Digital decarbonisation in Denmark

How digital technologies enable decarbonisation across all sectors of our society

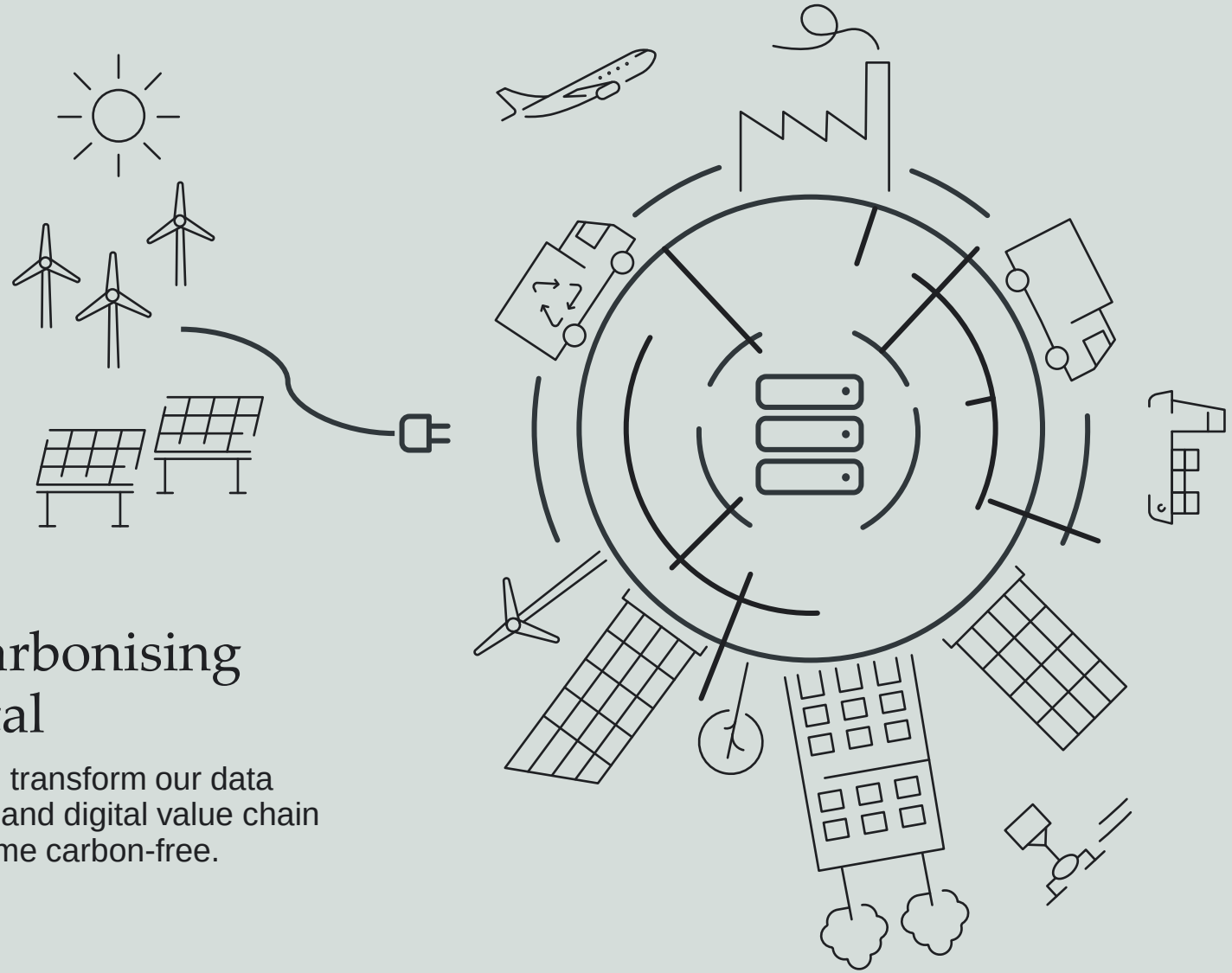
… and how we can decarbonise the digital value chain

September 2023

The Digital Decarbonisation report addresses two equally important priorities:

1. Digital decarbonisation

How digital technologies enable the transition to a net-zero Danish society.



2. Decarbonising digital

How we transform our data centres and digital value chain to become carbon-free.

> We must ensure that we identify the untapped potential and remove barriers to the use of new energy-efficient and digital technologies”

CHRISTIAN IBSEN
CEO Concito,
Denmark's leading climate think tank

Table of contents

Summary

20-25% of the greenhouse gas reductions needed for Denmark's 2030 target require digital enablement to work at scale and at socially acceptable cost

- Denmark has ambitious climate goals of 70% reduction by 2030 and achieving net-zero by 2050
- Digital technology is already making major contributions to achieving sustainability goals, including decarbonising our economy.
- Digital processes and new technologies are helping us to **save energy** and use it more efficiently, **use resources more sustainably**, **reduce travel** by using video conferencing instead of air travel or to work from home, and increase our use of **renewable electricity** with **intelligent power grids**
- The **digital sector** is also on its own decarbonisation journey. Decarbonisation enabled via digital solutions will outweigh emissions from data centres and future gains are significant. Frontrunners in the sector are committing to 24/7 carbon-free energy as the most efficient way to progress towards a fully carbon-free digital sector.
- If all data centres in Europe achieved 100% hourly carbon-free energy (24/7 CFE), the EU will save **6-18 million tons of CO_2 in 2030** – this corresponds to Denmark's agriculture and manufacturing emissions combined.

As digital frontrunner, Denmark's **win-win approach** to competitiveness and the green energy transition should have two parallel tracks:

- **Digital decarbonisation**: Maximising the enabling role of digital technologies by accelerating already available digital solutions at scale.
- **Decarbonising digital**: Minimising the carbon emissions across the entire European digital value chain by decarbonising all operational electricity emissions, and addressing the emissions related to devices as well as servers and buildings etc.

The **digital decarbonisation** priority is about accelerating the uptake of digital solutions enabling climate change mitigation. This will require an enabling policy framework.

Digital technologies often works together with other technologies to make the green transition happen.

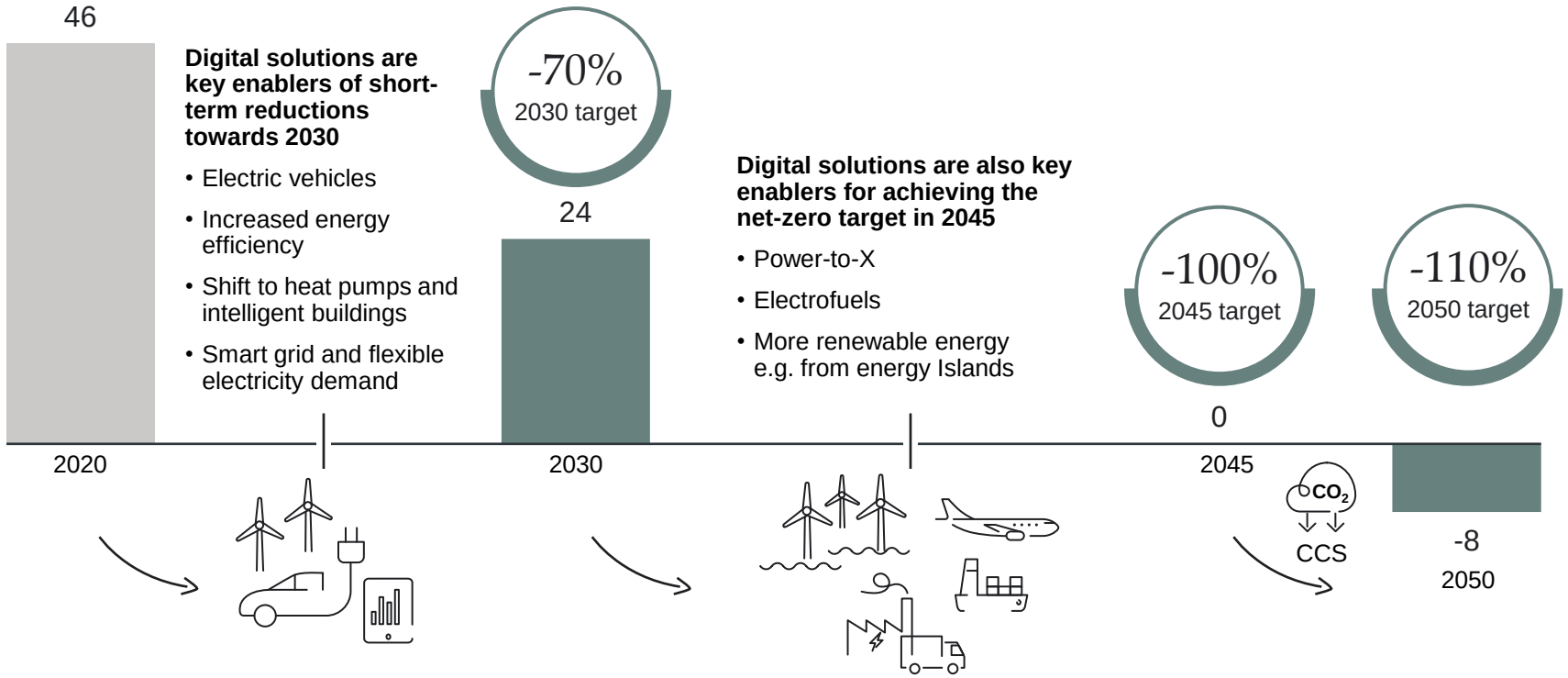
- Denmark's **domestic transport** sector accounts for around 26% of total emissions. Around 70-80% of the reductions in transportation towards 2030 is expected to come from a switch to electric cars, trucks and buses. Smart charging apps, digitally integrated charging stations, smart grid solutions are already at work enabling this transformation.
- Denmark's **agriculture** sector is responsible for around 30% of total emissions. Drones and artificial intelligence are used to making climate-friendly land-use easier and more accurate. Estimates suggest that 20-25% of the emission reductions in agriculture will require some degree of digital enablement.
- The **building sector** emitted around 5% of total Danish emissions. The heating of our homes and buildings is already being transformed by new building management systems using AI and machine learning. A big part of the decarbonisation journey is replacing gas and oil boilers with electric heat pumps or district heating and digital solutions will help provide the needed flexibility and efficiency.
- The **manufacturing** sector is responsible for around 12% of total Danish emissions. At least 10–15% of these emissions are to be reduced by improved energy efficiency and electrifying lighter industrial processes, which is being enabled by digital technologies such as predictive AI.
- In the longer perspective, **Power-to-X** (PtX) will play a key role in achieving the net-zero target. The Danish Government has set a goal of establishing 4-6 GW of PtX capacity in Denmark by 2030 of which a significant share will be for export. Digital solutions are key to ensuring maximum flexibility and efficiency in the PtX value chain. Production at the PtX plant will be managed and optimised using IoT, while digital twin solutions will be used to simulate and optimise the integrated system of plants, suppliers and off-takers.

The estimates and examples are not exhaustive, and there are numerous other ways in which digital solutions are already enabling the decarbonisation journey.

Digital technologies are important enablers of the green transition

Denmark aims to become net-zero by 2045. Digital innovation is seen as one of the driving forces to achieve a net-zero economy. Digital technologies will play a role in decarbonising almost every corner of our society – hence, the grand idea of the twin green and digital transition.

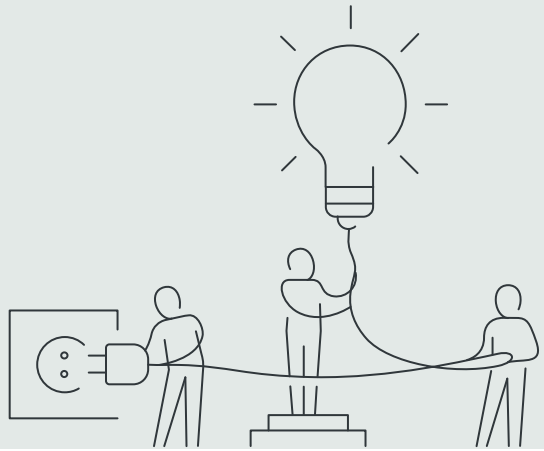
Denmark's net greenhouse gas emissions
$MtCO_2e$



—
Net zero is a state where the amount of greenhouse gases (GHGs) released into the earth's atmosphere is balanced by the amount of GHGs removed.

What is the twin transition?

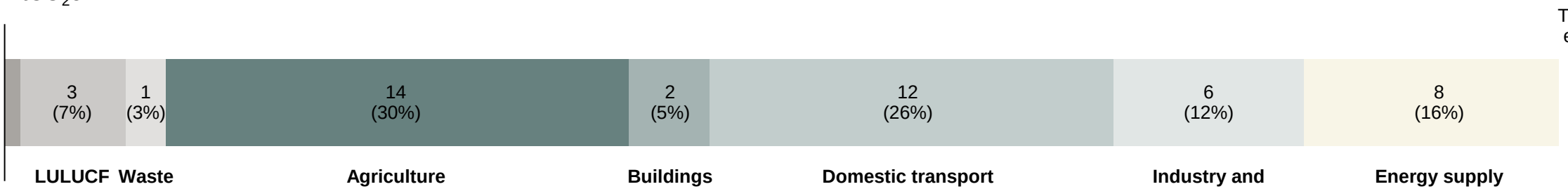
Twin transition refers to the interplay between digital and green transitions. Digital technologies will help economies reduce carbon emissions. Similarly, the green transition of our energy system will help the digital sector reduce its operational emissions.



Note: Emissions are defined as emissions from Danish territory and thus do not include international transport. Climate targets are defined as in the Danish Energy Agency report "Klimastatus og -fremskrivning 2023". Denmark is aiming towards reaching net-zero by 2045 and a 110% reduction in 2050 compared to the level in 1990, as outlined in the government's coalition agreement 2022 (link). Net zero as defined by the UN (link).
Source: Implement Economics based on Danish Energy Agency

The current emissions from the Danish territory are concentrated in four main sectors

Denmark's net greenhouse gas emissions, 2020
$MtCO_2e$



Decarbonisation initiatives in main sectors
(non-exhaustive)

Agriculture
- Efficiency improvements from precision farming
- Reduced food waste
- Changes in land-use
- Green fuels based on PtX for heavy machinery

Buildings
- Smart buildings
- Transition to heat pumps
- Improved energy efficiency
- Sustainable building materials

Domestic transport
- Electrical cars, vans, busses and small trucks
- Efficient and eco-friendly driving
- Reduced travel by use of digital tools (work-from-home and video-conferences)
- Green fuels based on PtX for ships, aircraft and heavy vehicles

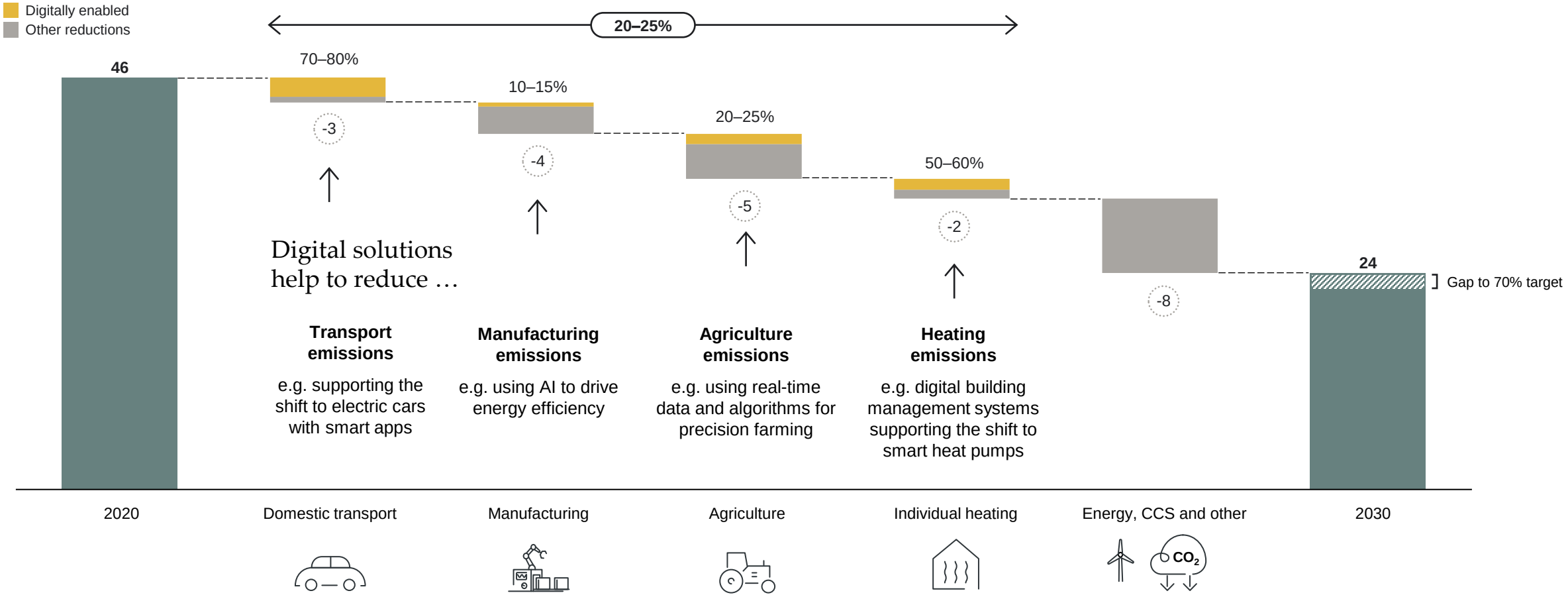
Industry and manufacturing
- Smart factory with AI systems
- Efficiency improvements
- Electrification of lighter processes
- Green fuels from PtX for heavy processes

Energy supply
- Expansion of renewable energy
- Electrification
- Smart grid
- Flexible electricity demand

Note: Data on net greenhouse gas emissions and removals, sent by countries to UNFCCC and the EU Greenhouse Gas Monitoring Mechanism (EU Member States). This data set reflects the GHG inventory data for 2022 as reported under the United Nations Framework Convention for Climate Change. CRF inventory categories: Energy supply: CRF 1A1 (energy industries) + 1B (fugitives); Industry and manufacturing: CRF 1A2 (manufacturing industries and construction) + CRF 2 (industrial processes and product use); Domestic transport: CRF 1.A.3; Residential and commercial: CRF 1A4a (commercial) + CRF 1A4b (residential); Agriculture: CRF 1A4c (agriculture, forestry and fishing) + CRF 3 (agriculture); Waste: CRF 5 (waste); LULUCF: CRF 4 (LULUCF); Other combustion (CRF1A5a + CRF1A5b + CRF indirect CO2).
Source: Implement Economics based on the European Environment Agency (EEA).

20-25% of the carbon reductions needed for Denmark's 2030 target require some degree of digital enablement

Denmark's net greenhouse gas emissions
$MtCO_2e$



Note: 'Agriculture' includes emissions from agriculture and LULUCF. 'Other' includes emissions from waste.
Source: Implement Economics based on Klimarådet, Malmodin, J. and P. Bengmark, Danish Government, and Implement Consulting Group.

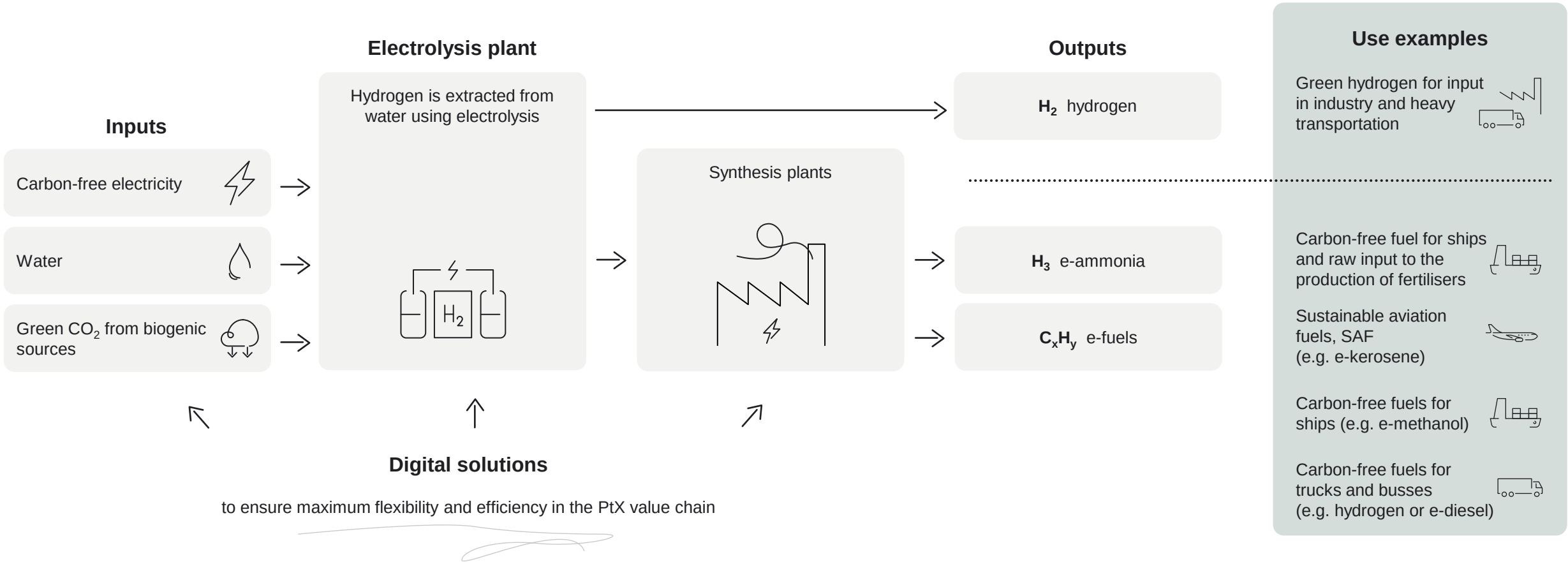
Power-to-X

> Digitalisation is an important tool, but it is just that – a tool, not the solution. We must also invest in large-scale physical infrastructure, such as the establishment of very large energy plants in the North Sea.

Brian Vad Mathiesen
Professor at Aalborg University

Power-to-X is a key technology in achieving full decarbonisation

Green hydrogen and e-fuels are critical components in the future energy system. Without them, it will be impossible to achieve full decarbonisation. Power-to-X (PtX) uses electricity, water and CO_2 to produce green hydrogen and carbon-free e-fuels to be used for transportation, agriculture and manufacturing. The PtX value chain needs digital solutions to be efficient and flexible.



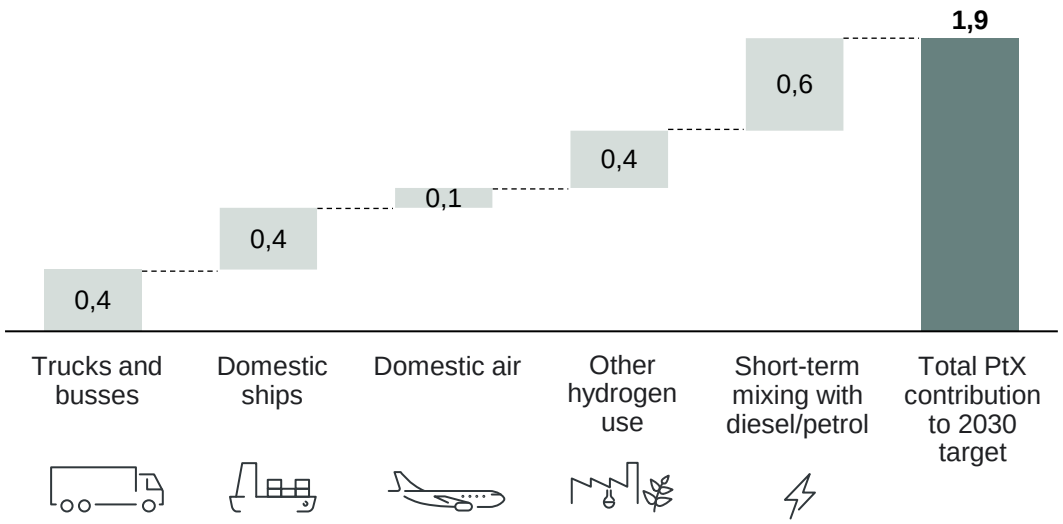
Source: Implement Economics based on Dansk Energi.

Power-to-X will contribute to Denmark's 2030 target and play a key role in achieving the 2050 target

2030

PtX is expected to contribute to Denmark's 2030 target (3-4% of 2021 emissions).

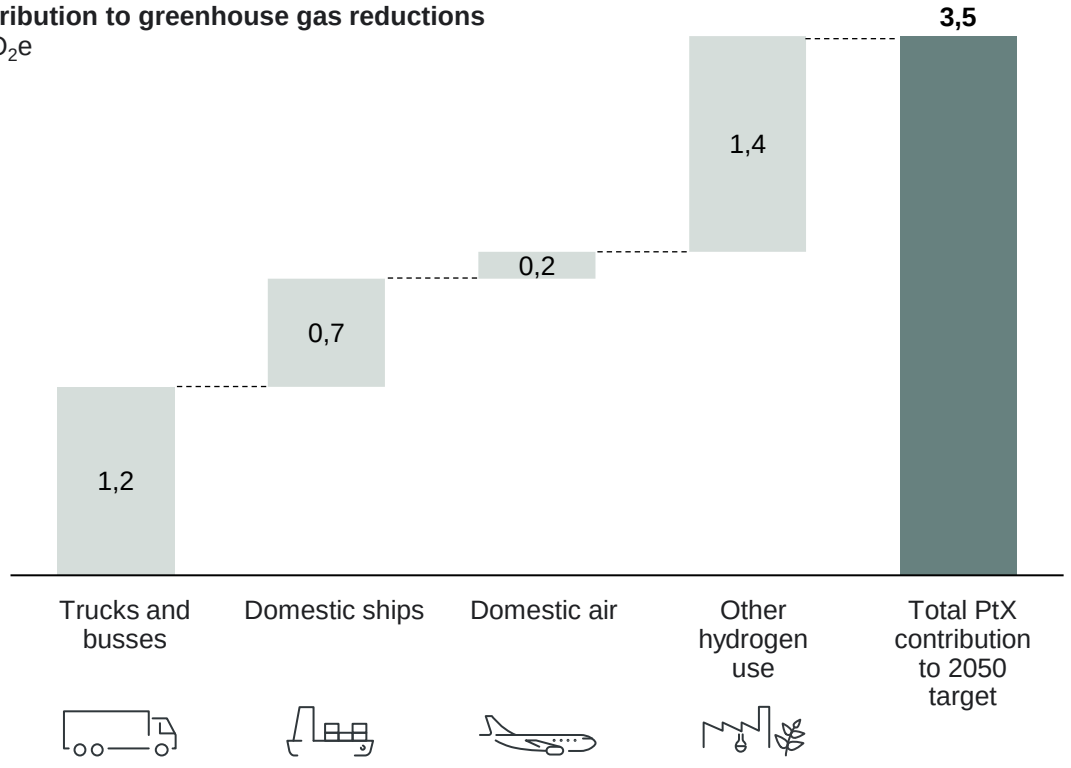
Contribution to greenhouse gas reductions
$MtCO_2e$



2050

PtX will contribute considerably to Denmark's 2050 target (7-8% of 2021 emissions).

Contribution to greenhouse gas reductions
$MtCO_2e$

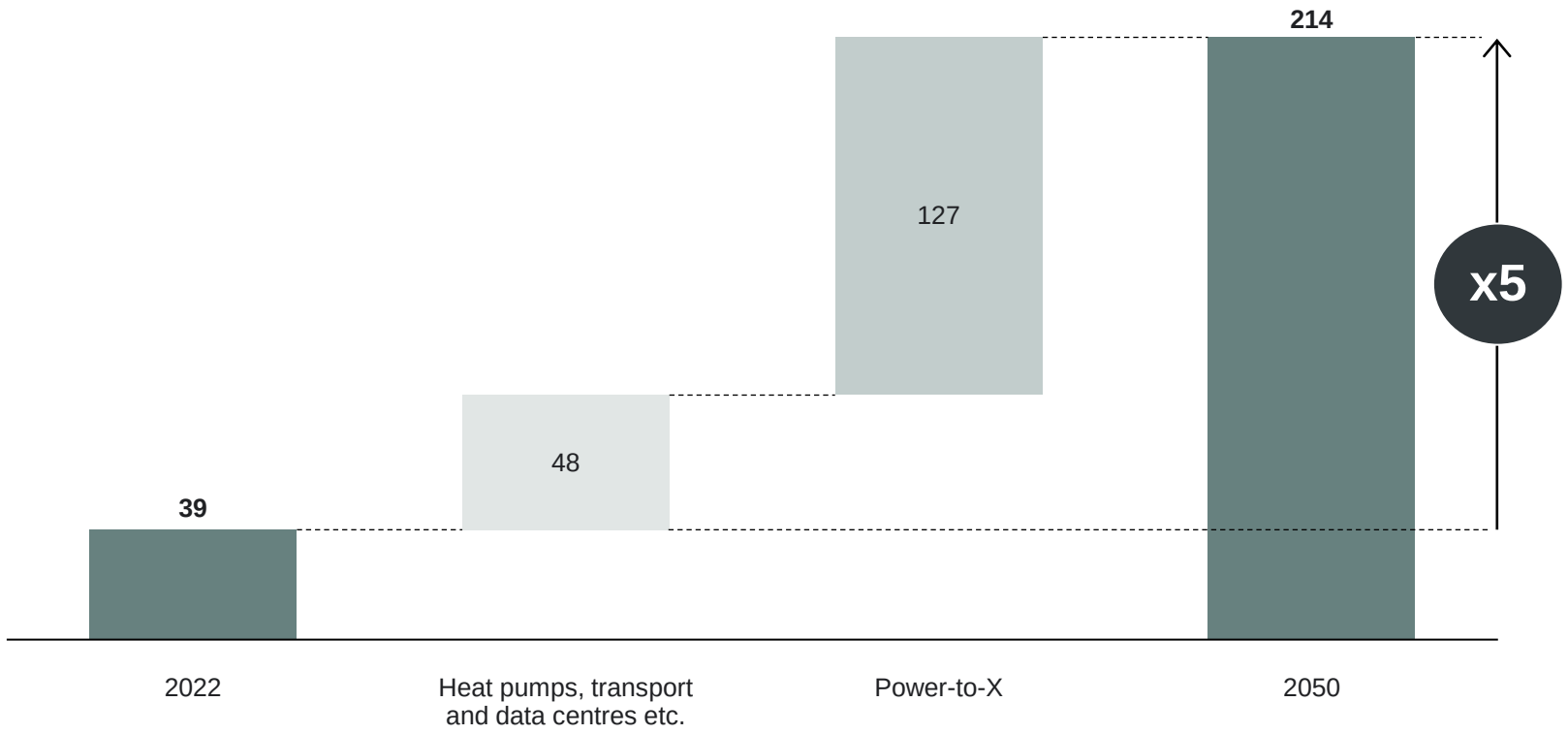


Source: Implement Economics based on Kraka.

Achieving global net zero is expected to involve massive build-out of Power-to-X, and Denmark plans to becoming net exporter of Power-to-X

Denmark and the countries around the North Sea have a unique position to use the large wind energy potential to produce PtX. The Danish Government has set a goal of establishing 4-6 GW of PtX capacity in Denmark by 2030. According to independent studies, more than half will be for export.

Electricity demand in Denmark
TWh



Increased export of PtX technology

Initial estimates from the Danish hydrogen industry suggested a 15-20% Danish market share of the EU electrolysis capacity in 2030 and suggested that PtX technology exports could be as high as DKK 30 billion in 2030 (based on 2021 report).

Increased export of green hydrogen

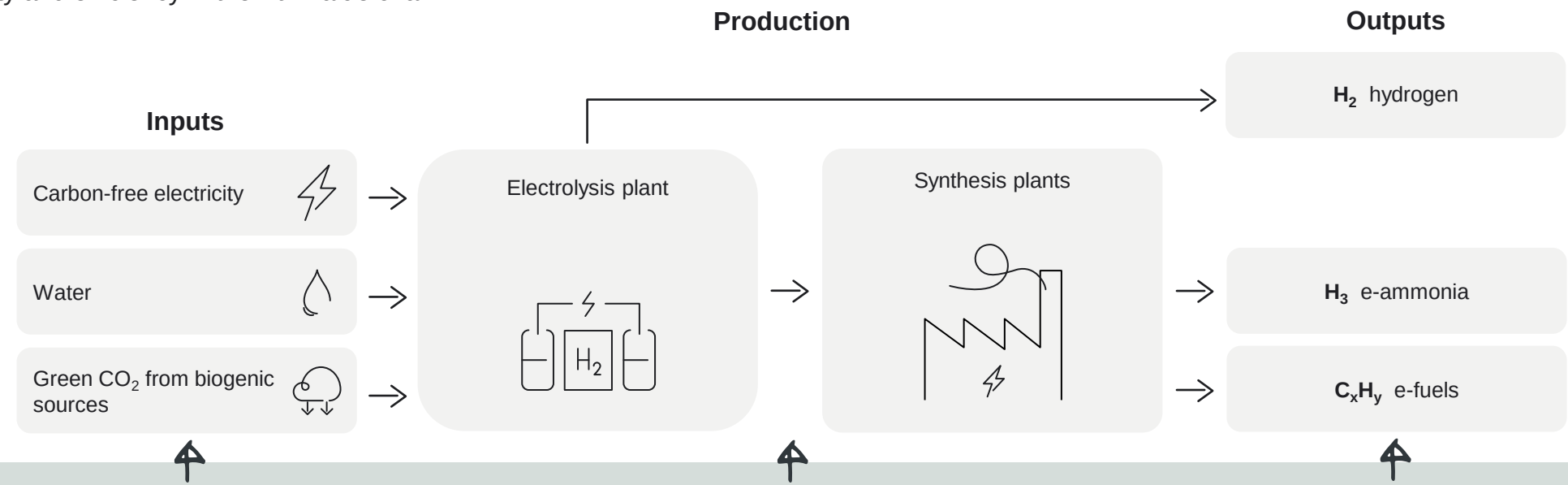
Back in 2021, the Danish hydrogen industry also predicted that 3-4 GW of the Danish PtX capacity in 2030 could be used for export with a value of up to DKK 3.5 billion in 2030.

To capture these export potentials, Danish companies must be among the best at leveraging digital technologies.

Note: 'Heat pumps, transport and data centers etc.' includes electricity demand from households, businesses, heat pumps, transport, data centers, DAC and other.
The figure only includes electricity demand for the part of Power-to-X connected to the collective electricity grid. Hence, the part of Power-to-X that will be established as offshore hydrogen turbines is not included.
Source: Implement Economics based on Danish Energy Agency (AF23), Danish Government, Kraka and Brintbranchen.

Digital solutions are key enablers across the PtX value chain

PtX technology is still in an early stage.[1] According to estimates from the International Energy Agency (IEA), the world will need to produce 540 million tons of hydrogen to achieve net-zero emissions by 2050. This translates into a cumulative investment need of about EUR 10 trillion in hydrogen projects. It will be critical to make the power demand from PtX-production as flexible as possible and develop its responsiveness hour-by-hour to fit into the future energy system. Digital solutions are key to ensuring maximum flexibility and efficiency in the PtX value chain.



01 AI and real-time data to ensure that PtX is produced with carbon-free energy as required under EU regulation.

02 Digital platform for interacting with the "host plant" providing the green CO_2 (key input for the PtX process).

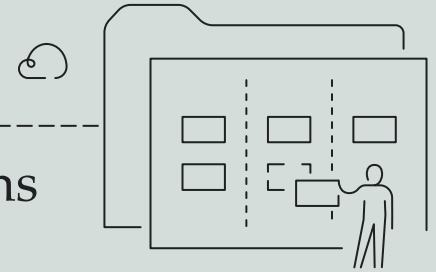
03 Digital platform for supply of water (the other key input to PtX).

04 IoT to manage and optimize the production at each plant.

05 Digital twin to simulate and optimize the integrated system of plants, suppliers and off-takers.

06 Digital platform for off-takers of hydrogen or PtX fuels.

Digital solutions



Note: Some 80% of announced low-carbon hydrogen projects worldwide are still in the planning stage, see: https://www.bcg.com/publications/2023/breaking-the-barriers-in-financing-hydrogen-and-carbon-capture.
Source: Implement Economics based on EU Directive and BCG.

CASE | Digital solutions supporting the emerging PtX value chain in Fredericia

Denmark has large-scale PtX ambitions and is aiming to build 4-6 GW of electrolysis capacity by 2030, which will entail significant exports.

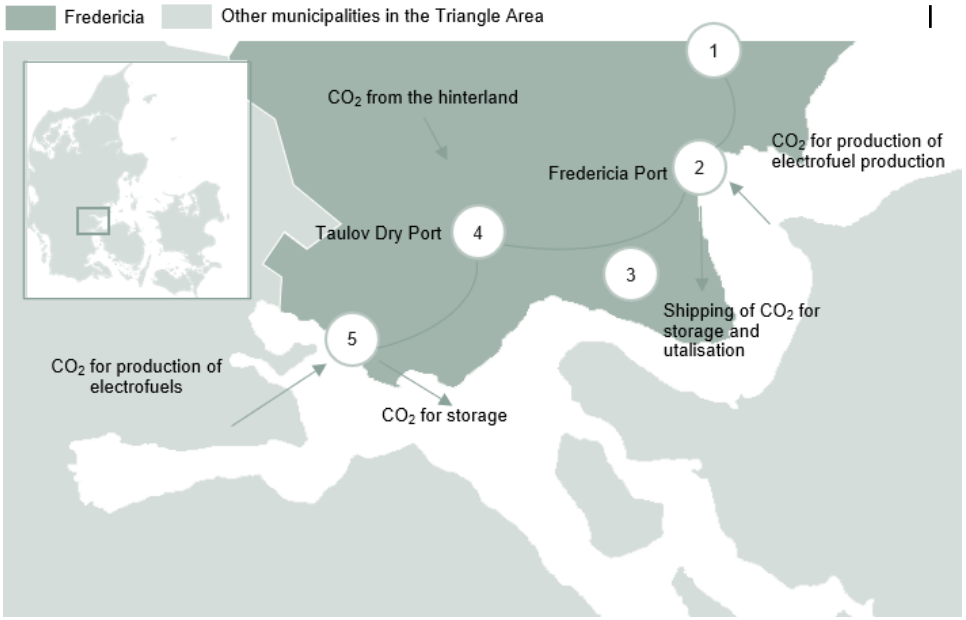
PtX plants are being developed at several locations across Denmark, each with their role in the PtX value chain.

PtX in the Triangle Area

The Triangle Area around Frederica is developing a cluster of PtX production building on long-standing expertise in refinery of fuels as well as Ørsted's heat-power plant, and Denmark's third largest harbour with vast experience in handling complex propulsion fuels and raw materials.

Additionally, the area is connected to the German market through a gas transmission pipeline and is a hub for heavy transport that will serve as off-takers of electrofuels.

Today, the Triangle Area hosts the largest PtX facility in Denmark of 20 MW and plans to expand its PtX capacity to 300 MW by 2025.



1 Everfuel

Everfuel is establishing a large-scale production and storage facility of green hydrogen.

In 2023, 20 MW will be in operation, with the capacity expanding to 1 GW by 2030.

1 Crossbridge Energy

Crossbridge Energy is an off-taker of green hydrogen, which will be used as input in the refinery's electrofuel production. The refinery is constructing CCS facilities and expects to capture 400,000 tons of CO_2 annually by 2026.

3 ENERGINET

Energinet owns, operates and develops Denmark's transmission systems for electricity and gas, and is responsible for connecting electrolysis plants to the electricity transmission grid. Together with Evida, Energinet will own and operate the pipelines for transporting hydrogen within Denmark and for export.

2 + 4 ADP

ADP is responsible for establishing and operating the PtX infrastructure in the Triangle Area. Fredericia Port will be a hub for receiving CO_2 used in electrofuel production and shipping CO_2 for storage and utilisation. Taulov Dry Port will be a CO_2 terminal from hinterland industries, plants and incinerators.

5 Ørsted

Ørsted owns and operates Skærbækværket, which produces electricity and heat. The plant is constructing CCS and PtX facilities, expecting to capture 250,000 tons of CO_2 annually.

Digital platform facilitating interactions between the two plants and other digital solutions are being developed to integrate and optimise production.

AI will help optimise grid flow and system stability, which is a necessity in PtX production.

Digital solutions are crucial for securing input and off-takers of green hydrogen and e-fuels. Real-time data and AI will help ensure input to production is carbon-free and detect infrastructure irregularities.

Digital twin will help optimise production and digital platforms will ensure supply of input and off-takers.

centerdenmark

Center Denmark's data platform collects data across the energy sector (for more details see slide 14)

Source: Implement Economics based on Børsen, Triangle Energy Alliance, Danish Ministry of Climate, Energy and Utilities, Energinet, Center Denmark, and Statistikbanken.

CASE | Data platform connecting actors in the PtX value chain will be essential to realise Denmark's PtX ambitions

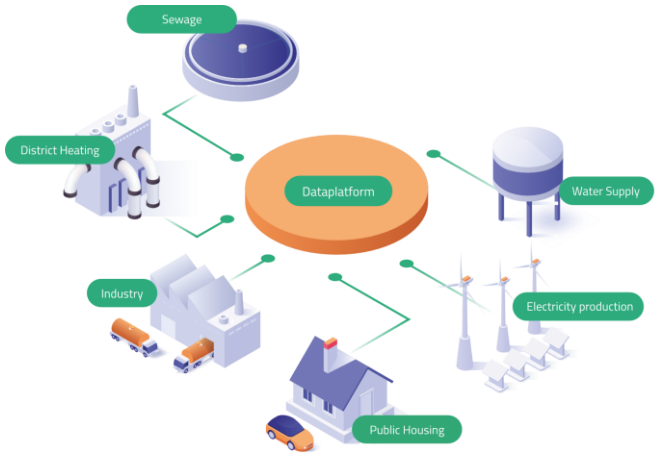
Establishing a data platform that connects actors in the PtX value chain and utilises advanced technologies like AI for predictive forecasting is essential for the PtX production.

Center Denmark is a non-profit company bringing utilities, companies and universities together to stimulate the development of data-driven digital tools for the energy sector.

Their data platform collects data on energy consumption and production, which can be used for new data-driven services.

1 Energy data is collected

The data platform collects data across the energy sector from both the consumer and supply side.



2 Data is analysed

The platform uses AI and other intelligent data services to analyse and leverage data in collaboration with utilities, companies and universities. For example, data is used for predictive forecasting of energy supply and demand.

3 Business development

The platform enables the testing of new digital services and business models in representative real-world environments, ensuring scalability for the actual market.

Source: Implement Economics based on Center Denmark.

CASE | Digital platform documenting 24/7 carbon-free energy in production will be a key technology in the PtX value chain

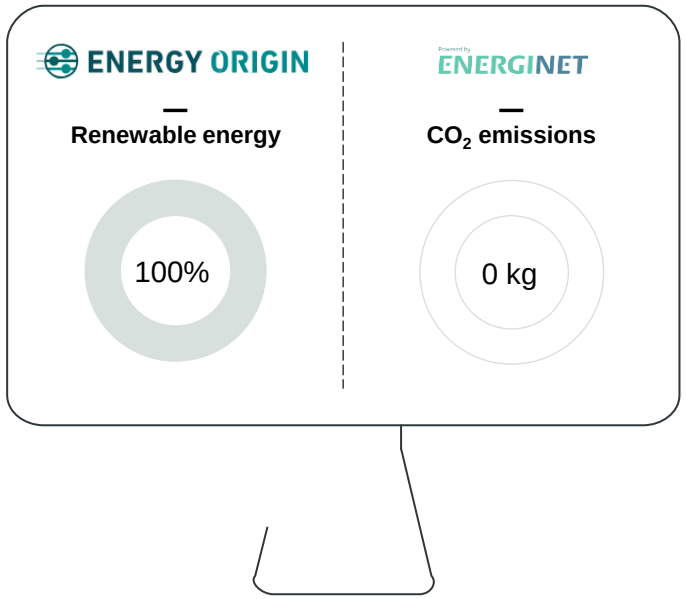
Hydrogen and electrofuels can only be classified as ‘green’ if they are produced using renewable electricity fulfilling the requirements outlined in the EU Delegated Act on Green hydrogen production.

Energy Origin is a digital platform developed by Energinet using blockchain technology to trace and document the origins of energy and corresponding emissions on an hourly basis.

The platform will be a key technology in the upstream part of the PtX value chain (see page 12) to document that hydrogen and e-fuels are produced with carbon-free energy every hour, every day, and thus truly green.

The solution enables the issuance of hourly certificates guaranteeing renewable electricity, supporting better matching of electricity demand and production.

The platform is still under development but is now mature enough for pilot testing.

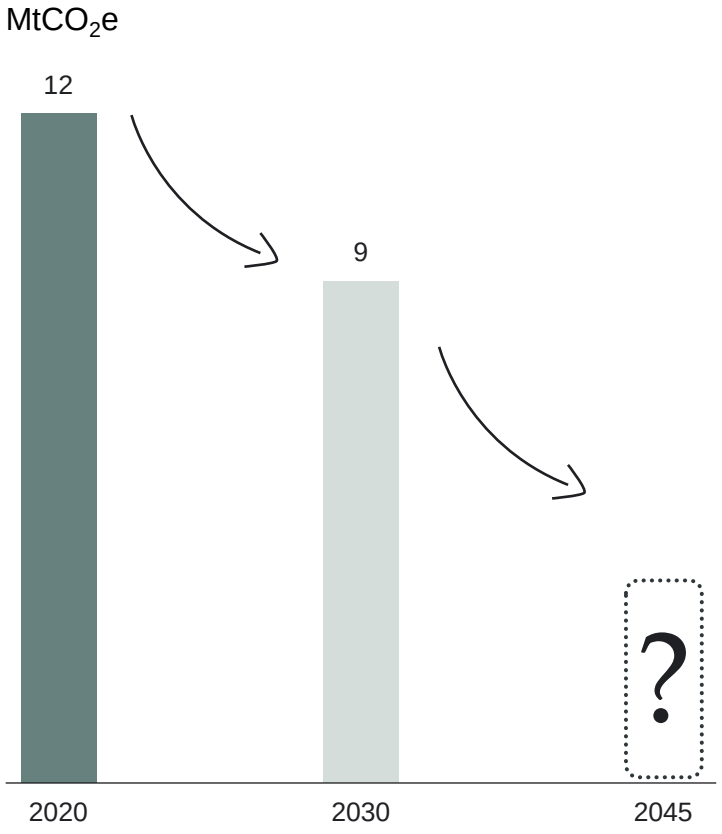


Note: As of January 2030, hydrogen must be produced by using additional renewable electricity that is produced at the same time and in the same area as the hydrogen to meet the requirements outlined in the EU Delegated Act on Green hydrogen production.
Source: Implement Economics based on European Commission, Bech-Bruun, and Energy Origin.

Transport

Digital technologies are key enablers of the transition to carbon-free transportation

Net greenhouse gas emissions from Denmark's domestic transport



Decarbonising transport emissions requires …

01. Change how we fuel our travel

02. Change the way we travel

03. Change how much we travel

Digital solutions can help this transition alongside other technologies by …

- Digital solutions optimise charging of electric vehicles (EVs) and ensure that green hydrogen and e-fuels from PtX give drivers carbon-free alternatives to fossil fuels.
  → *See Monta case.*

- Digital ride-sharing platforms contribute to lower emissions by enabling higher utilisation of vehicles.
- Digital solutions in public transport improves passenger experience and ease the transition to low-emissions options like trains and buses.
- Eco-routing software (e.g. Google maps), helping drivers to choose the most energy efficient route together with digital solutions optimising traffic lighting and mobility (e.g. project Green Light).

- Video-conferencing and work-from-home saves transportation emissions

70-80%
of the emission reductions in domestic transportation towards 2030 is expected to come from electrification and PtX, which in turn requires digital solutions to happen at scale and at acceptable social cost.

Source: Implement Economics based on the EEA and Klimarådet.

CASE | Digital app enabling flexible EV charging, supporting the Danish ambition of 1 million EVs by 2030

Monta has developed a smart operating platform powering the EV charging ecosystem serving drivers, companies, cities, and the electricity grid. Their mission is to provide the best technology solutions for the entire EV charging ecosystem.

Technology

Monta is a Danish digital company founded in 2020.

Monta's solution makes it easier for EV drivers to charge anywhere and for charge point operators to manage, monitor and optimise EV charging.

The solution enables EV owners to reduce their carbon footprint by enabling them to charge when the CO_2 intensity in the grid is low while also saving costs by avoiding peak demand on the grid.

On the road, the solution provides access to over 450,000 charge points, soon covering the majority of charging stations in and outside Europe.

It also gives charge point owners the opportunity to make their charge point public with customised time schedules and prices. The software offers full transparency over individual usage, consumption and pricing and is compatible with over 350 charge point models.

At workplaces, it enables smart charging including optimising EV fleet charging. By utilising digital technologies, the solution makes it possible to meet the growing charging demand by optimising the utilisation rate.

Effect

Monta simplifies EV charging and makes it more reliable, easing the transition to EVs. Further, the different features of Monta's solution aids in preventing costly unnecessary grid expansions by utilising the existing grid efficiently.

Decarbonisation potential

Road transport has an outsized impact on the environment, accounting for 20% of EU27's GHG emissions and 23% of Denmark's GHG emissions.

EVs are a key component in achieving net-zero transportation, and solutions like Monta that ease the shift to greener cars are essential in the transition.

Source: Implement Economics based on Monta, Danish Ministry of Finance, and the EEA.

MONTA

Sector

- Transportation

Type

- Do differently

Objectives

- Optimise EV charging

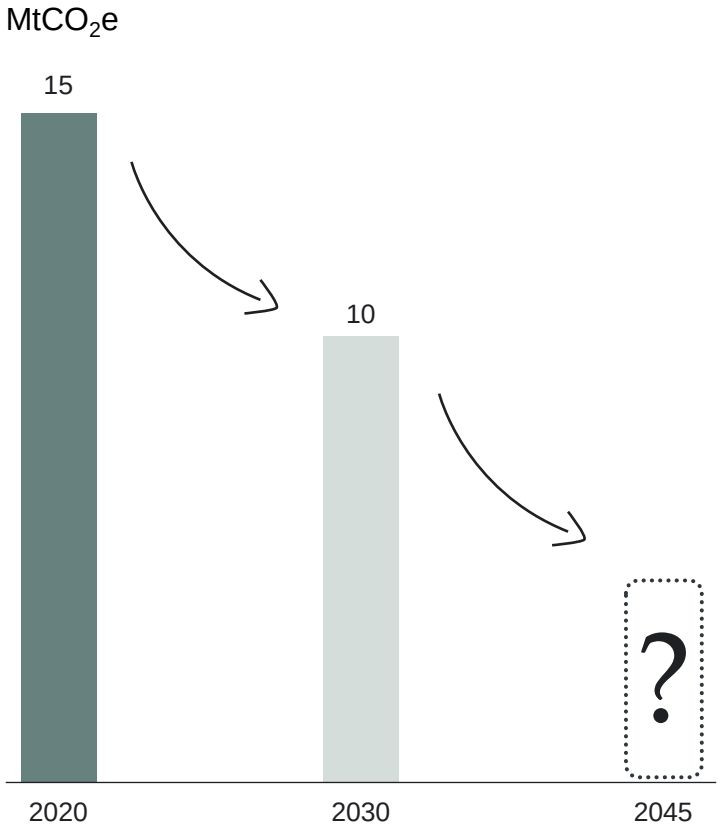
Technology

- Cloud technology, machine learning, AI, IoT

Agriculture

Digital technologies are helping the transition to a less greenhouse gas intensive farming sector

Net greenhouse gas emissions from Denmark's agriculture



Decarbonising agricultural emissions requires …

01. Change how we farm

02. Change what we eat and reduce food waste

03. Change how we manage our land

Digital solutions can help this transition alongside other technologies by …

- New technologies such as PtX to produce green ammonia.
- New agriculture practices such as data-driven *precision farming* can reduce emissions.

- Digital solutions can help reduce food waste which will reduce agriculture production without reducing consumption, such as for example the Danish digital start-up *Too Good to Go*.

- Drones and artificial intelligence can help identify land use possibilities and to provide the greatest climate gain with lower greenhouse gas emissions.
  → *See ReDoCO2 case.*

20-25%
of the emission reductions in agriculture will require some degree of digital enablement

Note: Agricultural emissions are calculated as CRF 3 (agriculture) + CRF 4 (LULUCF), which represent the emissions in the agricultural sector that are part of the reduction target.
Source: Implement Economics based on the EEA, Klimarådet, Danish Government, McKinsey and Malmodin, J. and P. Bengmark.

CASE | Drones and AI optimise rewetting, supporting the agricultural reduction target of 6-8M tons of CO_2 by 2030

ReDoCO2 is an innovation project funded by the Danish Innovation Fund. Drones and artificial intelligence are used to improve the mapping of peat soils and develop a decision-making tool that can optimise the efforts to rewet areas. This helps achieve the greatest climate gain in the form of lower greenhouse gas emissions.

Technology

The decision-making tool utilises advanced technologies like drones, sensors, artificial intelligence, and 3D software to revolutionise mapping of peat soils that will make rewetting easier and more accurate and as climate efficient as possible.

Effect

Increased intensification has led to the drainage of peat soil areas to facilitate land cultivation. When peat soils are drained, the stored CO_2 is released into the atmosphere, turning these areas into major sources of emissions.

If the areas are taken out of farming again and are rewetted, it is possible to slow down the emissions of CO_2. In such a scenario, *ReDoCO2* can help map the areas and identify where the biggest reduction in CO_2 can be achieved.

Decarbonisation potential

The agricultural sector is among the largest emitting sectors in Denmark, responsible for 36% of greenhouse gas emissions when including land-use emissions (LULUCF). Therefore, reductions in agricultural emissions are required for Denmark to meet its climate target by 2030.

Digital solutions, like *ReDoCO2*, can help the agricultural sector meet its reduction target by 2030.

Source: Implement Economics based on DCA-Nationalt Center for Fødevarer og Jordbrug.

IM_

Sector

- Agriculture

Type

- Do differently

Objectives

- Reduce agricultural emissions

Technology

- AI, drones, sensors, field data, 3D software

Buildings

“

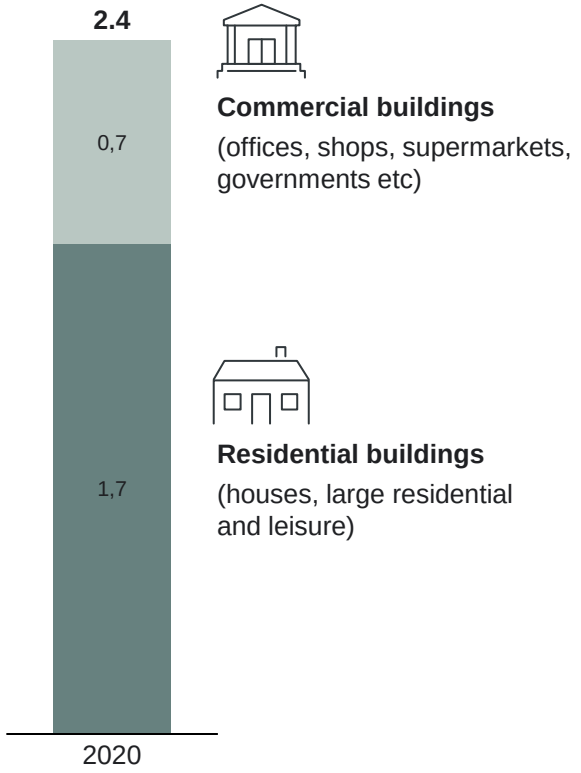
Digitalisation is crucial for being able to unlock the flexibility needed for an efficient transformation of our energy system.

Henrik Madsen
Professor at Technical University of Denmark

Digital solutions are helping to make buildings smart which helps reducing carbon emissions

Net greenhouse gas emissions from buildings

$MtCO_2e$



Commercial buildings
(offices, shops, supermarkets, governments etc)

Residential buildings
(houses, large residential and leisure)

Decarbonising building's emissions requires …

01. Change how we heat and cool our shops and offices

- New building management systems using AI and machine learning improves energy efficiency of office buildings and shops. Digital solutions can also help enable switch to heat pumps and/or intelligent district heating.

02. Change how we heat and cool our homes

- New building management systems using AI and machine learning improves energy efficiency of large residential buildings. Digital solutions enable switch to heat pumps and provides demand flexibility. AI is also used in intelligent district heating systems.
  → *See Danfoss Leanheat case.*

03. Change how we construct and design our buildings

- Advanced technologies like IoT, artificial intelligence and machine learning make buildings smart, improving performance while reducing carbon emissions.
  → *See Trifork case.*

Digital solutions can help this transition alongside other technologies by …

50-60%
of individual gas heating is expected to be heat pumps, which in turn requires digital solutions to be efficient and flexible.

Source: Implement Economics based on the EEA and Klimarådet.

CASE | AI solution for district heating system reduces peak power usage by up to 20%

Danfoss has developed the digital solution, *Leanheat* enabling end-to-end optimisation of district heating systems – from plant and distribution to buildings and homes. Today, the solution is used in more than 200,000 apartments worldwide and it is the world's largest IoT solution for collective heating.

Technology

Leanheat is a cloud-based AI solution using IoT technology. The solution offers end-to-end software systems and services for the control and optimisation of district energy systems. It includes an advanced software tool for forecasting, planning and optimising district heating across the value chain covering production, distribution and the demand side. By combining real-time data, weather forecast, and historical data, the tool predicts heat consumption six days ahead with more than 95% accuracy.

On the demand side, climate sensor data from buildings is send to the cloud and processed using AI along with real-time data, weather forecast and prices. Subsequently, real-time commands are sent to the building's central heating system on how to adjust heating to reach the optimal indoor climate.

Effect

On the supply side, *Leanheat* helps utilities optimise operational efficiency, achieve resource optimisation by avoiding inefficient fossil fuels, increase uptime and reliability, reduce maintenance and energy costs, as well as reducing carbon emissions.

On the demand side, it optimises energy consumption and climate in buildings and optimise temperature and pressure according to real-time needs.

Leanheat-connected buildings allow the district heating company to use up to 20% less power at peak hours. Less peak power means less CO_2 emissions.

The solution enables aggregating buildings into a Virtual Heat Storage (VHS) for utilities making 30-40% of buildings heating consumption flexible, helping to balance supply and demand.

Additionally, it reduces heating cost saving 10-20% of a typical building's energy cost.

Decarbonisation potential

Replacement of individual heating with district heating is an important part of Denmark's decarbonisation journey.

Solutions like *Leanheat* help foster the green transition by improving energy efficiency, less peak power and providing more flexibility and responsiveness in the heating system.

Source: Implement Economics based on Danfoss.

Sector

- Buildings

Type

- Use less

Objectives

- Energy efficiency, smart district heating utilities and buildings

Technology

- IoT, AI, cloud technology, sensor technology

CASE | Smart building concept is aiming to reduce emissions in construction and operation by 50%

Trifork's Smart Building concept aims to demonstrate how building's emissions can be significantly reduced by incorporating digital technologies from the beginning of the construction and design process.

Technology

Trifork's concept decarbonises buildings through construction with sustainable materials, utilisation of sustainable energy sources, such as geothermal heat and solar energy, as well as data collection and analysis used to continuously control and optimise energy consumption and indoor climate.

The utilisation of digital technologies will not only optimise energy consumption but also reduce operational costs.

Effect

Trifork's Smart Building concept will contribute to the creation of sustainable and energy-efficient buildings while setting new standards for future construction.

The aim is to reduce emissions by at least 50% compared to conventional construction. In addition, studies have found that operational emissions can be reduced by up 50% through the integration of digital solutions in buildings.

Decarbonisation potential

Buildings account for 13% of the EU27's GHG emissions and 5% of Denmark's GHG emissions. Smart buildings can help mitigate the carbon footprint from buildings.

TRIFORK.

Sector

- Buildings

Type

- Do differently

Objectives

- Smart buildings, energy efficiency

Technology

- Cloud technology, sensor technology, AI, IoT

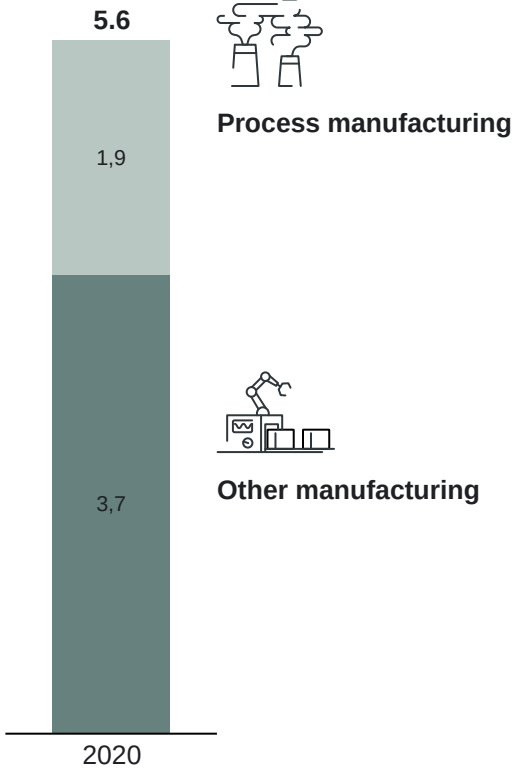
Source: Implement Economics based on Trifork, IT-BRANCHEN, Implement Consulting Group, and the EEA.

Manufacturing

Digital solutions are helping to improve manufacturing energy efficiency, supporting electrification and reduce over-production

Manufacturing's net greenhouse gas emissions

$MtCO_2e$



Decarbonising manufacturing emissions requires …

01. Change production processes

02. Change how we fuel our plants

03. Change how we forecast demand

Digital solutions can help this transition alongside other initiatives by …

- **Energy efficiencies with digital**. Digital solutions are used to optimise production processes at the factory floor and in the supply chain and is increasingly used for energy efficiency purposes

  → *See Renault case.*

- **Transition to heat pumps with digitally enabled smart grids**. Lighter industrial processes can switch from natural gas to heat pumps, which requires integration with smart grid solutions and flexible demand, which requires digital enablement.

- **Reducing overproduction with digitally enabled demand forecasting**. AI and machine learning can help to better forecast demand in for example food production or clothing leading to less overproduction and hence less energy use.

10-15%
of the emission reductions in manufacturing towards 2030 will require some degree of digital enablement.

Source: Implement Economics based on the EEA and Implement Consulting Group.

CASE | Cloud solutions are used to build the smartfactory of the future

Renault, the French car manufacturer, has entered a partnership with Google Cloud to build the smart factory of the future that are more efficient and consume less energy.

Technology

Google Cloud's solutions are used to digitalise Renault's production facilities and supply-chain.

Big data and machine learning analyse over half a billion data points from Renault's factories every day, transforming them into actionable and easily understood information. This enables fine-grained monitoring and proactive detection of irregular behavior.

A custom energy consumption dashboard keeps track of energy usage and suggests actions to reduce it, resulting in a 10-20% reduction in overall energy use.

Effect

The digitalisation of Renault's production facilities and supply-chain enables proactive maintenance, extending the lifetime of assets and resulting in more efficient resource usage, while also reducing energy consumption and carbon emissions.

Decarbonisation potential

Manufacturing generates 21% and 12% of carbon emissions in the EU27 and Denmark, respectively. Making factories smart by utilising digital solutions will be key to reducing the sector's emissions and ultimately reaching net-zero.

Source: Implement Economics based on Google Cloud, Implement Consulting Group, and the EEA.

IM_

RENAULT

Sector

- Manufacturing

Type

- Use less

Objectives

- Energy saving, smart factory

Technology

- IoT, AI, cloud technology, big data, digital twin

Decarbonising digital

Decarbonisation enabled via digital solutions will outweigh emissions from data centers and future gains are significant

Share of total EU emissions in 2020

Reductions will happen via …

Digital tech crucial to this:

Transport (21%)

A. Electric vehicles
B. Alternative fuels
C. Energy efficiency
D. Reduced passenger transportation
E. Reduced freight transportation

- **Smart charging apps**
- **AI and ML**
- **MaaS platforms**
- **Videoconferencing and online collaboration tools**

Buildings (13%)

A. Insulation
B. Energy efficiency
C. District heating
D. Heat pumps
E. Alternative energy sources

- **Grid control of heating**
- **AI and ML**
- **Smart thermostats**

Manufacturing (21%)

A. Energy efficiency
B. Processes efficiency
C. Reduced waste

- **AI, ML and IoT**

Agri (13%)

A. Grow sustainably
B. Reduce consumption of livestock and other carbon-intensive products
C. Increase efficiency of crops

- **Sensors**
- **Satellite data**
- **Drones**
- **AI, ML and IoT**

Data centres (~0.5%)

A. Energy efficiency
B. 24/7 CFE
C. Net-zero supply chain

Source: Implement Economics based on the EEA and the IEA.

24/7 carbon-free energy is the most efficient way to progress towards a fully carbon-free digital sector

This part of the report focuses on the energy use and carbon emissions related to the operation of data centres. Although they are only responsible for part of the total footprint of the digital sector, data centres are a segment of the digital sector under the direct control of tech companies, and where tech companies can act – and have acted – to minimise their environmental impact.

24/7 Carbon-free Energy

24/7 Carbon-free Energy (CFE) means that every kilowatt-hour of electricity consumption is met with carbon-free electricity sources, every hour of every day, everywhere.

The tech sector was among the first to acquire additional carbon-free energy through power purchase agreements (PPAs) and has been responsible for 45 percent of new carbon-free energy deployed through PPAs between 2010–2020 according to the International Energy Agency (IEA).

Many are going even further. After meeting its goal to match 100 percent of its electricity consumption with carbon-free energy on an annual basis, Google became the first major company to commit to operating on 24/7 carbon-free energy (CFE), which it aims to do at all in of its data centres and office campuses across the world by 2030.

Other companies such as Microsoft and Iron Mountain are also on this journey. A new global effort has been created under Sustainable Energy for All and UN-Energy to coordinate among companies, governments, and non-governmental organisations to develop new solutions to this challenge.

Google has set a goal to run on 24/7 carbon-free energy (CFE) on every grid where they operate by 2030

Google's decarbonisation journey in Denmark

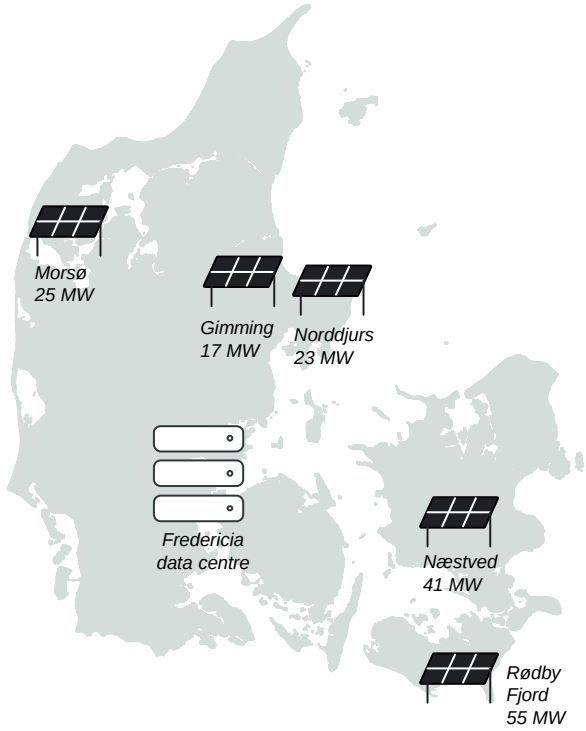
90%

CFE-score for Google's operations in Denmark in 2022.

160 MW

Renewable energy projects in Denmark supported by Google's agreement with Better Energy and European Energy.

The carbon-free energy score (CFE Score) measures the degree to which each hour of electricity consumption on a given regional grid is matched with carbon-free energy.

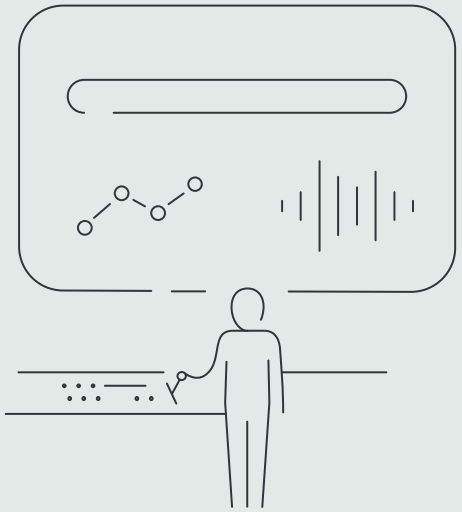


Note: Carbon-free energy is any type of electricity generation that does not directly emit carbon dioxide, including (but not limited to) solar, wind, geothermal, hydropower, and nuclear. Sustainable biomass and carbon capture and storage (CCS) are special cases considered on a case-by-case basis, but are often also considered carbon-free energy sources. An overview of Google's 24/7 energy is available at https://sustainability.google/progress/energy/. A further introduction to Google's approach to 24/7 carbon-free energy is available at https://www.gstatic.com/gumdrop/sustainability/24-7-explainer.pdf and the methodologies and metrics are available at https://www.gstatic.com/gumdrop/sustainability/24x7-carbon-free-energy-methodologies-metrics.pdf.

Source: Implement Economics based on UN 24/7 Carbon-free Energy Compact, Google, and Danish Broadcasting Corporation.

A fully decarbonised data centre industry will enable the full potential of digital decarbonisation

Decarbonising digital means minimising the carbon emissions across the entire digital value chain by decarbonising all operational electricity emissions, as well as addressing the embodied emissions

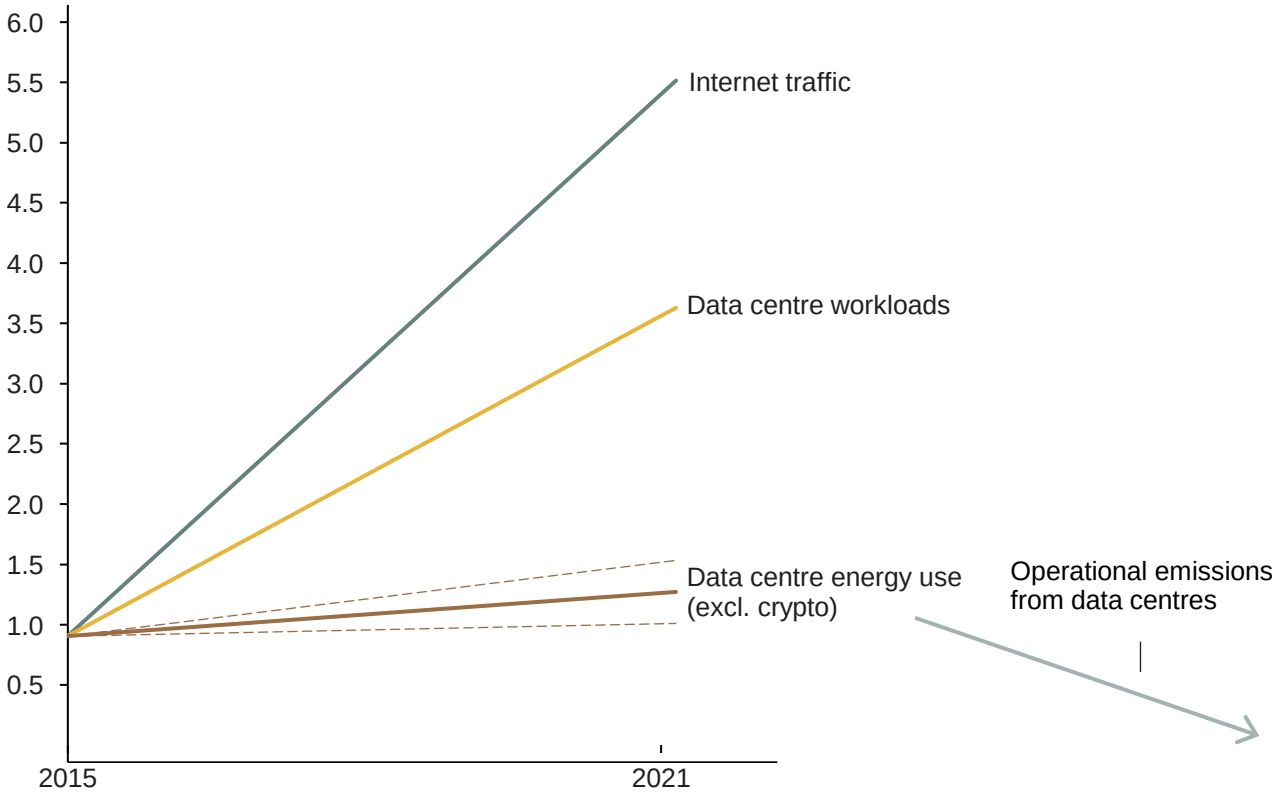


	Data centres	Networks	Devices
Operational emissions[1] *(scope 2)*	24/7 carbon-free electricity portfolios such as Google's *CFE Manager*[2] would be the most effective approach.	24/7 carbon-free energy deals, but networks do not have the same load-shifting possibilities as data centres.	Improved energy efficiency of devices plus decarbonisation of the general power supply.
Actions to make it happen:	• Accelerate carbon-free technology deployment. • Provide companies and consumers with a better measurement of real decarbonisation.		
Embodied emissions *(scope 3)*	Data centres should be working with their suppliers to bring down scope 3 emissions.	Network operators should be working with their suppliers to bring down scope 3 emissions.	Device manufactures should reduce operational footprint and improve circularity of products.
Actions to make it happen:	• Improved circularity in the digital sector through recycling, reusing, refurbishing, and maintaining. • Improving efficiency of EU climate policies through e.g. the proposed cross-border adjustment mechanism		

Note: 1) The International Energy Agency (IEA) estimates global data centre energy use at 240-340 TWh in 2022 and global data transmission network energy use at 260-340 TWh in the same year, see https://www.iea.org/energy-system/buildings/data-centres-and-data-transmission-networks.
2) A CFE Manager is an energy service provider that an energy buyer tasks with assembling a portfolio of CFE projects. See more at: https://cloud.google.com/blog/topics/sustainability/a-new-clean-energy-purchasing-model-to-drive-decarbonization

Decarbonising Europe's data centres with 24/7 carbon-free energy will save 6-18 million tons of CO_2 in 2030

Global internet traffic, data centre workloads and energy use



If all data centres in Europe achieved 100% hourly carbon-free energy (24/7 CFE), we will save **6-18 million tons of CO_2 in 2030.**

This corresponds to Denmark's agriculture and manufacturing emissions combined.

Decarbonising digital towards 2030

Carbon-emissions will fall if all EU data centres meet 24/7 carbon-free energy goals such as those set by the frontrunner companies.

Source: Implement Economics based on the IEA and Montevecchi et al.

Data and digitisation play an important role in achieving Denmark's climate goals. We must use intelligent systems to shift power consumption to the hours when the power is green, the price is low, and where there is capacity in grid. Data and digitisation are essential for us to utilise energy across sectors.

Kristian Jensen
CEO Green Power Denmark

The full report is available at:
https://implementconsultinggroup.com/article/digital-decarbonisation/