Hard facts. Clear stories.

Copenhagen Economics

THE ECONOMIC VALUE OF SUBMARINE CABLES IN THE ARCTIC

An analysis of the societal value of digital infrastructure investments in the Nordic countries, and R&E networks' potential role in these projects

NORDUNET
2 MAY 2022

AUTHORS AT COPENHAGEN ECONOMICS

Helge Sigurd Næss-Schmidt
Dr Bruno Basalisco
Morten May Hansen
Charlotte Skovgaard Kjærulff
Jasper Lutz

Copenhagen Economics

PREFACE

Global digital connectivity is essential to drive future economic growth and coherence between continents. Fast and reliable internet is vital for all parts of modern society, from private use to businesses, governments, and research and education (R&E) institutions—and will be even more so going forward, as digital transformations in society require more robust, more resilient, more performant, and more digital capacity, while also having to reduce the carbon footprint.

In Europe, the digital transformation is anchored in the EU's Global Gateway strategy[1] and the European Digital Gateway Platforms Declaration[2].

Governments, telecommunication operators, tech companies, and national R&E networks (NRENs) are therefore investing in digital infrastructure, including fibre optic submarine cables and data centres, to supply users with fast and reliable digital connectivity. These installations are the "unsung heroes" that power the growth of the internet, enabling both a better local user experience and global traffic stability.

However, digital infrastructure investments are not made in all areas of the world. The assessment of when an investment makes sense economically often extends to the cost-benefit of the cable connection itself, which does not include the societal spillovers on productivity, resilience, R&E institutions, or environmental impacts that the added connectivity may bring, which are spillovers that do not materialise if connections are not established.

Against this backdrop, NORDUnet, the common Nordic R&E network,[3] has asked Copenhagen Economics to analyse the key societal benefits in the Nordic region from potential new Arctic submarine cables, and how R&E networks can play into this arena.

Specifically, we were asked to:

1. Describe the expansion needs of Europe's critical digital infrastructure.
2. Quantify the climate and network economic potential from digital infrastructure in the Nordic region and from global digital network connections to and from the Nordic region.
3. Discuss how to realise the potential expansions of digital infrastructure in the Nordic region and of global digital network connections to and from the Nordic region.

---

1 European Commission (2021g)

2 European Commission (2021h)

3 NORDUnet is owned and operated by the national R&E networks in Norway (Sikt, former Uninett), Sweden (SUNET), Finland (CSC – Funet), Denmark (DeiC), and Iceland (RHnet).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

APAC	Asia-Pacific
CAGR	Compound annual growth rate
CEF2	Connecting Europe Facility
EU	European Union
FLAP	Frankfurt, London, Amsterdam, Paris
GDP	Gross Domestic Product
HPC	High-performance computing
HVDC	High-voltage direct current
IP	Intellectual property
IPCEI-CIS	Important Project of Common European Interest in next-generation Cloud Infrastructure and Services
ISP	Internet Service Provider
JU	Joint Undertaking
LUMI	Large Unified Modern Infrastructure
LCOE	Levelised cost of energy
NREN	National research and education network
PoP	Point of presence
PUE	Power usage effectiveness
REN	Research and education network
R&E	Research and education
VLBI	Very-long-baseline interferometry

EXECUTIVE SUMMARY

At a global level, digital transformation is driving steady growth in the need for infrastructure to facilitate the transport of data between producers and consumers, as internet data traffic is doubling every three years. Looking forward, key drivers of this growth will be artificial intelligence, the Internet of Things, big data from scientific instruments, video streaming, and other cloud and on-premises data services. Data centres and digital connectivity are essential for enabling these flows.

The need for more resilient infrastructure, such as data centres and submarine data cables, to support continued digital transformation has been recognised by the EU. Several policies have been adopted, including financing EUR 300 billion to boost critical infrastructure. A key EU priority is to strengthen connectivity with global trading partners. Increasingly, businesses are relying on solutions that require the ability to transport data at speed and a high degree of reliability and resilience between continents. Yet existing cables, for example to Asia, are relying on congested, expensive, and unstable routes, such as through mainland Russia and the Suez Canal.

The Nordic region is an attractive option for strengthening external connectivity, and as an area for data centre business solutions. The NORDUnet 'Vision 2030' for Arctic digital connectivity contains a high-potential submarine cable project through the Northwest Passage of the Arctic, as well as a developing submarine cable project (Borealis) to pass trans-Arctic straight under the sea ice covering the North Pole, both connecting the Nordic region to the US West Coast and Asia, for example, Japan.

At the same time, low temperatures and ample access to renewable energy sources allow data centres to be more energy effective and to emit less CO_2 in the Nordic region than competing options in the present European centre of digital connectivity around Frankfurt, London, Amsterdam, and Paris. Indeed, it is a smart use of the ample renewable energy sources, notably in the northern part of the Nordic region: it is far more costly to build interconnectors to send power to data centres in Central Europe than to build cables to transport data between the Nordic region and the rest of the EU. Additionally, data centres in the Nordic region powered by Nordic energy free up renewable energy sources in Central Europe.

A focus on new, Nordic-centred digital infrastructure is not only an attractive option for the EU, but also offers an additional source of growth for the Nordic region itself. Experience shows that the location of submarine cables and data centres leads to substantial spillover effects to the regions in which they are placed. There will be new jobs associated with the location of data centres and associated support services, but more importantly, the improved connectivity associated with a strengthened network from the Nordic region will provide new local business opportunities and increased productivity and trade. Sparsely populated areas in the Nordic regions may benefit considerably from improved connectivity. As an illustration, and including some of these benefits, we estimate that an Arctic cable, for example, to Japan, could boost GDP in the Nordic region by more than EUR 1 billion annually if fully utilised.

However, we have also identified three barriers that may prevent the identified infrastructure investments from materialising, despite a prospective high return to society. First, building submarine cables in the Arctic entails substantial risk. Second, demand for traffic through new cables is uncertain and will also be influenced by factors beyond the control of commercial investors, hence raising the costs of finance to a level that makes commercial funding highly expensive. Third, some of the gains from increased connectivity will not accrue to direct investors but to wider society, not least the consumers and businesses in the Nordic region.

To avoid potential market failures, governments can support the development of submarine cable projects indirectly through R&E networks acting as anchor tenants. By underwriting long-term contracts, R&E networks lower commercial risks, thus enhancing the economic viability of other cable owners. R&E networks have ample experience in serving and guaranteeing demand from R&E institutions in cable projects.[4] Today, R&E networks support a range of projects around the world that rely on high bandwidth, low latency, and secure data transfers. Such a long-term commitment is the counterpart to the substantial positive spillover impacts expected on research, education, and innovation from R&E network participation in Arctic cable projects.

Our suggestion to realise the potential of Arctic submarine cable projects is in line with the EU and Nordic countries' political goals: ensuring a robust, more resilient digital infrastructure based on climate-friendly energy supply while also providing a new source of growth for the Nordic regions, including remote areas with limited alternative sources of growth, and benefitting R&E institutions. Utilising completely new cable trajectories reinforces both Nordic and EU digital resilience.

4 In fact, the current-day internet has its roots in such R&E networks.

CHAPTER 1

THE EXPANSION NEEDS FOR EUROPE'S CRITICAL DIGITAL INFRASTRUCTURE

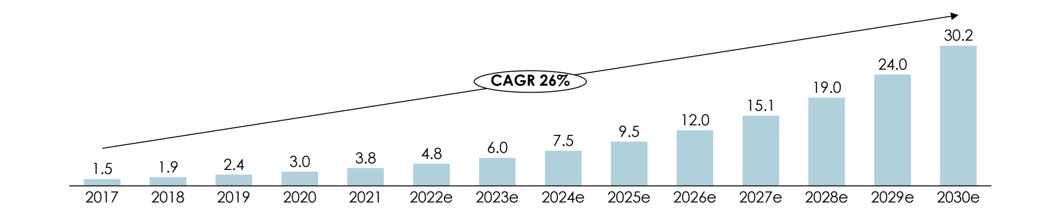
The demand for data will increase significantly in the years to come and requires large investments in digital infrastructure, which we shed light on in this chapter. We research the drivers of demand for data (1.1), the global digital infrastructure (1.2), and the investment needs in Europe to meet this demand (1.3). We further present digital strategies in Europe to support these investments (1.4) and describe how digital transformation supports decarbonisation in Europe (1.5).

1.1 THE DEMAND FOR DATA INCREASES DUE TO VARIOUS DRIVERS

The global economy is increasingly using digital tools and therefore relying more on strong and resilient digital infrastructure to store, process, and transfer large amounts of data quickly and securely. Trends such as artificial intelligence, machine learning, the Internet of Things, new space- and earth-observing scientific instruments, big data (e.g., in science), and "Industrialisation 4.0" are all expected to result in a large demand for data and processing power in the coming years.

By 2025, the total global datasphere is expected to reach 175 zettabytes (with 21 zeros)[5], which includes non-entertainment imaging (medical imaging, surveillance cameras), entertainment (movies), productivity enablers (supercomputers, servers), and mobile phones. The global demand for internet data traffic between different users,[6] as a subset of the global datasphere, doubles every three years. In the last 30 years, global internet traffic has increased from almost nothing, reaching around 4.8 zettabytes in 2022, and could reach 30.2 zettabytes in 2030 if the growth continues, see Figure 1.

Figure 1
Global internet data traffic demand, 2017-2030
Zettabytes

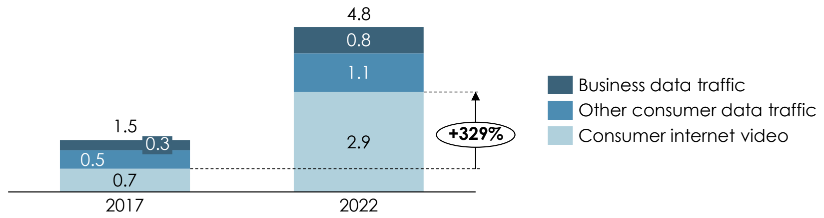


Note: These numbers show consumer and business IP traffic and exclude internal data centre IP traffic as well as IP traffic between data centres. 2023–2030 own calculations based on a fixed CAGR of 26 per cent for the years 2017–2022, as reported by Cisco.
Source: Cisco Visual Networking Index: Forecast and Trends, 2017–2022

5 Source: IDC (2018). 1 zettabyte equals 1.000.000.000.000.000.000.000 bytes ≈ 3.9 billion computers' storage capacity, calculated based on a computer with 256 gigabytes storage.
6 Internet data traffic is the data traffic from servers to users and vice versa.

The main drivers for the increased data flows are video streaming and the use of cloud services. Within internet data traffic, the data demand from video streaming has increased by almost 330 per cent since 2017, see Figure 2. This includes online business meetings, entertainment videos, and online lecture streaming.

Figure 2
Distribution of internet traffic, 2017-2022
Zettabytes per year



Note: Business data traffic contains internet traffic and managed IP traffic of businesses. Other consumer data traffic contains managed IP traffic, web, email, online gaming, and file-sharing data traffic. All data traffic is measured in IP traffic.
Source: Cisco (2018) and Cisco (2019).

The global demand for data centre traffic[7] increased as well, from 5.8 zettabytes in 2017 to 17.5 zettabytes in 2022, which comes on top of this demand.[8]

Data centres are essential for data flow—especially for digital services that require storage of large amounts of data as well as fast and reliable access to this data, such as video streaming and cloud services. The data centre landscape has hence become a focal point for users, data providers, governments, and other stakeholders as an integral part of the digital infrastructure network.

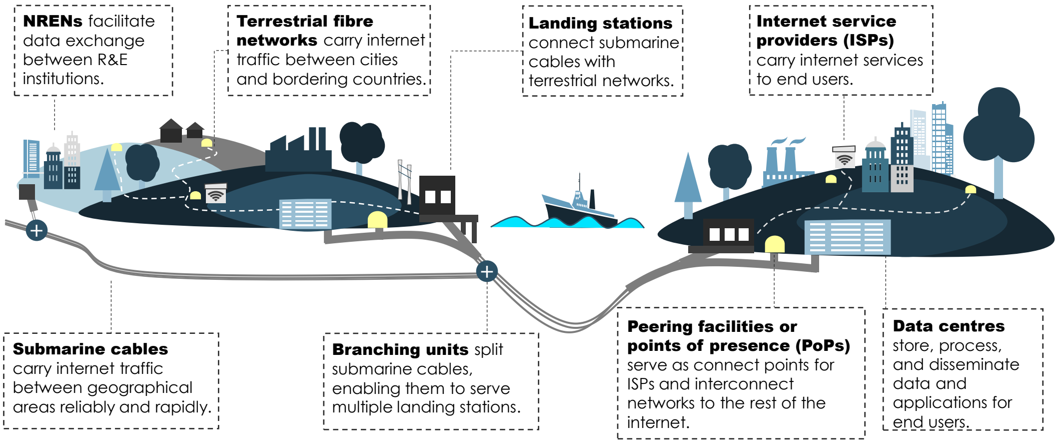
1.2 GLOBAL DIGITAL INFRASTRUCTURE: A COMPLEX NETWORK OF CABLES, DATA CENTRES, AND INTERNET SERVICE PROVIDERS

To meet the increasing demand for data, continuous investments must be made to expand and improve digital infrastructure. Solid and resilient digital infrastructure enables fast connections between users and providers of digital services.

Global digital infrastructure comprises complex networks of submarine and terrestrial fibre cables, data centres, PoPs, and stakeholders, including private and business users, internet service providers, datacentre owners, and NRENs connecting scientific instruments, large computing and massive storage facilities, see Figure 3. The submarine and terrestrial cables carry internet traffic, with branching units splitting the cables to connect at landing stations. Data centres store, process, and disseminate data, while internet service providers and NRENs bring internet services to users.

[7] Data centre traffic is the data traffic between data centres and within data centres.
[8] Cisco (2018) and Cisco (2019).

Figure 3
Illustrative digital infrastructure landscape



Source: Copenhagen Economics based on Copenhagen Economics (2021)

As global data demand increases, private companies, governments, and NRENs are increasingly investing in digital connectivity to provide data users with fast, reliable, and resilient infrastructure to facilitate the digital economy's additional demand pressure on the networks. NRENs play an important role in digital infrastructure networks, as they facilitate data exchanges between R&E institutions, scientific instruments, and users across the globe, see Box 1.

Box 1 National Research and Education Networks (NRENs)

Research and education (R&E) networks are often publicly-owned digital networks that provide reliable, high-capacity, high-speed network connectivity and services to universities and research institutions, thereby meeting the institutions' unique needs.

NRENs do so for R&E institutions in a specific country. GÉANT is the overarching European R&E network that coordinates the creation of an information ecosystem of infrastructure to advance research, education, and innovation.[9] Similarly, NORDUnet is the overarching Nordic R&E network.[10]

NRENs are not-for-profit entities. Their operational expenses are covered by fees and service charges of their members, as well as state funding. NRENs often have a single board, representing funding and other stakeholders, to oversee activities and their own responsibility. The implementation of the decisions should be managed by NREN management, while the levels of authority should be clearly defined by the government.[11] NRENs fulfil a multitude of purposes, including organising national and international connectivity, interconnectivity with the commercial internet, providing user support, supporting e-governments, engaging in digital regulation, or generally contributing to technology development.

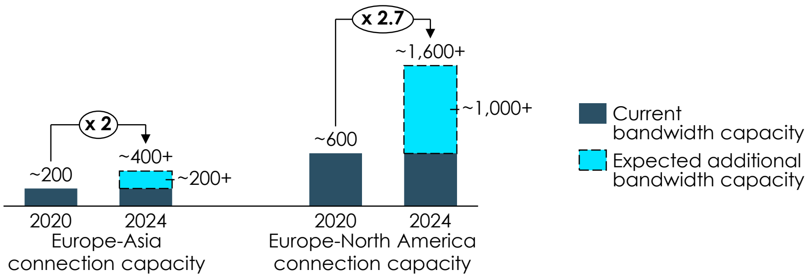
9 GÉANT website.
10 On a global scale, efforts are coordinated around the concept of the Global R&E Network (GREN), see NORDUnet website: GREN – Global networking.
11 Dai Davies (2016).

1.3 EUROPE NEEDS SUBSTANTIAL INVESTMENTS IN INTERNAL AND EXTERNAL DIGITAL INFRASTRUCTURE

At the continental level, internet data traffic tripled in Europe and quadrupled in Asia-Pacific between 2017 and 2022.[12] In North America, internet data traffic almost tripled in the same period. The increase in data demand is thus widespread across several continents, rather than being driven by single regions.

Bandwidth capacity between Europe and Asia is expected to double between 2020 and 2024. In the same period, the bandwidth capacity between Europe and North America is expected to triple, see Figure 4. The increase in internet data traffic demand creates a need to expand the bandwidth capacity *between different continents as well as within*. To install the needed bandwidth capacity, Europe needs substantial investments in intercontinental submarine cables to connect to other continents, as well as internal capacities within Europe.

Figure 4
Bandwidth capacity on the Europe-Asia and Europe-North America connections, 2020 and 2024
Terabits per second

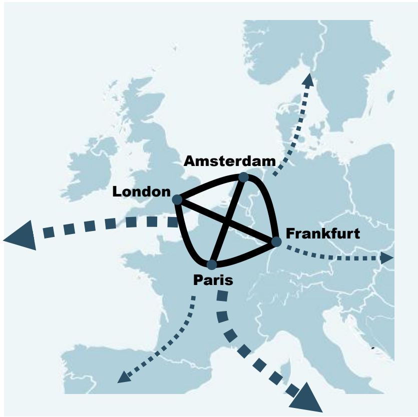


Note: 2024 numbers are expected capacities. Numbers are extracted from an illustration in the source report.
Source: UNCTAD (2021), based on TeleGeography.

Today, the European landscape for digital connectivity is centred around an axis in the Central Europe region of Frankfurt, London, Amsterdam, and Paris (FLAP region), which connects to other European and global regions by terrestrial and submarine cables, see Figure 5. The FLAP region is characterised by low-priced, high-bandwidth capacity, and low latency internally.

[12] Based on numbers from Cisco (2019).

Figure 5
Illustrative map of the FLAP region in Europe



Source: Copenhagen Economics, based on interviews with various stakeholders.

However, the data transfer routes in the region are starting to get congested by high data flows and a limited bandwidth capacity to and from the region. This could ultimately lead to queuing and congestion in the network nodes and potential disruptions if connectivity is not upgraded.[13]

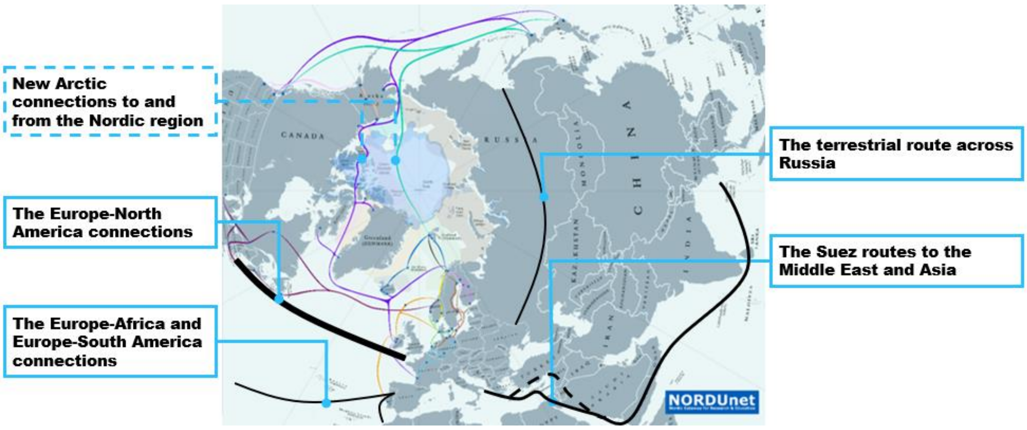
The connectivity of the FLAP region does not have sufficient resilience, as some terrestrial cables to and from the FLAP region run through Russia, while submarine cables cross the Atlantic Ocean to North and South America, and through the Mediterranean Sea and the Suez Canal to the Middle East and Asia, see Figure 6. The routes through Russia and the Suez Canal are less stable, more expensive, and less reliable than the other routes.[14] Thus, the FLAP region relies on only a few routes that partially run through politically unstable areas. The Europe–Africa and Europe–South America connections are relatively new and have yet to prove their resilience.

A multitude of cable routes to and from Europe add to the resilience of the region. In the case of an outage, or damage to one of the routes, reserve capacity on other routes can serve the demand.

[13] Data Center Knowledge (2017).

[14] Rostelecom announced a new cable, TEA NEXT, to replace existing ones, see Rostelecom (2020). Egypt controls the submarine cables through the Suez Canal and uses its control to exercise pressure on dependent governments. Alternative routes through Israel, Jordan, and Saudi Arabia are emerging, e.g., the Blue Raman cable, see Google (2021).

Figure 6
Existing European cables to other continents and possible Arctic expansions



Note: Currently existing routes include the transatlantic connections to the US/Canada, the Europe–Africa and Europe–South America connections, the terrestrial routes across Russia, and the routes passing the Suez Canal. New connections over the Arctic are planned. NORDUnet provided the map for this illustration.
Source: TeleGeography; Interviews with NRENs

The Nordic region is currently a “stub” on the European digital map. Terrestrial and submarine fibre connectivity goes from Central Europe to the Nordic region, but currently, there is no data connection from the Nordic region going north, thereby passing over the Arctic. As the connection over the Arctic is the shortest route from Central Europe and the Nordic region to East Asia, such a connection would reduce latency between Europe and Asia. Data transfer services that rely on low-latency transmission of data, as well as real-time data transfers (e.g., stock exchange trading), will benefit from such connections.

New submarine connections from the Nordic region through the Arctic to, for example, the US West Coast, Canada, or Japan, would move the European digital gravity northwards, increase European digital resiliency, and support the Open Digital Autonomy[15], which follows the Nordic NRENs’ vision for key future cable projects in the Arctic, see Box 2. This could change the Nordic region’s status into a digital hub, potentially initiating additional digital investments in the region.

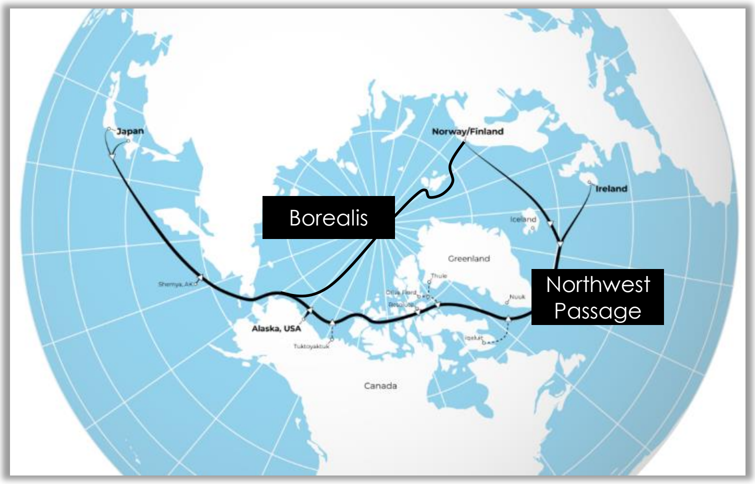
[15] European Commission (2021d).

Box 2 Possibilities for digital infrastructure investments in the Nordic region

The Nordic NRENs have started to design a '**Vision 2030**' for submarine cable projects through the Arctic. This vision is centred around planned Arctic and polar ring structures around the North Pole. These structures are established via two differently advanced submarine cable projects: the **Northwest Passage** connection from Northern Scandinavia, via the US West Coast and Canada to Japan, recently announced by Cinia, as well as the **Borealis** transpolar project that is planned further in the future, see Figure 7. Currently, the Northwest Passage project is more mature, with Cinia and Far North Digital planning to build a cable,[16] whereas the Borealis project is more complex. The latter cable would cross straight under Arctic polar ice and thus face high capital expenses due to more complex engineering. However, the Borealis route is shorter than through the Northwest Passage and once in place, the cable is placed in a safer environment as it lies in deeper waters. The Borealis trajectory potentially meets the need to replace the current mainland-Svalbard connection which reaches its end-of-life around 2029.[17]

Moving the digital gravity from the FLAP region north to the Nordic region is one of the purposes of Arctic submarine cable connectivity. The development of submarine cables in the Arctic will form a highway for data from Central Europe through the Nordic region to the West Coast of the US, Canada, and Asia. Such a highway could add better connectivity and increased resilience to today's patchwork of submarine and terrestrial data cables between these regions.

Figure 7
Illustration of the potential routes for the Northwest Passage and Borealis projects



Note: Far North Digital provided the map for this illustration.

16 Epressi (2021).

17 The mainland-Svalbard cable was taken into operation in January 2024 and has an expected lifetime of 25 years, see Gjesteland (2004).

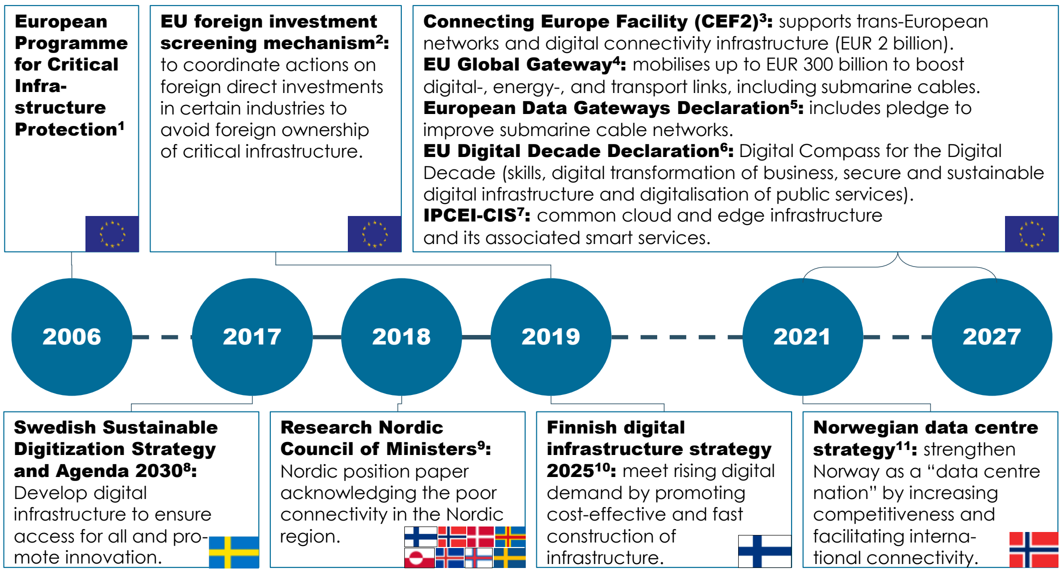
1.4 EUROPEAN AND NORDIC STRATEGIES CAN FACILITATE DIGITAL INVESTMENTS

The EU and Nordic countries have several strategies in place to increase European involvement in critical infrastructure and mobilise funding for digital networks. These strategies include the EU Global Gateway, the EU Connecting Europe Facility programme, and national digital infrastructure strategies, see Figure 8. The strategies aim to support building a digital infrastructure in Europe that is resilient to crises and autonomous from digital infrastructure owned by foreign companies.

The EU Global Gateway plans to mobilise EUR 300 billion between 2021 and 2027. It targets connectivity projects that safeguard the European Open Digital Autonomy, which aims to free Europe from connectivity dependency on unstable routes.

The EU Global Gateway spans five sectors: digital, climate and energy, transport, health, and R&E. For the digital sector, investments in strong connections between Europe and the world, including digital submarine cables, are funded by the EU Global Gateway. For the R&E sector, investments in digital education are funded by the EU Global Gateway, which also strengthens cooperation on research and innovation between EU partner countries.

Figure 8
Digital infrastructure strategies in the EU and the Nordic region



Source: 1) European Commission (2006); 2) European Commission (2020a); 3) European Commission (2021a); 4) European Commission (2021g); 5) European Commission (2021c); 6) European Commission (2021d); 7) IPCEI-CIS (2021); 8) Swedish Government 2018; 9) Nordic Council of Ministers (2018); 10) Digital Infrastructure Strategy Finland (2019); 11) Norwegian data centre strategy (2021)

The EU further has initiated so-called "Joint Undertakings" to coordinate advancement between EU and European countries and private partners, for example, the EuroHPC JU, see Box 3. Such JUs can generate the financing and demand needed to develop a critical, large digital infrastructure and foster innovations.

Box 3 EuroHPC Joint Undertaking (JU) – LUMI

The EuroHPC JU is a joint initiative created in 2018 between the EU, European countries, and private partners to develop a high-performance computing (HPC) ecosystem in Europe.[18] The budget of the EuroHPC JU of EUR 7 billion is financed by the EU, members of the programme,[19] and private investors.

The EuroHPC JU has the purpose of widening the use of HPC, for example, to advance deep learning and large-scale simulations by developing exascale supercomputing[20] on a European level. This requires connectivity that is second to none to allow for high-speed, reliable, and secure data transport to partners outside of Europe, as declared in the Connecting Europe Facility (CEF2).[21]

The EuroHPC JU covers seven supercomputers, the largest of which is the Large Unified Modern Infrastructure (LUMI), located in Finland. The entire building infrastructure has a power capacity of around 200 megawatts, running 100 per cent on low-price and renewable hydropower. The LUMI computing power is over 550 petaflops per second.[22] LUMI is connected to Funet (Finnish NREN), which is connected to the global R&E network through NORDUnet.[23]

Norway, Sweden, and Finland have separate digital strategies in place for general digital infrastructure, and Norway has one specifically for data centres, but none of these strategies deals with submarine cable connectivity in detail. However, the strategies in the Nordic countries have been developed in distinct political arenas. The last common statement from the Nordic countries dates to 2018.[24] An overall, aligned Nordic strategy for the development of digital infrastructure is therefore lacking.

1.5 DIGITAL TRANSFORMATION: AN ENABLER OF DECARBONISATION IN EUROPE

The digital economy is important for decarbonisation in Europe from two angles.

First, digital transformation is an enabler of decarbonisation in other sectors in Europe. The following examples outline areas and industries where digital transformation enables European decarbonisation:

---

18 European Commission (2021e).

19 JU Member States are Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and Turkey.

20 Exascale supercomputing conducts a billion exactable operations per second, compared to ten billion operations per second of ordinary laptops.

21 European Commission (2021a).

22 LUMI website. Floating point operations per second ("flops per second") is a measure of processing speed and thereby computer performance.

23 Hitsa website (2020).

24 Nordic Council of Ministers (2018).

- Cloud computing helps to optimise energy systems (so-called 'smart grids') or to reduce waste.[25]
- Fast and reliable internet connections allow for remote work and online meetings instead of physical meetings, thereby reducing emissions from transport.
- Connections to central data centres, servers, and other data hubs decrease the need for companies to have their own servers, resulting in lower energy consumption.[26]

Second, the digital sector must itself be carbon neutral in the future. The data centre industry in the EU must be climate neutral by 2030, according to the European Commission[27], while the German government decided that all new data centres in Germany must be climate neutral already by 2027.[28] The European cloud and data centre industry itself complies with these policies, as stated in its Climate Neutral Data Centre Pact, which aims to make data centres climate neutral by 2030.[29] In addition, data centres can deliver excess heat for district heating in office buildings, homes, and campuses.[30]

Thus, data centres increasingly demand renewable energy to operate.[31] The Nordic data centre industry is leading the implementation of sustainable data centres to comply with the new EU taxonomy for sustainable activities.[32]

While there are numerous opportunities to expand the data economy in the Nordic region with renewable energy and efficient cooling, the increased demand for green power for digital infrastructure creates additional competition for renewable energy. Other electrification processes and products, such as electric vehicles, electrification of manufacturing, electro fuels, and battery manufacture, will also demand green power, and we could therefore expect to see some competition for additional renewable energy in areas where this is available.

[25] Telius (2022).
[26] Masanet et al. (2020).
[27] European Commission (2020b).
[28] German government (2021).
[29] Climate Neutral Data Centre Pact (2020).
[30] Fortum press release (2022).
[31] IEA (2021).
[32] European Commission (2021b).

CHAPTER 2

THE CLIMATE POLICY AND NETWORK ECONOMIC POTENTIALS FROM DIGITAL INFRASTRUCTURE IN THE NORDIC REGION

There are considerable societal benefits from digital infrastructure investments in the Nordic region, such as environmental and socioeconomic benefits. We identify the potential of using renewable energy in the Nordic region and how it helps decarbonise the digital economy (2.1). Furthermore, we examine the cost savings of serving European data demands by digital infrastructure in the Nordic region (2.2). Finally, we estimate the economic effect on the Nordic region (2.3) and shed light on the benefits for remotely located communities (2.4).

2.1 DIGITAL INFRASTRUCTURE IN THE NORDIC REGION BRINGS SOCIETAL BENEFITS

Access to an additional supply of renewable energy is crucial for the successful expansion of green digital infrastructure to meet data transfer demands.

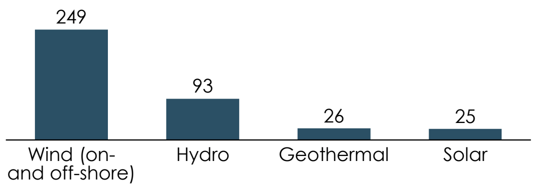
The Nordic power supply is, to a large extent, renewable and can serve as a stable, green source of energy for digital infrastructure. In Norway, the share of renewable electricity is as high as 98 per cent.[33] Renewable electricity primarily stems from hydropower. In Sweden, the share of renewable electricity is around 50 per cent.[34]

The renewable power supply in the Nordic region can even be expanded in the future, as there is a very large potential for renewable energy in the Nordic region, especially for wind energy, see Figure 9. An additional supply of renewable energy in the Nordic region would not solely be used to substitute for the emitting power supply, as would be the case in other parts of Europe.

33 Norwegian government website.

34 Swedish Energy Agency (2021).

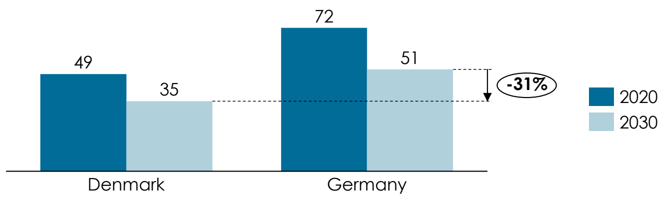
Figure 9
Renewable energy potentials in the Nordic region
Terawatt hours (annual)



Note: Where numbers for wind were reported in TW, we converted to terawatt hours assuming 2,300 yearly full-load hours.[35] We include only socioeconomically realistic potentials.
Source: Svensk Vindenergi (2019), Statnett (2018), Solenergiklyngen report, Energinet (2015), Energistyrelsen (2019), Vedvarende Energi (2014), Hiilineutraalisuomi (2021), and Nordregio website.

The cost of producing renewable energy is also *lower in the Nordic region* than, for example, in Central Europe, especially for wind power, see Figure 10. The levelised cost of energy for offshore wind power in Denmark is estimated to be 31 per cent below the cost in Germany in 2030. Other sources of renewable energy, such as additional hydropower and geothermal power, are not even available in Central Europe.

Figure 10
Levelised cost of energy for additional offshore wind in Denmark and Germany, 2020 and 2030
EUR per megawatt hour



Note: The levelised cost of energy is the net present value of the average electricity production cost for a power plant over its lifetime.
Source: Stattnett (2020).

The potential may, however, be halted or slowed down due to local concerns. In some areas, people are concerned about renewable energy when the physical infrastructure interferes with local landscapes. No new onshore wind power projects in Norway, for example, will be developed in the coming years due to local concerns.[36]

[35] On-shore wind power projects in Norway will not be further developed in the coming years due to local concerns, see link. However, new off-shore wind projects are announced in Norway, see link.
[36] Forskning.no (2021).

At the same time, we see many offshore wind projects coming on stream in areas near the shores of the Nordic region, including the North Sea. These additional sources of renewable energy will be available to operators in the Nordic region.[37]

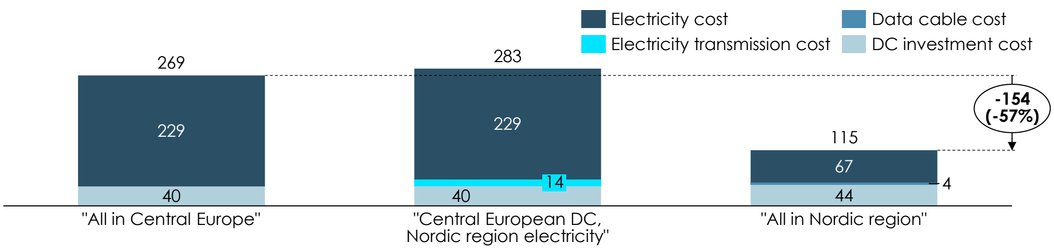
2.2 THE NORDIC REGION OFFERS LOW COSTS FOR SERVING EUROPEAN DATA DEMAND

In a stylised example, we show that the annual cost for serving data demand in Central Europe from a hyperscale data centre in Norway is EUR 150 million lower than in Germany, primarily driven by lower electricity and cooling costs, see Figure 11.

The example compares three setups for a data centre:

- First, a data centre in Germany is supplied by Central European energy ("All in Central Europe"), where the data centre is close to European demand. The data centre will have to compete heavily for additional renewable energy in the region.
- Second, a data centre in Germany is supplied by Nordic renewable energy ("Central European DC, Nordic region electricity"), where the data centre is also close to European demand. The data centre is powered by renewable energy from the Nordic region, which adds cost to the business case.
- Third, a data centre in the Nordic region is supplied by local energy ("All in Nordic region"), which is further from the European demand but has a lower cost of renewable energy.[38] The data is transferred through a submarine data cable to the European demand.

Figure 11
Stylised examples: Annualised costs for a 150 MW data centre serving demand in Central Europe
Million EUR



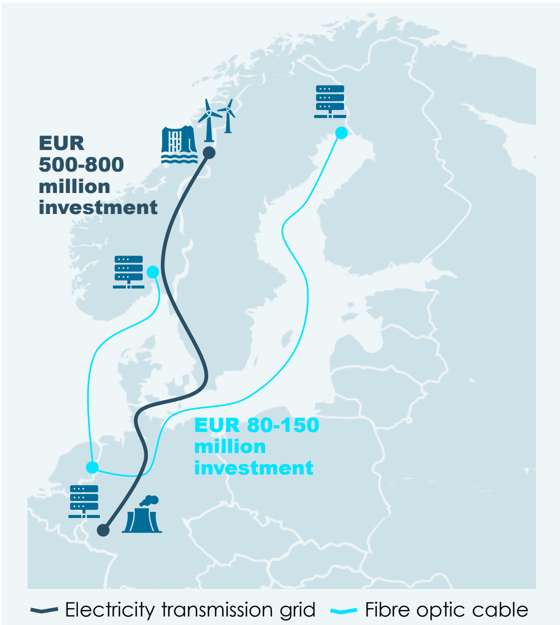
Note: Assumptions: See Appendix A. Other operational and investment costs (for example, connection to the local grid) are not included, and these are assumed to be the same. The loss of electricity in transmission (around 5 per cent, see e.g. EIA (2021)) would not change the stylised example and is not included here.
Source: Datacenterdynamics (2020a); Green Mountain; IEA (2014); Submarine Cable Networks; Norwegian government (2018); Interview with Bulk Infrastructure

Thus, it is more cost-effective to transfer data than power from the Nordic region to Central Europe, in other words, "*transferring bits is cheaper than watthours*". It costs at least EUR 500-800 million

37 For an overview, see e.g., Clean Energy Wire (2022).
38 The data centre may compete with other consumers of additional renewable energy, such as Power-to-X production. Power-to-X is a process to convert electricity into "X", which could, e.g., be hydrogen or ammonia. These products can at another time be used again, e.g., to fuel cars or heat spaces. Power-to-X is then a means to store energy.

to build a power transmission network from Norway to Central Europe. At the same time, it costs EUR 80–150 million to build a data highway from the Nordic region to Central Europe, see Figure 12.

Figure 12
Illustrative map of power generation and data centres in Central Europe and the Nordic region



Note: We assume that the electricity transmission grid has a lifetime of 40 years, whereas the submarine fibre optic cable is expected to have a lifetime of 20 years. We have indications that the investment costs might be even higher, compare the NordLink HVDC transmission between Germany and Norway at EUR 1.7–1.8 billion.[39]

Source: Copenhagen Economics based on Datacenterdynamics (2020a); Green Mountain; IEA (2014); Submarine Cable Networks; Norwegian government (2018); Interview with Bulk Infrastructure

Additionally, data centres in the Nordic region have reduced cooling needs compared to other areas. As data processing within data centres generates heat, the energy or water used to cool data centres constitutes a cost pillar. The climate in the Nordic region is cooler than, for example, in Central Europe. Hence, placing data centres in the Nordic region has the potential to reduce energy and water costs for cooling.[40]

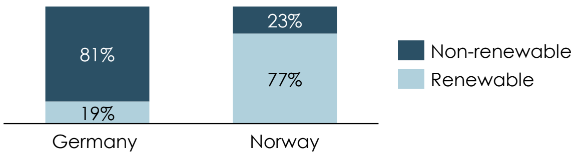
Excess heat as a residual product from high-scale processing activities can be reused in district heating systems.[41] Surplus heat from digital infrastructure has a higher and more cost-effective reusability potential in the Nordic region compared to, for example, the FLAP region. The waste heat from the

39 Stattnett website (2021).
40 Interview with Bulk Infrastructures.
41 This replaces the need for other sources of energy to heat buildings in residential areas and offices. Fortum press release (2022).

LUMI supercomputer, for example, can provide up to 20 per cent of the energy needed by households for district heating in the city of Kajaani.[42] 95 per cent of the waste heat from the Betzy supercomputer at the NTNU in Trondheim delivers heating energy to the NTNU campus buildings.[43]

Moving data centres north also frees up renewable energy supplies in Central Europe, to be used for decarbonisation exiting energy demands in Central Europe, where the share of renewable energy in total energy consumption is much lower than in the Nordic region, see Figure 13.[44]

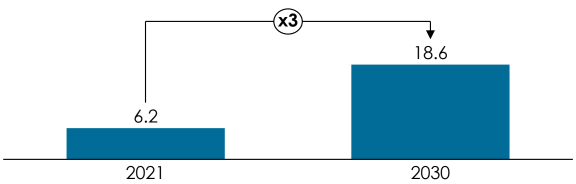
Figure 13
Consumption of energy from renewable sources in Germany and Norway, 2020
Per cent



Source: Eurostat Database (2021)

The increased demand for digital connectivity in Europe, the environmental benefits in the Nordic region, and the low cost of transporting data from the Nordic region are also evident from the expected expansion of the data centre landscape in the Nordic region. The total energy consumption in large data centres in the Nordic region is expected to triple from 2021 to 2030 to almost 19 terawatt hours, see Figure 14.

Figure 14
Expected large data centre energy use in the Nordic region
Terawatt hours



Note: 'Large data centre' refers, e.g., to hyperscale data centres that typically use 100 to 200 MW.
Source: Danish Energy Agency (2021b); Swedish Energy Agency; Norwegian Water Resources and Energy Directorate (NVE); Finnish Prime Minister's Office (2020); Icelandic National Energy Authority

Colocation of submarine cables and data centres in the Nordic region, therefore, has multiple societal and company cost benefits. The colocation of 'green' production industries and renewable power

42 LUMI website.
43 HPCwire website (2020).
44 The most recent share of renewable energy in many energy systems worldwide can be retrieved from the electricityMap (link).

sources has proven successful elsewhere, for example in Iceland, which has had success with the colocation of aluminium smelters and hydropower plants to create a more sustainable aluminium smelter industry.[45]

2.3 SUBMARINE CABLES CAN DRIVE ECONOMIC ACTIVITY IN THE NORDIC REGION

Arctic and European cable connectivity is also expected to benefit the **Nordic region** economically from increased GDP arising from different transmission mechanisms, including increased investments, higher productivity, and lowered cost of trade, see Table 1. The two factors that drive these mechanisms are increased bandwidth and lower latency, which arise from the new cable connections.[46] These drive direct, indirect, and spillover investments and can enable higher productivity and lower costs in other industries.

Table 1
Economic benefits to the Nordic region from increased Arctic submarine cable capacity

<table>
<tr><th>Transmission mechanism</th><th>Increased internet bandwidth</th><th>Lower latency to Asia/North America</th><th>Literature estimates of impact</th></tr>
<tr><td>Direct and indirect investment impacts</td><td colspan="2">• The direct impacts are the economic activities from the cable investments, i.e., the colocation of the Arctic cable and data centres which enable increased bandwidth and lower latency in the Nordic region.
• The indirect impacts stem from the local supply chains from these investments.</td><td rowspan="2">• The investment size for an Arctic cable is expected to be €1.0-1.5 billion. Once built, the cables are not expected to deliver large direct and indirect GDP contributions.[1]
• The annual GDP impact for just one data centre in Europe is found to be EUR 105–600 million from an upfront investment of EUR 85-335 million.[2]</td></tr>
<tr><td>Spillover impact on other digital investments</td><td colspan="2">• The investments in cable infrastructure and data centres can attract additional digital investments, as the investments signal that the Nordic region is a good place to invest in.
• In addition, the increased bandwidth and lower latency in the Nordic region can also attract other digital investments in the Nordic region.</td></tr>
<tr><td>Submarine cables enable higher productivity and lower the cost of trade in other industries[1]</td><td>Increased bandwidth …
• increases the potential for automation of tasks operated remotely.
• enables seamless voice and video applications, for example, online meetings and teleworking, to reduce costs and transportation time.
• lowers the cost of transporting data, resulting in increased trade in services, for example, data processing services.</td><td>Lower latency …
• enables precision operations, for example in remote surgery and online music education.
• lowers the time it takes to provide remote computation services.
• lowers the time lag for trading in the financial sector
• Improves user experience and the feasibility of two-way real-time applications for example, video calls.</td><td>• A doubling of the number of cables is found to increase by 6.7 and 11.3 per cent in exports of transport and travel services, respectively.[3]
• GDP per capita is found to increase by 0.11–0.18 per cent per 10 per cent increase in bandwidth consumption.[4]</td></tr>
</table>

Source: 1) Based on information from interview, 2) Copenhagen Economics (2020; 2021a), 3) El-Sahli (2020), 4) Number for African countries, see RTI (2020, p. 13).

45 *New York Times* (2017)

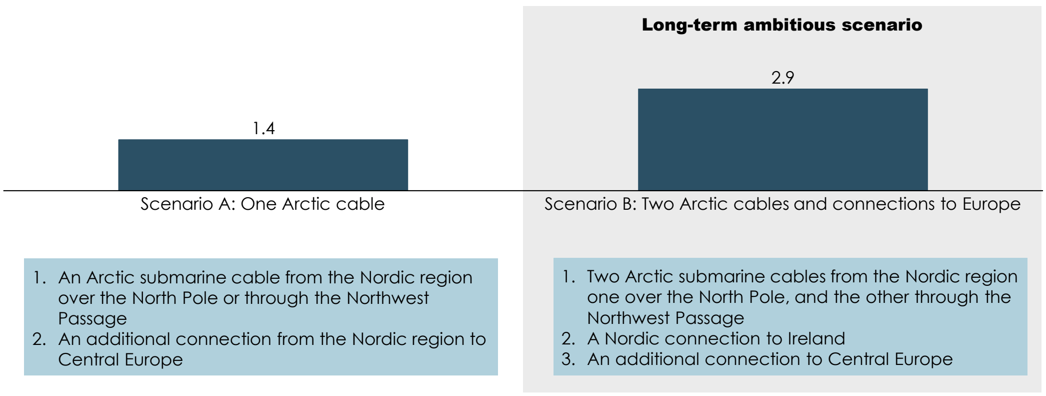
46 In addition, digital connectivity may also reduce costs for broadband users.

In addition to these impacts, additional connectivity lowers the risks of connectivity loss in the Nordic region. Such loss of connectivity could entail a loss of productivity and other major social issues.

In total, Arctic submarine cables from the Nordic region to Japan could contribute **EUR 1.4 billion annually to Nordic GDP**, see Figure 15.[47] Such cables could, for example, be those planned on the Northwest Passage and the Borealis route, see Box 2.[48] A long-term ambitious scenario with more cables through the Arctic region could achieve a larger economic impact on the Nordic region.

For the potential GDP impacts to materialise, **cable connectivity must be utilised.** If the cable(s) have stranded capacity, or the Nordic region works purely as a transit region, the GDP impacts are expected to be smaller.

Figure 15
Two scenarios for an annual GDP impact in the Nordic region from additional Arctic submarine cables
EUR billion, 2020 prices

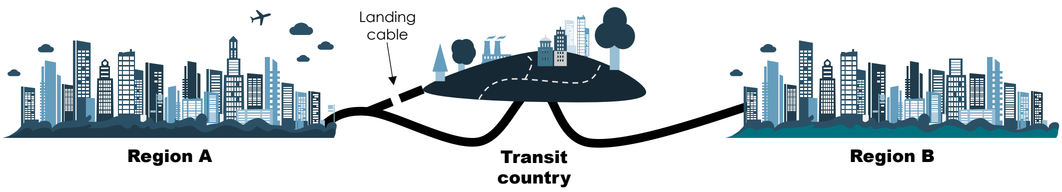


Note: Scenario A is modelled to be achieved from 2024 if the connectivity is in place and fully operational. Scenario B is a long-term scenario, but both are measured in 2020 prices for comparison. See Appendix B for a description of the methodology. The impact is summarised as a GDP effect, which is the potential impact per year associated with improved digital infrastructure from the submarine cables. The effect is a long-term and recurrent annual impact, sustained as long as the infrastructure is in use.
Source: Copenhagen Economics

There is a small risk that submarine data cables over the Arctic may turn the Nordic region into a pure transit region between the Asian and Northern American endpoints and the FLAP region, see Figure 16. The submarine data cable from Region A to Region B passes through the transit country with potential landing points in this transit country.

47 For full methodology, see Appendix B.
48 We find that almost 80 per cent of the impact is driven by increased bandwidth. The remaining impact stems from reduced latency.

Figure 16
Illustration of a transit country



Source: Copenhagen Economics

The Nordic region can still benefit from being a transit country by ensuring that the cable installs landing points in the Nordic region, which enhances connectivity in these areas. This enhanced connectivity creates an attractive landscape for data centres and other digital infrastructures. The Nordic region can hence host digital infrastructure to serve both Region A and Region B in Figure 16. To unfold the potential, access to the landing stations should be open to multiple fibre tenants.

The potential to install landing points and benefit from transiting data flows depends on the split between transit and regional traffic. If all data traffic crossing the Nordic region from the FLAP region to the US and Asia is pure transit data, there will be no capacity left for the Nordic region to connect. If, however, the split between transit and regional traffic is, for example, 80 to 20 per cent, the Nordic region can install landing points to utilise the 20 per cent capacity on the submarine data cable for its own capacity needs.

A transit region further benefits from submarine cable installation when providing contractors to build local infrastructure. This generates revenue for contractors, which supports local jobs and economic value to the transit country.

Considerations around the implications of being a transit region are, for example, seen in Israel with the Blue and Raman cables[49] and the Cinturion TEAS system[50] connecting Europe, the Middle East, and India. On this route, the cables transit Israel, which benefits from the possibility of building landing stations and thereby updating the current ageing fibre cable connections to Europe and Asia with new, low-latency connections. Israeli contractors oversee the building of the landing stations and thus benefit from this, even as a transit region.

2.4 INCREASED SUBMARINE CONNECTIVITY BOOSTS REMOTE REGIONS' ACCESS TO A DIGITAL ECONOMY

Increased submarine connectivity can increase consumer welfare and benefit local enterprises in remotely located communities, including those in the Arctic region. Additional submarine connectivity provides more bandwidth, lower latency, and route diversification. This improves the possibility of participating in global digital activities.[51]

49 Google (2021) and Haaretz (2020).
50 Cinturion website.
51 Interviews with Nordic NRENs, Vodafone (2021), Desira (2020), RUMRA & Smart Villages.

As remotely located communities in the Arctic are currently not, or only slightly, connected via submarine cables,[52] any additional connection will have a relatively larger effect on these communities than for well-connected areas. One additional cable connection to a remote region with currently only one available cable increases the region's resilience towards cable cuts[53] and potentially increases the bandwidth connectivity manifold. An additional cable connection to a well-connected region will increase its resilience and bandwidth relatively less.

Increased digital connectivity provides remotely located populations with broader access to services. Further, it allows local enterprises better access to global markets. This provides at least three benefits.

First, consumer welfare increases with better digital connectivity, as remotely located communities, particularly in Northern Norway and Finland, gain access to a broader variety of online services. Such services include video streaming services, access to cloud storage and processing services, and access to remote education services, which increase consumer welfare. In addition, online tools can help remotely located people to be socially connected with family and friends and gain easier access to public institutions in other areas.

Second, the increased digital connectivity of remotely located communities boosts local enterprises' access to the global economy. Faster broadband enables remotely located people and businesses to participate in the global economy, offering services digitally that otherwise would not be possible.

Third, remote areas can host scientific institutes and instruments that rely on low-latency connectivity. For example, the Nordic region is home to some of the world's most advanced earth and climate observation research centres, such as the EISCAT_3D[54] radar or the very-long-baseline interferometry (VLBI) station[55] on the Arctic archipelago Svalbard.[56]

Increased connectivity for remotely located communities entails reduced latency, reduced instability, and lower prices, which enable individuals, companies, and research in remote regions to become more digitally integrated with the rest of society.

---

52 Nordregio (2020) and Submarine Cable Map.

53 The likelihood that both cables are out of order at the same time is less than the likelihood that one single cable is out of order.

54 Eiscat 3D website.

55 Researchers from over 30 nations come to Svalbard annually. Research from Svalbard website and Norwegian government (2018).

56 Further, Svalbard is one of the world's best suited locations for low orbit satellite communication, demonstrated by the Svalbard Satellite Station, see ESA website.

Copenhagen Economics

CHAPTER 3

HOW TO REALISE THE POTENTIAL EXPANSIONS OF DIGITAL INFRASTRUCTURE IN THE NORDIC REGION

R&E networks can help overcome potential market failures that the business case leaves behind, which would also benefit R&E institutions. We start by establishing the business case and the potential market failure arising from it (3.1). Next, we outline how R&E networks can function as anchor tenants in Arctic cable projects, (3.2) and what benefits this would bring to R&E institutions (3.3).

3.1 A CHALLENGING BUSINESS CASE FOR PRIVATE INVESTORS

While Arctic submarine cable connectivity bears large societal potential, the business case for potential investors may not necessarily be profitable, due to at least three key classes of barriers that reduce profitability and the deployment of purely commercial Arctic submarine cable projects:

First, the cost of an Arctic submarine cable project may be too high. We highlight three potential reasons for the high costs of the deployment of submarine cables in the Arctic region:[57]

1) The weather and climate in the Arctic region impact submarine cable projects. The climate is cold, and the sea ice cover only melts during the few summer months through the Northwest Passage or does not melt at all across the North Pole. For a submarine cable straight over the North Pole, such as the Borealis initiative, it is thus difficult to deploy a submarine cable under Arctic ice. Similarly, in the Northwest Passage, it may be difficult to deploy a cable in one single summer season if the path is not fully accessible for a long enough time. In addition, floating icebergs constitute a problem, with potential cable cuts of submarine cables in shallow waters on parts of the Northwest Passage route.
2) The project may face a long lead time due to complicated regulatory challenges. The Arctic region brings together many different nations, jurisdictions, and territorial claims, and a submarine cable over the Arctic could cross different territorial waters.
3) Laying Arctic submarine cables also requires novel solutions not previously experienced in other cable projects. To deploy an Arctic cable in the Arctic environment close to the North Pole may require a customised cable-laying ship which does not currently exist, and this would add further costs to the project.

Second, risks from absent demand can lower the expected profitability of submarine cable projects in the Arctic. Currently, there is no transpolar submarine data cable. The demand for such a cable must primarily come from a general increase in demand for digital connectivity but could also stem from the other existing route connections, which the new cable substitutes. To make a viable business case, data centres, agreed bandwidth offtake, and submarine cable connectivity need to be collocated to ensure sufficient demand.

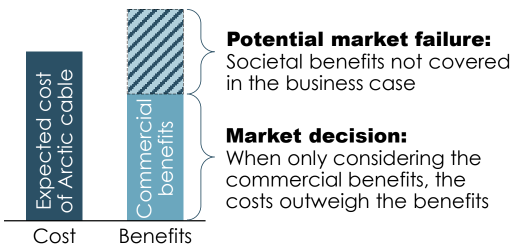
57 Some of these challenges can be studied and potentially mitigated with the help of appropriate tools.

Third, commercial investors do not account for the broader societal values of Nordic submarine cable connectivity to Europe. We identify at least five such societal benefits:

1) Enhanced digital infrastructure, such as data centres and submarine cable connectivity, attracts other digital investments to the Nordic region through spillover effects.
2) Digital infrastructure brings broader economic benefits to the Nordic region in productivity, trade, and consumer welfare.
3) Submarine cables over the Arctic add additional digital routes to and from Europe, which improves European digital resilience and autonomy. Digital resilience has high importance in current European political agendas. A ring structure consisting of two or more Arctic cables lifts resilience to an even higher level.
4) As a side effect of an Arctic submarine cable system, remote communities in the Nordic and polar regions will be able to experience better connectivity, which provides societal benefits for remotely located regions.
5) Besides their functionality to transfer data, submarine cables can also function as scientific instruments when their physical characteristics are exploited. As submarine cables are mostly in direct contact with the seabed, they can be used for Earth observation and seismic research, for example, to detect early-stage earthquakes,[58] to measure water temperature, flows, and salinity, and to capture submarine bioacoustics signals, as e.g., produced by whales.[59] As there are no other cables in the Arctic, this would add data points that are otherwise difficult to obtain.

The exclusion of additional societal benefits in the business case leads to a potential market failure from an economic perspective, see Figure 17. The commercial benefits may not suffice to cover the high costs and risks of an Arctic submarine cable project. However, adding the economic value of the additional societal benefits *could* increase the total benefits over total costs and make Arctic submarine cable projects viable.

Figure 17
An illustrative example of potential market failure



Source: Copenhagen Economics

[58] See e.g., SFI Centre for Geophysical Forecasting at NTNU (NO) in cooperation with JASMTEC (Japan).
[59] Bouffaut et al. (2022).

3.2 GOVERNMENTS CAN SUPPORT R&E NETWORKS' ROLE AS ANCHOR TENANTS

The participation of R&E networks in submarine cable projects could lower the risks for commercial operators and potentially make the project a reality. At the same time, this boosts digital resiliency in Europe and helps achieve broader societal benefits to the Nordic economy and European R&E institutions.

To avoid potential market failures, governments can indirectly support the development of submarine cable projects in which R&E networks take up their role as anchor tenants, financially supported by governments.[60] As anchor tenants, R&E networks guarantee a *certain minimum demand* in submarine cable projects, as they ensure R&E institutions' needs for connectivity are met.

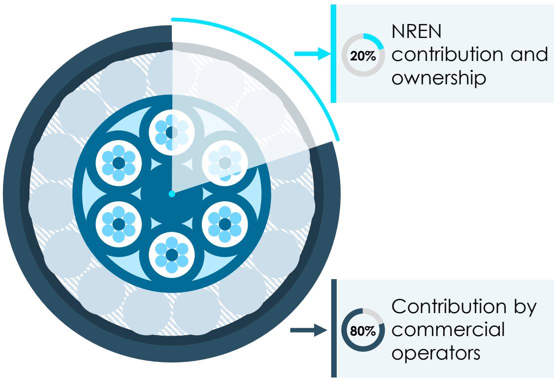
R&E networks would then support the financing of submarine cable projects through an upfront investment. This guarantees R&E networks' life-long access to capacity on the submarine cable system, see Figure 18. Such financing would lower the perceived risks by commercial operators because part of the financing is in place and there is public support for the project. Such contracts typically last for the lifetime of the submarine cable, that is, 15–20 years.

In an Arctic submarine cable project, Nordic R&E networks[61] could be anchor tenants. The EU, EU Member States, and non-EU countries, such as Norway, Iceland, US, Canada, or Japan, can co-finance the guaranteed demand through their respective NRENs. Historically, NRENs have been beneficial in spurring investments in digital infrastructure. This was the case for the EllaLink transatlantic cable, see Box 5. The overarching European R&E network GÉANT served as an anchor tenant to support the financing of this project.

60 This support will remain within the convention of the state aid rules in effect.

61 NORDUnet is the overarching R&E network in the Nordic region, comprising five NRENs: SUNET (Sweden), Sikt (Norway), DeiC (Denmark), Funet (Finland), and RHnet (Iceland).

Figure 18
Illustration of national R&E network (NREN) contribution to submarine cable ownership



Note: The 20 per cent NREN contribution and ownership in this illustration is arbitrary and could be any other percentage needed to cover the R&E demand.
Source: Copenhagen Economics.

If the long-term commitment by R&E networks to co-financing projects as anchor tenants is successful, the Arctic submarine cable has a higher chance to be built, which benefits the green transition, the Nordic economy and population, the European digital resiliency, and R&E institutions. The natural counterpart to such long-term commitments by R&E networks is the possibility of serving R&E institutions with new and improved connectivity.

3.3 R&E NETWORK PARTICIPATION IN CABLE INVESTMENTS WOULD BENEFIT R&E INSTITUTIONS

Nordic R&E network participation in Arctic cable projects will benefit R&E institutions that are connected via R&E networks. Such benefits could spill over into broader societal benefits. We identified at least five impact areas of R&E networks' involvement in Arctic submarine cable investments:

First, R&E network involvement guarantees reliable, secure, and resilient data transfers of, for example, health data, earth and climate observations.[62] Enhanced global connectivity will boost such activities. A multitude of R&E network routes creates a resilient network in instances of cable outages due to natural disasters, trawling ships cutting the cables, or political instability.

[62] AARNet (2021b); Marguerite (2020); EllaLink Geolab (2019); CalTech (2021).

Second, R&E network involvement creates low buffering needs for data-dense correlation analyses.[63] Some data-dense research cannot be done without available cable capacity access through R&E networks, as local storage capacity is not available to buffer or store large amounts of data.[64] R&E networks can further enhance possibilities for Nordic research institutions to participate in global research projects.

Third, R&E network involvement secures low-latency connections for connected R&E institutions and online education possibilities.[65] Low latency is important for R&E institutions, for example, when conducting remote computing, in education to train remote robotic surgery, or for complex data transfers such as remote synchronising of live music education and Earth observations.[66]

Fourth, R&E network involvement provides relevant capacity to R&E institutions at a cost-effective level.

Finally, R&E network involvement enables international cooperation and innovation.[67] Global challenges require global R&E cooperation, for example, within climate change, natural disasters, and pandemics (including COVID-19).[68] Such cooperation could advance research around artificial intelligence, machine learning, and high-performance computing, see the case examples in Box 4 and Box 5.

---

63 AARNet (2021a).

64 For example, this is the case for nuclear research in CERN and telescopic data computations. The discoveries include the Higgs boson particle in 2012 and the picture of a black hole. Another example is the European Spallation Source, the world's most powerful neutron source, currently under construction in Lund, Sweden (see Spallation Source website). Another example is the EISCAT_3D research infrastructure in the Nordic region.

65 NORDUnet (2012).

66 See e.g., VLBI geodetic stations.

67 Morgan et al. (2018); JISC (2021); AARNet (2021c).

68 For example, seismological sensors placed on submarine cables to gather real time data can benefit research on seismology and oceanic conditions, as has been done on the EllaLink cable. Research that leads to faster tsunami warnings and earthquake detections can save lives. Research stations and projects include Ny Ålesund (Arctic research on natural and environmental research and monitoring, link), ELIXIR in Finland (life science research, link), or Eiscat 3D (Earth observation, link).

Box 4 The case of INDIGO

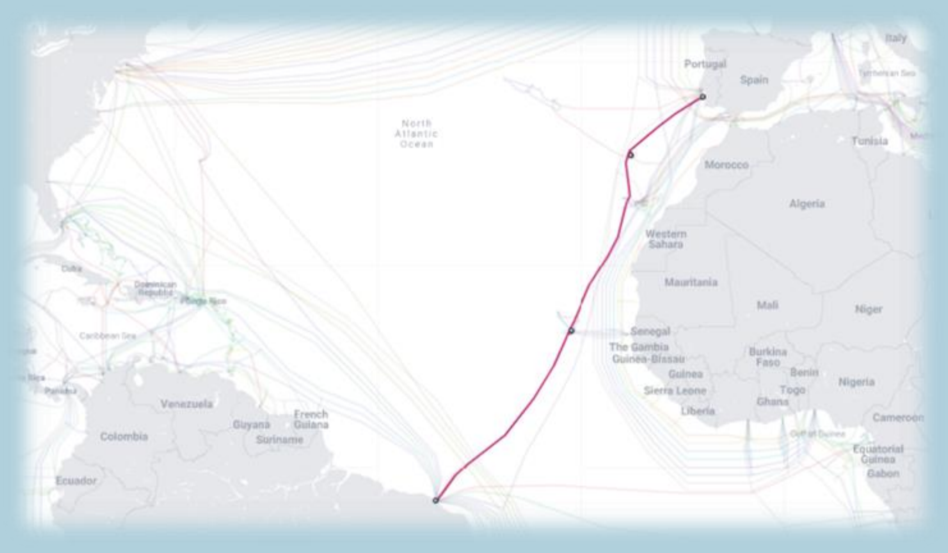
Design capacity	36 Tbps
Length	9,450 km
Ready for service	June 2019
Investment	More than EUR 330 million
Ownership	AARNet, Google, Indosat Ooredoo, Singtel, Telstra, SubPartners

Indigo is Australia's first transcontinental fibre optic submarine cable, connecting Australia to Southeast Asia with main points in Sydney, Perth, Jakarta, and Singapore. The project satisfies the key need of growing demand for data between Asia and Australia, to double the capacity by 2025. The consortium owners constitute an R&E network (AARNet), Google, an infrastructure provider (SubPartners), and telco operators, serving different demands with the cable.

The cable provides critical infrastructure to support future growth in collaborative data-intensive and transnational education. For example, the cable supports advancements in scientific research at the ***Square Kilometre Array telescope*** system in Australia, or for the discovery of the ***Higgs boson particle in the CERN Large Hadron Collider*** in Switzerland.

Source: SubTel Forum (2021a); TechCrunch website (2019); ZD Net website (2019); Square Kilometre Array website.

Box 5 The case of EllaLink



Design capacity	100 Tbps (with 190 Tbps landing in Portugal)
Length	5,900 km
Ready for service	June 2021
Investment	More than EUR 177 million
Ownership	EllaLink (Investor: Marguerite)

The EllaLink cable is a four-fibre-pair submarine cable between Europe and Latin America offering secure high-capacity connectivity access points in Portugal, Spain (inland), Brazil, and the remotely located Canary Islands and Cape Verde.

EllaLink is a carrier-neutral* and open access** cable and reduces latency to below 60 milliseconds (50 per cent decrease) that addresses the increasing demand for data between Europe and South America. The project is financed by six European public financial institutions, the European Commission, and the European REN organisation, GÉANT, participating with the ***GeoLab project***.

The EllaLink is the first digital submarine cable to be provided with sensors to ***provide real-time data on seabed conditions*** to examine Atlantic seismology, volcanology, marine ecology, and oceanic conditions. The cable also offers secure and low-latency data transfers to the ***European Southern Observatory*** in Chile, which has large data transfers to European research facilities.

Note: * Data centres that allow interconnection between many colocation and interconnection providers. It is not owned by a single ISP; instead, it offers a wide variety of connection options to its colocation customers. ** Refers to all electronic resources that are made widely available on the internet without licensing and copyright restrictions.

Source: SubTel Forum (2021a); SubTel Forum website (2021b); EllaLink GeoLab (2019); EllaLink website; Marguerite (2019); European Southern Observatory website.

REFERENCES

AARNet (2021a): *Global research and education networks collaborate to connect the Asia Pacific Oceania region with the Asia Pacific Oceania Network collaboration & Academia Europa. The role of National Research and Education Networks Providing Connectivity and Advanced Network Services to Virtual Communities in Collaborative R&E Projects.*

AARNet (2021b): *Co-creating a network for genomics research*, link

AARNet (2021c): *Facilitating high-energy physics experiments on a global scale*, link

Arctic research on natural and environmental research and monitoring, link

Bouffaut et al. (2022): *Eavesdropping at the speed of light: distributed acoustic sensing1of baleen whales in the Arctic,* link

CalTech (2021): *Using Submarine Cables to Detect Earthquakes*, link

Cinturion website, link

Cisco (2018): *Cisco Global Cloud Index: Forecast and Methodology, 2016–2021.*

Cisco (2019): *Cisco Visual Networking Index: Forecast and Trends, 2017–2022*

Clean Energy Wire (2022): *German offshore wind power - output, business and perspectives*, link

Climate Neutral Data Centre Pact (2020), link

Copenhagen Economics (2020) and (2021a): *Google's European hype-scale data centres and infrastructure ecosystem*

Copenhagen Economics (2021b): *The Economic Impact of the Forthcoming Equiano Subsea Cable in Portugal*

Dai Daives (2016): *NREN Organizational Best Practices*

Danish Energy Agency (2020): *Basisfremskrivning 21,* link

Data Centre Knowledge (2017): *This is Europe's Hottest Emerging Data Center Market*, link

Datacenterdynamics (2020a): *Building at Scale: Hyperscalers aim to build at $6M per MW*, link

Desira (2020): *The State of Rural Digitalisation in Europe*

Digital Infrastructure Strategy Finland (2019): *Turning Finland into the leader in communications networks—Digital Infrastructure Strategy 2025*

EIA (2021): *How much electricity is lost in electricity transmission and distribution in the United States?,* link

Eiscat 3D: *Earth observation*, link

Electricity map website, link

ELIXIR in Finland: *Life science research*, link

EllaLink Geolab (2019): *EllaLink and Emacom launch the 'EllaLink Geolab' SMART submarine cable initiative,* link

EllaLink Website, link

El-Sahli (2020): *Submarine cables, the internet backbone, and the trade-in services*

Energinet (2015): *How much land wind is there room for in Denmark?,* link

Energistyrelsen (2019): *The offshore wind potential in Denmark—screening of Danish waters for possible locations for new offshore wind.*

Epressi (2021): *Cinia and Far North Digital Sign MoU for Pan-Arctic fiber cable*, link

European Commission (2006): *European Programme for Critical Infrastructure Protection*

European Commission (2020a): *EU Foreign Investment Screening Mechanism*

European Commission (2020b): *EU Strategy for Energy System Integration*

European Commission (2021a): *Connecting Europe Facility*

European Commission (2021b): *Corporate sustainability reporting*

European Commission (2021c): *Data Gateways Declaration*

European Commission (2021d): *Digital Decade Declaration*

European Commission (2021e): *EuroHPC JU*

European Commission (2021f): *Europe's Digital Decade and Autonomy*

European Commission (2021g): *Global Gateway*

European Commission (2021h): Digital Day 2021: *Europe to reinforce internet connectivity with global partners*

European Southern Observatory website, link

European Spallation Source website, link

Europe's digital decade and autonomy (2021)

Eurostat database (2021): *Share of energy from renewable sources*, link

ESA website: *Managing signals at the top of the world,* link

Finnish Prime Minister's Office (2020), *Impact of carbon neutrality target to the power system*

Forskning.no (2021): *Hardly much more wind power in the next 5 to 10 years*, link

Fortum press release (2022): *Fortum and Microsoft announce world's largest collaboration to heat homes, services and businesses with sustainable waste heat from new data centre region*, link

GÉANT: *NREN*, link

German government (2021): *Coalition agreement*.

Gjesteland (2004): *Technical solution and implementation of the Svalbard fibre cable*, link

Google (2021*): Announcing the Blue and Raman subsea cable systems*, link

Green Mountain (2020): *Data Centre Power Costs*, link

Hiilineutraalisuomi: *Renewable energy potential in the provinces*, link

Hitsa (2020): *100 Gbps connection between Estonia and Finland is now operational*, link

Haaretz (2020): *Israel to Play Key Role in Giant Google Fibre-Optic Cable Project*, link

HPCwire website (2020): *Norway's Supercomputer Betzy Reaches Position 56 on the Top 500 List*, link

Icelandic National Energy Authority: *Raforkuspá 2021 – 2060,* link

IDC (2018): *The Digitalization of the World—From Edge to Core*

IEA (2014*): Electricity Transmission and Distribution*, link

IEA (2021): *Data Centres and Data Transmission Networks*, link

In the Field(a): *About R&E Networks*, link

In the Field(b): *Why R&E networks?* link

IPCEI-CIS (2021): *IPCEI on Next-Generation Cloud Infrastructure and Services*, link

JISC (2021): *Understanding the causes of disease is crucial to identifying potential treatments and, ultimately, finding cures*

Life in Norway, Ny Ålesund: *International research station on Svalbard*, link

LUMI website, link

Marguerite (2019): *Marguerite closes EllaLink submarine cable investment*, link

Marguerite (2020): *EllaLink & Emacom Launch the "Ellalink Geolab" Smart Submarine Cable Initiative,* link

Masanet et al. (2020): *Recalibrating global data centre energy-use estimates*, link

Morgan et al. (2018): *New opportunities for South Atlantic R&E Network collaboration between Africa, Brazil, and the US*, pages 6–8

New York Times (2017): American Companies Still Make Aluminum in Iceland., link

Nordic Council of Ministers (2018): *Data centre opportunities in the Nordics, an analysis of the competitive advantages*, link

Nordregio (2020): *Household access to broadband 100Mbps*, link

Nordregio (2007): *Iceland's possible geothermal and hydropower energy fields*, link

NORDUnet (2012): *e-Infrastructure Challenges Towards 2020*

NORDUnet website: *GREN—Global networking,* link

NORDUnet website: *The Nordic NRENs,* link

Norwegian Ministry of Local Government and Modernisation (2021): *Norwegian data centres*, link

Norwegian Government (2018): *Strategi for forskning og høyere utdanning på Svalbard*, link

Norwegian government guide (2018): *How to establish a data centre in Norway*

Norwegian government website, link

Norwegian Tax Administration: *Avgift på elektrisk kraft*, link

Norwegian Water Resources and Energy Directorate (NVE): *Energibruk I industrier,* link

Orkustofnun Iceland, link

Research in Svalbard website, link

Rostelecom (2020): *Rostelecom launches the next generation Transit Europe – Asia project*, link

RTI (2020): *Economic Impacts of Submarine Fibre-Optic Cables and Broadband Connectivity in South Africa*

RUMRA & Smart Villages: *Broadband access in rural and mountainous areas in the EU*, link

SFI Centre for Geophysical Forecasting at NTNU (NO) in cooperation with JASMTEC (Japan), link

Solenergiklyngen: *Roadmap for the Norwegian solar power industry towards 2030*, link

Square Kilometre Array website: *A new observatory to explore the universe*, link

Statnett (2018): *Increased wind power production and effects in the transmission network differences in flow*, link

Statnett (2020): *Langsiktig markedsanalyse*, link

Submarine Cable Networks (2018): *A new coming for Submarine Cable Systems—Independent Infrastructure Developers*, link

SubTel Forum (2021a): *Submarine cable map*, link

SubTel Forum (2021b), EllaLink: *"The new submarine cable between Europe and Latin America will reduce the current latency by 50%, to below 60 milliseconds",* link

Svensk Vindenergi (2019): *100 percent renewable 2040: Windpower for climate benefit and competitiveness*, link

Swedish Energy Agency: *Långsiktiga scenarier*, link

Swedish Energy Agency (2021): An overview of Energy in Sweden 2021 now available, link

Swedish government (2018): *Digital infrastructure,* link

TechCrunch website (2019): *Google's Indigo subsea cable is now online*, link

TeleGeography: Submarine cable map 2021, link

Telius (2022): *Green cloud computing 101*, link

Umwelt Bundesamt (2021): *Renewable energies in figures*, link

UNCTAD (2021): *Digital Economy Report*, link

Vedvarende Energi (2014), link

VLBI geodetic stations*: Research in Svalbard Portal* (2019), link

Vodafone (2021): *Enhancing Rural Connectivity*, link

ZD Net (2019): *Indigo subsea cable made ready for use*, link

APPENDIX A
CALCULATION OF DATA CENTRE COST

In order to estimate the data centre costs in different scenarios, we assess different cost metrics in relation to data centres. We do this for potential scenarios for the placement of data centres and the source of additional renewable energy. We calculate the cost of running a data centre in three scenarios, using the example of Germany, see Figure A.1:

1. The data centre is close to the Central European demand for computing power in Germany. The data centre will be powered by the German electricity supply.
2. The data centre is in Germany, but it is supplied with power from the Nordic region. This requires transporting energy from the Nordic region to Germany through transmission cables.
3. The data centre is in the Nordic region and is supplied with local electricity. This requires the transport of data from the Nordic region to Central Europe.

For this exercise, we assume a hyperscale data centre with a capacity of 150 MW, which runs around 730 hours per month (full-time). We use power prices from Eurostat (2020 S2). The data centre has a Power Usage Effectiveness (PUE) of 1.15, which we confirmed as a realistic measure in one of our interviews with data centre stakeholders. If waste heat is reused, the PUE of the data centre operations would further be decreased.

From this interview, we further established that the investment cost of developing a data centre in the Nordic region is around 10 per cent more expensive than developing a data centre of the same capacity in Central Europe. This is due to higher costs for construction because of an expensive construction workforce and potentially less accessible terrain. Land costs do not constitute a large part of investment costs. The expected investment costs in Central Europe, therefore, amount to around EUR 5.3 million per MW,[69] while the investment costs in the Nordic region amount to EUR 5.8 million per MW.

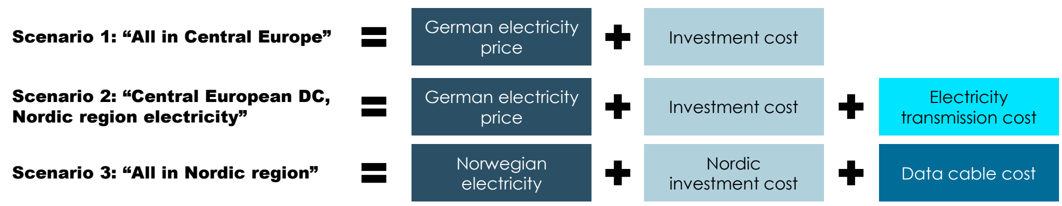
The typical lifetime of a data centre is around 20 years, and the same is assumed for a submarine data cable.[70] We assume that the lifetime of a power transmission cable is 40 years.

To calculate the cost of the cables, we use a distance between the data centre/power supply and data demand of 3,000 km, which roughly represents the distance between Tromsø (NO) and Frankfurt (DE).

For the second scenario, we assume that the electricity grid connection between Tromsø and Frankfurt has the capacity to serve the demand from a new data centre. Hence, no congestion fees apply. However, a data centre placed in Germany that is supplied by power from Norway must still pay German electricity prices, and the new transmission is not expected to impact German power prices noticeably.

69 Datacenterdynamics (2020a).
70 Data Center Knowledge (2015).

Figure A.1
Cost overview for the three scenarios



Source: Copenhagen Economics

Sensitivity analysis

We compare our results to the literature and include additional parameters to check our sensitivity.

We estimate cost savings of around EUR 150 million when placing the data centre in the Nordic region. In the literature, we find cost savings for businesses hosting their computations in Norwegian data centres compared to German ones of around EUR 2.5 to 3 million per MW,[71] which equates to savings of EUR 375 to 400 million for a data centre of 150MW. We may therefore be on the lower end of the actual cost savings.

In addition, Norway currently has tax cuts of around 95 per cent for power use in new data centres.[72] If we include these tax reductions in our estimation, the cost savings from placing a data centre in the Nordic region increase to over EUR 200 million and come closer to the estimate from the literature. As it is uncertain whether such a tax cut will persist going forward, especially considering the expansion of data centres in the Nordic region, we have decided to disregard this in our main estimate.

71 Datacenterdynamics (2020b).
72 Norwegian Tax Administration.

APPENDIX B

CALCULATION OF GDP IMPACT FROM SUBMARINE CABLES

In order to estimate the economic impacts for the Nordic region, we set up a small economic model using findings from empirical studies that link submarine cables with economic growth through how submarine cables affect internet bandwidth and end-user latency, which ultimately leads to economic growth. We will do this for different scenarios of new submarine cables in the Arctic region.

As a starting point, we specify two scenarios (A, B) for the potential cable connections in the Nordic region, increasing the number of external cables in the region by **2** and **4**, respectively, see Table B.1. Scenario A is the most likely scenario, whereas Scenario B is a long-term ambitious scenario. Currently, **26** submarine cables are connected to the Nordic region,[73] of which many have low capacity, are approaching the end of their technical lifetime, and only a few are connected to other continents outside Europe.[74]

Table B.1
New cables defined in each scenario connected to the Nordic region

CABLES	SCENARIO A	SCENARIO B
Arctic cable	1	2
European cable	1	2
Total	**2**	**4**

Note: Scenario B is defined as a long-term ambitious scenario.
Source: Copenhagen Economics.

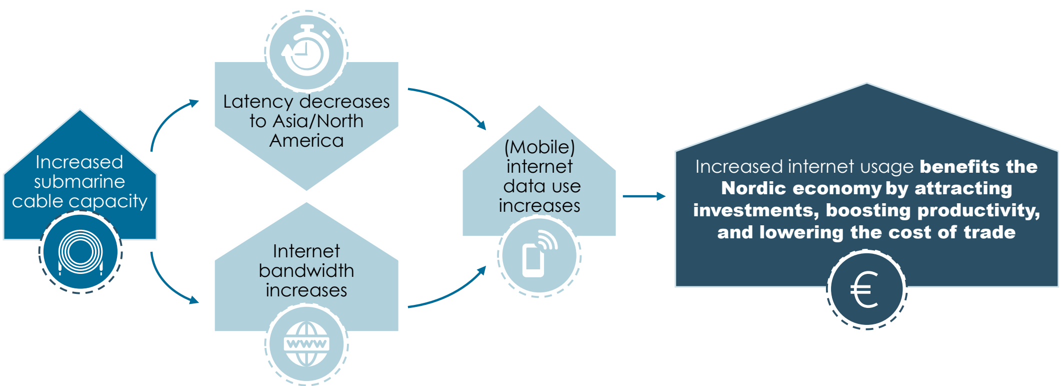
To estimate the impact on GDP,[75] we focus on two main channels: 1) Internet bandwidth and 2) latency, based on the main literature linking submarine cables and GDP growth, primarily Analysys Mason (2020), which we also used in a previous study.[76] In Asian-Pacific countries, Analysys Mason (2020) finds that Google's submarine cables increase the internet bandwidth and reduce the latency,[77] and well-connected APAC countries are found to have 74 per cent lower prices than less connected countries in the region.[78] Below, we argue why we use this study in a Nordic context.

The study finds that these effects increase mobile internet data use, see Figure B.1, which is used as a *proxy for internet usage in general*. Furthermore, the study finds a positive link between internet usage and a country's GDP. These findings follow the traditional economic relationship between infrastructure and economic growth, in other words, submarine cables generate socioeconomic value

73 Based on a mapping of the submarine cables in service by 2024 or before, we infer the starting, end and additional landing points for each submarine cable. A submarine cable is defined in scope whenever these points involve at least one Nordic and one non-Nordic country.
74 This is without counting submarine cables that *only* connect countries in the Nordic region.
75 Temporary construction effects are not assessed.
76 See Copenhagen Economics (2021).
77 Analysys Mason (2020), p. A-4 to A-6.
78 Analysys Mason (2020), p. 36-37.

to society, just as any other infrastructure investment. We use this reasoning and results for our estimation of the impacts of Arctic submarine cables on Nordic GDP.

Figure B.1
Illustration of the link from increased submarine connectivity on the Nordic economy



Note: Mobile internet data use is here a proxy for internet usage in general.
Source: Copenhagen Economics based on Analysys Mason.

With increased internet capacity, different transmission mechanisms drive investment and productivity, lowering the cost of trade, which ultimately leads to growth, as mentioned in the report.

We use the results found in Analysys Mason (2020) in the Nordic setting in the following way: The GDP impact estimation is a sequence of three steps, each based on a stand-alone econometric regression:

1. The report finds the impact of *an additional submarine cable* on internet bandwidth and latency. These estimators are measured, giving a per cent increase in the number of submarine cables following the introduction of a new cable.
   i. Estimate for internet bandwidth: 4.05, i.e., a 1 per cent increase in the number of submarine cables increases internet bandwidth by 4.05 per cent (p. A-5 in Analysys Mason, 2020).
   ii. Similar estimate for latency: -1.36 (p. A-5 in Analysys Mason, 2020).

2. The report finds the impact of internet bandwidth and latency on mobile internet data usage.
   i. Impact on internet bandwidth: 0.63, i.e., a 1 per cent increase in internet bandwidth leads to a 0.63 per cent increase in mobile internet data usage (p. A-8 in Analysys Mason, 2020).
   ii. Impact on latency: -0.54, i.e., lower latency leads to increased mobile internet data usage (p. A-8 in Analysys Mason, 2020).

3. The report finds the impact of mobile internet data usage on GDP per capita.
   i. Effect of mobile internet data: 0.008, i.e., a doubling of mobile data use implies a 0.8 per cent increase in GDP per capita (p. A-10 in Analysys Mason, 2020).

Multiplying these together gives approximately 0.0204[79] and 0.0059[80] for the internet bandwidth and latency impacts, respectively, i.e., the impact on GDP per capita per *percentage point increase in the number of submarine cables*. In our impact calculation, we use a total of **0.0263**[81]. The interpretation of this number is that a 1 per cent increase in the number of submarine cables increases the GDP by 0.0263 per cent.

The findings of Analysys Mason (2020) reflect the economic relationships in a set of APAC countries over the past decade. This is a geographic and temporal context different from Nordic connectivity looking ahead. It is likely that some of the GDP growth effects identified historically in the APAC region have been stronger than they would be for the Nordic region, which is more economically developed and a region that is currently connected with submarine and terrestrial cables.

For this reason, we choose to use the lowest bound of the impact results from the APAC study as a *conservative measure* when applying them to the Nordic region. Particularly, we achieve this by scaling down the result by a conservative factor of **46.6 per cent**, which is the ratio between Analysys Mason's lower conservative impact and the so-called base-case impact reported in the study for "bandwidth and edge impact".[82]

As the Nordic GDP is forecast to be **EUR 1,520** billion in 2024 (in 2020 prices),[83] we find that the conservative impact on GDP is as illustrated below for Scenario A, with numbers highlighted in **bold** in the text above:

$$\text{GDP impact} = \text{Pct. change in the number of cables} \cdot \text{GDP impact} \cdot \text{Conservative factor} \cdot \text{Nordic GDP}$$

$$GDP\ impact = \frac{2}{26} \cdot 0.0263 \cdot 46.6\% \cdot €1{,}520\ \text{bn} \approx €1.4\ \text{bn}$$

Similar calculations are made for Scenario B.

Several observations around the impact should be considered when interpreting the results. In our estimation, around 80 per cent of the impact is driven by *increased bandwidth* and only around 20 per cent by lower latency. Furthermore, the GDP impact is expected to be lower if the cable(s) have stranded capacity, or if the Nordic region works purely as a transit region between Asia and the FLAP region.

Sensitivity Discussion

We calculate the GDP impact using top-down estimates in the literature based on econometric research on the number of cables in APAC countries.[84] Because the Nordic region is a more digitally developed region, we take the conservative estimates in the literature to apply to a Nordic setting. Therefore, we consider the following aspects of the estimation:

---

79 $4.05 \cdot 0.63 \cdot 0.008 = 0.0204$.

80 $-1.36 \cdot -0.54 \cdot 0.008 = 0.0059$.

81 $0.0204 + 0.0059 = 0.0263$.

82 $\frac{118}{253} = 0.466$, where 118 is the conservative scenario and 253 is the base-case. See p. A-17 in Analysys Mason (2020).

83 Based on GDP numbers from Eurostat and real GDP growth from IMF.

84 This assessment is based on similar sensitivity discussions in Copenhagen Economics (2021).

The elasticity for the impact of the number of cables on internet bandwidth (4.05) is a simplification of the capacity. There are two (opposing) directions for why this may influence the results for the Nordic region:

1) New submarine cables are likely to have relatively large capacities (in Tbit/s). When considering only the number of cables, this does not capture the *relative change in capacity*. While this effect could go both ways, it may be that literature findings (i.e., regression parameter for bandwidth of 4.05) may **underestimate** the parameter, and thus the subsequent impacts on GDP.
2) However, the Nordic region is already well connected with several submarine cables *and* terrestrial cables to the FLAP region, but not to other continents. Many APAC countries (e.g., Australia, Japan, Indonesia, the Philippines, and Taiwan) can, to a large extent, *only connect* to the global internet via submarine cables.[85] Therefore, the *additional* effect of a new submarine cable on internet bandwidth and latency in APAC countries may be relatively larger than in the Nordic region. This means that we risk **overestimating** the impact (the regression parameter for bandwidth of 4.05 would be too high), as the relative importance of submarine cables would be greater in the APAC countries than in the Nordic regions.

Similar arguments can be made for the latency parameter (-1.36).

As we are taking a conservative approach to the estimation, we think that we are more likely to underestimate than overestimate the impacts. Other studies found larger results, suggesting that our results are on the conservative end of the impact studies.

- Analysys Mason (2020) finds GDP impacts of EUR 100–815 billion over the period of 2020 to 2024, attributable to Google's network investments in APAC countries.[86] This corresponds to an average *annual* impact of EUR 20–165 billion. However, since our estimation is based on the most conservative outcome of this paper, we are confident that this is also reflected in our results.
- RTI (2020) estimates the impact of the 2Africa cable and finds a GDP impact of 0.42 per cent to 0.58 per cent for all of Africa, equivalent to EUR 22–31 billion in GDP at purchasing power parity. This also covers land-locked African countries and African countries not directly linked to the submarine cable. We find a lower percentage impact for the Nordic region (0.09 per cent of GDP). Results for the Democratic Republic of the Congo, South Africa, and Malaysia show a much larger impact of submarine cables ranging from 6–19 per cent increase in GDP per capita.

85 Satellites are an option that only provides low bandwidth connections.
86 Analysys Mason (2020, p. A-17). The impact range depends on the connectivity components and modelling scenarios.