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Copenhagen Economics

GOOGLE'S HYPERSCALE DATA CENTRES AND INFRASTRUCTURE ECOSYSTEM IN EUROPE

Economic impact study

CLIENT: GOOGLE
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EXECUTIVE SUMMARY

Digital transformation is a defining challenge and opportunity for the European economy, providing the means to reinvent and improve how firms, consumers, governments, and citizens interact and do business with each other. European consumers, firms, and society stand to benefit from the resulting innovative products, processes, services, and business models – contributing to EU productivity. To maximise these benefits, it is key that the private and public sector can rely on an advanced and efficient cloud value chain.

Considerable literature exists on cloud solutions and their transformative impact across the economy. This report contributes by focusing on the analysis of the cloud value chain, taking Google as a relevant case study. It assesses the economic impact of the Google European hyperscale data centres and related infrastructures which, behind the scenes, underpin online services such as cloud solutions. Thus, the report is an applied analysis of these infrastructure layers "above the cloud" (upstream inputs to deliver cloud solutions) and quantifies Google's European economic contribution associated with these activities.

Double-clicking the cloud

Services, such as Google Cloud, are a key example of a set of solutions that can serve a variety of European business needs and thus support economic productivity. For cloud solutions to deliver value to society to the fullest – and in an efficient manner – considerable investment and infrastructural organisation behind the scenes is needed. This report researches what is going on 24/7 in the background and what activities, jobs and economic contribution for Europe derive from it.

Cloud computing refers to solutions that rely on distributed IT resources – engineers used to draw them in network diagrams as overlapping circles of servers and end users, connected to each other, with those circles merging into the shape of a cloud. What happens if we zoom in and look inside it?

If data is the lifeblood of the digital transformation, large-scale data centres are the hearts and brains of the digital infrastructure. Networking connectivity delivers this lifeblood instantly where information, computing and decision making is needed – all powered by the necessary energy. The explosive growth in data traffic, storage and processing driven by consumers' and firms' demand for online services require significant investment in all of the above components to serve existing and new needs from old and new digital users. For this growing demand to be handled efficiently, it is key that computing can be performed at scale. Thus, this report investigates Google's **(i)** hyperscale data centres in Europe, its related **(ii)** network connectivity and **(iii)** energy sustainability aspects.

A data centre is a facility that houses large numbers of high-performing computers storing data, known as servers, as well as networking equipment and communication links. This allows computing that is performed at scale and with efficiency. While we see prominently our devices as we consume digital services, data centres are performing a lot of the heavy lifting behind the scenes, making services work seamlessly. The largest type of data centres is called hyper-scale, associated with best in class performance and efficiency in using resources. Google's European fleet of hyper-scale data centres are at the centre of this study.

Network connectivity. Linking the end users (mobile devices, computers, factories etc.) with the data centres requires several assets; in a nutshell, internet access links and internet backbone links. The internet access links are often evident in the connections in our residential and business districts, performing the important job of reaching / cabling the last mile, taking the internet to homes and workplaces. At the same time, the present-day internet relies on considerable assets that interconnect networks, link up data centres and bring the computation and content closer to the consumers – the much less visible internet backbone connectivity. To ensure that the latter meets demand for online services, Google has supported the development of a significant network interlinking European cities and countries – as well as connecting European users to the global internet.

Energy sustainability. Consumers' and firms' demand for digital services calls for energy to power the computation and transmission of the data that services rely on. The internet industry is increasingly aware of the users' wishes to shift their activity and consumption to more and more digital services, while ensuring the greatest energy efficiency and optimal sourcing of renewables. Google has led the way in achieving a 100% renewables target and is the largest corporate backer of renewables-supporting PPA deals.

Key findings of this study

Google data centres deliver large benefits to the European economy

Google has invested heavily and widely in data centres and related infrastructures in Europe. Currently, it operates hyper-scale data centres across Europe: St. Ghislain-Mons in Belgium, Hamina-Kotka in Finland, Dublin in Ireland, Eemshaven-Groningen in the Netherlands and soon Fredericia in Denmark and Agriport in the Netherlands.

From 2007 up to and including 2018, Google has invested EUR 6.9 billion in European data centre and related infrastructure investments. Investments considered include:

- Construction, civil engineering and restoration of the data centre sites
- Ongoing data centres' operation, including site reliability engineering and all support functions
- Connectivity links serving the EU and related networking assets

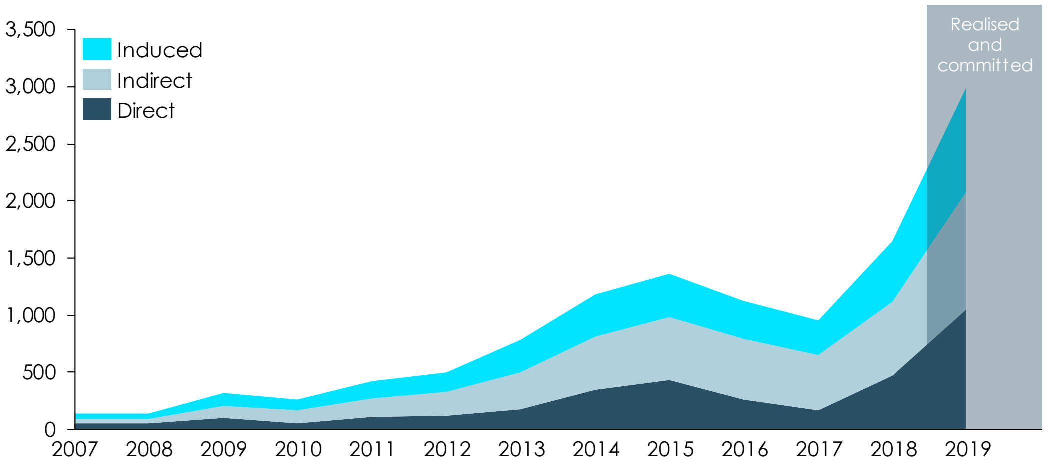
Every time a firm (domestic or foreign) deploys an investment, it is reasonable to ask: how much of this investment flows through to local impact vs is spilling out e.g. via imports? Therefore, we have applied an established economic (input / output) model to measure the impact of these investments, in terms of economic (GDP) and employment contribution supported within Europe.[1]

We have measured the extent to which these investments have converted into economic and employment benefits for European countries, finding as main results that:

- Google's investments have supported economic activity in Europe of **EUR 730 million per year** in gross domestic product (GDP) on average in the period 2007-2018; in other words, **EUR 8.8 billion in total for the whole period**
- Google's investments have supported **9,600 jobs** per year on average (full-time equivalents), across the value chain and a wide set of European industries

[1] The CE input / output model compared the Google expenditure sectoral pattern and mapped it against the official national statistics. The model is calibrated on the basis of Eurostat sectoral accounts that are built on the latest information on the EU countries' national economy and sectoral patterns, across all value chains.

Figure 1 Economic impact supported by Google data centres&related infrastructures
EUR millions per year



Note: The figure shows the supported economic contribution in the EU, due to the construction and operation of Google's European data centres and related infrastructures. 2019 covers effects of expenditure already realised as well as the expected amount to be completed, based on committed investments.
Source: Copenhagen Economics based on data provided by Google, Eurostat and World Input-Output Database

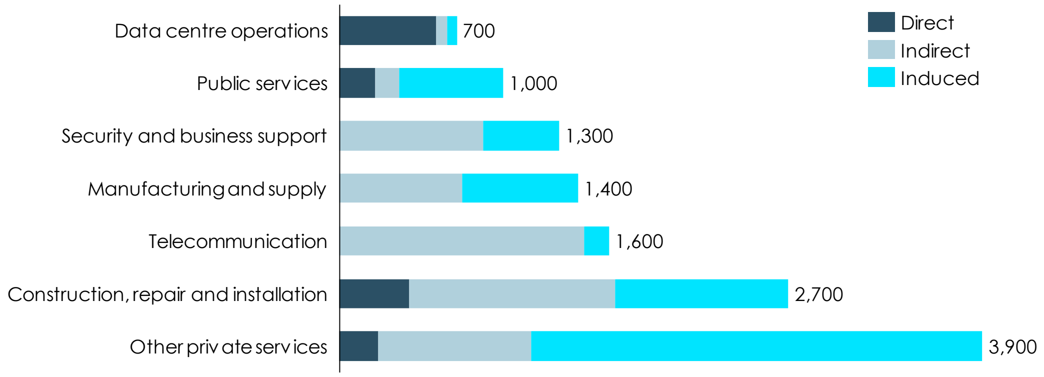
A track-record of investment and new developments underway
As shown in a study for the European Commission, the data economy in Europe is expected to continue to grow systematically and persistently.[2] Google is serving fast-growing demand from European consumers and businesses. Thus, Google has an ongoing set of committed investments and operational expenditures on the set of infrastructures covered in this study.

Between 2019-2021 Google has announced **committed investment of EUR 5.0 billion** in European data centre and related infrastructure investments, as announced up to August 2019. Summing up with investments realised so far, **by 2021 Google will have invested around EUR 11.9 bn** in European data centre and related infrastructures. Based on these commitments, we have a basis to forecast, all else equal, the evolution of European economic impact from these investments in the near future.

- Google's commitment to further investments is estimated to support an additional economic activity in Europe of **EUR 2.1 billion** per year and **27,200 jobs** per year on average, over the period 2019-2021;[3] in other words, **EUR 6.4 billion total for the period** 2019-2021
- Summing up realised effects and the forecast based on committed investments, **by 2021 Google will have a supported a total of EUR 15.2 billion of** economic activity across Europe (2007-2021) – corresponding to **13,100 jobs (FTE) per year** on average
- The European jobs supported by these investments have grown over the years, such that:
  - 2007–2010: Google supported **2,800 jobs** per year on average (FTE)
  - 2011–2014: Google supported **9,400 jobs** per year on average (FTE)
  - 2015–2018: Google supported **16,700 jobs** per year on average (FTE)
  - 2019–2021: Google is expected to support **27,200 jobs** per year on average (FTE)

[2] IDC (2017), *The European Data Market Study: Final Report*. Study for the European Commission.
[3] Job impacts include direct, indirect and induced channels of supported employment, as detailed in chapter 2.

Figure 2 Employment supported by the Google data centres & related infrastructures
Yearly average for the period 2007 – 2020



Note: 'Other private services' include (but are not limited to) retail trade, transport, hotels and restaurants, real estate, and legal, accounting and employment activities.
Source: Copenhagen Economics, based on data from Google, Eurostat and World Input-Output Database tables.

Network connectivity links EU cities and countries together and to the global internet
We now zoom into the impact of a fundamental infrastructural component: the networking layer (a key driver of the overall results presented above). Typically associated with the telecommunications industry, this type of network component is also a key area of focus for Google's infrastructural efforts. This is because of the importance of connecting the backbone of the internet, linking data centres all the way to the exchange points where retail telecommunications companies take over and serve retail customers (fixed and mobile home broadband, workplace connectivity etc). The backbone of the internet infrastructure goes in tandem with the internet access links, ultimately linking consumers and devices with the computation and service provision, as well as with each other.

We have measured the extent to which this connectivity expenditure (a subset of the expenditure already accounted for in the previous pages) has converted into economic benefits for European countries, finding as main results that:

- Google's connectivity network past and committed expenditure in Europe is expected to reach **EUR 2.9 billion, invested over the period 2007 – 2020**
- This corresponds to a **supported economic activity amounting to EUR 270 million per year** and **3,900 jobs** per year on average across the connectivity value chain and a wide set of European industries; in other words, **EUR 3.8 billion total for the period** 2007-2020

We have double clicked on these networks in place and documented examples of links developed across European countries, around and between cities, along strategic cross-border infrastructure corridors, as well as connecting via subsea cables Europe to the global internet. Europe comes closer together and becomes even closer to the world thanks to such infrastructure developments, with benefits for citizens across Europe.

Energy efficiency and environmental investments supporting Google data centres
Every time we as users choose to consume products and services, we are also sending an economic signal (indirect demand) to procure the energy that firms need to supply such services. As non-digital activities are shifted to new digital applications, we as users continue to consume energy – the question is then the efficient use of this energy and its sustainability of supply.

While storing and processing data to deliver our preferred services requires energy, the solutions that Google has introduced bring opportunities to increase the energy efficiency by which data is handled. In fact, large data centres are more energy efficient than individual servers and, by pooling the server needs of many customers, a lot of energy can be saved. Here, scale matters, in both achieving business and environmental aims.

Since 2017, Google has achieved its target of matching 100% of its data centres' and offices with purchases of renewable energy. In doing so, Google has developed the largest portfolio worldwide of corporate renewable Power Procurement Agreements (PPA). Via PPA deals, Google signs contracts with renewables' developers and supports the production of carbon free energy – for example by reducing the risk and improving business conditions of these renewables' developers and investors. Google has signed 24 PPAs with renewable energy developers across Europe. This constitutes a total of almost 1.7 GW of wind and solar power capacity.

A cloud-to-data centres value chain staying fit for Europe's future

The European Commission has reaffirmed its commitment to promoting digital transformation and green ICT to back this. Cloud computing, via its scale and efficiency, is a valuable resource towards these aims. Therefore, any initiatives aiming to strengthen cloud's role and its value to EU should also be aware of the value generated by the infrastructures that underpin the cloud.

Having reviewed the functioning of this emerging and fast-growing infrastructure layer across Europe, based on the in-depth case study of Google, we have considered the question of what policies and initiatives are best placed to serve the interest of European citizens/consumers and firms. For this value chain to function at its maximum potential serving EU digital transformation processes, a bird's eye view of the entire infrastructural needs and framework conditions is certainly recommended. We highlight as follows, for the consideration of European policymakers:

- **Data centres**
  - Tackling **education** as a key front line to ensure that future employment opportunities are met with a workforce with data centres' relevant skills
  - Tapping into data centres for regional cohesion aims; **skills and local infrastructures** to empower diverse local economies where DC investment is and can be further attracted
- **Network connectivity**
  - Considering **fragmentation in telecoms infrastructure suppliers** between EU countries (due to national legacy) as a Single market obstacle for new inter-EU networks
  - Fostering greater awareness at EU and country level of **subsea cables as valuable infrastructure** to be safeguarded and promoted in the European interest
- **Renewable energy**
  - Ensuring a **coherent implementation of the internal electricity market** for renewables' investors and PPA backers to come together across national boundaries
  - Assessing the case for reducing the **cross-country infrastructure bottlenecks** that constrain a deeper EU energy union and the most efficient deployment of renewables

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CHAPTER 1

INTRODUCTION: INFRASTRUCTURE FOR THE DIGITAL FUTURE OF EUROPE

1.1 A TRANSFORMATIVE SHIFT, ENABLED BY HIGH-TECH INFRASTRUCTURE – THE CLOUD

1.1.1 Cloud enables enhanced division of labour and specialisation between firms – a key source of economic progress

Adam Smith, seminal 18th century economist, visualised the concept of division of labour via the example of a pin factory where specialised workers achieved a greater output than a craft setup with all workers assigned to perform all tasks in parallel.[4] Smith noted that the productivity of an overall process improves when there is greater specialisation and distinction between its activities and who does what. While his original example was focused on within-firm working processes, the economic intuition has been extended to apply to intra-firm and economy-wide working processes, and the role of different firms in creating value by specialising on what they do best, while relying on other firms for other activities.

Waves of the industrial revolution have been defined by the role of infrastructures in providing a common platform that many different users could tap into progressively more and more, allowing for greater division of labour and specialisation. For example, at the time of electrification, more and more factories would stop generating their own power and instead rely on the grid and specialised suppliers of electricity. Factory work and processes would be rearranged accordingly.

Today, digitisation is the major transformative wave sweeping through our economies. Digitisation is the driver of manifold technological developments, innovative solutions and new business ideas that are changing our economy and society – today as well as in the near and distant future. Cloud solutions provide an advanced platform that can cater for many different computation and information management requirements that serve the evolving demand of firms, governments – and ultimately individuals.

Organisations across the private and public sector can develop even further what they do best, by relying on cloud solutions to support their needs and processes. These advances in the economy-wide division of labour bring benefits and further opportunities across European manufacturing and service sectors. This reflects a combination of benefits for organisations, such as improved efficiency, lower costs, reduced lead times, new services and features offerings, and increased consumer convenience.

1.1.2 The role of cloud within digital transformation processes

When digital technologies emerged, firms increasingly digitised existing processes and tasks to improve efficiency and work streams. Digital computers, record-keeping and communication

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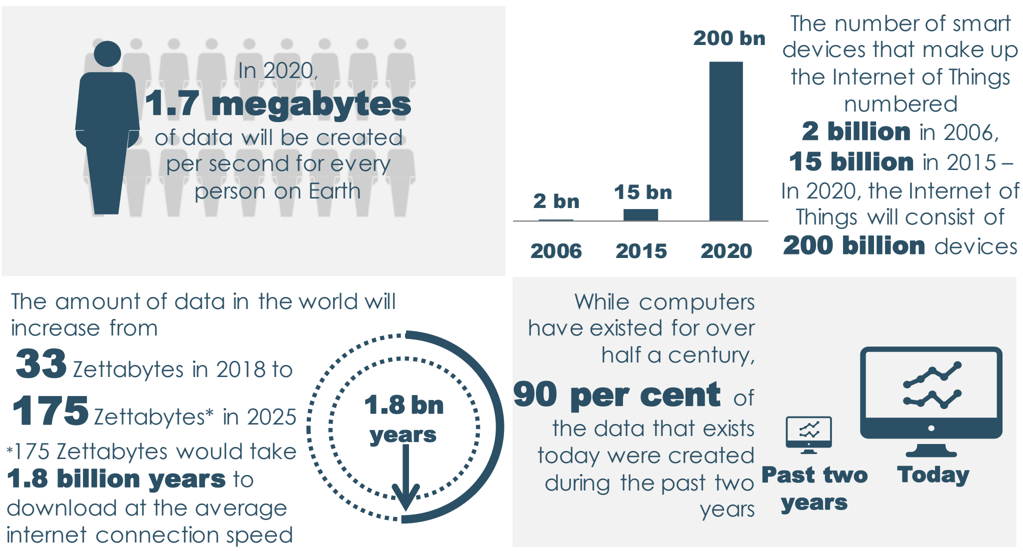
4 Smith, A., 1776, *An Inquiry into the Nature and Causes of the Wealth of Nations*.

technologies proved superior to the mechanical and analogue technologies. As technology progressed, more and more activities were digitised and, importantly, whole new solutions and ways of organising production have emerged. Today, we are moving into the fourth industrial revolution – the cyber-physical era – crucially dependent on firms' ability to tap into the data processing infrastructure.

Machines and components communicate with each other in smart factories and autonomous production can optimise flows by, for example, identifying maintenance needs and adapting to individual customer requirements in real time. Additionally, further developments in robotics technology create increasingly sophisticated robots at lower costs. Additive manufacturing (3D printing) is expected to revolutionise the industry by offering profitable production of specialised goods (even in small scale) and by enabling individualised products on order. Similarly, the Internet of Things (IoT) revolution, equipping products and process equipment with sensors, enables embedded systems to communicate and manage advanced processes.

Cloud solutions are a key component and driver of digital transformation. Since digitisation is underpinned by an ever-increasing creation, demand and supply of data – the lifeblood of the digital economy – the computing power and scalability of cloud in handling data is a key engine and enabler of this economy-wide transformation.

Figure 3 The future of data



Source: Copenhagen Economics based on: DOMO, 2018, *Data never sleeps 6.0*, Intel, *A guide to the Internet of Things* (https://www.intel.com/content/www/us/en/internet-of-things/infographics/guide-to-iot.html), IDC, 2018, *The Digitization of the World – From Edge to Core*, and Forbes, 21 May 2018, *How Much Data Do We Create Every Day? The Mind-Blowing Stats Everyone Should Read*.

The gains from increased specialisation span over multiple crucial areas of data processing. Not only are cloud solutions necessary to process the ever-increasing volumes of data or to provide the advanced digital solutions that enable firms to stay at the competitive edge, they also make data processing more secure. By assigning the task of data processing to designated cloud service providers, scale opportunities allow for sizable investments, pooling of IT security experts and other efforts into strengthening the security beyond what an individual firm can achieve on its own.

By using cloud capabilities, tools and infrastructure, security incidents may be reduced by 60 per cent.[5] In sectors where data security is a critical concern – such as healthcare, finance, and public sector services – cloud adoption is increasing at a rapid pace as it is becoming apparent that on-premises data processing cannot match the security capabilities offered by cloud service providers.[6]

While the Cloud does not have a universally agreed definition, it can be seen as a large toolbox of ICT solutions and services that are instantly available and provided to customers over the internet, usually from several large-scale servers at remote locations unknown to the user, i.e. data centres.

Cloud solutions are not necessarily provided by a specific server or data centre, but rather a network of data centres. Instead of assigning the ICT solutions to an exact geographical spot, it is easier to perceive the solutions and services as being placed somewhere in "the clouds".[7]

The ICT solutions or services provided through the Cloud can be divided into three main categories:

- Infrastructure-as-a-Service (IaaS) provides storage space, where customers can save various types of data, and computing power, that enables customers to run heavy programmes or execute data queries at a much faster pace
- Platform-as-a-Service (PaaS) provides access to a digital framework, similar to a workshop or a playground, where developers can create their own solutions and applications. It also provides tools for data analytics and business intelligence
- Software-as-a-Service (SaaS) provides ready-to-use applications, often directed at end-users. This can, for example, be web-based e-mail services such as Google's GSuite or Microsoft's Office 360, or video sharing platforms such as YouTube or Vimeo

Cloud computing provides access to all these services on-demand, everywhere in the world at any point in time. The only requirement is that the user has an internet connection. Equally important, the Cloud has transformed an infrastructure that used to require individual firms to assign heavy investments and maintenance costs into an affordable utility that firms of any size can enjoy. As with electricity, cloud computing allows payment schemes where customers pay for what they consume, when they consume it – they do not need to construct and maintain their own electricity grid or piping system.

The benefits of cloud computing promote the digital transformation by making new, valuable ICT solutions available for companies of all sizes, all around the world. With the Cloud, start-ups are no longer held back by a need to invest heavily in ICT equipment, SMEs can try out various platforms and applications before choosing their preferred solution and large enterprises can easily scale up storage capacity and computing power when demand is high, and likewise scale down when demand is low.

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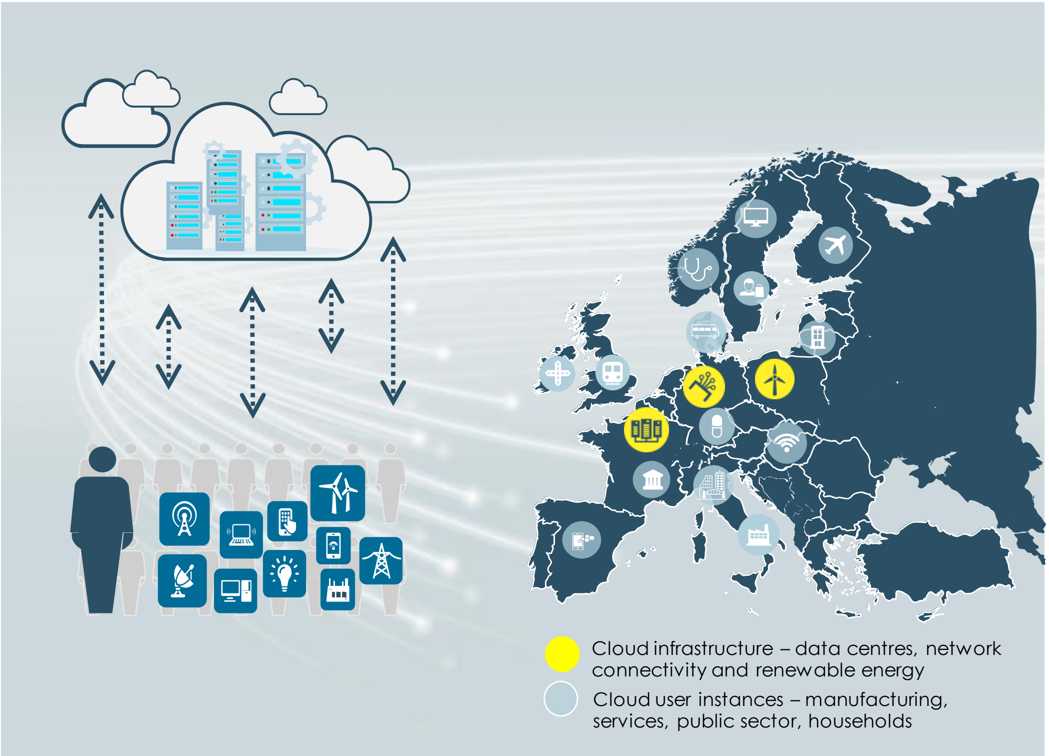
[5] Gartner, 2016, *How to Make Cloud as IaaS Workloads More Secure Than Your Own Data Center*.

[6] Eplexity, 2018, *Why the public cloud is more secure than on-premises data center*, available at: https://eplexity.com/why-the-public-cloud-is-more-secure-than-an-on-premises-data-center/.

[7] Kommerskollegium (2012), "How Borderless is the Cloud? An introduction to cloud computing and international trade"

Figure 4 Infrastructure, platform and software available anywhere, anytime



Source: Copenhagen Economics

1.1.3 Data centres and related infrastructures – how does this work?

Behind the Cloud, millions of servers are hidden in hyper-scaled data centres. These data centres are the backbone of the digital infrastructure and the physical assets that actually store, process and/or distribute the data that customers send to the Cloud.

The data centres are connected in a worldwide network through a core fibre grid and long-distance cables. Inside Europe, the data centres and other key infrastructural assets (e.g. receiving masts connected to the internet) are linked through the European cable network that allow data to flow quickly from one location to another, while international cables cross the continent's boarders to connect the European data centres with the rest of the world.[8]

The network of data centres is what allow cloud users to do much more, much faster. Instead of solving one task at a time, using one or a handful of servers on-premises, customers can send data from their local computers to the data centres, where thousands of servers can carry out numerous tasks, simultaneously.

8 Copenhagen Economics (2017), "Finland's economic opportunities from data centre investments"

1.2 CLOUD AND BEYOND – POLICIES SUPPORTING THE EU'S DIGITAL TRANSFORMATION

1.2.1 A renewed priority under the incoming European Commission

Unsurprisingly, given the benefits linked to the Cloud, there is increasing policy attention on how to support its role as part of the EU's digital transformation ambition.

A centre-piece of the incoming 2019-2024 European Commission's priorities – A Europe fit for the digital age – centres on the advancement of Artificial Intelligence, the Internet of Things and Big Data in Europe, thus harnessing the opportunities from data sharing.[9] At the same time, the new Commission has said it will prioritise progressing the Green Deal for Europe.

AI, IoT and Big Data advances can be deployed efficiently relying on the cloud. Thus, it is to be expected that the role of cloud computing, as well as that of green ICT infrastructures enabling the efficient and sustainable use, can play a pivotal role in achieving the core policy objectives of the EU under the von der Leyen Commission and the new European Parliament.

1.2.2 Multiple layers of cloud and data initiatives across Europe

The EU data economy is forecasted to represent up to 5.4 per cent of the EU's GDP in 2025, according to the strictest definition of the data economy.[10] Accenture employs a wider definition of the digital economy and expects that it will represent up to a third of GDP in some EU countries in 2020.[11]

Regardless of definition or label one uses, data and data centres are a significant and growing part of the EU economy. This is widely recognised by the EU, who for the past years have been working to ensure that the EU Single Market is "*fit for the digital age*" under the Digital Single Market (DSM) Strategy[12] through the removal or updating of outdated regulatory barriers. Indeed, the European Commission has proposed to invest EUR 9.2 billion into the Digital Europe programme to further the digitisation of the European economy.[13]

In addition to the EU initiatives, there are also national policy initiatives being undertaken. Notably, Estonia has developed the Government Cloud solution[14] and the UK has adopted a Cloud First policy, meaning that the public sector should turn first to the cloud when buying IT products and services.[15] France has developed a Cloud strategy to expand the use of cloud services and solutions among French public sector bodies.[16]

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9 Ursula von der Leyen, 2019, *A Union that strives for more – My agenda for Europe*, and European Commission, 2019, *Mission letter to Margrethe Vestager, Executive Vice-President-designate for a Europe fit for the digital age*.

10 IDC and the Lisbon Council, 2018, *Updating the European Data Market Study Monitoring Tool*. "*The Data Economy measures the overall impacts of the Data Market on the economy. It involves the generation, collection, storage, processing, distribution, analysis elaboration, delivery, and exploitation of data enabled by digital technologies. The Data Economy also includes the direct, indirect, and induced effects of the Data Market on the economy*."

11 Accenture, 2016, *Digital disruption: The Growth* Multiplier. The digital economy is defined as *"the share of total economic output derived from a number of broad "digital" inputs. These digital inputs include digital skills, digital equipment (hardware, software and communications equipment) and the intermediate digital goods and services used in production. Such broad measures reflect the foundations of the digital economy."*

12 https://ec.europa.eu/commission/priorities/digital-single-market_en.

13 https://europa.eu/rapid/press-release_IP-18-4043_en.htm.

14 https://e-estonia.com/solutions/e-governance/government-cloud/.

15 https://www.gov.uk/government/news/government-adopts-cloud-first-policy-for-public-sector-it.

16 https://www.numerique.gouv.fr/espace-presse/le-gouvernement-annonce-sa-strategie-en-matiere-de-cloud/.

Box 1 Selected Digital Single Market (DSM) policy initiatives critically related to a well-functioning data centre infrastructure

- **Building a European data economy**[17]
The Commission has adopted a number of legislative pieces, such as the so-called *Free Flow of Data Regulation* (FFoD), to remove barriers that impede firms' ability to fully benefit from cloud computing, big data analysis, and the Internet of Things. These technologies are key to the EU's competitiveness, and especially so for SME competitiveness. A concrete measure is the industry-led efforts, mandated in the FFoD, to develop Codes of Conduct on portability between cloud service providers to further improve the functioning of the EU single market for cloud services. Another example is the setup of CSPCert as a result of the *EU Cybersecurity Act*, a working group of industry actors to advise and recommend how to strengthen a system of trusted cloud service providers in the EU. In the same vein, the EU Cloud Code of Conduct ensures and strengthens cloud service providers' compliance with the *General Data Protection Regulation* (GDPR).
- **The European Cloud initiative**[18]
The Commission develops a European Open Science Cloud and a European Data Infrastructure that will benefit scientists, researchers, the public sector, and industry by creating greater opportunities to make use of the technological advancements. It will do so by increased shareability and access to data, improved interoperability and access to powerful analytical tools that one single actor cannot feasibly develop or maintain on their own. Additionally, the European Commission is currently undertaking a study into further optimising the energy consumption of ICT services – so-called *Green ICT* – through cloud computing technologies.[19]
- **The Internet of Things (IoT)**[20]
The Commission is fostering the uptake of and deployment of IoT in Europe, for example by setting up the Alliance for the Internet of Things Innovation. Its aim is to create a European IoT ecosystem that would strengthen the competitiveness of the European IoT market, ensure a human-centred IoT approach and to create a single market for IoT. A single market for IoT must be able to handle the number and diversity of connected devices and the data they produce, while at the same time ensuring the secure handling of interoperability of the connected devices.
- **Artificial Intelligence (AI)**[21]
The Commission is promoting and supporting research and development into AI technologies and platforms to encourage the AI uptake of private and public actors. It also supports the socio-economic transition into an economy where AI plays in increasingly important role, such as education, training and retraining schemes. Equally, if not more, important is the EU's efforts to ensure an ethical use of AI across Europe. To support the implementation of the EU's AI strategy, the *AI High-Level Expert Group* issues guidelines and recommendations to ensure an ethical AI development in the EU.
- **Big data**[22]
As the name suggests, big data means the processing of large amounts of data. The Commission identifies that exploiting the potential of big data requires investment in ideas, infrastructure for a data-driven economy, develop building blocks such as licenses, open data, incubators for SMEs and training, and ensuring trust and security both regarding data protection for individuals as well as trade secrets and commercially sensitive data.
- **High-Performance Computing**[23]
There is an increasing number of data-intensive applications and solutions that rely on computers with the capability to process an enormous amount of operations within a short period of time, so-called supercomputers. In the coming years it is expected that some supercomputers will be able to perform one trillion operations per second, which will help to come up with cutting-edge innovations. The EU is working to provide industry, SMEs and researchers with access to such supercomputers, with the explicit aim to make the EU a leading actor in this field.

Source: European Commission, specific web references in footnotes

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17 https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52015DC0192.
18 https://ec.europa.eu/digital-single-market/en/%20european-cloud-initiative.
19 https://www.cloudefficiency.eu/home.
20 https://ec.europa.eu/digital-single-market/en/policies/internet-things.

All these policy initiatives, whether at the EU or national level, reflect a solid understanding and vision that embracing, promoting and supporting the use of new digital solutions is crucial to strengthen competitiveness and improve the economic performance across Europe.

A successful development of the European data economy rests on many key components and actors, with cloud as a key pillar. In turn, for cloud to be a success, a central factor is a well-functioning data centre infrastructure. Data centres are the core of the data economy. Therefore, any policy makers and interested parties which are vested with the development of the cloud in the EU should also pay close attention to the data centre and related infrastructure layer.

As the case studies researched in this chapter illustrate, all over Europe, private and public sector organisations are turning to more and more advanced cloud solutions. These require an equally advanced data centre and infrastructure support – going hand in hand with the ability of cloud to empower firms and public sector to embark on further digital transformation. For this reason, ensuring and facilitating sound framework conditions for the data centre infrastructure is key to help the EU, national governments, firms and citizens make the most of the digital transformation.

1.3 CLOUD-DRIVEN DIGITISATION IMPROVES FIRM PRODUCTIVITY AND EU COMPETITIVENESS

The Cloud has transformed how companies purchase ICT equipment and services. With the introduction of the Cloud, large up-front investments in hardware and software are no longer needed for companies to compete in the market. Companies can now tailor a basket of hardware and software that covers their specific needs and get the basket delivered on-demand, through the cloud in a matter of minutes.

Cloud solutions are not only for large firms but firms of all sizes. New entrants can gain access to all the storage space and computing power capacity they need in a pay-as-you-go manner and subscribe to advanced applications at an affordable price.

The flexibility and cost-efficiency of cloud computing lower entry barriers for start-ups and allow SMEs to scale quickly without having to invest heavily in new ICT. Cloud computing enables a higher degree of specialisation, where data processing takes place in data centres operated by cloud service providers, while user firms focus on their core business.

The scalability of the cloud has also led to completely new business models, for example employed by companies such as Spotify, Netflix and AirBnB.[24] The European Commission estimates that the adoption of cloud will create 303,000 new businesses in EU28 from 2015 to 2020.[25] Cloud computing will, in particular, promote many new SMEs, leading to the creation of new jobs and increased competition in the EU Single Market to the benefit of the economy and the consumers.

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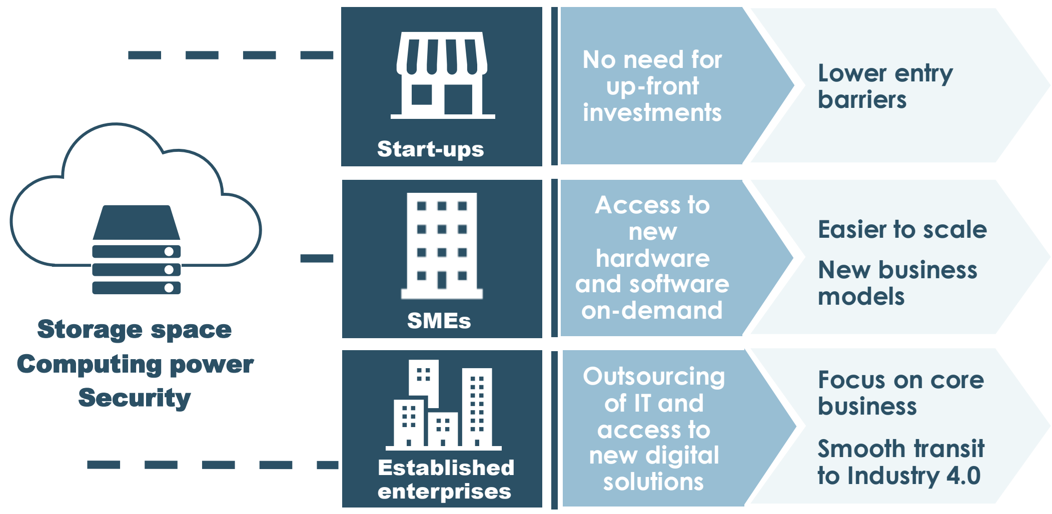
21 https://ec.europa.eu/digital-single-market/en/artificial-intelligence.
22 https://ec.europa.eu/digital-single-market/en/policies/big-data.
23 https://ec.europa.eu/digital-single-market/en/policies/high-performance-computing.
24 T. DeStefano et al. (2019), "Cloud computing and firm growth"
25 European Commission (2017), "Measuring the economic impact of cloud computing in Europe, Digital Single Market"

The cloud does not just lower entry barriers. It offers increased flexibility since employees and executives can have access to the company's entire data repository and internal systems via a laptop, tablet, or even a smart phone. Firms with over 100 years in business that have gathered enormous amounts of data about materials, machines, processes, and products can discover new insights thanks to the superior computing power of the cloud compared to in-house server facilities. With sophisticated encryption and round-the-clock monitoring by IT and internet security experts, the cloud offers secure data storage and processing superseding that of an in-house system.

Furthermore, cloud computing enables a more optimal allocation of resources at the macroeconomic level, where firms use their capacities on what they do best and increase productivity. Specialised providers (e.g. cloud computing companies) operate hyper-scale data centres and provide firms with low-cost, high-quality hardware products and software services through the cloud. Meanwhile, firms can free up time and resources by outsourcing hardware and software solutions to third-party experts, allowing them to focus on, and develop, their core business.

In addition, cloud computing is integral for firms' transition to Industry 4.0, where autonomous machines and systems will be a significant part of production.[26] Companies can, and sometimes must, use cloud solutions to upgrade their automated work processes of the third industrial revolution into the cyber-physical systems of smart, connected and self-improving devices and machines of the fourth industrial revolution.

Figure 5 The cloud offers solutions to all types of firms



Source: Copenhagen Economics

[26] https://www.forbes.com/sites/bernardmarr/2018/09/02/what-is-industry-4-0-heres-a-super-easy-explanation-for-any-one/#5339c6b69788

1.4 CASE STUDIES: INFRASTRUCTURE-BACKED CLOUD SOLUTIONS ENHANCE BUSINESS FOR EU FIRMS

Our research question for this chapter centred on the links between the data centre infrastructure and the ability of state-of-the-art cloud solutions to intercept the evolving needs of European organisations. To do so, we have conducted four case studies which are representative of several key European markets and sectors of economic activity. We have relied as additional information source on access to a set of cloud experts and we have focused our deep dives amongst a set of users of the Google Cloud Platform – curious to find out more about:

- The business situation of the organisation adopting cloud
- The nexus between advanced cloud solutions and the data centres and infrastructure layers, how the latter supports the former
- The business impact for the user, thanks to the transformation enabled by data centres' infrastructures and the cloud solutions – and its wider socio-economic significance

In the following, we present two cases of how European firms have been able to transform their business offerings and models by using advanced cloud solutions. The interested reader can find additional documentation at the end of the study on the two additional case studies, highlighting how the cloud, data centres and related infrastructures support the digital transformation of the European manufacturing industry to improve productivity, and the public sector's ability to monitor complex infrastructural systems and networks.

CASE STUDY

France: Airbus Intelligence boosts quality and accessibility of its satellite imagery via real-time scalable computing power for old and new clients

Airbus Intelligence is a unit of Airbus Defence and Space division. Today, Airbus Intelligence produces comprehensive high-quality images all around the world every day, using 14 satellites, and provides the captured satellite imagery and data to more than 1,200 customers in 100 different countries in near real-time.

In the past, production and delivery of satellite imagery and data was a much slower and cumbersome process than today. Customers had to choose the images they wanted from a catalogue and then wait several hours before they received them. Many smaller organisations were also indirectly excluded from accessing the imagery as they did not have the necessary technical capability and capacity to receive and use it.

As Airbus started adding more satellites to their fleet and the technology became more sophisticated, both the volumes and the quality of the satellite imagery and data increased significantly. The speed of production and delivery grew into a bigger concern for the company, as Airbus could not meet the growing expectations of the customers.

To overcome this challenge, Airbus decided to use Google Cloud Platform (GCP) to build a new platform, called the OneAtlas Platform. GCP enabled Airbus to create a highly secure, scalable, online platform that could provide its customers with large amounts of satellite imagery in real-time. The cloud also gave the capability to put multiple applications on the same platform.

Customers can now stream images in less than half a second instead of waiting multiple hours for delivery, and they have access to more and better imagery and applications. Furthermore, the new platform means that Airbus' satellite imagery and data are available for smaller and less specialized organisations because the technical requirements have been reduced by the platform's streaming technology and API's. In addition, the cloud has made the data available on-demand, giving customers access to the imagery without signing up for expensive subscriptions.

As a result, Airbus Intelligence's services today benefit a wide range of companies and civilian use case. From insurers detecting damages of larger areas to shipping companies monitoring their fleet of ships or government agencies monitoring deforestation.

The scope and flexibility of GCP has also future-proofed Airbus' new OneAtlas Platform solution. Airbus plans to add more satellites and high-altitude drones to their fleet, which will increase the company's data storage requirements from 500TB to 2PB per year. Thanks to the cloud's scalability, this is seamless. Airbus is also working on expanding the OneAtlas Platform to include even higher resolution imagery, elevation data, automated change detection and a PaaS to allow its less specialized customers to use some of Airbus' own tools and possibly also third-party analytics.

Airbus Defence and Space is a key contributor as data provider to The International Charter Space and Major Disasters. The organisation supports public agencies around the globe in monitoring and managing disasters. Recently, its satellite imagery of the amazon rainforest fires was used to measure the impact of these fires, identifying instances in Bolivia of fires started near already deforested area.

Source: Copenhagen Economics, based on https://cloud.google.com/customers/airbus/, https://www.intelligence-airbusds.com/en/9305-amazon-rainforest-fire-sentinel-2-and-pleiades-are-being-tasked-in-bolivia, supplemented by industry engagement.

CASE STUDY

Germany: METRO has built a scalable high-reliability B2B e-commerce platform complemented by new advanced analytics on how to serve its clients best

METRO is one of the world's largest B2B wholesalers and food specialists. It sells products to its customers through a user-friendly e-commerce platform, as well as via stores and its delivery service. To do so, the firm stores incoming data from customers in a data lake, enabling it to gain new insights and improve its products and services.

Over the last couple of years, METRO has experienced that customers have started using online platforms when placing their orders, moving away from more traditional methods such as telephones and faxes. To keep up with the development, METRO realised that they needed to create a new, scalable e-commerce platform to handle the increased number of orders and meet the needs and expectations of its customers.

With the Google Cloud Platform (GCP), METRO can create a highly scalable micro-service platform, saving time and resources of customers while increasing their experience.

As a further advantage, METRO can use its new cloud solution together with Google's BigQuery to build a highly scalable data lake, capable of storing data of all types from various sources, e.g. traces from the customers when purchasing products and navigating through the platform. GCP gave METRO access to Google's advanced machine learning and AI solutions for data analysis, far superior to what METRO could build in-house.

Today, the new cloud-based e-commerce platform is live in 14 countries and offers stable, scalable services to customers with a positive impact on both overall sales and the number of ordering customers. Periods of instability have decreased by up to 80 percent after the migration to the cloud and METRO has not experienced any major breakdowns. The migration also means that METRO can buy storage space and computing power on-demand, giving the company the opportunity to scale its usage up and down as it likes. This cuts the company's infrastructure costs by 30 to 50 per cent. The combination of the data lake and the scalability of computing power brings METRO a wide range of possibilities and allows the company's data scientists to explore various integrated analytics and run complex models with high computing power.

By connecting data points from the data lake, METRO can offer advice on hygiene laws for certain foods, or information on provenance to its customers. METRO can even integrate the local weather forecast to ensure that the local store does not run out of ice cream on a sunny day. Most importantly, METRO's sales team can use these new pieces of information to reach out to customers and help them making more accurate buying decisions that will both save them money and reduce their waste.

METRO is still in the process of optimizing and exploring all the new opportunities that GCP provides. To do so, METRO has selected key solutions to focus on in the near future, such as integrating dashboards with KPIs all across the company to set priorities, improving customer analytics and optimizing the supply chain.

One specific goal is to trace a customer's whole experience of interacting with METRO. When implemented, METRO hopes to achieve omnichannel analytics, and thereby, further improve customer experience.

Source: Copenhagen Economics, based on https://cloud.google.com/customers/metro/, supplemented by industry engagement.

1.5 FROM CLOUD TO DATA CENTRES

If data is the lifeblood of the digital transformation, large-scale data centres are the hearts and brains of the digital infrastructure. Thus, the explosive growth in data traffic, storage and processing driven by consumers and firms require significant investment in data centres to facilitate this growth.

Data centres house servers, i.e. high-performance computers that run all the time, store and supply data whenever needed. The term data centre is broad and may encompass everything from a few servers in a small company's storage room to a facility with thousands of servers in a factory-like setting.

Figure 6 Google's data centre in Eemshaven, the Netherlands

Source: Google.

Large-scale data centres contain complex systems packed with mechanical, electrical and controls components, as well as networking equipment and communication links. When you use an online service, such as a search function or cloud-based email, the servers in the data centres do the work for you, around the clock and around the world. In order to function, data centres also need energy and water, both for powering the servers and for managing surrounding features such as cooling. Data centres also need staff, such as IT specialists, engineers, security guards, catering staff and facility managers.[27]

Advanced digital solutions require large amounts of data processing power and storage space. Large-scale data centres offer just that. When governments, firms, machines and consumers access and use digital solutions and services, such as e-mail, applications, and advanced analytical tools, they do so by connecting to data centres via the internet. Our devices – computers, smart phones, cars, fridges, robots, etc – can use and access the computing power of data centres almost anywhere

[27] https://www.google.com/about/datacenters/inside/locations/eemshaven/.

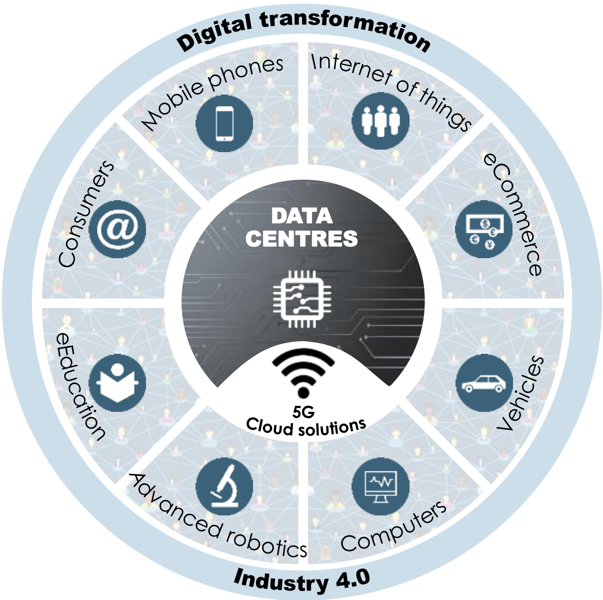
and anytime, as if ever-present but never in the way. Thus, the term used for this type of computing is cloud computing, or simply – the Cloud.

The foundation for the success and usefulness of the cloud for EU firms and citizens rests on three key infrastructural pillars: data centres, network connectivity, and access to renewable energy. The three pillars are key for realising and delivering the digital services and solutions that enable European firms – old and new, large and small, across all sectors – to stay on top of global competition by using state-of-the-art data processing and to lead the way into the fourth industrial revolution.

This report analyses the extent to which Google's data centres deliver a significant economic contribution to Europe – an appraisal set across multiple lines of inquiry, one for each of the three key infrastructural pillars, in the following chapters.

It must be remarked that the report's focus is on first-order impacts of the data centres and related infrastructures layers of the digital value chain. What is not considered further in the report (given its research scope) but is equally important for future research, is the broader positive effect that data centre infrastructures have as a core underpinning of the provision of digital services (see figure below).

Figure 7 Data centres at the heart of the European digital future



Source: Copenhagen Economics

This report analyses the following set of impacts of Google's data centres and related infrastructures in Europe.

- The economic impact of Google's construction and operation of data centres in all parts of the supply chain is estimated in chapter 2.

- Network connectivity associated with Google's European data centres is appraised in chapter 3, together with its economic contribution
- The potential of expanding Google's approach to energy efficiency performance and procurement of renewables more widely across the data centre industry is discussed in chapter 4
- Finally, chapter 5 is a focused summary of areas of policy awareness so to increase the beneficial EU economic impacts of data centres and related digital infrastructures investments

CHAPTER 2

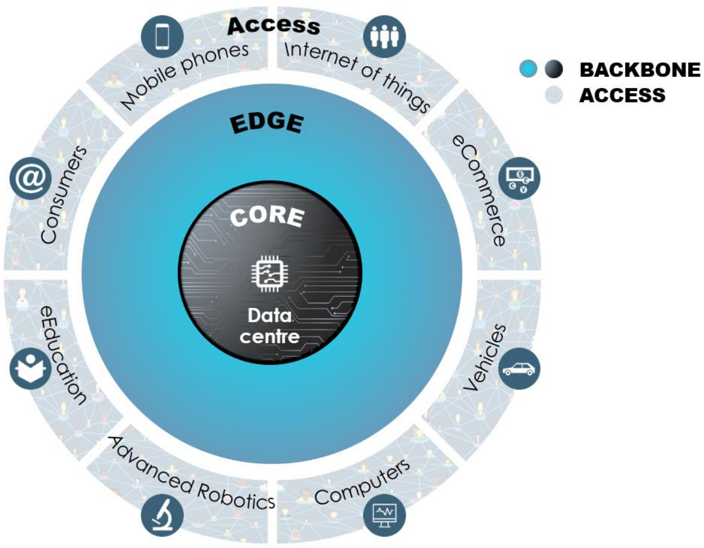
THE DIRECT AND WIDER ECONOMIC IMPACT OF GOOGLE ON JOBS AND GDP

2.1 INTRODUCTION: DATA CENTRE GROWTH & DRIVERS

Before analysing the economic and employment contribution of data centres – focusing on the case study of Google – it is helpful to provide the big picture context of why the data centre layer of digital infrastructures has emerged and its wider trends. Digitalisation of the global economy has been occurring over the last 20 years – this is a given. However, the drivers of this digitalisation have been diverse. The emergence of cloud computing is seen as the latest innovation to be driving the digital expansion. Its expansion has had a two-fold impact on the digital economy. First, it represents the latest addition to the repertoire of digital services available to individuals and enterprises. Second, and importantly, it represents a force-majeure for change in the fabric of the internet itself – its infrastructure.

Cloud computing represents one of the core data services that has fed demand for the expansion of hyperscale data centres globally. Specifically, the importance of cloud data is highlighted as the primary driver of *core* datasphere expansion – the area of the internet's infrastructure associated with datacentres. The datasphere also contains the edge – enterprise-hardened servers and appliances separate to data centres – and the endpoint – user devices incl. internet of things (see Figure 8).[28]

Figure 8 The core, edge and access links (endpoint) of the internet

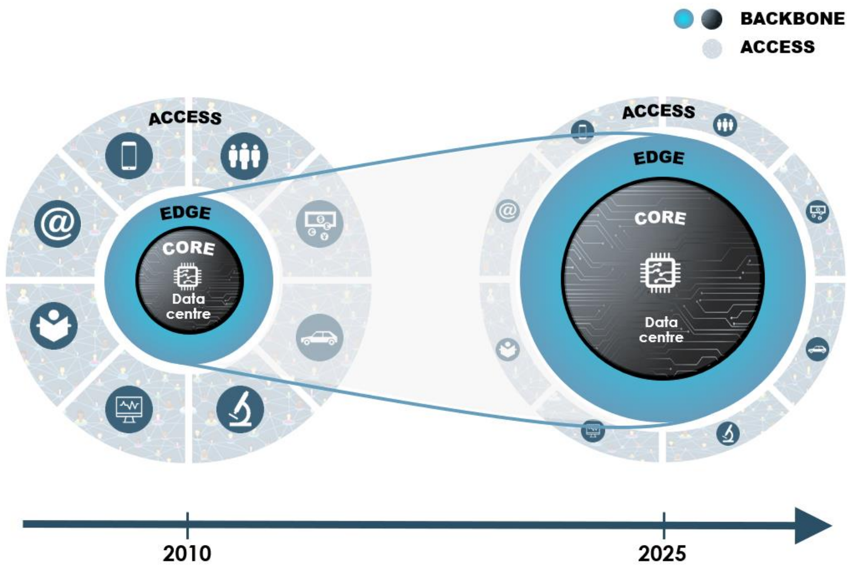


Source: Copenhagen Economics

[28] Seagate (2018)

The growth in demand for cloud computing is argued to be driving a reversal of data storage location, away from the internet access links and edge, towards the core. This is expected to be a significant reversal in data storage location from 2010, see Figure 9. These findings concur with findings from Gartner, reporting that "*between 70% and 90% of all organisations are now using cloud, that the 18% CAGR primarily comes from migration and new applications*".[29] However, this growth in the core is now also said to be spreading to the edge as demand for high speeds accompany the increased cloud utilisation.[30]

Figure 9 Storage in the core is becoming increasingly important



Note: This is purely figurative – hence relative sizes should not be taken as fact
Source: Copenhagen Economics

In terms of data centre workloads, Cisco estimates that by 2021, 94 percent of workloads will be processed via cloud computing in dedicated cloud data centres. The remaining 6 percent is anticipated to remain in a diverse array of traditional data centres.[31] Furthermore, Gartner predict that by 2025, 80 percent of enterprises will shut-down on-premise data centres in favour of shifting to third party providers like Google.[32]

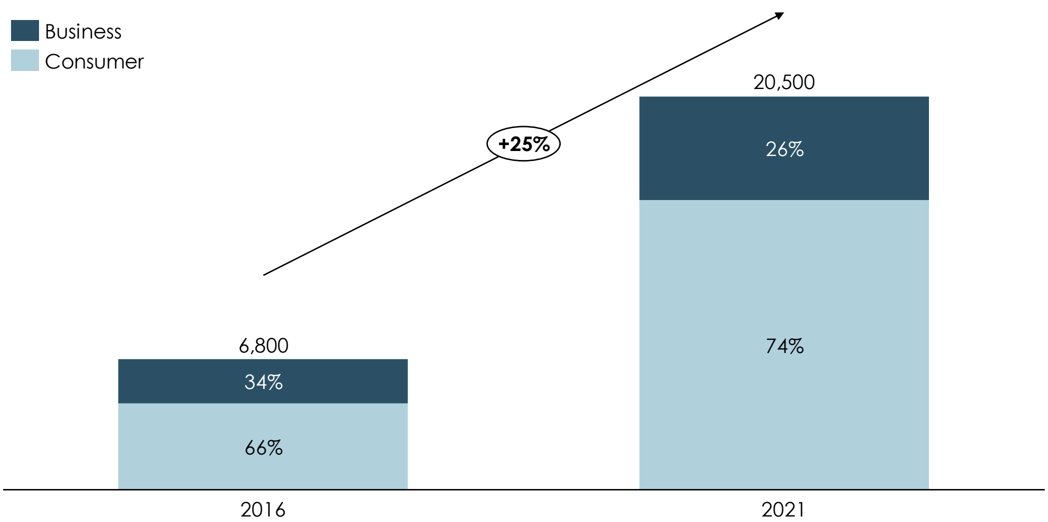
Growth in data centre capacity: an economic opportunity

The increasing demand for cloud services, such as e-mails, photos and music, means that global internet companies such as Amazon, Apple, Facebook and Google are now among the strongest drivers of the global data centre capacity growth. As suggested, global internet companies capture scale advantages by consolidating storage and processing of data in large hyperscale data centres, thereby shifting the landscape towards larger-scale, purpose-built facilities with a focus on operational costs and efficiency.

[29] https://data-economy.com/how-hyperscale-investments-are-behind-mega-growth-of-europes-data-centre-market/
[30] Interview with Stijn Grove, Managing Director, Dutch Data Center Association in July 2019.
[31] Cisco (2018)
[32] Gartner (2019)

However, concerns emerged via a Turner & Townsend survey where only 12 percent of respondents believed that the data centre construction industry was able to meet industry demand in 2018.[33] This is alongside exponential growth in the market for data centres, likely to compound the issue further.[34] Therefore, reflecting this shift, hyperscale data centres[35] are becoming increasingly important due to their ability to scale up their computing power to meet demand. Cisco estimates that by 2021, hyperscale data centres will constitute around 53 percent of datacentre servers, up from 27 percent in 2016. In terms of the data centres themselves, global data centre traffic in exabytes is estimated to increase at a CAGR of 25 percent between 2010 to 2017, see Figure 10.[36]

Figure 10 Global data centre traffic, 2016 – 2021
Zeta-byte per year



Note: +25% is on a compound annual growth rate (CAGR) basis.
Source: Cisco (2018)

COWI reports that the reliability of Cisco's estimates is high, given a prior study by Cisco in 2010 that estimated annual global data centre traffic of 4.8 ZB in 2015 versus the realised traffic volume of 4.7 ZB.[37] Similar growth projections emerge from a report by IDC that suggests that the total size of the data sphere will increase from 33 ZB in 2018 to 175 ZB by 2025, representing a CAGR of 27 percent.[38]

In essence, data transport and processing are subject to large scale economies and such is the case, therefore, in the functioning of data centres. Concentration of the data keeps the costs of data storage and operations of its services down, which ultimately benefits all internet users. Moreover, data

33 http://www.turnerandtownsend.com/en/perspectives/data-centre-cost-index-2018/
34 https://www.future-tech.co.uk/why-europes-data-centre-market-is-getting-in-a-flap/
35 Hyperscale data centres refer to those data centres that have an ability to scale their computing capacity in response to increased demand. Scaling in turn refers to the ability to increase computing power through better infrastructure, storage facilities, or memory.
36 Cisco (2018)
37 COWI (2018)
38 IDC (2019)

security is an important aspect and companies focus heavily and invest accordingly to ensure that data is kept safe at their data centres.

Hence, a report from CBRE estimates that the commercial FLAP (Frankfurt, London, Amsterdam, Paris) markets doubled in size from 2016 to 2018.[39] The Netherlands broadly has seen a consistent doubling of the market size every four years, with the digital hub in Amsterdam representing the fastest growing of the FLAP markets.[40] This could be driven by demand for localised digital hubs.

Therefore, just as is the case for players across the industry, the expected future growth in user demand for Google services suggests that Google's investments in data centres in Europe can also continue to increase over time – as they have already done in the past. Consequently, Google's economic impact to Europe would also increase over time.

However, as we will discuss below, for this efficiency and its benefit to be realised, it is imperative that data can move freely across national borders, for instance between one EU country and another – otherwise the benefits of the larger European market are lost.

2.2 INVESTMENTS REALISED AND COMMITTED SO FAR IN CONSTRUCTING AND OPERATING THE GOOGLE DATA CENTRES

Google's investments in digital infrastructure in EU member states help to propel the EU further forward as a digital economy hub. This digital infrastructure consists of data centres, network infrastructure and equipment, management, access and computation – elements that are crucial for our increasingly digital culture.

2.2.1 Google's data centres in Europe

Google is one of the largest suppliers of data in the world and serves a significant share of users from their data centres in Europe. Since 2007, six hyperscale data centres have been constructed in Europe, requiring substantial amounts of labour and inputs (see Figure 11).

39 https://data-economy.com/how-hyperscale-investments-are-behind-mega-growth-of-europes-data-centre-market/
40 Interview with Stijn Grove, Managing Director, Dutch Data Center Association in July 2019.

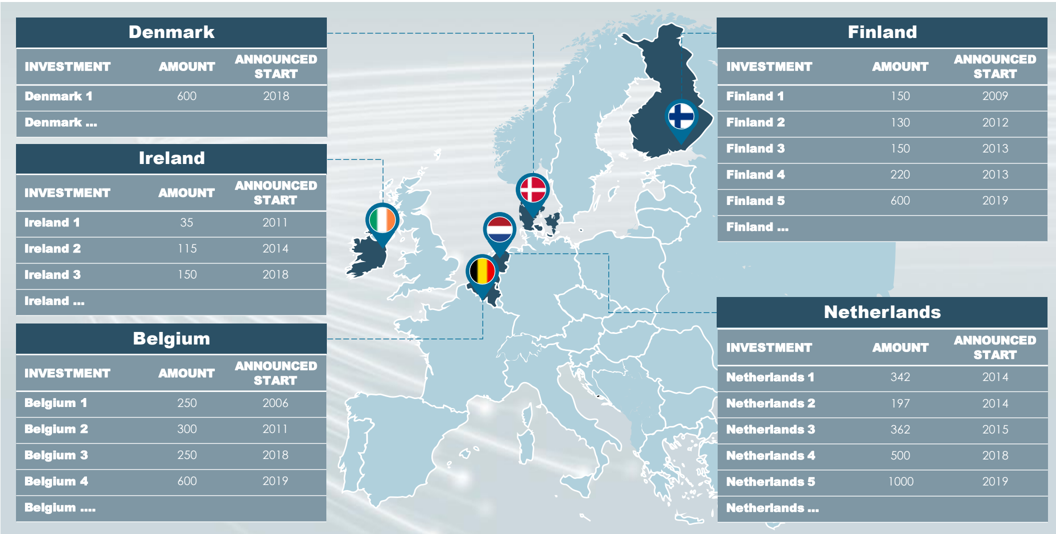
Figure 11 Google's data centres in Europe, 2007 - 2019

Source: Google

Construction of the first facility started in 2007 in St. Ghislain, Belgium, and was fully operational in 2010. The second facility was completed two years later, located in an old paper mill in Hamina, Finland. The third facility is located close to Google's European headquarters in Dublin, Ireland, and became operational in 2012. The fourth centre in Europe is located in Eemshaven, Netherlands, and started its operations in 2016. The fifth centre is under construction and is located in Fredericia, Denmark. Lastly, the sixth data centre is also under construction and is in Agriport, The Netherlands.

The research question for this chapter is to assess quantitatively the extent to which Google's six data centres (active or in construction) have delivered and are benefiting the European economy by supporting jobs and European GDP. This support includes invariably a component localised around communities close to their data centres, whereby their positive economic effects go beyond their own supply chain.

Figure 12 Ongoing investment in Google's Europe-wide network of data centres



Denmark

INVESTMENT	AMOUNT	ANNOUNCED START
Denmark 1	600	2018
Denmark ...		

Ireland

INVESTMENT	AMOUNT	ANNOUNCED START
Ireland 1	35	2011
Ireland 2	115	2014
Ireland 3	150	2018
Ireland ...		

Belgium

INVESTMENT	AMOUNT	ANNOUNCED START
Belgium 1	250	2006
Belgium 2	300	2011
Belgium 3	250	2018
Belgium 4	600	2019
Belgium		

Finland

INVESTMENT	AMOUNT	ANNOUNCED START
Finland 1	150	2009
Finland 2	130	2012
Finland 3	150	2013
Finland 4	220	2013
Finland 5	600	2019
Finland ...		

Netherlands

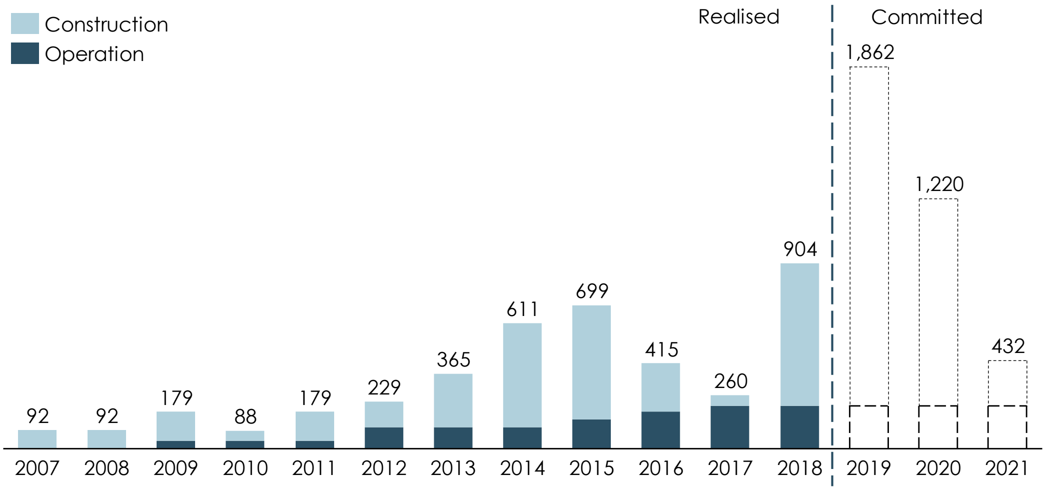
INVESTMENT	AMOUNT	ANNOUNCED START
Netherlands 1	342	2014
Netherlands 2	197	2014
Netherlands 3	362	2015
Netherlands 4	500	2018
Netherlands 5	1000	2019
Netherlands ...		

Source: Copenhagen Economics based on Google data centres website and data provided by Google

Since 2007, Google has invested a total of EUR 4 billion in constructing and operating the six hyperscale data centres, with an average of EUR 330 million per year (see Figure 12). Expenditures for constructing the data centres are, for instance, the costs of materials used to build the data centres, wages for construction workers, and purchases of machinery and electrical equipment. These expenditures are large and only occur when a data centre is under construction – once built, there are, by definition, no more construction expenditures. Expenditures for operating the data centres, on the other hand, are ongoing annual expenditures once it has been built. They include, for instance, the annual wages for Google employees and contractors working at the data centres, costs of electricity, and repair expenditures, while excluding servers, which is consistent with prior literature in this field.[41]

[41] BCG (2014) Digital Infrastructure and Economic Development; Oxford Economics (2018), Google Data Centers: Economic Impact and Community Benefit; RTI International (2018) The Impact of Facebook's U.S. Data Center Fleet; Copenhagen Economics (2018), European data centres.

Figure 13 Google's construction and operation expenditure at European data centres, 2007 - 21
EUR millions



Note: These numbers represent the total impacts per year, therefore including both operational and construction expenditure. The period from 2019 covers expenditure already realised as well as the expected amount to be completed, based on committed investments. Projections of operational expenditure beyond 2018 are kept constant and therefore likely represent a conservative estimate of future expenditure. The expenditures are annual averages.

Source: Copenhagen Economics based on data provided by Google

The majority of Google's expenditure (71 percent) in the period 2007-2018 has gone towards constructing the data centres, which is a reflection of Google's ongoing investments into construction for the six data centres throughout the period. In total, Google has since 2007 spent EUR 2.8 billion– an average of EUR 240 million per year - on data centre construction. On top of the construction expenditure, Google has spent EUR 1.2 billion since 2009 on operations of the facilities– an average of EUR 120 million per year.

A large majority of the construction and operational expenditures within the research scope are spent within the EU. In total over the period, 97 percent of expenditures within the research scope have been spent directly within the EU.

2.3 DIRECT, INDIRECT AND INDUCED IMPACTS OF GOOGLE'S DATA CENTRES

2.3.1 A framework for understanding the economic impact of Google's data centres in the EU

Data centres are important hubs for both technological and economic reasons and are a key part of the digital infrastructure on both a global, national, and regional level. Moreover, data centres provide a substantial economic impact to the regions in which they are located through *direct*, *indirect,* and *induced* effects.

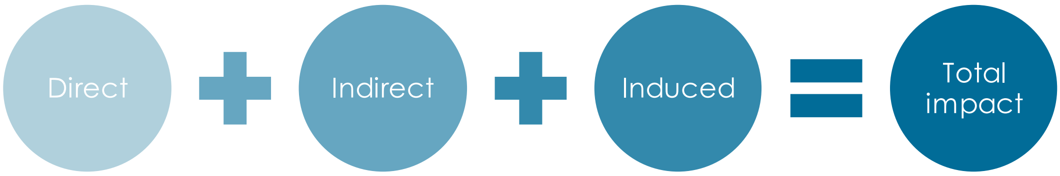
The *direct effect* includes the economic impact supported directly by the data centre and its construction contractors. The directly supported jobs in operations include positions in management, mechanical- and electrical maintenance and repair, IT and systems technicians, plumbing and water management, and hardware operations.

The indirect effect includes the economic impact through suppliers of goods and services. The indirectly supported jobs include positions in security, catering, cleaning, and in the construction and supply industries as well as at suppliers in upstream industries across the economy.

Moreover, we refer to *the induced effect* as the supported economic impact that occurs when employees at the data centre, and their supplier industries, spend their wages throughout the economy. The *induced* jobs are primarily service-related jobs in industries such as retail trade, transport, accommodation, restaurants, housing, and finance.

The source data for our analysis is information received from Google on expenditures and employment at Google's data centres in Belgium, Finland, Ireland, the Netherlands, and Denmark. For more information see our separate methodological appendix.

Figure 14 Direct, indirect and induced effect



Source: Copenhagen Economics

2.4 THE SUPPORTED ECONOMIC IMPACT OF GOOGLE'S DATA CENTRES AND RELATED INFRASTRUCTURES

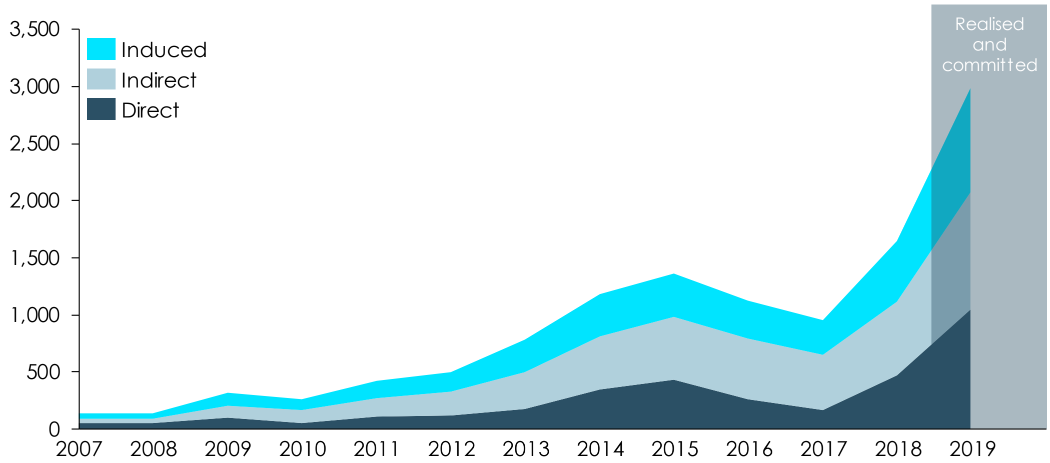
2.4.1 Economic contribution so far

We now turn to quantifying the economic impact of the combined set of investments, i.e. in data centres as well as related infrastructures. Thus, investments considered amount to EUR 6.9 billion (2007-2018) and include:

- Construction, civil engineering and restoration of the data centre sites
- Ongoing data centres' operation, including site reliability engineering and all support functions
- Connectivity links serving the EU and related networking assets

Our input / output model calculation finds that when considering the direct, indirect, and induced effects, Google's investments in the six data centres and related infrastructures has a supported economic impact of **EUR 8.8 billion in GDP cumulatively over the period 2007-2018**, growing over time from a yearly impact of EUR 100 million to a yearly EUR 1.7 billion (see Figure 15).

Figure 15 Economic impact supported by Google's European data centres and related infrastructures, 2007 - 2019
EUR millions



Note: The figure shows the supported economic contribution in the EU, due to the construction and operation of Google's European data centres and related infrastructures. 2019 covers effects of expenditure already realised as well as the expected amount to be completed, based on committed investments.
Source: Copenhagen Economics based on data provided by Google, Eurostat and World Input-Output Database

As shown in a forward-looking study for the European Commission, the data economy in Europe is expected to continue to grow.[42] Hence, we would equally expect that Google's investments in Europe would expand to serve fast-growing demand from European consumers and businesses. Indeed, Google has recently announced a new investment of EUR 1 billion to expand its presence in the Netherlands.[43] Therefore, the impact assessed above is likely to be part of an evolving picture.

2.4.2 Commitments to further data centre expansion and projected economic contribution in the near future

Obviously, larger data centres imply bigger infrastructures and even larger contributions to the EU economy. Looking at the period from 2019-2021, Google's commitments to future expansions in the EU (a committed investment of EUR 5 billion, based on announcements as of August 2019) is estimated to support an average contribution to the EU's GDP of EUR 2.1 billion per year. This includes direct, indirect, and induced effects.

Combining the past and projected estimates, by 2021, Google will have invested a total of EUR 11.9 billion. Our input / output model quantifies the corresponding impact in Europe, amounting to a supported EUR 15.2 billion in GDP over the same period.

2.5 THE SUPPORTED EMPLOYMENT IMPACT OF GOOGLE'S DATA CENTRES

[42] IDC (2017).
[43] https://www.cbronline.com/news/google-netherlands-data-centre

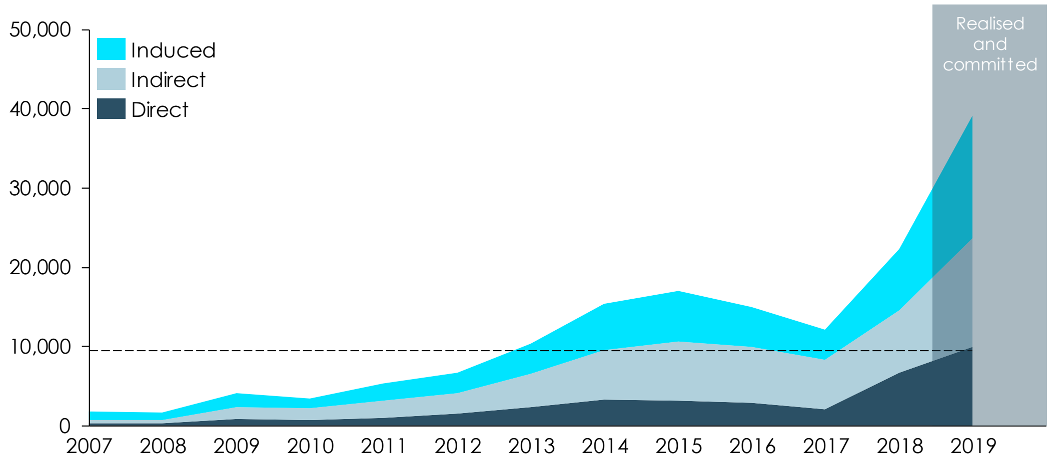
2.5.1 Google's data centres and related infrastructures have supported 9,600 FTEs on average per year since 2007

Our input / out model tracks employment characteristics across all the sectors of the economy supported by the Google expenditure analysed in the above sections.

Due to the linkages throughout the European economy, data centres and related infrastructures support many different types of jobs in almost all sectors of the economy. The indirect jobs are mostly supported in the industries supplying the data centre such as construction, electric machinery, and installation as well as electricity and other utilities.

Over the past years, the total supported employment impact of Google's data centre network has been **9,600 jobs per year on average** , on a full-time equivalent (FTE) basis, see Figure 16. This effect has fluctuated due to the varying intensity of construction work required to build the six data centres and when they were put into operation.

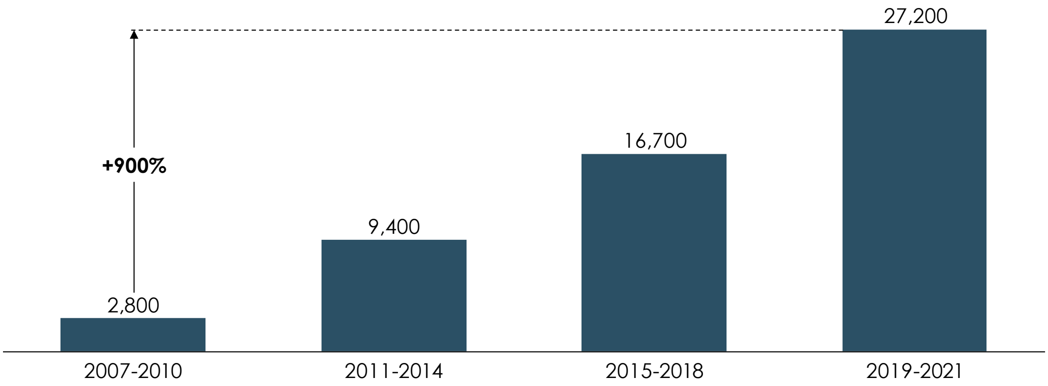
Figure 16 Employment impact supported by Google's European data centres
Full Time Equivalent jobs



Note: The figure shows the supported economic contribution in the EU, due to the construction and operation of Google's European data centres and related infrastructures. 2019 covers effects of expenditure already realised as well as the expected amount to be completed, based on committed investments.
Source: Copenhagen Economics based on data provided by Google, Eurostat and World Input-Output Database

Through committed expenditures to 2021, Google's data centres and related infrastructures will make an ongoing employment contribution to the EU of up to 27,200 supported FTEs per year (during 2019-2021) including direct, indirect, and induced effects (see the progression displayed in Figure 17).

Figure 17 Growth of European employment supported by Google's data centres and related infrastructures
Full Time Equivalent jobs, annual averages



Note: Figures include direct, indirect and induced employment associated with the expenditures in scope of this research. 2019- 2021 figures reflect committed Google expenditures.
Source: Copenhagen Economics based on data provided by Google, Eurostat and World Input-Output Database

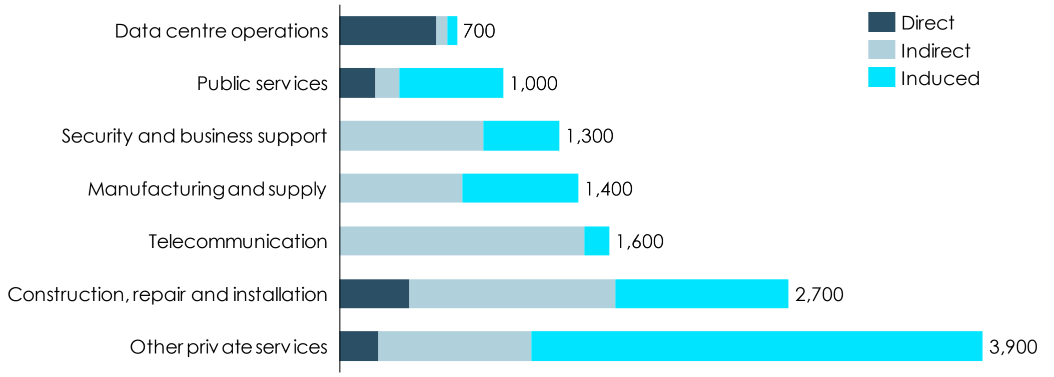
2.5.2 Employment supported throughout the economy

It is possible to explore in greater detail what types of jobs are supported by Google's data centre activity. Are these all IT jobs, since the data centre is typically associated with the IT industry? Far from the truth. Based on data sourced from WIOD and provided by Google, we have analysed how the Google data centre activity flows through the economy and supports jobs across all sectors of the economy.

We find that within the period 2007 – 2018 the data centre construction and operation support jobs primarily in the construction (2,700 FTEs per year) and security and business support (1,300 FTEs per year) industries.

In addition to these industries, the data centre activity stimulates consumer consumption, as workers spend their wages throughout the economy. These induced effects support jobs mostly in private services, as this is where employees tend to spend their wages. This mechanism supports up to 3,900 FTEs per year in private service industries such as retail trade, transport, hotels and restaurants, real estate, and legal, accounting, and employment activities, as reported below.

Figure 18 Employment supported by the Google data centre
Yearly average for period 2007 – 2020



Note: 'Other private services' include (but are not limited to) retail trade, transport, hotels and restaurants, real estate, and legal, accounting and employment activities.
Source: Copenhagen Economics based on data provided by Google, Eurostat and World Input-Output Database

Some of these industries, such as security, are proximity services and thus certainly in local areas; other goods or services can be supplied from further afield. The jobs supported by Google will therefore not only support local employment but also employment in other parts of the country in which data centres are located. Similarly, as supplier firms and workers spend the income obtained from data centre work on other products and services, the indirect and induced ripple effects extend also to both the local communities and the rest of the member state.

CASE STUDY

The Netherlands is a digital gateway to Europe thanks to its data centre eco-system

The Netherlands has been a main gateway to Europe for centuries, for example through the port of Rotterdam, and it is set to continue that tradition also in the digital era.

The Netherlands has emerged as one of the preferred choices for data centre establishments in Europe. Around one-third of European data centres are located in the Amsterdam area, as part of 95 data centres across the entire country. The data centre and cloud industry attracts around 20 per cent of total inward FDI, making it a key driver of inward FDI into the Netherlands. Has this outcome emerged as of itself or were specific structural features, strategies and policies key to this outcome? A number of factors make the Netherlands a favourable environment for data centres:

1. A stable and reliable policy environment. This includes both the general business environment, coupled with high-standard data protection policies ensuring that both personal information and business secrets are well-protected.

2. People with the right skills. A successful and well-functioning data centre needs maintenance, hardware and software development and other service skills to ensure that it caters to the evolving and growing demands of its customers. A data centre is not run by and on its own – a digitally skilled and varied workforce is needed to grease the digital wheels.

3. A hub of supporting firms. The stable business environment is not just beneficial for the data centres themselves, but it is equally important that innovative firms located in the country to make it an attractive location for data centres.

4. A sustainable supply of energy. Data centres need large amounts of energy to run and cool down the servers. Any locational choice of a data centre will depend heavily on the energy infrastructure available. The data centre sector is committed to green energy and needs renewable energy at affordable prices. Since data centres generate heat as a by-product, they are also able to offer heating to provide heating to other sectors of the economy with the right power grid infrastructure.

5. State-of-the-art connectivity. As data centres process data and provide digital services to firms located all around the world, the connectivity of the data centre is integral to its success. This goes both for the connection across continents, as well as shorter distances where every micro second counts.

According to DDA, it is important that policymakers work to ensure that all five of the above factors are as favourable as possible, including via EU-wide harmonisation measures.

As for the major challenges ahead, the DDA notes an ever-increasing demand for digitally skilled workers. Currently, education systems are unable to keep up the pace with the market and technology developments, thus making skill shortages a bottleneck for data centre development broadly. A similar issue can be seen with regards to the energy supply. The current power grids of Europe are not built for the data centre sector and efforts must be put in to ensure that the energy infrastructure is fit for the digital age.

Source: Copenhagen Economics, based on interview with Stijn Grove, Managing Director, Dutch Data Center Association in July 2019

2.6 KEY POLICY AREAS RELEVANT TO DATA CENTRES

Expanding the infrastructural support of the internet and associated services is becoming increasingly necessary as digitalisation increases demand for these services. However, investments made in the construction and operation of data centres, including hyperscale data centres, face several challenges in the EU – especially at the member state level.

Obstacles faced by the data centre construction industry include skills shortages, energy infrastructure constraints, and a general lack of awareness around the need for physical infrastructure in an increasingly digital economy.

Thus, we have highlighted a set of areas of policy relevance to inform a conversation on the opportunities from the development of the data centre infrastructure layer to serve European needs. We summarise as follows.

Digital awareness – towards a paradigm shift:

- The role that physical infrastructure plays in supporting and supplying the economy with internet connectivity and in turn, digital services, has largely flown under the radar
- The existence of several large digital hubs in the EU and a general commitment to sustainable development means that the EU remains a key player in the global data sphere
- The opportunities presented through digitisation has the potential to add considerably to GDP and employment as demand for infrastructure continues to grow alongside greater digitisation throughout all sectors of the economy

Education – preventing skill shortages:

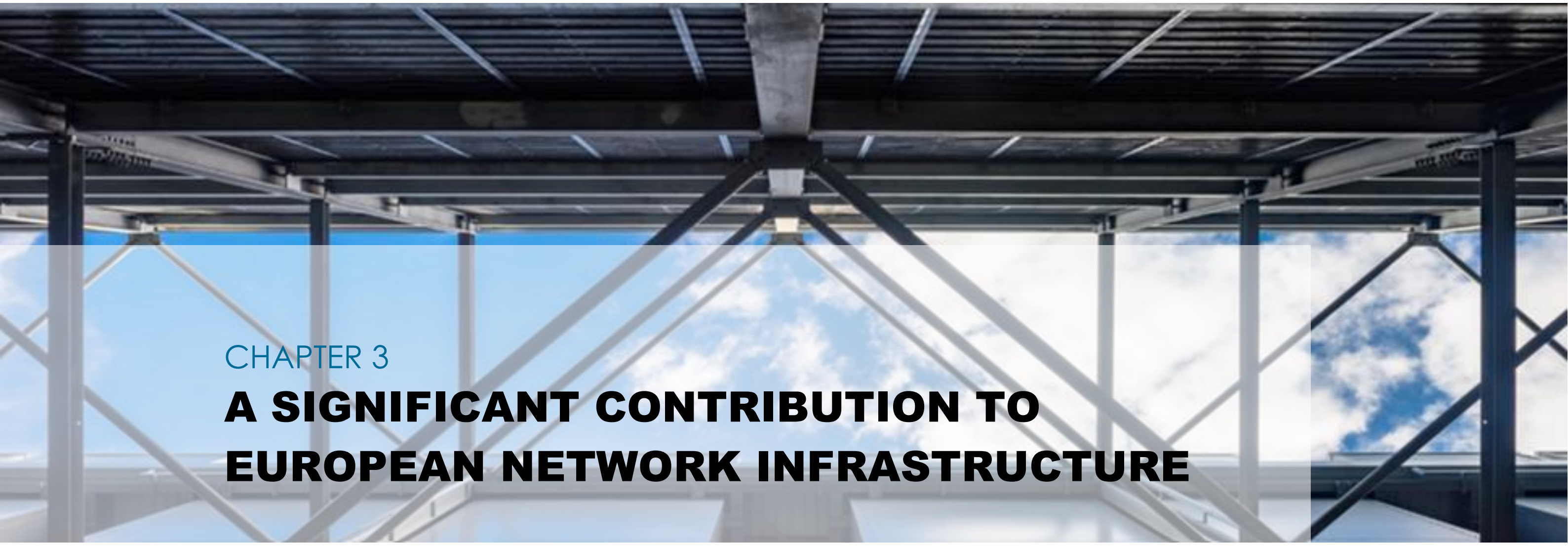
- Potential shortages in the workforce skills relevant to data centres are a factor of concern to industry; relevant skills include a broad range of all aspects of data centre operations, from general repairs required by plumbers or roofers, through to specialist operations of servers or engineering[44]
- Focus on the right training programmes is an important consideration in this matter; while some training can be done in-house by the data centre firms, much will need to come from outside sources such as local community colleges, private training companies, as well as colleges and universities[45]

Local infrastructures – for data centres to support cohesion across peripheral areas:

- While some data centres are located in metropolitan areas, many others (incl. hyperscale DCs) deliver economic activity and jobs in peripheral areas, which act as a regional cohesion tool
- The investment attraction and planning authorities play a key role in engaging with the data centre industry as a key potential investor – and their strategies can benefit peripheral areas
- To enable investments in peripheral areas, local infrastructures (physical and human capital) is key to empower local economies where DC investment is and can be further attracted

44 Interview with Stijn Grove, Managing Director, Dutch Data Center Association in July 2019.

45 https://www.datacenterknowledge.com/uptime/addressing-data-center-skills-shortage



CHAPTER 3

A SIGNIFICANT CONTRIBUTION TO EUROPEAN NETWORK INFRASTRUCTURE

3.1 NETWORK CONNECTIVITY SUPPORTING THE GROWTH OF ONLINE DEMAND AND DATA CENTRES

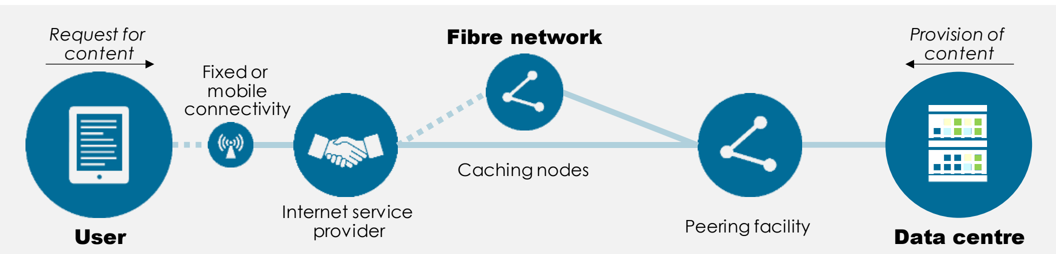
The previous chapter set at centre stage the role of Google's hyperscale data centres and their economic impact. We now turn to the network connectivity layer. This is the spinal cord and nervous system that enables the brain (the data centres) to function.

As a result, to complement the investment in European data centres, Google annually invests millions of euros in a range of facilities such as fibre networks, subsea cables, servers, caching equipment and routers. Google's activity in Europe related to data centres has led to significant network investments in every major European country. The firm does so to ensure that its online services, content and cloud solutions are delivered with high quality to end-users and to guarantee a high level of service reliability, quick response and high resolution.

One key driver for this type of investment is to bring the benefits of Google compute and cloud resources closer to customers (see at the end of this report the case study on the deployment of Cloud Interconnect in Helsinki). This type of network connectivity allows customers to connect to their core Cloud services by meeting Google in a nearby city, on dedicated infrastructure, rather than a harder-to-reach hyperscale data centre.

From a consumer's perspective, the visible reality of the internet tends to be what is regarded in the industry as the internet access links. The internet access links consist mainly of ISPs – often telecommunications companies that provide the fixed service in the home or office, often accompanied by a modem, or the mobile service through mobile telephone subscriptions or other similar wireless devices, see Figure 19. Thus, not all consumers would be aware that ISPs are not the only players backing connectivity infrastructure.

Figure 19 How data centres reach users: Google's design, high level view

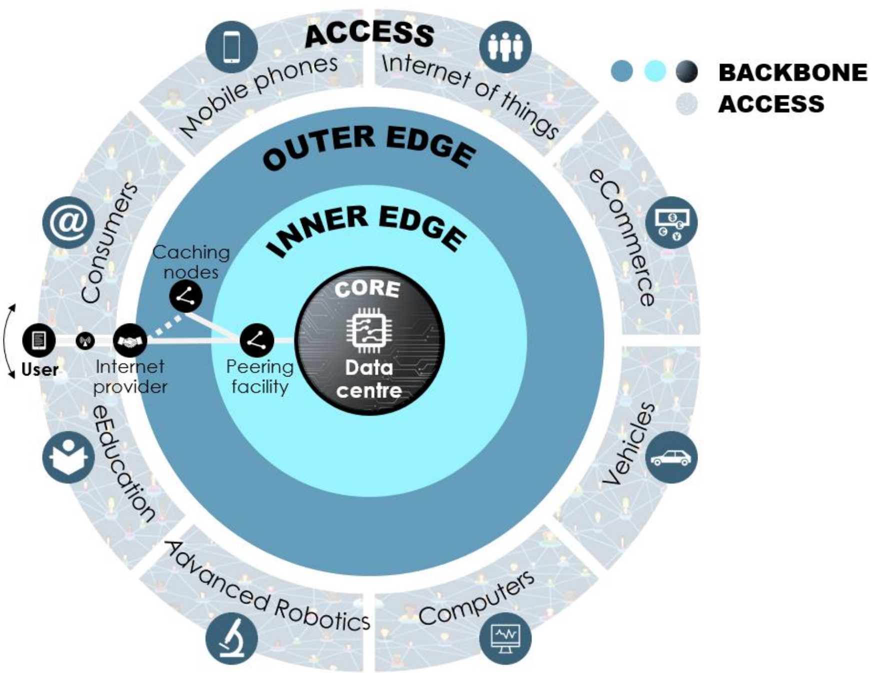


Source: Copenhagen Economics based on Google

This less visible, i.e. inner part of the internet, is what is referred to as the backbone of the internet ('core' and 'edge', broadly speaking). At the core, data centres host files and apply computational processes so that the information can serve users' requests. To reach users, the hosting activity needs a high capacity transport network that connects data centres to peering facilities. This network infrastructure (over fibre) reaches peering facilities or Points of Presence (PoPs). The latter connect Google's network to the rest of the internet – at the proverbial 'edge' of the network. PoPs can also serve as a connecting point for internet service providers (ISPs). From the peering facilities, internet traffic is handed over to ISPs, which take responsibility for the outer part of connectivity, including the access links that carry the internet service to homes and offices (see figure below).

This is why Google procures and maintains a major global network interconnecting key infrastructure such as data centres, cities and network hubs. This network, spanning continents and oceans, connects the world – with global sub-sea connectivity landing into several points in Europe. Equally importantly – and perhaps a surprise to some – Google's global network includes a major terrestrial network footprint all across Europe. This continental scale network has key north-south and east-west connectivity corridors, extensive city-scale networks, edge networks to more regional locations and access connectivity to more far-flung corners of Europe. Ultimately, Google's network connectivity effort reflects the business and market imperative to ensure the best experience for the firm's users and customers.

Figure 20 Zooming into the internet backbones



Source: Copenhagen Economics

3.1.1 The importance of connectivity to exchange points

Interconnection and internet content delivery rely on peering processes and Internet Exchange Points (IXPs) play a key role to facilitate this process of exchange. Within Europe can be found three of the largest IXPs (London, Amsterdam, and Frankfurt), which reflects a positive peering environment. The more vibrant the peering ecosystem, the better the performance for applications and services delivered to European consumers and firms.

OECD-backed research[46] and subsequent follow up surveys[47] have found that over 99.5 percent of peering agreements were "handshake" agreements, thus based on the general, ubiquitous understanding of the terms and conditions of the Internet interconnection model and how to service it.

Furthermore, Google also has an extensive network of edge nodes (called Google Global Cache, or GGC), that occur beyond the peering facilities at the 'outer edge'. These nodes can be used to bring data even closer to the ISP, and therefore user, thereby speeding up the deployment of certain Google services and popular internet content. With the shift occurring towards the core, these networks will become increasingly important in order to transfer data with the least latency, for both Google and telecom providers.

Box 2 Google's Content Delivery Network (CDN)

Google aims to deliver its services with high performance, high reliability, and low latency for users, in a manner that respects open internet principles. Google has invested in network infrastructure that is aligned with this goal and that also allows Google to work with network operators to exchange traffic efficiently and cost-effectively.

A typical data journey starts when a user opens a Google app or requests one of its web pages. Google responds to the user's request from an Edge Network location that will provide the lowest latency. Its Edge Network receives the user's request and passes it to the nearest Google data centre. The data centre generates a response that is optimised to provide the best experience for the user at that time. The app or browser retrieves the content required; this can come from multiple Google locations, including its data centres, Edge Points of Presence, and Edge Nodes.

Source: Interviews with Fionnán Garvey, Global Network Acquisition at Google in July 2019.

Google is currently turning-up a new fibre optic span connecting the Nordics to Central Europe along the east side of the Baltic Sea to interconnect its Finnish data centre in Hamina to those across the rest of Europe.

In the following section, we will provide examples of how Google's investments in cable network capacity can be swapped and pooled with other actors to ensure optimal network connectivity for multiple organisations across Europe. Further below, at the end of this report, the interested reader can find further case studies reporting how Google's infrastructural effort is cutting latency by developing metropolitan network connectivity in the Frankfurt and Helsinki regions.

46 Internet Traffic Exchange, OECD, 2013 - http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=DSTI/ICCP/CISP(2011)2/FINAL&docLanguage=En

47 2016 Survey of Internet Carrier Interconnection Agreements, PCH

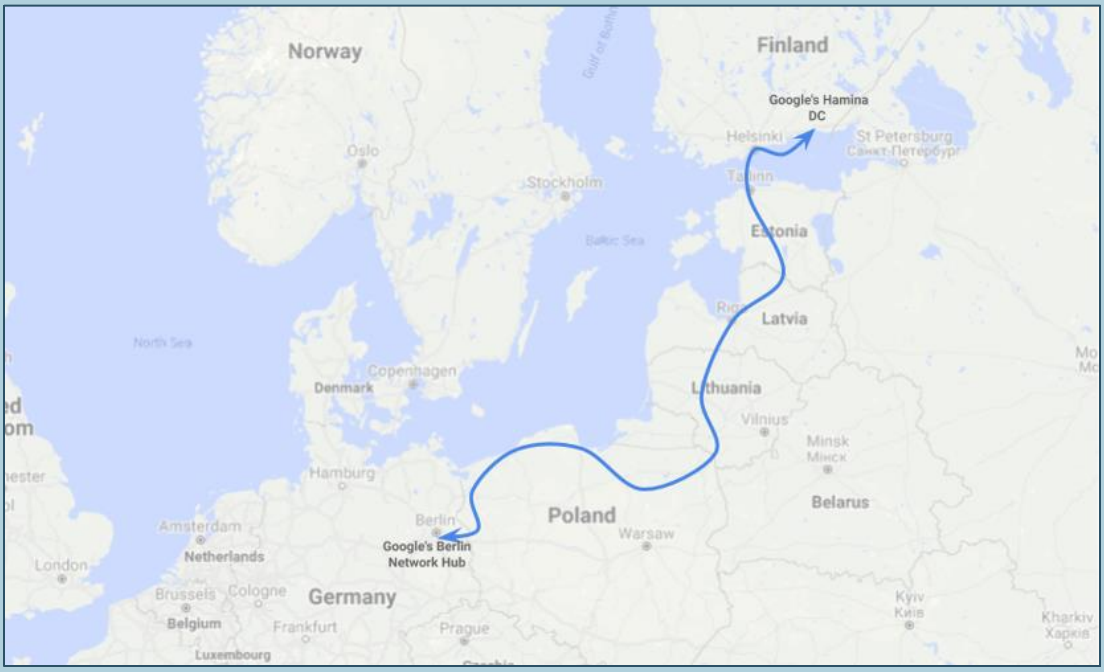
CASE STUDY

Finland to Germany: A Major North/South Connectivity Corridor

Google's major new north/south connectivity corridor takes an innovative route from Hamina, Finland to central Europe through Estonia, Latvia, Lithuania, Poland to reach Berlin, Germany; one of many major interconnection points in Google's core network mesh. This is in contrast to most existing key telecom routes connecting the Nordics to Central Europe which traditionally go via the Sweden-Denmark corridor.

Google is working with multiple vendors to create this new route to add to their other scalable, secure, resilient paths connecting Google's Finnish data centre. This helps ensure that its network can cope with common connectivity failures such as sub-sea cable damage, terrestrial fibre cuts or unexpected network congestion, without adversely impacting the data centres.

Expanding global network connectivity through new countries and regions brings great benefits but also great challenges. This route enables connectivity with minimal delay, or 'latency', equivalent to existing, traditional route performance. Google collaborates with several vendors across the region to stitch together the many component parts forming the end-end solution. Close partnerships with local vendors and mutually beneficial outcomes help Google grow trust and long term relationships across these new countries fostering future collaboration and continued growth for its partners.



Source: Copenhagen Economics, based on interviews with Fionnán Garvey, Global Network Acquisition at Google in July 2019.

The North-South connectivity corridor is one of many examples of long-distance infrastructures orchestrated by Google and ultimately serving the European interest. Further case studies are researched in section 3.3, providing an intuition, visualising some specific examples of what the components (e.g. links) of this network look like, how they came about, as well as related wider economic implications.

Section 3.2. quantifies the European economic and employment impact resulting from the development of this network.

3.2 ECONOMIC AND EMPLOYMENT CONTRIBUTION OF GOOGLE'S EXPENDITURE IN NETWORK CONNECTIVITY FOR EUROPE

This section focuses on the impact of the networking component, which is a key element within the ones considered when computing the results presented in Chapter 2. Typically associated with the telecommunications industry, this type of network component is also a key area of focus for Google's infrastructural efforts. This is because of the importance of connecting the backbone of the internet, linking data centres all the way to the exchange points where retail telecommunications companies take over and serve end users, e.g. fixed and mobile home broadband, workplace connectivity, etc. Thus, the backbone of the internet infrastructure goes in tandem with the internet access links, ultimately linking consumers and devices with the computation and service provision, as well as with each other.

We have measured the extent to which this connectivity expenditure supporting the internet backbones across Europe (a subset of the expenditure already accounted for in the chapter 2 totals) has converted into economic benefits for European countries. To do so, we will start with mapping the relevant expenditure.

3.2.1 Economic contribution

In Europe, Google is investing significantly in both the core network in European countries and in the international network, i.e., subsea cables.[48] Over the period 2007 to 2018, Google has spent an estimated EUR 2.0 billion on improving European network infrastructure (see Figure 21).[49] In addition to this, Google is expected to contribute an extra EUR 850 million in the coming two years. Therefore, by 2020, Google's network connectivity infrastructural efforts will amount to a total of EUR 2.9 billion.

Based on this expenditure profile, our input / output model quantifies economic and employment contributions specific to the network connectivity infrastructural effort. These are a subset of the results presented in the previous chapter (which covered data centres and related infrastructures).

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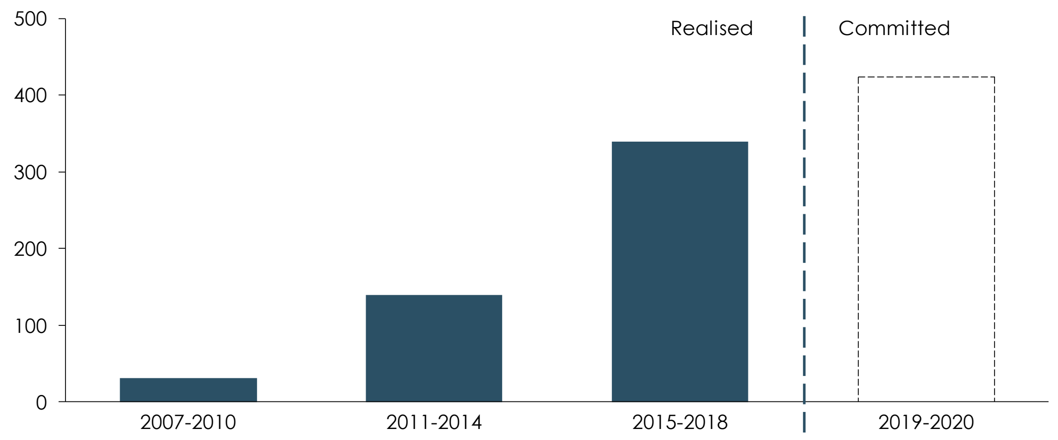
[48] We focus the research scope on the part of subsea cables expenditure that satisfies two conditions: (i) it is linking Europe to the world; and (ii) it refers to expenditure to European value chains.

[49] This includes: leases of fibre capacity for 15 years; construction costs for redirection; and relevant space and power in data centres to power the ends of fibres. Furthermore, this amount includes connections to DCs, connections to subsea cable landing sites; share of expenditures on subsea cables for EU suppliers; intercity (i.e. metro-to-metro) links; metro fibre; PoPs and caching equipment.

Figure 21 Google's network connectivity expenditure in Europe
EUR million multi-annual average

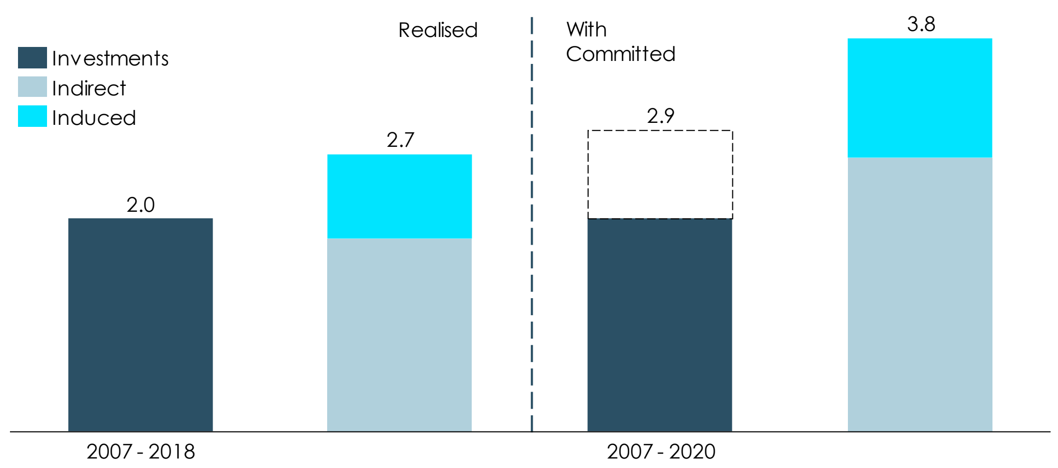


Note: The figure includes network infrastructure and equipment expenditures.
Source: Google

In total, these network connectivity investments have a supported an economic impact of EUR 2.7 billion in GDP, cumulative over the 2007-2018 period. Due to the nature of Google's network infrastructure and equipment, the impact occurs through indirect and induced effects. Averaged out over the same period, this equates to a yearly average of EUR 220 million, see Figure 22.

Projecting forward to 2020, Google's GDP contribution is expected to increase to EUR 3.8 billion, reflecting a marked increase over time in Google's network connectivity effort. Thus, for the 2007 – 2020 period, the average GDP supported by this activity is almost EUR 300 million per year.

Figure 22 Economic impacts of Google's network connectivity investments
EUR billions total



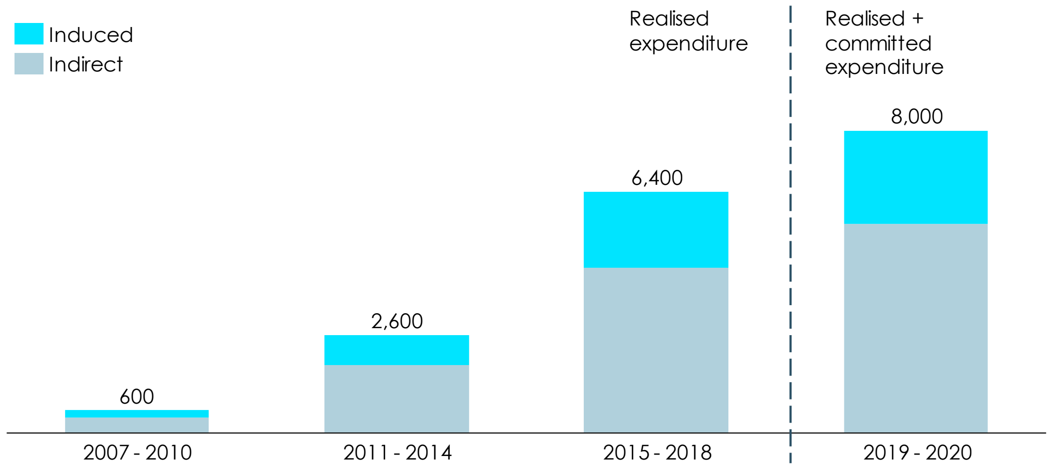
Source: Copenhagen Economics based on data provided by Google, Eurostat and World Input-Output Database

3.2.2 Employment contribution

These investments supported over the same 2007-2018 period an average of **3,200 full-time jobs per year;** these are external to Google – being across the value chain – with a majority based in the telecommunications sector. Once factoring in the committed expenditure up to 2020, this yield an increased average supported jobs to 3,900 full time jobs (2007 – 2020), which include both indirect and induced effects.

Reporting the 2007 – 2020 period into four phases shows clearly the increase in average jobs supported by Google's network connectivity effort. While in the period 2007-2010, this Google activity supported 600 full time jobs per year on average, this will increase to 8,100 full time jobs in 2019-2020 (yearly average, including indirect and induced effects).

Figure 23 Increased Google connectivity expenditure has led to increased jobs
Full Time Equivalent jobs (FTE)



Note: Investments in Google's network infrastructure and equipment is assumed impact jobs numbers through indirect and induced effects. Up and until 2018, the jobs are supported from realised investments, whereas the jobs 2019-2020 are expected to be supported from committed investments.
Source: Copenhagen Economics based on data provided by Google, Eurostat and World Input-Output Database

3.3 CASE STUDIES OF IMPACTS OF CONNECTIVITY INVESTMENTS

3.3.1 Spill-over effect enabling infrastructure for other services' quality improvements

The investments discussed above can also have broader implications, with Google acting as an anchor tenant and thus ensuring fibre is built that can be used by others. For example, the functioning of undersea cables is such that – while funding members are anchor tenants and use capacity for their business services – additional capacity is available for all kinds of services and data transfers that become faster and more efficient via the cable.

In this case, undersea cables constructed by Google do not only deliver benefits when European consumers and businesses use Google services, but also for any other services that rely on flow of information and data over the same connectivity infrastructure. Domestic core networks function in a similar way and effects can therefore apply therein too.

Terrestrial networks do not always require massive scale from the outset. In some cases, it makes more economic sense to lease assets from vendors in a region as the demand for the route grows.

When a corporate buyer like Google agrees a leasing deal with a telecoms supplier, often this involves the buyer covering the cost of the civil engineering work of building the necessary additional links (digging up roads, laying fibre etc – traditionally the most expensive part of telecoms activity). Therefore, Google as a buyer, via so call "construction charges", pre-funds the installation of new links which can then be made available to all possible societal uses – reaching beyond Google's digital services.

Thus, Google's leasing of services enables local service providers to grow their network footprint and revenue driving a virtuous cycle of expansion. As a result, Google's investment in such infrastructure lowers barriers for businesses to supply digital services. This implies that consumers are in a better position to benefit from the entire set of applications and services available via the internet.

CASE STUDY

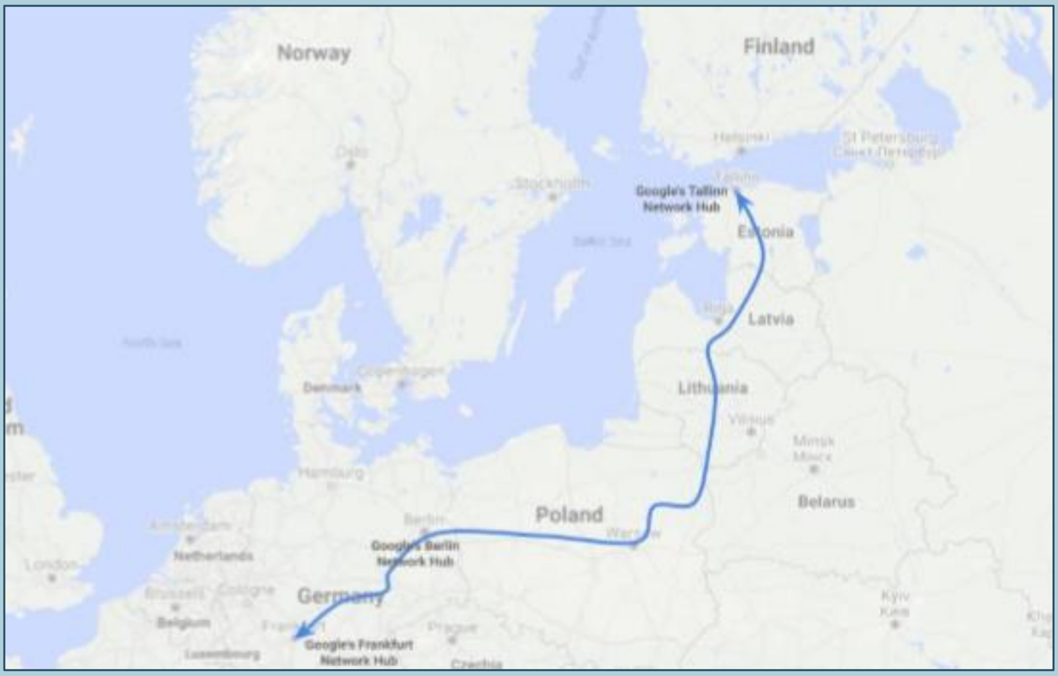
Tallinn to Frankfurt: Additionality from leasing connectivity assets

An example of Google's leasing services is their connectivity path, using optical spectrum, from Tallinn to Frankfurt via Warsaw. In developing this route Google partnered with multiple vendors to stitch the underlying end-end infrastructure together with an overlay of optical services provided by a single Internet Service Provider (ISP).

Furthermore, the ISPs could then provide services to other customers throughout the region using spare capacity on the route. In shouldering the majority of the initial cost of such deployments Google helps new routes and services develop where otherwise they may not. Thus, consumers and firms using any digital services (not just Google's) stand to gain from these improvements in connectivity.

One particularly interesting aspect of this route pertains to Poland.

Google secured access to a key route traversing the country through a mutually beneficial swap of infrastructure with a national research entity. The latter needed access to connect its researchers to the European Council for Nuclear Research (CERN) facility in Geneva which houses the world's largest and most powerful particle accelerator, the Large Hadron Collider. Google had excess infrastructure from Germany to Switzerland which they were able to offer to the national research facility to solve their connectivity challenge and support their critical research at CERN, while in return establishing connectivity for Google across Poland.



Source: Copenhagen Economics, based on interviews with Fionnán Garvey, Global Network Acquisition at Google in July 2019.

3.3.2 Subsea links connecting Europe to the global internet

Creating networks of glass (i.e. optic fibre) carrying information between continents, at near-light speed under the sea, is a challenge at the best of times. There are a few different ways to do this. The first is to simply purchase capacity on an existing or upcoming cable. The second is to create a consortium of partners with similar needs to build a cable together. The third is for a firm to build it itself.

All of these options come with different pros and cons. Google uses a combination of all three methods to best serve their customers. When approaching a new cable project and deciding on which of the three methods to use, Google considers its needs, as informed by customer demand specifications across a set of parameters and features, as analysed below.

Box 3 Demand drivers of investment and planning of subsea cables

Performance and latency: Cables are often built to serve a very specific route. When Google builds privately, it can choose this route based on what will provide the lowest delay, or 'latency' for the largest segment of customers.

Capacity: The bandwidth that Google wants to deliver can vary widely, depending on what already exists and where their customers need more, now and into the future. Google's capacity planning includes estimates of their own and their customers' needs for the future.

Guaranteed bandwidth for the lifetime of the cable: The life of a cable varies from 15 to 25 years, but as with many infrastructure projects, they sometimes continue to serve the route beyond their initial projected lifespan. Google's ability to guarantee their customers a certain level of connectivity helps them confidently plan for their businesses going forward.

Source: Interviews with Fionnán Garvey, Global Network Acquisition at Google in July 2019.

Google's investments in both private and consortium cables meet the same objectives: helping people and businesses take advantage of all the cloud has to offer. This drives the search for the best ways to improve and expand networks towards that aim. Investing in its own network infrastructure has supported Google in offering better reliability, speed and security performance compared to the nondeterministic performance of the public internet.

With the above in mind, Google became the first major non-telecom company to build a private intercontinental cable with their investment in the Curie cable, announced in January 2018. Google continues to expand their submarine investments in consortia and private cables with three major Europe-landing examples including the following.[50]

[50] Additional detail is presented at the end of the study.

Table 1 Major subsea cables connecting Europe and supported by Google

CABLE NAME	INVESTMENT	ROUTE	TIMING
Havfrue	Consortium	Denmark and Ireland to the US	2020
Dunant	Private	France to the US	2020
Equiano	Private	Portugal to South Africa	2021

Source: Google

At the same time as global connectivity networks are being expanded – requiring the laying of subsea cables in select locations – marine resources are also the basis of economic activities in industries such as energy extraction / mining. All of these industries generate economic activity and serve consumers' and firms' needs, while relying on shared marine resources in different ways.

The International Seabed Authority is an intergovernmental body established by the United Nations Convention on the Law of the Sea. Its purpose is to coordinate and regulate all mineral-related activities in the international seabed ocean area which is beyond the limits of national jurisdiction. A range of European countries are members, as well as the European Union. Some EU countries have displayed greater awareness of the value of coordination – for example France, which has clearly supported reform safeguarding subsea cables when the ISA Authority consulted on draft regulation on exploitation of mineral resources.[51]

3.3.3 Connecting the geographical periphery

Connecting remote areas to high speed fibre has the potential to encourage development in remote communities, supporting cultural heritage and vulnerable tradition. Lisbon, the capital of Portugal and Europe's western-most capital city, is a key Google network nexus even if located at Europe's edge geographically. Continental connectivity between dense population centres in central Europe to the far south-west tip of Europe helps to bridge the geographical barriers across the continent.

[51] ISBA/24/LTC/WP.1/REV.1.

CASE STUDY

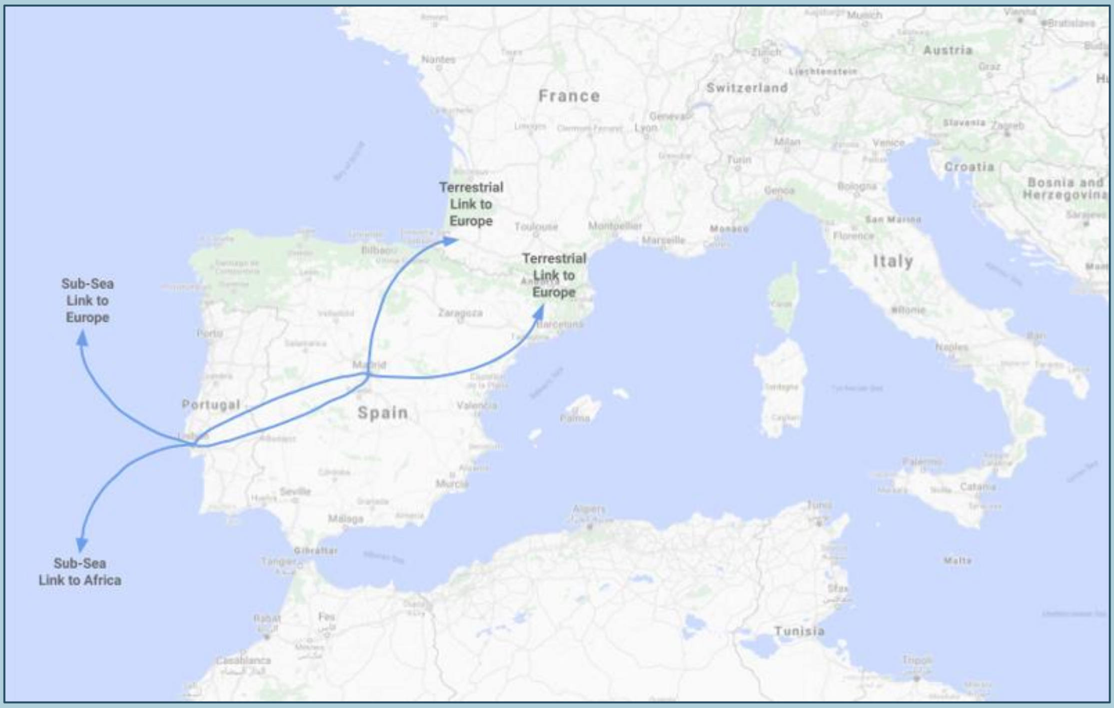
Lisbon: Connecting countries & continents bridging geographical disadvantages

Google has long had critical network presence in Lisbon facilitating key existing submarine connectivity routes between Europe and Africa. With the landing in Lisbon of our future private submarine cable to Africa, called Equiano, the importance of this coastal European city continues to grow.

Other innovative submarine routes are also expected to land into Lisbon in 2020 such as the external cable EllaLink connecting Southern Europe to South America. Colocation operators also continue to expand their footprint in the city offering global quality services in this space.

In addition to being a key network nexus, Lisbon is also succeeding in attracting foreign direct investment, for example in the Technical Support space, with major international companies, including Google, choosing this city as an important base of operations. Google also is currently trialling innovate network deployment methods in one of our production network locations in Lisbon.

All these developments and growth, in a city at the geographical edge of Europe, demonstrates clearly the bridging of geographical disadvantages through the deployment of large scale, critical network infrastructure.



Source: Copenhagen Economics, based on interviews with Fionnán Garvey, Global Network Acquisition at Google in July 2019.

3.3.4 Metro: connectivity on a super-scale

Google has established key Data Centre locations across Europe in countries like Ireland, Finland, Belgium, and the Netherlands. They have also established extensive presence in key cities across the continent and globe to allow them to be close to where their consumers and customers are.

Initially established as network 'Points of Presence' (PoP) as part of a wider network mesh, city-scale 'metro' networks are increasingly enabling the positioning of clusters of 'compute' closer to customers. This means that mini-datacentres (10's of MWs) with the capability to provide critical cloud-based services are located in the very city where enterprises need them most. This minimises complexity for customers to reach the Cloud and reduces network delay to reach resource-hungry apps and services. A great example of one such major network & cloud hub is Frankfurt (see documentation at the end of this report).

Frankfurt is one of the largest global peering network locations in the world. This implies that different network owners can interconnect and exchange information at this core network hub. Network growth as well as the advent of Cloud service continues to drive Google's investment in Frankfurt at a remarkable speed. The importance of this location for Google, and other network and digital services providers, has driven Google to establish many scalable, diverse paths connecting Frankfurt to the world. Service guaranteed, Cloud-based products, drives ever increased emphasis on super-high quality, secure networks with low latency and high availability. This key network nexus-point in Frankfurt links other major network hubs like London, Amsterdam, Paris etc. as well as extending connectivity to regional hubs, such as Moscow, Sofia, and Budapest, via 'long-haul' connectivity in all major directions.

3.4 RELEVANT POLICY QUESTIONS

As consumers' and firms' demand for online services increases, congestion and pressure will be felt particularly in the internet backbones, since this is the part of the network where traffic to/from end users get aggregated. Thus, backbone links will experience a faster traffic increase than access links, by definition.

Expanding the European network connectivity infrastructure underpinning the internet – in particular the backbones – is a relevant process, the outcome of which is key to meet the growing digital services' needs from our economy and societies.

However, there are challenges affecting investments made in the deployment of backbone links underpinning the growth of the internet serving European citizens and firms.

Thus, we have highlighted a set of policy relevant questions to inform a conversation on the opportunities from the development of this network connectivity infrastructure layer to serve European needs. We summarise as follows.

Fragmentation by country – an obstacle to the EU Single market?
Europe is world leader as to scale of its top 3 Internet Exchange Points (IXPs), which facilitate efficient peering, benefiting the performance for applications and services delivered to European consumers and firms.

In contrast, it is well known that telecoms networks were historically established along national boundaries and thus with a national scale to start with. This legacy structural constraint implies that – in most cases – European telecoms operators can compete and operate on the basis of own infrastructure in their national home markets, while cross-border operations require additional effort.

At the same time, this study has provided evidence of a fast-growing demand for Europe-wide backbone connectivity links, which naturally must span national borders. While the access links are localised and thus national by definition, the backbone links connect both cities and countries within Europe and thus present an inherent cross-border dimension that is not relevant to internet access infrastructure (and related policies)

Therefore, we see two questions that would be relevant to research and discuss further:

- Is the procuring and developing of new connectivity links cross-border within the EU affected by the structural constraint of the historical national fragmentation – and what impact on European citizens, firms and the functioning of the Single market?
- To what extent are existing rules and implementations reflective not just of national considerations but also of cross border aspects?

Subsea cables – is the European relevance of this infrastructure understood?
Subsea cables are a key asset to connect European consumers and firms to the global internet. This applies irrespective as to whether the end users are located in landlocked or coastal countries, since the subsea links deliver large scale, updated connections binding countries and continents together.

At the same time, the connectivity use of the marine ecosystem is only one of multiple traditional and contemporary activities which rely on the sea and in particular the seabed (which is where cables rest after being laid down across oceans and coastal areas). Other activities across sectors (extraction of raw materials incl. fossil fuels, energy infrastructures) are also relevant users active in the marine space.

One specificity of the subsea cable infrastructure is that, once it has been deployed, it is much behind the scenes, quietly operating “under the sea”. Yet, as shown in this study, this not so apparent infrastructure plays a vital role to connect European citizens and firms to the world.

Thus, in our view, there are two questions that would be relevant to research and discuss further:
- How can subsea cables protection and coordination with other industries that perform economic exploration and use of marine resources be fostered, in a way that ensures efficient development of global connectivity infrastructures?
- What procedures are best suited to facilitate deployment of new global connectivity infrastructures, in terms of point of contact (permitting, installation, maintenance, protection/repair) and coordination / spatial planning, in a way that is mindful of the role of subsea cables?

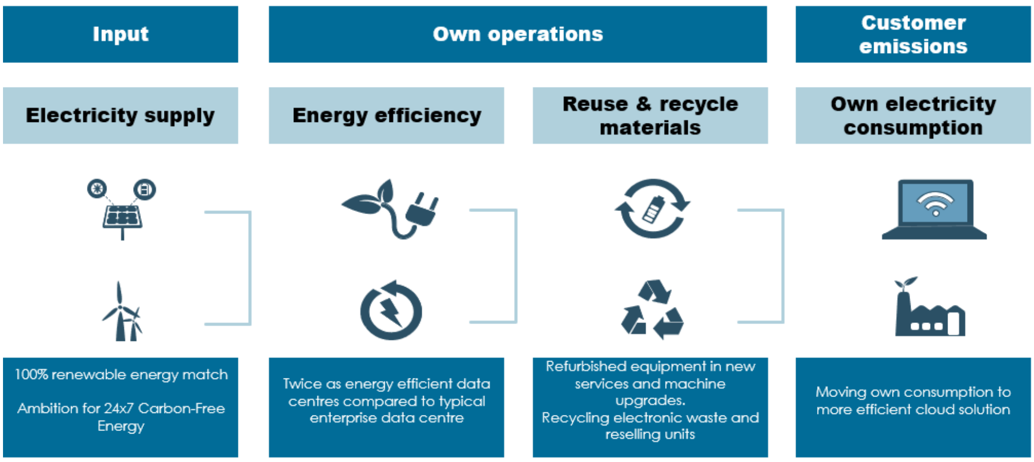
CHAPTER 4

SUSTAINABILITY EFFORTS IN THE DATA CENTER INDUSTRY: LEADING THE WAY ON ENERGY EFFICIENCY AND RENEWABLE ENERGY

Growing demand for digital services has led to significant substitution of energy consumption from 'traditional services' to digital operations. Going forward, this demand is expected to keep rising, thereby increasing the energy consumption in the IT-sector. Consequently, ambitious sustainability efforts of the data centre industry are, and will play, an important role in securing the carbon neutral transition.

Recognising its importance in this growing sector, Google has been bringing together its provision of data services with a clean and sustainable approach throughout its entire supply chain. Divided into the different parts of the value chain, Google is currently pursuing: 1) Sourcing electricity from 100% renewable energy sources and a long term ambition to match its consumption 24x7 with carbon-free energy, 2) Highly energy efficient operations and circular economy objectives for material reuse, and 3) Reducing customers energy consumption by moving on-site consumption to much more efficient servers in the cloud (see Figure 24).

Figure 24 Sustainability efforts across the supply chain



Source: Copenhagen Economics based on Google(2018), Moving toward 24X7 carbon-free energy at google data centres, Google's website on efficiency of data centres (https://www.google.com/about/datacenters/efficiency/internal/) and Uptime Institute (2019), Global datacentre survey, https://sustainability.google/projects/circular-economy/, Google(2018), Environmental report, Eurostat(isoc_ci_eu_en2, sbs_sc_sca_r2, nrg_pc_205) and Google(2011), Google's Green Data Centres

In order to appreciate the key drivers of energy aspects of data centres, it is valuable to start from the perspective of the ultimate decision makers of any technological change and societal transformation, i.e. citizens / consumers and firms across Europe – as users of old and new services and technologies. We will then turn to the role of firms' operation of data centres (efficiency performance) and finally to a key input to data centres, electricity, and how it can be sourced sustainably through the purchasing of renewable energy. A discussion of related policy barriers will conclude the analysis.

4.1 DEMAND SIDE: ENERGY SAVINGS BY MOVING TO THE CLOUD

Storing and processing of data has a corresponding energy use which is a derived demand from the end users' choice to go more and more digital. Energy consumption from this new demand replaces the energy previously used for alternative ways of obtaining services (e.g. paper-based processes, driving to several stores etc.).

New product lines that are the factors behind the derived demand can be less energy intensive than old solutions. As demand for new and better digital services increases, these services also become more energy efficient. Obtaining a service through a newer digital solution, will therefore often require less energy consumption. However, at the same time, demand has increased significantly which can lead to increased overall consumption even if the consumption for each individual service has decreased.

Energy efficiency of data centres and cloud-based internet services are significantly higher than own in-house servers and storage. Users demand for digital services will require storage and processing of data which can be done in two ways. Either each firm across the economy can rely on own in-house servers and data centres, or alternatively specialised providers dedicated to providing this service can be used.

Using remote and dedicated storage in a data centre usually requires less energy due to economics of scale. Energy consumption of data centres requires energy for computing equipment, cooling, and to maintain the general functioning of a large-scale facility. Due to the scale, it is therefore possible to maximise server utilisation and use virtualisation and scalable computing. Further, since electricity costs are a large share of operation costs there is a significant incentive for operators to use electricity efficiently.

Significant energy savings can be made if more data is stored in large data centres – such as Google's – and accessed via cloud computing. With cloud computing, it is for example possible for companies to host their emails, documents, and CRM systems on a remote server in a data centre. Relying on more efficient and scalable cloud computing can help enterprises to reduce capital and operational expenses.

Handling e-mail data through the cloud is more energy efficient

Many services and applications can be handled through the cloud, but as an illustrative example we look at the implications if e-mail services were handled through the cloud. This is, however, just one example where moving from in-house servers to data centres data storage would increase energy efficiency significantly. An in-house e-mail server can use up to 175 kWh annually per user. This can be compared to the 3.3 kWh annually per user which is used in an average European data centre.[52] Being even more efficient, Google's data centres use only 2.2 kWh annually per user.[53]

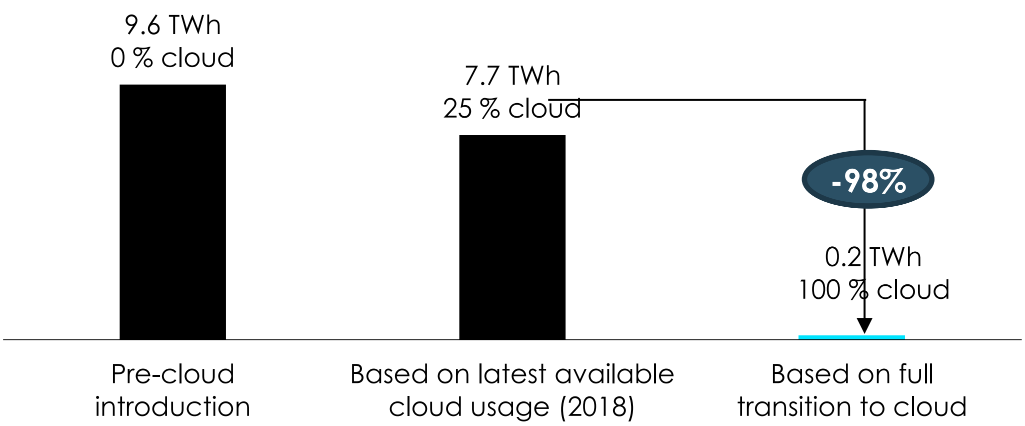
Electricity used to power in-house servers for e-mail storage in the EU is estimated at 7.5 TWh annually which corresponds broadly to the annual household consumption of electricity in Ireland.[54] This estimation is based on the number of staff working with computers in firms of different size and the share of cloud use within classes of firms, by their size – as reported by Eurostat. Average cloud use across companies is estimated at 25%.[55]

Moving all e-mail services to the cloud based on data centres with an efficiency equivalent to Google's would:

- Reduce current electricity use for e-mail services in individual companies by 7.7 TWh
- Increase electricity consumption in data centres by 0.2 TWh

This would provide a net effect of a 7.5 TWh decrease which corresponds to reduce current usage by 98 percent, as shown in Figure 25.[56]

Figure 25 Electricity savings by moving to cloud-based e-mail services
TWh



Note: The Eurostat survey data provides binary yes/no information on cloud use, without capturing the type of setup chosen by businesses that report not to use cloud. Since some of those may be using off-site servers, the 7.7 TWh figure may be overestimated insofar as some of those Eurostat respondents rely on more energy efficient solutions for their servers than the standard in-house server.

Source: Copenhagen Economics based on Eurostat(isoc_ci_eu_en2, sbs_sc_sca_r2, nrg_pc_205) and Google(2011), Google's Green Data Centers

Improving energy efficiency by moving all e-mail services to the cloud would lower electricity bills and provide an additional benefit of lower CO_2 emissions. At current electricity prices this would

52 Assuming that differences in energy use between Google's data centres and an average European data centre is only due to overhead energy efficiency.

53 Google (2011).

54 Source: Eurostat table nrg_105a.

55 Source: Eurostat table isoc_ci_eu_en2 and sbs_sc_sca_r2.

56 Figure and prior calculations assume that all the resulting new data centre activity would be as energy efficient as Google's data centres.

amount to an approximate saving of EUR 880 million each year.[57] On top of this, the current CO_2 emissions are estimated to be reduced by almost 2 megatons annually.[58]

4.2 DATA CENTRE OPERATIONS: ENERGY AND RESOURCE EFFICIENCY THROUGH STATE-OF-THE ART DATA CENTRES

4.2.1 Google as a benchmark for the efficiency potential of the European data centre industry

Electricity is a large component in the operation of data centres. The more energy efficient a data centre can be per service delivered, the fewer investments is needed in (green) electricity generation.

Energy performance of specific data centres is typically split into 1) energy use of servers, and 2) energy use of overhead which can be things like coolers, high-efficiency batteries, and interior design. While numbers like this is typically not public information, Google has estimated that its servers use 25 percent less energy than typical servers.[59] Further, industry benchmarks do exist on the so-called overhead energy consumption. This is measured through the so-called power usage effectiveness factor (PUE). PUE is a scale indicator where 1.00 is the theoretical maximum efficiency, and anything higher is therefore less efficient.[60]

Taking Google as an example, it has been demonstrated that PUE can improved significantly through focus on innovation and efficiency operations. Since 2008, Google has been able to improve its PUE from about 1.22 to just 1.11 on average across its data centres, as shown in Figure 28. This improvement can be attributed to e.g.:

1. High-efficiency batteries, kept as close as possible to equipment that needs power
2. Removing unnecessary parts, encouraging suppliers to produce energy-efficient components and optimising the internal design of data centres
3. Server consolidation and utilisation which allows Google to do more with fewer servers and less energy. When there is less computing work to be done, servers only use limited energy while waiting for a task. Consequently, e.g. cooling fans only spin as fast as is necessary to keep the servers cool enough to run[61]

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57 Using an average electricity price excluding VAT and other recoverable taxes and levies of EUR 11.7 cents per kWh (source: Eurostat table nrg_pc_205).

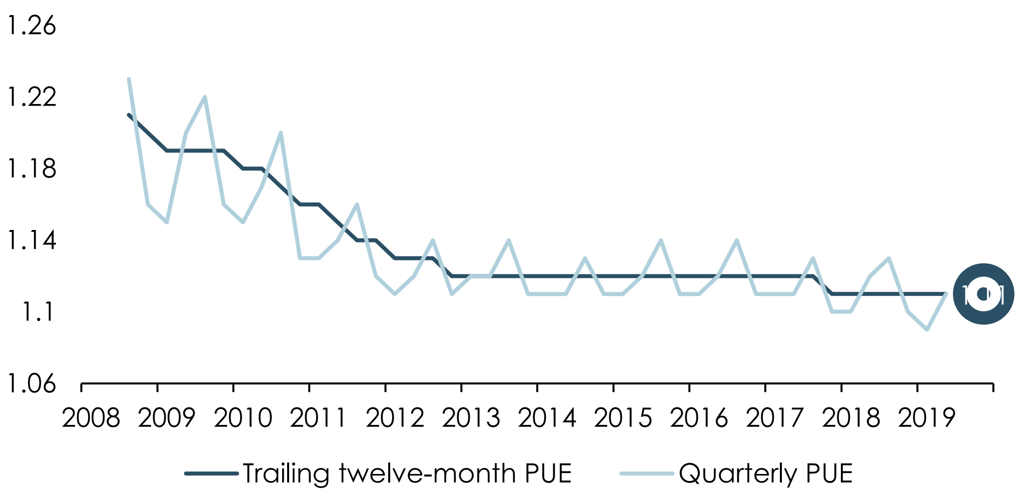
58 Using an average CO_2 intensity of 260 g/kWh. This is calculated as the emissions of CO_2 equivalents from public electricity production (source: UNFCCC data interface) in relation to total gross electricity production in the EU (source: Eurostat tables nrg_105a and nrg_106a).

59 https://www.google.com/about/datacenters/efficiency/internal/#servers

60 Power usage effectiveness (PUE) measures how efficiently a computer data centre uses energy. It is expressed as the ratio of the total amount of energy used by the data centre facility, to the energy used by the actual computing equipment. A PUE of 1 is the lowest possible value and means that all power going into the data centre is being used to power IT equipment. A PUE of 2.0 means that for every watt of IT power, an additional watt is consumed to cool and distribute power to the IT equipment.

61 Google (2016), Environmental report

Figure 26 Reduction in IT-related overhead energy use in Google's data centres since 2008
Average PUE for all Google data centres



Source: Google's data centres information centre: https://www.google.com/about/datacenters/efficiency/internal/.

Based on industry benchmarks of PUE, Google's data centres are amongst the most efficient when it comes to overhead energy consumption with a PUE of 1.11 compared to the industry benchmark of 1.67 (see Figure 26).

If all other data centres across Europe could achieve a similar server and overhead efficiency, this could potentially cut electricity consumption for the European data centre industry from 97 TWh down to 49 TWh.[62] This saving of 48 TWh each year is larger than the annual electricity use of all Swedish households.[63] As such, there could be a very large untapped potential for the data centre industry to increase energy efficiency and lower overall electricity consumption.[64]

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62 Currently, the European data centre industry use an estimated 97 TWh per year according to EU Green Public Procurement for Data Centres (2018), Draft Technical report v3.0. Estimate is based on the interpolated electricity consumption for 2019 based on the estimated consumption for 2015 and 2020 in the report.

63 Source: Eurostat table nrg_105a

64 In general, a data centre energy efficiency will depend on multiple factors, e.g. technology & design, as well as the choice of location, since low outside temperatures can ease the cooling performance.

Table 2 PUE for Google and the European data centre industry

LOCATION	PUE
Average European data centre industry	1.67
Google fleet-wide data centres	1.11

Note: Please note that a comparison of PUE between data centres rely on a relatively similar energy use by IT-equipment/servers.
Source: Google's website on efficiency of data centres (https://www.google.com/about/datacenters/efficiency/internal/) and Uptime Institute (2019), Global data center survey.

Achieving this level of efficiency in Google's data centres has in part been due to the increased usage of machine learning (ML) to optimise cooling. In collaboration with its fellow Alphabet company DeepMind, a ML based recommendation system has been developed. This system identifies and implements actions to improve cooling efforts and thereby reduces the electricity use. As more data is collected, it provides examples for the AI to use in determining optimal cooling. More examples available to the AI can therefore increase energy savings. Energy savings in cooling based on this system has been about 30 percent when tested in Google's data centres.

Google has a history of sharing its knowledge on effort to increase efficiency of its data centres. Based on previous experience, Google has shared five best practices which can be used to improve efficiency of both small and large data centres.[65] Along with this, several summits have been hosted by Google, and a case study with concrete investments and savings has been released.[66]

More recently, Google has also joined the collaboration of the Open Compute Project. The collaboration consists of multiple tech-companies and aims to create a space for sharing intellectual property related to hardware in the same way as open source has for software. Initially the focus was data centre efficiency, but it quickly expanded to hardware technology more generally.

Applying ML in other sectors could provide large efficiency gains. An example of this is a DeepMind project seeking to utilise wind power more efficiently by applying ML to predict a wind farm production as well as supply and demand of electricity. This boosted the value of energy produced at the wind farm by 20 percent.[67]

4.2.2 Circular economy and resource efficiency at the forefront

Besides improving energy efficiency, sustainability efforts in data centres own operation can be addressed through resource efficiency. Resource efficiency and circular economy is about making more products with less: both less input material and less waste streams, in particular through recycling and reuse of materials.

EU regulation is a main driver of the circular economy transition. A number of initiatives has been set in motion by the EU in recent years to initiate a move towards a more circular economy. Importantly, the action plan for the transition was included in the *Circular Economy package* presented by the European commission in December 2015.

65 https://www.google.dk/about/datacenters/efficiency/external/index.html#best-practices
66 Google (2011), Google's Green Data Centers
67 https://deepmind.com/blog/machine-learning-can-boost-value-wind-energy/

Corporate reality and consumer behaviour are also factors in a transition to a circular economy. Sustainability matters to private consumers, and they prefer to buy products from companies that are environmentally and socially responsible. In Europe 40 percent of consumers find this so important that they are willing to pay extra for such products.[68] Communicating the responsibility of a company's activities, its so-called corporate social responsibility (CSR), has therefore become much more important in recent years. This has come to show by 73 out of the 100 largest companies publishing CSR reports in 2015 across 45 countries compared to 53 out of 100 in 2008.[69]

Efforts towards transitioning to circular data centres can provide large savings both in terms of material use and costs. Increasing the focus in data centres on designing and procuring hardware that enables circularity will lead to less new materials used to produce hardware going forward. As such, costs of production will be lowered while at the same time reducing waste. This can be combined with an increased recertification and remanufacture of systems, remarketing of part and lastly recycling the residual. The potential from this has been estimated to be more than $ 50 billion in value recovered from total cost of ownership and 360 thousand tons of equipment to be deferred from waste streams.[70]

Google has already engaged in the effort for a more circular economy into four overarching strategies, which has led to a 97 percent landfill diversion rate from Google's global datacentre operations in 2018.[71]

Box 4 case study: four strategies to ensure circular economy in data centres

Google has devised a set of strategies to manage resource use of computing equipment at its data centres along the circular economy approach.

The first strategy is *maintain*. This means to increase the life time of every single material. Repairing or upgrading machines in data centres can rely on the use of refurbished inventory. Increased focus has made it possible for Google to use 19 percent in 2018 of components for machine upgrades from refurbished inventory.

This leads to *the second strategy*, which is *refurbish.* As an old server is nearing the end of its life time, it is wiped for data and dismantled into its separate components which can then be used to build remanufactured servers.

For *the third strategy* Google focus on *reuse*. When Google no longer has use for a particular piece of technology it can still hold value to other organisations. With this in mind, nearly 3.5 million units were resold into secondary market in 2018.

Lastly, *the fourth strategy* is *recycle.* Hard drives that can't be resold and other electronic waste are sent to a recycling partner.

Source: Google (2019), Environmental Report

68 Nielsen 2014 study, available at: https://www.nielsen.com/content/dam/corporate/us/en/reports-downloads/2014%20Reports/global-corporate-social-responsibility-report-june-2014.pdf
69 Leonskiand Beyer (2017) Reporting as an Important Instrument of Corporate Social Responsibility
70 https://www.itrenew.com/circular-data-center
71 Google (2019), Environmental Report

4.3 INPUT SIDE: SUPPORTING RENEWABLE ENERGY TRANSITIONS THROUGH LONG-TERM FINANCING

4.3.1 Corporate power purchase agreements (PPAs) support the transition to renewable energy

An increasing number of firms are committing to rely on buying power from renewable energy sources. As a result, Power Purchase Agreements (PPAs) are becoming more and more widespread since they are a key instrument to achieving this goal. In the latter years, institutions across the world have recognised that corporate PPAs have an increasing role to play.[72]

A PPA is quite simply a long-term contract between a buyer of electricity on the one side and a supplier of electricity on the other side. The PPA typically specifies a fixed price for a fixed volume for a specific duration of time, but the parties are free to structure the PPA as they wish.

Using bilateral PPAs is not a new development. Many companies are regularly buying/selling parts of their needs through bilateral PPAs, and the rest on market platforms such as NordPool. The reason, however, that PPAs are increasingly attractive is linked to the build-up of new large renewable electricity plants such as, and especially, wind – but also solar – parks. These renewable energy facilities are – like hydro but unlike thermal plants – characterised by having almost all costs upfront as CAPEX and very little OPEX during the lifetime of the installation. This concentrates all risk with the project developer upfront, which has increased the attractiveness of long-term price stability to mitigate project risk for developers and improve access to financing.

Risk hedging is also important for buyers of electricity. For a large off-taker of electricity with relatively high capital costs, a PPA will reduce the risk related to the future power price, thereby improving stability and predictability of a major cost component.

In addition to the pure risk hedging properties, PPAs with a renewable energy plant can be bundled with so-called Guarantee of Origin (GO) certificates. Even though the PPA buyer is only directly linked to the seller through the power grid, a GO allows the buyer of power to credibly claim ownership of a certain amount of renewable electricity, as shown in Figure 27.

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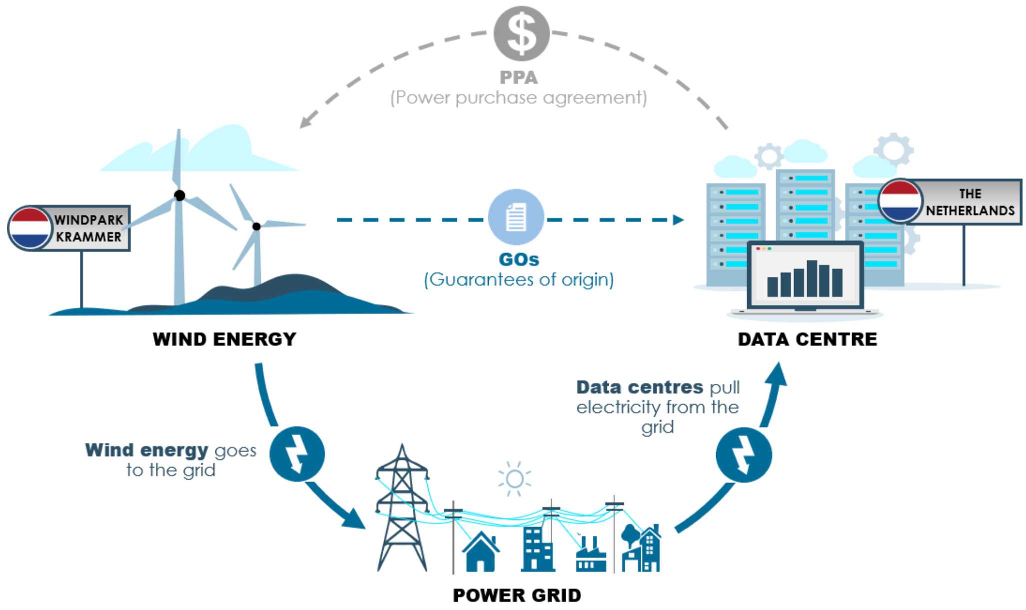
[72] See the description provided by the World Bank PPPIRC https://ppp.worldbank.org/public-private-partnership/sector/energy/energy-power-agreements/power-purchase-agreements and the United States Environmental Protection Agency Green Power Partnership at https://www.epa.gov/greenpower/solar-power-purchase-agreements.

Figure 27 Common structure of a corporate PPA



Source: Copenhagen Economics

The use of PPAs is expected to grow further in the future and is, by many, seen as a vehicle for developing renewable energy deployment by sourcing private financing into these investments and reducing the need for public support. Indeed, in the recent approach to determining renewable energy subsidies through auctions, renewable energy developers bid for a specific subsidy, which can be lower if both residual private funding and ownership of GOs is in place.

4.3.2 PPAs allow data centre providers to source 100% renewable energy

Google is one example of a data centre provider committing to sustainability. In 2012 Google committed to a goal of purchasing energy from renewable energy sources corresponding to 100 percent of power used in its operations. Stated simply, Google will purchase renewable electricity, which on an annual basis is equal (in MWh) to the electricity consumed by its global operations.[73] In this way, Google reduces the carbon footprint of the electricity inputs used for its services. In both 2017 and 2018 Google achieved this goal.[74]

Achieving Google's renewable energy goal requires different methods across the globe since energy markets in the different countries of operation vary greatly. In Europe, this goal is accomplished by

[73] Google (2016) Achieving Our 100% Renewable Energy Purchasing Goal and Going Beyond
[74] https://www.blog.google/outreach-initiatives/sustainability/100-percent-renewable-energy-second-year-row/

signing PPAs with project developers.[75] PPAs can also be facilitated between multiple developers and off-takers, as explained in Box 5.

Box 5 Windpark Krammer showcases the possibility of PPA between a developer cooperative and a corporate consortium

WindPark Krammer in Zeeland, the Netherlands started producing wind energy in 2017. When finalised in 2019 the wind parks production capacity is a total of 102 MW. The wind farm has been developed by a cooperative owned by 4,800 people. In 2016 Google along with 3 other corporates entered into a 15-year PPA with this developer cooperative to off-take and pay for the electricity produced by WindPark Krammer.

This agreement marked the first time Google teamed up with local citizens to create what is effectively a consumer-to-business energy partnership. This plays into the EU's broader ambition to ensure that all citizens benefit from the energy transition. In the recent "Market design directive" as part of the Clean Energy Package, there is a specific provision regarding "citizen energy communities" which the EU is keen to promote.

Source: Rocky Mountains Institute(2017), The Dutch Wind Consortium and https://www.windenergie-magazine.nl/joning-forces-in-the-largest-citizens-initiative/

Since 2010, Google has signed long-term PPA contracts which have enabled investments in renewable energy projects across the globe of over EUR 6 billion. Of this, over EUR 2.3 billion is in Europe.[76] These investments are spread across the 24 PPAs that Google has signed in Europe and they constitute ca. 1.7 GW of wind and solar energy capacity, as can be seen in Figure 28.

To the industry outsider, 1.7 GW of capacity is hard to compare to a reference point. While the extent of renewables deployment across different EU countries varies, we provide an intuition by comparing this amount to the wind energy capacity in the following. The 1.7 GW renewables capacity backed by Google PPAs across Europe are equivalent to:[77]

- 2.5x the installed wind power capacity in Bulgaria
- 50-60 percent of the installed wind power capacity in Belgium or Romania
- 20 percent of the installed wind power capacity in Italy

That notwithstanding, this is still the capacity associated with a single firm's initiative to purchase renewable energy through PPA deals; 1.7GW corresponds to 1 percent of the EU-wide wind power capacity (2018 figures, as per above). What would happen to the business case for renewables' investors and thus to the EU stock of renewables if all firms across Europe pursued the same path as Google and other PPA backers in their energy purchasing decisions?

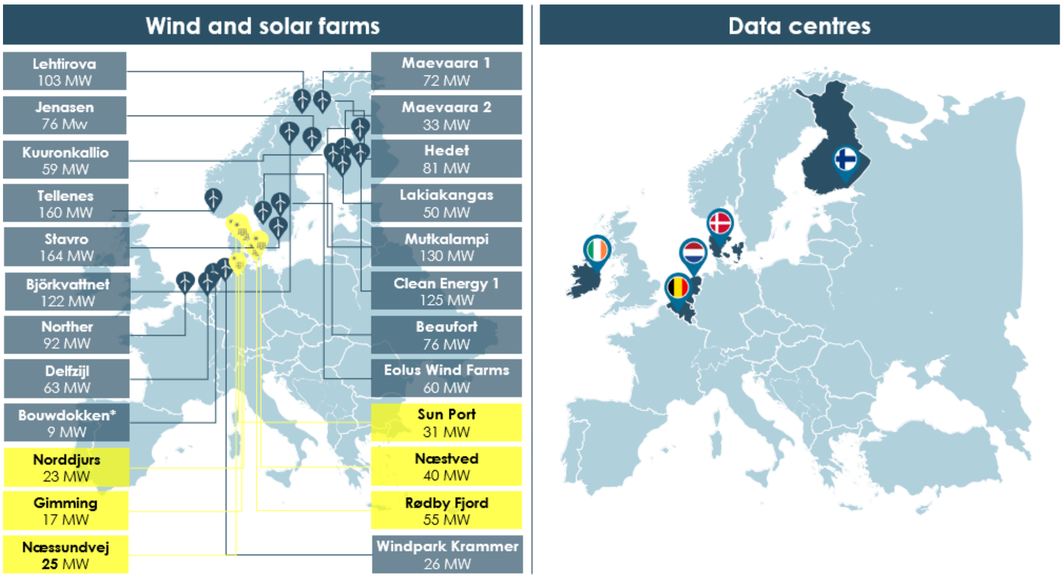
75 The power produced at the PPA-beneficiary plants is conveyed to the local energy grid (accounting for prior use of the renewable certificates). Guarantees of Origin (GOs) are market-based instruments used to track renewable electricity from the point of generation to the consumer. One GO embodies the renewable attributes of one MWh of generation and can be sold separately (unbundled) or together (bundled) with the underlying electricity. GO schemes vary between countries or regions; Sweden and Norway have for example a common electricity certificate market.

76 Internal Google estimate as of September 2019, based on information provided by project developers.

77 Copenhagen Economics, based on country figures from Wind Europe (2019), Wind energy in Europe in 2018

Across the entire globe, Google has signed 52 PPAs which represents nearly 5.5 GW of renewable energy production capacity. Currently, this means that Google is the world's largest corporate buyer of renewable energy.[78]

Figure 28 Renewable energy power plants in Europe reflect Google's commitment in reaching its 100% renewable energy target



Note: Capacities are the total capacities of the wind and solar PV plants. *Google is in a consortium of four companies, thus the Google offtake is 25 per cent.

Source: Copenhagen Economics based on https://cloud.google.com/sustainability/

Google seeks to maximize the level of additionality in all its PPAs. This means that Google seeks to ensure the projects that they buy renewable energy from to be new to the grid and displace generation that is more carbon intensive. Additionality increases Google's impact on the reduction of carbon in the grid and further promotes the green energy transition.[79]

4.4 CARBON-FREE ENERGY 24/7 TO ASSIST A NEEDED PUSH FOR ELECTRICITY SYSTEM BALANCING

Meeting the 100 percent-renewable energy target has been the first step in Google's clean energy strategy. As outlined recently,[80] Google is also pushing towards ensuring that its electricity consumption is matched with carbon-free energy sources at all hours of the day and night – including hours when the wind typically does not blow, or the sun does not shine. The objective is called 24x7 Carbon-Free Energy.

[78] See Bloomberg https://www.bloomberg.com/news/articles/2017-11-30/google-biggest-corporate-buyer-of-clean-power-is-buying-more and ZME Science, https://www.zmescience.com/ecology/renewable-energy-ecology/google-renewable-energy-04122017/ and https://cloud.google.com/sustainability/.

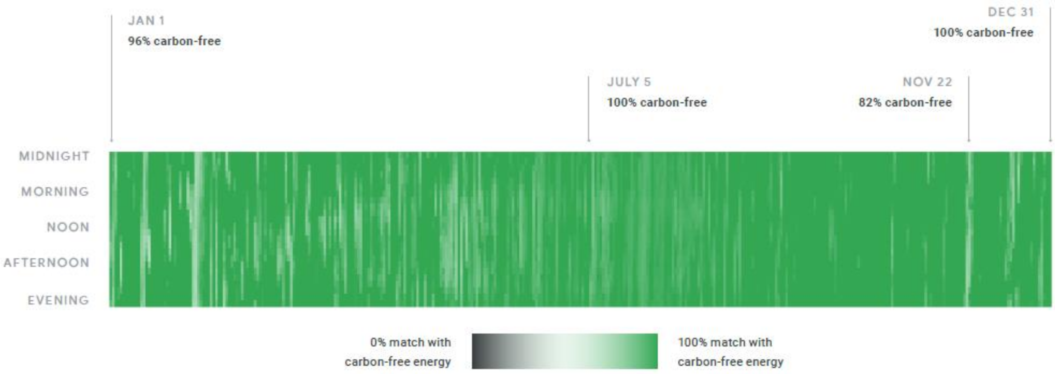
[79] See Rocky Mountain Institute (2017) for an example of how Google in a consortium of four companies constructed PPAs in Krammer and Boudokken power plants in the Netherlands.

[80] https://storage.googleapis.com/gweb-sustainability.appspot.com/pdf/24x7-carbon-free-energy-data-centers.pdf (October 2018)

One of Google's data centres in Finland has almost reached this goal already. In many days throughout the year it is matched exclusively with carbon-free energy sources. This is made possible due to multiple wind energy PPAs signed by Google in the region and a large share of other carbon-free sources in the Finnish power grid. Overall in 2017, 97 percent of the electricity consumption of the data centre was matched with such sources on an hourly basis.

To visualise the variation during the year and at different times of the day, a carbon heat map can be used. It shows the share of energy consumption matched with carbon-free sources throughout each hour of every day during a year. In a limited number of days during 2017 the consumption is not matched 100% with carbon-free energy, as seen in Figure 29.

Figure 29 Carbon heat map for Google's datacentre in Finland, 2017



Source: Google(2018), Moving toward 24X7 carbon-free energy at google data centres

Importantly, what Google is setting out to achieve on a company level, is directly in line with the main challenge of future electricity markets dominated by renewable energy; namely, the variability of some renewable energy sources like wind and solar. As generation sources are fluctuating, there will be more and more hours where either electricity supply is so abundant to overshoot demand (which may result in very low or even negative prices), or electricity supply is so limited to under-shoot demand (which may result in very high prices and even consumer curtailment). Addressing this issue is one of the main challenges for future electricity markets and grid operators, and – as discussed in the Google white paper – new innovations in technology, business models and policy will be needed to achieve carbon-free energy 24x7.[81] In other words, finding solutions to address this structural challenge is not just one firm's ambition but it can only be addressed as a whole-of-society endeavour.

[81] Google(2018), Moving toward 24X7 carbon-free energy at google data centers

In order to deliver on both Google's 24x7 vision and the equivalent societal challenge, development and deployment of emerging technologies is needed. This includes potentially a combination of demand side flexibility, energy storage, carbon capture and storage, and advanced nuclear. Taking storage technology as a promising example, this technology could be integrated close to the fluctuating renewable energy sources to help balance the electricity system. Such improvement would not only contribute to Google's 24x7 carbon free energy strategy but could deliver substantial economic benefits to European economies by storing energy when it is cheap to produce and consuming it when it is expensive to buy Thereby also reducing the need for expensive grid investments; benefits that will accrue to the entire electricity system. Similarly, other technologies could contribute to the solution.

By setting up the 24x7 objective, Google has recognised the core challenge facing electricity systems and is embarking new efforts to help address it. While one company only has limited power, this push could help pave the way for further private sector involvement in large scale projects. As was the case with corporate PPAs for financing renewable energy projects, there are uncertainties, risks and administrative burdens related to private sector involvement e.g. in large scale storage. These issues need to be identified and overcome. Defining ownership structures, standardising contracts and addressing electricity market design barriers are all examples of issues that could help support development of key technologies for the future electricity system. We have identified a number of barriers and address these in more detail in the next section.

4.5 POLICY CONSIDERATIONS: REGULATORY IMPEDIMENTS IDENTIFIED

4.5.1 Barriers to corporate PPAs

As demonstrated, the use of corporate power purchase agreements (PPAs) have substantially increased in use particularly as a means of providing a stable and secure stream of private capital to wind park developers. There are however some barriers to the widespread use of. Generally, these barriers can be divided into two broad categories: structural and regulatory. While the structural barriers to some extent is a basic term of entering into a PPA, regulatory barriers represent issues that could be addressed through regulatory action.

The need to address regulatory barriers is directly recognised in the Renewable Energy Directive of the Clean Energy Package (article 15.8) stipulating that: *"Member States shall assess the regulatory and administrative barriers to long-term renewables power purchase agreements, and shall remove unjustified barriers to, and facilitate the uptake of, such agreements. Member States shall ensure that those agreements are not subject to disproportionate or discriminatory procedures or charges".*[82] Except for requiring Member States to define national pathways in their national energy and climate plans, the legislation does not offer more specific guidance as to how to address regulatory barriers.

Based on our research, we have identified the following group of barriers that seem to be holding back increased use of PPAs as a source of private financing of renewable energy investments (see Figure 30).

[82] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN

Figure 30 Structural and regulatory barriers identified

Structural	Administrative complexity	• Legal complexity in contracts • Risk assessment complexity • Implies sizeable transactions which makes it unviable for smaller companies
	Risk exposure in long-term contracts	• Electricity markets undergoing substantial policy driven changes • Electricity market prices dependent on availability of grid connections e.g. cross-border transmission lines • Curtailment risk from grid capacity limitations
Regulatory	Unequal treatment across borders	• Differences in whether market designs ensure compensation for renewable energy curtailments • Consuming power through PPAs means that companies can become ineligible for indirect carbon cost compensation • Restrictions on e.g. third party ownership, number of buyers per installation and number of suppliers per metering point • Differences in tax regimes and legal systems
	Guarantees of origin (GOs)	• GOs system currently does not ensure transparent and traceable green electricity. Risk of double counting. • Some countries do not allow issuance of GOs if RE-facilities receive government support – even if only a minor share

Source: Copenhagen Economics based on RE-Source Platform (2019), Policy Recommendations, WindEurope (2017). Creating a business case for wind after 2020, K2 Management for Energistyrelsen(2019), Analysis of the potential for corporate PPA for renewable energy production in Denmark, EC (2019), Competitiveness of corporate sourcing of renewable energy, Annex A.3 Part 2 of the study on the competitiveness of the renewable energy sector, Case study: Google, Bird and Bird (2018) - Corporate PPAs - An international perspective, 21st Century Power Partnership (2017), Policies for Enabling Corporate Sourcing of Renewable Energy Internationally, Baker McKenzie (2017), Green Hedging

The *structural barriers* restricting the use of PPAs is linked to the commercial reality of trading power through long term fixed price contracts. Any such contracts in any market will be exposed to legal complexity and risk exposure which must be managed by all parties to the contract. In electricity, complexity is especially high as the delivery of the product from seller to buyer is crucially dependent on the underlying grid infrastructure and how that infrastructure is being used at the specific time of delivery. Historically, that has implied that PPAs have only been used by large companies with large capital investments looking to manage their risk exposure. Large companies trading large amounts of electricity have had the scale required for engaging in PPAs.

Several initiatives are currently working towards making PPAs a more accessible tool for also smaller companies. Standardised contract templates providing more reliability on the legal side for smaller companies can effectively reduce administrative cost and transaction complexity, thereby making PPAs more attractive as a means of trading electricity.[83]

[83] See e.g. WindEurope (2017), Creating a business case for wind after 2020, and a standardised template for a PPA here: https://efet.org/standardisation/cppa/?ref=re-source

Exposure to long-term price developments is a natural part of a long-term contract. By agreeing to a certain volume and a fixed price e.g. 10 or 20 years into the future ensures delivery/offtake of electricity and removes the risk of price fluctuations. However, at the same time agreeing to a fixed price entails the risk that the market price at a given time deviates in the 'wrong' direction. Electricity markets are undergoing substantial changes – changes which are largely policy-driven. It is important that key price drivers in the electricity markets such as grid build-outs, renewable energy deployment mechanisms etc. are as transparent and rule-based as possible to make the transition and subsequent risk exposure as transparent as possible for investors and other stakeholders.

The *regulatory barriers* restricting the use of PPAs are in particular linked to issues that are handled differently in different Member States, and to the treatment of Guarantees of Origin (GOs).

Renewable energy curtailments are the reality in many electricity markets due to grid capacity limitations. Such curtailments can be necessary; however, Member States tend to treat curtailments differently e.g. with respect to compensation. In countries with well-functioning balancing markets, downregulation of renewable energy is priced in the market. In other countries, compensation for curtailment is more unclear.[84] This poses a challenge for e.g. wind producers having committed to delivering energy through a PPA.

One identified barrier is that companies engaging in a PPA can become ineligible for receiving compensation for increased so-called indirect carbon costs.[85] Compensation is granted by Member States to reduce the risk of carbon leakage as electricity prices will increase in response to a higher ETS price. However, there is uncertainty in the current State aid framework about whether entering into a PPA will make the electricity consumer ineligible of receiving compensation. This uncertainty makes PPAs a less attractive means for procuring electricity.

Often individual Member States will have other specific regulations in place that work as a barrier for PPAs. Issues such as the allowed number of buyers per installation and number of suppliers per metering point has been identified as barriers.[86] Moreover, traditional barriers such as differences in tax regimes and legal systems are also issues when engaging in PPAs.

Getting access to green energy is for many consumers a main motivator for engaging in PPAs. A PPA coupled with Guarantees of Origin certificates from the renewable energy plant provides a tangible link from the electricity consumer to the green electricity. Not only can an electricity consumer make a credible claim to consume certified green electricity, the PPA also links the consumer closer to the actual RE generation.[87]

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84 See e.g. WindEurope (2016), WindEurope's views on curtailment of wind power and its links to priority dispatch

85 See e.g. Re-Source (2019), Key Policy Recommendations / Charter and European Aluminium (2019), Vision 2050

86 See e.g. Re-Source (2019), Key Policy Recommendations

87 BEUC(2016), Current practices in consumer-driven renewable electricity markets

However, limitations have been identified with the current GO system.[88] Uneven implementation in the EU represents a risk of double counting, e.g. through different tracking systems.[89] Moreover, in order to avoid overcompensation, some Member States have not allowed issuance of GOs when a RE-facility has received subsidies. This is a barrier for funding RE-projects with PPAs, as GOs make up an important part of the total business case for the consumer. The risk of overcompensation is also being reduced concurrently with subsidies becoming auction-based, as renewable energy developers can include the revenue from selling GOs into the business case thereby reducing the required subsidy.

4.5.2 Barriers to securing balance efficiently in the electricity system

Delivering on Google's 24x7 clean energy strategy, several emerging technologies could play an important role. For all technologies, substantial research, and development efforts is needed. Efforts and technologies that would significantly bring down costs of the green transition by reducing the need for electricity grid investments and improving security of supply. As witnessed with Google's push for corporate PPAs, one company can help bring attention to and overcome certain barriers, but regulatory support is likely to be needed as well.

Most of the technologies that can support balancing the electricity supply need further research and development efforts. For example, most storage technologies are not yet commercially viable in larger scale, and further development is needed to get there. One identified barrier is that the value brought forward by storage can be difficult to include in standardised selection criteria for funding, such as in the EU Project of common interest (PCI) framework. The PCI provides funding for key cross border infrastructure projects based on their assessed value to help EU achieve its energy policy and climate objectives. If the value from storage is not properly included in the cost benefits assessments forming the prioritisation behind the PCI selection, storage projects will not be treated equally with other projects.[90]

Specifically, for storage projects, several barriers have been identified. In many countries for example, storage facilities are being taxed/charged tariff for both its demand and supply of electricity. This gives a double taxation compared to other market participants, where conversely it could be argued that storage facilities can reduce a cost-pressure on the grid and hence should face lower tariffs. Another identified barrier is that the value storage can bring in terms of balancing and congestion management is not fully reflected in market designs yet. Technologies like batteries can provide very fast and very precise regulation compared to other sources; a service which will become increasingly relevant and valuable going forward. Consequently, balancing or congestions management products (sometimes very local products) should be defined and properly priced. A final and important barrier is the need for further cooperation between TSOs and DSOs in managing local resources e.g. such as storage facilities, and how such resources should be able to react to broader energy market price signals such as frequency stabilisation, and more local congestions management issues.

88 See e.g. European Commission (2019), Competitiveness of corporate sourcing of renewable energy

89 WindEurope(2017). Creating a business case for wind after 2020 and BEUC(2016), Current practices in consumer-driven renewable electricity markets

90 See e.g. Proposed methodology for the assessment of candidate projects for the 3rd PCI list Electricity transmission and storage projects

4.5.3 Barriers to digital transformation of processes: the effect of EU indirect carbon cost compensation in an increasingly digitised world

When designing its climate policy, the EU has recognised that, insofar as its environmental ambitions are higher than other regions this entails a risk of the EU industry losing competitiveness to other regions. This phenomenon is called carbon leakage and is problematic as it simply shifts carbon emissions from environmentally ambitious regions to less ambitious regions, with no gain from a global viewpoint. In fact, it could even increase emissions if the less ambitious regions also have higher carbon intensity or lower energy efficiency.[91]

In order to deal with leakage, the EU has adopted a framework for leakage-compensation measures, where energy intensive industries get a degree of compensation for the increased energy costs due to EU climate policies. For electricity intensive sectors, the compensation must be granted directly by Member States within the framework of EU State aid guidelines.[92]

Eligibility is based on electro-intensity and trade intensity indicators suggesting whether certain products are likely to be exposed to international competition. The list of eligible industries was developed with traditional manufacturing industries in mind and did not anticipate the widespread expansion of digitisation throughout the European economy and the associated infrastructure requirements. As a result, the ICT sector is not considered as even potentially relevant for these measures defending the European economic interest.

With ETS prices expected to increase going forward, European power prices are also expected to increase. If the difference in power prices between EU Member States and non-EU countries becomes sufficiently large, there may be a risk of ICT investments flowing – at the margin – into these countries and the supported jobs, GDP and other spill over benefits shifting elsewhere. This would consequently imply an accrual of benefits to non-EU countries. Furthermore, since most countries outside the EU currently feature fewer renewables, the displaced energy impact out of Europe could land in markets with less green energy capacity. In other words, digital transformation in the European economy, driven by evolving needs of citizens/consumers and firms, calls for a reappraisal of the case for different sectors of the economy to be potentially considered for anti-carbon leakage measures.

91 See, inter alia, Copenhagen Economics (2019), Carbon leakage from a Nordic perspective.

92 European Commission (2012), Guidelines on certain State aid measures in the context of the greenhouse gas emission allowance trading scheme post-2012

CHAPTER 5

CLOSING REMARKS: A MULTI-SECTOR POLICY APPROACH TO REAP EUROPE'S DIGITAL INFRASTRUCTURES' OPPORTUNITY

To conclude this study, we turn back and reflect on what, as economists, we have learned as part of this research journey and what related elements could be of socio-economic and policy interest. On this basis, we present exploratory suggestions on what to research and discuss further.

First, we note that the area of digital infrastructures is a relatively novel area and knowledge on the topic is still developing. Telecommunication economics and business aspects have long been analysed, including their socio-economic impacts. Further business, economics, and policy analyses can help contribute to the wider understanding of how firms' activities and assets are developing to meet and enable evolving customer needs for online services – and the framework conditions informing this process.

Second, environmental considerations are top of the current agenda in Europe and achieving these will depend on vision, as well as attention to detail. We have identified and analysed a series of regulatory impediments that are key for policy makers to be aware of, as they consider solutions to develop and meet green ICT agendas and the wider decarbonisation and Green Deal initiatives progressing across Europe.

Third, efficiency in delivering digital solutions relies on scale and thus on the ability to serve multiple markets at once, while adapting to customer demand. We have observed a tension between the desired Europe-wide functioning and embracing of digital transformation processes and the national boundaries that still separate one European country from another. The development of pan-European digital infrastructures involves a lot of nitty-gritty such as cross-border electricity interconnector capacity, multi-country telecom infrastructure provision, regulatory differences in national treatment of renewables, variations in educational systems across countries. While the EU motto is "United in diversity", researching digital and digital infrastructures matters brings inexorably the attention to critical Single market challenges which persist and affect all sectors of the economy, including the fostering of digital infrastructures and thus digital transformation Europe-wide.

Last, the topic of digital infrastructures is inherently multi-disciplinary. We have seen that globally leading firms, like Google, bring together experts from different specialisations to develop and make use of infrastructures. It is equally, or even more relevant, for policy makers to come together, interact, and collaborate to ensure a timely and sustainable infrastructure development supporting the European digital transformation. The sectoral-specific expertise of policy makers from the areas such as education, employment, energy, environment, planning, telecoms is key to enhance the collective awareness of how policies interact in informing the framework conditions for the development of European digital infrastructures such as those analysed in this study.

ADDITIONAL DOCUMENTATION MATERIAL

This study is accompanied by a separate methodology annex, which provides also a full list of bibliographic references.

The section directly below reports supplementary case study material informing the findings of the following chapters:

- Chapter 1. Introduction: infrastructure for the digital future of Europe
- Chapter 3. A significant contribution to European network infrastructure

CASE STUDY

The UK: The Department for Transport analyses railway passenger usage data in real time, while developing traffic monitoring and planning insight

The Department for Transport (DfT) is a government department in the UK responsible for the transportation network, e.g. railways and roads. To understand better how the rail network operates and functions, DfT runs a customised version of an application called LENNON (Latest Earnings Networked Nationally Overnight), that provides data, including ticket sales and franchise earnings, on a daily basis.

The LENNON system is huge and includes more than 10 terabytes of data, and slow query times were a real concern for the DfT and rail industry back when the data was still stored on local servers. Accessing and processing relevant data typically took several hours. The lack of speed to process the data meant that DfT could not exploit all the opportunities and information that the system contains.

After undertaking a discovery exercise with Google, DfT decided that the customised LENNON application should migrate to Google Cloud Platform (GCP). GCP was exactly the solution that DfT needed for LENNON. In the cloud, queries can be completed much faster and multiple queries can be executed in parallel due to the scalability of the cloud computing.

Although DfT is still in the process of adopting the cloud solutions, GCP has already had a remarkable impact on the performance of LENNON. The execution time of data queries has dropped from several hours to less than 20 seconds, quickly supplying the right data to the right employees.

The reduction of query times means that DfT's data scientists can perform much richer and insightful analyses than ever before. The enhanced analytics provide DfT with an opportunity to explore more dimensions of their data and potentially understand the dynamics of the rail network even better.

Moving to the cloud has also decreased the need for maintenance of the LENNON application, thereby freeing up employees' time and resources that can now be redistributed towards new valuable projects and tasks. One of those projects is to transfer more of DfT's on-premise services and applications to the cloud with the aim of improving efficiency further. The transformation of DfT digital services will not only benefit the department itself – but the entire rail industry in the UK.

Source: Copenhagen Economics, based on https://dftdigital.blog.gov.uk/2019/02/26/transformation-of-lennon-rail-data-application/, supplemented by industry engagement.

CASE STUDY

Sweden: Sandvik's new manufacturing-based services add value as an Industry 4.0 platform

Sandvik is a global engineering group with more than 46,000 employees, specializing in tools and services for mining, construction and cutting of metals. Today, Sandvik's metal cutting team uses its own state-of-the-art app to design virtual prototypes of metal components in 3D and then uses the app to programme traditional metal cutting machines to manufacture the components with increased precision.

However, just a few years ago the cutting of metal was a very time-consuming process, with risks of human errors delaying the process further. Engineers spent hours programming the traditional CNC machines, using only their experience and complicated manuals to work out how the metal components would look like. The machine stood idle during the programming process and simple coding mistakes would cause the machines to break or the cutting pieces to be rejected.

Sandvik saw a potential to cut time and resources substantially if the company created a visualization application that would allow the engineers to construct the metal components in a virtual 3D-environement and assist them programming the CNC machines according to this 3D-sketch.

Sandvik found that Google Cloud Platform could help the company to build such an application and distribute the solution to their employees worldwide. In only seven months, Sandvik Center of Digital Excellence (CODE) built the new app, PRISM, that enabled Sandvik's engineers to create and visualize a prototype of the metal components on a tablet, and with a single click, the app generates the code for the CNC machine.

The app has revolutionized the coding of the metal-cutting CNC machines. Engineers can now set up the machines to produce new components in less than 10 minutes and errors are down by around 90 percent. This has led to a productivity increase in the cutting of metals, a reduction of material waste, while freeing up the engineers' time to perform other important tasks within Sandvik.

Sandvik's new cloud solutions are all built to scale. This enables Sandvik to tap into innovative business models and move up the advanced manufacturing (Industry 4.0) value chain. For example, Sandvik has recently commercialized the PRISM-app, offering monthly subscriptions. With more than 2 million CNC machines around the world, the potential for this new stream of income is very large and thanks to the scalability of GCP, the app is fully prepared to handle thousands of users in the future.

Source: Copenhagen Economics, based on https://cloud.google.com/customers/sandvik/, supplemented by industry engagement.

CASE STUDY

Finland: Growing Google's Interconnected Cloud

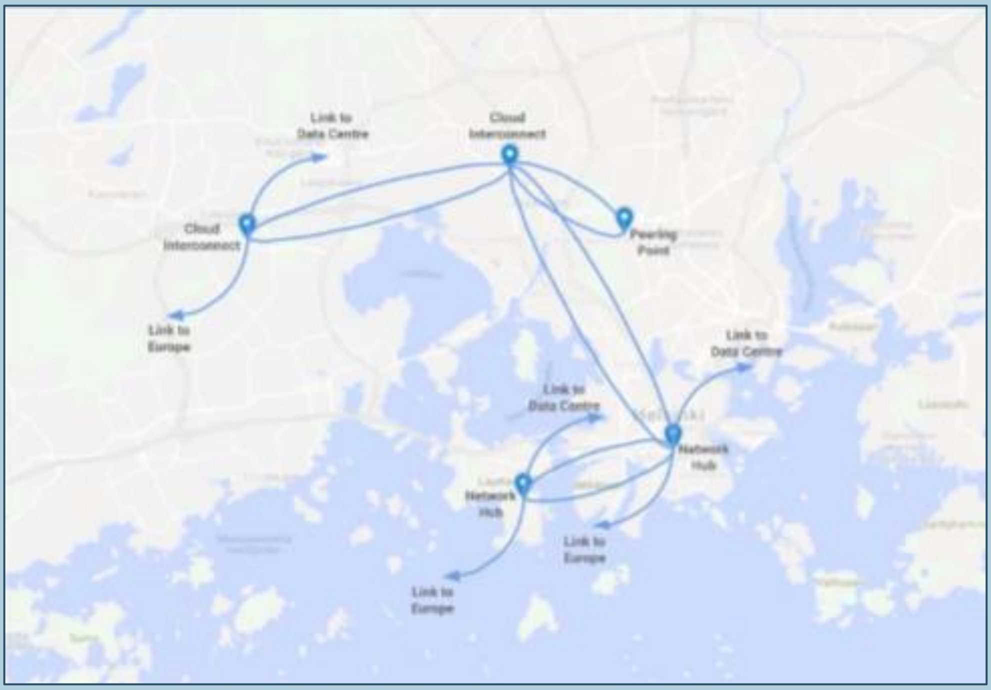
The connectivity behind digital infrastructures covers not only international links but also investments specific within a country and city network – we provide an example in what follows.

In Europe, with its rich history and many countries, it can be the case that enterprise cloud customers in one country, such as Finland, might connect to Google Cloud services from a different country. This comes with all the costs, complexities and delays that can sometimes occur. By opening up a major presence in Helsinki in 2020 for customers and partners to connect to Google, Google is taking the burden of that challenge from customers while providing lower latency access to near-by data centre-based computing.

Enterprises of all kinds, such as the Financial Services, Healthcare, Technology, Manufacturing and Public sector services, all especially prevalent in Helsinki, will all benefit from lower latency connectivity to compute. Customers will also have less regulatory complexity to consider by connecting to compute in-country.

Google's Helsinki investment aims to make it easier for Cloud customers to connect to Google while at the same time ensuring the reliability and availability of their infrastructure for their business-critical services and applications. In time, this type of architecture will also allow Google to simplify requirements for their Cloud customers to obtain high availability guarantees.

Google is also taking the opportunity to establish a full edge and peering presence in Helsinki with connections to major peering locations to improve their users' and customers' experience for all Google products and services. Improved quality of service for Google users in this region will be delivered – be they gamers using Stadia, people using Search to learn or navigating home with simplicity using Google Maps.



Source: Copenhagen Economics, based on interviews with Fionnán Garvey, Global Network Acquisition at Google in July 2019.

CASE STUDY

Focus on Google's subsea cables of European relevance

Havfrue: To increase capacity and resiliency in Google's North Atlantic systems and to generally expand their network, Google is working in a consortium, including Aqua Comms, Bulk Infrastructure, and Facebook on a direct subsea transatlantic cable system constructed by TE SubCom called Havfrue (Danish for "mermaid"). Havfrue will connect Denmark and Ireland to the U.S.

Dunant: The Dunant cable is 100% funded by Google and is named after the first Nobel Peace Prize winner and founder of the Red Cross, Henri Dunant. The cable spans the Atlantic to connect the west coast of France to Virginia Beach, U.S. It will expand Google's network to help it serve better its users and customers, supplementing one of the busiest routes on the global internet with high-bandwidth, low-latency, highly secure connectivity. Google will work with Orange telecom to land the cable in France and for the onward connectivity across France. As an added benefit and spill-over, Orange will also have use of Dunant trans-Atlantic.

Equiano: Google's key new sub-sea endeavour, called Equiano, will connect Western Europe to South Africa with branching units along the way to extend connectivity to more African countries, the first of which is expected to be Nigeria.

This new cable is fully funded by Google allowing it to expedite its construction timeline and coordination processes. This infrastructure (Google's third private international cable after Dunant and Curie and 14^{th} subsea cable investment globally), is named after Olaudah Equiano, a Nigerian-born writer and abolitionist who was enslaved as a boy.

The Equiano cable is a state-of-the-art infrastructure based on space-division multiplexing (SDM) technology with approximately 20 times more network capacity than the last cable built to serve this region. It will be the first subsea cable to incorporate optical switching at the fibre-pair level rather than the traditional approach of wavelength-level switching. This greatly simplifies the allocation of cable capacity, giving the flexibility to add and reallocate it in different locations as needed.

Source: Copenhagen Economics, based on interviews with Fionnán Garvey, Global Network Acquisition at Google in July 2019.

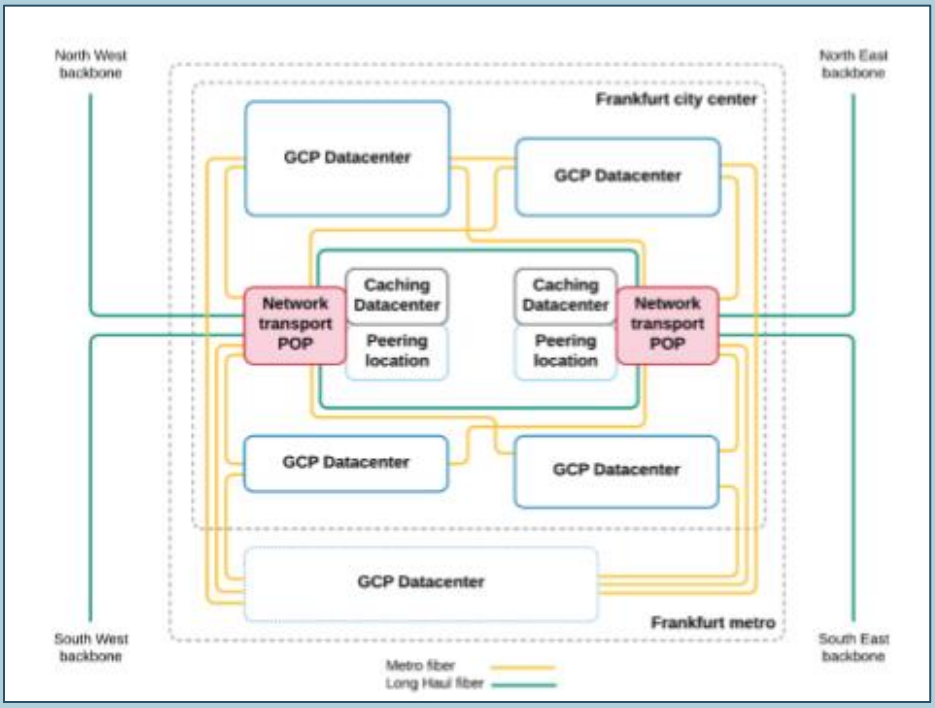
CASE STUDY

Frankfurt: network infrastructure for a major business and connectivity centre

Frankfurt demonstrates well the many challenges Google faces in the major global pivot towards Cloud computing. Traditionally a network hub, growth in demand for low-latency compute and connectivity services in enterprise centres is changing the shape and scale of Google's presence in cities like Frankfurt which now has dozens of ever-larger points of presence and many network links of all shapes, sizes and functions.

Within the metropolitan area of Frankfurt, Google needs to ensure high availability of its assets and security of supply of interconnections between those assets meshing long-distance network locations, external interconnection peering points, backbone network locations and also locations hosting Cloud services across several major campuses and dozens of locations.

Such a large and complex undertaking involves major investment by Google in local enterprises, infrastructure and highly skilled labour. Underlying metro network assets at this scale are almost entirely dark fibre based with active optical equipment providing high capacity links and the ability to quickly scale to meet new demand between Google's compute spaces and network hubs around the city. Cloud specific architectural solutions providing hardened, highly available services to enterprise customers are strategically located around the city in addition to existing network PoPs and caching locations storing content as close to the consumer as possible for even more efficient use. Google is also present at DE-CIX in Frankfurt, one of the world's largest internet exchange points (IXPs) globally, which holds over 1,600 connected autonomous systems.



Source: Copenhagen Economics, based on interviews with Fionnán Garvey, Global Network Acquisition at Google in July 2019.