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# INSIDE FINLAND

## Google's European hyperscale data centres and infrastructure ecosystem

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*Dear Reader,*

*This research piece on Finland follows the September 2019 pan-European re-search 'Google's hyperscale data centres and infrastructure ecosystem in Europe: economic impact study' (available here). The following pages provide a deep dive into the economic effects descending from Google's Hamina data centre and related network infrastructure ecosystem in Finland.*

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

## FINLAND: A VITAL CONNECTION IN EUROPE

Finland is well placed on the path of digital transformation. The Finnish government has recognised the value of the digital platform economy and acknowledged it as essential to remain agile and competitive.[1] Additionally, public sector organisations in Finland are considered pioneers when it comes to providing digital services to citizens.[2] This is supported by the legislation on the provision of digital Services (enforced 1.4.2019), making authorities obliged to provide their customers with accessible and high-quality digital services and enable electronic transactions.

**Growth and jobs.** Google is facilitating even greater EU-wide connectivity via Finland. It has done so as part of a wider infrastructure programme which

- Delivered cumulative realised investments of **EUR 1.2 billion** in the Hamina data centre and related network infrastructures, over the period from 2009 to 2019
- This has supported **EUR 1.4 billion in GDP** in Finland during the same period
- Furthermore, **1,700 jobs per year on average** have been supported, during the same period

**Network infrastructure.** This digital infrastructure effort includes an important, often underappreciated, part of Google's European economic contribution, namely the investment in network connectivity such as fibre links spanning the European continent and linking Europe to the global internet.

In addition to the digital transformation supported by Google's investments, Google's Hamina hyperscale data centre is on the forefront of the green transition in digital energy. The Hamina data centre was the first in the world to run using an advanced sea water cooling system based on water directly from the Bay of Finland.

**Energy efficiency.** Every time we as users choose to rely on services provided online, we channel indirect demand for energy. As traditional non-digital activities continue to shift to new digital applications, the way energy is being consumed is changing. The data centre industry **has significantly raised its energy efficiency**. In fact, recent global research established that while demand for data driven services has increased exponentially (by 550 percent) over the past 10 years, data centre energy usage has remained relatively stable (increasing by only 6 percent).[3] At the same time, there is potential to improve efficiency even further. We estimate that, if across Europe all business email servers were hosted by data centres as efficient as Google's, this would **save the equivalent of the annual household consumption of electricity in Ireland**.

**Renewable energy.** Driving the green revolution forward, Google is also the largest corporate buyer of renewable energy sources. It does so by committing to and signing Power Purchase Agreements (PPAs), key enablers for the renewable energy project developer/investor. As of September 2020, Google had signed 24 PPAs for energy production from European wind and solar farms to match the energy consumption of its data centres. In addition, in September 2020 Google stated that it will be carbon-free by 2030.[4]

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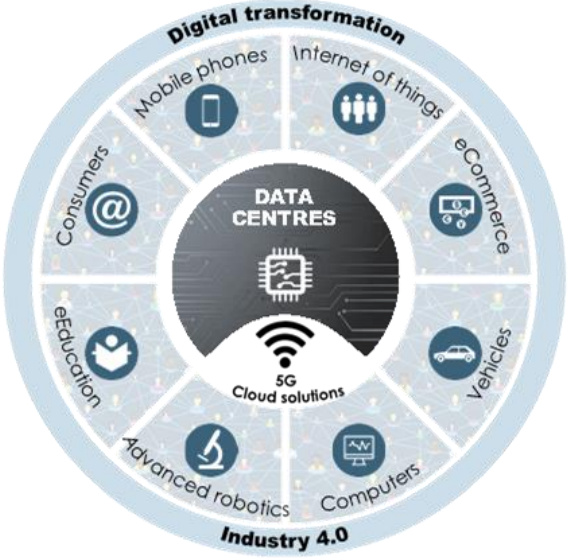
1 Business Finland, Finnish Government and Ministry of Economic Affairs and Employment (2017). Digitaalisen alustatalouden tiekartasto;
2 Ministry of Finance:"Digitaalisten asiointipalvelujen tiekartta"; https://vm.fi/digipalvelujen-tiekartta
3 Masanet, E, et.al. (2020) Recalibrating global data center energy-use estimates
4 Google (2020), Our third decade of climate action: Realizing a carbon-free future. https://blog.google/outreach-initiatives/sustainability/our-third-decade-climate-action-realizing-carbon-free-future/

# 1 DATA CENTRES SHAPING THE DIGITAL FUTURE THROUGH CLOUD COMPUTING

The cloud has transformed how companies purchase ICT equipment and services. Cloud computing removes the need for large up-front investments in hardware and software otherwise required for companies to compete in the market. New entrants can increasingly gain access to 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. Behind the cloud, millions of servers are quietly and efficiently operating in hyper-scale data centres. These data centres are the "brains" of digital infrastructure around the world. They are the physical assets that store, process and/or distribute the data that customers send to the cloud. Hence, to facilitate future growth in data traffic, storage and processing driven by consumers' and firms' use of cloud computing, investments in data centres need to increase.

**Figure 1**
**Data centres at the heart of the European digital future**




Source: Copenhagen Economics

Current EU-level and national policies increasingly understand the benefits that the cloud can bring. A priority of the current European Commission is 'a Europe fit for the digital age' – focusing on the advancement of Artificial Intelligence, the Internet of Things and Big Data in Europe, and harnessing the opportunities from data sharing.[5] 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 and the building of a European data economy.

In parallel, the current European Commission has stated that it will prioritise progressing the Green Deal for Europe. Therefore, the sustainability angle will be key in underpinning each of the policy

[5] 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*.

efforts that can contribute to the success of the European digital transformation, such as work in the areas of:

- The European Cloud initiative
- The Internet of Things (IoT)
- Building a European data economy including big data
- Artificial Intelligence (AI)
- High-Performance Computing

For these digital advancements to take place, the cloud is a key pillar. In turn, an effective, sustainable and efficient cloud needs support from well-functioning digital infrastructure with data centres at the core. National policy makers and other interested parties also vested in the development of the digital economy in the EU should thus continue to foster support for the data centre and related infrastructure layer, as discussed in our September 2019 study.[6]

**Box 1 Digital and cloud policy in Finland**

The Finnish government has recognised the value of the digital platform economy and acknowledged that the implementation of a full digital strategy, that encompasses both public and private sectors, is essential in remaining agile and competitive. In the Government's roadmap to a digital platform economy, cloud computing services is seen as an elemental component in this transformation[7]. In addition, Finland supports the European Cloud Initiative, but also emphasises the need for further clarification on some matters, for instance interoperability and regulation to achieve flexible transitions, genuine scalability and cost-effectiveness[8].

Public sector organisations in Finland are considered pioneers in providing digital services to citizens. By 2023, the goal is that the services of public authorities for business entities, registered associations, foundations and housing companies would be offered exclusively in digital form[9]. This is supported by the legislation on the provision of digital Services (enforced 1.4.2019), whereby authorities are obliged to provide their customers with accessible and high-quality digital services and to enable electronic transactions.

In support of the public sector digitalisation, the Government has outlined the policies concerning public sector cloud services, with the aim of supporting decision making in the Government, countries and municipalities in their adoption of new cloud services and in Finland's digitalisation journey. As dictated in the policies, the government stresses that cloud technologies should be used when designing public sector services, but also that necessary vigilance concerning cloud technology-specific risks should be practised[10].

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6 Copenhagen Economics (2019) Google's Hyperscale Data Centres and Infrastructure Ecosystem in Europe.

7 Business Finland, Finnish Government and Ministry of Economic Affairs and Employment (2017). Digitaalisen alustatalouden tiekartasto;

8 Finnish Transport and Communications agency (2020) Perusmuistio (LVM2020-00037): "Komission tiedonanto Euroopan digitaalisesta tulevaisuudesta, komission tiedonanto Euroopan datastrategiasta ja komission valkoinen kirja tekoälystä"; https://www.eduskunta.fi/FI/vaski/Liiteasiakirja/Documents/EDK-2020-AK-295429.pdf

9 Ministry of Finance:"Digitaalisten asiointipalvelujen tiekartta"; https://vm.fi/digipalvelujen-tiekartta

10 Ministry of Finance (2018). Guidelines for Public Sector on Data Communications Service; http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161294/VM_35_2018_Julk_hallinnon_pilvipalvelulinjaukset.pdf

The increasing demand for cloud services (e-mails, music, general data storage, etc) means that global internet companies like Google are now among the most efficient facilitators of global data centre growth. Global internet companies are especially efficient as they are able to consolidate storage and cloud-processing of data in 'hyperscale' data centres.[11] This translates to larger-scale, purpose-built facilities with a focus on operational costs and efficiency that are better positioned to meet the growth in demand for cloud services and the like. The importance of these efficiency gains is evident in global market trends. Cisco estimates that by 2021 hyperscale data centres will constitute around 53 percent of data centre servers globally – up from 27 percent in 2016.[12] Similarly, Arizton estimates that the hyperscale data centre market will continue to expand from 2019 to 2024 at a compound annual growth rate (CAGR) of 9 per cent.[13] In terms of the entire 'datasphere' (the data lifecycle from creation, capture, and replication) growth projections from IDC suggest the total size will increase from 33 ZB[14] in 2018 to 175 ZB by 2025, representing a CAGR of 27 percent.[15]

Therefore, just as is the case for players across the industry, there is expected growth in user demand for Google services. These include many services widely used for general productivity and consumer benefit (provided with open access akin to public goods) such as Gmail, Google Maps, Search and Android. This suggests that Google's investments in data centres in Europe will continue (as observed in the past years) to increase over time as demand for and use of these services expands given the important consumer benefits delivered. As summarised below (and analysed in our September 2019 report), as users choose to rely on services provided online, cloud infrastructures play a key role in an efficient delivery of these services, including in terms of energy efficiency. Besides, we find that the data centre industry has significantly improved its energy efficiency performance, while Google's data centres outperform the industry average. Furthermore, an important recent development associated with the Covid-19 crisis is a societal push for faster and deeper digital transformation across sectors of economic activity. Consequently, **Google's economic contribution to Finland and Europe will very likely continue to increase in importance**.

[11] 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.

[12] Cisco (2018), Global Cloud Index (2016-2021), see: https://newsroom.cisco.com/press-release-content?articleId=1908858

[13] Arziton (2019) Hyperscale Data Center Market - Global Outlook and Forecast 2019-2024

[14] This refers to 'zettabytes', were 1 ZB is equal to $1000^7$ bytes

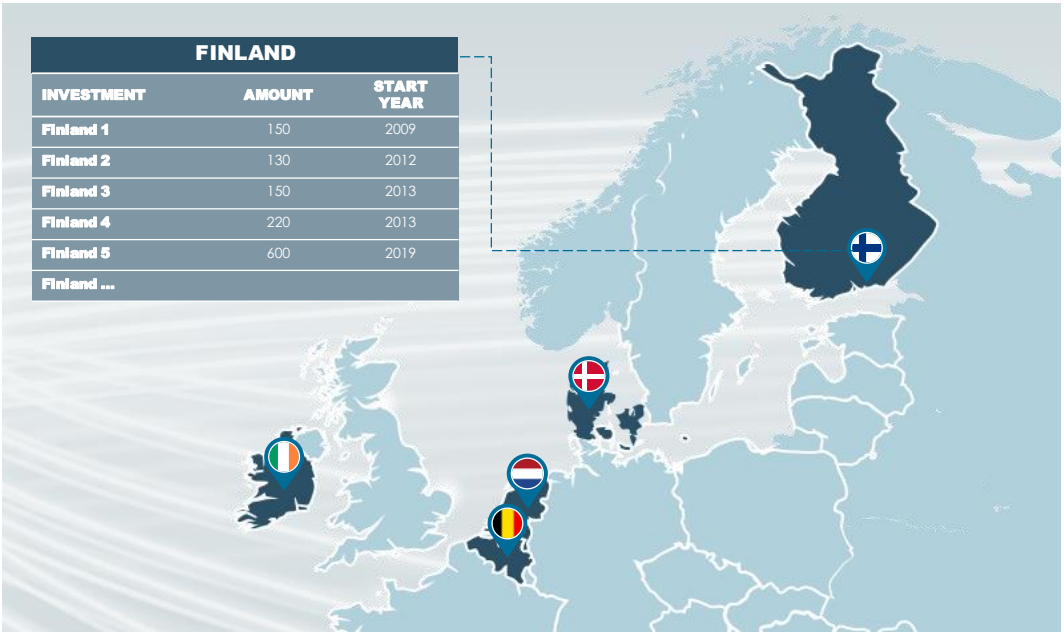
[15] IDC (2018) The Digitization of the World: From Edge to Core

# 2 QUANTIFYING THE GDP AND JOBS IMPACTS OF GOOGLE'S DATA CENTRE INVESTMENTS

Google's investments in digital infrastructure in Finland help to propel the country further forward as a leading digital economy. These digital infrastructure investments include data centres, network infrastructure and equipment, management, and access and computation – elements that are vital to sustaining our increasingly digital culture.

As one of the largest technology companies in the world, Google serves a significant share of users from their data centre in Finland. Google's data centre at Hamina started construction in 2009 before becoming fully operational in 2011 (see Figure 2).

**Figure 2**
**Ongoing investment in Google's national data centre**




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

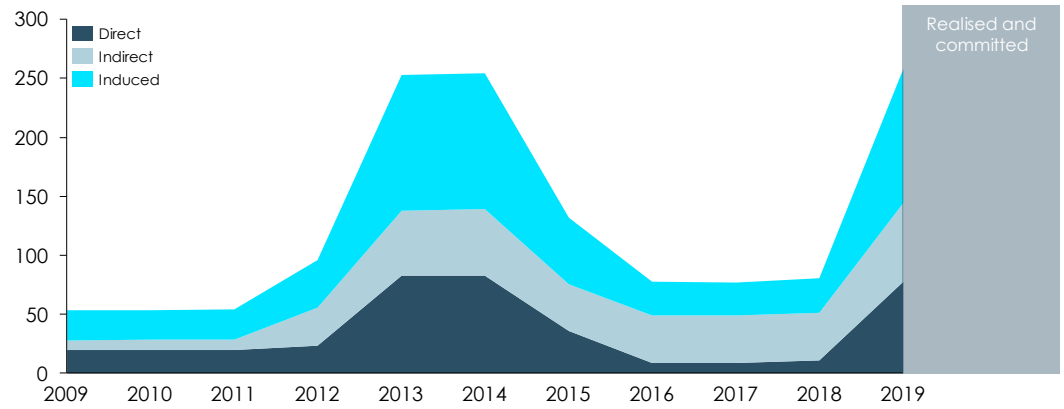
Every time a firm (domestic or foreign) invests in construction and infrastructure like Google's data centre in Finland, it is reasonable to ask – how much of this investment will remain local versus will leave the region or country (via imports, etc)? To help answer this question, we have applied an established economic (input - output) model to measure the impact of Google's investments. We do this by measuring two dynamics – supported economic activity (GDP) and supported jobs (FTEs)[16] by Google in Finland.[17]

[16] FTE refers to Full Time Equivalent job, where 1 FTE equals 40 hours per week

[17] The CE input / output model compared the Google expenditure sectoral pattern and mapped it against the official national statistics, from Statistics Finland (Tilastokeskus). 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.

We find that when considering the direct, indirect, and induced effects, Google's total investments in the Hamina data centre and related infrastructures has a supported economic impact of **EUR 1.4 billion in GDP cumulatively over the period 2009-2019.** This impact has grown over time from a yearly impact of EUR 50 million to a peak yearly EUR 260 million (see Figure 3). Committed expenditure through to 2021 is expected to increase the supported cumulative economic impact to **EUR 2.0 billion.**

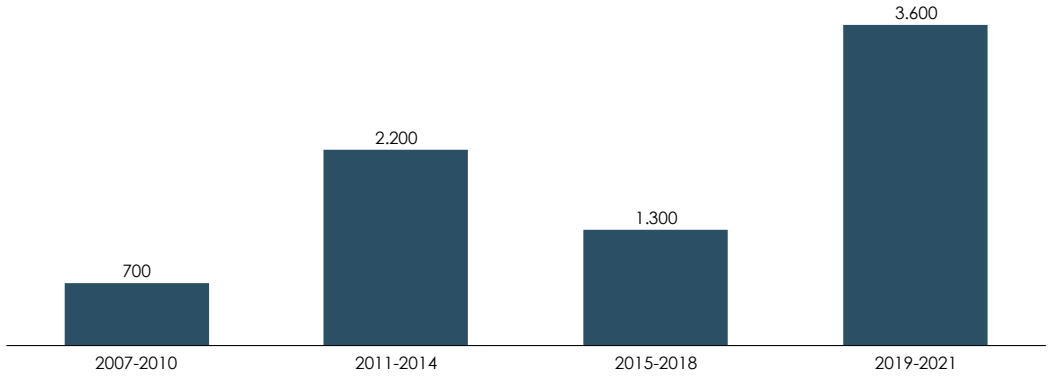
**Figure 3**
**Economic impact supported by Google data centres and related infrastructure**
EUR millions per year




Note: The figure shows the supported economic contribution in Finland due to the construction and operation of Google's Hamina data centre and related infrastructures.
Source: Copenhagen Economics based on data provided by Google, Eurostat and World Input-Output database

Through committed expenditures to 2021, Google's Hamina data centre and related infrastructures will support an ongoing employment contribution of up to 3,600 FTE jobs per year (during 2019-2021) including direct, indirect, and induced effects (see Figure 4 ).

**Figure 4**
**Jobs supported by the Hamina data centre & related infrastructure**
Full Time Equivalent jobs, annual averages

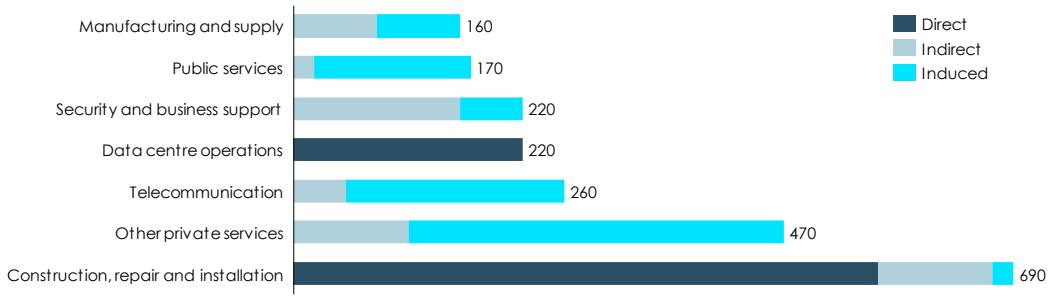



Note: Figures include direct, indirect and induced employment associated with the expenditures in scope of this research. 2019-2021 figures reflect committed Google expenditures.
Source: Copenhagen Economics based on data provided by Google, Eurostat and World Input-Output database

We find that within the period 2009 – 2019 the data centre construction and operation support jobs primarily in the construction (approx. 690 FTEs per year) and security and business support (approx. 220 FTEs per year) industries.

In addition to these industries, data centre activity at Hamina stimulates consumer consumption, as workers spend their wages throughout the Finnish economy. These induced effects support jobs mostly in private services, as this is where employees tend to spend their wages. This mechanism supports approx. 470 FTEs per year in private service industries such as retail trade, transport, hotels and restaurants, real estate, legal, accounting, and employment activities, as reported below in Figure 5.

**Figure 5**
**Jobs supported by the Hamina data centre and related infrastructure, by industry**
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 provided by Google, Eurostat and World Input-Output database

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

# 3 HELPING TO SUPPORT MULTIPLE LOCAL REGIONS AROUND HAMINA

The economic literature on the role of foreign direct investments in promoting a country's productivity points to skills transfers as a key channel by which a country stands to benefit from these kinds of investments, especially relative to new technologies.

In the case of data centre investments, the case study of Google shows a particular form of skill transfer, taking place via collaboration with educational institutions aimed at promoting the skill base in the local and national workforce. This delivers win-win-win benefits to students, to Google and other firms operating data centres (or industries relying on comparable skills), as well as the country as a whole, since an up-to-date skill base is key to succeed in a knowledge economy.

**Box 2 Directly supporting Finlands' digital future**

Ekami is the Joint Authority of Education of the Kotka-Hamina Region Group (Etelä-Kymenlaakson ammattiopisto) – a multi-disciplinary education institution in the southern Finnish region Kymenlaakso. In addition to running the South Kymenlaakso Vocational College with 5,000 enrolled students, Ekami facilitates regional workshops with a focus on rehabilitating educationally marginalised youth. Through their activities, Ekami yearly reach nearly 10 percent of the local population. As such, they are a major contributor to the local development of the region. Ekami focuses its training on forming enduring skillsets, which has resulted in ICT, electricity and programming being the most popular fields among their students.

Since 2011, Google has collaborated with Ekami to develop a hands-on study track focused on setting up, managing and operating data centres. The course was first offered in 2012 and has been offered every year since then. With support from Google, Ekami has set up a fully functioning miniature data centre on campus. This data centre is used to help the students understand the inner workings of modern hyperscale data centres. Each year, the students (re-)build the data centre as part of the learning experience. This is only one part of the course, which is planned and tailored around the needs of data centre employers and the data centre industry. Both the technical aspects and the curriculum of the course are developed in parallel with Google.

Ekami is currently taking steps to develop and refine its offerings within the areas of tech and data centres. This has materialised to a formal cooperation with the Finnish Data Centre association as well as educational institutions with tech and data centre offerings outside of Finland. Besides, via Google, Ekami has established links with other similar educational institutions throughout the EU. The aim of this network is to improve the skillset developed at Ekami to increase the value for students, the local region and the tech industry.

In addition, Ekami is planning to exploit the cross-disciplinary task of powering data centres through local renewable energy sources (such as geothermal energy production) as a learning experience for their students. A specific course on the 'green data centres' for professionals is Integrated into the Ekami programme.

As part of its dedication towards developing enduring skillsets and contributing to society, Ekami is developing an open-to-all project with a focus on sparking the interest for technological advancements in the local population. The pilot project, "Technology Playground for Future Jobs", was launched late 2019, and offers the citizens of Kymenlaakso an outlet for the tech-curiosity by letting them experiment with advanced technology. With Google as a partner, the next phase will launch in the fall of 2020 with, among others, the ambition to offer an interactive virtual reality look into the actual workings of a data centre.

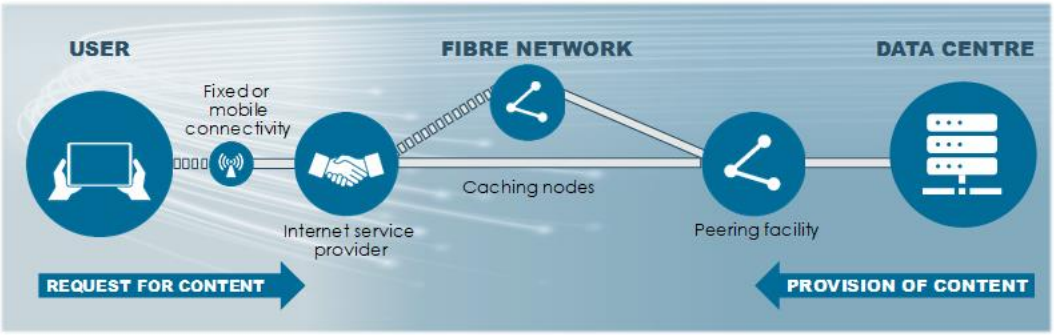
Source: Interview with Sami Tikkanen (Principal and managing director), Ekami, 3rd of July, 2020

# 4 NETWORK INFRASTRUCTURE STRENGTHENS LINKS BETWEEN FINLAND, EUROPE AND THE WORLD

A key driver encouraging network investment is to bring the benefits of Google computing and cloud resources closer to customers. In internet network design jargon, this is the often-underappreciated role of "edge" infrastructure – the vital links in proximity to where consumers and firms use digital services. Providing network connectivity allows Finnish to reach core cloud services by connecting with Google closer to their point of use. By facilitating this connection on dedicated infrastructure in nearby cities or towns, the speed at which these cloud services can be reached is increased. In effect, this brings the services of the harder-to-reach Hamina data centre closer to Finnish consumers, ensuring a faster and more responsive cloud experience.

From a consumer's perspective, the visible reality of the internet tends to be what is regarded in the industry as internet access links. Internet access links consist mainly of Internet Service Providers (ISPs) – often telecommunications companies that provide either 1) fixed services in the home or office, often accompanied by a modem, or 2) mobile services through mobile telephone subscriptions or other similar wireless devices, see Figure 6. Thus, some consumers might believe that ISPs are the only firms backing connectivity infrastructure – however, this is incorrect.

**Figure 6**
**How data centres reach users: Google's design, high level view**




Source: Copenhagen Economics based on Google

The inner network part of the internet (less visible compared to the connections to homes and firms) is what is referred to as the backbone of the internet (split broadly onto the 'core' and 'edge'). At the core, data centres host files and apply computational processes so that the information can serve users' requests. To reach users, hosting activity needs high capacity transport networks that connect data centres to peering facilities. This network infrastructure (increasingly fibre) reaches peering facilities, or Points of Presence (PoPs), at the 'edge', connecting Google's network to the rest of the internet. At that point, PoPs serve as the connecting points for the ISPs at the front end of the internet. From the PoPs, internet traffic is handed over to ISPs, which take over the responsibility for carrying the internet services to homes and offices. In addition to this, Google also maintains the Google Global Cache (GGC) network through caching nodes, provided to ISPs. These smaller pieces of infrastructure at the "edge" enable basic data requests to be brought even closer to consumers, providing even greater responsiveness.

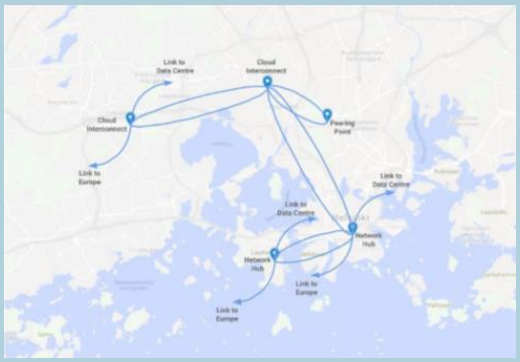
As a result, **Google procures and maintains a major global network connecting key infrastructure** such as data centres, cities and towns, and network hubs. Google's network connects Europe through several major sub-sea landing points to the rest of the world. Of equal importance – and perhaps a surprise to some – Google's global network includes a **major terrestrial network spanning across Europe**. Covering the continent, this network includes 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 firms' users and customers within Finland and abroad.[18]

[18] Read more about these in the main report, found here.

**Box 3 Growing Google's Interconnected Cloud**

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 some-times occur. By opening a major presence in Helsinki 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 sectors especially prevalent in Helsinki, will all benefit from lower latency connectivity to compute. Customers in country will also have less regulatory complexity to consider by connecting to compute in-country.




Google's core focus in this significant expansion in Helsinki is 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 – whether they are gamers using Stadia, people using Search to learn or navigating home with simplicity using Google Maps.

Source: Interview with Fionnán Garvey, Global Network Acquisition at Google in August 2020.
Further information on the role of subsea cables is in the Copenhagen Economics (2019) Google's Hyperscale Data Centres and Infrastructure Ecosystem in Europe.

# 5 DATA CENTRES HELP DIGITAL USERS CONSUME ENERGY MORE EFFICIENTLY AND SUSTAINABLY

Every time we choose to use services online, we channel indirect demand for energy. As traditional non-digital activities continue to shift to new digital applications, the way energy is being consumed is changing. Therefore, we need to examine

(i) the efficiency of this energy use;
(ii) the sustainability of its supply; and
(iii) the role of energy users' procurement in promoting renewable energy

*Energy efficient provision of online services via cloud and data centres*

Contrary to the belief that the rapidly increasing demand for data will lead to a one-to-one increase in energy usage, ongoing improvements in global data centre efficiency have prevented this from transpiring. In fact, **data centre energy usage over the past 10 years has remained relatively stable** (increasing by only 6 per cent), **despite the exponential growth in demand** for data driven services (by 550 per cent).[19] This confirms the energy efficient trajectory and achievements of digital solutions provided via cloud computing through hyperscale data centres.

While storing and processing data requires energy to deliver services, Google's solutions exhibit a meaningful improvement to the energy efficiency of this data-handling process. Large data centres like Google's site at Hamina are significantly more energy efficient than the individual servers that they often replace. By pooling the server needs of many customers in this manner, a lot of energy can be saved. Indeed, we have analysed the yearly energy savings that moving service to a cloud-based provision delivers and we find significant savings (see calculation reported in the box below).

*Sustainable supply of energy for data centres*

As well as improving the energy efficiency of delivering digital services, Google also aspires to ensure that its energy consumption is as sustainable as possible. Since 2017, Google has matched 100 per cent of the annual energy demand of its data centres and offices with direct purchases of renewable energy on a global basis. Continuing to operate data centres with entirely clean energy is a key objective for firms like Google, the wider corporate world and our societies.

At the same time, even though the company buys a total amount of renewable energy matching its electricity use each year, it must still contend with times and places when the sun does not shine or the wind does not blow – indeed a society-wide challenge. During those hours, Google data centres (and likely most other energy users across the economy) often must rely on electricity sources such as coal and gas power plants, which emit carbon. Tackling this societal challenge, in a significant further step, Google announced its intent to run on carbon-free energy everywhere, at all times (24/7), by 2030.[20] In other words, the company is raising further its sustainability by shifting from a 'global and annual' match, to a 'local and hourly' match of clean energy to its use – a first in the corporate world.

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[19] Masanet, E, et.al. (2020) Recalibrating global data center energy-use estimates

[20] See Google (2018) Moving toward 24x7 Carbon-Free Energy at Google Data Centers: Progress and Insights and Google (2020) 24/7 by 2030: Realizing a Carbon-free Future, https://storage.googleapis.com/gweb-sustainability.appspot.com/pdf/24x7-carbon-free-energy-data-centers.pdf ; https://www.gstatic.com/gumdrop/sustainability/247-carbon-free-energy.pdf

Machine Learning and Artificial Intelligence tools can be used to help achieve this complex balancing act. Google is now integrating carbon-intelligent computing platforms into their data centres, having already tested such solutions. These systems would allow data centres to balance server usage with clean energy across time. This means that some percentage of that computing power can be shifted to times when greener sources of energy are in surplus. [21] The scale of the data centre matters in both achieving business and environmental aims, giving a socio-economic advantage to hyperscale data centres. [22]

**Box 4 National energy savings of handling e-mail through the cloud**

Many services can be handled through the cloud, but as an illustrative example we look at the implications of shifting e-mail handling services to cloud servers. This is, however, just one example where moving from in-house servers to data centre storage would greatly increase energy efficiency. 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 used in an average European data centre.[23] In contrast, Google's even more efficient data centres use only 2.2 kWh annually per user.[24]

For our calculation we assume that Finnish firms that are not using cloud are using in-house equipment. We estimate the related electricity for in-house storage to be 61 GWh annually. This estimation is based on official survey statistics capturing the number of staff working with computers in firms of different sizes, and the share of cloud use by firm size. Average cloud use across companies is calculated to be 37 percent.[25]

Hence, moving all e-mail services to the cloud based in data centres with an efficiency equivalent to Google's would:

- Reduce current electricity use for e-mail services in individual companies by 61 GWh
- Increase electricity consumption in data centres by 2 GWh

Based on the distribution of firm sizes in the national economy, we estimate that the above corresponds to a net reduction in current usage of 96 percent, equivalent to a decrease by 59 GWh.[26] This is broadly equivalent to about 9 percent of electricity produced by wind power in Finland in November 2018.[27]

Source: Copenhagen Economics, based on Eurostat

*Renewable energy procurement supporting the Finnish digital transformation*

The high energy efficiency of the Hamina data centre is one way in which Google supports sustainable digital services in Finland. Further improvements to the overall sustainability of these services are achieved through Google's energy procurement strategy. As noted previously, since 2017 Google

[21] See Google, (2020) Our data centers now work harder when the sun shines and wind blows (blog)
[22] Further information on energy efficiency is available in Copenhagen Economics (2019) Google's Hyperscale Data Centres and Infrastructure Ecosystem in Europe.
[23] Assuming that differences in energy use between Google's and average European data centres are due solely to overhead energy efficiency
[24] See Google (2019) Environmental report and Google (2011) Google's green computing: efficiency at scale.
[25] Eurostat data found in isoc_ci_eu_en2 (2018) and sbs_sc_sca_r2 (2017)
[26] Calculations assume that all the resulting new data centre activity is as energy efficient as Google's data centres (2011)
[27] Statistics Finland, Supplies and total consumption of electricity, GWh by Year, Season, Data and Production/Supply

has matched 100 per cent of the annual energy demand of its data centres and offices with purchases of renewable energy.[28] As part of this, Google has developed the largest portfolio worldwide of corporate renewable Power Purchase Agreements (PPA).

Via PPA deals, Google signs contracts with developers of renewable projects and supports the production of carbon free energy. Entering these transactions enables wind and solar farms to secure the financing they need to get built, something that is promoted by Google's intervention and commitment. In this way Google's operations in Finland drive the development of new renewable energy assets.

In 2019, Google invested in the largest renewable energy purchase ever, consisting of 18 individual deals globally.[29] A result is that throughout the year Google's Hamina data centre 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 2019, 77 percent of the electricity consumption of this data centre was matched with such sources on an hourly basis.[30]

Specifically in Finland, Google's role as customer committing to PPA deals has supported the development of five wind energy farms, totalling 445 MW of production capacity, namely:

- Hedet (81 MW – already in operation);[31]
- Lakiakangas (50 MW – already in operation);[32]
- Kuuronkallio (59MW – already in operation);[33]
- Mutkalampi (130MW procured by Google, out of total farm capacity of 250 MW);[34] and
- Piiparinmäki (125 MW procured by Google, out of total farm capacity of 211 MW).[35]

Across Europe, Google has signed nearly 1,700 MW of PPAs with renewable energy developers, **making Google the largest corporate buyer of renewable energy** in Europe (it is nearly 5,500 MW globally, equivalent to a million rooftop solar panels).[36] As a result, it has been possible for every kilowatt hour of electricity consumed at Google data centres to be matched, on an annual basis, by a kilowatt hour of renewable energy from a wind or solar farm. Google's contracts have enabled investments in renewable energy projects across the world of over EUR 6 billion, including EUR 2.3 billion in Europe.

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28 Google (2020) Our data centers now work harder when the sun shines and wind blows.
29 See Google (2019): Our biggest renewable energy purchase ever.
30 See Google (2020, p.19) 24/7 by 2030: Realizing a Carbon-free Future.
31 https://www.neoen.com/var/fichiers/1536664387-neoen-ppagoogle-veng.pdf
32 https://www.cpc-germania.com/portfolio/lakiakangas-12/
33 https://www.wpd.se/wpd-concludes-power-purchase-agreement-with-google/
34 https://www.neoen.com/var/fichiers/19-09-22-neoen-media-release-finland-mutkalampi-ppa-google.pdf
35 https://ilmatar.fi/en/ilmatar-energy-announces-new-wind-farm-adding-new-clean-energy-to-the-grid/
36 See Copenhagen Economics (2019) Google's Hyperscale Data Centres and Infrastructure Ecosystem in Europe.

# 6 CLOSING REMARKS: A MULTI-SECTOR POLICY APPROACH TO REAP FINLAND'S AND 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, our September 2019 study has highlighted exploratory suggestions on what to research and discuss further.

First, environmental considerations are top of the current agenda across Europe and achieving these will depend on vision, as well as attention to detail. Regulatory impediments can block or delay the private sector's role in fostering the green transition via smart procurement of renewables. National divergence in regulatory conditions and best practices can discourage efficient PPA procurement across Europe. The latter is key to satisfy the internet users' demand for digital services to be underpinned by green ICT, as firms and citizens transform their consumption from physical (and its energy inputs) to digital products and processes (and their energy inputs).

Second, the development of pan-European digital infrastructures involves a lot of nitty-gritty at the national and local level. This includes electricity network capacity, telecom infrastructure provision, educational systems delivering up to date technical skills – as well as traditional matters such as efficient planning and permitting processes.

Last, the topic of digital infrastructures is inherently multi-disciplinary. Just as the private sector (Google is a case in point) brings together experts from different specialisations to develop and make use of infrastructures – it is very relevant for national policy makers to come together, interact, and collaborate to ensure a timely and sustainable infrastructure development supporting the digital transformation. It follows that a combination of sectoral expertise and public policy processes (areas such as education, employment, energy, environment, planning, telecoms) are key to design in theory and ensure in practice, virtuous framework conditions for the development of digital infrastructures such as those analysed in this study.

*Note on Covid-19: Our calculations are based on information (public statistics such Eurostat, as well as Google expenditure data) made prior to the recent Covid-19 pandemic. While the overall method, relying on Eurostat input-output tables, remains a relevant basis to assess economy-wide effects of investments, future research may shed light on any changes in patterns of economic activity across value chains. This will rely on any updates from national statistics, as they gather retrospectively information about economic activity.*

*Disclaimer: the reports are Copenhagen Economics analysis based inter alia on Google publicly available investment announcements.*

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