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Copenhagen Economics

THE VALUE & BENEFITS OF FUTURE-PROOF DIGITAL INFRASTRUCTURE FOR DENMARK

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Copenhagen Economics

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PREFACE

Telecommunications infrastructure is the backbone of the digital economy, alongside other digital infrastructure such as data centres, cloud services and software solutions.

In this report, we focus on telecommunications infrastructure as a fundamental enabler of the economy and society as a whole. Activities facilitated via telecommunications infrastructure are both business-related – e.g., payment, e-commerce, and productivity software – and related to wider societal functions – e.g., e-health and e-governmental services, communications, and entertainment.

Danish companies are among the best in the EU at integrating digital technology (ranked second in 2022) which allows them to take advantage of digital transformation. Around one quarter of enterprises had integrated AI and Big data in 2021 – technologies which are likely to become even more important in the future.[1]

The pace of the technological evolution requires constant adaptation and upgrading of the telecommunications infrastructure. As reliance on digital systems grows, so does the need for resilient infrastructure capable of handling increasing data volumes, ensuring cybersecurity, and facilitating seamless connectivity.

To ensure that Denmark and Europe remain at the forefront of cutting-edge digital technology, significant continued investments in telecommunications infrastructure will be required. However, there are concerns that the telecommunications sector in Europe and in Denmark may face challenges in ensuring sufficient financial incentives to support future investments.

In light of this, Dansk Erhverv has commissioned Copenhagen Economics to conduct a research study to i) investigate the value of the telecommunications sector and its continued infrastructure investment to the economy and society at as a whole, ii) to examine the potential need for further investment to ensure futureproof digital infrastructure and the associated socio-economic value and iii) to discuss the policy framework that can support continued investment.

[1] European Commission (2023), Digital Economy and Society Index (2022) – Denmark (link)

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THE TELECOMMUNICATIONS SECTOR HAD A SUBSTANTIAL ECONOMIC IMPACT IN 2023

+DKK 45.1 bn in GDP contribution
(DKK 7,600 per citizen)

+41,600 jobs

SECTOR OPERATIONS

+DKK 38.6 bn to GDP
(DKK 6,500 per citizen)

+32,300 jobs

SECTOR INVESTMENTS

+DKK 6.5 bn to GDP
(DKK 1,100 per citizen)

+9,300 jobs

THE TELECOMMUNICATIONS SECTOR SUPPORTS ADDITIONAL SOCIO-ECONOMIC BENEFITS

Enabling economic growth
Boosting productivity in other sectors by supporting digitisation

Up to +DKK 16.8 bn to GDP annually (DKK 1,800-2,800 per citizen)

Enabling the green transition
Supporting substantial reductions in CO_2 emissions

Network's improved energy efficiency reduced the network's emissions by 31 per cent (2019-2023)

Enabling use of advanced and green technology across the economy

Ensuring cybersecurity and resilience
Socio-economic benefits from avoiding costly disruptions and data breaches

large potential societal costs related to breakdown of telecommunications services

EXECUTIVE SUMMARY

Telecommunications infrastructure is the backbone of the digital economy. Advanced network technologies that support high capacity, security and resilience have brought and will continue to bring substantial benefits to Danish consumers and businesses. While Denmark currently fares well in international comparisons regarding the rollout and take-up of high-speed fixed and mobile connectivity, more remains to be done as the sector undergoes important transformation. The recent Draghi report on EU competitiveness has singled out the telecommunications sector among key economic areas worthy of policy attention and consideration, so that Europe can improve its competitiveness. EU-level but also national policymakers need to consider how best to fine-tune policy conditions to empower further competitiveness in this sector and thus achieve enhanced and future-proof digital infrastructure.

Considering this, in this study we assess firstly the economic contribution supported by the operations and investments of the telecommunications sector to the Danish economy. Secondly, we investigate how the well-developed digital infrastructure enables wider socio-economic benefits for the Danish economy and society. Thirdly, we examine why further investments are required and assess how continued development of the digital infrastructure will continue to enable wider benefits for the economy and society as a whole. Lastly, we discuss how policymakers can support continued investment while achieving other policy objectives to ensure that future benefits materialise.

At a glance: Key Insights from the study

The telecommunications sector plays a vital role in the functioning of society and its economic contribution amounts to 1.6 per cent of GDP

In 2023, the telecommunications sector contributed **DKK 45.1 billion** to the Danish economy through its operations and investments. This corresponds to around 1.6 per cent of Danish GDP, equivalent to DKK 7,600 per Danish citizen. This contribution includes direct effects, representing the gross value added generated by the sector's own activities, and additional economic activity stimulated throughout the supply chain, reflected in a multiplier of 1.6 for every unit of direct contribution. The telecommunications sector's supported a total of **41,600 jobs** in Denmark, including 13,000 within the sector itself.

In addition, futureproof digital infrastructure has an enabling function and supports economic growth by boosting productivity. We estimate that digital infrastructure enabled economic gains **in a range of 11 to 17 billion in GDP** annually between 2014 and 2023, equivalent to up to DKK 2,800 per citizen, through increased download speeds and broadband adoption.

The telecommunications sector generates wider socio-economic benefits by enabling the green transition and mitigating potentially substantial costs related to cyber breakdown

Futureproof digital infrastructure contributes to the green transition by i) lowering CO_2 emissions from the network and ii) enabling the use of advanced, more energy efficient technology across the economy and society. From 2019 to 2023, CO_2 emissions from network electricity consumption decreased by 36 per cent. While some part of this is attributable to the decrease in the CO_2 intensity of electricity in Denmark, **31 percentage points of this decrease in CO_2 emissions since 2019 are attributable to the increased energy efficiency of the network** compared to a scenario where the network's energy efficiency had stopped improving in 2019.

Digital infrastructure in Denmark, similar to the rest of Europe and the world, faces significant cyber threats. To lower the risk of cyberattacks and network breakdowns, the sector engages and invests in many activities. This in turn **diminishes the likelihood of disruptions which undoubtedly would be associated with substantially large costs to Danish businesses, the economy and society at large**.

Continued investments are needed to make digital infrastructure futureproof

Several developments are underway which impose new and higher requirements for telecommunications networks in the future. (1) There is a continued **need for the deployment and upgrading of fibre and mobile networks**. Further upgrading of the networks are required to meet (2) **increasing data needs** and (3) to fulfil high requirements for telecommunications infrastructure in terms of capacity, latency, resilience and security due to **innovative technologies**, such as AI and quantum computing. Advanced telecommunications networks also (4) contribute to supporting the **green transition**, whilst simultaneously (5) ensuring network **resilience** and (6) mitigating growing **threats to cyber security and digital fraud**. At the same time, we observe that investment levels have decreased by 11 per cent since 2021 (controlling for inflation) and returns are modest. Furthermore, historic structural challenges continue to affect this sector in Denmark as Danish mobile operators serve on average fewer customers than the EU average.

Operators in Denmark may face challenges that weaken their ability and incentive to invest

Administrative barriers, low return on investments in digital infrastructure and lack of scale may challenge the attraction of sufficient investment. Policymakers and regulators can promote continued investments by streamlining and speeding up currently burdensome and lengthy **permitting processes** at the local government level. Different forms of **collaboration and consolidation** can enable operators to pool their resources to invest in upgrading existing and building new networks more cost effectively. While authorities will assess each collaborative arrangement on their merits, competition enforcement recognises that reaping the economies of scale can be critical for faster and more extensive roll-out of network investments to the benefit of consumers.

In Detail: Chapter-by-Chapter Insights

Investment in digital infrastructure has supported Denmark's economic performance

As we explain in Chapter 1, we find, based on an input-output model, that the telecommunications sector contributed DKK 45.1 billion in 2023 to the Danish economy, corresponding to almost 1.6 per cent of total Danish GDP or DKK 7,600 per Danish citizen, through i) its operations and ii) its investments. In comparison, we estimate using a similar methodology that the operations of the Danish agriculture sector contributed DKK 46.6 billion to the Danish economy.

- The telecommunications sector's operations contributed DKK 38.6 billion to the Danish economy in 2023 and supported 32,300 jobs. This captures the immediate impact of the industry's operations, such as the value added from its activities and the jobs it directly creates (direct effect) as well as additional value added and employment generated through its supply chain via the sector's demand for goods and services from other sectors (indirect effect).

- The telecommunications sector's investments (i.e. which amounted to DKK 10.5 billion in 2023) contributed an additional DKK 6.5 billion to the Danish economy and supported 9,300 jobs (direct and indirect effect).

Over the last 10 years, the telecommunications sector has invested DKK 85 billion to improve Denmark's digital infrastructure and investments as a share of revenue have grown 7.5 percentage points from 15.6 per cent in 2014 to 23.1 per cent in 2023.

These efforts by the sector have put Denmark at the forefront of digitisation compared to other European countries. Denmark is leading in 5G coverage with 100 per cent 5G coverage in 2023 relative to the EU average of 79 per cent – although further investments will be required to deliver 'full' / 'stand-alone' 5G across Denmark. Denmark is also among the top three European countries regarding Fixed Very High Capacity Network (i.e. optical-fibre network or equivalent in terms of performance) with 97 per cent total coverage and 91 per cent in rural areas. This is to the benefit of Danish citizens and businesses.

Advanced digital infrastructure has far-reaching socio-economic benefits

As we demonstrate in Chapter 2, beyond its technological importance, future-proof digital infrastructure delivers significant socio-economic benefits and is critical to achieving key policy objectives in three areas: 1) supporting GDP growth by boosting productivity, 2) promoting the green transition, and 3) enhancing IT security as well as ensuring resilience and security of supply.

Advancements in digital infrastructure support *GDP growth*. High-quality digital infrastructure is essential for businesses, research facilities, public authorities etc. to adopt digital technologies that contribute to more efficient business processes, technological progress and innovation and thereby to boost productivity across the economy. Based on estimates from existing studies scaled to the Danish context, we estimate that digital infrastructure enabled economic gains of between DKK 10.8 and 16.8 billion in GDP each year between 2014 and 2023, equivalent to DKK 1,800 to 2,800 per Danish citizen each year. We estimate this GDP contribution by considering the impact of two cumulative measures of advancement in digital infrastructure discussed in the academic literature, i.e. the impact of fixed broadband download speed and the impact of broadband adoption.

Infrastructure investments also advance the *green transition* and thereby EU's environmental targets. First, we find that continued investments in digital infrastructure led to improved energy efficiency of the mobile and fixed broadband network in Denmark. Since 2019, the energy intensity of the mobile and fixed broadband network has declined by 33 per cent, from 12 to 8.1 MWh of electricity per PB of data in 2023. We estimate, based on the network's electricity consumption, that CO2 emissions from network electricity consumption decreased by 36 per cent, of which 31 percentage points are attributable to increased energy efficiency compared to a scenario where the network's energy efficiency had stopped improving in 2019. Second, we describe how advancements in digital infrastructure could enable up to 15 per cent emission reductions in other sectors, for instance through the development of smart grids in the energy and utility sector, or data sharing and route optimisation in transports.

According to the Centre for Cybersecurity, Denmark faces a high to very high threat regarding cyber espionage, cyber activism and cyber-crime. How well the telecommunications sector can mitigate *cyber threats* and *ensure network resilience* has far reaching consequences across all sectors and for all citizens and businesses using digital infrastructure. As the reliance on digital infrastructure grows, the costs associated with a potential network break-down for whole regions or a cyber-attack can be large and are likely to be even larger in the future. Some studies attempt to provide an indication of the magnitude of the potential costs associated with a breakdown in digital infrastructure. A widely referenced report from the analysis company Gartner in 2014, for example, reports that large companies face costs of USD 5,600 per minute of unplanned downtimes and small companies between USD 137 – 427 per minute.[2] This corresponds to DKK 2.3 million per hour for large companies and DKK 57,000 – 177,000 per hour for smaller companies (not adjusted for inflation). As an illustrative example, this per minute cost range for small and large companies suggests that it could cost Danish companies as much as DKK 3.5 to 6.5 billion per hour[3] if digital infrastructure breaks down and companies experience downtime - these are high-level, exploratory estimates that come with a margin of uncertainty and do not constitute a full-fledged model of the economy. To mitigate cyber threats, the sector invests in making networks safe and comply with national security regulations, e.g., by upgrading designated infrastructure assets to vendors compatible with Danish regulations, which involves significant additional costs. The sector also invests in network resilience to minimise downtime and to reduce cyber-crime at user level.

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2 Forbes (2022), How to Guard Against The Cost Of Unplanned Downtime And Network Outages (link) and Pingdom (2023), Average Cost of Downtime per Industry (link).

3 We extrapolate the per minute cost linearly to estimate the cost per hour. However, the true cost might be decreasing with time as companies adjust operations.

Continued investments are needed to make digital infrastructure future-proof and deliver further benefits

As we examine in Chapter 3, despite high 5G coverage and Fixed Very High Capacity Network penetration in Denmark, continued investments are needed to improve capacity and handle increasing demand for digital services, keep up with technological developments, and meet increasing security requirements and legislation.

If market and policy conditions are such that future investments would stay at similar levels as realised in 2019-2023, we estimate that investment will support DKK 5.6 billion to GDP and 8,000 jobs annually in direct and indirect effects until 2030. In addition, as an example of how investments lead to better infrastructure which ultimately supports GDP, we estimate the effect of further increases in download speeds on GDP. We find that further increases in Denmark's already high download speeds could contribute 0.10 to 0.18 per cent to GDP annually until 2030, equivalent to between DKK 2.9 and 5.0 billion in GDP contribution. Finally, we estimate that from 2023 to 2030, CO_2 emissions from the network's electricity consumption could decrease by a further 83 to 89 per cent. Of this total potential reduction, 17 to 24 percentage points could be attributable to further improvements in the network's energy efficiency.

These benefits will only materialise when the sector has the ability and incentives for further substantial investments, which necessitates a policy and regulatory framework that ensures incentives to invest by allowing sufficient returns that are commensurate with the risks involved. However, in Denmark, similarly to the rest of Europe, there may be potential barriers to sustained levels of investment.

There may be challenges to continued investment

As we discuss in Chapter 4, the policy debate and current market conditions suggest two main challenges potentially hindering future investments.

- *Long, complex and burdensome administrative procedures* may weaken operators' ability and incentive to invest in digital infrastructure. Operators face two significant issues in deploying network infrastructure such as masts, towers or ducts. *First*, there are significant restrictions associated with municipal plans and rules to deploy infrastructure, and rules can vary significantly between municipalities, making compliance burdensome. *Second*, municipalities often lack the resources to expedite permitting and the approval processes are lengthy, taking up to 11 months.

- *Recent financial performance of operators in the EU and Denmark is indicative of concerns over insufficient returns to support future investments*. There is a concern that the recent and expected low returns on investments stem from a lack of sufficient scale. While case-specific considerations are required, there are sound economic reasons to enable forms of collaboration that have limited impact on competition while allowing operators to spread fixed costs over a sufficient number of users to leverage economies of scale.

Policymakers and regulators can make use of various tools to support operators' ability and incentive to invest in digital infrastructure. In doing so, they seek to strike the right balance between supporting investments while achieving other policy objectives and protecting competition:

- Policymakers should consider how administrative and financial constraints are day-in and day-out impacting operators' ability to make timely investments in digital infrastructure. Streamlining lengthy and cumbersome permitting processes at the local government level is very impactful for the telecoms sector and should deserve special attention. The entry into force of the Gigabit Infrastructure Act (GIA) is an opportunity to review the Danish legislation and improve conditions for investment.

- There are sound economic reasons to enable forms of collaboration that have limited impact on competition while allowing operators to spread fixed costs over a sufficient number of users to leverage economies of scale. Operators can benefit from improved economies of scale through co-investments, network-sharing agreements and mergers. Competition authorities have a central role in determining boundaries to forms of collaboration that are conducive to network investments while preserving competition. While competition authorities will continue to scrutinise proposed consolidations and collaborative agreements on their merits, there is a growing policy impetus in Europe towards a more thorough consideration of investment-related benefits:
    - *First*, competition authorities can consider whether and how the full suite of potential efficiencies manifested through enhanced network investments and higher quality are balanced against any competitive effects of collaborative agreements or consolidation. The authorities face a balancing act whereby, for example, an assessment of investment (and hence quality) related benefits may warrant considering a longer time horizon than short-term competitive effects.
    - *Second*, where relevant, the commitments required to approve mergers, or other agreements should be those required to mitigate potential harm to consumers. Depending on case-specific circumstances, authorities can consider whether structural remedies reduce the benefits of consolidation and whether behavioural remedies – e.g. investment commitments or pricing remedies - may be appropriate and sufficient to safeguard competition whilst supporting investment incentives.

CHAPTER 1

INVESTMENT IN DIGITAL INFRASTRUCTURE HAS SUPPORTED DENMARK'S ECONOMIC PERFORMANCE

Digital infrastructure supports an increasing part of the functions and activity in society, thus enabling digital communication, payment, streaming, and other digital services.[4] High investments by the telecommunications sector have ensured that Denmark is one of the leaders in terms of digitation.

In this chapter, we analyse firstly the economic contribution of the telecommunication sector in terms of GDP and employment supported via its operations and investments throughout the economy. We find that the sector supported DKK 45.1 billion to the Danish economy in 2023 and 41,600 jobs in Denmark (Section 1.1). Secondly, we show that the sector invested DKK 10.5 billion in 2023 and DKK 85 billion in total from 2014 to 2023. These investments stay primarily in Denmark and support blue collar jobs in the construction sector (Section 1.2). Thirdly, we discuss how the efforts made by the sector have put Denmark at the forefront of digitation compared to other European countries to the benefit of Danish citizens and businesses (Section 1.3).

1.1 The telecommunications sector contributed DKK 45.1 billion to the Danish economy in 2023

In this section, we examine the economic contribution of the telecommunication sector in 2023 based on input-output modelling and publicly available data. We find based on input-output modelling that the sector contributed DKK 45.1 billion to the Danish economy in 2023, which corresponds to around 1.6 per cent of Danish GDP, DKK 7,600 per citizen in Denmark in 2023, and is more than the cost of the Great Belt Bridge (DKK 43.7 billion in 2023 prices).[5]

Of this total, DKK 38.6 billion in GDP contribution (accounting for direct and indirect effects) is supported through the telecommunication sector's operations (see Section 1.1.1). In comparison, we estimate, using a similar methodology, that the operations of the Danish agriculture sector (accounting for direct and indirect effects) contributed DKK 46.6 billion to the Danish economy. In addition, the telecommunication sector's investment (accounting for direct and indirect effects) contributed another DKK 6.5 billion (see Section 1.1.2), see Figure **1**.

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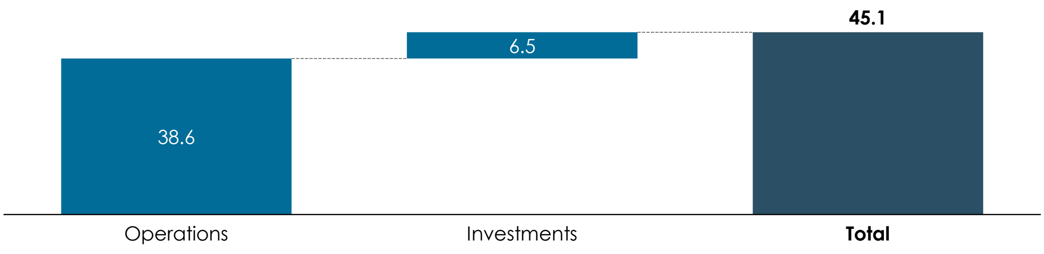
[4] See e.g. Tænketanken for Digital Infrastruktur (link).

[5] We adjust the cost of DKK 21.4 billion in 1988 prices (see Storebælt, Om Storebælt (link)) to 2023 prices using Danish CPI (see Statistics Denmark, Pris112 (link)).

Figure 1
National economic contribution supported by the telecommunications sector through operations and investments in 2023
Billion DKK, 2023



Note: The figure includes the direct and indirect effects we estimate in Sections 1.1 and 1.2. See Appendix A for an overview of the methodology behind the two elements.
Source: Copenhagen Economics based on Statistics Denmark, Input-output (link) and Klimadatastyrelsen, Økonomiske Nøgletal for Telebranchen 2023 (link).

1.1.1 The operations of the telecommunications sector contributed DKK 38.6 billion to the Danish Economy in 2023

In this section, we estimate the economic contribution of the telecommunications sector's operations and find that in 2023 the sector contributed DKK 38.6 billion to the Danish economy.

To estimate the economic contribution, we employ an input-output model based on the latest available input-output tables from Statistics Denmark.[6] These tables provide insights into how each sector of the economy procures goods and services from the rest of the economy and demonstrate how the output of one industry impacts other industries and the overall economy. Using this model, we estimate the telecommunications sector's impact on GDP and employment. The sector contributes to the economy through profits, product taxes, salaries, and purchases of intermediary goods and services from other domestic companies. Thus, this captures the economic contribution through the entire value chain of the sector – except for the effect of investments, which we cover separately in Section 1.2.

When estimating the economic contribution, we distinguish between the direct, indirect, and induced effects:

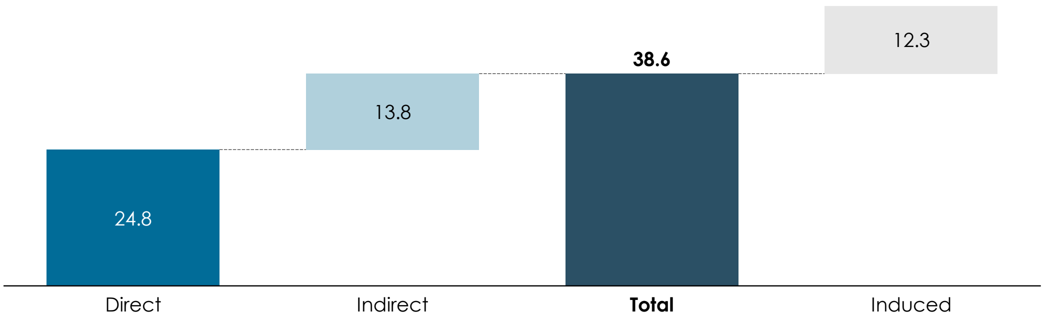
- *Direct effects* refer to the immediate impact of the telecommunications sector, such as value added through its activities and the jobs it directly creates.
- *Indirect effects* capture the ripple effects of the sector's demand for goods and services from other sectors. This includes the additional value added and employment generated through its supply chain.
- *Induced effects* measure the additional economic activity generated by employees in the telecommunications sector and its supply chain, spending their wages on goods and

[6] Statistics Denmark, Input-output (link).

services. This consumption drives further demand and supports additional jobs in the broader economy.[7]

We find that in 2023 the telecommunications sector's operations contributed DKK 38.6 billion to the Danish economy. This corresponds to almost 1.4 per cent of total Danish GDP in 2023 or around DKK 6,500 per Danish citizen.[8] The sector contributed DKK 24.8 billion directly and DKK 13.8 billion indirectly, see Figure **2**, which implies a multiplier of 1.6 for every unit of direct economic contribution in the broader economy. In addition, the sector supported a further DKK 12.3 billion in induced effect in 2023.

Figure 2
National economic contribution supported by the telecommunications sector through its operations in 2023
Billion DKK, 2023 prices



Note: We have adjusted results by inflation to get results in 2023 prices instead of 2022 prices. Find a complete description of the methodology in Appendix A.
Source: Copenhagen Economics based on Statistics Denmark, Input-output (link).

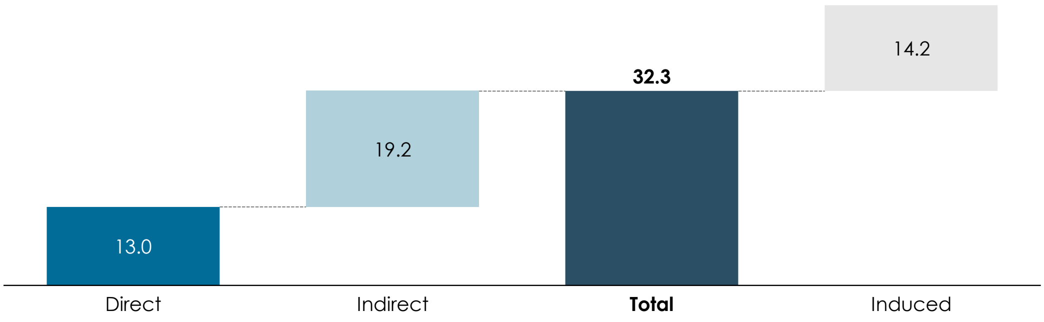
Similarly, we find that the telecommunications sector supported Danish employment with 32,200 jobs in 2023, see Figure **3**. This corresponds to 1 per cent of total Danish employment in 2023.[9] Of the 32,300 jobs, 13,000 were supported directly by the telecommunications sector (direct effect), while 19,200 jobs were supported through purchases from other Danish companies (indirect effect). Furthermore, we estimate that the telecommunications sector supported an additional 14,200 jobs through induced effects.

7 We assess the induced effects separately and do not include them in the total economic contribution since these effects are generated through the consumption of wages. Employees in the telecommunications sector and its supply chain would eventually find other jobs if the sector where to vanish because individual companies or even industries do not affect the 'structural employment' level. Thus, while these effects are important, they cannot be attributed to the sector's presence in the same way as the direct and indirect effects.

8 Based on a GDP of DKK 2,805 billion, see Statistics Denmark (link), and on a population of 5,961,249 in ultimo 2023, see January 2024 in Statistics Denmark, Befolkningstal (link).

9 Based on employment of 3,000,600 persons in August 2023, see Beskæftigelsesministeriet (2023), Aldrig set før – 3 millioner i beskæftigelse (link).

Figure 3
Danish employment supported by the telecommunications sector through its operations in 2023
Thousand FTEs

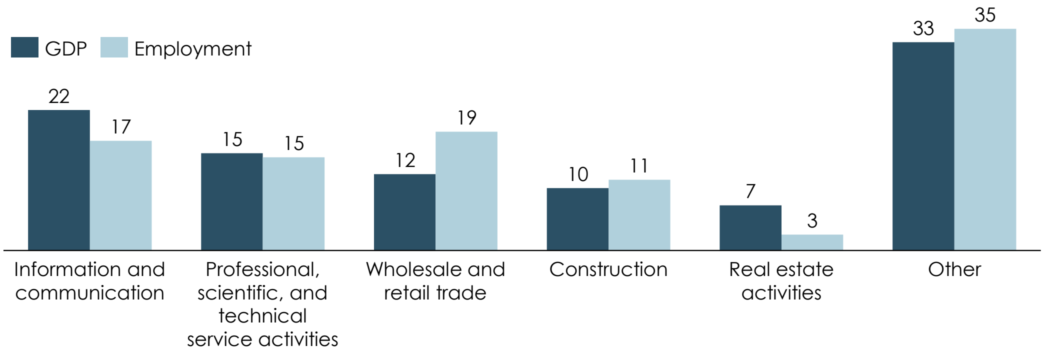


Note: The sum of the direct (13,000) and the indirect (19,200) does not add up to the total (32,300) in the figure due to rounding of the two. Find a description of the methodology in Appendix A.
Source: Copenhagen Economics based on Statistics Denmark, Input-output (link).

The indirect value supported by the telecommunications sector's operations is centred around a few specific industries that provide most of the goods and services the telecommunications sector relies on. We find that the impact was largest in the information and communications sector, which accounts for 22 per cent of the indirect GDP contribution, see Figure **4**. This was followed by professional service activities (15 per cent), wholesale and retail (12 per cent), construction (10 per cent), and real estate activities (7 per cent).

The picture is fairly similar for employment except that the effect is largest in the wholesale and retail sector with 19 per cent, see Figure **4**. These differences can be explained by the different labour intensity across these sectors such that a million DKK in revenue does not support an equal number of jobs in each sector.

Figure 4
GDP and employment supported by the telecommunications sector through its operations across key sectors
Per cent of indirect GDP contribution and employment supported



Note: We are using OECD's sector classifications. Information and communication include the following sectors: Publishing; IT and other information services (sector codes 58-60 and 62-63). Professional service activities include the following sectors: Legal, accounting, management, architecture, engineering, technical testing and analysis activities; Scientific research and development; Other professional, scientific and technical activities (sector codes 69-75). Wholesale and retail include: wholesale; retail (sector codes 45-47). Construction include: Construction (sector codes 41-43). Real estate activities include: Real estate activities (sector code 68). The remaining sectors are included in Other.
Source: Copenhagen Economics based on Statistics Denmark, Input-output (link).

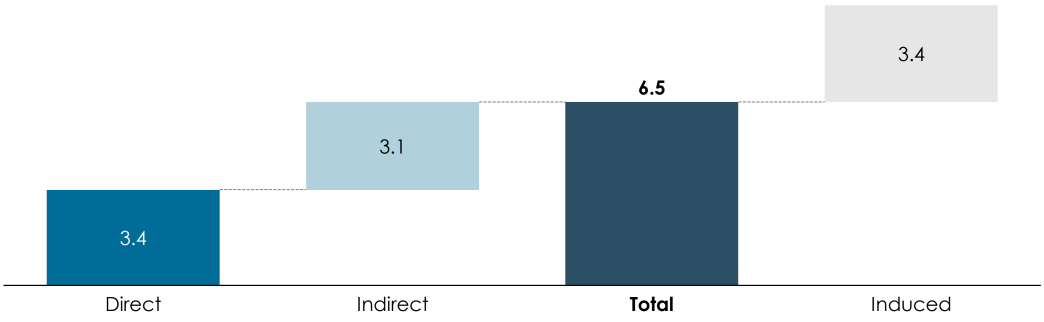
1.1.2 The investments made by the telecommunications sector supported an additional DKK 6.5 billion to the Danish economy in 2023

Employing the input-output model we can also estimate the economic contribution of investments made by the telecommunications sector in addition to the footprint of the sector's operations, covered in Section 1.1.1. Investments contribute to the Danish economy as they constitute purchases of goods and services from the sectors that receive the investments – here that is mainly construction companies, see Figure **8**.

Concretely, we estimate that the investments of DKK 10.5 billion made by the telecommunications sector in 2023 contributed to the Danish economy with DKK 6.5 billion, see Figure **5**. This is equivalent to 0.2 per cent of GDP or DKK 1,100 per citizen in Denmark.[10] Of this total contribution, DKK 3.1 billion comes from indirect effects, nearly matching the direct contribution of DKK 3.4 billion, resulting in a multiplier of 1.9. This means that for every unit of direct contribution, a similar additional amount is generated in the broader economy. Additionally, we estimate that the investments contributed to the Danish economy with DKK 3.4 billion in induced effects – this is the economic activity supported by the consumer expenditure linked to workers' earnings across the telecommunications value chain.

[10] Based on a GDP of DKK 2,805 billion, see Statistics Denmark (link), and on a population of 5,961,249 in ultimo 2023, see January 2024 in Danmarks Statistik, Befolkningstal (link).

Figure 5
Contribution to the Danish economy via investments made by the telecommunications sector in 2023
Billion DKK, 2023 prices



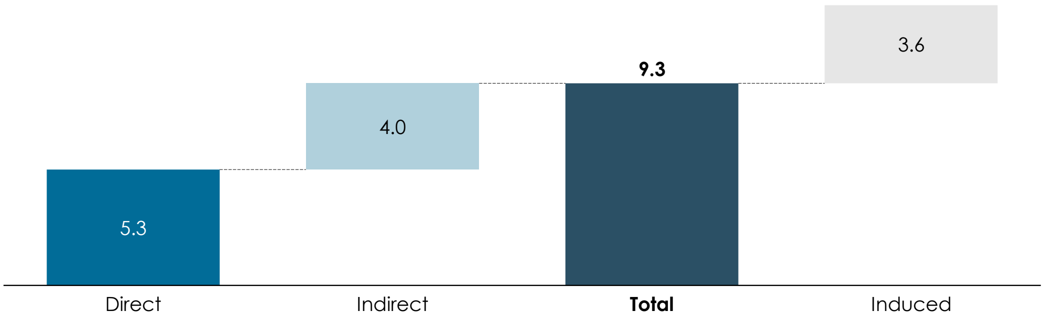
Note: We have used data from Klimadatastyrelsen on the total investments in 2023 by the telecommunications sector and data from IO-tables in the period 2015-2019 from Statistics Denmark to calculate a split between sectors receiving these investments and splitting them into foreign and domestic investments. We used the calculated domestic investments per sector to estimate impact using multipliers calculated using the newest IO table from 2023, find a description of the methodology in Appendix A.
Source: Copenhagen Economics based on Statistics Denmark, Input-output (link) and Klimadatastyrelsen, Økonomiske Nøgletal for Telebranchen 2023 (link).

We estimate the impact of investments by calculating 'revenue-multipliers' for all sectors that receive investments from the telecommunications sector. These multipliers express the effects on direct, indirect, and induced GDP contribution and employment per DKK in revenue. For example, we find that the direct and indirect revenue multipliers of the construction sector are 0.32 and 0.31, respectively. Based on this, we estimate that a DKK 1 billion investment from the telecommunications sector in construction yields DKK 0.32 billion and DKK 0.31 billion in direct and indirect GDP contribution, respectively. Direct multipliers capture profits, product taxes, and salaries in the relevant sector. Indirect multipliers capture purchases of intermediary goods and services from *domestic* companies. Imports of goods and services are not included, since they do not add to *Danish* GDP.[11]

In terms of employment, we find that the investments made by the telecommunications sector in 2023 supported Danish employment with 9,300 jobs (direct and indirect effect), see Figure **6**. Additionally, we find that a further 3,600 jobs were supported by the investment accounting for induced effects.

[11] See Appendix A for a complete description of the methodology.

Figure 6
Danish employment supported by investments made by the telecommunications sector in 2023
Thousand FTEs



Note: We have used data from Klimadatastyrelsen on the total investments in 2023 by the telecommunications sector and data from IO-tables in the period 2015-2019 from Statistics Denmark to calculate a split between sectors receiving these investments and splitting them into foreign and domestic investments. We used the calculated domestic investments per sector to estimate impact using multipliers calculated using the newest IO table from 2023, find a description of the methodology in Appendix A.
Source: Copenhagen Economics based on Statistics Denmark, Input-output (link) and Klimadatastyrelsen, Økonomiske Nøgletal for Telebranchen 2023 (link).

1.2 The sector invested DKK 85 billion from 2014 to 2023

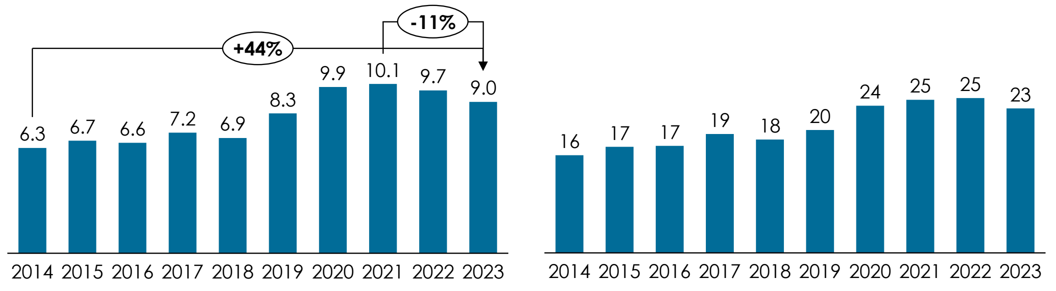
We find that the telecommunications sector has invested DKK 85 billion from 2014 to 2023 in nominal terms.[12] Annual investments have grown 44 per cent from 2013 to 2023 when controlling for inflation, see the left panel of Figure 7. In the same period, investment as a share of revenue has grown from 16 per cent in 2014 to 23 per cent in 2023, which illustrates that the sector has increased the focus on investments, see the right panel of Figure 7. However, we also note that investment levels peaked in 2021 at DKK 10.1 billion and have decreased by 11 per cent since then to DKK 9 billion in 2023. Similarly, investments as share of revenue have decreased from 25 per cent in 2021 and 2022 to 23 per cent in 2023.

[12] Klimadatastyrelsen, Økonomiske Nøgletal for Telebranchen 2023 (link). Note this is in nominal terms and thus does not match the sum of investments in real terms in Figure 7.

Figure 7

Investments by the telecommunications sector
Billion DKK, real prices

Investments by the telecommunications sector as a share of sector revenues
Per cent of revenue



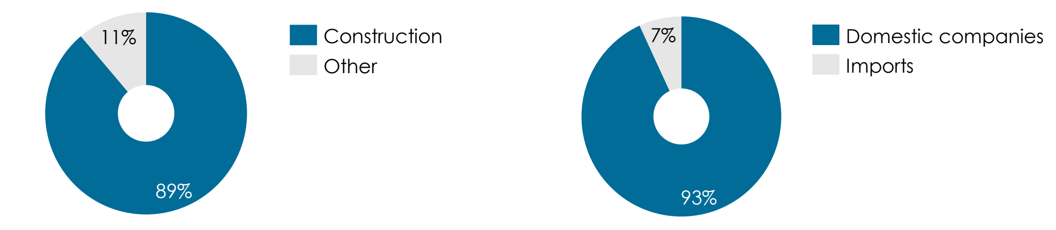
Note: Since we consider real prices in the left panel, investments sum to less than DKK 85 billion which is in nominal terms.
Source: Klimadatastyrelsen, Økonomiske Nøgletal for Telebranchen 2023 (link).

The investments made by the telecommunications sector particularly support blue collar jobs in Denmark. We find that 89 per cent of the investments flow into the construction sector,[13] see the first panel of Figure **8**, and stay with 93 per cent within Denmark, see the second panel of Figure **8**.

Figure 8

Average share of investment by the telecommunications sector going to construction vs. other industries
Per cent, 2015-2019

Average share of investments made by the telecommunications sector going to domestic companies vs. import
Per cent, 2015-2019



Note: The numbers are based on first-order purchases only. We have calculated the shares using Input-output investment tables from 2015 to 2019. We have calculated the total investments into each sector in the period and calculated the shares using the total investments.
Source: Copenhagen Economics based on Statistics Denmark, Input-output (link).

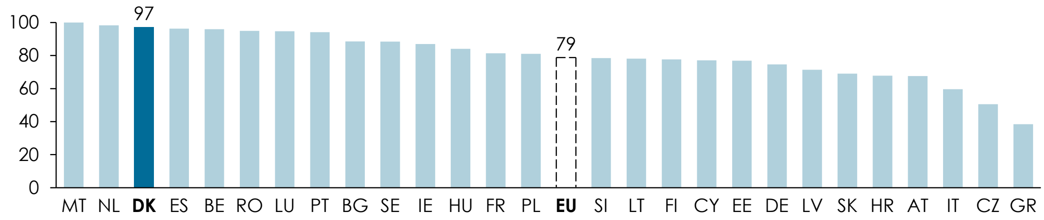
[13] Construction includes general and specialised construction activities for buildings and civil engineering works. It includes new work, repair, additions and alterations, the erection of prefabricated structures and constructions of a temporary nature, see Eurostat (2008), NACE Rev.2 - Statistical classification of economic activities in the European Community (link).

1.3 Denmark is at the forefront of digitisation compared to other European countries

In this section, we discuss how advanced Denmark is in terms of 5G and Very High Capacity Networks (VHCN). VHCN refers to an optical-fibre network connection, or a connection that is equivalent in terms of performance.[14] We find that high levels of investment by the telecommunications sector have positioned Denmark as one of the most digitalised countries in Europe.

In Denmark, both urban and rural populations benefit from advanced digital infrastructure. This is reflected in Denmark's coverage of VHCN, which stands at 97 per cent — the third highest in Europe — and is well above the EU average of 79 per cent, see Figure **9**. Also in rural areas, Denmark ranks third with 91 per cent coverage, exceeding the EU average 56 per cent in rural regions.[15]

Figure 9
Very High Capacity Network coverage
Per cent of households, 2023

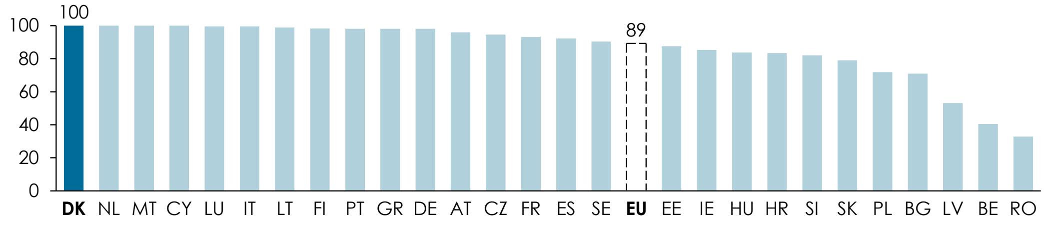


Note: Very High Capacity Network refers to an optical-fibre network connection or a connection that is equivalent in terms of performance to what is achievable by an optical fibre installation.[16]
Source: Copenhagen Economics based on Eurostat, Broadband internet coverage by technology (link).

Denmark also ranks top in Europe regarding 5G coverage, sharing the highest position with three other countries at 100 per cent, while the EU average is at 89 per cent, see Figure **10**. However, we note this is not yet 'Full' or 'Stand-alone' 5G in all networks across the country since most 5G networks rely on 4G core, which does not fully support 'next-generation' capabilities.[17] Also the fibre network is not yet at full coverage and further upgrades are needed e.g. to ensure sufficient capacity and security of the network, see further discussion in Section 3.1.

[14] See e.g. Thomson Reuters, Practical Law – Glossary (link).
[15] Eurostat, Broadband internet coverage by technology (link).
[16] Thomson Reuters, Practical Law – Glossary (link).
[17] See e.g. p. 98 in ETNO (2024), State of Digital Communications 2024 (link).

Figure 10
5G coverage
Per cent of households, 2023



Note: The Netherlands, Malta, and Cyprus also has a coverage of 100 per cent.
Source: Copenhagen Economics based on Eurostat, Broadband internet coverage by technology (link).

Both individuals and companies in Denmark gain from the high degree of digitalisation. For *individuals*, Denmark's high level of digitalisation brings convenience and efficiency. Citizens benefit from innovative digital solutions like NemID/MitID, which allow secure access to public services, banking, and private platforms online. Additionally, Digital Post ensures all communications from public authorities are received digitally, reducing paperwork and streamlining processes. Nearly 99 per cent of Danes use e-Government services, making Denmark a leader in the EU.[18]

For *companies*, digitalisation enhances business efficiency and competitiveness. Denmark ranks sixth globally in the Cisco Digital Readiness Index, excelling in areas like digital infrastructure (number one globally) and ease of doing business (number one globally). These strengths and a high level of technology adoption (number 15 globally) enable businesses to thrive in a highly digitalised economy.[19]

In this chapter, we have demonstrated that the telecommunications sector contributes significantly to GDP and supports jobs through its operations as well as investments, which put Denmark at the forefront of digitalisation. In the next chapter, we will examine how a well-developed digital infrastructure contributes even further to the Danish economy by enabling productivity growth for those using the infrastructure and by creating wider socio-economic benefits such as reducing emissions and increasing cybersecurity and resilience.

18 European Commission, DESI indicators – e-Government users (link).
19 Cisco, Digital Readiness Index (link).

CHAPTER 2

ADVANCED DIGITAL INFRASTRUCTURE HAS FAR-REACHING SOCIO-ECONOMIC BENEFITS

In today's fast-evolving digital landscape, futureproof digital infrastructure – designed to be adaptable, scalable, and resilient – is essential for addressing both current and emerging challenges and needs. Beyond its technological importance, it delivers significant socio-economic benefits, as we discuss in this section. Specifically, we explore how resilient digital infrastructure is critical to achieving key policy objectives in three areas: fostering productivity growth, promoting the green transition, enhancing IT security and resilience as well as ensuring the security of supply.

Firstly, we find that improvements to digital infrastructure contributed to economic growth. Based on estimates from existing studies scaled to the Danish context, we find that the average annual contribution to GDP from increases in download speeds and broadband adoption was between 0.38 and 0.60 per cent annually, equivalent to DKK 10.8 to 16.8 billion (DKK 1,800 to 2,800 per citizen) in GDP, over the last ten years (see Section 2.1).

Secondly, we discuss how futureproof digital infrastructure contributes to the green transition by i) lowering CO2 emissions from the network and ii) enabling the use of advanced technology downstream. We estimate that from 2019 to 2023, the network's improved energy efficiency reduced the networks emissions by 31 per cent. Substantial further reductions are enabled for those using advanced digital infrastructure by supporting the use of new, more energy efficient technology across the economy and society (see Section 2.2).

Thirdly, we discuss that according to the Centre for Cybersecurity, Denmark faces a high to very high threat regarding cyber espionage, cyber activism and cyber-crime. Efforts made by the telecommunications sector to mitigate those cyber threats provide far reaching benefits across all sectors and for all citizens and businesses using of the digital infrastructure (see Section 2.3).

2.1 Digital infrastructure drives economic growth by boosting productivity across the economy

In this section, we discuss how digital infrastructure supports economic growth by improving the productivity across the economy. Studies show that adoption and improvements in digital infrastructure is associated with achieving more efficient business processes, technological progress and supporting innovation,[20] which are key ingredients for economic growth.

To estimate the GDP contribution of improved digital infrastructure in Denmark specifically, we rely on results from existing studies scaled to the Danish economy. Overall, we estimate that advancements in digital infrastructure enabled economic gains of between DKK 10.8 and 16.8 billion in GDP annually between 2014 and 2023, equivalent to DKK 1,800 to 2,800 per Danish citizen annually.

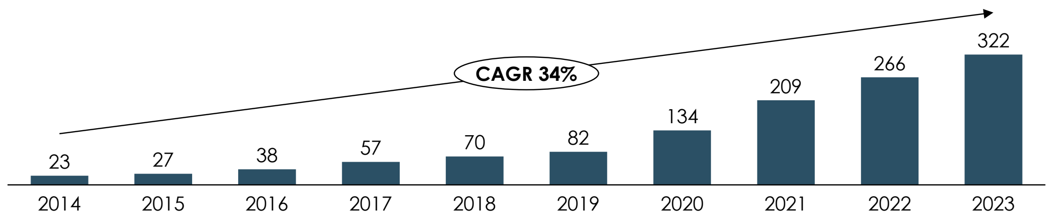
[20] Telecom Advisory Services (2020), Assessing the Economic Potential of 10G Networks (link). Briglauer, Krämer, and Palan (2023), Socioeconomic benefits of high-speed broadband availability and service adoption: A survey (link).

We estimate this GDP contribution by looking at the impact of two cumulative measures of advancement in digital infrastructure, which have been discussed in the academic literature: 1) the impact of fixed broadband download speed and 2) the impact of broadband adoption.[21] According to existing studies, improvements in broadband speed drive the adoption of more efficient business processes and accelerate the introduction of new products, services, and innovative business models.[22] Further, increased broadband adoption leads to positive effects in product innovation, technological progress, and efficiency gains.[23] According to Briglauer, Krämer, and Palan (2023), all these positive effects ultimately lead to an impact on GDP.[24] Digital infrastructure is likely to have an impact on productivity and economic growth also via other channels, however, those are less widely studied.

GDP impact of fixed broadband download speed

Historically, fixed broadband download speeds have increased rapidly. In Denmark, fixed broadband download speeds have increased 14-fold in the last ten years, from a median speed of 22.5 Mbps in 2014 to 321.9 Mbps in 2023.[25] This corresponds to a compound annual growth rate (CAGR)[26] of 34 per cent over the last ten years, see Figure **11**. This substantial14-fold increase is attributable both to an increase in the availability of high-speed internet, and to an increase in high-speed internet adoption.[27]

Figure 11
Median fixed broadband download speed in Denmark
Mbps



Note: CAGR (Compound Annual Growth Rate) represents the average annual growth rate over a specified period, assuming consistent growth each year.
Source: Klimadatastyrelsen, Internet dataark, 2. halvår 2023 (link).

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21 In total, these two effects give an annual GDP contribution of 0.38 per cent to 0.60 per cent, as we derive below, equivalent to DKK 10.8 to 16.8 billion in GDP annually.
22 Telecom Advisory Services (2020), Assessing the Economic Potential of 10G Networks (link).
23 Briglauer, Krämer, and Palan (2023), Socioeconomic benefits of high-speed broadband availability and service adoption: A survey (link).
24 Briglauer, Krämer, and Palan (2023), Socioeconomic benefits of high-speed broadband availability and service adoption: A survey (link), p. 9.
25 Klimadatastyrelsen, Internet dataark, 2. halvår 2023 (link).
26 CAGR (Compound Annual Growth Rate) represents the average annual growth rate over a specified period, assuming consistent growth each year.
27 According to European Commission, DESI indicators – Fixed Very High Capacity Network (VHCN) coverage (link), coverage grew from 63 per cent in 2017 to 97 per cent in 2023. Further, according to Klimadatastyrelsen, Internet dataark, 2. halvår 2023 (link), the number of fibre subscribers (fibre to private) in Denmark grew from 331,246 in the first half of 2014 to 1,167,052 in the second half of 2024.

A study by Telecoms Advisory Services[28] finds that a 100 per cent increase in fixed broadband download speed results in a GDP increase of 0.26 per cent for download speeds below 40 Mbps, and a 0.73 per cent increase for download speeds above 40 Mbps. Their estimates are based on panel data for 159 countries, between 2008 and 2019. In their econometric model, they include the broadband adoption rate to be able to separate the speed effect from the broadband adoption effect. The estimates by Telecom Advisory Services (2020) are comparatively more conservative compared to other studies, such as Carew et al. (2018)[29] who find that a 100 per cent increase in internet speed results in a GDP increase of 1.97 per cent, and Kongaut et al. (2017)[30] who find that a 100 per cent increase in broadband speed leads to a 1.47 per cent increase in GDP.

Scaling the results of Telecom Advisory Services (2020) to Denmark, we estimate that increased download speeds resulted in an average annual GDP contribution of 0.08 per cent for the period 2014-2017 (where the median download speed was below 40 Mbps[31]), and an average annual contribution of 0.25 per cent for the period 2018-2023 (where the median download speed was above 40 Mbps).[32]

GDP impact of broadband adoption

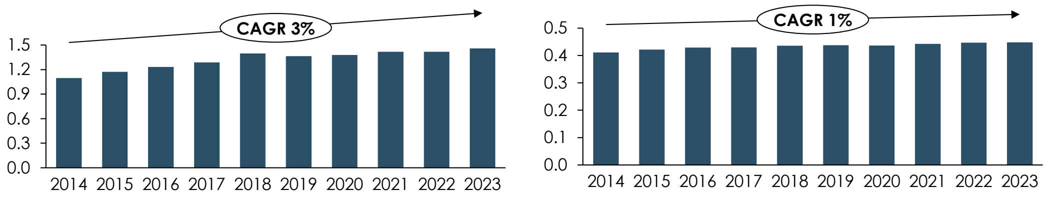
Apart from the increase in download speeds, the adoption of mobile and fixed broadband has also increased substantially over the last ten years. From 2014 to 2023, the number of mobile broadband subscriptions per capita in Denmark increased from 1.10 to 1.46, and the number of fixed mobile broadband subscriptions increased from 0.42 to 0.44, see Figure **12**.

28 Telecom Advisory Services (2020), Assessing the Economic Potential of 10G Networks (link).
29 Carew, Martin, Blumenthal, Armour, and Lastunen (2018), The Potential Economic Value of Unlicensed Spectrum in the 5.9 GHz Frequency Band (link).
30 Kongaut and Bohlin (2017), Impact of broadband speed on economic outputs: An empirical study of OECD countries (link).
31 Even though the median download speed in 2017 was above 40 Mbps, our estimate for the contribution to GDP in 2017 is included in the <40 Mbps period. This is because the median download speed in 2016, which we use in calculating the annual growth in 2017, was below 40 Mbps.
32 Our estimate is based on median download speeds in Denmark, while Telecom Advisory Services (2020) (link) use average download speeds to estimate the GDP impact. Consequently, our median-based estimate may differ compared to what would be obtained using average download speeds.

Figure 12

Mobile broadband adoption
Subscriptions per capita

Fixed broadband adoption
Subscriptions per capita



Note: Mobile broadband subscriptions include all subscriptions, both data-only and combined data and voice subscriptions, that give access to mobile-broadband networks that provide a minimum download speed of 256 Kbps. CAGR (Compound Annual Growth Rate) represents the average annual growth rate over a specified period, assuming consistent growth each year.

Source: OECD, Going Digital Data Kitchen - Mobile Broadband (link) and OECD, Going Digital Data Kitchen - Fixed Broadband (link).

To estimate the historical effect of increased broadband adoption on GDP, we use an estimate from Briglauer, Cambini, and Gugler (2023)[33] who study the effect of an increase in fixed and mobile broadband adoption on GDP. Briglauer, Cambini, and Gugler (2023) show that a 1 per cent increase in fixed broadband adoption raises GDP by 0.026-0.034 per cent, and that a 1 per cent increase mobile broadband adoption raises GDP by 0.079-0.088 per cent. Their estimates rely on comprehensive panel data for 32 OECD countries for the years 2002 to 2020.

Combining the results from Briglauer, Cambini, and Gugler (2023) with data on per capita broadband subscriptions in Denmark, we find that from 2014 to 2023, the rise in fixed and mobile broadband adoption contributed an average of 0.018-0.024 per cent per year to GDP for fixed broadband and 0.29-0.32 per cent per year for mobile broadband.[34]

[33] Briglauer, Cambini, and Gugler (2023), Economic benefits of high-speed broadband network coverage and service adoption: Evidence from OECD member states (link).

[34] If we instead use the results of Czernich, Falck, Kretschmer, and Woessmann (2011), Broadband infrastructure and economic growth (2011) (link), who find that a 10 percentage point increase in fixed broadband penetration (defined as the number of fixed broadband subscriptions per 100 inhabitants) leads to a 0.9-1.5 per cent increase in GDP, we find a larger annual GDP contribution, on average 0.03-0.04 per cent for the 2014-2023 period.

2.2 Infrastructure investments enable the green transition by reducing CO2 emissions

In the following, we discuss how digital infrastructure investments advance the green transition and thereby the emission targets of the Danish Climate Act[35]. Firstly, we investigate how investments in digital infrastructure enable more energy-efficient technologies related to data use in the network directly. Secondly, we discuss how advanced digital infrastructure enables new solutions downstream, for instance smart grids in the energy sector and route optimisation through data sharing in the transport industry.

We find that compared to a scenario where energy efficiency had not improved since 2019, improved energy efficiency contributed 31 percentage points to the total reduction in the network's CO2 emissions from its electricity consumption between 2019 and 2023. We estimate this following two steps.

Firstly, we estimate that the CO2 emissions from network electricity consumption have decreased by 36 per cent (from 43,137 to 27,542 tons) between 2019 and 2023.[36] This is driven by two factors: 1) decrease in the CO2 intensity of electricity in Denmark and 2) increased energy efficiency of the network implying lower CO2 emissions per unit of data consumed.

Secondly, we estimate the CO2 emission in a counter factual scenario where energy efficiency levels had stayed at 2019 levels and find that CO2 emission would have only decreased by 5 per cent in the same period. In absolute numbers, this means that, in total, 42,292 metric tonnes of CO2 emissions have been avoided between 2019 and 2023 due to the increased energy efficiency of the mobile and fixed broadband network in Denmark compared to 2019 levels.[37] This is equivalent to the emissions of 3,250 Danes.[38]

While data needs have been steadily increasing[39], continued investments in digital infrastructure have led to improved energy efficiency of the network. At 12 MWh of electricity per PB of data still in 2019, by 2023 the energy intensity of mobile and fixed broadband had dropped to 8.1 MWh of

35 Danish Ministry of Climate, Energy and Utilities, Climate Act (english translation) (link)

36 We estimate the CO2 emissions from the network electricity consumption by firstly estimating the total amount of traffic (units in data) in the Danish mobile and fixed broadband network. To calculate this, we use information on the total data traffic in TDC Net's entire network between 2019 and 2023 (Annual Report 2023 (link)), split between fixed and mobile via the total up and download traffic at the consumer level in the fixed and mobile broadband network (Klimadatastyrelsen, Internet dataark, 2. halvår 2023 (link); Klimadatastyrelsen, Hovedtal dataark, 2. halvår 2023 (link)) and scaled to all of Denmark based on TDC market shares (TDC (2016), Svar på Erhvervsstyrelsens høring om bredbåndsmarkeder (link); TDC Net (2023), Annual Report 2023 (link)). Secondly, we use information on the energy intensity, i.e. the amount of electricity (MWh) consumed per unit of data (PB), in TDC Net's network between 2019 and 2023 (TDC Net (2023), Annual Report 2023 (link)), assuming this is the same across the Danish network. Thirdly, we use information on the average amount of CO2 used to produce and deliver one unit of electricity, i.e. the annual average CO2 intensity of electricity from Energinet (Energinet (2023), Baggrundsdata for Miljøberetningen 2023 (link)). See Appendix A for more details.

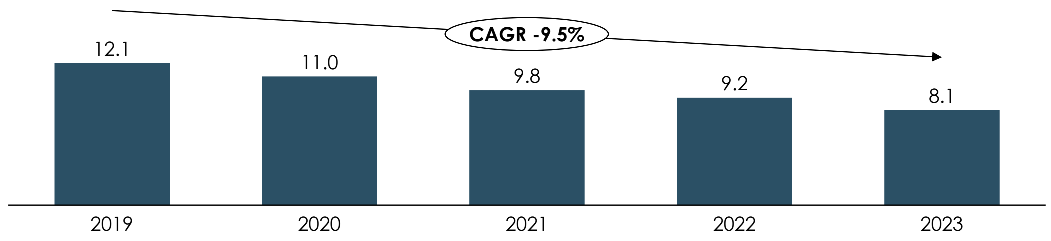
37 To calculate avoided emissions, we use the average annual historical and future emission intensity of electricity (CO2 per unit of electricity) from Energinet (2023), Baggrundsdata for Miljøberetningen 2023 (link). If the network's electricity consumption is in reality uneven throughout the year, using the average annual emission intensity means that we either over or underestimate the avoided emissions due to network energy efficiency improvements.

38 According to CONCITO (2023), Danmarks globale forbrugsudledninger, the average Dane's global emissions is 13 tons annually.

39 See for instance Klimadatastyrelsen, Internet dataark, 2. halvår 2023 (link), Klimadatastyrelsen, Hovedtal dataark, 2. halvår 2023 (link), which shows that total consumer traffic in the mobile network grew from 449,151 TB in 2019, to 1,207,361 TB in 2023, and from 3,579,408 TB to 6,677,543 TB in the fixed network.

electricity per PB of data. This corresponds to a compound annual decline of 9.5 per cent over five years, see Figure **13**.

Figure 13
Development in the mobile and fixed broadband network's energy intensity
MWh of electricity/PB of data



Note: We assume that the development in the rest of the Danish network is the same as the development in TDC NET's network. CAGR (Compound Annual Growth Rate) represents the average annual growth rate over a specified period, assuming consistent growth each year.
Source: TDC Net (2023), Annual Report 2023 (link).

The increase in energy efficiency has been made possible by employing more energy-efficient technologies, such as fibre instead of copper and 5G instead of 4G.[40] According to Telefónica, FTTH broadband (fibre to the home) is 85 per cent more energy efficient than the copper network.[41] According to Ericsson[42] and Nokia[43], 5G is between 70 per cent and 90 per cent more energy efficient than 4G. In rural areas, sleep mode solutions mean that 5G could consume as little as one tenth the amount of electricity that 4G does to deliver one unit of data through the network. In urban areas, an energy reduction of up to 70 per cent is achievable if the entire network is upgraded to 5G.[44] We note however that while 5G is more efficient than 4G per unit of data, 5G users tend to consume more data.[45]

In addition to reduced emissions due to the increased energy efficiency of the network, future advancements in ICT technology can enable other industries to reduce emissions, which is crucial for reaching climate goals and Net Zero targets. Estimates from The World Economic Forum suggest that ICT solutions, and in particular 5G, could "*help reduce global carbon emissions by up to 15% – or one-third of the 50% reduction required by 2030 – through solutions in energy, manufacturing, agriculture and land use, buildings, services, transportation and traffic management*."[46]

40 Teleindustrien, Dansk Erhverv, and DI (2024), Aftale om Digital Infrastruktur 2025 – 2030, p. 16 (link); TDC Net (2023) Annual Report 2023, p. 31 (link).
41 Telefónica (2019), Telefónica issues the first green bond of the telco sector, amounting to 1 billion euros (link).
42 Ericsson (2023), ICT energy - The energy use and enablement effect of the Information and Communication Technology industry (link).
43 Nokia (2020), Nokia confirms 5G as 90 percent more energy efficient (link).
44 Ericsson (2023), ICT energy - The energy use and enablement effect of the Information and Communication Technology industry (link).
45 See for instance Nokia (2024), Nokia report reveals 5G data consumption four times faster than 4G in India (link), which reports that "5G users on average consume up to 3.6x more data compared to 4G users."
46 World Economic Forum (2019), Digital technology can cut global emissions by 15%. Here's how (link).

Smart grids in the energy sector and route optimisation through data sharing in the transport industry are examples for how developments in digital infrastructure could enable the green transition, see Box 1. In addition to these two examples, there are many other ways in which digital infrastructure enables substantial emission reductions. Other examples are digital services replacing CO_2-intensitve physical products, or better digital access enabling online meetings which reduced travel-related emissions.

Box 1 Examples for how developments in digital infrastructure could enable new solutions downstream supporting the green transition

Electricity generation and utilities

Electricity demand is expected to increase over the coming two decades. At the same time, renewables such as solar and wind will generate a substantially larger share of electricity. According to Ericsson, when the utility sector relies more on renewable energy, electricity producers will face management and operational challenges. Energy production will be more volatile, with many small, scattered power sources and grid capacity limits, putting strain on load balancing and energy planning. In addition, these challenges will be complicated further by more households installing solar panels, leading them to become both producers and consumers – known as *prosumers* – of electricity.[47]

According to a MIT Technology Review Insights report[48], connected and automated smart grids, supported by 5G, will play a crucial role in tackling these management and operational challenges. Through real-time data from smart meters and sensors, smart grids will bring improved automation and control, enabling power companies and utility operators to manage the two-way energy flows from prosumers and balancing renewable energy fluctuations.[49]

Transports

Integrating transportation and communication networks—such as telematics, smart city analytics, and traffic management—can lead to efficiencies that reduce emissions. However, according to MIT and Ericsson, a key challenge in speeding up decarbonisation of the transport sector through connectivity is that most transport systems remain siloed. "*Fleets of trucks operated by logistics firms, public subway operators, or individual drivers of vehicles largely exist in separate parallel data universes*"[50].

One example of how the transportation sector can reduce emissions through data sharing is route optimisation for electric vehicles, which requires data on road conditions, traffic patterns, congestion, charging infrastructure, grid use, and vehicle location. This enormous flow of this data relies on cellular communications, with 5G being essential for a fossil-free transportation sector.[51]

Other examples of how digital infrastructure could enable the green transition include optimisation of port processes, automated building management systems, automated field robots in agriculture, smart city solutions, and many more.[52]

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47 Ericsson (2023), ICT energy - The energy use and enablement effect of the Information and Communication Technology Industry (link).
48 MIT Technology Review (2021), Decarbonizing industries with connectivity & 5G (link).
49 See also European Commission, Flexibility markets (link).
50 Ericsson (2023), ICT energy, The energy use and enablement effect of the Information and Communication Technology Industry (link).
51 Ericsson (2023), ICT energy, The energy use and enablement effect of the Information and Communication Technology Industry (link).
52 European Green Digital Coalition, Case study calculators (link).

2.3 Investments are required for keeping digital infrastructure resilient and safe against cyber-attacks

As societies and economies become more reliant on digitalisation, digital infrastructure is likely to become even more central for generating economic growth and benefits. However, the increased digitalisation will not only create more benefits but also more risks in terms of cyber threats.[53]

As we discuss in this section, digital infrastructure in Denmark, similar to the rest of Europe and the world, faces significant cyber threats. To lower the risk of attacks and network breakdowns, the sector engages and invests in many activities. As the reliance on digital infrastructure grows, the costs associated with a potential network break-down or a cyber-attack on an individual or company level, or for whole regions can be large and are likely to be even larger in the future. Strengthening network resilience and cybersecurity safeguards the Danish economy and society as a whole, with the true cost of failure only revealed when the systems break down.

The Centre for Cybersecurity states that "*Denmark is still [2024] a prime target for malicious actors*".[54] We can distinguish threats, as identified by the Danish Centre of Cybersecurity, by the agent and the purpose as well as whether they occur at the user level or the structural level:[55]

- *Threats at structural level*: Cyber espionage, destructive cyber-attacks and cyber activism are the most common tactics in state-on-state cyber operations and are mainly done by state-sponsored hackers to steal information or disrupt activities. The purpose of cyber terrorism is to conduct terrorism via the cyber domain.
- *Threats at user level*: The actors conducting cyber-crime are typically non-political and opportunistic in pursuit of financial gain. Consequently, cyber-crime can affect everyone.

According to the Centre for Cybersecurity, Denmark as a whole faces a high or very high threat regarding two out of four structural threats (i.e. cyber espionage and cyber activism) and a very high threat on user level (i.e. cyber-crime) across all industries, see Figure **14**. On sector level, the risk of cyber espionage and cyber activism are especially high for Energy and Transport.

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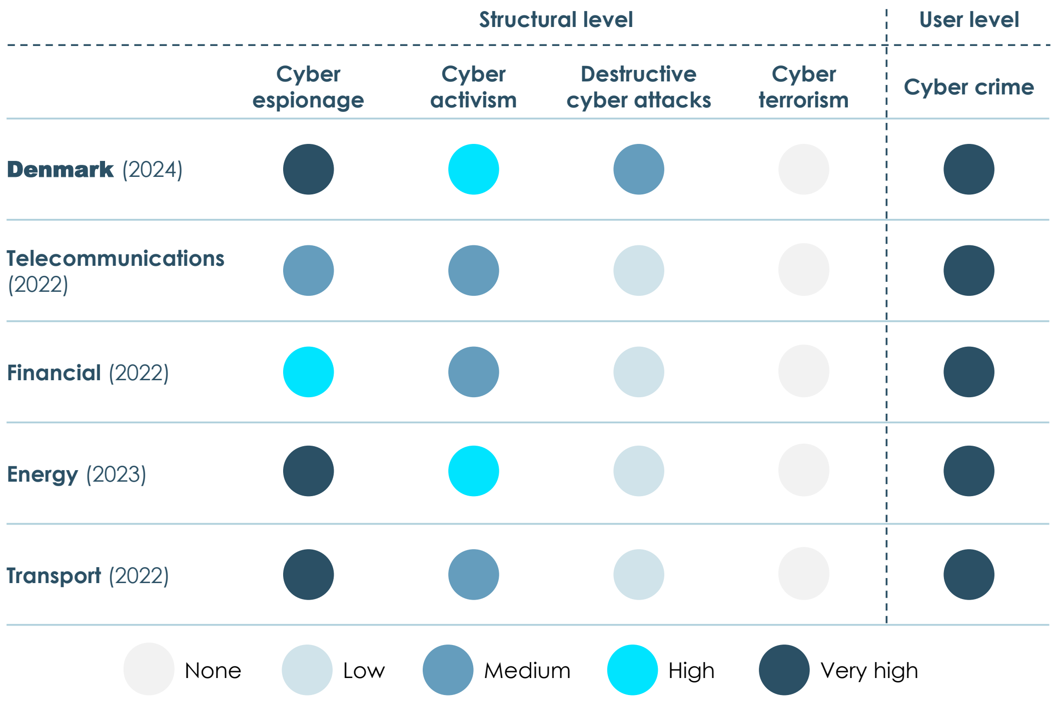
53 European Commission (2020), The EU toolbox for 5G security (link).
54 Centre for Cybersecurity (2024), The cyber threat against Denmark (link), p. 6.
55 Based on Centre for Cybersecurity (2024), The cyber threat against Denmark (link).

Figure 14
The cyber threat against Denmark and key sectors
Centre for Cybersecurity threat assessments across sectors (year of assessment)



Note: The threat assessments are not all from the same year and older assessments might be lower than what is the case.

Source: Denmark: Centre for Cybersecurity (2024), The cyber threat against Denmark (link); Telecommunication: Centre for Cybersecurity (2022), The cyber threat against the telecom sector (link); Financial: Centre for Cybersecurity (2022), The cyber threat against the Danish financial sector (link); Energy: Centre for Cybersecurity (2023), The cyber threat against the Danish energy sector (link); Transport: Centre for Cybersecurity (2022), The cyber threat against the Danish land and air transport (link).

While the specific threat to the telecommunications sector is not higher than for other key sectors, efforts to mitigate the threats by the telecommunications sector will likely affect the ability to resist cyber threats across all sectors. The Centre for Cybersecurity has highlighted that more complex technologies will create increasing demands on the sector to keep digital infrastructure updated and adequately protected to resist cyber threats.[56]

The telecommunications sector exerts continued efforts to make networks safe (i.e. improve cybersecurity and minimise cyber-threats) and resilient (i.e. minimise downtime) with far reaching benefits across all sectors and for all citizens and businesses using the digital infrastructure. The efforts include for example increasing cyber security (e.g. updating systems and educating personnel), risk management (e.g. updating risk management system), business continuity management (e.g. disaster recovery and crisis management), physical safety (e.g. data centre and site safety), and following

[56] Centre for Cybersecurity (2022), The cyber threat against the telecom sector (link).

current legislation (e.g. NIS2 activities).[57] While in the following we will focus mainly on cybersecurity, we note that efforts to improve cybersecurity often also support network resilience if for example cyber-attacks that threaten the security of supply can be mitigated.

To mitigate **structural level threats**, the sector's efforts are twofold:

- The sector invests to ensure safe networks, avoid espionage, support anti-terror activities, and similar. Besides working closely together with governmental bodies,[58] operators comply with legal guidelines when selecting equipment suppliers – even when this limits the number of available vendors and/or could lead to higher costs for operators.[59]
- The sector exerts efforts to build resilient networks with no downtime. This is done by an ongoing focus on resilience against and fast response to potential incidents.[60]

Structural failures leading to wider breakdowns of telecommunications services can have considerable consequences for all users of the infrastructure and the entire economy. For example, businesses may face loss of revenue (for businesses that rely on online sales or provide online services) or face operational disruptions and productivity losses (as e.g. communication channels, cloud-based data and computing systems, supply chains and logistics break down). Critical services like healthcare, emergency response, and energy supply may also be affected with far reaching consequences not just for the economy but society at large. The total costs associated with an internet breakdown is likely to depend on the exact scale, duration and sectors affected.

We have investigated publicly availably sources to find estimates on the potential costs associated with a breakdown in digital infrastructure. There are some studies that attempt to provide an indication of the magnitude of such costs:

- A widely referenced report from the analysis company Gartner in 2014 reports that large companies face costs of USD 5,600 per minute of unplanned downtimes and small companies between USD 137 – 427 per minute.[61] This corresponds to DKK 2.3 million per hour for large companies and DKK 57,000 – 177,000 per hour for smaller companies.[62]
- A more recent study conducted by the Ponemon Institute from 2016 finds that the average cost of an unplanned outage was USD 9,000 per minute per incident for data centres.[63] This corresponds to DKK 3.7 million per hour.[64]
- A study by Deloitte in 2016 of the economic impact of disruption to internet connectivity finds that temporary internet shutdowns in 'high connectivity' countries (corresponding to a 35 per cent broadband penetration which is very low today) could lead to an economic loss of around 1.9 per cent of daily GDP.[65]

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57 Based on information from telecommunications operators.
58 Center for Cybersikkerhed (2022), En sikrere teleinfrastruktur i Danmark (link).
59 See e.g. Berlingske (2024), TDC Net bekræfter: Alt Huawei-udstyr er væk til tiden (link).
60 See e.g. TDC Net (2023), Annual report 2023 (link), p. 47.
61 Forbes (2022), How to Guard Against The Cost Of Unplanned Downtime And Network Outages (link) and Pingdom (2023), Average Cost of Downtime per Industry (link).
62 We do not adjust prices by inflation. We have converted to an hourly DKK cost by multiplying with 60 (number of minutes) and using the average 2023 USD/DKK exchange rate of 6.8895.
63 Ponemon Institute (2016), Cost of Data Center Outages
64 We do not adjust prices by inflation. We have converted to an hourly DKK cost by multiplying with 60 (number of minutes) and using the average 2023 USD/DKK exchange rate of 6.8895.
65 Deloitte (2016), The economic impact of disruptions to internet connectivity

As an illustrative example, we use the per minute cost range for small and large companies, from Gartner 2014 mentioned above, to calculate a high-level, exploratory estimate of the cost associated with a one-hour breakdown of telecommunications services. This illustration suggests that in aggregate it could cost Danish companies as much as DKK 3.5 to 6.5 billion per hour[66] if digital infrastructure breaks down and companies experience downtime. The effect will be larger with longer periods of downtime. These sources are high-level estimates with a margin of uncertainty and do not constitute a full-fledged model of the economy, thus also the numbers which, on this basis, we have calculated for Denmark should be interpreted as high-level, exploratory estimates.

Regarding **user level threats**, the telecommunications sector exerts efforts to reduce cyber-crime by providing spoofing protection, blocking links and websites, and providing SMS and mobile identity protection.[67] Such efforts generate benefits to citizens and businesses lowering the societal cost related to cyber-crime, see Box 2.

66 We estimate this using an estimate of the average cost of downtime of USD 5,600 per minute for large enterprises and between USD 137-427 for smaller companies. We extrapolate this per minute cost linearly to estimate the cost per hour and for longer time intervals. However, the true cost might be decreasing with time as companies adjust operations. We use the number of large companies in Denmark (927) and the number of companies with between 10-249 employees (24,456) in 2022, see Statistics Denmark. FGF3: Preliminary general enterprise statistics by industry (link). We exclude the companies with less than 10 employees to reduce the risk of overestimating the effect. See Appendix A for a detailed description of the methodology.

67 See e.g. Teleindustrien, Dansk Erhverv, and DI (2024), Aftale om Digital Infrastruktur 2025 – 2030 (link).

Box 2 The cost of cyber-crime

Cyber-crime affects both individuals and businesses and can in some cases have wide societal impacts.

Cyber-crime targeting individuals can lead to considerable costs for those affected:

- A German study from 2015 estimated that cyber-crime against individuals – phishing, identity theft, consumer fraud, and malware – leads to societal costs of 0.1 per cent of GDP every year.[68]
- Translating this finding to a Danish context, we estimate that the yearly societal cost of cybercrime could be up to DKK 2.8 billion.[69]

Cyber-crime targeting companies can lead to considerable costs for the company and within certain sectors cyber-attacks lead to even larger societal impacts.

- One example of cyber-crime targeting a key societal sector, is the digital ransomware attack on the Colonial Pipe – a pipeline from Texas to New Jersey in the US – in 2021. The cyber-attack created a widespread disruption of US fuel supply along the East Coast, such that the president declared a state of emergency.[70] We do not know the exact societal cost of such an attack, but they are significant.
- An example from Denmark is the cyber-attack on A.P. Møller Mærsk in the summer of 2017, which disrupted shipping and terminal operations for 12 to 24 hours. The attack resulted in a direct loss for Mærsk of around DKK 1.6 to 1.9 billion[71] and likely impacted customers by interrupting their supply chains.

Leading US experts expect the global annual cost of cybercrime to triple from USD 8.4 trillion in 2022 to more than USD 23 trillion in 2027.[72] Assuming a similar trend in Denmark, the cost of cybercrime could increase rapidly in the coming years.

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68 DIW Berlin (2015), Tatort Internet: Kriminalität verursacht Bürgern Schäden in Milliardenhöhe (link).

69 Using GDP in 2023 of DKK 2,805 bn. Note this is only an approximation since the results are almost 10 years old and Denmark is significantly more digitalised than Germany. This can have conflicting effects since Danes are likely more internet literate which, we expect, would decrease the cost of cybercrime but on the other hand Denmark is more digitalised and hence likely more vulnerable to cybercrime.

70 See e.g. Coverlink (2024), Cyber Case Study: Colonial Pipeline Ransomware Attack (link).

71 See Finans (2017), Hackerangreb på Mærsk koster mindst 1,6 mia. kr. (link).

72 U.S. Department of State (2023), Digital Press Briefing with Anne Neuberger, Deputy National Security Advisor for Cyber and Emerging Technologies (link).

CHAPTER 3

CONTINUED INVESTMENTS ARE NEEDED TO MAKE DIGITAL INFRASTRUCTURE FUTUREPROOF AND DELIVER FURTHER BENEFITS

In this chapter, we outline the need for continued investment in digital infrastructure to ensure that it remains future-proof and continues delivering socio-economic benefits. As digital demands grow and technological developments such as 5G, edge computing, and AI reshape the landscape, substantial investments are required to keep pace with new advancements, meet connectivity targets and increasing safety requirements (see Section 3.1).

Furthermore, we explore how ongoing investments can deliver significant benefits to society. First, we show that continued investments at levels similar to the last five years will support DKK 5.6 billion in GDP and 8,000 jobs yearly until 2030 (see Section 3.2.1). Secondly, we find that increased download speeds by further adoption of modern broadband technologies could contribute 0.10 to 0.18 per cent annually to GDP until 2030 (see Section 3.2.2). Finally, we explore how further adoption of modern broadband can reduce CO_2 emissions (see Sections 3.2.3).

3.1 Substantial investments are needed to keep up with connectivity targets, demand, and technological developments

Historically, the Danish telecommunications sector has been fast at embracing and implementing new technologies. This has made Denmark one of the most digitalised countries in Europe and the world and has created economic benefits for society, as discussed in Chapters 1 and 2. However, past successes do not ensure future ones, and today's telecommunications networks are facing a major transformation. A future-proof digital infrastructure relies on networks capable of responding to evolving societal needs alongside significant technological advancements.

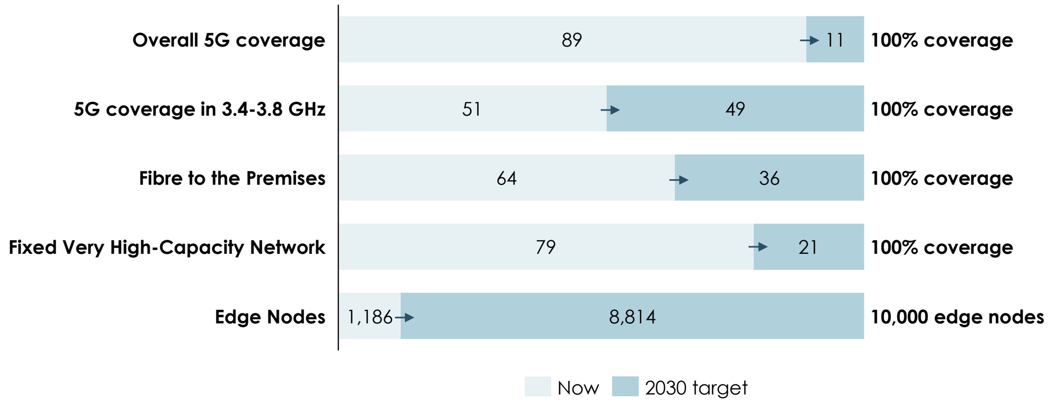
As we discuss in this section, futureproof digital infrastructure needs to i) achieve the EU's 2030 connectivity targets[73], and ii) respond to the increasing demand for bandwidth, speed, low latency, and ubiquitous access required to iii) support the mass adoption of emerging technologies such as edge computing, cloud computing, or artificial intelligence, and iv) comply with increasing security requirements and legislation. This requires large-scale investments, including network equipment, civil engineering works, and labour.

Firstly, the European Commission has set ambitious **connectivity targets** for the EU and has estimated that the investment needed to reach connectivity goals in Europe alone could be as high as

73 European Commission (2024), State of the Digital Decade 2024 report (link).

EUR 148 to 227 billion.[74] The digital infrastructure targets include 100 per cent coverage by 2030 of known technologies such as 5G, Fibre to the Premises, and Fixed Very High-Capacity Networks, see Figure **15**. Additionally, the European Commission aims to increase the number of edge nodes in the EU tenfold to 10,000 in 2030 and have targets for both semiconductor production and quantum computing.[75]

Figure 15
European digital infrastructure targets



Note: We have only included targets directly targeting the telecommunications sector.
Source: European Commission (2024), State of the Digital Decade 2024 report (link).

While the investments needed to reach the connectivity targets are likely lower in Denmark compared to other EU countries, since Denmark is a leader in terms of digital infrastructure (see Section 1.3), some additional investments are still required to reach all targets fully. Similar to the rest of Europe, 5G in Denmark is not yet 'Full 5G' or 'Stand-alone 5G', which requires new 5G core to support the new technologies with 'next-generation capabilities',[76] but to some extent still uses 4G infrastructure.

Secondly, expected **growth in data consumption** – especially over mobile networks – will require further investment in digital infrastructure to ensure a robust network that can accommodate future data consumption. The demand for digital services is expected to increase substantially both in Denmark and in the EU as a whole. In Denmark, data consumption over mobile networks is forecasted to increase from around 22 GB per month in 2022 to 96 GB per month in 2030 corresponding to a compound annual growth rate (CAGR)[77] of 20 per cent, see Figure **16**. The trend is similar for fixed infrastructure where consumption will increase to more than 1,000 GB per month in 2030

[74] European Commission (2024), White Paper – How to master Europe's digital infrastructure needs? (link). The range is including additional investments in 'transport corridors': *"current Digital Decade targets for Gigabit connectivity and 5G may require a total investment of up to EUR 148 billion (…). A further EUR 26-79 billion of investments may be required under different scenarios to ensure full coverage of transport corridors including roads, railways, and waterways, bringing the required total investment needs for connectivity alone to over EUR 200 billion".*

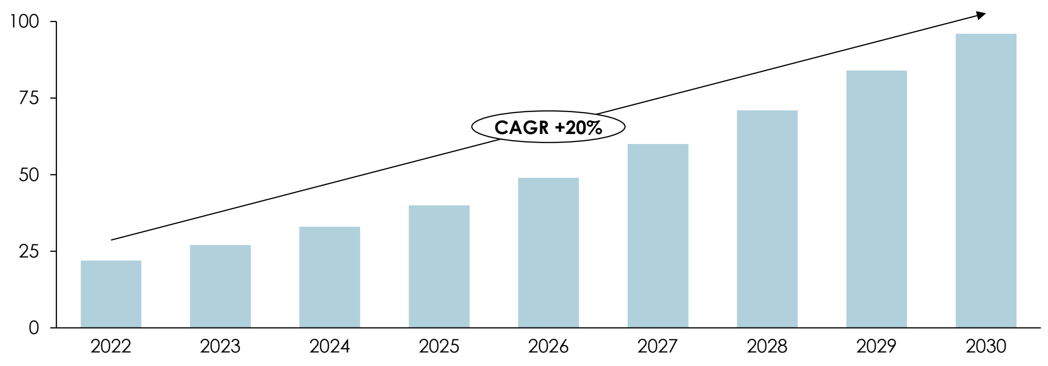
[75] European Commission (2024), State of the Digital Decade 2024 report (link).

[76] See ETNO (2024), State of Digital Communications 2024 (link), p. 98.

[77] CAGR (Compound Annual Growth Rate) represents the average annual growth rate over a specified period, assuming consistent growth each year.

up from 278 GB per month in 2022 corresponding to a CAGR of 18 per cent.[78] We expect that especially for – but not limited to – mobile networks further investments are needed to accommodate the growth in data consumption.

Figure 16
Forecast of data consumption over mobile infrastructure in Denmark
GB per month



Note: CAGR (Compound Annual Growth Rate) represents the average annual growth rate over a specified period, assuming consistent growth each year.
Source: Arthur D. Little (2023), The evolution of data growth in Europe (link), Table 1.

Thirdly, **new technologies** will drive an increased need for investments. In a whitepaper concerning digital infrastructure needs, the European Commission states that new business models and entirely new markets are emerging from technological developments around the App Economy, IoT, Data Analytics, or AI. These applications will require a continuous exponential increase in data processing, storage, and transmission. A new model of networks relies not only on traditional electronic communications equipment, network and service providers but also on a complex ecosystem of cloud, edge, content, software and component suppliers, amongst others.[79]

In the same white paper, the European Commission highlights that Europe's traditional position of strength could be at risk as hybrid networks, edge computing, and full cloud migration change the nature of digital infrastructure. To preserve a leading global position in telecommunication equipment and competencies, it is important to embrace and integrate the new technologies when they become available.[80]

These new technologies and business cases entail that successfully reaching connectivity goals and preparing for future demand will not imply that digital infrastructure is fully developed. Instead, it will only be a step in the continued development that requires significant investments going forward.

78 Arthur D. Little (2023), The evolution of data growth in Europe (link), Table 1.
79 European Commission (2024), White Paper – How to master Europe's digital infrastructure needs? (link).
80 European Commission (2024), White Paper – How to master Europe's digital infrastructure needs? (link).

Finally, the implementation of **stricter security requirements and legislation** across the EU, such as the NIS2 Directive and the Critical Entities Resilience (CER) Directive, are expected to increase investments in both cybersecurity and physical security measures.

The NIS2 Directive, which came into force in 2023, modernises cybersecurity requirements to account for the growing digitisation and evolving threats across sectors. It expands the scope of cybersecurity measures and imposes new requirements on both public and private entities, including the telecommunications industry.[81] This expansion is likely to compel telecommunications operators to invest in enhancing their cybersecurity infrastructure, including systems for incident response, physical security upgrades, and recovery.[82]

The Critical Entities Resilience (CER) Directive, which came into effect in early 2023, imposes obligations on Member States to ensure the resilience of essential services, including those provided by the digital infrastructure sector. This directive covers telecommunications networks as a critical service, requiring operators to conduct regular risk assessments and implement measures to safeguard their infrastructure.[83]

3.2 Continued investments are required to keep delivering value and socio-economic benefits

In this section, we demonstrate how future telecommunication infrastructure investments, along with the adoption of better technologies, will provide continued value and socio-economic benefits to the Danish economy.

Firstly, we find that if the telecommunications sector's infrastructure investments continue at the levels realised in 2019-2023, they will contribute DKK 5.6 billion to the Danish economy and support 8,000 jobs annually until 2030 in direct and induced effect. Secondly, we explore how future increases in download speeds will contribute to GDP, identifying an annual contribution of 0.10-0.18 per cent to GDP until 2030. This is equivalent to between DKK 2.9 and 5.0 billion in GDP contribution annually. Finally, we estimate that between 2023 and 2030 further improvements in the network's energy efficiency could contribute between 17 and 24 percentage points to the total further reductions of 83 to 89 per cent in the network's emissions from electricity consumption.

We also note that in addition to these findings, continued investments in cybersecurity and resilience will generate significant socio-economic benefits in the future as digital dependency is likely to become even stronger.

3.2.1 Future investments will continue to provide value to the Danish economy

Over the last 10 years, the telecommunications sector in Denmark has invested 20 per cent of revenue on average with higher levels in recent years (2019-2023) than previously (2014-2018), see Figure 7. These (past) infrastructure investments have provided substantial economic value and socio-economic benefits, as described in Chapters 1 and 2.

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81 European Commission (2022), Directive on measures for a high common level of cybersecurity across the Union (NIS2 Directive) (link).

82 NIS2Directive, Digital Infrastructure sector (link).

83 Critical-entities-resilience-directive, The Critical Entities Resilience Directive (CER) (link).

While legacy investments will continue to provide benefits, substantial further investments by the sector are required to keep pace with technological developments and increasing demand for digital services and to fulfil connectivity targets, as discussed above. However, future investment levels are uncertain by nature and are driven among other things by the framework conditions faced by the sector.

If future investments stay at similar levels as realised in 2019-2023, i.e. DKK 10.3 billion yearly, we estimate that investment will contribute DKK 5.6 billion to the Danish economy and support 8,000 jobs yearly in direct and indirect effects until 2030. Additionally, induced effects will contribute DKK 3 billion to GDP and support 3,100 jobs yearly. This level of investments is in line with what the sector considers as potential yearly investments towards 2030 (i.e. DKK 60 billion) if framework conditions are investment friendly.[84]

However, if investments drop to a lower level, the economic contributions of GDP and employment will consequentially also be lower. For example, if investments drop by 33 per cent, we estimate that this will – all else equal – lead to DKK 1.9 billion lower GDP contribution and 2,700 fewer jobs (direct and indirect effects) supported by investments in the telecommunications sector every year.[85]

3.2.2 Continued investments in modern broadband technologies could contribute 0.10 to 0.18 per cent annually to GDP until 2023

As evident in Figure **11**, download speeds have increased significantly in recent years. With continued technological advancement, as described in Section 3.1, and the adoption of modern broadband technologies, this trend is likely to continue.

To estimate the future impact on GDP of increasing download speeds, we consider two download speed growth scenarios, see Figure **17** below. First, for the optimistic scenario, we assume that download speeds will grow at the Cisco[86] forecasted compound annual growth rate (CAGR)[87] plus 5 per cent, resulting in a projected CAGR of 24.2 per cent. Second, for the conservative scenario, we apply the Cisco forecasted CAGR minus 5 per cent, giving a projected CAGR of 14.2 per cent.

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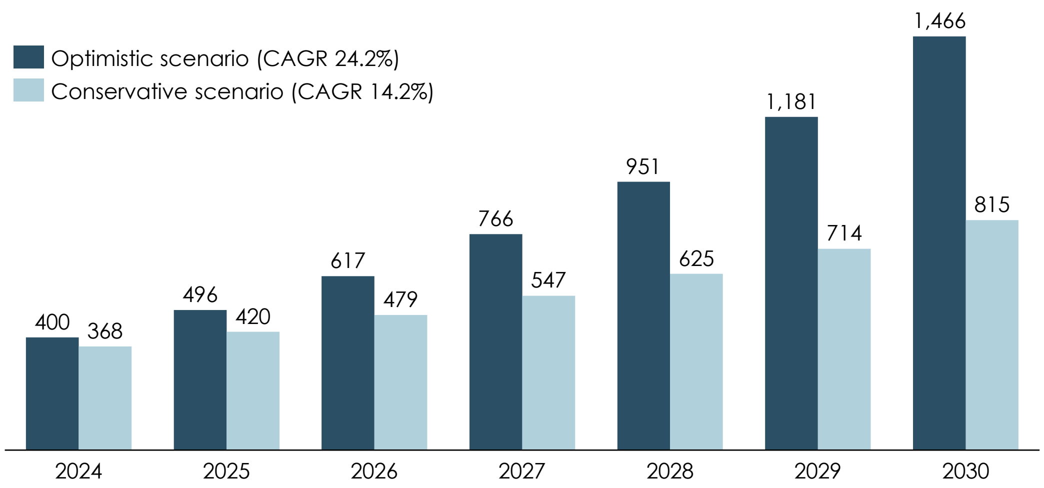
84 Teleindustrien, Dansk Erhverv, and DI (2024). Aftale om Digital Infrastruktur 2025 – 2030 (link).
85 We estimate his using the same method as in Section 1.1.2, see Appendix A for further information.
86 A CAGR of 19.2 per cent is estimated in Cisco (2020), Cisco Annual Internet Report (2018-2023) White Paper (link).
87 CAGR (Compound Annual Growth Rate) represents the average annual growth rate over a specified period, assuming consistent growth each year.

Figure 17
Scenarios for future fixed broadband download speeds in Denmark
Mbps



Note: Cisco estimates a CAGR of 19.2 per cent. Based on this, we add 5 per cent in our optimistic scenario, resulting in a CAGR of 24.2 per cent, and subtract 5 per cent in our conservative scenario with a CAGR of 14.2 per cent. CAGR (Compound Annual Growth Rate) represents the average annual growth rate over a specified period, assuming consistent growth each year.

Source: Copenhagen Economics based on Klimadatastyrelsen, Internet dataark, 2. halvår 2023 (link) and Cisco (2020), Cisco Annual Internet Report (2018-2023) White Paper (link).

Based on these two growth scenarios for future fixed broadband download speeds, we estimate for Denmark an average annual GDP contribution from increasing download speeds of 0.10 per cent in the conservative scenario, and 0.18 per cent in the optimistic scenario, equivalent to DKK 2.9 to 5.0 billion in GDP[88].

Since fixed and mobile broadband adoption, measured in the number of subscribers, have been stable in recent years in Denmark, we do not estimate the future contribution of broadband adoption to GDP – while broadband adoption as a driver of GDP has already been established in the literature and should be considered an ongoing economic effect contributed by the present digital infrastructure in Denmark.

3.2.3 Further adoption of modern broadband technologies could reduce CO2 emissions further

Past investments in digital infrastructure in parallel with consumers' increased adoption of modern broadband technologies led to improved energy efficiency of the network, as discussed in Section 2.2. Improvements in the network's energy efficiency observed in the past (see Figure **13**) are likely to continue in the future if sufficient investments materialise and increased adoption continues. 5G will continue to become even more energy efficient as the technology matures. Orange estimates that 5G technologies "*divide the energy consumption per gigabit transported by a factor of 10*

[88] Based on the GDP in 2023 of DKK 2,805 billion, see Statistics Denmark (link).

compared to 4G once they reach maturity by 2025, and then by a factor of 20 by 2030"[89]. In addition, further technological advancements, for example optimisation of the network based on artificial intelligence, are likely to have an impact on future energy efficiency.[90]

To estimate the environmental benefits of future network energy efficiency improvements, we consider two scenarios.

First, for the **optimistic scenario,** we assume that the network's total electricity consumption remains constant. This is in line with Ericsson's finding that there does not seem to be a correlation between data traffic and electricity consumption.[91] In addition, we use forecasts for data traffic growth in Denmark by management consulting firm Arthur D. Little, who estimate a 20 per cent and 18 per cent CAGR for mobile and fixed data traffic, respectively.[92] Combined, the electricity consumption and data traffic forecasts result in an acceleration of network energy intensity reductions, from a historic CAGR of -9.5 per cent between 2019 and 2023, to a CAGR of -15.5 per cent from 2024 to 2030.

Second, for the **conservative scenario,** we assume that the network energy intensity continues to decrease at the historical rate, that is a CAGR of -9.5 per cent, see Figure **18**.[93]

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89 Orange (2020), 5G : energy efficiency "by design" (link).

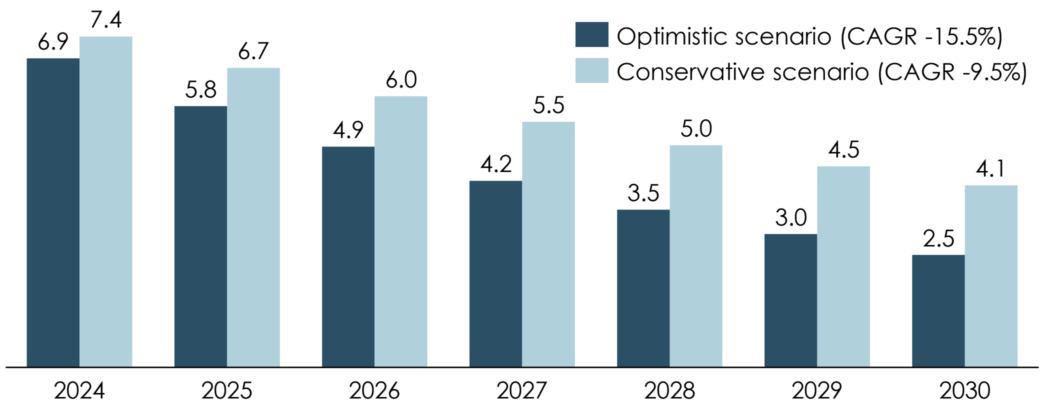
90 Teleindustrien, Dansk Erhverv, and DI (2024), Aftale om Digital Infrastruktur 2025 – 2030 (link), p. 16.

91 Ericsson (2023), ICT energy - The energy use and enablement effect of the Information and Communication Technology Industry (link).

92 Arthur D. Little (2023), The evolution of data growth in Europe (link), Table 1 and 2.

93 For a more detailed description of the methodology, see Appendix .

Figure 18
Future development in the mobile and fixed broadband network's energy intensity
MWh of electricity/PB of data



Note: In the conservative future scenario, we assume that the historical trend continues. In the optimistic future scenario, we assume that the network's total electricity consumption remains at its 2023-level, while the data traffic in the network increases by 20 per cent and 18 per cent annually for the fixed and mobile infrastructure, respectively. CAGR (Compound Annual Growth Rate) represents the average annual growth rate over a specified period, assuming consistent growth each year.

Source: Copenhagen Economics based on TDC NET (2023), Annual Report 2023 (link); Arthur D. Little (2023), The evolution of data growth in Europe (link).

We estimate that in Denmark, the network's emissions from its electricity consumption could decrease by 89 per cent in the optimistic scenario, or 83 per cent in the conservative scenario, between 2023 and 2030. Of this total reduction, we estimate that improvements in the network's energy efficiency could contribute between 24 percentage points in the optimistic scenario, and 17 percentage points in the conservative scenario.

CHAPTER 4
CHALLENGES TO CONTINUED INVESTMENT

As covered in previous chapters, continued investments will be required to ensure future-proof digital infrastructure. However, operators across the EU and in Denmark may face challenges that weaken their ability and incentive to continue investing in digital infrastructure.

Firstly, we explain the challenges that may weaken the sector's ability and incentive to invest, including administrative constraints and low return on investments in digital infrastructure (see Section 4.1).

Secondly, we explain how the regulatory framework that governs the telecommunications sector may influence the sector's ability and incentive to invest. We focus on sector-specific regulation, administrative processes, and competition law which sets boundaries for operators' ability to collaborate and consolidate (see Section 4.2).

4.1 Challenges that may weaken the sector's ability and incentive to invest

Similarly to the rest of Europe, operators in Denmark may face challenges that weaken the sector's ability and incentive to invest. In this section, we describe how operators' ability and incentive to invest may be weakened by administrative and financial obligations as well as by insufficient returns on investments.

4.1.1 Administrative and financial obligations

Long and burdensome administrative procedures may weaken operators' ability and incentive to invest in digital infrastructure. Investments in fixed or mobile network infrastructure (e.g., masts, towers or ducts) often involve administrative procedures such as permit granting, as well as the conditions at which agreements are obtained. This creates at least two challenges for operators. *First*, permitting rules can vary between regions of municipalities, making compliance complex and uncertain. *Second*, processes can be lengthy and burdensome, thus consuming resources and potentially delaying network deployment or expansion.

The European Commission has acknowledged that administrative procedures can hinder investments in networks and tried to address it. Several European initiatives have sought to reduce the administrative burden of deploying network infrastructure.[94] For example, the Gigabit Infrastructure Act established principles to simplify licensing and authorisation procedures in the EU

[94] E.g. European Parliament and the Council (2024), Regulation (EU) 2024/1309 (Gigabit Infrastructure Act, "GIA") (link) and European Parliament and the Council (2014), Directive 2014/61/EU (Broadband Cost Reduction Directive, "BCRD") (link).

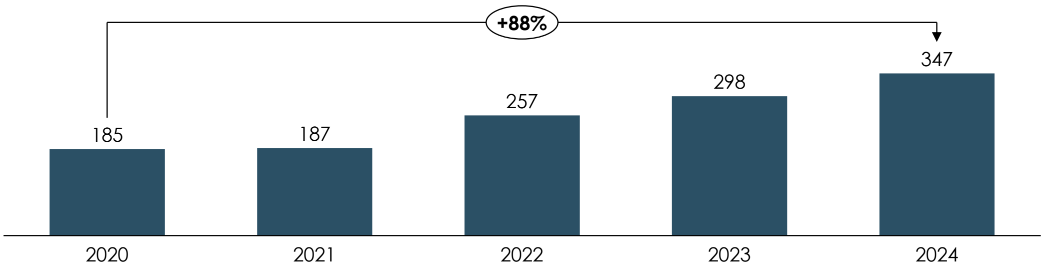
(including permitting and rights of way) and sought to address the lack of harmonisation that previous initiatives failed to eliminate.[95]

In Denmark, operators have faced important barriers to timely investments. Danish operators contributing to this study told us that they spend significant resources in selecting and getting agreements from landowners and in obtaining municipal permits to build masts and fibre infrastructure across the country. This is also in line with reports from Danish Authorities, as we outline below.

Firstly, operators report that finding suitable areas to deploy infrastructure is challenging, both in cities and rural areas. In cities, there are significant restrictions due to local urban planning and legislation. In rural regions, there are frequent issues concerning the closeness to current structures, while confirming that the site is conducive for mast placement is a related uncertainty. An additional challenge concerns voluntary agreements with landowners, with some operators reporting an increasing tendency for landowners to withdraw their agreement during the installation of infrastructure.

Secondly, permitting can be lengthy and burdensome. The main challenges relate to the complexity of the processes, the lack of resources to handle the procedures in the municipalities and the lengthy processing (e.g., through political committees and planning appeals boards involved in the approval process). Based on input from a tower company active in Denmark, getting a permit can take on average more than 11 months from when the request is submitted. The average time for permit approvals experienced by some operators has increased 88 per cent in the last 4 years, see Figure **19**.

Figure 19
Average waiting time for mast permit approval
Days



Note: The waiting time is measured as the number of days between the date of the application for a permit, and the date at which all permits have been granted.
Source: Copenhagen Economics based on input from a Danish tower company.

95 The lack of harmonisation in the implementation of the BCRD was one of the reasons why the European Commission replaced the BCRD with the GIA. According to BEREC (2021), BEREC Opinion on the Revision of the Broadband Cost Reduction Directive (link), the BCRD “was transposed with significant delays in most Member States and its implementation has been inconsistent across the EU, therefore, hindering the potential to foster a more efficient and fast deployment of electronic communications networks across the EU”.

This is consistent with reports from the Danish Authorities, which in recent years have underlined the need to simplify procedures related to installing digital infrastructure. For example:

- In 2020, in the action plan for 5G rollout published in 2020, the Danish Energy Authority (DEA) recognised the need to (i) reduce *"administrative barriers to rolling out 5G networks*" (ii) "*prepare guidelines on standardised case administration for public authorities*" and noted that it was '*of great importance to mobile operators to have good and predictable conditions for their work*'. They proposed to create such conditions by ensuring smooth case administration and hereunder a more uniform case administration across the country's municipalities.[96]

- In 2021, the DEA noted that "*Strict Danish rules governing access to the rural open landscape and the preservation of the open coastal line are, however, still among the main challenges for the operators in providing full coverage. This is true even though the societal need for a nationwide digital infrastructure is well acknowledged*."[97]

- In 2022, the Agency for Data Supply and Infrastructure published a toolbox to facilitate the rollout of digital infrastructure and reduce the complexity associated with building antennas and masts faced both by the telecommunications sector and the municipalities. The toolbox recognises that municipalities retain significant autonomy in establishing rules affecting network rollout and provides advice to municipalities to create transparency about documentation needs and an established practice that the operators can follow.[98]

In addition to administrative procedures, potential financial obligations can further limit operators' ability and incentive to invest. Such obligations translate into additional costs, i.e., consuming financial resources that could otherwise be channelled to investments. Such obligations include (i) spectrum licencing fees, (ii) regulatory compliance costs, (iii) infrastructure sharing and access fees, and (iv) taxes and levies.[99]

4.1.2 Recent financial performance is indicative of concerns over sufficient returns on future investments

Many European policymakers have expressed concern regarding the economic sustainability of investments in digital infrastructure. The low profitability of these investments is perceived by some as a significant threat to the operators' ability and incentive to continue making further investments. The lack of economic sustainability of investments is especially a concern given the ongoing digital transformation in the EU where substantial investments are needed to keep up with technological developments, as noted by the European Commission[100] and in the Draghi report[101].

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96 See Danish Energy Agency (2020), 5G Action Plan for Denmark (link), p. 8.

97 International Telecommunication Union (2020), Balancing infrastructure sharing – The Danish experience (link).

98 Styrelsen for Dataforsyning og Infrastruktur (2022), Otte gode råd til kommuner om mastesager (link).

99 While not clear-cut, there is some evidence that high spectrum costs hamper investments and reduce consumer welfare under certain circumstances. See e.g., NERA (2017), The Impact of High Spectrum Costs on Mobile Network Investment and Consumer Prices (link).

100 European Commission (2024), White Paper - How to master Europe's digital infrastructure needs? (link), p. 10.

101 Draghi notes that "*the declining profitability of the telecom sector now may represent a risk for industrial companies in Europe, in a phase when state of the art infrastructure is required to digitise manufacturing, supply and distribution chains. this poses significant challenges to raise capital from lenders and investors*." Draghi (2024), The future of European competitiveness - In-depth analysis and recommendations (link), p. 70.

There is a growing concern that operators may have been unable to recover the costs of their recent investments. For example, Draghi (2024) notes that "*in recent years, return on capital has been lower than the weighted average cost of capital*"[102]. Similarly, the European Commission has also recently suggested that investments by EU operators yield low profitability.[103]

Insofar as returns on investment are insufficient to recover the costs and enable sufficient return on investments, operators could see future investments as uncertain and potentially unsustainable. This may impact their ability and willingness to continue to invest in new digital infrastructure. As the European Commission explains, low profitability may lead to "(…) *lack of market confidence in the potential for sustainable long-term growth in revenues*", thus hindering operators' ability and incentive to invest.[104, 105]

It would be necessary to conduct a detailed analysis of profitability to assess whether operators in Denmark have been able to recoup the costs of their investments. While an exhaustive profitability analysis is beyond the scope of this study, there is indicative evidence suggesting that operators in Denmark face similar challenges as the industry across the rest of the EU, see Box 3.

Box 3 Return on capital employed in the Danish telecommunications sector

There are different methods to assess operators' profitability, financial performance and investment incentives. One of the methodologies involves comparing the Return on Capital Employed (ROCE) and the Weighted Average Cost of Capital (WACC). This comparison measures the efficiency with which an operator generates profits from its investments (i.e., capital expenditure).

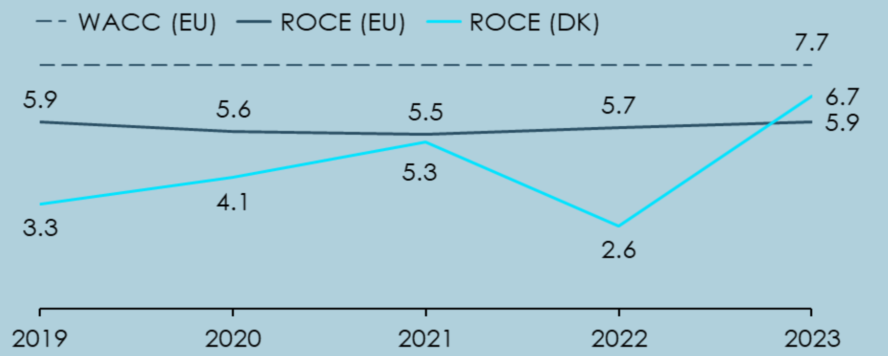
In recent years, the Return on Capital Employed (ROCE) by the largest telecommunications operators in Denmark has been lower than the Weighted Average Cost of Capital (WACC) in the EU proposed by Draghi (2024), see Figure **20**. Low profitability can signal that operators will be unable to recover the cost of future investments (similar to past investments in recent years), which can also affect operators' ability to secure enough funding for new investments.[106]

While the WACC analysis provides a valuable point of reference and has been reported in EU policy reports and by the UK regulator Ofcom, it should be approached with caution. Firstly, a ROCE vs WACC comparison offers only a partial view on profitability, and a more detailed analysis (out of the scope for this report) would require complementary analysis. Secondly, an average WACC at the EU level may not accurately represent the cost of capital faced by

102 The report compares the EBIT adjusted return on employed capital with the average weighted cost of capital (WACC).
103 See, e.g., European Commission (2024), White Paper - How to master Europe's digital infrastructure needs? (link).
104 European Commission (2024), White Paper - How to master Europe's digital infrastructure needs? (link).
105 Draghi also discusses how low profitability can make "(…) *the financing of future investments problematic*". See Draghi (2024), The future of European competitiveness - In-depth analysis and recommendations (link), pp. 71.
106 Financing large-scale investments typically requires a combination of instruments beyond the reinvestment of operational profits, involving borrowing capital (through debt instruments) or ensuring equity infusions. Regardless of the instrument or combination of instruments chosen, the expected profitability of investments likely affects the ability to secure funding for investments in digital infrastructure.

Danish operators (due to different economic conditions or regulatory environment).[107] Third, there is some uncertainty about how the WACC from Draghi (2024) was calculated (e.g., whether it includes only network operators or also virtual operators) and other authors have estimated different costs of capital for telecom operators in Europe.[108]

Figure 20
Return on capital employed is below the weighted average cost of capital per year
DKK/month



Note: Recognising that there are company and country-specific differences in the WACC, for the purposes of this illustration, we have used the WACC of the EU-wide telecommunications sector in line with the comparison set out by Draghi (2024). ROCE is a pre-tax measure of the return of the capital employed. We calculated the weighted average ROCE in Denmark based on aggregated financial data from TDC Net, 3DK, Telenor DK, Telia (estimated ROCE for operations in Denmark, see appendix).[109] It is unclear whether the WACC reported by Draghi (2024) is pre-tax or post-tax. We take a conservative approach and consider that the reported WACC is pre-tax (thus potentially underestimating it). The comparison between ROCE and pre-tax WACC offers a reasonable basis to assess profitability without accessing companies' management accounts.[110]

Source: Copenhagen Economics based on Draghi (2024) for WACC (EU) and ROCE (EU) and publicly available information from financial statements and reports to calculate ROCE (DK) (see detailed calculations for ROCE in Denmark and sources in the Appendix A).

107 For example, i) KPMG estimated that cost of capital for telecom operators in Germany, Austria and Switzerland in 2022 and 2023 was on average 5.8 and 7.3 per cent, respectively - see KPMG (2023), Cost of Capital 2023 (link); ii) PWC estimates that the average WACC for telecom operators in Germany was 5.8 per cent – see PWC's eValuation Data (link).

108 For example, Professor Aswath Damodaran of NYU Stern, using several sources (Bloomberg, Morningstar, Capital IQ and Compustat), estimates that in the beginning of 2023 and in the beginning of 2022 the WACC for companies in Europe providing telecom services was 7,18 and 3.92 per cent, respectively – below the estimates presented in Draghi (2024). See Damodaran Online (link).

109 Norlys Fibernet – Norly's group arm owning the fibre network – was not included because the publicly available financial information does not allow for a comparison of Norly Fibernet's ROCE across the period considered. The available financial information is not adjusted to account for the impacts of (i) the merger of Norlys Fibernet A/S with both SE Fibernet A/S and Verdo A/S, and (ii) the demerger of the Digital Business activities to Stofa A/S.

110 See, e.g., Oxera, Ava, (2003), Assessing profitability in competition policy analysis, Economic Discussion Paper 6, pp. 10-12. (link).

In particular, Danish operators appear to have faced a challenging balance between high investments and low retail prices. In 2022, Denmark was estimated to have the highest capex (encompassing costs related to upgrading and maintaining networks) per capita among 27 European countries.[111] At the same time, Denmark has been one of the countries in Europe with the lowest prices for mobile and fixed broadband.[112] [113] Additionally, we note that operator's profits (EBIT) have decreased by 13.4 per cent in 2023 compared to 2022 in real terms.[114]

One commonly cited reason for insufficient profitability is insufficient scale. It is well documented that telecommunications networks exhibit significant economies of scale with high up-front investments in establishing infrastructure (cables, masts, antennas, etc.). Larger scale allows operators to spread large fixed costs over a greater number of users, thereby leveraging economies of scale to make investments more efficient. Consequently, as operators increase their customer base, they can significantly lower their average costs, enhancing their investment capacity.

Several reports, including from the European Commission, suggest that operators in the EU may lack the scale necessary to make investments in digital infrastructure – i.e., that market fragmentation may be weakening the operator's ability and incentive to invest significantly in infrastructure.[115] The policy reports suggest that European operators generally have less scale compared to operators in other regions as they have fewer customers on average.[116]

While a detailed analysis of the economies of scale of Danish operators is beyond the scope of this study, indicative evidence suggests that operators in Denmark face similar challenges as the industry across the rest of the EU. By way of an indication, we note that the Danish mobile operators serve on average fewer customers than the EU average, i.e. less than half the average European operator's scale. While Danish mobile operators serve on average less than 2 million customers[117], the average number of subscribers per operator is 5 million in the EU, as Letta reports.[118]

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111 See Analysys Mason (2024), Higher-income European countries have the highest capex intensities (link).

112 See European Commission (2022) Mobile and Fixed Broadband Prices in Europe 2022 (link).

113 Caution should be exercised with simple ARPU comparisons. For instance, these comparisons may not account for differences in vertical integration among operators, nor do they distinguish between market power and higher quality (and thus more expensive) services.

114 Klimadatastyrelsen, Økonomiske Nøgletal for Telebranchen 2023 (link).

115 See e.g., Draghi (2024), The future of European competitiveness - In-depth analysis and recommendations (link); European Commission (2024), White Paper - How to master Europe's digital infrastructure needs? (link); Letta (2024), Much more than a market - Speed, Security, Solidarity (link), pp. 52: "*enduring fragmentation hinders the scale and growth of pan-European operators, limiting their ability to invest*".

116 See e.g., Letta (2024), Much more than a market - Speed, Security, Solidarity (link), pp. 52: "*The scale of disparity is stark: an average European operator serves only 5 million subscribers compared to 107 million in the United States and a staggering 467 million in China.*"

117 Average number of mobile subscribers of Telenor, Telia, 3DK and Nuuday, based on financial statements.

118 Letta (2024), Much more than a market - Speed, Security, Solidarity (link). The exact methodology used by Letta, or source, is unclear (e.g., it is not indicated whether it considers only MVNOs or MNOs, and whether mobile operators only or also fixed operators).

4.2 Policy instruments that affect the sector's ability and incentive to invest

In this section, we discuss the key elements of the legal framework governing the telecommunications sector. Policymakers and regulators can use legislation and policy to influence operators' ability and incentive to invest in digital infrastructure. Firstly, we set out the main regulatory tools that policymakers can use to address administrative and financial constraints. Secondly, we outline how different forms of consolidation and network sharing can increase investment incentives by generating cost efficiencies and discuss how there is a growing emphasis in EU policy debate on considering also non-price benefits when scrutinising collaboration and consolidation in light of competition law.

4.2.1 Telecommunications operators must comply with sector-specific regulation

Telecommunications operators in the EU must comply with a specific regulatory framework established primarily by the European Electronic Communications Code (EECC). This framework covers multiple dimensions[119] and is primarily aimed at promoting competition, the internal market, consumers' interests and pursuing a connectivity objective[120], prescribing that "*[b]oth efficient investment and competition should be encouraged in tandem, in order to increase economic growth, innovation and consumer choice.*"[121]

Ex-ante regulation continues to be central to (especially fixed) the telecommunications sector and consists of ex-ante remedies that seek to pre-empt any exploitation of market power that could be detrimental to competition and ultimately consumers. To impose ex-ante remedies, National Regulatory Authorities (NRAs) – in Denmark, the Danish Business Authority (DBA) – must demonstrate that operators have significant market power (SMP) and that significant structural barriers to competition exist.[122] Remedies may include, for example, requiring network access for competitors and service providers and enforcing non-discrimination or structural separation measures.[123] Under the EECC, regulators conduct regular market reviews to determine if ex-ante remedies are necessary and proportional, considering the costs and benefits of each measure.[124,125] Generally, it is well-documented that any ex-ante regulation should be proportionate in addressing the specific type of competition concerns identified – i.e., the choice of remedies should be the least burdensome possible

119 The EECC addresses various aspects of telecommunications services, including for example market competition, consumer protection, network access, spectrum allocation and management and broadband deployment.

120 See, e.g., European Parliament and the Council (2018), Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code (EECC) (link), recital 23.

121 See, European Parliament and the Council (2018), Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code (EECC) (link), recital 26, pp. 7. The same principle was made clear in the European Commission's Digital Single Market For Europe, where the Commission noted that "*the review of the telecommunications framework would focus, on measures that aim to provide incentives for investment in high-speed broadband networks*", among other aspects (EECC, recital 3, pp. 1).

122 Ex ante regulation should be applicable only in market all of the following criteria are met: (i) high and non-transitory barriers to entry, (ii) a structure that does not tend towards effective competition and (iii) competition law alone is insufficient to adequately address the identified market failures (see.

123 Non-exhaustive. For a more comprehensive set of remedies that NRAs can impose on operators in different circumstances, see e.g., articles 60-69 of the EECC.

124 Considering, e.g., how regulation may affect incentives for investments and the market position of affected operators.

125 In designing remedies, regulators are encouraged to weigh, and avoid, possible disincentives to further investments. See, e.g. European Commission (2024), Recommendation on the regulatory promotion of gigabit connectivity (link).

to achieve the regulatory aim. Several dimensions can be adjusted to ensure this balance, including price, duration, geographic scope and operational targets.

Certain administrative regulatory aspects are determined at the national level. The EECC provides a harmonised framework for telecommunications regulation across the EU. However, some aspects are determined by each Member-state, such as i) the assignment of radio frequencies and associated conditions, ii) the granting rights of way for the roll-out of networks and associated facilities or the iii) universal service obligations.

4.2.2 The GIA act is an opportunity to improve administrative processes that affect infrastructure investment incentives

As we described in Section 4.1.1 challenges faced by the sector due to long and burdensome administrative procedures may weaken operators' ability and incentive to invest in digital infrastructure. Policymakers could simplify authorisation and permitting processes to overcome municipal barriers to investment. Streamlining and harmonising the permitting across different areas can minimise delays and uncertainties, thus facilitating a more efficient rollout of new infrastructure.

Potential solutions could include establishing i) standardising local regulations, ii) maximum response times for permitting, iii) standardising requirements across municipalities and iv) identifying challenges that rendered previous attempts at simplification ineffective. This is particularly relevant considering how previous measures seem to have been insufficient in preventing long and burdensome procedures associated with network rollout (see Section 4.2.1).

The entry into force of the **EU Gigabit Infrastructure Act (GIA)** is an opportunity to review the Danish legislation and improve conditions for investment. The Gigabit Infrastructure Act Regulation is set to take effect in November 2025 and member states need to ensure that national legislation does not contain any obstacles to its uniform and effective application. In this process, policymakers should consider implementing measures that could help overcome local barriers to the rollout of high-capacity digital infrastructure and accelerate investments.

Moreover, policymakers could consider whether any existing financial burdens could be alleviated. One of the levers to alleviate financial burdens on operators is for example spectrum fees. While we have not investigated the effect on investment in the Danish context specifically, lower spectrum fees can under certain conditions alleviate the financial burden on the sector and strengthen operators' ability and incentives to invest.[126] A possible approach entails converting spectrum fees into specific investment targets and aligning administrative procedures with the wider policy goals of promoting efficient investments.

[126] See footnote 94.

4.2.3 Competition law sets boundaries for operators' ability to collaborate and consolidate

As we describe in this section, different forms of collaboration and consolidation between operators can increase their incentives to invest by achieving greater scale and can be associated with several benefits. Any form of collaboration needs to comply with general competition law and benefits need to outweigh any harm from a reduction of competition. While competition authorities will continue to scrutinise proposed consolidations and collaborative agreements on their merits, there is currently a growing policy impetus in Europe towards a more thorough consideration of non-price benefits, such as innovation and investment enabled by greater scale. This is reflected in the approval i.e. clearance of a 'four-to-three' merger between Vodafone and 3UK by the UK Competition and Markets Authority.

Recent policy reports have suggested that low returns on investment and lack of scale are associated with how regulators have historically disincentivised consolidation and favoured infrastructure-based competition.[127] One the one hand, different forms of collaboration and consolidation can allow greater scale and result in lower average costs if operators can spread their costs efficiently across a larger user base, thereby supporting increased incentives to invest. On the other hand, market fragmentation may adversely affect operators' scale and agility to adapt to technological changes.[128]

However, collaboration between competitors can also reduce competitive pressure between them, which can in some cases reduce incentives to invest. Competition authorities scrutinise different forms of in-market collaboration and consolidation in accordance with competition law and seek to strike the balance between reaping the benefits from economies of scale while preserving sufficient competition on prices and on quality, e.g. through network investments. This trade-off has been central to concerns voiced by some policy makers and industry stakeholders alike.[129, 130]

Different forms of collaboration and consolidation to reduce the need for network duplication and achieve economies of scale include:

- **Co-investments** where two or more operators invest together in network infrastructure,
- **Network-sharing agreements** where e.g. operators share the fibre infrastructure used to provide fixed broadband access or share basic site infrastructure, radio access networks or spectrum for mobile broadband, and
- **Mergers** where two or more companies consolidate into a single entity.

From an economic perspective, these types of collaboration and consolidation can result in benefits to consumers. Plausible benefits include cost reductions to the extent they are passed on to

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127 Draghi (2024), The future of European competitiveness - In-depth analysis and recommendations (link), p. 70. Other authors include e.g., Letta (2024), Much more than a market - Speed, Security, Solidarity (link), pp. 52, where the author points to how competition authorities' approach may have contributed to the lack of scale of telecom operators in the EU. E.g., "*an antitrust approach focused on market entry when evaluating mergers led to the same result* ["*of excessive small-scale, territorial focused operators*"]".

128 For example, in October 2023, the European commissioner for the Internal market argued that "*Telecoms operators need scale and agility to adapt to this technology revolution, but market fragmentation holds them back. Too many regulatory barriers to a true telecoms Single Market still exist, on spectrum acquisition, consolidation, legacy networks, security, and so on*". See Commissioner Breton's Linkedin blog post, 10 October 2023 (link).

129 See e.g., Letta (2024), Much more than a market - Speed, Security, Solidarity (link).

130 European Commission (2024), White Paper - How to master Europe's digital infrastructure needs? (link).

consumers, and enhanced ability to invest in higher-quality networks.[131] Some empirical analysis suggests that the impact of mergers on industry investment and quality has typically been positive.[132] However, other authors have found that consolidation in the telecommunications sector may lead to higher prices for users with limited positive effects[133] and that the impact on total investments is not conclusive[134]. On the whole, the available evidence and regulatory case practice suggest that the effects depend crucially on the design of the transaction or collaborative arrangement and the market circumstances. It is therefore important that each transaction is assessed on its merits, recognising both the price effects and implications for operators' incentives and ability to engage in quality-enhancing investments and innovation. In practice, case law confirms that competition authorities' scrutiny has frequently led to interventions, e.g. through the imposition of structural remedies forcing operators to divest network assets or spectrum, see Box 4.

131 See European Commission (2023), Guidelines on the applicability of Article 101 of the Treaty on the Functioning of the European Union to horizontal co-operation agreements (link); European Commission (2004), Guidelines on the assessment of horizontal mergers under the Council Regulation on the control of concentrations between undertakings (link) and European Parliament and the Council (2018). Directive (EU) 2018/1972.

132 See, e.g., Padilla (2024) Do Four-to-Three Mobile Mergers Harm Consumers? A Deep-Dive into the UK Market (link).

133 European Commission (2024), Protecting competition in a changing world, Evidence on the evolution of competition in the EU during the past 25 years, (link), p. 131.

134 Genakos, Valletti, and Verboven (2018). Evaluating market consolidation in mobile communications. Economic Policy, 33(93), 45-100 (link).

Box 4 Collaboration and consolidation in telecoms is closely scrutinised

Different examples across Europe illustrate how some operators have struggled to get regulatory approval for in-market collaboration and consolidation.

- Since 2012, almost all mergers in Europe that reduce the number of players from four to three we conditional on structural commitments imposed by competition authorities, such as divesting spectrum to new entrants.[135]
- In 2020, following a decision by the European Commission, operators engaging in a network sharing agreement in Czechia had to make a set of commitments to address competition concerns.[136]
- In Italy, in 12 months between 2020 and 2021, "four investigations or decisions [were] conducted in relation to domestic network sharing deals (…)". The deals that were cleared "are subject to strict commitments relating to non-discriminatory access and transparency."[137]
- In 2024, a merger between MasMovil and Orange in Spain was cleared but only with substantial commitments.
- In 2024, the Belgian Competition Authority opened an investigation into a proposed joint investment in Belgium between Proximus and Telenet.[138]

In Denmark, regulators have also scrutinised collaboration and consolidation closely in several cases, which may have reduced the potential for more economies of scale:

- In 2012, the Danish Competition and Consumer Authority analysed a network-sharing agreement between Telia and Telenor, imposing conditions to clear the agreement.[139]
- In 2015, Telenor and Telia abandoned a proposed merger following an in-depth investigation by the European Commission.[140]
- Recently (2024), the Danish Competition and Consumer Authority concluded its investigation into Norlys' purchase of Telia's Danish business, imposing several conditions to clear the agreement.[141]

[135] Copenhagen Economics (2024), VODAFONE/3 UK: Signs of A new playbook for mobile mergers? (link).
[136] Foros, Hansen, and Vergé (2023), Co-operative investment by downstream rivals: network sharing in telecom markets (link); Maier-Rigaud, Ivaldi, and Heller (2020), Cooperation Among Competitors: Network Sharing Can Increase Consumer Welfare (link).
[137] CMS (2021), The latest trends in network sharing regulation - a snapshot (2018-2021) (link).
[138] Telecompaper (2024), Belgian competition watchdog confirms investigation into Proximus, Telenet fibre alliance (link).
[139] Danish Competition and Consumer Authority (2012), Radio Access Network sharing agreement between Telia Denmark A/S and Telenor A/S (link).
[140] European Commission (2015), Statement by Commissioner Vestager on announcement by Telenor and TeliaSonera to withdraw from proposed merger (link).
[141] Danish Competition and Consumer Authority (2024), The Competition Council intervenes in Norlys' acquisition of Telia Company AB's Danish activities (link).

While existing competition rules already recognise that pro-competitive effects of collaborative arrangements may outweigh competition risks in some circumstances,[142] there is a growing policy impetus in the EU whereby several authors and stakeholders, including Draghi, propose that competition authorities put an even greater emphasis on the pro-competitive effects of mergers such as innovation and investment.[143] The European Commission has also recognised in 2021 the need of competition policy to contribute to the EU's main economic and societal challenges, including the digital transition and the need for investments in digital infrastructure.[144, 145] These 'non-price' aspects are seen as crucial for innovation and network resilience, and as enablers of the green transition.

As already became evident in the UK with the approval i.e. clearance of the Vodafone/3UK merger by the Competition and Markets Authority (CMA)[146], authorities across Europe may, going forward, place a greater emphasis on thoroughly assessing innovation and investment related benefits in reviews of consolidations and network sharing, and consider behavioural remedies. Each transaction is still expected to face scrutiny and require appropriate economic evidence to substantiate that benefits achieved through a merger and associated remedies will indeed materialise and would not be possible otherwise.

While it is premature to determine how the Commission and national authorities will, in practice, conduct the 'balancing act' between costs and benefits going forward, we foresee at least three important aspects that appear to warrant consideration:

First, competition authorities can consider whether and how an assessment of collaboration between operators should account for **non-price benefits**, including efficiencies that accrue to the consumers, that are (conceivably) harmed by a reduction in competition, in the form of increased connectivity and higher-quality services. Economic tools are available to quantify benefits derived from, for example, enhanced quality of services associated with network investments enabled by a collaborative arrangement or a merger.

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142 For example, the recently revised Guidelines on horizontal agreements includes new guidance for the assessment of mobile telecommunications infrastructure sharing and recognise potential benefits that come from cost reductions or quality improvements. See European Commission (2023), Questions and Answers on adoption of the new Horizontal Block Exemption Regulations and Horizontal Guidelines (link).

143 For example, Draghi (2024) proposes that "*In the EU's rules for clearing mergers* [including in the telecom sector], *increase the weight of innovation and investment commitments, as well as efficiencies in the form of improved quality vis-à-vis price levels through extended assessment timelines"*. Other authors (see e.g., Duso, Motta, Peitz, and Valletti (2024)) have opposed the views that competition law need to have a different approach to consolidation in telecommunications markets, arguing that "*Empirical evidence consistently shows that telecoms mergers lead to higher prices and are unlikely to boost investment*".

144 See e.g., European Commission (2021), Competition: Commission outlines contribution of competition policy and its review to green and digital transition, and to a resilient Single Market (link). As noted by the European Commission, "*Connectivity networks are particularly important for the development of the digital economy and society, and are relevant to virtually all businesses and consumer*".

145 For example, the European Commission emphasises that "*To increase the cost-effectiveness of their network roll-out, the Commission encourages private operators to cooperate in so-called "network sharing", whilst ensuring that this is done without unduly reducing competition*" (European Commission (2021), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A competition policy fit for the new challenges (link), pp. 12-13).

146 The CMA found that 5G network investment commitments in tandem with short-term price commitments for both retail and wholesale customers would (i) be sufficient to address competition concerns; and (ii) boost competition in the longer term. See CMA (2024), Press Release, CMA clears Vodafone / Three merger, subject to legally binding commitments, (link).

Second, authorities may need to consider a **longer time horizon to assess the claimed benefits**. While any adverse effects on competition manifested through higher prices are more likely to take effect in the short-term, benefits from investments such as higher-quality networks may only materialise in the longer term.

Third, authorities may consider on a case-by-case basis which **least intrusive combination of remedies** can protect competition while also the pro-competitive effects of collaboration. Where relevant, the commitments required to approve e.g. a merger or network sharing agreement should be strictly required to mitigate otherwise potential harms to consumers. Competition authorities consider in each case i) whether structural remedies reduce the benefits of consolidation and ii) whether behavioural remedies may be appropriate and sufficient to safeguard competition. For example, the CMA in the UK has in the cleared Vodafone / Three merger considered new types of behavioural remedies that seek to prevent price increases and require investment commitments from the merging operators.[147]

[147] The legally binding commitments for this merger are: (i) "*Delivery of the joint network plan, which sets out the network upgrade, integration and improvements Vodafone and Three will make to their combined network across the UK over the next 8 years. The group has concluded that by significantly improving the quality of the combined network, the full implementation of this plan would boost competition between the mobile network operators in the long term, benefiting millions of people who rely on mobile services.*" (ii) "*Capping selected mobile tariffs and data plans for 3 years, directly protecting large numbers of Vodafone / Three customers from short-term price rises in the early years of the network plan.*" (iii) "*Offering pre-set prices and contract terms for wholesale services (again for 3 years) to ensure that virtual network providers can obtain competitive terms and conditions as the network plan is rolled out.*" See CMA (2024), Press Release, CMA clears Vodafone / Three merger, subject to legally binding commitments, (link).

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APPENDIX
METHODOLOGY

In this Appendix, we describe the methodology behind the key quantifications in the report. The methodology is presented in the order in which it is used in the text:

- Input-output modelling: Estimate the economic impact of the telecommunications sector's operations. This is used to estimate the sector's contribution to GDP and employment (Section 1.1).
- Input-output modelling: Estimate the economic impact of the telecommunications sector's investments. This is used to estimate the economic effects of investments in the sector (Sections 1.2 and 3.2.1).
- How digital infrastructure drives economic growth by boosting productivity. This is used to estimate the impact of improved digital infrastructure on GDP (Sections 2.1 and 3.2.2).
- How digital infrastructure enables the green transition by reducing CO2 emissions. This is used to estimate the telecommunications sector's role in reducing CO2 emissions (Sections 2.2 and 3.2.3).
- The cost of a breakdown in digital infrastructure for Danish companies. This is used to estimate the potential financial impact of infrastructure failures related to e.g. cyber attacks (Section 2.3).
- Financial performance of the telecommunications sector in terms of return on capital employed (ROCE). This is used to evaluate the sector's financial performance (Section 4.1.2).

INPUT-OUTPUT MODELLING: ECONOMIC FOOTPRINT OF THE TELECOMMUNICATIONS SECTOR'S OPERATIONS

In Section 1.1, we estimate the economic impact of the telecommunications sector in Denmark by using an input-output (IO) model based on tables from Statistics Denmark.[148] The IO model provides insights into how the telecommunications sector interacts with the broader economy by capturing the flow of goods and services between industries. This allows us to estimate the direct, indirect, and induced effects of the telecommunications sector on the Danish economy.

The **direct effects** reflect the immediate economic activity generated by the telecommunications sector in Denmark, such as GDP and job creation within the sector itself.

The **indirect effects** arise from the sector's demand for inputs from other industries. For example, when the telecommunications sector purchases equipment or services from other sectors, it stimulates economic activity along its supply chain. These indirect effects are calculated using multipliers derived from the IO tables.

The **induced effects** capture the additional economic activity generated by employees in the telecommunications sector and its supply chain spending their wages on goods and services. This consumption drives further demand and supports additional jobs in the broader economy.

We have excluded intra-industry purchases within the telecommunications sector to avoid double counting.

[148] Statistics Denmark, Input-output (link)

We use the IO tables from Statistics Denmark to model these effects, which describe the inter-industry linkages specific to the Danish economy. The Danish IO tables include all activity across 69 distinct economic sectors and include both domestic purchases and imports.

Our analysis focuses solely on the Danish context, ensuring that the results are tailored to the structure and characteristics of Denmark's economy.

INPUT-OUTPUT MODELLING: EFFECTS OF TELECOMMUNICATIONS SECTOR'S INVESTMENTS

In addition to estimating the overall economic footprint of the telecommunications sector, we use the IO model to estimate the specific impact of investments made by the sector in Section 1.2. The following four steps outline our approach.

1) Revenue-Multipliers for GDP and Employment:
We first estimate **revenue-multipliers** using the IO model. These multipliers describe the direct, indirect, and induced effects of revenue in each of the 69 sectors in the economy on GDP and employment. They provide the basis for understanding how each unit of revenue generates economic activity across the Danish economy.

Direct multipliers capture profits, product taxes, and salaries in the sector. Indirect multipliers capture purchases of intermediary goods and services from domestic companies.[149] Induced multipliers capture when employees in the sector spend their salaries.

2) Sectoral Breakdown of Investment:
Using the five most recent IO investment tables (2015-2019),[150] we estimate the average distribution of investments made by the telecommunications sector across the 68 other sectors. This helps us understand which sectors benefit from these investments. Additionally, we calculate the share of investments that remain within the domestic economy versus those used to import goods and services.

3) Estimation of 2023 Investment Allocation:
We apply the shares estimated in Step 2 to recent data on the telecommunications sector's investments from Klimadatastyrelsen for 2023.[151] This allows us to estimate how these investments were distributed across sectors, how much of the investment remained within Denmark and how much of the investments are used to import goods and services from other countries.

4) Multiplying by Revenue-Multipliers:
Finally, we apply the multipliers from Step 1 to the sectoral breakdown from Step 3. By doing this, we calculate the direct, indirect, and induced effects of the 2023 telecommunications sector investments in different sectors on GDP and employment in Denmark.

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[149] When the sum of direct and indirect is below 1, it is due to purchases from foreign suppliers.
[150] Statistics Denmark, Input-output - Danish Investment matrices (DB07) (link).
[151] Klimadatastyrelsen (2024), Økonomiske Nøgletal for Telebranchen 2023 (link).

EFFECTS OF DIGITAL INFRASTRUCTURE ON PRODUCTIVITY AND ECONOMIC GROWTH

In Sections 2.1 and 3.2.2, we estimate the effect on GDP of advancements in i) increase in fixed broadband download speeds, and ii) increase in mobile and fixed broadband adoption. The following outlines our approach.

The effect on GDP of increasing fixed broadband download speeds

1) GDP increase due to an increase in broadband download speeds

We use the results from Telecom Advisory Services (2020)[152], who find that a 100 per cent increase in fixed broadband download speeds lead to a 0.26 per cent increase in GDP for download speeds between 10 Mbps and 40 Mbps, and a 0.73 per cent increase in GDP for download speeds above 40 Mbps.

2) Annual growth in fixed broadband download speeds

We use data from Klimadatastyrelsen on the median download speeds between 2013 and 2023. To forecast the future development of fixed broadband download speeds, we consider two scenarios, which we construct based Cisco (2020)[153] who estimate that download speeds will continue to grow at a CAGR of 19.2 per cent.

- In the **optimistic scenario**, we assume that download speeds will grow at the Cisco forecasted CAGR plus 5 per cent, resulting in a projected CAGR of 24.2 per cent.
- In the **conservative scenario**, we apply the Cisco forecasted CAGR minus 5 per cent, giving a projected CAGR of 14.2 per cent.

Then, we calculate the annual growth in the median download speed between 2014 and 2030, both in the optimistic and conservative scenario.

3) Annual GDP contribution from increased download speeds

Finally, we calculate the annual GDP contribution from increased download speeds by combining the estimate from step 1) by the annual growth in the median download speed from step 2).

The effect on GDP of increasing fixed and mobile broadband adoption

1) GDP increase due to an increase in mobile and fixed broadband adoption

We use the results from Briglauer, Cambini, and Gugler (2023)[154], who find that a 1 per cent increase in fixed broadband adoption (measured in subscriptions per capita) leads to an increase in GDP between 0.026 per cent and 0.034 per cent. For mobile broadband adoption, they find that a 1 per cent increase leads to a GDP increase between 0.079 per cent and 0.088 per cent.

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[152] Telecom Advisory Services (2020), Assessing the Economic Potential of 10G Networks (link).
[153] Cisco Annual Internet Report (2018-2023) White Paper (link).
[154] Briglauer, Cambini, and Gugler (2023) Economic benefits of high-speed broadband network coverage and service adoption: Evidence from OECD member states (link).

2) Annual growth in mobile and fixed broadband adoption
We use information from OECD on the number of subscribers per capita for mobile[155] and fixed[156] broadband in Denmark from 2013 to 2023. Using this data, we calculate the annual growth in mobile and fixed broadband adoption. Due to stagnation in adoption in recent years, we do not consider the future effect of mobile and fixed broadband adoption on GDP. Therefore, we do not forecast adoption.

3) Annual GDP contribution from increased mobile and fixed broadband adoption
Finally, we calculate the annual GDP contribution from increased mobile and fixed broadband adoption by combining the estimates from step 1) by the annual growth in adoption from step 2).

ENABLING THE GREEN TRANSITION BY REDUCING CO2 EMISSIONS

In Sections 2.2 and 3.2.3, we estimate the environmental benefits of increased network energy efficiency. In particular, we estimate the CO2 emissions avoided due to historical and future improvements in the mobile and broadband network's electricity consumption. The following four steps outline our approach.

1) Total amount of data traffic in the Danish mobile and fixed broadband network
First, we estimate the total amount of traffic, measured in units of data, in the Danish mobile and fixed broadband network. To do this, we use information on the total data traffic in TDC Net's entire network between 2019 and 2023[157]. To estimate the total data traffic in all of Denmark, we first estimate how much of the total traffic is in the mobile and fixed broadband network, respectively. To do this, we use information on the total up and download traffic at the consumer level in the fixed[158] and mobile[159] broadband network. Combining this with TDC's network market shares in the fixed[160] and mobile[161] broadband network markets, we calculate the total amount of data traffic in Denmark.

We forecast the total amount of data traffic in the Danish mobile and fixed broadband network until 2030 using a CAGR of 20 percent, and 18 per cent for the mobile and fixed broadband traffic, respectively.[162]

2) Electricity consumption per unit of data traffic
Second, we estimate the amount of electricity consumed by the network to deliver a unit of data. To do this, we use information on the energy intensity, i.e. the amount of electricity (MWh) consumed per unit of data (PB), in TDC Net's network between 2019 and 2023[163]. We assume that the rest of the Danish network consumes the same amount of electricity per unit of data as TDC Net's network.

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155 OECD, Going Digital Data Kitchen - Mobile Broadband (link)
156 OECD, Going Digital Data Kitchen - Fixed Broadband (link)
157 TDC Net (2023), Annual Report 2023 (link).
158 Klimadatastyrelsen, Internet dataark, 2. halvår 2023 (link).
159 Klimadatastyrelsen, Hovedtal dataark, 2. halvår 2023 (link).
160 TDC (2016), Svar på Erhvervsstyrelsens høring om bredbåndsmarkeder (link).
161 TDC Net (2023), Annual Report 2023 (link).
162 Arthur D. Little (2023), The evolution of data growth in Europe (link).
163 TDC Net (2023), Annual Report 2023 (link).

We forecast electricity consumption per unit of data traffic in two scenarios.

- In the **optimistic scenario**, we assume that the network's total electricity consumption remains constant. This is in line with Ericsson's finding that there does not seem to be a correlation between data traffic and electricity consumption.[164] In addition, we use forecasts for data traffic growth in Denmark by Arthur D. Little, who estimate a 20 per cent and 18 per cent compound annual growth rate (CAGR) for mobile and fixed data traffic, respectively.[165] Combined, the electricity consumption and data traffic forecasts result in an acceleration of network energy intensity reductions, from a historic CAGR of -9.5 per cent between 2019 and 2023, to a CAGR of -15.5 per cent from 2024 to 2030.
- In the **conservative scenario,** we assume that the network energy intensity continues to decrease at the historical rate, that is a CAGR of -9.5 per cent (from 12.14 MWh per PB of data in 2019, to 8.15 MWh per PB of data in 2023).

3) CO2 intensity of electricity

Third, we use information on the average amount of CO2 used to produce and deliver one unit of electricity, i.e. the annual average CO2 intensity of electricity. We use historical and forecasted values from Energinet.[166]

4) Calculate the avoided emissions due to improvements in network energy efficiency

Finally, we calculate the avoided emissions due to improvements in network energy efficiency. We calculate the annual emissions from the network's electricity consumption as the product of the total data traffic from step 1), the electricity consumption per unit of data from step 2), and the CO2 intensity of electricity from step 3).

To calculate the historical avoided emissions, we present in Section 2.2, we calculate the difference in emissions in two scenarios: 1) the scenario where the electricity consumption per unit of data traffic decreases, from 12.14 MWh/PB in 2019, to 8.15 MWh/PB in 2023, and 2) the scenario where the electricity consumption per unit of data traffic remains constant at the 2019-level of 12.14 MWh/PB. The difference in emissions allows us to isolate the emissions avoided due to improvements in the energy efficiency of the network.

To calculate the future avoided emissions, which we present in Section 3.2.3, we follow the same approach as for the historical avoided emissions. We consider the difference between a scenario where the energy efficiency of the network keeps decreasing until 2030, and a scenario where the energy efficiency of the network remains at the 2023-level of 8.15 MWh/PB.

[164] Ericsson (2023), ICT energy - The energy use and enablement effect of the Information and Communication Technology Industry (link).

[165] Arthur D. Little (2023), The evolution of data growth in Europe (link), Table 1 and 2.

[166] Energinet (2023), Baggrundsdata for Miljøberetningen 2023 (link).

THE POTENTIAL COST OF A BREAKDOWN IN OPERATIONS FOR DANISH COMPANIES RELATED TO A BREAKDOWN IN DIGITAL INFRASTRUCTURE

In Section 2.3, we estimate the potential cost of a telecommunications breakdown for companies in Denmark to highlight the risks of inadequate digital infrastructure protection against cyber-attacks. Our approach uses two key factors: the average cost of a one-hour breakdown for large and smaller companies and the number of large and smaller companies (i.e. more than 250 employees and between 10 and 249 employees) in Denmark. By multiplying these two, we estimate the hourly cost of a nationwide telecommunications outage causing a halt in operations.

We use an average cost of DKK 2.3 million per hour for large companies and between DKK 57,000 – 177,000 for smaller companies, based on an estimated average downtime cost of USD 5,600 per minute for large companies and USD 137 to 427 per minute for smaller companies.[167] This was converted to DKK by multiplying by 60 (for minutes) and applying the 2023 average USD/DKK exchange rate of 6.8895.[168] For example, the estimate for large companies is calculated as 5,600 * 60 * 6.8895, which equals DKK 2.31 million.

We assume that the cost per minute can be linearly expanded to estimate the hourly cost associated with downtime. This might be an overestimation if companies can adjust their operations. However, since we do not have any evidence of how the cost would develop over time, we assume linearity.

According to 2022 data from Statistics Denmark, there were 927 large companies and 24,456 smaller companies in Denmark in 2022.[169] Based on this, we estimate that a nationwide breakdown would cost these companies between DKK 3.5 and 6.5 billion per hour.

FINANCIAL PERFORMANCE OF THE TELECOMMUNICATIONS SECTOR IN TERMS OF RETURN ON CAPITAL EMPLOYED (ROCE)

In Section 4.1.2, we estimate the return on capital employed (ROCE) of different Danish telecoms operators – TDC Net, Three Denmark (3DK), Telenor (Telenor DK), Telia (Telia DK) and Norlys Fibernet – based on publicly available financial statements. We use this to evaluate how well the sector performs under current market conditions.

ROCE is a before-tax measure of the operating return on debt plus equity and was calculated according to the following formula:

$$ROCE = \frac{EBIT}{Capital\ Employed}, \text{ where } Capital\ Employed = Total\ assets\ - current\ liabilities$$

The financial information used and calculations for each operator is presented below.

167 Forbes (2022), How to Guard Against The Cost Of Unplanned Downtime And Network Outages (link) and Pingdom (2023), Average Cost of Downtime per Industry (link).
168 See e.g. Exchange-rates.org, US Dollar (USD) To Danish Krone (DKK) Exchange Rate History for 2023 (link).
169 See Statistics Denmark. FGF3: Preliminary general enterprise statistics by industry (link).

Table 1
ROCE calculation for TDC NET
(million DKK)

METRIC	2019	2020	2021	2022	2023
(a) Revenue	7,050	6,828	6,674	6,639	6,461
(b) EBITDA	4,415	4,434	4,498	4,520	4,695
(c) EBIT	1,043	1,409	2,036	1,979	1,691
(d) Total assets	27,826	28,583	30,244	36,420	34,716
(e) Total equity	8,152	8,756	9,796	2,964	1,867
(f) Total liabilities	19,674	19,827	20,448	33,456	32,849
(f1) non-current	15,979	15,853	14,165	25,848	23,315
(f2) current	3,695	3,974	6,283	7,608	9,534
(g) Capital Employed (d-f2)	24,131	24,609	23,961	28,812	25,182
(h) Investments	2,841	2,759	2,985	2,579	2,323
(i) ROCE (c/g)	4.3%	5.7%	8.5%	6.9%	6.7%

Source: Copenhagen Economics based on TDC Net (2023), Annual Report 2023 (link); TDC NET (2021), Annual report (2021) (link); and TDC Net (2020), Annual Report 2020 (link).

Table 2
ROCE calculation for Three Denmark (3DK)
(million DKK)

METRIC	2019	2020	2021	2022	2023
(a) Revenue	2,736	2,741	2,787	2,905	2,899
(b) EBITDA	755	603	645	626	528
(c) EBIT	400	234	21	-717	35
(d) Total assets	4,658	4,037	4,350	3,936	3,866
(e) Total equity	3,625	2,869	2,842	2,253	2,240
(f) Total liabilities	1,033	1,169	1,508	1,683	1,626
(f1) non-current	503	426	781	981	852
(f2) current	529	742	726	702	773
(g) Capital Employed (d-f2)	4,129	3,295	3,624	3,234	3,093
(h) Investments	194	153	685	768	373
(i) ROCE (c/g)	9.7%	7.1%	0.6%	-22.2%	1.1%

Source: Copenhagen Economics based on HI3G Denmark (2019), Annual Report for 2019 (link); HI3G Denmark (2020), Annual Report for 2020 (link); and HI3G Denmark (2023), Annual Report for 2023 (link).

Table 3
ROCE calculation for Telenor DK
(million DKK)

METRIC	2019	2020	2021	2022	2023
(a) Revenue	4,064	4,013	3,914	3,690	3,775
(b) EBITDA	1,102	968	998	869	817
(c) EBIT	460	291	312	199	110
(d) Total assets	5,426	5,518	6,131	9,312	9,354
(e) Total equity	1,851	1,801	2,586	5,967	5,361
(f) Total liabilities	3,575	3,717	3,545	3,345	3,993
(f1) non-current	2,421	2,431	2,312	2,127	2,557
(f2) current	1,154	1,286	1,233	1,218	1,436
(g) Capital Employed (d-f2)	4,272	4,232	4,898	8,094	7,918
(h) Investments	569	616	457	388	335
(i) ROCE (c/g)	10.8%	6.9%	6.4%	2.5%	1.4%

Source: Copenhagen Economics based on Telenor (2023), Annual report for the period 1 January – 31 December 2023 (link).

Table 4
ROCE calculation for Telia (estimates for Denmark based on group level data)*
(million DKK)

METRIC	2019	2020	2021	2022	2023
(a) Revenue Telia Group	85,965	89,191	88,343	90,827	88,785
(b) Total assets	264,072	226,683	237,025	222,793	226,468
(c) Total current liabilities	50,287	40,101	42,746	42,741	54,158
(d) Capital Employed (b-c)	213,785	186,582	194,279	180,052	172,310
(e) Revenue Telia DK	5,675	5,464	5,214	5,298	5,679
(f) Share of DK revenues (e/a)	7%	6%	6%	6%	6%
(g) Capital Employed DK (f*d)	14,113	11,430	11,466	10,503	11,022
(h) EBIT Telia DK	-45	-25	-299	-594	-253
(i) ROCE (h/g)	-0.3%	-0.2%	-2.6%	-5.7%	0.0%

Note: *The available annual report did not contain i) balance sheet information for operations in Denmark and ii) the EBIT for Telia Denmark in 2023. The following adjustments were made to allow an estimation of the return of capital employed: i) The capital employed for Telia Denmark was calculated based on group level capital employed assuming a split proportional to the weight of Danish revenues on the total revenues of the group; ii) EBIT for 2023 corresponds to the average annual EBIT margin (relative to revenues) as that of period 2019-2022. iii). The official currency exchange rates from the Danish Central Bank were used to convert SEK to DKK to enable aggregation with data from other operators.

Source: Copenhagen Economics based on Telia Company (2020), Annual and Sustainability Report 2020 (link); Copenhagen Economics based on Telia Company (2022), Annual and Sustainability Report 2022 (link); and Copenhagen Economics based on Telia Company (2023), Annual and Sustainability Report 2023 (link).

ARPU CALCULATION

Table 5
ARPUs of telecom operators in Denmark (2022)

OPERATOR	REVENUE (DKK)	USERS	ARPU (DKK/MONTH)
Mobile			
Telenor DK[1]	n/a	n/a	102.9
Telia DK[2]	2,681,371,440	1,712,000	130.5
Three Denmark[3]	2,821,045,500	1,513,570	153.0
Fixed			
TDC Net[4]	2,576,000,000	1,192,000	180.1

Note: 1) Mobile ARPU for Telenor was retrieved directly from the Telenor groups' Q4 2022 financial report; 2) We considered the Total service revenues in Denmark (reported in the group's Q4 2022 financial report, and the number of mobile subscriptions in Denmark (reported in the group's cover Annual and sustainability report 2022). Values in SEK were converted to EUR, using a 0.088 conversion rate; 3) We consider total revenues and the number of mobile subscribers at the end of 2022; 4) We considered the reported service revenue and the total number of broadband revenue generating units.

Source: Copenhagen Economics based on 1) Telia Company (2022), Year-end report January - December 2022 (link), p. 8; 2) Telia Company (2022), Year-end report January - December 2022 (link) and Telia Company (2022), Annual and Sustainability Report 2022; 3) HI3G Denmark (2022), Annual Report for 2022 (link); 4) TDC Net (2022), Annual Report 2022 (link).