innovation through data analytics, scalability, and accelerated product development. Forrester and IDC confirm substantial productivity gains from Google's cloud solutions, mainly driven by faster, efficient innovation (70-85 percent of impact), complemented by risk reduction and operational efficiency (see Table 3).[97]

"The ICT industry has always been characterised by a very high degree of innovation. (...) this is due to the fact that service providers in this segment use and remarket technologies from large IT groups whose services are highly innovative. This is passed on by the service providers and adapted to their customers."

– Hesse Ministry for Digital Strategy and Development [98]

Table 3.

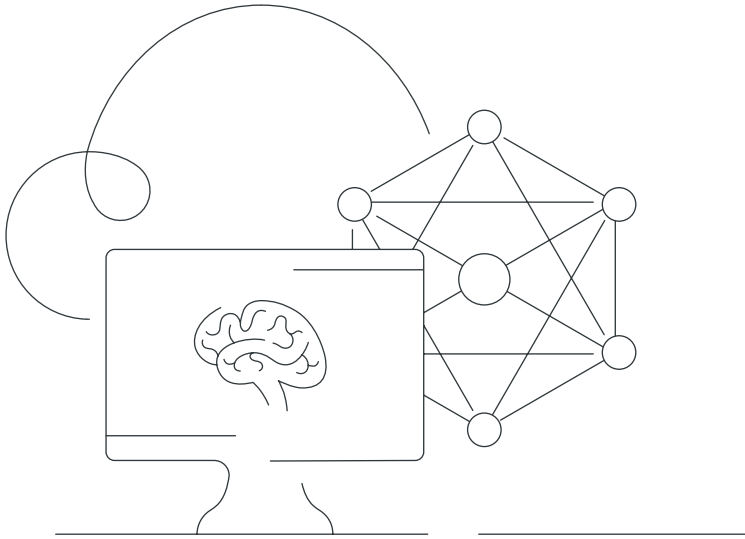
Business benefits from cloud computing

Value driver	Share of total productivity gain
Accelerated product development and scalability of operations Achieving product innovations through increased agility of the operating model, and access to computational power and advanced technologies.	**55 - 65%**
Innovation through advance analytics Business growth from using advanced analytics AI, IoT, and automation to gain insight on e.g., customer behaviour and financial data.	**15 - 20%**
Risk reduction Enhancing the organisational resilience of the business and minimising downtime.	**5 - 10%**
Operations optimisation Automating and digitising core operations and back-office functions.	**5 - 10%**
IT cost optimisation Optimisation of costs associated with developing applications, maintaining them, and managing IT infrastructure. The flexibility of the cloud service also optimise utilisation of IT capacity.	**0 - 5%**

Source: Implement Economics based on Dziadosz, P. et al. (2021)

Google's expanded use of cloud technology in Germany since 2017 is assessed to have generated about 1 billion euros in productivity gains for local companies in 2022.[99]

These benefits are particularly evident in manufacturing firms. As the backbone of the German economy, the manufacturing sector's adoption of cloud technology is lagging behind both the EU average and digital leaders. If the German manufacturing sector embraces cloud solutions, it could experience even greater productivity enhancements, ultimately bolstering the country's overall competitiveness.[100]



Box 8

Volkswagen case study: Designing energy-efficient cars with Google Cloud

Volkswagen and Google Cloud worked together on a research project to explore how machine learning (ML) can be used to quickly and affordably estimate the drag coefficient of cars. The drag coefficient is a crucial factor in determining energy efficiency.

The project involved gathering data on different car designs and their corresponding drag coefficients. This data was then used to develop a deep learning model capable of accurately predicting the drag coefficient of cars.

The Google Cloud Vertex AI platform was used to collaborate across time zones and two organisations, and to train a new model. The data was stored in Google Cloud Storage and the code in Cloud Build. The result was a faster and cheaper feedback loop for designers to evaluate and refine designs, which ultimately leads to more energy-efficient vehicles.

Source: Implement Economics based on Ayad, A.,Bohlke, H. and Menzel, M. (2022).

AI and Cloud services, such as those offered by Google, provide substantial assistance to German SMEs (Mittelstand) as well as start-ups, delivering cost savings, scalability, enhanced customer experiences, streamlined operations, and heightened market competitiveness. Google's commitment to German startups is evident through initiatives like Grow with Google and Google for Startups Growth Academy (see Box 9).

The 'Mittelstand' plays a pivotal role in Germany's economic landscape, constituting the majority of businesses and contributing to over half of the nation's revenue and nearly 60 percent of employment opportunities. However, there has been a decline in new business establishments lately, with a 22 percent decrease in Germany's new enterprises in 2020 compared to 2012. In contrast, the EU and leading digital economies experienced growth rates of 9 percent and 24 percent during the same period.[101] Enhancing accessibility to digital tools, including cloud computing, can amplify the 'Mittelstand's' competitive advantage and promote resilience and economic growth.

Box 9

Google for Startups Growth Academy

The Google for Startups Growth Academy supports female founders by sharing proven growth strategies as well as mentorship, networking and funding opportunities. Co-founder of the successful healthtech startup FORMEL skin, Dr. Sarah Bechstein, says that the Growth Academy was instrumental in helping the company define its key growth objectives, as well as providing much-needed support: "*Meeting all of these smart, like-minded people with whom I could share our vulnerabilities helped me during my daily business at FORMEL Skin, and also in my personal growth. After the Growth Academy program, we were able to refine our absolute north star.*"

Source: Implement Economics based on Google Blog 'Take it at face value: The German dermatology startup leading the way in European healthtech'.

5.3.2. Impact on public budget: Contributing to public budgets

Material topic
Local tax income

Digital infrastructure adds to the local economy through tax contributions. Tax income is essential for governments to support critical services such as education, healthcare, infrastructure, defence, and social welfare, while also addressing debts, initiating new projects, and stabilising the economy during emergencies.[102] Digital infrastructure investments generate tax income through direct, indirect, and induced effects in the economy.

In 2022, Google's investment and operation in Germany is estimated to have contributed approximately 210 million euros in direct, indirect and induced tax revenue for Germany from economic activities in the digital infrastructure value chain.[103] Moreover, the adoption of cloud computing spurred heightened economic activity, resulting in an estimated 190 million euros in additional tax income during the same year.

5.3.3. Impact on industrial land prices: Contributing to increases in industrial land prices

Material topic
Industrial land prices

Industrial land plays a vital role in local communities, and municipalities aim to balance its various commercial uses. Elevated land prices can limit the access of some businesses to prime locations. Digital infrastructure requires land for buildings and this demand for land feeds into the general demand for industrial land, and thereby forms part of the price formation for industrial land.

Most of Google's digital infrastructure in Germany is centred in the greater Frankfurt area. We find the following impact on industrial land prices in the area:

- The Frankfurt area has seen increasing industrial land prices since 2019. The increase can be attributed to a number of factors. An increasing demand from many industries and a limited supply of land in combination with low interest rates and strong economic growth has contributed to the increase in industrial land prices in the Frankfurt area.[104]
- Data centres are estimated to take up around 1 percent of industrial land in the relevant area around Frankfurt. However, data centres are estimated to make up around 10 percent of the transaction volume in recent years.
- Recent data centre acquisitions have certainly been part of the price formation for industrial land in the greater Frankfurt area alongside many other factors.

In our assessment, Google's contribution to the overall industrial land price formation is limited. Google's acquisition of industrial land is unlikely to influence the housing market, as these are distinct markets. Hence, the effect of Google's infrastructure investments on housing prices and residential rents in its German locations is anticipated to be very limited.

5.3.4. Conclusion on economic impacts

Google's investment in digital infrastructure and cloud services fosters sustained local business demand, amplifies productivity, enhances global competitiveness for cloud user firms, and substantially reinforces public budgets.

Indicator	Google's impact
GDP impacts	**Positive impact** on GDP due to capital investments and operational expenditures generating business opportunities for German companies and in total contributing 550 million to GDP in 2022.
Productivity gains	**Positive impact** due to Google's cloud solutions, which are enabled by the digital infrastructure, providing IT cost optimisations and innovations valued at 0.9-1 billion euro in 2022.
Local income tax	**Positive impact** on local tax income due to Google's investments and operations supporting an estimated 210 million euro in tax income to the German public budgets in 2022.
Industrial land prices	**Limited impact** on industrial land prices due to Google's land purchases.

5.4. Total planet, people and prosperity impact

Google is supporting the digital transformation of the German economy while balancing environmental responsibility, economic opportunity and social diligence throughout the supply chain.

Planet
Google's digital infrastructure stands out for its sustainability and eco-friendliness when compared to traditional data centres. This distinction arises from Google's efforts to make data centres more energy efficient, to use clean energy sources, and to ensure water security with air cooling systems.

In 2022, Google's CFE Manager agreement with ENGIE supported 182 MW of renewable energy capacity and Google's digital infrastructure operations in Germany were nearly carbon-free. Additionally, the impact on local air pollution from Google's operations is negligible.

By assessing factors such as renewable energy, carbon emissions, water stress, and air quality in the Better Life framework, it is evident that Google's digital infrastructure in Germany supports responsible resource use and aligns with the country's decarbonisation objectives. Envisaging a scenario where Germany's entire digital infrastructure mirrors the efficiency of leading large-scale cloud operators and incorporates their commitment to renewable energy, there lies the potential to significantly curtail carbon emissions—from an estimated 8 MtCO2e to approximately 1 MtCO2e.

People
Google's infrastructure investments and operations in Germany are assessed to support more than 5,200 stable and export independent jobs. In addition, Google's cloud solutions enabled by the German digital infrastructure are assessed to support 7,500-8,000 jobs at user firms. Google's grants to digital training and provision of numerous free online courses help tackle the digital skill gap in Germany and better prepare the young generation for the future. These impacts are assessed to have a positive impact on the Better Life indicators: *Employment rate*, *personal earnings*, *digital skills*, *teacher ICT skills and wage premium with digital skills.*

Prosperity
Google helps German companies innovate and optimise their businesses via the cloud solutions enabled by the German digital infrastructure. This contributed about 1.2 billion euro to German GDP in 2022. Delivering these substantial benefits to the German economy requires inputs like land, energy, computers and labour, all of which impact the environment and social conditions in Germany.

Overall contribution to better life in Germany

In essence, Google contributes to improving life in Germany by providing essential digital infrastructure for the country's digitization efforts, with a strong emphasis on environmental sustainability and social responsibility.

5.4.1. Combined societal value of Google's investment

The analytical framework evaluates the various societal impacts by combining social and economic factors into a unified measure. This social return number consolidates quantified social and economic effects, relative to the extent of Google's investment (refer to the annex for in-depth details).

The resulting outcome is a social return of 2.1 euros for each euro Google invested in 2022. Essentially, for every euro Google dedicated to digital infrastructure in Germany during 2022, it contributed to generating 2.1 euros in societal value.

This societal impact is rooted in advanced digital infrastructure that leads the way in sustainable utilisation of natural resources. Google's environmental contribution is positive, as it develops digital solutions with an eco-conscious approach, surpassing the standards established by the typical digital infrastructure in Germany.

Importantly, we consciously opted not to monetize the environmental impacts. This choice underscores the non-negotiable significance of achieving climate objectives and safeguarding water resources and air quality. Consequently, we depict these impacts in tangible quantities, refraining from assigning monetary values to environmental consequences.

CHAPTER 6 Conclusion

Google manages its digital infrastructure to align with stakeholder priorities, driving carbon-free energy development and operational efficiency. This approach can contribute to a sustainable and mutually beneficial environment in Germany. Google's advanced digital infrastructure offers energy-efficient data centres, nearly complete carbon-free energy usage, and robust cloud security for customers, public administration and citizens. Google also invests in upskilling through training and grants, creating stable jobs in Germany. These features maximise societal value while minimising resource use.

Having already invested around 1 billion euros in Germany's digital infrastructure, Google's impact on renewable energy, productivity, stable jobs, and upskilling has rapidly grown since 2017. The social return in 2022 was 2.1 euros per invested euro.

Google's investment of about 1 billion euros between 2017 and 2022 in digital infrastructure and clean energy aligns with Germany's transition to net-zero emissions and digital economy. Achieving 100 percent carbon-free energy requires strategic planning and innovation. To attain this goal, industry and policymakers must collaborate to increase carbon-free energy capacity and enhance power grids.

As technologies, such as AI, boosts compute power demand, expanding digital infrastructure near major cities is crucial. Google and local partners should collaborate to ensure growth is sustainable and balanced with other land use needs. Google is actively working to balance computing power needs with energy efficiency and the 100 percent CFE goal by 2030.

In summary, Google's digital investment and expansion offer significant environmental, societal and economic benefits, especially in Germany's journey to a carbon-free and digitally-driven future.

ANNEX
Approach and methodology

Google's digital infrastructure investment has economic, social, and environmental impacts. In this annex, we describe the overall approach and methodology applied in this study.

A.1. Overall approach based on the OECD *Better Life* index

The report investigates how Google's digital infrastructure investment in Germany is helping to move the country's digital transformation and sustainability forward and how that affects social, environmental and economic conditions in the country.

The impact assessment relies on a broad set of indicators from the OECD's *Better Life Index*. The leading idea behind *Better Life Index* is to assess well-being across a range of indicators that are essential for material living conditions and quality of life. This includes indicators such as GDP and the underlying drivers of economic prosperity such as productivity and employment.

The report goes beyond purely economic indicators and adds a broader set of indicators reflecting what matters to stakeholders (see section A.5) and how Google's activities affect people's social life, their concern for the planet, and their interest in current and future living conditions. It also includes more subjective measures such as people's self-reported life satisfaction.

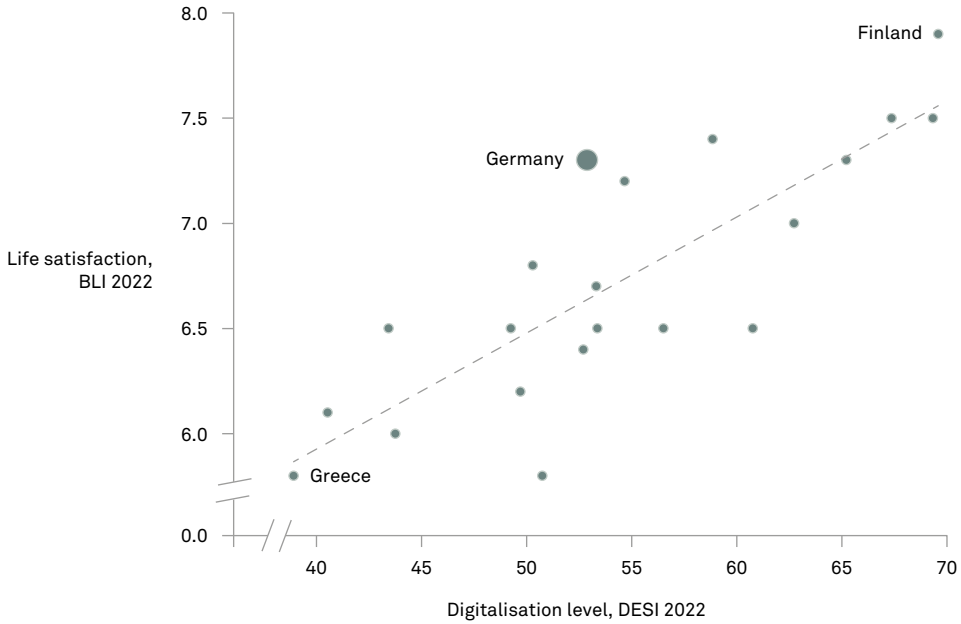
A.2. Cross-country analysis: Digitalisation and life satisfaction goes hand in hand

Identifying and synthesising common patterns of digital transformation across all dimensions of people's lives is difficult. In this section, we assess this complex phenomenon by comparing digital development levels with self-reported life satisfaction across countries (see Figure 7).[105]

OECD and Eurostat data for 21 European countries reveals a significant positive relationship, indicating that highly digitalised countries in Europe also tend to have the highest average life satisfaction. Germany, despite having a moderate level of digitalisation, already exhibits a high level of life-satisfaction (7.3) and is ranked seven out of the 38 OECD countries despite a moderate level of digitisation.[106]

Figure 7.

Life satisfaction and digitalisation



Note: Implement Economics analysis based on data from the OECD and the European Commission. The analysis uses data for all 21 EU countries with available OECD BLI data.

While it's important to acknowledge that life satisfaction is influenced by numerous factors beyond digitalisation, the positive relationship remains evident. Detailed analyses by the OECD confirms that digitalisation is in fact a positive contributing factor to life satisfaction when taking other factors into account. OECD research shows that people with Internet access report a life satisfaction 0.28 points higher (on a 0-10 scale) than those who lack access to the Internet.[107]

All other things equal, Germany could enhance life satisfaction by embracing accelerated digital transformation. Life satisfaction is rated as the number one most important indicator by Germans according to OECD's *How's Digital Life* research. If Germany manages to move from the current digital middle position to become a frontrunner on digitalisation, it would generally also improve well-being and life satisfaction.[108]

A.3. OECD recommendation: A policy framework to mitigate digital risks

Accelerated digitalisation brings both benefits and risks. Digital technologies drive innovative and efficient solutions to business, public sector and sustainability. They enhance efficiency in health, education, shopping, teleworking, and energy management.[109]

To ensure digitalisation and well-being go hand-in-hand, a robust policy framework is crucial to mitigate risks. According to OECD recommendations[110], a policy framework for digitalisation should:

Adequately address the digital divide
Increased digitalisation may widen the gap between those with and without digital skills. Bridging this divide is essential to prevent reinforcing existing socio-economic disparities. The digital divide manifests itself through the differential Internet usage across age and socio-economic groups, and in the wage gap between high and low-digital skill workers.

Digital literacy development is key for societal well-being
While utilising digital solutions provides novel and beneficial avenues for work, communication and socialisation, it is important to ensure a positive impact on social well-being. This is why it is crucial to develop digital literacy, including skills in critical assessment and self-control, to effectively harness digital technologies while safeguarding well-being. Google's digital skills training is an example of this.

Digitalisation in secure digital environments is key to data security
Establishing trust in digital tools and applications is vital to fully benefit from the well-being advantages of digital transformation. Data security is an absolute requirement for successful digital transformation, and is a primary concern for the German Government. Safeguarding and fostering technology and innovation is part of Germany's first-ever National Security Strategy.[111]

Digitalisation must occur in an environmentally sustainable way
Digital solutions play a vital role in facilitating the attainment of sustainability goals. The policy framework should focus on maximising the potential of digital technologies by accelerating existing digital solutions at scale across all sectors of the economy. Simultaneously, the framework should consistently strive to reduce and ultimately remove the carbon emissions through the entire digital value chain. This involves decarbonising all operational electricity emissions associated with devices, servers, buildings and other related factors.[112]

A.4. Strong political support for Germany's digital transition

Germany's commitment to digitalisation is evident through the ambitious plans set by the federal government. The government has allocated 12 billion euros in its broadband plan[113] to invest in fibre optic connections, recognising their importance. Additionally, the German Government is also keen to enhance business dynamics and foster more start-ups. With its new *Digital Strategy 2025*[114], the German Government outlines initiatives to establish Germany as an appealing business location, focusing on strengthening its position as a financial centre, implementing an open data policy, promoting startups and delivering modern public digital services.

Supporting small and medium-sized enterprises (SMEs) in their digital transformation is another priority for the German government. The SME Digital initiative provides assistance to SMEs through networking opportunities, investment schemes and cybersecurity measures.[115]

Furthermore, the German Government acknowledges the need to accelerate the adoption of cloud solutions in the public sector. The *Cloud Strategy*, introduced in 2020[116], aims to accelerate the implementation of digital solutions within the German public sector.

A.5. Method to identify stakeholder priorities

A purposeful impact assessment involves engaging with the people impacted by Google's activity in Germany to identify the topics of highest importance to stakeholders and highest influence on Google's business success, cf. Figure 2.

To identify what matters most to stakeholders, Implement has conducted 40 personal interviews with people representing businesses, NGOs, utilities, public sector, civil society and media.

To determine the most relevant topics to stakeholders, Implement conducted an assessment three-step process:

Step One: Identification of topics and stakeholders. Over 200 environmental, social and economic topics were evaluated.[117] This comprised 162 topics from six different organisations[118] and 51 topics suggested by Google (213 in total). Of these, 33 topics were deemed relevant to Google's business activities, and stakeholders were asked to assess them during the interviews.[119]

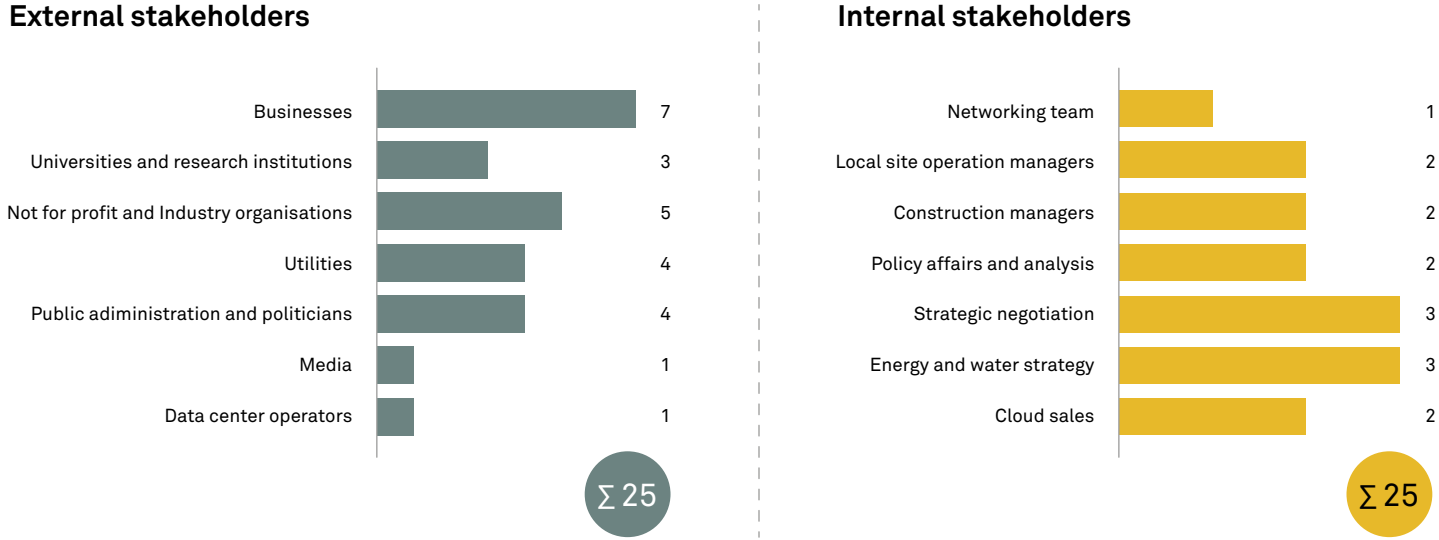
Step Two: Engagement of stakeholders. 40 interviews were conducted with a range of external stakeholders, including businesses, NGOs, utilities and public sector representatives. To ensure a comprehensive understanding of stakeholder perspectives related to data centres, the interviews were semi-guided. This approach allowed the interviewer to ask about specific predefined topics and gave the interviewees the opportunity to discuss any additional topics they considered relevant in relation to data centres. The name Google was not mentioned to external stakeholders. A large number of interviews were held with external stakeholders that do not have intricate knowledge of the business models of data centres. Hence, the majority of ratings in the category "influence on business success" were either reputational reflections about data centres, i.e. what would lead to high acceptance by the public, or reflections by businesses about the usage and benefits of cloud services and applications. Internal stakeholders were interviewed covering teams within Google, such as operations and construction, cloud sales, and energy, were also interviewed.

Step Three: Assessment and prioritisation. The interview notes were carefully analysed and summarised to create a mapping of stakeholder priorities. This map highlights the key topics based on stakeholder perceptions.

The stakeholder priority assessment is a qualitative assessment of social, environmental and economic topics important to stakeholders (the y-axis in Figure 3) and Google's business success (x-axis). The mapping of topics is dual by reflecting both the perceived *outwards* impact of Google on society and the *inwards* impact of socio-environmental issues on Google e.g. dependency on a resource or reputational issues. The perceived inwards and outwards impacts can be of a positive or negative character.

Figure 8.

Stakeholder types



Source: Implement

A.6. Socio-economic impact model

Input-output model

To quantify the impact of the digital infrastructure, we have applied an input-output model that is based on data from national accounts describing the flow of final and intermediate goods and services between industries.

The relationship between an industry's inputs and outputs is assumed to be constant in input-output models, which implies that industries operate under constant returns to scale.[120]

Based on the input-output tables, we have calculated a set of multipliers, reflecting the expenditures for the digital infrastructure, for assessing the economic impacts of both the digital infrastructure investments in and operations of the digital infrastructure on the rest of the economy. The input-output tables allow us to compute the GDP (value-added), employment and labour income multipliers.

The impacts assessed in an input-output model are gross impacts, meaning that they do not consider any potential diversion of resources from other activities in the German economy.

Data sources applied in the study

This study relies on two complementary sources:

- OECD Structural Analysis Database (STAN) 2021 ed.
  This data provided harmonised national input-output tables for 45 industries. The STAN database provides employment data (total employment) and labour compensation data by industry.

- Google's technical infrastructure investment, operational expenditure and employment
  Google has shared information on capital investments and operational expenditure.

Productivity model
OECD research shows that the adoption of cloud services increases firm productivity and that even small increases in adoption rates can increase industry-wide productivity growth.

Relying on adoption rates at an industry level, the OECD study finds a positive and statistically significant impact of cloud adoption on firm-level multi-factor productivity (MFP).[121] To measure the impact of cloud adoption on firm-level MFP as accurately as possible, the econometric model controls for:

- **Innovation spillovers |** MFP growth of the productivity frontier (average MFP among the five percent most productive firms in the industry) is included to control for industry differences in frontier productivity.

- **Convergence |** Lagged distance to the frontier is included to control for industry differences in how firms below the frontier benefit from catching up.

- **Firm characteristics |** Firm size and age are included to account for differences in firm-level productivity.

- **Fixed effects |** Industry and country-year fixed effects are included to account for unobserved common productivity drivers.

To estimate Google's contribution to productivity growth, the study takes the following approach:

- Estimating the overall productivity contribution of cloud adoption

  – Calculating the increase in cloud adoption for German firms based on Eurostat DESI.

  – Calculating the MFP productivity growth impact in manufacturing and services from the increase in adoption rate using a non-cumulative interpretation of the parameter estimate from the OECD study.

  – Using German value added firms with more than ten employees based on the Federal statistics Office of Germany (Destatis).

- Estimating Google's share of the total cloud market in Germany.[122]

Counterfactual share
The societal value calculation takes the counterfactual situation into account to only account for the net impact of Google's activity. The historical period from 2017-2022 is marked by the very peculiar situation caused by the covid-pandemic. The counterfactual share captures the proportion of the impact that would have occurred anyway, i.e. in the absence of Google's investment.

For the labour impacts, high counterfactual shares are applied for the years 2017-2019 to reflect the labour market bottlenecks. During these years, almost all technical skilled persons in the metropolitan area of Frankfurt or Berlin would have been able to find another job, should they lose the one they have. Therefore, counterfactual shares of 95 percent are used for the direct and indirect employment and labour income, implying that 95 percent of the people employed in these positions would have found another job had Google not

Table 4.

Counterfactual shares

	2017	2018	2019	2020	2021	2022	Average
Direct	95%	95%	95%	75%	75%	75%	85%
Indirect	95%	95%	95%	75%	75%	75%	85%
Induced	75%	75%	75%	50%	50%	50%	63%

invested. During the covid-period, these factors are reduced to 75 percent to reflect the stark reduction in activity during these years. While this adjustment reflects the actual impacts in the specific historical period analysed, it also means that the results during this very specific period cannot be extrapolated to future periods.

The local jobs associated with the induced impacts are predominantly low skilled jobs and with less bottlenecks than for the more technical skilled direct and indirect jobs. For this reason, the counterfactual shares are set lower to reflect that these jobs will be harder to replace with other jobs if Google had not invested.

Since the counterfactual shares are smaller than 100 percent, it means that a smaller part of the people employed as a result of Google's investment would have been out of work if Google had not invested. Consequently, Google's investment supports people in jobs that would otherwise have been unemployed and hence would have been dependent on support from the German Government.

The societal value calculation takes into account that in order to support individuals losing their job, the German Government would need to raise revenue via taxes in order to transfer resources to the unemployed.

The societal value of this transfer from taxpayers to unemployment beneficiaries is not zero. Raising public revenue via taxes has a distortive effect on labour supply (known as the tax wedge). We include the societal value of avoiding this distorting impact by applying the average German labour compensation rate and the average German tax distortion rate.

Finally, it is assumed that 50 percent of the productivity contribution that can be attributed to Google's market share would have happened anyway. This means that only 50 percent of the full productivity contribution is included in the social value calculation. In other words, we assume that half of Google's cloud business in Germany would have been captured by other cloud providers had Google not invested.

Endnotes

1 Implement's 1 billion euro investment estimate incorporates the German deflator and exchange rate adjustment for the period.

2 Implement's 1 billion euro investment estimate incorporates the German deflator and exchange rate adjustment for the period.

3 See Annual report 2020/21 by German Council of Economic Experts.

4 Size of cloud market in Germany based on IDC data.

5 See database Eurostat (2021). Cloud computing services.

6 Carbon-free energy is any type of electricity generation that does not directly emit carbon dioxide, including (but not limited to) solar, wind, geothermal, hydropower, and nuclear. Sustainable biomass and carbon capture and storage (CCS) are special cases considered case-by-case.

7 In 2022, the CFE score for Germany for 2022 was 96 percent as shown in Google's 2023 Environmental Report. Google's new Hanau facility and Berlin-Brandenburg cloud region were not fully operational in 2022. In 2023 and coming years, the CFE score may change as this score is dynamic and depends on a complex set of factors. Google's goal is to achieve 100 percent CFE by 2030.

8 Implement's 1 billion euro investment estimate incorporates the German deflator and exchange rate adjustment for the period.

9 In 2022, the CFE score for Germany for 2022 was 96 percent as shown in Google's 2023 Environmental Report. Google's new Hanau facility and Berlin-Brandenburg cloud region were not fully operational in 2022. In 2023 and coming years, the CFE score may change as this score is dynamic and depends on a complex set of factors. Google's goal is to achieve 100 percent CFE by 2030.

10 The impact assessment relies on OECD Structural Analysis Database (STAN), Eurostat, The Federal statistics Office of Germany (Destatis) and data provided by Google. See annex A.6 for further detail.

11 See annex for details.

12 Currently being developed.

13 See Google blog announcing the power agreement and Google's 2023 Environmental Report.

14 Listen to Inside the Strategy Room podcast with Thomas Kurian, CEO of Google Cloud.

15 See World Bank GDP ranking for 2022.

16 See Annual report 2022/23 by German Council of Economic Experts.

17 See Annual report 2022/23 by German Council of Economic Experts.

18 See OECD Economic policy reforms 2021.

19 Frontrunners in the Digital economy and society index (DESI) are Finland, Sweden, Denmark, Estonia, Netherlands, Belgium, Ireland and Luxembourg.

20 See Eurostat data on cloud adoption.

21 See analysis on the ICT sector in Hessen 2020/21 by the Hessian Ministry for Digital Strategy and Development.

22 See Germany's DESI country profile (2022). Frontrunners in the Digital Economy and Society Index (DESI) are Finland, Sweden, Denmark, Estonia, Netherlands, Belgium, Ireland and Luxembourg.

23 See Digital Strategy Germany (2022).

24 See IMF economic outlook, "A Rocky Recovery".

25 In 2023 and coming years, the carbon-free score may change as Google's German facilities increase their load.

26 See article in Nature Journal (2018).

27 For example, Google has optimised power consumption by taking low voltage off the grid instead of the standard and thereby save a lot of energy, cf. interview with Thomas Kurian, CEO of Google cloud.

28 PUE, or Power Usage Effectiveness,is a measure that shows how much energy a data centre uses compared to the energy it provides for the actual computing equipment. See Efficiency for Google Data Centers. Among other things, this is a result of Google's ability to run computers "hot", which saves a lot of energy, see Google blogpost.

29 Water-cooled data centres use about 10 percent less energy than many air-cooled data centres, see Google blogpost on efficient cooling.

30 See Datacenter Outlook Germany 2022 .

31 See amendment of the Federal Government "Draft of a law to increase Energy efficiency and amending the Energy Services Act", from 4 July 2023.

32 Google's data centres operate with PUEs around 1.1 at most locations according to data from the second quarter of 2023 (trailing 12 months). For more information on Google's PUE performance, including quarterly updated numbers, see: https://www.google.com/about/datacenters/efficiency/.

33 Hyperscale data centres, also known as cloud data centres, are large, centralised, and custom-built facilities that are operated by a single company, but providing cloud services to multiple companies and organisations. Enterprise data centres are smaller private facilities that are owned and operated by an individual organisation to meet its own IT infrastructure requirements.

34 See Google's 2023 Environmental Report.

35 See case study of the U.S. General Services Administration (GSA).

36 See Google study on the impacts of using a cloud based email service compared to a self-standing on-premise company solution.

37 As of 2022, cloud data centres accounted for less than 40 percent of the total installed data centre capacity in Germany according to Bitkom market update 2023 (in German).

38 A typical German household consumes around 3,100 kWh per year according to Destatis data.

39 See Google blogpost on climate-conscious data centre cooling.

40 Water-cooled data centres use about 10 percent less energy than many air-cooled data centres, see Google blogpost.

41 See recent coalition government decision on Germany's 2045 goal in "Modernisierungspaket für Klimaschutz und Planungsbeschleunigung" from March 2023.

42 See the net-zero scenario in the study commissioned by Stiftung Klimaneutralität and Agora.

43 The German Federal Ministry of Economics and Climate Protection (BMWK) presented an updated proposal for the bill in May 2023.

44 For more details on Google's new approach to clean energy purchasing, see Google blog post (2022).

45 See announcement from November 2021.

46 See Google blog post (2021).

47 The annual CFE score is a load weighted average of all hourly CFE scores during the year. For more details, see Google CFE methodology.

48 CFE data for 2020 is available here and for 2021 here. 2022 data is from Google's 2023 Environmental Report.

49 Based on data from Google.

50 Based on interview with ENGIE. It has not been possible to assess how large a share of the portfolio that would have been retired in the absence of the CFE agreement. This means that the 2022 portfolio cannot be said to be fully additional.

51 The carbon-free energy score (CFE Score) measures the degree to which each hour of electricity consumption on a given regional grid is matched with carbon-free energy on an hourly basis. The annual CFE score is a load weighted average of all hourly CFE scores during the year. For more details, see Google CFE methodology.

52 See Google's 2023 Environmental Report. Google's new Hanau facility was not operational during 2022 and its Berlin-Brandenburg cloud region only started towards the end of 2022. In 2023 and coming years, the CFE score may change as this score is dynamic and depends on a complex set of factors. Google's goal is to achieve 100 percent CFE by 2030.

53 See Google's 2023 Environmental Report.

54 See Google blog on sustainability goals.

55 In 2022, the CFE score for Germany was 96 percent as shown in Google's 2023 Environmental Report. Google's new Hanau facility was not operational during 2022 and its Berlin-Brandenburg cloud region only started towards the end of 2022. In 2023 and coming years, the CFE score may change as this score is dynamic and depends on a complex set of factors. Google's goal is to achieve 100 percent CFE by 2030.

56 See Google Cloud Blog (2022).

57 See Bitkom market update 2023 (in German). This report uses a so-called location-based approach assigning grid average emission-coefficients to all electricity use and is thereby not taking the impact of PPAs into account

58 For more on the 24/7 decarbonisation journey, see the report "A Timely Match" at Eurelectric's 24/7 hub.

59 See recent coalition government decision on Germany's 2045 goal in "Modernisierungspaket für Klimaschutz und Planungsbeschleunigung" from March 2023.

60 See Implement's Digital Decarbonisation study for Germany.

61 See Google's approach to data centre heat recovery (leaflet, 2023).

62 For more information see Google blogpost from 2020.

63 See Google's 2023 Environmental Report. In 2023 and coming years, the carbon-free score may change as Google's German facilities increase their load.

64 See Skills intelligence database by European Centre for the Development of Vocational Training (CEDEFOP).

65 The average wage for Google ICT employees and temporary vendor contracts is favourable compared to the industry average for the ICT industry in Germany, see statistics from Destatis.

66 See Google blog on building your future at Google.

67 The impact assessment takes this into account by assessing the net impact (see Annex).

68 See analysis on the ICT sector in Hessen 2020/21 by the Hessian Ministry for Digital Strategy and Development.

69 See academic paper by Jin (2022) and Gal et al. (2019).

70 Based on the report from Hesse Ministry for Digital Strategy and Development (2020).

71 Frontrunners are Finland, Sweden, Denmark, Estonia, Netherlands, Belgium, Ireland and Luxembourg.

72 See report by the European Commission (2019) Europe's Digital Decade: digital targets for 2030

73 See Google blog How digital skills training helped three young friends found a startup.

74 See Google blog How digital skills training helped three young friends found a startup.

75 See academic articles by Fitzenberger et al. (2013), Bolvig et al. (2017) and Doerr (2017).

76 See the Vodafone Stiftung Deutschland survey of 2,000 young people between the ages of 14 and 24.

77 See Google for Education.

78 Based on information from Google.

79 See article Google to expand misinformation 'rebunking' in Europe .

80 The approach is based research from leading universities such as Cambridge University, see https://www.cam.ac.uk/stories/inoculateexperiment

81 The initiative is operated by DELFI, the largest online news publisher in the Baltics and funded by Google Digital News Innovation Fund, DNI. See https://newsinitiative.withgoogle.com/dnifund/report/battling-misinformation/ai-fact-checking-tools-to-combat-misinformation/

82 See How's Life in the Digital Age? by OECD.

83 Google has clear data privacy commitments and their products regularly undergo independent verification of privacy. See Privacy and Compliance offerings by Google Cloud.

84 See article (2023) in Tech Republic.

85 See news article (2023) by Technical University of Munich.

86 See online course in data engineering by Google.

87 See Trusted infrastructure by Google Cloud.

88 See Google Cloud Blog about supercharging security with generative AI.

89 See Threat Intelligence Index 2023 by IBM.

90 See report about the total economic impact of Google Cloud's operations suite by Forrester.

91 The total GDP impact is the sum of the net direct, indirect, and induced impacts, as well as the upstream impacts at user firms stemming from the productivity gains from adopting cloud.

92 See Annex for details of the assessment of the so-called counterfactual share of impacts..

93 Based on Implement analysis of Google investment data for Germany. Implement's 1 billion euro investment estimate incorporates the German deflator and exchange rate adjustment for the period.

94 See appendix for a detailed breakdown of the impacts.

95 See Annual report 2022/23 by German Council of Economic Experts.

96 Productivity is the ratio of produced output per input (e.g. capital and labour). In the long term, productivity is essential for raising prosperity. See paper about labour productivity by Kuntze, P., Mai, C-M.

97 The studies are case based and point to the benefits stemming from IT staff productivity increases, consolidation of legacy tools, enhanced security posture, scalability, and improved reporting and analytics. See report about the total economic impact of Google Cloud's operations suite by Forrester and report about the business value of improved performance and efficiency with Google Cloud platform by IDC.

98 See report State Chancellery of Hessen, Minister for Digital Strategy and Innovation (January 2023). IKT branche in Hessen 2021/22. Text translated from German.

99 Implement Economics applied results from recent studies from MIT and the OECD, which find that firms experience higher productivity growth after adopting cloud services. See academic paper by Gal et al. (2019) and academic paper by Jin (2022).

100 Frontrunners in the Digital Economy and Society Index (DESI) are Finland, Sweden, Denmark, Estonia, Netherlands, Belgium, Ireland and Luxembourg. In 2021, 38 percent of German manufacturing firms had adopted cloud, while the EU and digital frontrunner averages were 40 percent and 62 percent, respectively. Implement Economics based on Eurostat data.

101 See OECD report on Tax and fiscal policies after the COVID-19 crisis.

102 See OECD report on Tax and fiscal policies after the COVID-19 crisis.

103 The estimate is based on official tax rates as reported by the OECD, sourced by Country representatives in the OECD Working Party: Tax Policy and Tax Statistics of the Committee on Fiscal Affairs. The estimate includes business taxes, personal income taxes, and social security contributions generated from Google and its employees, and from local suppliers and businesses supported by Google's investment and operations. Note that the tax contribution includes contributions to both the Federal and State level.

104 The Greater Frankfurt area has a diverse range of industries that have driven demand for industrial land, including finance and banking, logistics and transportation, pharmaceuticals and life sciences, information technology, and automotive and engineering.

105 Life satisfaction is ranked by German individuals as the number one issue among the 11 different main topics in the OECD's Better Life index (based on nearly 17.000 responses). See Better Life Index.

106 Germany is performing well on other dimensions that also matter for life satisfaction such as job possibilities, housing and personal income.

107 See the OECD report How's Life in the Digital Age?

108 See for example Strategy& report finding that countries that have achieved advanced levels of digitisation have realised significant benefits in their economies, their societies, and the functioning of their public sectors.

109 See Implement study on Digital Decarbonisation Germany.

110 See the OECD report How's Life in the Digital Age?

111 See German National Security Strategy.

112 See Implement study on Digital Decarbonisation Germany.

113 Federal Ministry for Digitalisation and Mobility (2022). Federal Broadband Funding.

114 See Digital Strategy Germany (2022).

115 European Commission (2022). Digital Economy and Society Index.

116 Federal Ministry of the Interior, Building and Community (2021). Germany's Government Cloud Strategy: Target Architecture Framework, Division DG II 2 Digital Sovereignty for Public Administration IT.

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