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Digital Nordics

Staying Ahead of the Digital Revolution

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The 21st century holds challenges as well as opportunities for our cities. Rapid urbanization, air pollution and international competition for talent and investment are some of the challenges we are facing today. Digitalization offers solutions to many of these problems.

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Foreword

The 21st century holds challenges as well as opportunities for our cities. Rapid urbanization, air pollution and international competition for talent and investment are some of the challenges we are facing today. Digitalization offers solutions to many of these problems. We can use digital technologies to make our infrastructure more efficient, to reduce our environmental impact, to improve the quality of life in our cities and to drive economic growth and innovation of cities. But to remain digital frontrunners, we must also create the environment in which digital innovation can flourish.

With this in mind, we have produced "Digital Nordics". This report shows how digitalization is central to the region's growth and how citizens, businesses and the environment can benefit from digital solutions. Innovative projects are already taking place all over the Nordics, a number of which are featured in this report. We hope that showcasing these examples will contribute to a dialogue among the Nordics that will ultimately lead to a broader uptake of these technologies throughout the region.

And who should be reading this report? City and Government officials in the Nordics should certainly take a look. Anyone focused on providing services within the Nordics which could benefit from digitalization. Anyone who lives, works and plays in the Nordic cities whom has an interest in maintaining and further improving competitiveness and quality of life. In fact, anyone who wants to learn from the Nordic cities and maybe even compete with them!

Ulf Troedsson
President and CEO of Siemens Nordics

Introduction

The Nordic countries of Denmark, Finland, Norway and Sweden are among the most digitalized countries in Europe[1]. Their people, businesses and governments have embraced the opportunities of digitalization from an early stage, with wide environmental, societal, and economic benefits[2].

Today, all Nordic countries are well known for their digital capabilities. Denmark is regularly crowned as a leader in digital government services[3], Finland and Sweden are home to an extraordinary density of startups[4], and Norway is the global leader in the adoption of e-vehicles[5]. Further promoting the uptake of digital technologies will play a major role in addressing many of the challenges the Nordic cities and countries are facing today:

Urbanization

Stockholm, Copenhagen, Oslo and Helsinki are among the five fastest growing cities in Europe[6]. The large influx of people into the Nordic capitals poses a challenge to local infrastructure. Using digital technologies, cities can make their energy grids more resilient and improve the efficiency of their transport networks.

Demographic change

As the Nordic societies grow older, pressure on the healthcare system rises[7]. Digital innovations in the healthcare sector, such as telehealth and personalized medicine, are vital in maintaining efficient and high-quality treatment.

Climate change

The Nordic countries have set ambitious targets to reduce their environmental impact. By 2030 Norway aims to become carbon neutral, with Sweden and Finland following by 2045, and Denmark by 2050. Copenhagen's target is to be carbon neutral by 2025 and is seen by many as a leader in this field. Digital innovations in transport, energy, buildings and industry are improving the energy-efficiency and increasing the uptake of renewable energy.

Air pollution

Air pollution, which is mainly caused by local traffic emissions, is the main environmental health risk factor in the Nordics[8]. In 2012, the WHO estimated that dangerous levels of air pollution contributed to the loss of 40,000 healthy life years in the region[9]. Digital technologies can improve air quality, by creating better and more efficient transport systems. Forecasting and modelling software furthermore enables city authorities to implement short-term measures before pollution peaks are likely to happen.

Global competition

Since 2000, the Nordics have lost one in three manufacturing jobs, many of which have been moved to countries with lower production costs[10]. To remain competitive the Nordic countries need to continuously increase productivity and deliver the best products and services. The adoption of digital technologies is key to reaching this goal. Studies have shown, that more than half of productivity growth achieved in the Nordics can be attributed to digitalization[11]. The Nordic Council, has furthermore described digital manufacturing as an opportunity for re-industrialization in the Nordics[12].

Given these challenges, the need for digital solutions is higher than ever. At the same time, the adoption of digital technologies has slowed down in the Nordics, while countries like China, Singapore or South Korea are developing at a much faster pace[13]. If the Nordic countries want to remain digital leaders and successfully tackle the above-mentioned challenges, they need to accelerate their uptake of digital technologies.

With this in mind Digital Nordics is intended to shine a spotlight on the leading position and the many digital and innovative projects already taking place in the Nordics. In doing so, we hope to contribute to a dialogue among the Nordic countries, in which best practice experiences are shared, and innovative technologies gain a broader uptake throughout the region. If successful, the Nordic countries will be able to create cleaner and more livable cities, reduce their environmental impact, and sustain their high standard of living well into the future.

This report is structured as follows: Chapter 2, gives a general overview of the ways in which digitalization has transformed the Nordics, and how its uptake has slowed down in recent years. Chapter 3, highlights the role of Nordic cities as a hotbed of digital innovation. Chapter 4, describes the benefits of digitalization for citizens, businesses and societies, and presents case studies from all over the Nordics. Finally, Chapter 5 addresses the barriers to further adopting digital technologies and includes a number of policy recommendations and best practice examples from the region.

The Nordics

Population - Total and Capital

👤 = 100,000

5.75 million – total Denmark population
1.3 million – total capital population (Copenhagen)

5.5 million – total Finland population
1.2 million – total capital population (Helsinki)

5.25 million – total Norway population
0.9 million – total capital population (Oslo)

10 million – total Sweden population
1.5 million – total capital population (Stockholm)
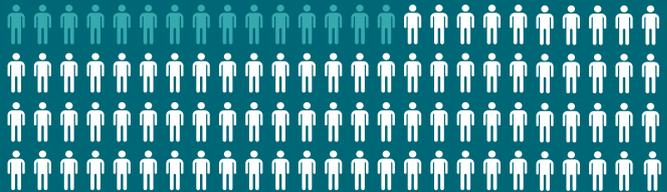
Area and Population Density

👤 = 3 people per km²

Denmark 134 people per km²
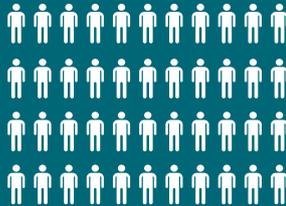
Sweden 22 people per km²

Norway 16 people per km²

Finland 16 people per km²

Denmark - 42,926 km²

Finland - 338,430 km²

Sweden - 447,435 km²

Norway - 323,781 km²

Indicators

$59,350
GDP/capita in 2016 for Norway
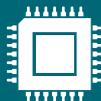
153
ICT patents per million inhabitants in Sweden

29%
Market share of electric cars in Norway

96%
Internet usage in Denmark

[1]Urban settlement (2016)

	Denmark	Finland	Norway	Sweden	OECD
GDP per capita (2016, PPP)	$49,837	$43,364	$59,350	$49,074	$42,075
Productivity growth (average annual rate, 1995-2016)	1.0%	1.5%	0.9%	1.9%	1.5%
Employment rate (2016)	75%	69%	74%	75%	67%
ICT patents per million inhabitants (2016)	42	149	37	153	39
Urban population (densely & intermediate urbanized areas, 2016)	60%	70%	59%	75%	74%
Life expectancy (at birth in 2016)	80.8	81.6	82.4	82.3	80.5
Elderly population (above 65 years, 2017)	19%	21%	17%	20%	16%*
Internet usage (percentage of population using the Internet in the last year, 2014)	96%	96%	93%	92%	85%
Greenhouse gas emissions (tonnes per capita, 2015)	9.3	10.1	10.4	5.5	9.5
Particulate matter emissions (PM_{10}, kg per capita, 2015)	5.4kg	5.9kg	7.6kg	3.9kg	14.8kg
Energy consumption from renewable sources (% of total consumption, 2016)	32%	40%	69%**	54%	12%*
Market share of electric cars (battery electric and hybrid, 2016)	0.6%	1.2%	29%	3.4%	1.1%
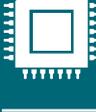
*2014 ** 2015 **Sources:** OECD, World Bank, Nordic Council, World Economic Forum, International Energy Agency, Eurostat, and Reuters.

The Nordics and digitalization

The Nordic countries and cities are all unique, yet they also share some common features. Their economies are well advanced, with high wage levels and an even income distribution. Trust in public institutions is high, and the Nordic populations are among the most educated in the world. Outside of the region, the Nordics are well known for their generous welfare systems, as well as for regularly occupying top positions in rankings on human development, gender equality and happiness.

In terms of digitalization, the Nordic countries fare equally well. Their governments have been early adopters of digital technologies, now offering many services over the internet. Digital skills and internet usage are widespread among the Nordic populations, and many innovative tech firms, including Spotify, Skype, or iZettle were founded in the Nordics. Given the progress the region has made in digitalizing their societies, governments, and businesses, it comes as little surprise that the countries of Denmark, Norway, Finland & Sweden came out top in the European Commission's Digital Environment and Society Index (DESI)[14].

2.1 Digital People

The Nordic people are world leading when it comes to the use of digital technologies. More than 95 percent of the populations of Denmark and Norway use the Internet at least once a week, a number only beaten by Iceland, Luxembourg, and Andorra. Sweden and Finland rank close behind, with 90 percent. The Nordic populations are leading in digital competences, with three out of four people having at least basic digital skills, compared to just every second person in the EU[15].

The widespread use of digital technologies has helped the Nordics adopt a number of innovative solutions. An example is the Nordic's leadership in digital payment services. With cash only being used in ten percent of retail transactions[16], the Nordics far outrun their European neighbors, where cash is being used in more than half of all retail transactions. This transition has been facilitated through technologies such as iZettle, a mobile card reader, and mobile payment apps, allowing users to instantly send money to anyone else with the app. Backed by major banks, these apps have gained increasing traction in all Nordic countries. The Swedish version, Swish, is now being used by more than half of the Swedish population, while the Danish equivalent, MobilePay, is regularly used by two out of three Danes. For the Nordics, the increased use of digital payment methods is not just about convenience: a study by the Danish National Bank estimated the costs related to cash payments, e.g. the costs for security or staff handling cash, to be twice as high as those related to electronic payments[17].

Fig. 1 The Nordics are the most digitized countries in Europe.

Digital Economy and Society Index (DESI), weighted scores, 2017
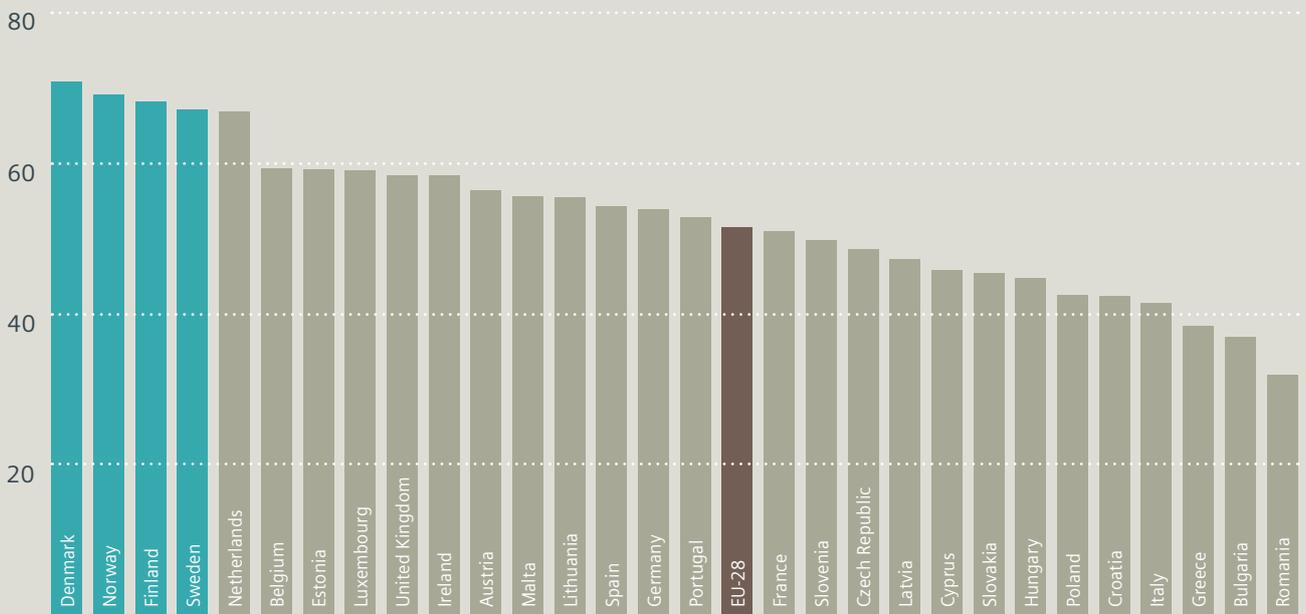
Source: European Commission
The Digital Economy and Society Index (DESI) is a composite index published by the European Commission. It summarizes relevant indicators on European countries' digital performance. The indicators include connectivity (25%), human capital (25%), use of internet (15%), integration of digital technology (20%) and digital public services (15%).

2.2 Digital Government

The enthusiasm with which Nordic citizens have welcomed digitalization has been strongly encouraged by their governments. Denmark launched a digital strategy in 2001 and today, all Nordic countries have strategies in place. These aim to create the conditions in which the opportunities of digitalization can best be harnessed. They lay out the countries' plans to invest in education and broadband infrastructure. They underline the importance of open data platforms, and carefully address questions of data security. In their strategies, most countries also recognize the need for regulatory changes to accommodate the new digital realities, as well as the significance of coordinating efforts across governmental levels. In response to the rapid developments in the technology sector, Denmark has appointed its first ambassador for digitalization. Based in California's Silicon Valley, the ambassador maintains close ties to major tech firms, thus helping Denmark to stay on top of current developments, while also promoting the country's interests.

The Nordic governments have also undertaken strong efforts to digitalize their own operations. One example is the introduction of digital signatures and postboxes, which serve as the cornerstone of many digital services.

Using these technologies, citizens are now able to go online to file their tax reports, apply for unemployment benefits or register a change of address. Some digital government services even save lives, as in the example of a Swedish service called SMSLifesaver. Implemented by the Swedish government, trained citizen volunteers receive an SMS text when there is a heart attack victim nearby, allowing volunteers to quickly reach the victim and provide cardiopulmonary resuscitation (CPR). In half of cases, these citizen volunteers reach the victim before an ambulance arrives, thus significantly improving the chances of survival.

The governments' efforts to digitalize their services have been met with great interest from the Nordic populations. Overall, more than 80 percent of the Nordic population uses the internet to interact with authorities, compared to less than half of people in the EU. Given these figures, and the wealth of services the Nordic governments provide online, it is certainly justified that all Nordic countries achieved high rankings in the United Nation's E-Government Survey of 2016.

Figure 2
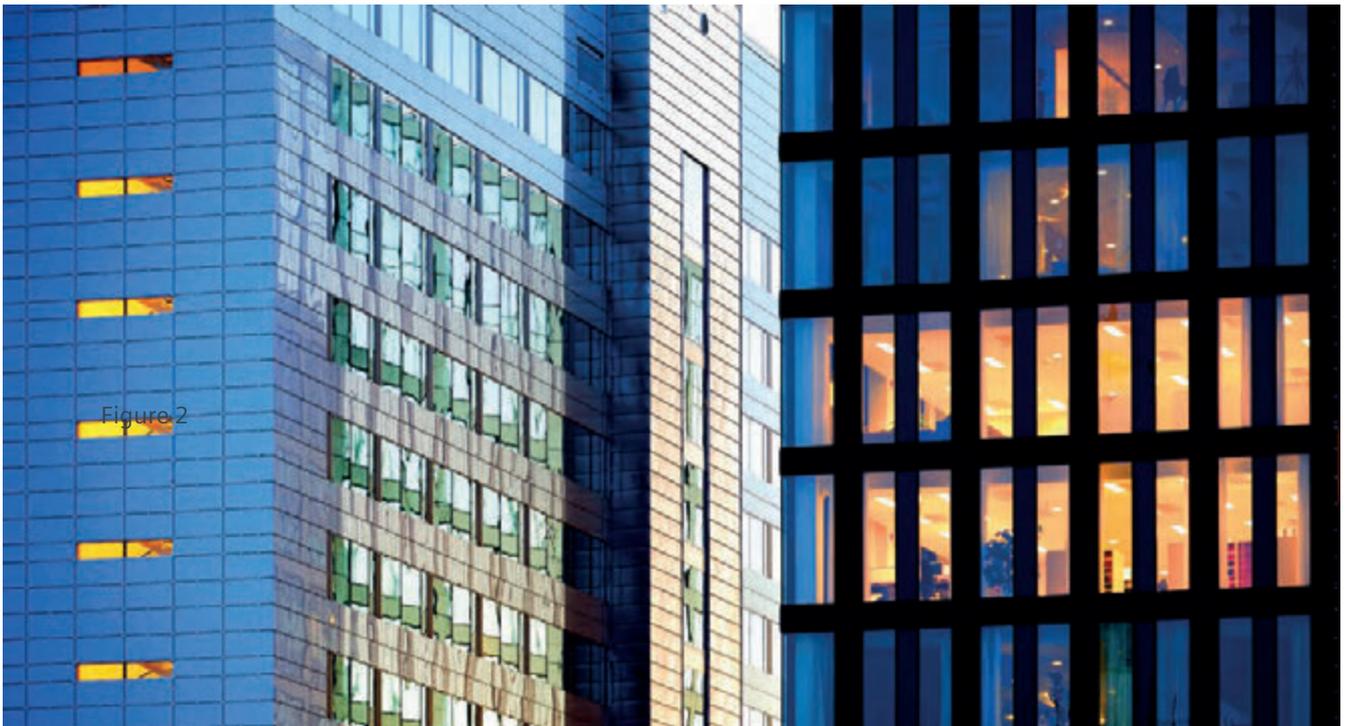
2.3 Digital Business

To understand the state of digital businesses in the Nordics, two aspects require close attention. Firstly, the number of highly successful startups exceeding valuations of $1bn, that have emerged out of the Nordics. Referred to as unicorns, 11 of these startups have been founded in the Nordics. Measured on a per-capita basis, this makes the region the most prolific startup hub globally[18]. Among the most successful Nordic startups are Spotify and Skype, but also e-commerce businesses such as Klarna or iZettle. For Stockholm, the capital of the Nordic startup region, the benefits are abundant: 197,000 people are employed in the high-tech sector, the highest per capita concentration of high-tech employees in Europe[19].

A second aspect is the state of digital businesses in the Nordics. In order to remain competitive, while producing in a high-wage environment, manufacturers in the Nordics have taken considerable efforts to automate their production facilities. One example is the Swedish automotive startup Uniti. Its new production facilities in southern Sweden are designed to produce "with the lights off" 22 hours per day, meaning that no manual interference is needed.

Using a virtual copy of the production facility, the entire manufacturing process can be tested on a computer, enabling engineers to anticipate problems and avoid delays or extra costs during production. The example of Uniti is indicative of the current state of automation, particularly in Sweden and Denmark. Both countries have one of the highest automation rates worldwide. Measured by the adoption of industrial robots per manufacturing worker, they only rank behind South Korea, Singapore, Japan and Germany.

Finland is in the top group as well, with 126 industrial robots per 10,000 industry workers, compared to a global average of 69. So far, only Norway lies slightly below the global average with a robot density of 60[20]. According to the Norwegian Board of Technology[21], the relatively low level of automation in Norway may become a distinct hindrance in the country's efforts to maintain its current number of manufacturing jobs. Overall though, Nordic businesses are at the forefront of making use of digitalization, as the high rates of automation and the region's thriving startup scene show.

Fig 2. Sweden and Denmark have one of the highest rates of automation worldwide.

Number of industrial robots per 10,000 employees in the manufacturing sector, 2015

Source: International Federation of Robotics[22]

2.4 Digitalization creates value for the Nordics

Digitalization has benefitted the Nordics in countless ways. In the last two decades, more than half of productivity growth in the region was achieved through digitalization[23]. As companies began to implement digital technologies, the demand for skilled workers able to operate those systems increased. Today, more than six percent of Sweden and Finland's labor force is employed in the ICT sector, the highest share within the European Union. In cities such as Stockholm, this share even reaches 18 percent of the total workforce, the highest density of ICT professionals in Europe[24]. The high share of ICT specialists in the Nordic's workforce can be seen in Figure 3.

In addition to economic benefits, digitalization has made the Nordics more energy-efficient. Since the turn of the millennium, the Nordic countries have cut their GHG emissions by over 20 percent. Research by the Global e-Sustainability Initiative shows that digitalization will enable further CO_2e reductions of 33 percent by 2030, based on 2015 levels[25].

For society, digitalization presents a wide range of benefits including health improvement, time savings and cost efficiency. As transport systems get more efficient air quality can be improved, and citizens save time on their daily commutes. Innovations in e-government services allow states to reduce administrative costs and to divert these resources to providing better conditions overall.

Fig 3. ICT makes up an important employment sector for the Nordics.

ICT specialists as a percentage of total employment, 2015

	2%	4%	6%
Finland			
Sweden			
Norway			
Denmark			
EU28			
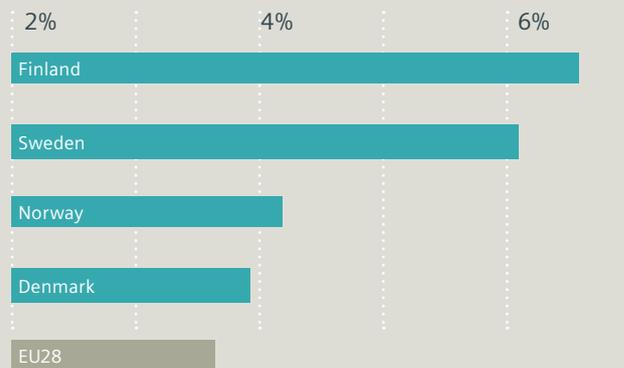
Source: Eurostat[22]

Fig 4. The Nordic countries are highly digitalized, but their rate of digital development is below-average.

State of digitalization vs. pace of digitalization*
*= measured over an eight-year period (2008-2015)
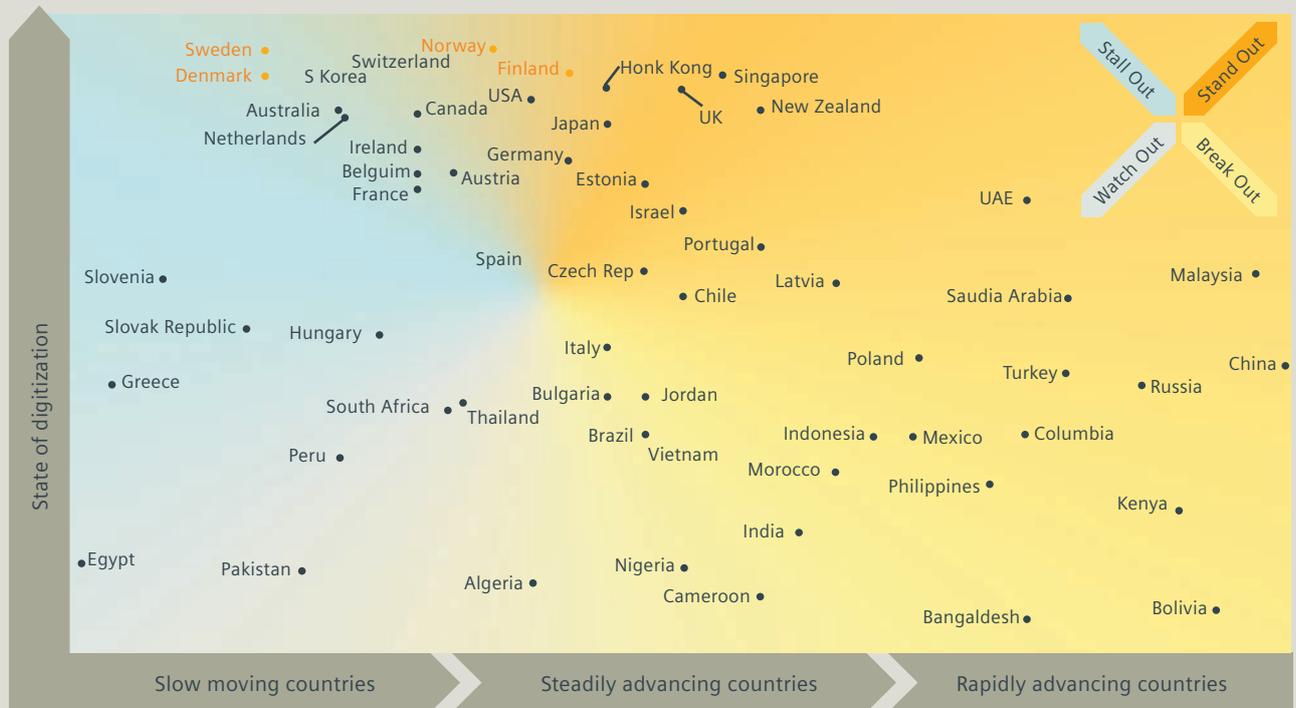
Source: The Fletcher School, Tufts University

2.5 The slow-down of digital growth

Despite the benefits the uptake of digital technologies has slowed down considerably in recent years. Although the Nordics still rank as the most digitally advanced in Europe, a study conducted by the Fletcher School at Tufts University expects them to lose their digital leadership within the next years, as their rate of digital development is lower than those of other countries[26]. Figure 4, plots countries' current state of digital development against its rate of digital development. In the graph, all Nordic countries fall into the top left quadrant, which represents high rates of current development, yet slow digital growth rates. Other countries such as Singapore, Hong Kong or Japan, experience much higher growth rates, while also having achieved a high level of digitalization already.

An indicator reflective of the rates with which these countries are catching up with, and even overtaking the Nordics, is the innovativeness of their digital sectors, measured by the number of ICT patents per capita (Figure 5). Comparing the Nordic's performance on this dimension with that of Hong Kong, Japan, Singapore and South Korea, shows that they have lost their lead.

While the patent density in the Nordics has stagnated since 1999, the Asian comparison group has managed to increase its patent output by a factor of six, overtaking the Nordics in 2009.

The speed with which Asian competitors are currently growing has also been highlighted by Denmark's Digital Growth Panel[29]. The Panel argues, that the low rate of digital growth in Denmark (and the Nordics) could pose challenges to the region's competitiveness, thus endangering local jobs and the region's prosperity overall.

The Growth Panel is certainly right in assessing that the slow rates of digital growth are challenging the Nordic's competitiveness. For ten years, the Nordic countries have experienced only very limited rates of productivity growth (see Figure 6). Since digitalization accounts for more than half of remaining productivity growth in the Nordics, the region should push for a faster uptake of digital technologies. Doing so, would alleviate the region's productivity problem, thereby increasing the region's competitiveness overall.

Fig 5. Losing the digital leadership

ICT patents per 100,000 inhabitants

— Nordics (incl. Denmark, Finland, Norway & Sweden)   — Asian competitors (incl. Hong Kong, Japan, Singapore, South Korea)
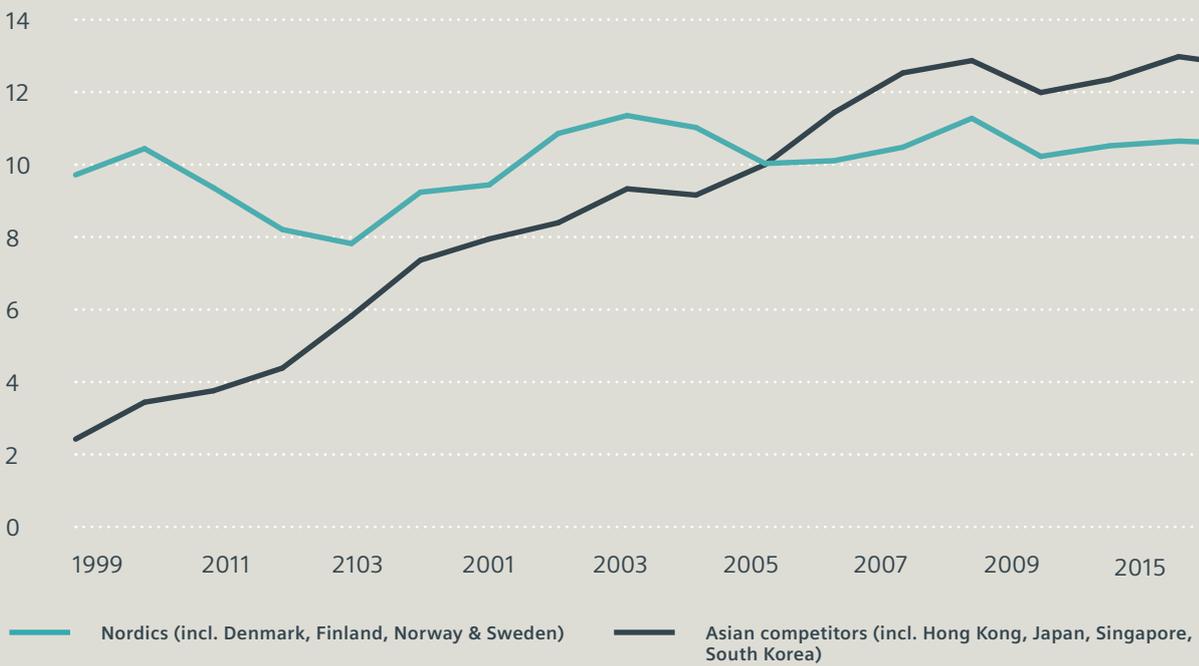
Sources: OECD[27] and WEF[28]

Fig 6. Productivity growth has slowed down in the Nordics

Productivity growth in the Nordics (1990-2016) Index 1990 = 100

— Sweden   — Finland   — Norway   — Denmark
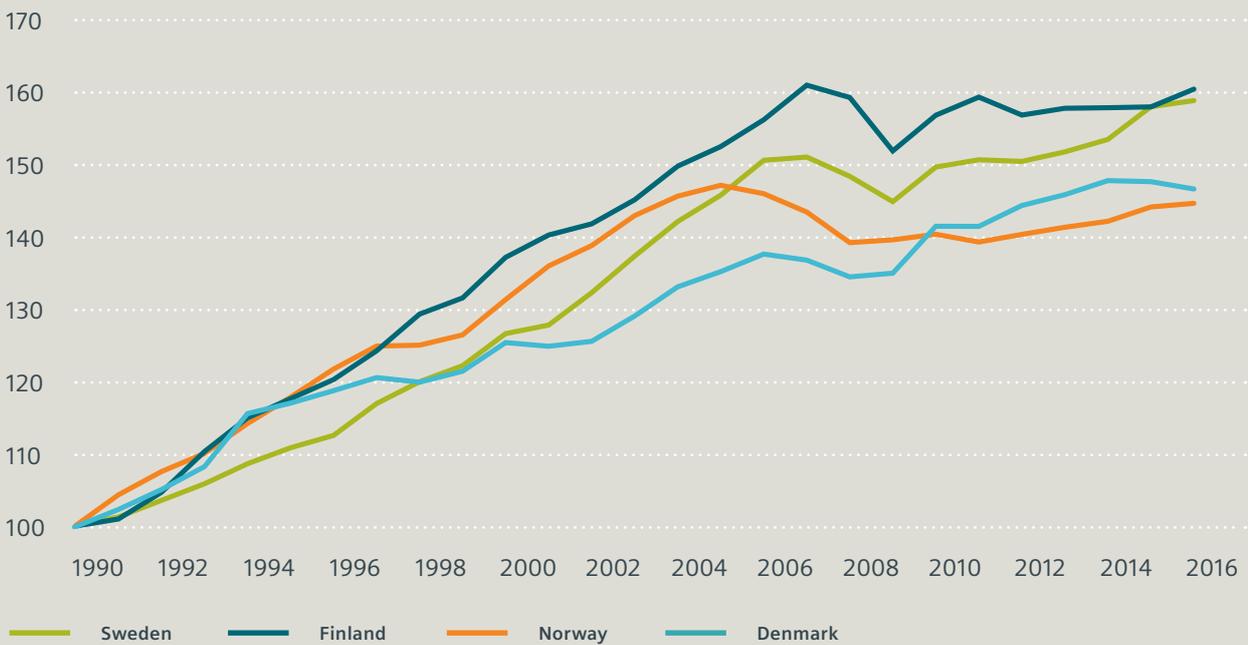
Sources: OECD[30]

2.6 Overcoming the digital plateau

Despite the Nordic countries being digital frontrunners, many cities in the Nordics have reached a stage where the uptake of digital technologies has slowed down. Businesses are frustrated by "pilot sickness" where pilot projects are carried out without subsequently being scaled up[31]. A lack of funding, a lack of public leadership and unaddressed public concerns pose some of the main barriers to accelerating digital transformation.

However, each of these barriers can be overcome, and positive examples where this is already being done exist throughout the Nordics. Sweden and Denmark have recently introduced long-term funding programs to move digital projects beyond the pilot phase, ensuring that new technologies can be widely implemented. Several cities in the Nordics have introduced open data platforms to spur the development of smart city solutions and cities like Copenhagen have created internal innovation networks to strengthen cross-departmental organization. Cities and governments also need to address public concerns regarding digital technologies for example when it comes to issues of data privacy.

"Norway has a successful history of major transitions. As individuals, Norwegians are now leading the way in adopting new technology, however industry and public sector are not as tech savvy. We have many reasons to be proud, but we must avoid becoming complacent.

In an increasingly global business-world we must exploit our current advantages to unleash innovation and create growth. To succeed we need more people with advanced digital skills, we need to invest in lifelong learning, increase investments in research, and we need to enable Norwegian startups to succeed internationally. This will require brave politicians, smart legislation that supports innovation and we need business leaders that are not afraid to take on major shifts."

Kjetil Thorvik Brun,
Head of ICT and digital industries
Abelia

The role of digitalization for cities

Challenges such as rapid urbanization, dangerous levels of air pollution and strong international competition are encouraging Nordic cities to come up with innovative responses (see Figure 7 and 8). As cities are tackling these challenges, they increasingly develop and implement digital technologies to manage their infrastructure more efficiently and to reduce their environmental impact. Yet Nordic cities are not only implementing technologies to tackle their own challenges but are developing products and services for the world market. These cities are front runners in driving digital technologies.

Cities have always been a place of innovation. As people move closer together, new social ties are formed, allowing people and firms with diverse bases of knowledge to exchange ideas and innovate. The Nordic cities have done especially well in harnessing the creativity of their citizens. This is facilitated by a strong collaborative culture that stretches across academia, the public and the private sector. An example is Kista Science City in Stockholm. Created in the 1980s by a coalition of industry, academia and the public sector, the goal was to create a center for electronics research. Today, the area is home to 1,000 ICT companies and more than 6,800 university students take courses at the Kista campus of Stockholm's technical university.

Wireless communication technologies such as GSM or EDGE have been developed in the area and a local startup incubator helps Stockholm to foster its position as a global startup hub[32].

Stockholm serves as a global hub for startups and is the birthplace of worldwide success stories such as Skype, iZettle or Minecraft. In 2018, 5G services will be rolled out throughout Stockholm and Helsinki. The technology's low latency and high connection speeds will be particularly useful for data-heavy technologies such as connected cars or industrial automation. Implementing this technology quickly and ahead of other European cities will provide the Nordics with a competitive advantage in the further development of smart cities and industries.

In addition to this collaborative culture, Nordic cities benefit from their access to capital and a strong economic performance overall. Serving as economic centers, cities attract investment and talents from all over the world, further creating opportunities for the development of digital innovations. Taken together, these factors make the Nordic cities more than the sum of their parts. Figure 9 shows, how digital innovativeness increases, even on a per capita basis, as population size increases.

Fig 7. Rapid urbanization requires cities to function more efficiently

Population growth in major Nordic cities (municipal level)

Copenhagen (+13%)

613K (2018) → 706K (2030)

Gothenburg (+15%)

565K (2018) → 662K (2030)

Helsinki (+11%)

643K (2018) → 720K (2030)

Malmö (+13%)

334K (2018) → 386K (2030)

Oslo (+13%)

684K (2018) → 788K (2030)

Stockholm (+16%)

950K (2018) → 1,135K (2030)
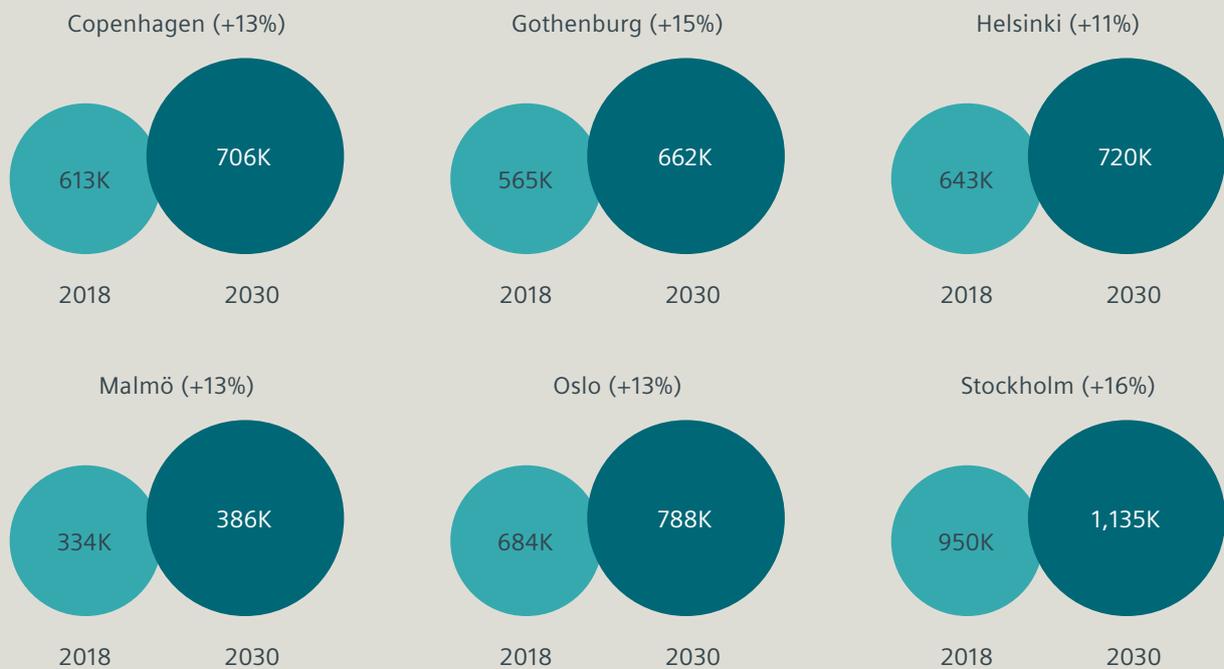
Sources: Nordstat.

Fig 8. Air pollution is a serious health issue in Nordic cities

Annual deaths caused by air pollution and road traffic accidents in Nordic cites

	Copenhagen	Gothenburg	Helsinki	Malmö	Oslo	Stockholm
Premature deaths caused by air pollution	950	200	175	80	185	138
Road traffic deaths	13	10	3	2	4	4

Sources: City of Copenhagen, City of Helsinki, City of Malmö, Statistics Norway, Ministry of the Environment (Finland), Danish Road Directorate, Transport Analysis Sweden, University of Stockholm, University of Gothenburg and Norwegian Broadcasting Corporation.

The Nordic cities are not just leaders when it comes to digital innovation. They are also setting themselves ambitious targets in relation to environmental sustainability. Already today, the Nordic cities make up 85 percent of the population, but only consume 59 percent of the region's energy supply[33]. The cities' ambitions can also be seen by comparing their carbon emission targets with those of their countries. With the exception of Norway, where both capital and country aim to become carbon neutral by 2030, all other Nordic capitals have set more ambitious goals than their countries. Stockholm has set a target for 2040, five years earlier than Sweden. In Helsinki carbon neutrality shall be achieved by 2035, ten years earlier than Finland as a whole. Copenhagen aims to become carbon neutral by 2025, 25 years earlier than Denmark.

The Nordic cities like many others globally, are facing serious challenges, but their innovative culture and ambition allows them to develop and implement the technologies needed to tackle these challenges successfully. If the Nordic cities are able to further build on their strengths, they will not only achieve cleaner cities and better quality of life. They will also provide the foundations for the digital businesses and industries of an ever more digitalized and connected world.

Nordic cities make up 85 percent of the population, but only consume 59 percent of the region's energy supply

Fig 9. Cities drive forward digital innovation

ICT patents per capita by population size
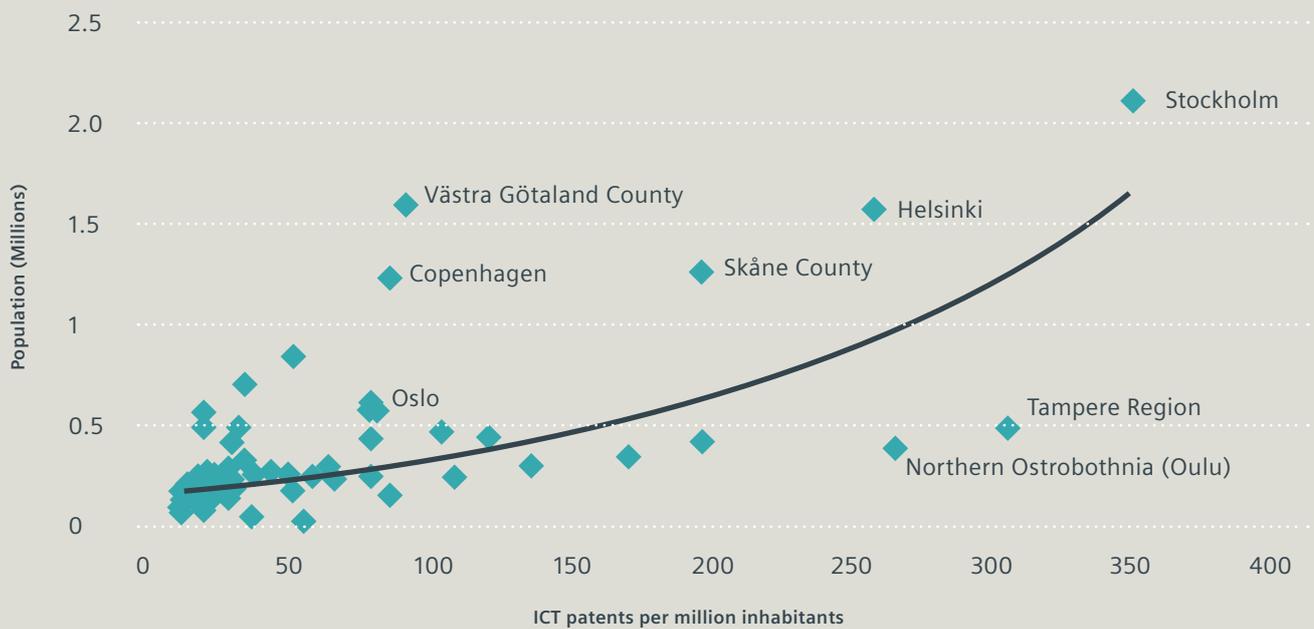
The impact of digitalization

Fig 10. Annual GDP growth could nearly double in Denmark and Finland.

Potential for increased economic growth under world-class digitization scenario

Legend:
- GDP CAGR '14-'20
- Potential GDP CAGR

(Chart showing Denmark, Finland, Sweden)
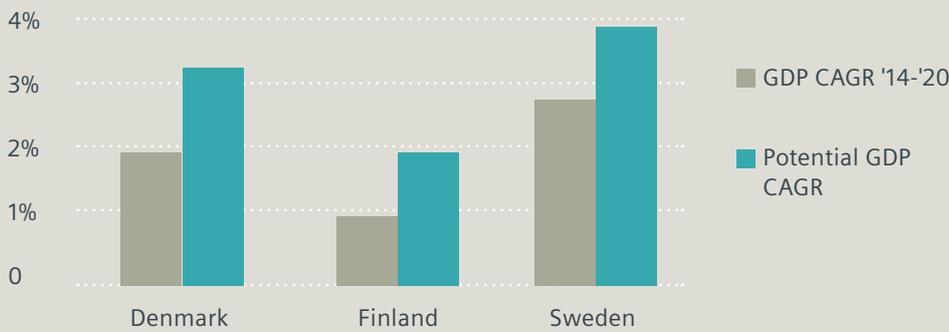
Source: The Boston Consulting Group[36]

The world has never been more connected. From buildings to trains, to manufacturing and medical equipment, the physical world is taking on a digital dimension. In the Nordics, the number of connected devices is set to reach six per person in 2021 – four times as many as in the rest of the world[34]. This increasing convergence of the physical and virtual world offers boundless opportunities for almost all areas of society. The Nordics are especially well equipped to harness these opportunities, as their digital infrastructures are well advanced and their people are the most proficient users of digital technologies in Europe.

34%

Digitalization can lead to 34% less CO_2e emissions by 2030*

*based on 2015 levels

Connected assets in the smart city	
Energy	Turbines, wind turbines, batteries, smart meters, substations, compressors, district heating networks
Transportation	Trains, subway stations, ships, trucks, logistics, container, traffic lights, streets lights, bikes, cars. pavegen
Industrial Production	Machines, conveyers, controls, drive trains, pumps, valves
Building Technology	Heating, ventilation, air conditioning, lightning, access & security, fire & safety, water and waste water, waste and recycling
Healthcare	Medical equipment, implants, hospitals
and many more	Agriculture, smart home, retail

Today, the Nordics are experiencing the benefits of digitalization in a number of areas:

- Commuters arrive quicker and more comfortably at their destinations, as intelligent mobility solutions increase the availability of public transport, optimize throughput and create an improved passenger experience.

- Efficient building management systems control every aspect of a building, creating an ideal working and living environment while also reducing operational costs.

- Smart grids bring the Nordics closer to achieving their environmental goals, as they enable power operators to manage energy more efficiently and incorporate electricity from distributed and renewable sources.

- Community energy projects such as LO3's Brooklyn microgrid.

- Businesses all over the Nordics develop digital business models, creating new revenues and jobs for the region.

- In manufacturing new digital technologies allow engineers to design entire production processes in a virtual environment, significantly reducing costs and speeding up time-to-market.

According to a study by the Boston Consulting Group (see Figure 10), GDP compound annual growth rate (GDP CAGR) could nearly double in Denmark and Finland, if digital technologies were fully embraced. In Sweden, GDP growth could increase by an additional percentage point, equivalent to a €5 billion increase of GDP every year. For Norway, which was not part of the study, a similar growth increase can be assumed.

Beyond economic benefits, digital technologies have the potential to sharply reduce greenhouse gas emissions, as resources can be used more efficiently. A study by the Global e-Sustainability Initiative estimated the potential reduction of greenhouse gas emissions through digitalization by 2030 as 300 megatons CO_2e for Germany and 180 megatons CO_2e for the UK[35]. For both countries, this is equivalent to a 34 percent reduction compared to 2015 emission levels. Assuming a similar potential for the Nordic countries, it is clear that a further adoption of digital technologies will play an essential role in the region's path to a more sustainable future.

4.1 The impact of digitalization on citizens

4.1.1 Digitalization saves money

According to Denmark's Digital Growth Panel, digitalization will save citizens around €1,000 per person each year from 2025 onwards[37]. These savings are related to reduced consumer prices, caused by digital and more cost-efficient production methods and retail channels. They also include reduced energy needs, e.g. through the use of more efficient devices, as well as lower energy prices overall, caused by the increasing efficiency of smart energy grids. Shared mobility services will furthermore allow citizens of the Nordics to consume mobility as a service, diminishing the need for private ownership of vehicles.

€1,000

Digitalization could save citizens €1,000 per person a year. These savings are related to reduced consumer prices

Case study:

In Helsinki people buy journeys, not cars

Partnering with organizations from the private and public sector, Helsinki has established a dynamic trip-planning and ticketing service. Using a single app named Whim; citizens can choose their preferred route to destination, using public transport, a taxi, or a private rental vehicle. In contrast to other route-planning services, Whim also allows users to pay for their journeys via the app, further adding to the convenience of the service.

Recognizing the need for alternatives to car ownership, Whim also offers monthly plans, which include unlimited use of public transport, taxis and rental cars. Currently this service is priced at €500 a month, thus considerably cheaper than the €684 that Finnish car owners pay for their car each month[38].

The benefits of mobility services like these go well beyond cost savings for citizens. Dynamic trip-planning services have been shown to increase the overall use of public transport by 2%, as users are better able to consider the transport modes available to them, as well as their economic and environmental impacts. As a result, services like these are estimated to cut transport emissions in cities by up to 6%[40].

Case study:

A blockchain-based land registry for Sweden

In most countries buying a property involves additional fees that go beyond the price of the property. One example is notary fees needed to cover the costs for registering real estate transactions. But the current system is not just costly, it is also slow. In Sweden, it can currently take three to six months after signing the contract until the land title finally changes hands[41].

This is why Sweden's land registry authority, Lantmäteriet, initiated a collaboration with banks and technology companies to develop and test a blockchain-based solution for real estate transactions. Using the technology, transactions can be verified almost immediately by all involved actors, such as buyer and seller, the land registry and banks. Besides being a secure and transparent verification system, the blockchain also serves as a storage service for property transactions, eliminating the need for physical archives. Sweden's land registry estimates that the benefits of faster transactions, reduced paperwork and increased security amount to € 100 million per year for Swedish society[42].

While the technology is ready, digital signatures for purchasing properties are not currently accepted under Swedish law. This prevents a wide-scale implementation of a blockchain-based land registry. Nevertheless, Lantmäteriet is confident that this legal obstacle can be resolved, citing the increasing legal acceptance of digital signatures in Swedish society. Indeed Sweden is not the only place aiming to move its land registry to blockchain. The United Kingdom, Dubai, and Georgia all have announced similar plans. Currently however, Sweden is the country that is furthest along in implementing the technology, and land registries from other countries have already approached the Swedish team for a blockchain solution of their own[43].

4.1.2 Digitalization saves time

Three kilometers outside of Helsinki's city center lies the smart district of Kalasatama. The district is one of Helsinki's most ambitious innovation projects. Here, over 200 stakeholders from the private and public sector pilot smart city solutions in a real life environment. The project's foremost goal is to create an environment that saves one hour of citizen's time every day.

Indeed, people all over the world lose time as they wait in queues and travel through their cities. Smart city solutions have the potential to speed up travel times, as traffic can be managed more efficiently. In many cases, waiting times can be abolished overall, as citizens can access services via the internet, as in the case of e-Government services.

Case study:

In Stockholm traffic lights keep buses on time

Between 2015 and 2020, Stockholm's population is set to grow by an additional 11%, making the city the fastest growing of Europe. The continuous influx of people poses a challenge to the city's traffic system, as streets and public transport systems quickly need to adapt to the new demands. With average commuting times up by over 20 percent between 1995 and 2013, the city needed to find a solution to make travelling in the city more efficient[45].

One of these solutions makes sure that buses behind schedule receive priority at traffic lights. Tracked via GPS, buses automatically send a request to the city's traffic control system as they approach an intersection after which the lights switch to green. When the bus has passed the junction, the traffic lights switch back to their normal switching routine.

The benefits are increasing punctuality and attractiveness of public transport, encouraging citizens to switch to these modes of transport. Punctual buses however, are not just an amenity for commuters. In London, where buses have slowed down considerably within the last years, it is estimated that lost fares from customers choosing other modes of transport have led to a fare loss of €226 million per year[46].

Helsinki aims to save citizens 1 hour every day through digital technologies

Case study:

In Helsinki smart street lights find motorists a parking space

Despite a recent slow-down[47] the number of vehicles in Helsinki grew over the last decade . This creates challenges for the city, as parking spaces become increasingly scarce and cars trying to park congest streets. On average, drivers spend 100 hours a year looking for a parking space, which accounts for 30 percent of all urban traffic . To counter the resulting time loss, congestion and unnecessary emissions the City of Helsinki has partnered with private developers to pilot a smart parking solution[50].

The pilot uses miniature video cameras mounted on the street lights to monitor parking spaces. The cameras, which are connected to the Internet, forward the data to a cloud-based image analytics software, assessing whether parking spaces are available. This data can then be shared with city authorities and motorists, for example through a trip-planning app.

Studies have shown, that intelligent parking solutions like these cut time spent looking for parking spaces by over 40%, saving the average driver 40 hours per year[51]. For residents, the service furthermore reduces air pollution and traffic noise. Wider applications of the technology include the measurement of speed and traffic conditions or the detection of parking violations.

Adding to the environmental benefits of the service, trip-planning apps can propose public transport if no parking spaces are available.

4.1.3 Digitalization leads to healthier lives

Changing demographics pose a challenge to developed countries all over the world. As populations age, the demand for health services increases – and so does public spending. In 2016 the Nordic countries spent an average of 10.3 percent of their GDP on health, 3 percentage points more than at the start of the millennium[52]. As a result, health care systems face constant pressures to deliver their services more efficiently.

While societies have grown older, digital technologies have matured as well. Today, healthcare systems around the world use digital technologies to improve the quality of their service, while also reducing costs. Applications include remote monitoring of patients, electronic medical records, and even the development of personalized medicine, based on the analysis of patients' genetic data.

10.3%

In 2016 the Nordic countries spent an average of 10.3 percent of their GDP on health. 3 percentage points more than at the start of the millennium

Case Study:

Denmark's digital healthcare system

Denmark's healthcare sector has embraced the opportunities of digitalization from an early stage. In 1990, Denmark saw its first electronically transmitted prescription. Two years later, 60 percent of Danish General Practitioner's (GPs) were keeping electronic medical records, and in 1994, a standardized health data network, known as MedCom, was introduced throughout Denmark[53].

Today, virtually all communication between healthcare providers is done electronically, saving Danish doctors an average of 50 minutes a day in administrative work[54]. As Denmark has been collecting this data for many years, researchers are able to tap into a unique pool of knowledge, leading to a better understanding of which treatments are most effective. By analyzing a person's genetic data, Danish hospitals are also able to provide patients with better and more targeted treatment. Having produced positive results in the treatment of cancer, Denmark is currently developing strategies to expand personalized medicine into other disease areas[55].

To give citizens a high level of insight into their medical data, Denmark introduced a national e-health portal in 2003. Sundhed.dk offers citizens access to their medical records, and serves as a point of contact for people engaging with the healthcare sector. Here, patients can book appointments with their GPs, access information on their conditions or read about the medication they have

been given. The platform also offers online forums, where people with chronic diseases can share their experiences. Evaluations have shown, that patients using the service are better informed, and feel less anxious about their health[56].

Recognizing that patients with reduced mobility find it challenging to regularly visit a hospital, Denmark's Northern Jutland region has started a pilot project in telemedicine. Patients with Chronic Obstructive Pulmonary Disease (COPD) measure their weight, oxygen saturation, heart rate and blood pressure themselves. The results are automatically transferred to healthcare professionals at the local hospital, who analyze the data and adjust medication if needed. The project saves costs for hospitals, but also gives patients greater autonomy and improves understanding about how diet, exercise and medicines adherence influences their results. Due to the success of the pilot, the project will be introduced throughout Denmark by 2019.

As the examples above show, Denmark's ambition to digitally transform its healthcare sector yields positive results for the quality of treatment and its cost-effectiveness. Today, patient satisfaction in Denmark is at 93%[57] and it is estimated that further implementation of digital technologies will save €1.7 billion a year from 2025 onwards[58].

4.2 The impact of digitalization on businesses

Digitalization holds a wealth of opportunities for businesses in the Nordics. Automation and new technologies such as digital twins enable manufacturers to produce ever more efficiently. Startups all over the Nordics develop digital business models, generating new revenues and jobs for the region. Businesses also benefit from automated building management systems, creating perfect conditions for employees and customers, while reducing operational costs. Furthermore, smart government solutions allow businesses to automatically exchange bookeeping data with authorities, reducing administrative burden.

Productivity in the manufacturing sector is growing by 3 percent annually, three times as much as in the total economy.

Using digital simulation, Volvo expects to reduce time-to-market by 45%

4.2.1 Digitalization increases productivity in manufacturing

Nordic manufacturing has undergone dramatic changes in the past decades. Many production sites have moved to lower-cost countries, and one in three manufacturing jobs have been lost since the beginning of the millennium[59].

Despite this decline, manufacturing still plays an important role for the Nordic economies. Productivity in the manufacturing sector is growing by 3 percent annually, three times as much as in the total economy. In addition, fifty percent of Nordic exports stem from the manufacturing sector and between 33 (Norway) and 77 percent (Finland) of private research and development are carried out in manufacturing[60].

Recent developments in digitalization have been described as an opportunity to promote industrial growth in the Nordics. The Nordic Council has noted that robotics and computer aided manufacturing systems allow for leaps forward in labor productivity, making it easier for the Nordics to compete in international markets[61]. Researchers from Copenhagen Business School have estimated that a further uptake of automation in manufacturing could enable productivity gains of 15 percent in the Nordic countries.

As these technologies require a highly skilled digital workforce, the Nordic countries[62] are particularly well placed to quickly adopt these innovations.

To achieve maximum gains in productivity, digital technologies need to be adopted across the industrial value chain. This includes the following stages:

Design and engineering – accelerating time-to-market
Using a digital twin of a physical plant, it is possible to validate designs earlier, and test the configuration of the machine control system in a virtual environment. By carrying out checks earlier on in the engineering process, the risk of failures and delays in critical phases of the lifecycle is reduced. Further modifications can be tested and verified in the same way, thus accelerating the introduction of a new product. Using this technology, car manufacturer Volvo expects to reduce time-to-market for new models by 45%, from 36 to 20 months[63].

Production and operation – efficiency and resilience
Information technology, telecommunications, and manufacturing are merging, as the means of production become increasingly autonomous. In the factory of the future, machines will largely organize themselves. Delivery chains will automatically assemble and orders will transform directly into production information and flow into the production process.

Maintenance and service – reduced downtime through predictive maintenance
Machines are increasingly fitted with sensors and a communications interface for data transfer. By analyzing the data, artificial intelligence systems can monitor a machine's condition and detect irregularities. Maintenance can then be arranged before components break down and manufacturers can operate their systems more reliably and efficiently.

"At Uniti, 'autonomy' means more than self-driving cars. We aim to be lean and sustainable by doing more with less, and digitization enables just that. We are just getting started, but Moore's Law and ever-improving software means the future is bright for digitized development and production."

**Lewis Horne
CEO, Uniti**
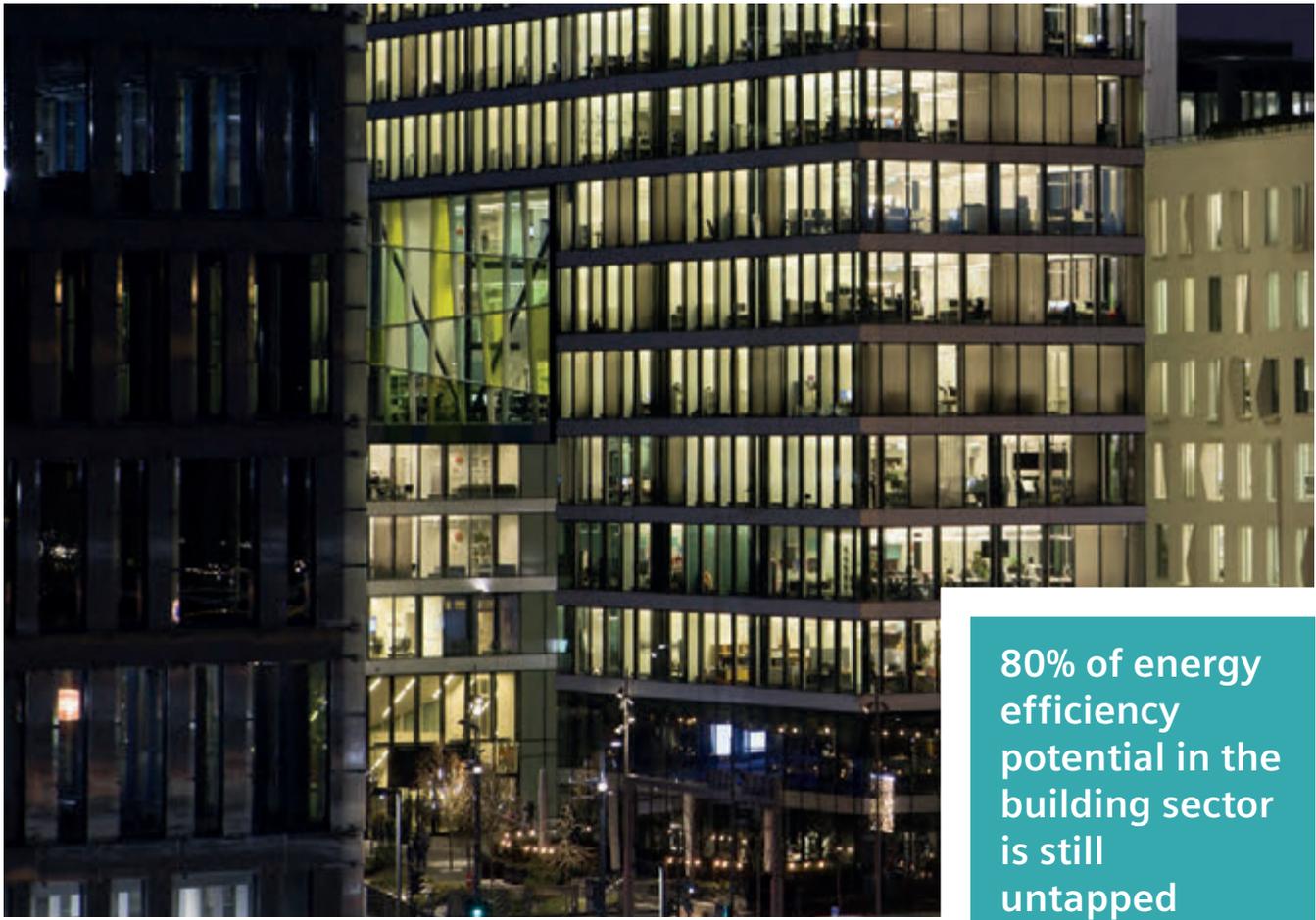
80% of energy efficiency potential in the building sector is still untapped

4.2.2 Digitalization creates better buildings

In the Nordics, buildings are responsible for 40 percent of all energy consumption[64]. This causes not only greenhouse gas emissions, but also massive costs for building owners and operators. Estimates show, that energy represents 40 percent of a building's lifetime cost. Making buildings more energy efficient in design and operation is therefore an important tool for businesses to increase competitiveness and reduce their environmental impact.

Digitalization holds many opportunities to create better buildings. In the construction phase, building information modeling (BIM) can improve quality, save time and lower costs of projects. Similar to the digital twins used in manufacturing, the BIM process starts with creating a digital model of the building. All stakeholders are involved in designing the model, which leads to better collaboration and a faster overall construction process with fewer errors. BIM's focus is not merely on planning, but has benefits for the entire lifecycle, as the existent data model facilitates maintenance. According to researchers at Stanford University, BIM reduces capital expenditure for buildings by up to 10%, and reduces operational costs by up to 9%. Due to better building quality, employee productivity can furthermore be increased by up to 3.5%, leading to additional benefits for operators.[66]

Technology innovations in the construction sector are not only reducing the costs and environmental impact of buildings, they also provide a major business opportunity for construction companies in the Nordics. A study by McKinsey found that overall, the construction sector is lagging behind in the use of digital technologies[67]. Implementing these technologies quickly can be a major competitive advantage for Nordic construction companies such as Skanska

During operation, building management systems can continually monitor and control all subsystems of a building, such as heating, ventilation, air conditioning, power, lighting, as well as fire safety and security. This yields positive results for energy efficiency, safety and the room climate overall. An example is the automatic adjustment of shading according to changes in the environment. As windows exposed to direct sunlight close their blinds automatically, costs for air conditioning can be reduced, and a comfortable work environment maintained. Building management systems are furthermore able to detect attendance in individual rooms and continuously adapt energy consumption for heating and ventilation.

Case Study:

Sello shopping center: A perfect place to come together

A 12-minute train ride takes the people of Helsinki to Sello, one of Scandinavia's largest shopping malls. The 102,000m^2 complex houses more than 170 stores, and even a concert hall and a library. Each year, more than 24 million people visit Sello, most of them via public transportation.

One of the challenges for Sello is to keep energy costs low, while creating perfect conditions for visitors and employees. Effective data collection is essential to achieving this; 1,500 energy and heating, ventilation and air conditioning (HVAC) data points throughout the building gather and evaluate information. By constantly measuring indicators such as temperature, CO_2 levels, and outside weather conditions, the maintenance staff and the automated building management system can operate ventilation, heating and air condition with maximum efficiency. Sello's building management system also increases the safety of its visitors: ensuring that entrances never freeze-over by automatically evaluating weather forecasts and preheating outside areas in case of snowfall.

For Sello, implementing a building management system was a success. With annual savings of at least €133.000 per year, the investment is set to amortize within only four years. Reducing CO_2 emissions by 20%, Sello furthermore strengthened its position as Europe's greenest shopping centre and was the first in Europe to receive LEED Platinum certification.

Case Study:

Using the digital twin in manufacturing

The new production facilities in southern Sweden, of automotive startup Uniti, are designed to produce "with the lights off" 22 hours per day, meaning that no manual interference is needed. Using a virtual copy of the production facility, the entire manufacturing process can be tested on a computer, enabling engineers to anticipate problems and avoid delays or extra costs during production.

A similar process was used during the design of the Uniti car. A digital twin of the car helped engineers to test and verify design choices from an early stage. Using the technology, crash tests as well as aerodynamic tests could be performed in a virtual environment, allowing Uniti to quickly make changes to the prototype in a cost-effective way.

For Uniti, the digital twin means faster time-to-market, increased production quality and reduced costs. Uniti's story shows how digitalization enables startups to compete in an industry that so far has been dominated by large corporations.
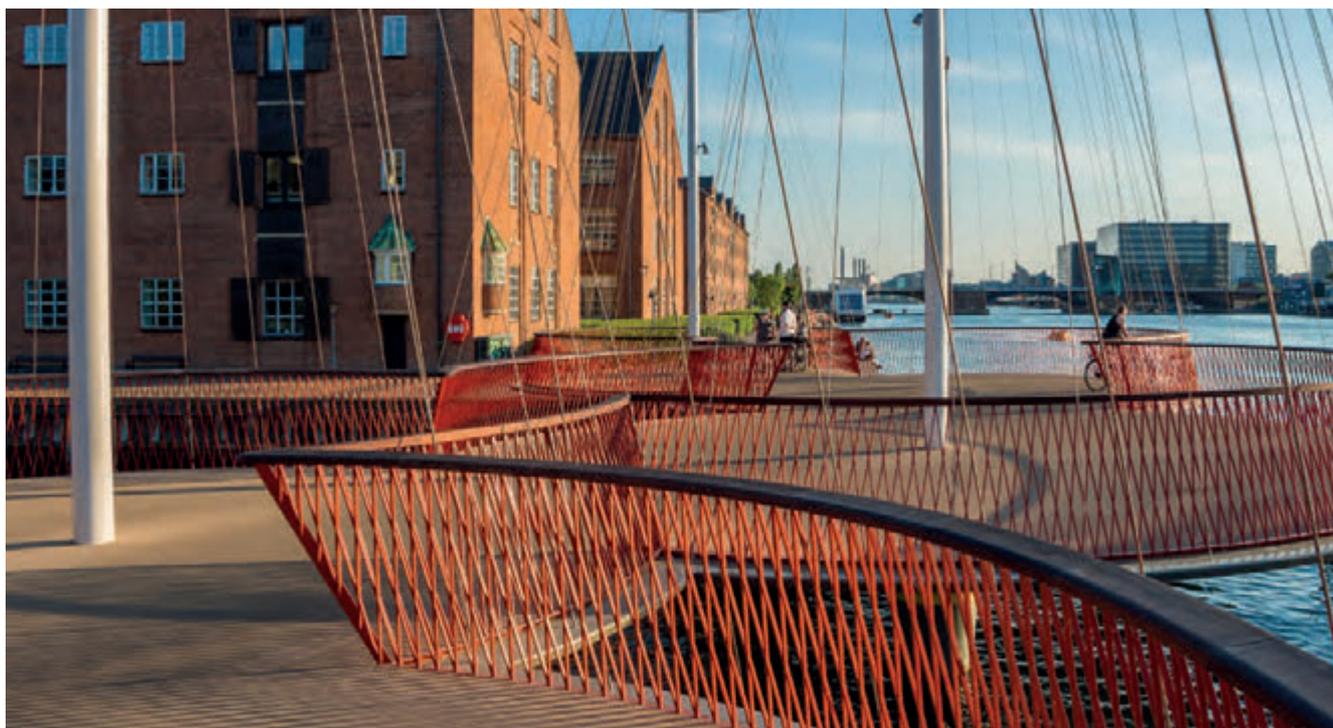
4.2.3 Digitalization creates new business models

Digitalization has brought about a variety of new business models and innovative services. From instant messaging apps, to online streaming services, to e-commerce and sharing economy solutions, digital businesses have altered the global economy. Businesses from the Nordics have been exceptionally successful in exploiting these opportunities. Measured on a per-capita basis the Nordic region has the most prolific startup hub globally[68]. 11 Nordic startups have exceeded valuations of $1bn, with many others set to follow the example.

For Stockholm, the capital of the Nordic startup region, the benefits are abundant: 197,000 people, or 18 percent of the local workforce, are employed in the high-tech sector, the highest per capita concentration of high-tech employees in Europe. To further build on this success, excellent digital infrastructures and a highly-skilled workforce will be key. In 2018, Stockholm and Helsinki will be the first cities in the world to experience the roll-out of 5th generation mobile networks (5G), opening up new possibilities for digitalization of industries and the Internet of Things[69]. Similarly strong efforts need to be undertaken to counter the daunting skills gap in the region. The fast growth of ICT businesses has led to a shortage of labor supply in these areas[70], limiting opportunities for local businesses to expand further.

4.2.4 Digitalization reduces administrative burden

The Nordic governments are amongst the most advanced in digitalizing their services and operations. Citizens of the Nordics are largely able to interact with their governments online, for example when filing tax reports, applying for welfare benefits or booking an appointment with a GP. Using this experience, several Nordic countries and organizations are collaborating on building a new digital infrastructure, aimed at making automated exchange of business data a reality.

The vision encompasses all kinds of data, including annual reports, VAT-reports, and other financial information. Instead of manually transferring this data to business registries, tax authorities or statistical offices, all data should automatically be transferred to a databank, and government authorities themselves make the aggregations they need. Besides business data, sensor data from manufacturers may be collected and used to enable live environmental monitoring.

Realizing this vision, holds wide-ranging benefits for businesses and governments alike. For businesses, costs related to mandatory business reporting will decrease significantly. In Denmark alone, the potential savings are estimated at €800 million annually, making Nordic companies more cost-efficient and competitive in globalized markets. The standardization of business data will furthermore increase transparency and improve conditions for collaboration between Nordic companies and their trade partners. Businesses can also expect a better market environment, as governments are more easily able to detect fraud, and can divert freed up resources to provide better framework conditions overall.

Fig 11. Decoupling economic growth from environmental impact

2000 = 100   **Nordic Countries** (DK, FI, NO, SE)

Sources: Nordic Council
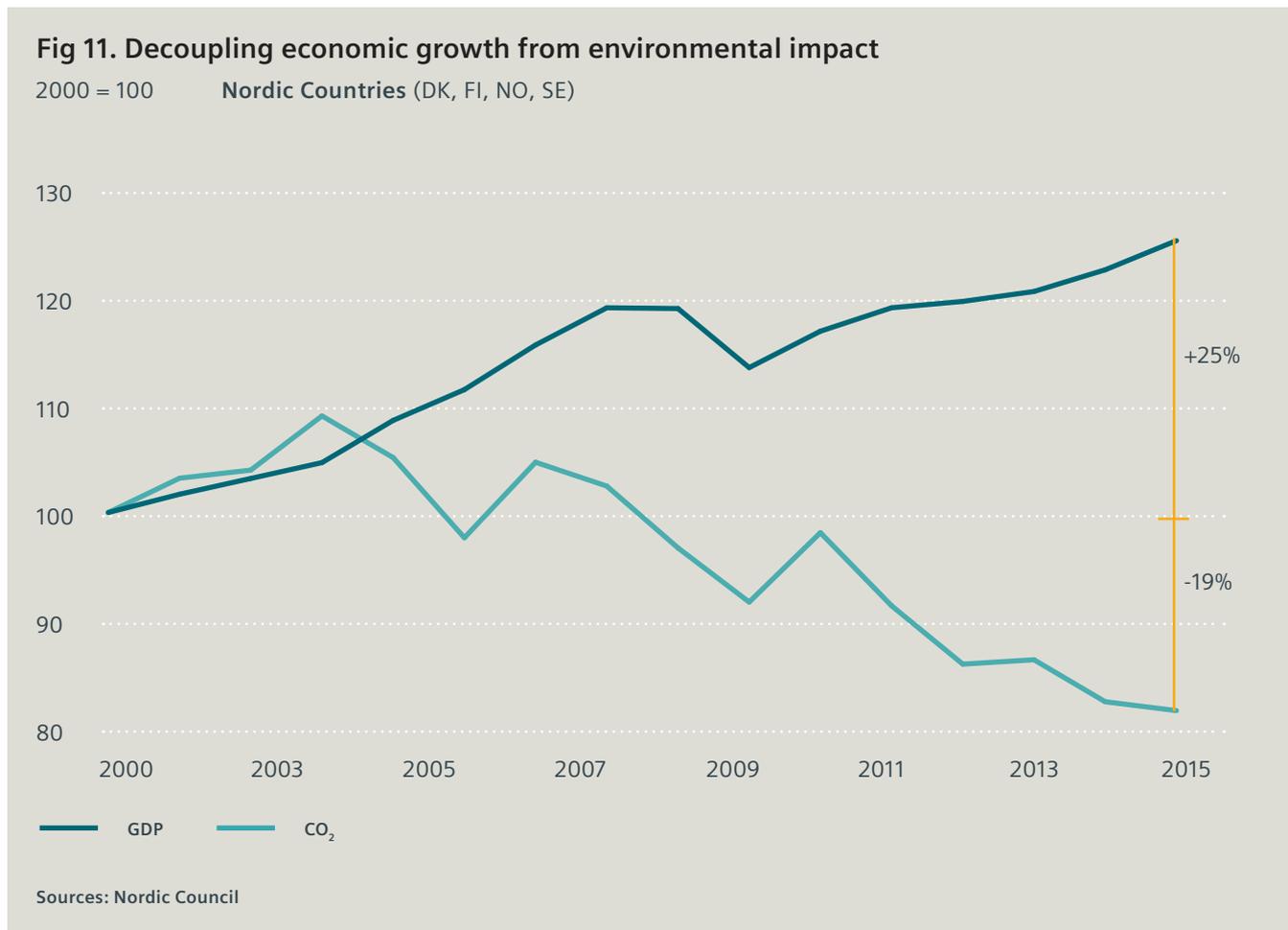
4.3 The impact of digitalization on society

4.3.1 Digitalization reduces greenhouse gas emissions and air pollution

The Nordic countries have set ambitious targets to decarbonize their economies and reduce their environmental impact. By 2030 Norway aims to become carbon neutral, with Sweden and Finland following suit by 2045, and Denmark by 2050. So far, the Nordic countries have done well in reducing their environmental impact, while further growing economically. Figure 11, presents the Nordic's performance in decoupling economic growth from environmental impact.

While strong efforts in reducing carbon emissions have been made a great potential remains untapped. Figures by the International Energy Agency show that 60 percent of energy efficiency potential in transport and industry, and 80 percent in the power generation and buildings sector remain unrealized. New digital technologies unlocking these potentials are already in use in various parts of the Nordics, however, to deliver on the region's ambitious emission targets, these need to be adopted more comprehensively.

Doing so, would not only reduce greenhouse gas emissions, but also improve air quality, which is an increasing problem in larger cities. In Gothenburg, 200 people die prematurely each year due to air pollution, which is mostly caused by local traffic emissions[72]. In the Nordics overall, the WHO estimates that dangerous levels of air pollution leads to the loss of 40,000 healthy life years[73]. While this figure may be low in comparison to other European countries, it nevertheless highlights the need to address the dangerous levels of air pollution.

Digital innovations in the transport, energy, building and industry sector allow the Nordics to reduce greenhouse gas emissions and air pollution. As the following examples show, the results are cleaner, greener, and more livable cities.

Clean transport

Digital innovations in transport can improve the attractiveness of public services and facilitate the deployment of carbon neutral modes of transport. By creating a better public service, cities can encourage a shift from private to public means of transport, thus considerably reducing their emissions of greenhouse gasses and air pollutants.

Digital Railway

Innovations in the rail sector are a good example of how digitalization adds to the appeal of public transport. Today, sensors installed along the tracks and in components of trains can provide experts with data on speed, braking, weight of connected railcars or the behavior of compressors. This results in a vast amount of data, as trains produce 1-2 billion data points every year[74]. By analyzing this data, operators can anticipate breakdowns before they occur, and arrange maintenance accordingly. Using this technology, Siemens teamed up with Spanish train operator Renfe to establish a joint venture that uses advanced data analysis for trains. This increased the punctuality of its route between Madrid and Barcelona to 99.98 percent.

As a result, there has only been one noteworthy delay out of 2,300 trips. The technology not only benefited busy travelers, but also reduced Spain's transport emissions. While only 20 percent of travelers between those cities took the train when the route started, this proportion has now risen to almost 80 percent, thus reducing the demand for airplane and private vehicle journeys[75].

Live-data from trains and trackside equipment, furthermore allows trains to run fully automated. On an automated line, trains can travel at intervals of only 80 to 90 seconds, and the capacity of a line can be increased by up to 50 percent. This is particularly useful in mass transit systems, as capacity can rarely be expanded by building new lines, and instead a more efficient use of existing infrastructure is necessary. Additionally, automatically controlled vehicles consume less energy due to optimized acceleration, traction and braking processes. Depending on the degree of automation, energy consumption can be cut by as much as 30 percent[76].

Case Study:

Copenhagen's driverless metro system

Between 2000 and 2030, Copenhagen's population is set to grow from 495,000 to 715,000 people[77][78], . To adjust the city's transport network to the growing influx of people, Copenhagen established its first metro system in 2002, with an additional circle line set to begin operations in 2019. The distinctive feature of the metro is that it runs fully automatically, decreasing operational costs and emissions, while guaranteeing high reliability, and safety[79].

To run automatically, the metro employs a block-based ATC-system (Automatic Train Control-system). Tracks are virtually divided into small blocks, which can only be entered by one train at a time. As trains approach a station and slow down, those blocks get smaller, allowing trains to drive in shorter distances behind each other. The technology allows trains to run at 2-minute intervals, with the trains of the new circle line being able to reduce this interval by another 30 seconds[80]. To improve the energy efficiency of the system, trains enter an uphill gradient as they approach a station, and a downhill gradient as they leave it, thus saving energy during acceleration and braking. Excess energy from braking is further converted into electricity and sent back into the metro's energy grid[81].

Copenhagen widely benefitted from the introduction of the metro. Two years after it began operation, car traffic decreased by 13 percent in certain parts of the city, leading to a reduction of noise, air pollution and greenhouse gas emissions[82]. As annual metro ridership has doubled to 60 million since then, it can be estimated that the metro is replacing even more car journeys today. Copenhagen's new circle line is predicted to double annual ridership again, reaching 116 million in 2019[83].

Case Study:

Norway's digital railway

This project is a major step in signaling history - a technology step only comparable to the change from relay to electronic interlockings in the 80s. Together with Bane NOR, Siemens will transform the complete Norwegian rail network into a full digital IP-based system – a true 'Internet of Things' system. This conversion will save much hardware, allow for maximized capacity and provide the basis for data-based minimized preventive maintenance. Ultimately, this will provide passengers with a far more efficient and reliable travel experience with far greater punctuality, increased capacity and more throughput. The system will be controlled via a central interlocking in Oslo, which will give the trains the authority to proceed via our ETCS Level 2 solution.

The investment in ETCS is a major step in a Norwegian railway revolution. Bane NOR will invest more than 2 billion euros in digitalization and automation of its railway network over a ten-year period. This will be done through Bane NOR's ERTMS (European Rail Traffic Management System) initiative, and will make Norway a pacesetter in using digital technology in the rail sector.

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E-mobility

As the Nordic countries are increasingly shifting towards renewable energy sources, the electrification of transport provides a huge opportunity to cut carbon emissions. In addition, e-vehicles can reduce air and noise pollution in cities. As their motors convert nearly 100 percent of energy into motion, they are three to four times more efficient than regular combustion engines[84]. To promote the adoption of electronic vehicles, adjustments to road, traffic and electricity infrastructure are required. Doing so, will help the Nordics to achieve their emission targets, and to create cleaner and more livable cities.

Electric ferries:

Due to the Nordic's geography, many communities rely on ferries for travelling. In Norway alone, there are around 180 ferries, operating on 111 routes. Increasing the use of electricity powered ferries decreases operational costs and reduces the emission of greenhouse gasses and air pollutants.

80%

Gothenburg's 100 percent renewable electricity bus route consume 80 percent less energy compared to diesel buses

Case Study:

Gothenburg's 100 percent renewable electricity bus route

In Gothenburg, 90 percent of air pollution is caused by local traffic and it is also the main source of noise pollution in the city . Researchers from Gothenburg University have shown that, in the past 40 years, air pollution caused on average 200 extra deaths per year in the city . 100,000 residents are furthermore exposed to noise levels exceeding national guidelines, potentially leading to impaired sleep and cardiovascular disorders . To tackle these problems, and to achieve Gothenburg's carbon emission targets, the city is promoting the use of vehicles with a low environmental impact. An example is the city's bus route 55, which is powered by 100 percent renewable energy.

The nine kilometer route 55 is served by three all-electric buses and seven electric-hybrids. The vehicles are equipped with battery packs that are charged with 100 percent renewable electricity. Siemens in collaboration with Göteborg Energi have provided two high power charging stations, one at each end of the route, are able to fully recharge the buses in four-ten minutes.

The benefits of the project are reduced air and noise pollution as well as improved energy-efficiency. The new electric buses consume 80 percent less energy compared to diesel buses. Due to the success of the project, Gothenburg is going to introduce additional charging infrastructure, and in 2018 electric buses will begin operations on route 16 . Implementing these projects on an even broader scale will enable Gothenburg to further cut carbon emissions and reduce dangerous levels of noise and air pollution.

Case Study:

The world's first electrically-powered car ferry

Norway is considered a world leader in the generation and use of renewable energy. 98 percent of its electricity production comes from renewable energy sources, with hydropower as the source of most production. Following endeavors to promote the adoption of electric vehicles, Norway aims to achieve a similar uptake of electrically-powered ships. At the Sognefjord, about 100 km north of Bergen, the world's first electrically-powered car ferry began operations in 2015.

The fully electric ferry travels across the fjord 34 times a day, with each trip requiring around 20 minutes. The ferry, which is 80 meters long, is driven by two electric motors, each with an output of 450 kilowatts. After each trip, the ferry recharges for ten minutes, while passengers and vehicles disembark. Due to the relatively weak power grid in the region, designed only for small villages, it was not possible to briefly consume so much energy directly from the grid. Instead, Siemens have installed lithium-ion batteries at each pier to serve as a buffer. The 260-kWh batteries supply electricity to the ferry while it waits and slowly recharge between journeys.

Compared to a traditional diesel vessel, the electric ferry emits no greenhouse gases or air pollutants. In addition to environmental benefits, the technology is economically worthwhile. Studies have shown, that 70 percent of all Danish and Norwegian ferries would operate more profitably by using battery power or a hybrid solution. The Norwegian Parliament has changed the legislation for ferries, requiring all new ferry concessions have low- or zero emission technology. After these changes the market for e-ferries has exploded and it is now expected that at least 60 ferries will be electric in the near future.

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Electric highways:

Since 2000, demand for road freight transport increased by 20 percent in the Nordic countries[89]. As a result, greenhouse gas emissions from the sector have grown[90]. A solution is the shift to electrically powered vehicles. Here, the main obstacle is the size and weight required for on-board storage of electrical energy. Another challenge, is to charge such batteries in an acceptable period of time, without disrupting the grid.

These problems can be solved by providing electrical power directly, while the vehicle is driving. On e-highways an overhead contact line provides adapted trucks with electricity. Equipped with an active pantograph, hybrid trucks can connect and disconnect with the overhead line at speeds of up to 90 km/h. The direct transmission of electrical energy safeguards an outstanding efficiency: 80 to 85 percent from substation infeed to the wheel. This is twice as high as that of conventional diesel engines[91]. The technology furthermore reduces greenhouse gas emissions and improves local air quality. A study by the German Federal Environment Agency (UBA) found that an overhead contact line system constitutes the most cost-efficient solution for carbon neutral long-haul road freight, even when costs for infrastructure are included[92].

So far the technology has been implemented in projects in Sweden, Germany, and the United States.

Sweden started its first tests on public roads already in 2016, with industries, ports and cargo companies as strong advocates of the systems.

Private electric vehicles:

Despite efforts to promote walking, cycling and the use of public transport, private vehicle registrations have soared by an average of 33 percent in all Nordic capitals since 2000[93]. This creates new challenges for the city, as regular cars create air and noise pollution, detrimental to citizens' health. A solution is the shift to electric vehicles, and several Nordic cities, particularly Oslo and Bergen, are among the world's best in doing so[94].

Case Study:

Oslo, the electric vehicle capital of the world

Out of all Nordic capitals, Oslo saw the strongest increase in the number of registered private vehicles. Since the beginning of the millennium, Oslo's vehicle stock grew by 90,000 new private vehicles, an increase of 49%[95]. To offset the negative effects regular vehicles have on local air quality, noise levels, and greenhouse gas emissions, Oslo and Norway introduced a number of technologies and policies, that paved the way for the world's fastest uptake of electric vehicles.

The earliest policies to enable a quicker shift to electric vehicles were introduced in the 1990s. Import tax for e-vehicles was permanently abolished in 1996 and one year later, e-vehicles were exempt from road tolls. In 2001, value added tax, usually at 25%, was scrapped for electric vehicles, greatly benefitting the technology's affordability. With no charges for municipal parking, free public charging and access to bus lanes, electric cars became a convenient and affordable alternative to fossil-fuel powered vehicles[96].

Besides incentivizing this shift through policy, Oslo contributed to the deployment of necessary charging infrastructure. With 2,000 charging points throughout the city, Oslo has about ten times as many charging points than Berlin, Paris, or London, when set in relation to the number of registered vehicles[97].

For Oslo, the shift to electric vehicles was urgently needed. 62 percent of the city's greenhouse gas emissions stem from the transport sector, making it a key factor in achieving the city's CO_2-targets[98]. The uptake of electric vehicles has furthermore benefitted local air quality. Whereas national NO_2 and PM10 limits have been exceeded on 47 respectively 23 days a year in 2010, these numbers could be reduced by 20 percent in 2016[99]. By 2025 Norway is going to phase out the sale of petrol and diesel cars altogether. With electric vehicles taking up a market share of 29 percent in 2017[100], this goal is now closer than ever.

Fig 12. Towards an energy-efficient economy

GDP (PPP, $) per unit of energy use (kg of oil equivalent) in the Nordics (DK, FI, NO, SE).

Sources: World Bank

Fig 13. Towards a renewable energy future

Share of renewable to total primary energy supply (TPES) in the Nordics (DK, FI, NO, SE).

Sources: OECD

Smart Energy

As the Nordic countries transform to low-carbon economies, their energy sectors are undergoing substantial changes. Digital innovations, such as smart meters and grids allow for a more efficient distribution of energy, leading to reduced costs, higher grid resilience, and less greenhouse gas emissions. Figure 12 reflects the Nordic journey towards an ever more efficient use of energy. Within 16 years the economic output per unit of consumed energy could be increased by 80 percent. As the rollout of energy grid infrastructure continues, the European Commission expects a nine percent reduction of emissions throughout the EU by 2020[101].

Another substantial change in the Nordic's energy system is the shift towards renewable and decentralized sources of energy (figure 13). In 2016, 37 percent of the total primary energy supply in the Nordic countries came from renewable sources, up from 30 percent in 2000[102]. Many of these renewable sources are dependent on short-term weather conditions, as in the case of Denmark, where a third of renewable energy production comes from wind and to a lesser degree from solar. Meanwhile, the traditional model of linear power generation and delivery is giving way to a more diverse and decentralized energy system with multiple actors. An example are private home owners who ever more often are prosumers, taking power from the grid, as well as feeding it back in.

These developments greatly increase the complexity of the Nordic electricity system and demand the introduction of new technological solutions[103].

One of these solutions, is the analysis of real-time grid and weather data, allowing operators to better forecast loads and adapt their systems accordingly. Doing so, operators will more easily be able to balance consumption and production fluctuations, facilitating the introduction of ever higher shares of variable renewable energy to the grid. Another example is the use of demand response management systems, allowing users to shift consumption to off-peak times, thus reducing the need for additional power generation during peak times. Further integrating the Nordic electricity market will provide strong security against supply uncertainties, and international interconnectors such as the ones between Norway and the UK, or Denmark and the Netherlands will enable the Nordics to export its clean electricity to the continent.

Today, the Nordic cities are leading the journey towards a more sustainable energy system. Urban regions account for 85 percent of the Nordic population, yet consume only 59 percent of the Nordic's energy supply. Higher population density and shorter distances facilitate the deployment of new technological solutions, as the case of e-mobility in Oslo has shown. In the future, the Nordic cities are facing an enormous challenge as they aim to decarbonize their energy systems, while their populations are expected to increase by 30 percent until 2050. Reaching this target will require the implementation of a number of technologies, including, for example, fourth generation district energy systems, which optimize the interaction of energy sources, distribution and consumption.

Furthermore, heat pumps can be utilized to integrate ambient and excess heat sources to the district heat network and serve to stabilize energy systems with high degrees of variable renewable energy. Digital technologies such as blockchain provide further opportunities to optimize the integration of renewable energy into the grid. In Brooklyn, a blockchain-based microgrid is in operation, allowing residents to trade excess energy produced by their solar panels with neighbors. The technology is not simply convenient but also increases the energy resiliency of the neighborhood in times of external shocks. In 2012, Hurricane Sandy caused blackouts in large parts of New York City.

Using battery storage units, the Brooklyn microgrid can keep the lights on at least temporarily during the next storm-related emergency[110].

The building sector, which comprises the largest single sector for energy consumption in the Nordics, is of particular importance for reducing energy demand[111]. Previous research by Siemens has shown that in Copenhagen, 40 building owners could reduce CO_2e emissions by ten percent if they were to invest five million euro's per year, a sum within a typical building renovation budget, in technologies such as building automation and building performance optimization[112].

Case Study:

Smart Grid EcoGrid pilot for the island of Bornholm

The Danish island of Bornholm is using Siemens technology to determine how electricity demand can be adjusted to match supply. The island has become the country's renewable energy laboratory. The "EcoGrid" project is one of the biggest smart grid projects in Europe. As part of the project, near to 1,900 households, were equipped with newly developed smart switching devices. Every five minutes, when they receive updated kilowatt-hour prices, the devices determine how much electricity is available. Depending on the data, the devices switch electric heating systems and heat pumps in private homes on or off automatically.

The aim of the project is to harmonize supply and demand. The price of electricity fluctuates in synchrony with the capacity of renewable energies. Electricity customers save money when smart control units calculate how to manage energy demand effectively.

The "EcoGrid" is a part of the vision to realize a "green island" on Bornholm; with renewable energy sources, electric cars, and environmentally friendly agriculture that might help to make the island a more attractive place to live.

Case Study

Case Study

Integrating the European electricity market

Despite a combined population of only 200, the Danish Endrup and the Dutch Eemshaven are set to become the sites of international trade. By 2019, the two towns will be connected by a 325 km long subsea power cable, enabling the further integration of the European electricity market. The € 600 million project will furthermore allow for a broader uptake of renewable sources of energy and bring wide financial and environmental benefits to the region[105].

To minimize transmission losses over the long distance, the connection will be constructed as a High-Voltage Direct Current (HVDC) cable. Two converter stations, one in Endrup and one in Eemshaven, will convert electricity supplied by the alternating-current (AC) grids of Denmark and the Netherlands to DC. On the other side, incoming DC will then be converted into AC again. The cable will have a total capacity of 700 MW, equal to the annual electricity consumption of 700.000 households.

Further integrating the European electricity market is essential for the growth and success of renewable energy. In times of excess production, Denmark will be able to export its wind energy to the Netherlands, where in turn the generation of fossil-fuel based energy can be lowered. It is estimated that the power link will cut CO_2 emissions in Denmark and the Netherlands by 940 kT a year, equivalent to three percent of Denmark's CO_2 emissions today[106].

Case Study

A smart grid for the greater Aarhus region

When Danish grid operator Konstant Net began to analyze its smart meter data for more than just billing operations, they discovered a treasure trove of digitalized information. With the right set of analytical tools, the data is helping them optimize operations, improve maintenance and predict the loads on their power grid.

The Danish grid operator rolled out smart meters in eastern Jutland between 2010 and 2014 – far earlier than other utility providers. The 225,000 smart meters send millions of data sets from houses, businesses and factories to the operator's nationwide data hub. Originally, the data was used only to account for a customer's electricity usage and deliver correct bills, but combining the smart meter data with the geolocation data, the grid operator could gain new insights into what was happening in the low-voltage grid.

Thus, Konstant Net can detect patterns in incoming error messages and use this knowledge to improve the management of the network. The smart meters also uncovered that 20 percent of the operator's transformers deliver electricity backwards from customers to the electricity grid. As a result, the power grids are exposed to challenges they were not originally built for, and the changes in the system could, without due care, threaten today's status quo of Danes who enjoy access to power 99.99 percent of the time.

Recently, Konstant Net has started using the data to make predictions. Based on around five million weather-related data sets collected over a two-year period, they can estimate how the load and the voltage in parts of the main grid will develop if the sun shines on the following morning.

Apart from cost savings related to efficiency gains, the technology has further environmental implications. Smart grids enable the integration of clean, but often variable sources of renewable energy into the grid. They furthermore reduce technical losses and allow grids to adapt to new energy consumption patterns caused by electric cars or heat pumps. According to a study by the International Energy Agency, the further deployment of smart grids will enable yearly CO_2 reductions of 0.13 Gt in European OECD countries by 2030. This is equivalent to 4 percent of the region's emissions today[104].

Fig 14. Direct and indirect benefits of digital solutions

Value of the data and the digital economy

Value of the project to the city, including benefits delivered to stakeholders not investing

Value of the additional benefits to the investor

Value of the project under normal cost-benefit assessment
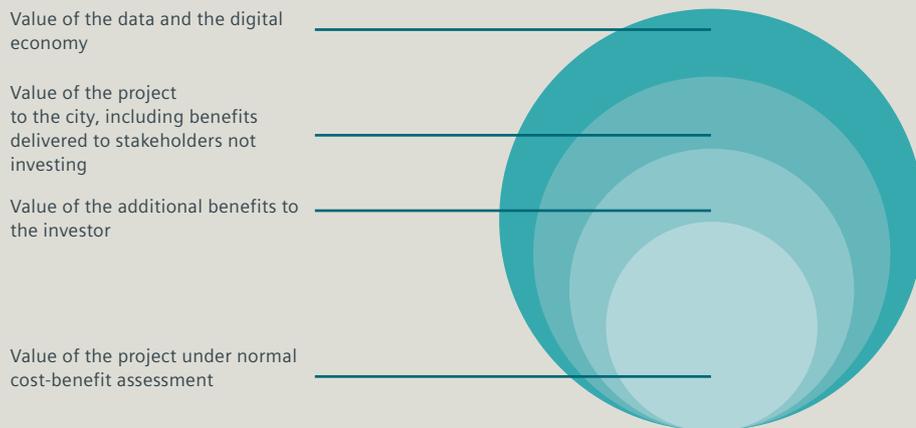
Source: Siemens, The Business Case for Smart Cities[114]

4.3.2 Digitalization reduces costs for society

Apart from environmental advantages, digital innovations can benefit society financially in a number of ways. Denmark's Digital Growth Panel has estimated that digital solutions in healthcare will not only improve treatment, but also reduce healthcare costs by approximately € 670 million in Denmark alone. Another example is public transportation. Due to technologies such as the predictive maintenance of rolling stock, costs for maintenance can be considerably decreased, leading to transport savings of € 400 million per year in the case of Denmark[113].

As public transport can be managed more cost-effectively, freed up resources can be reinvested to further improve the network of public transportation. A better transport network can then generate new revenues, e.g. by increasing a city's productivity due to improved mobility for citizens. As more and more citizens use public transportation, air quality will improve, leading to further savings in the healthcare sector. Figure 14 illustrates the various indirect effects digital improvements in infrastructure can have. These effects need to be considered by cities in order to establish a robust financial case for implementing smart city measures.

4.3.3 Digitalization makes Nordic cities fit for the future

Throughout the Nordics, cities are applying innovative solutions to tackle the challenges they are currently facing. In response to rapid population growth, Nordic cities developed innovative traffic management solutions to further guarantee a smooth flow of traffic. Challenges resulting from an aging population are met with advancements in the provision of personalized medicine and telehealth.

Digital technologies for constructing and managing buildings, as well as advancements in the distribution and generation of energy, allow the Nordic cities to further decrease their CO_2 emissions, continuing their path as environmental leaders. Finally, the digital factory holds new opportunities for manufacturing in high-cost countries, enabling Nordic cities to reclaim jobs once lost to places with cheaper labor costs.

These examples demonstrate the efficiencies that can be achieved by digitalizing selected infrastructure domains. The next level of intelligent infrastructure brings together all parts of this infrastructure puzzle. It allows system operators to respond in real-time to incidents and optimize operations across all domains and it connects the different infrastructures in a city through an operating system, to help cities manage systems as a whole. Cities such as Oslo or Helsinki are already experimenting with these concepts. In Oslo a climate dashboard is bringing together transport, weather and environmental data, allowing the city to forecast local air quality and potentially implement short-term measures. In Helsinki, a similar project measures and forecasts air quality throughout the city[120]. As infrastructure domains get more and more connected, these cities will be able to implement preemptive measures, such as limiting traffic flows in congested areas, or scheduling street cleanings at times of increased fine dust pollution.

As the examples in this chapter have shown, the Nordic cities have made tremendous efforts in digitalizing their infrastructures. If they are able to continue on this path they will achieve the vision of a real smart city, in which different infrastructure verticals, such as buildings, power grids, electric vehicles, transport networks and emergency services are integrated and managed holistically. Doing so will lead to vast efficiency gains in these cities, resulting in better quality of life, economic growth, and reduced environmental impact. In the next chapter the barriers to a faster uptake to digital solutions will be examined and a number of recommendations will be provided.

Case Study

Spending on patients, rather than energy bills

Hvidovre Hospital, just eight kilometers outside of Copenhagen, is one of Denmark's largest hospitals. After 40 years in operation, time was ripe for an energy efficiency upgrade. The project reduced the building's energy consumption, leading to energy savings of 33 percent per year[115].

Among the measures implemented were the expansion of the hospital's existing photovoltaic system, the installation of five wind turbines and a geothermal storage system. To further increase energy efficiency, air handling units and pumps were replaced and a total of 14,770 LED light tubes were deployed throughout the building. A modernized building management system further increased the building's efficiency[116].

As a result, heat consumption could be reduced by 41 percent and electricity consumption by 23 percent, leading to overall energy savings of 33 percent per year. The modernization also benefits patients, as the renewed building management systems allows them to control lighting, heating, ventilation as well as curtains and blinds directly from a bedside terminal.

Due to an innovative financing model, the project required no upfront investment by Hvidovre Hospital. Instead, Siemens financed the costs in advance and will be paid back over the next ten years from the energy savings achieved. The EPC project has been widely acclaimed, and in 2017 received a European Energy Service Award by the European Commission[117]. Denmark's Minister of Energy, Lars Christian Lilleholt, called the project a showcase for hospitals looking to reduce their energy costs while creating new opportunities to spend money on healthcare instead[118].
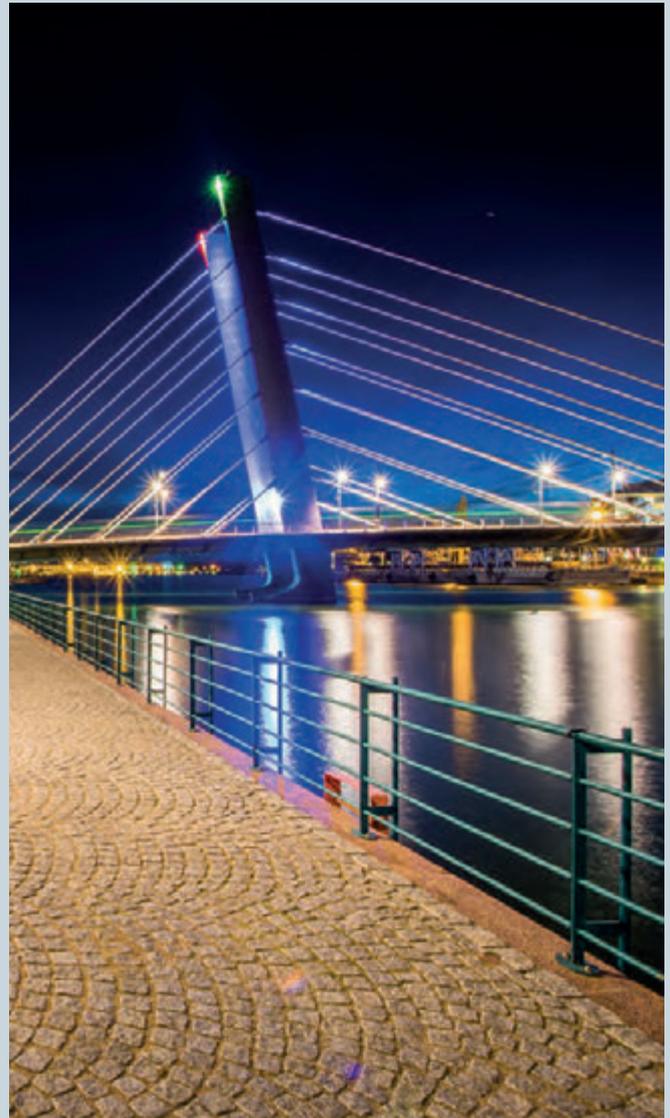
Case Study

In Helsinki, the digital city enhances citizen participation

Helsinki produced a 3D open data model of the city, allowing anyone to access the data for free. The visual model helps citizens to understand and interact with new planned developments in the city[121]. An example is the redevelopment of the Oulunkylä district in the north of Helsinki. During the planning process citizens were invited to virtually visit three alternative models for the district and share their opinions with the city. Using the model, citizens could for example assess whether a new building will block out the sun for a building next to it[122].

The model's overall goal is to develop the development of smart city initiatives in Helsinki. Due to the open data approach of the city, public and commercial research can be involved leading to the development of innovative use cases. These include insurers, using the model to more easily quantify the size of buildings and the risk inherent to them. The city also plans to combine the data with infrared photos to identify where energy is leaking or being wasted[123].

Moving past the digital plateau

The Nordic countries and cities are the most digitalized in Europe[124], yet their current rate of digitalization is falling behind of those of ever faster advancing places such as Singapore, South Korea, or Hong Kong[125]. Denmark's Digital Growth Panel is estimating that the Nordics will lose their current leadership in digitalization by 2025[126].

Have the Nordics indeed reached their digital plateau or is an acceleration in the rate of digital development possible? This chapter aims to give an overview of the barriers to digital development and showcases solutions to overcome these. As with the deployment of digital technologies, cities all over the Nordics have developed models to overcome the most common hindrances to digital development. Key to a faster and more competitive development within digitalization is the widespread application of these measures. Doing so, the Nordic countries and cities will likely be able to build on their current strengths and maintain their position as digital leaders, with wide implications on international competitiveness, quality of life, and environmental performance.

In the intellectual debate a number of barriers to the digital development of cities and countries have been identified. These include issues of funding[127], governance[128], and public concerns regarding the continuing convergence of the physical and virtual world[129]. In the following each of these three issue areas will be discussed in more detail and case studies from the Nordics on how to overcome those barriers will be provided.

Barrier 1: Lack of funding

A key challenge to delivering smart solutions is developing a clear business case to demonstrate the value of the investment. While this report has shown the wide-ranging benefits of digital solutions to citizens, businesses and the environment, the strength of the financial case usually comes down to a more narrow consideration of the return on investment for the investor[130].

The role of public funding
This gap between an economic and a financial case can be bridged, traditionally through public grants funded out of

state revenues. Due to limited capacity of public budgets, smart city projects are often financed through research and innovation grants, often with short time frames and high uncertainty for investors. This can prevent projects from being scaled up beyond a pilot phase and therefore poses a barrier to a faster and wider uptake of digital solutions in the Nordics[131]. Governments and municipalities need to recognize this shortcoming and commit long-term funds to the implementation of digital solutions. That way, innovative digital solutions will not be restricted to one-off implementations and can be deployed on a broader scale, unlocking their full potential.

An excellent example for how the public sector can signal its long term commitment is Sweden's Viable Cities program. The program has the primary goal of contributing to research and innovation within smart and sustainable cities and is being led by KTH Royal Institute of Technology in Stockholm with support from Sweden's innovation agency, research council and energy agency. With a time frame of 12 years and a total budget of 97 million Euros the

project will help to move projects beyond the pilot phase and increase the uptake of digital technologies in Sweden[132]. Denmark's new strategy for digital growth can be assessed as a similar step into this direction. With a total investment of 134 million Euros over a period of seven years, the program is a strong testament of the government's willingness to support digital innovations[133].

The role of private funding

Besides long-term public grants innovative financing models and the involvement of the private sector are needed to overcome the funding challenge. There is a range of commercial models and financial mechanisms that could help cities to deliver smart city measures[134].

Performance contracting:

Performance based contracts (PBCs) allows a client to procure and pay for services on an outcomes basis. Unlike conventional works contracts where the client would have to define and largely design the works to be provided, the client instead gives bidders the flexibility to determine the

Fig 15. Energy performance contracting financing mechanism
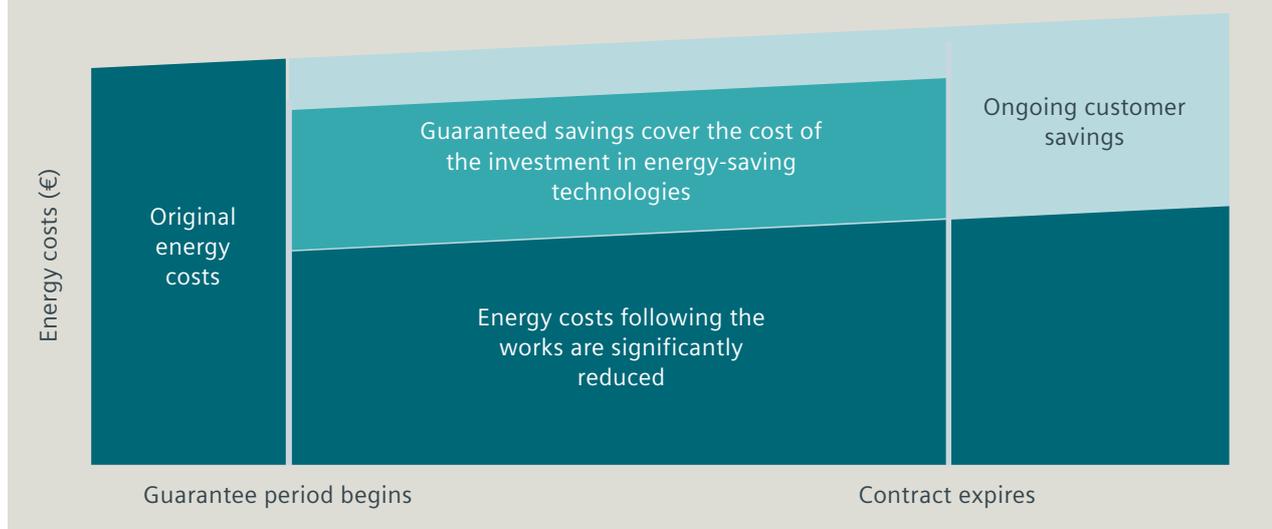
most cost-effective way to achieve the stated performance standard. PBCs also transfer performance risk from a client to the contractor.

Performance contracting can be used as a delivery and financing mechanism for energy improvements to existing buildings. Under an energy performance contract, a supplier finances and carries out works to a building to reduce energy use; the works could range from building fabric improvements to upgrading control systems. The customer then repays the investment through the savings the interventions yield. Asset ownership may rest with the funder as security against future payments, with assets reverting to the customer when the payments have been completed (Figure 15).

Performance contracting has been used to deliver energy-efficiency improvements at Hvidovre Hospital, just outside of Copenhagen (see page 51). Due to the financial model, the 23 million euro investment could be undertaken without additional capital expenditure by the hospital. Given the huge potential for further improvements in the energy efficiency of buildings, performance contracting should be more widely used in cities around the Nordics. Previous research by Siemens has shown that 80 percent of greenhouse gas emissions in cities like Copenhagen come from the building sector[135]. Realizing the huge potentials that lie in improving the efficiency of buildings, will greatly help the Nordics to reduce costs and improve sustainability, for instance that digitalization helps the owner to get improved information about their building stock after an EPC project.

Public-private partnerships:
There is no universally agreed definition for public-private partnerships (PPP); however the PPP Knowledge Lab defines it as "a long-term contract between a private party and government entity, for providing a public asset or service, in which the private party bears significant risk and

management responsibility, and remuneration is linked to performance[136]" If a city plans a large-sale investment in a roll out of smart initiatives, it could greatly benefit from entering a PPP to share the risk and financing.

The potential benefits of PPP reach beyond the ability of the public sector to attract private finance. A well-designed partnership would draw upon the strengths of each party:

- Private sector partners can bring expertise and management experience which a city may be lacking in-house.

- Public sector partners can leverage both formal and soft power to mobilize public support for proposed projects, which can materially reduce project risks compared with a private led approach.

Barrier 2: Lack of government initiative

While the Nordic countries and cities have undertaken strong efforts to introduce digital technologies, more can be done to accelerate the uptake of smart solutions. Three issues are of particular importance.

- First, cities need to improve the public availability of valuable city data to spur the development of smart city solutions.

- Second, cities need to strengthen cross-departmental collaboration to introduce digital solutions across infrastructure sectors.

- Third, cities and governments need to be aware of the role policy incentives can play in accelerating digital transformation.

With regards to the issue of data availability, several cities in the Nordics have taken initiatives to introduce open data portals. These portals exist in cities such as Aarhus, Copenhagen, Stockholm, Oslo and others; however there still remains work to be done with regards to the amount of

> Leading disruption is an oxymoron, I know. But we can do it. When cities, citizens, companies and the scholar community join forces to instigate the change in controlled test environments or platforms, such as our Helsinki Metropolitan Smart & Clean Foundation, it can be led. This will improve resilience to change and also create new, sustainable business. It just needs bravery, trust and cooperation. In Helsinki we have all of these.

Tiina Kähö

Executive Director, Helsinki Metropolitan Smart & Clean Foundation

data available on those platforms. Oslo and Helsinki's platforms provide visitors with 1,022 and 628 data sets, while the equivalent platforms in Stockholm and Copenhagen only offer a comparatively small number of 256 and 243 data sets. While this is only a one-dimensional assessment of these cities' efforts with regards to open data, it reflects the results of a European Union study on Open Data Maturity[137]. Here, Finland and Norway are among the leading European countries, while Denmark and Sweden only reached average and below average positions compared to other EU member states

Regarding the issue of cross-departmental collaboration, several Nordic cities have come up with solutions. An example is the City of Copenhagen's internal innovation network. The network is headed by a steering committee that includes the directors of all sub-departments. Within the network, ten innovation partners, one from each department, meet two days a week for the course of a year to implement smart city solutions. The network is backed by 280 members holding four annual meetings to discuss new ideas and goals for the future. Another positive example is the Nordic countries Smart Government program. Here, all five Nordic business registries work together to develop a solution for the automated exchange of business data with national tax authorities, business registries and statistics institutes, potentially saving billions of Euros currently being spent by businesses on financial reporting[138].

To maintain a position of digital leadership, the role of policy incentives can be critical. The example of Norway's experience with electric cars shows this. In Norway, the purchase of e-vehicles was heavily subsidized by the Norwegian government and supported by cities, which allowed holders of e-vehicles to use bus lanes and charge their batteries for free. Today, e-vehicles in Norway have a market share of 50 precent, Norwegian cities benefit from improved air quality and initial government subsidies are

slowly being phased out. In Denmark on the other hand, government subsidies for electric vehicles have been phased out earlier as initially planned. As a result, sales of e-vehicles in Denmark have plummeted and today Denmark is the only major European market where the sales of electric cars are slowing down[139].

Barrier 3: Unaddressed public concerns

Citizens of the Nordics have high levels of trust in each other and their governments. This has considerably helped the Nordics to implement new digital solutions, for example with regards to digital prescriptions or e-Government. Nevertheless, work remains to be done as numbers from Denmark show, where one third of the population still feels unsafe when using the public sector's digital services[140].

A potential issue concerns data privacy. At present, the General Data Protection Regulation (GDPR) safeguards the data privacy for all individuals within the European Union, addressing the exportation of data outside the EU.

Another problem that cities and governments need to address is the concern that digitalization might put a considerable number of jobs at risk. The Nordics need to be aware that digitalization is the single strongest contributor to productivity growth in the Nordics, ensuring that high-cost countries such as the Nordics remain competitive in an ever more international market[141]. While one in three manufacturing jobs in the Nordics have been lost since the beginning of the millennium, digital technologies can be an opportunity for re-industrialization in the Nordics as these require a high-tech environment and a highly digitalized labor force[142]. Investments in digital skills and education will help the Nordics to master the opportunities of digitalization and embracing it from an early stage will be an important factor in securing the regions prosperity well into the 21st century.

Conclusion

This study was initiated to assess the challenges Nordic cities and countries are currently facing and to investigate in how far digital technologies can provide solutions. The report presents a number of application areas in which citizens, businesses and the environment can benefit from digitalization. In all of these areas, we provided real-life use cases from around the Nordics. The resulting picture is one of highly digitalized cities and communities. If the Nordics are able to further build on their digital strengths, large benefits in terms of economic growth, environmental sustainability and quality of life will follow.

Key findings from the study included:

The Nordic countries and cities are among the most digitalized in Europe.

Citizens, businesses and governments in the Nordics are highly receptive of digital technologies. Internet usage and digital skills are among the highest in Europe. Businesses embrace the opportunities of digitalization, with Denmark and Sweden having one of the highest rates of industrial automation worldwide. Governments have digitalized many of their services, making the Nordics frontrunners in terms of e-government services.

Digital growth is slowing down in the Nordics.

Although the Nordics still rank as the most digitally advanced in Europe studies conducted by Denmark's Digital Growth panel and others expect the Nordics to lose their digital leadership within the next years. While having made fast progress in the early 2000s, the Nordics' rate of digital development has since then slowed down considerably, with countries such as the UK, Hong Kong, Singapore and New Zealand moving at a much faster pace.

Digital technologies will be key in tackling the challenges the Nordics are facing today.

The Nordic capitals are among the fastest growing cities in Europe. Congestion and air pollution become an increasing problem for the health and quality of life of citizens. Competition from an ever more global economy requires the Nordics to increase productivity growth, which however has slowed down markedly in the past decade. Digital solutions for transport, industry, buildings and energy can improve the efficiency of a city's infrastructure, reduce its environmental impact and contribute towards economic growth.

The Nordic cities can be a catalyst for digital development.

Rapid urbanization and dangerous levels of air pollution required cities to come up with innovative solutions. Their high population density, access to capital and a highly skilled workforce further benefits them in developing and implementing digital technologies. Today, Stockholm and Helsinki are global startup hubs, Oslo is the electronic vehicle capital of the world, and Copenhagen is aiming to become carbon neutral 25 years earlier than Denmark overall. These examples show how cities are at the center of driving forward the Nordics' path towards a more sustainable and digital future.

Innovative applications of digital technologies can be found all over the Nordics with wide benefits for…

… citizens
Digital innovations in transport save citizens time and money. According to Denmark's Digital Growth Panel digitalization will save citizens €1,000 per person and year

from 2025 onwards. In healthcare the development of personalized medicine or telehealth, can improve the treatment of patients and reduce costs.

...businesses:
Businesses benefit from efficiency gains achieved through digital factories and technologies such as digital twins or predictive maintenance. A study by Copenhagen Business School estimates that a further uptake of digital technologies in manufacturing could enable productivity gains of 15%. Innovations in the construction and management of buildings can further reduce capital expenditure and operational costs for real estate. Stockholm's path towards a global startup hub shows how digitalization creates new business models, providing jobs and growth for the region. Last but not least the Nordics aim to automate data exchange between businesses and authorities, leading to potential savings of €800 million annually in Denmark alone.

...and the environment:
Digital technologies can lead to a 34 percent reduction of CO_2e emissions by 2030 based on 2015 levels. Since 2000, the Nordics have reduced their carbon emissions by 19 percent while increasing their GDP by 25%, showing that sustainable development is possible. The introduction of automated metro lines in Copenhagen and the strong uptake of electric vehicles in Oslo both have had positive impacts on local air quality. However, 80 percent of energy-efficiency potential in buildings and power generation and 60 percent in transport and industry remain untapped. A stronger implementation of digital solutions will help the Nordics to tap into unrealized potentials.

The Nordics can accelerate digital growth

Issues of funding, governance and unaddressed public concerns are key barriers to a faster uptake of digital technologies in the Nordics. Long-term funding initiatives such as Sweden's Viable Cities program can help projects to move beyond the pilot phase. Performance contracting and public-private partnerships provide further opportunities to finance digital solutions. Cities can also accelerate digital growth by strengthening cross-departmental organization and by improving the public availability of city data. Finally, the Nordics need to address public concerns regarding digitalization. Doing so will help the Nordics to harness the opportunities of digitalization and embracing it from an early stage will be an important factor in securing the regions prosperity.

Driving the next wave of innovation

Nordic countries will need to keep ahead of the curve in order to continue competing on the global stage. As shown through this report, these countries are creating masses amount of real-time data that has the potential to be utilized. Siemens have developed a cloud based platform called MindSphere, an open Internet of Things (IoT) operating system that connects products, plants, systems, and machines, harnessing the large amounts of data generated. Through connecting real things to the digital world this platform can help drive business success and keep Nordic countries competitive. On the city level, it can effectively use the data created and identify new efficiencies and services that cities could implement. For instance Singapore is the first country in the world to pilot MindSphere. The creation of their digital hub complements the country's effort to become a Smart Nation and drive digitalization. Similarly, Siemens and Hong Kong Science Park have entered into an agreement to create Hong Kong's first smart city digital hub which is powered by MindSphere. It will tackle the cities challenges through an open, interactive and holistic approach. MindSphere's ability to connect systems under the umbrella of one cloud platform can lead to greater inter-city sharing and collaboration.

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