Nordic Energy Research

Progress towards Nordic Carbon Neutrality

Tracking Nordic Clean Energy Progress

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Nordic Energy Research
Nordic Energy Research is the platform for cooperative energy research and policy development reporting to the Nordic Council of Ministers. The Board comprises representatives from the authorities and ministries responsible for energy research funding in the five Nordic countries Denmark, Finland, Iceland, Norway, and Sweden, who also contribute to the majority of the organisation's funding.

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Foreword

“I hope that this report will inspire greater action in the areas where the Nordic countries are falling behind on the carbon neutral pathway”

Hans Jørgen Koch
CEO, Nordic Energy Research

The following publication is the result of work undertaken by Ea Energy Analyses and Gaia Group in close cooperation with Nordic Energy Research (NER), the platform for cooperative energy research and knowledge development that is used for policy development under the auspices of the Nordic Council of Ministers.

Nordic Energy Research and the International Energy Agency (IEA) published a Nordic Energy Technology Perspectives (NETP) report in both 2013 and 2016. Together, these publications represent the largest-ever collaborative IEA initiative on regional long-term, cost-efficient, low-carbon technology pathways. This report applies the global energy scenarios of the IEA’s Energy Technology Perspectives (ETP) to the Nordic countries, utilising rich national data and addressing opportunities and challenges specific to the Nordic countries.

After issuing two Nordic Energy Technology Perspectives (NETP), we considered it a natural next step to prepare a tracking report to illustrate the progress being made towards a carbon neutral society in the respective Nordic countries. It was important to us that this should be done in a way that was clear, concise and accessible to the widest possible readership.

The result is Tracking Nordic Clean Energy Progress 2019; a brief, illustrative report that charts Nordic progress towards a carbon neutral society by highlighting the most prominent trends and examining scenarios where Nordic solutions can have a global impact. In short, the report illustrates – for multiple technologies and key parameters – the latest progress in technology development and penetration, as well as market creation.

This report also aims to provide useful analytical insights into the progress made by the Nordic countries towards achieving Nordic Carbon Neutrality in line with the initiative adopted by the Nordic prime ministers in Helsinki in January 2019.

I hope that this publication will inspire greater action in the areas where the Nordic countries are falling behind on the carbon neutral pathway, as well as foster a belief that a low-carbon society is achievable, by highlighting cases where progress has been made.

Hans Jørgen Koch
CEO, Nordic Energy Research

Acknowledgements

Tracking Nordic Clean Energy Progress 2019 is a collaborative project between Ea Energy Analyses and Nordic Energy Research – an intergovernmental organisation reporting to the Nordic Council of Ministers.

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The individuals and organisations that contributed to this publication are not responsible for any opinions or judgements contained therein.

Glossary

2DS
2 Degrees Scenario. A scenario where global warming is limited to 2°C and the EU reduces GHG emissions by 80% by 2050.

4DS
4 Degrees Scenario. A scenario where global warming reaches 4°C.

CCS
Carbon capture storage.

CNS
Nordic Carbon Neutral Scenario (CNS). A scenario that achieves an 85% reduction in Nordic energy in terms of CO_2 by 2050 (from 1990 levels) at the lowest total cost possible.

CO_2
Carbon dioxide.

GHG
Greenhouse gas. CO_2, CH_4, N_2O, and fluorinated-gases (F-gases), sometimes also called Kyoto gases.

EV / BEV / PHEV
Electric vehicle / battery electric vehicle / plug-in hybrid electric vehicle

NETP
Nordic Energy Technology Perspectives 2013 and 2016. A collaborative project between the International Energy Agency (IEA), Nordic research institutions, and Nordic Energy Research.

Nordic countries
Refers in this publication to Denmark, Finland, Iceland, Norway and Sweden.

OECD
Organisation for Economic Co-operation and Development.

RE / RES
Renewable energy / renewable energy sources.

VRES
Variable renewable energy sources such a wind and solar.

Contents

About

Nordic Energy Technology Perspectives (NETP), was published by Nordic Energy Research and the International Energy Agency (IEA) in 2013 and 2016. A Nordic study based on the IEA global Energy Technology Perspectives, NETP presents a detailed scenario-based analysis of how the Nordic countries can achieve a near carbon neutral energy system by 2050. This report **evaluates progress towards Nordic Carbon Neutrality** and compares actual progress with the Carbon Neutral Scenario (CNS) in the NETP 2016 for **Denmark, Finland, Iceland, Norway and Sweden**.

NETP 2016 contains a large amount of historical data for the period up to 2013. This publication **also includes data for 2014-2016** and, where possible, 2017 and 2018.

Tracking Nordic Clean Energy Progress is divided into **10 two-page sections**, which cover the drivers required to achieve a carbon neutral energy system. Each two-page section can be read and used separately for specific dissemination purposes for a particular driver.

Are we on track?

On the opposite page, the colours red, yellow and green indicate progress achieved today towards reaching Nordic carbon neutrality in 2050. Three different perspectives are considered in the estimation of progress:

Measurable and timely progress – Is a measurable progress towards the target of the driver in question visible in statistical data? Is the gap between the present situation and the target for 2050 decreasing annually with a speed that suggests that the Nordic will be able to achieve the target in time?

Technical solutions – Do the key technical solutions exist? If the key technical solutions exist then what remains is to a higher degree within our control, namely improving efficiency, organisation, and pricing/market. If key technical solutions have not yet been developed and demonstrated full-scale then there is a higher risk of not achieving the necessary in due time.

Mix of initiatives – Initiatives critical for the transformation vary depending on the maturity and type of the critical elements for each driver. They may span from legislation such as minimum energy performance standards to RD&D, from market pricing to data services etc. A mix of strong initiatives activating a variety of stakeholders and change agents is expected to lend greater momentum to the green transition.

Red – Not on track / Insufficient steps

Yellow – Greater effort is required but critical steps are being addressed

Green – On track / Sufficiently promising efforts and impact

THE BIGGER PICTURE

All five Nordic countries have seen significant increases in the utilisation of renewable energy and the total Nordic primary energy demand per capita has been stable in recent decades. The Nordic region has achieved a steady decoupling of GDP from energy-related CO_2 emissions and declining CO_2 intensity in energy supply in recent decades. Progress in industry, transport, and buildings represents the biggest challenge. Energy efficiency and decarbonisation of end-use sectors need to play a prominent role in this decoupling going forward.

TRANSFORMING THE POWER SECTOR

CO_2 emissions from power generation have been reduced by more than one-third during the last ten years. Deployment of wind power and a fuel shift from coal and gas to biomass have been key to this transformation.

BOOSTING BIOENERGY

Overall demand for bioenergy has been increasing slightly over the past ten years, particularly for biofuels used in transport. Nonetheless, bioenergy is still mainly used for heating in the Nordic countries. Moving forward, these limited bioenergy resources will have to be used for high-quality biofuels for heavy transport, industries and the chemical sector.

ELECTRIFICATION OF TRANSPORT

Electrification is the key measure of long-term CO_2 reduction in the transport sector. Norway is the global leader in the deployment of EVs with a current market share exceeding 50%, yet on the Nordic level EV's only make up 3% of the total car fleet.

ELECTRIFICATION OF HEAT SUPPLY

Electrification of heating will free up biomass resources for other purposes and facilitate efficient integration of wind and solar power. The Nordic countries have high shares of individual electric heat pumps and they have ambitions to scale up the role of electricity for district heating.

DECARBONISATION OF INDUSTRY

The Nordic region is relatively energy and material efficient. Both factors have been key for competitiveness. Exploitation of residual heat and further decarbonisation of the industrial sector represent major technological and political challenges. Energy related CO_2 emissions have dropped 25% during the last 10 years.

ENERGY EFFICIENT & SMART BUILDINGS

The average energy demand of Nordic buildings has decreased only slightly over the last ten years, despite major potentials for energy renovation. However, CO_2 emissions per square metre have dropped markedly on the back of a large decrease in the use of oil burners.

GREEN MOBILITY

An increased focus on liveability and climate change demands new solutions for urban transport. Nordic cities are developing cycling polices, investing in electric buses and trialling new concepts for mobility as a service. However, cars still account for approximately 85% of all inland passenger transport.

ENERGY STORAGE & CCS

The large hydro reservoirs provide the Nordic countries with excellent and cheap storage options, which are already efficiently utilised. In the future, these will probably need to be supplemented with chemical storage in the form of batteries or hydrogen-based fuels. Carbon capture and storage may prove the key to reducing industrial CO_2 emissions or be applied to biomass combustion to generate negative CO_2 emissions.

/ NORDIC ENERGY TECHNOLOGY PERSPECTIVES

Staying on track for a low carbon energy future

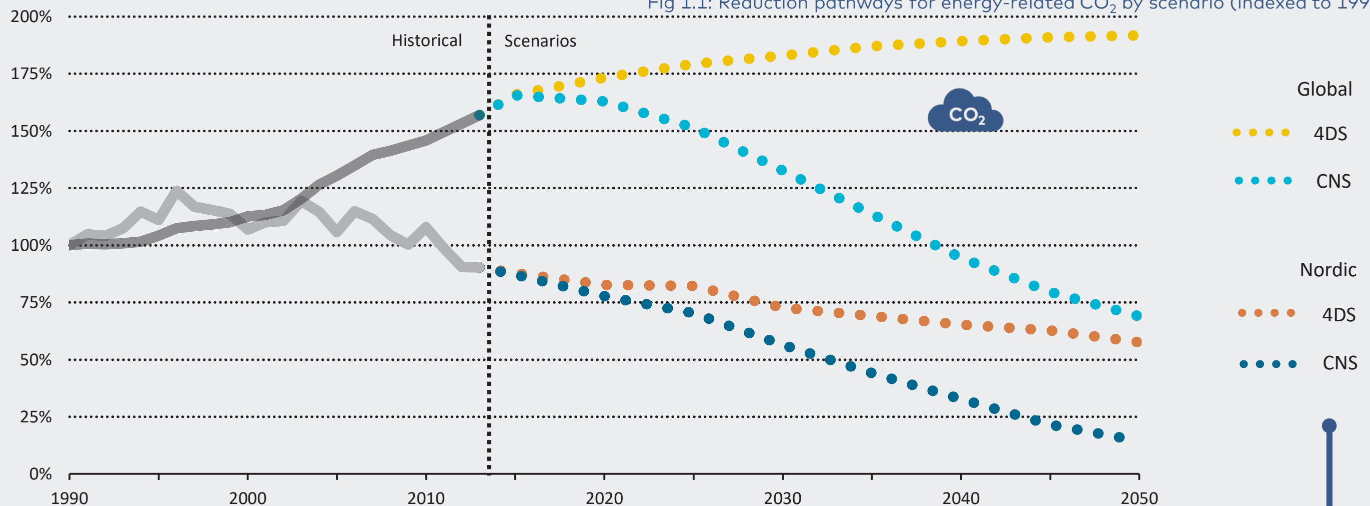
The five Nordic countries – Denmark, Finland, Iceland, Norway and Sweden – have some of the most ambitious energy and climate policies in the world. Despite this, achieving the Paris Climate Agreement's vision of maintaining the global temperature rise "well below two degrees" will require radical change.

Nordic Energy Technology Perspectives 2016 (NETP) presents a detailed scenario-based analysis of how the Nordic countries can achieve a near carbon neutral energy system by 2050. The report is a Nordic edition of the International Energy Agency's (IEA) global Energy Technology Perspectives 2016 (ETP).

This publication **evaluates the progress being made towards Nordic Carbon Neutrality** and compares progress with the Carbon Neutral Scenario (CNS) in NETP 2016. The NETP publication and this publication deal with energy-related CO_2 emissions, which account for just under two-thirds of total greenhouse gas (GHG) emissions in the Nordic region.

CO_2 emissions in NETP scenarios

Fig 1.1: Reduction pathways for energy-related CO_2 by scenario (indexed to 1990)



NETP scenarios

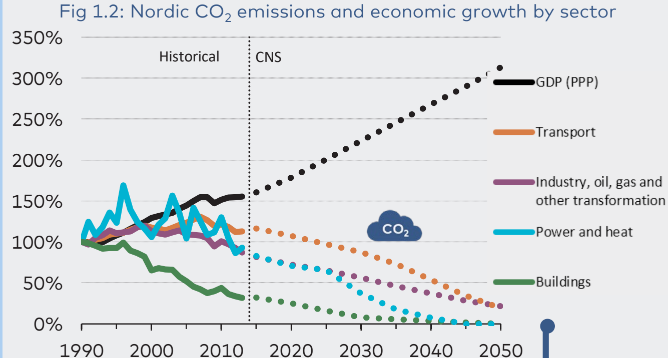
The figure above shows the CO_2 emissions in the NETP scenarios. NETP 2016 was published by Nordic Energy Research and the Nordic Council of Ministers in 2016 and is an integral part of the global analysis set out in IEA's ETP 2016.

The **Nordic 4 Degrees Scenario (4DS)** reflects the Nordic contribution to the IEA's global 4-degrees scenario.

The **ETP 2 Degrees Scenario (2DS)** requires global energy-related CO_2 emissions to be cut by more than half by 2050 (compared with 2013), and to ensure that emissions continue to fall thereafter.

The Nordic Carbon Neutral Scenario (CNS) is based on an 85% reduction in Nordic energy-related CO_2 emissions by 2050 (from 1990 levels) at the lowest total cost. The CNS targets even greater emissions reductions within the Nordic region than the IEA's global 2DS, while applying the same models and assumptions.

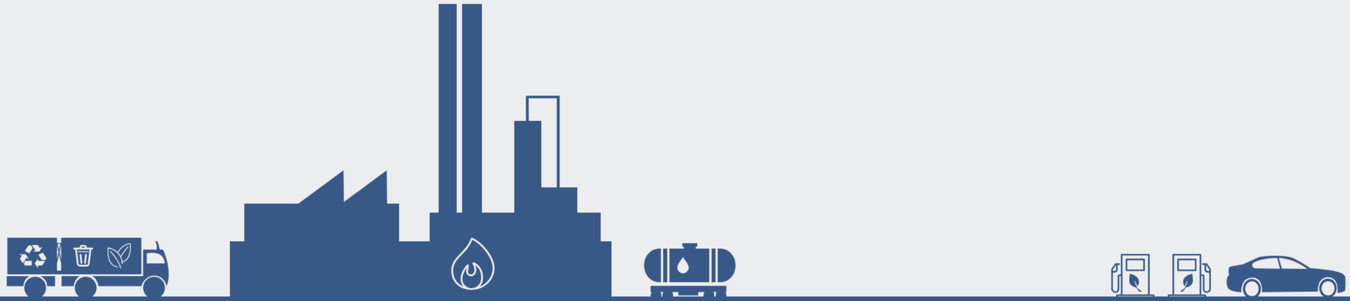
Fig 1.2: Nordic CO_2 emissions and economic growth by sector



Emissions decoupled from GDP

In the last ten years, CO_2 emissions have been further decoupled from Nordic GDP across all sectors, a process that will have to accelerate if the CNS is to be achieved.

Decarbonisation is taking place more quickly within power and heat generation and direct emissions from buildings than within transport and industry.



CNS establishes minimum requirements for mitigating CO_2 emissions

In October 2018, two years after the publication of the NETP, the **Intergovernmental Panel on Climate Change (IPCC) issued its Special Report on the impacts of global warming of 1.5°C** above pre-industrial levels. IPCC stresses that:

- The world **needs to limit climate change to 1.5°C** to reduce the likelihood of extreme weather events.
- **Emissions need to be curbed with far more urgency** than previously anticipated.

The analysis in NETP 2016 is based on a scenario where Nordic energy-related CO_2 emissions fall by 85% by 2050. The name – the Carbon Neutral Scenario (CNS) – reflects the wording used in official targets, although carbon neutrality requires offsets to be used for the remaining 15%. Thus, the CO_2 reduction pathway established in the NETP CNS should be viewed is a minimum requirement. To enable the world as a whole to limit global warming to 1.5°C, it is likely that additional abatement measures will be required.

Short-term policy recommendations

NETP 2016 outlines four key action areas for the Nordic countries:

1. Strengthening incentives for investment and innovation in technologies and services that increase the flexibility of the Nordic energy system.
2. Boosting Nordic and European cooperation on grid infrastructure and electricity markets.
3. Taking steps to ensure the long-term competitiveness of Nordic industry while reducing process-related emissions.
4. Acting quickly to accelerate transport decarbonisation using tried and tested policy tools.

Macro-level strategic actions

The Nordic Carbon Neutral Scenario (CNS) sets out three macro-level strategic actions that will be key to achieving the Nordic countries' climate targets by 2050.

1. Incentivising and planning for a Nordic electricity system that is significantly more distributed, interconnected and flexible than it is today.
2. Ramping up technology development to advance the decarbonisation of long-distance transport and the industrial sector.
3. Leveraging the momentum provided by cities to strengthen national decarbonisation and energy efficiency initiatives in transport and buildings.

"The aim of the Nordic countries is to be carbon neutral and to demonstrate leadership in the fight against global warming."

These were the words of the Nordic prime ministers in their declaration at a summit in Helsinki on 25 January 2019 as part of active Nordic climate cooperation under the auspices of the Nordic Council of Ministers.

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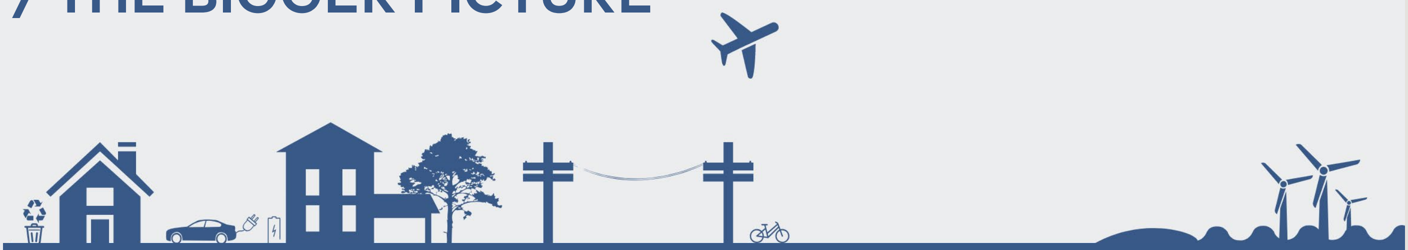
The Nordic countries must act as one

In October 2015, the Nordic Council of Ministers decided to carry out a strategic review of Nordic cooperation on energy and how this could be developed over the next 5-10 years. The remit was to present a number of concrete proposals that would further enhance cooperation in areas in which significant positive outcomes have been achieved over the past two decades.

The review found that competition from the larger global players in the area of green solutions is increasing rapidly. The Nordic countries must therefore act as one and avoid suboptimal national solutions. Among the 14 proposals formulated, the review recommended drawing up a vision for Nordic energy and energy research cooperation, creating a joint Nordic research and demonstration program and conducting Nordic peer reviews before deciding on and implementing national policies.

/ THE BIGGER PICTURE



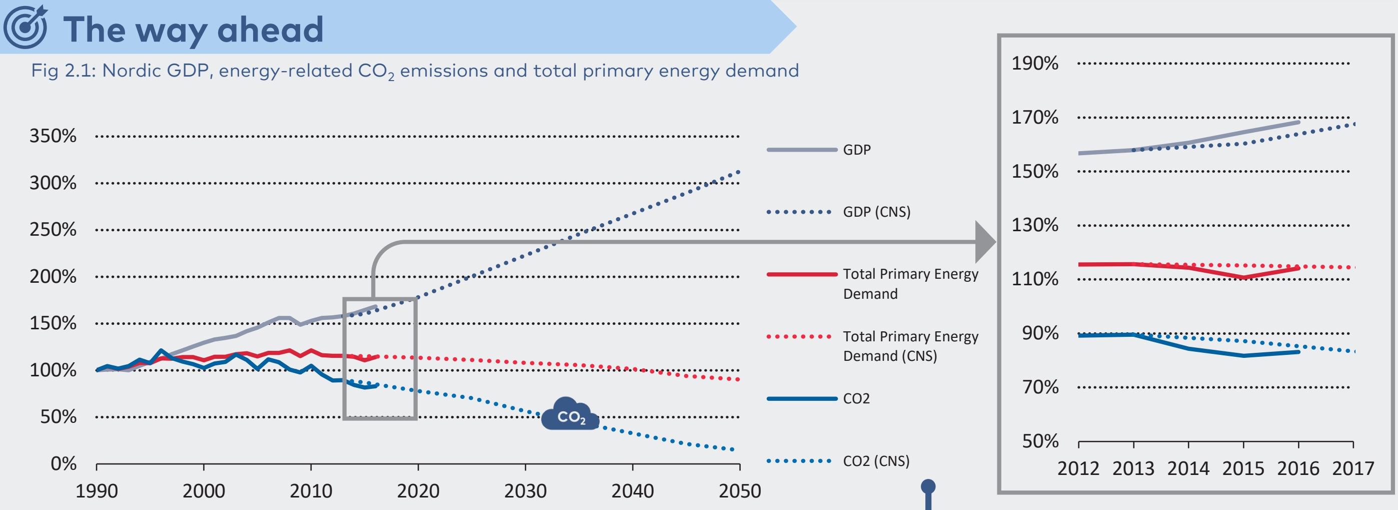
KEY MESSAGE: The Nordic countries have come far but need to go further

Compared with other parts of the world, the Nordic region is endowed with **vast renewable energy resources** – and the Nordic people have proved adept at utilising the opportunities these present.
Hydropower provides more than half of all electricity generated and is increasingly being supplemented by biomass and wind. Heat is primarily produced from electricity, district heating (which is to a large extent generated from renewable energy sources) and biomass.

The transport sector poses the greatest challenge when it comes to further decarbonisation of the Nordic energy system. Substantial achievements have been made in the deployment of electric vehicles in Norway and biofuels in Sweden and Finland. Nevertheless, the transport sector still accounted for some 45% of all energy-related CO_2 emissions in 2016. **Electrification and further deployment of variable renewables** such as wind and solar power are likely to become the key in the green transformation of the energy system.

The way ahead

Fig 2.1: Nordic GDP, energy-related CO_2 emissions and total primary energy demand



The above figure shows that the Nordic region has achieved a **steady decoupling of GDP from energy-related CO_2 emissions** and declining CO_2 intensity in energy supply in recent decades.

The Nordic region needs to continue to decouple energy-related CO_2 from GDP. Progress in industry, transport, and buildings represents the biggest challenge. Energy efficiency and decarbonisation of end-use sectors need to play a prominent role in this decoupling going forward.

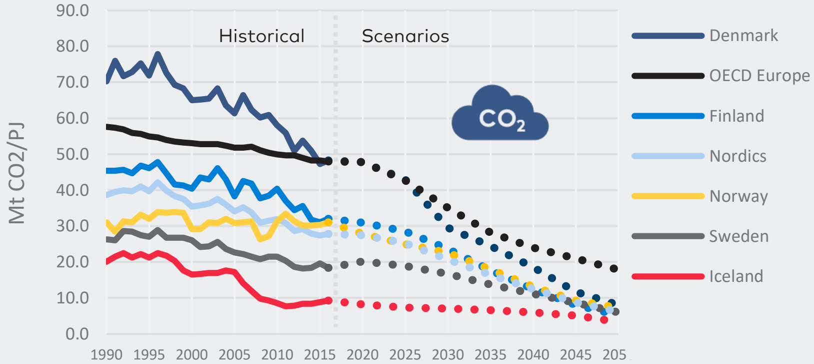
The **total primary energy demand** represents the total energy demand in the region and includes:

- consumption by the energy sector itself,
- distribution and transformation losses, and
- final energy consumption by end-users.

Note: Total primary energy demand = gross inland energy consumption

Nordic countries among the least CO_2 intensive

Fig 2.2: CO_2 intensity of total primary energy demand ($MtCO_2$/PJ)



The figure shows the CO_2 intensity of total primary energy demand in the Nordic countries (CNS) and the OECD Europe (2DS). CO_2 intensity in energy supply has been falling for decades. This trend must continue. Compared to the OECD average, the **Nordic countries are overall leading the way**, with Denmark as the last country to dip beneath the OECD Europe average in 2015.

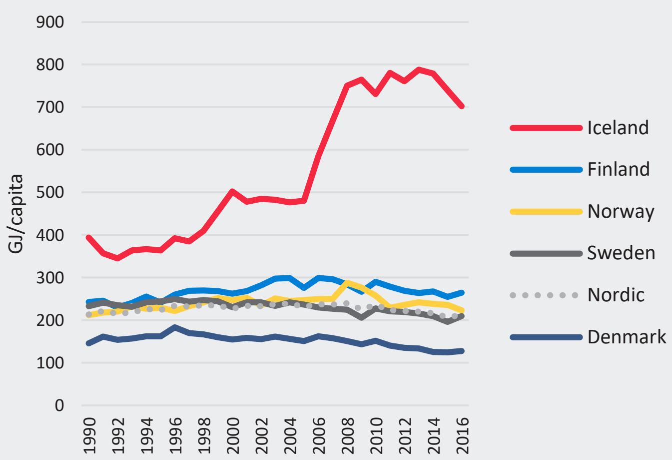
The figure is based on actual data until 2016. The subsequent years in the CNS are shown with dotted lines.

At the same time, limited **biomass resources will need to be re-directed** to the sectors where they provide the greatest value for the energy system. This means diverting biomass producing lukewarm water for heating to producing high quality biofuels for heavy transport, industries and the chemical sector.

Energy efficiency is a prerequisite for achieving decarbonisation, along with smarter alignment of supply and demand. Energy intensity has decreased significantly since 1990 – in part due to very deliberate efforts to achieve more with less energy, from, for example, industry and appliances. Taxation, voluntary agreements, minimum energy performance standards, labelling, and RD&D support are tried and tested tools, which will continue to be important moving forward.

It is anticipated that **cities will deliver** much-needed renewed momentum for the green transition.

Fig 2.3: Nordic total primary energy demand per capita (GJ/cap)



Stable energy demand

Total Nordic primary energy demand per capita has been stable in recent decades.

One exception is total Icelandic primary energy demand per capita, which is high relative to the other Nordic countries and has increased significantly. This is mainly due to the country's energy-intensive industries, such as aluminium smelting, which have moved to Iceland to benefit from low electricity prices. There are currently three such plants, where the effect of the start of operation of the second plant in 1998 and the third plant in 2008 can be clearly seen in the figure. A hydropower station was constructed to operate the third plant, enabling Iceland to retain first spot in terms of the renewable energy share in the Nordic region, despite its very energy-intensive industry.

Share of renewables has increased

All five Nordic countries have seen significant increases in the utilisation of renewable energy.

Compared to primary energy demand, the overall renewable share at Nordic level has risen from 29% in 2006 to 39% in 2016.

Increasing use of bioenergy is the main reason behind the upwards trend.

Fig 2.4: Share of RE in total primary energy demand

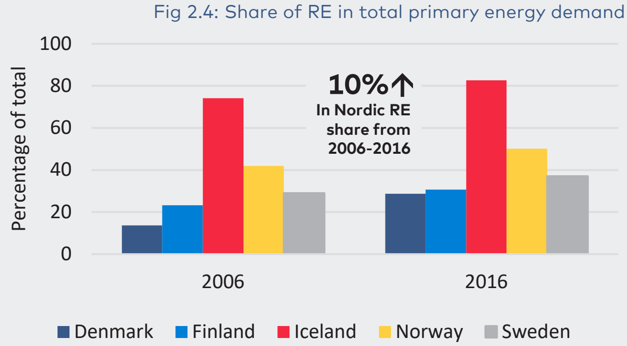
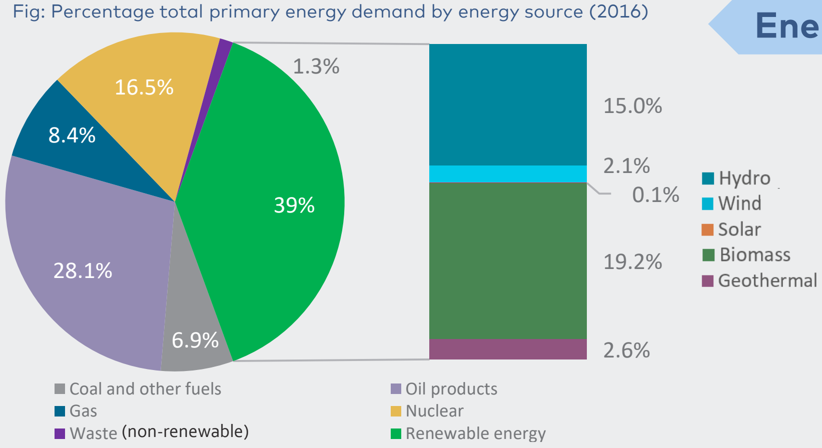


Fig: Percentage total primary energy demand by energy source (2016)



Energy demand by energy source

In 2016, fossil fuels still accounted for some 44% of total primary energy demand in the Nordic countries. Oil, which is primarily used in the transport sector, accounts for about two-thirds of total fossil fuel consumption. Natural gas is mainly used in industries and for heating.

Although the contribution from wind power has increased significantly in recent years, biomass and hydropower remain the most important sources of renewable energy by far.

/ TRANSFORMING THE POWER SECTOR

Today, Nordic electricity generation is already close to being decarbonised (87% carbon-free) and the Nord Pool area is well suited for integrating wind. However, transformation of the power sector **is contingent on continuously improved balancing** through a combination of flexible supply, demand response, storage and electricity trading.

The utilisation of abundant Nordic wind resources, together with more active use of existing dispatchable hydropower – and energy efficiency measures to control demand – offer the Nordic region an opportunity to play a stronger European role. The Nordic region can both export electricity and balance European variable renewables, generating major economic revenues and facilitating the transformation of the European energy system.

The way ahead

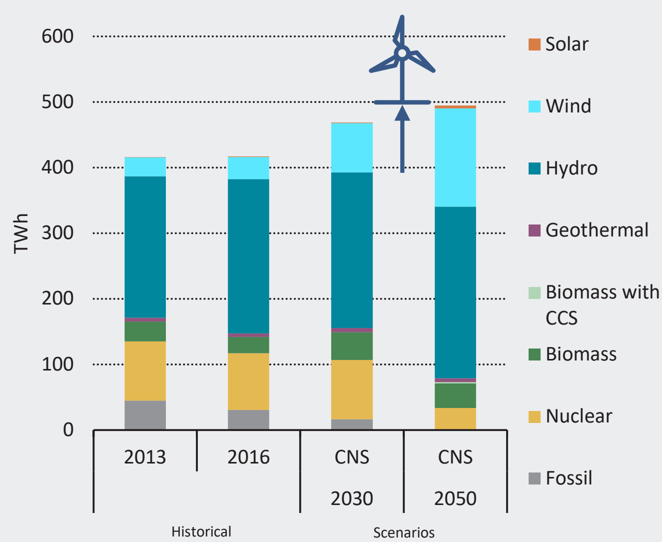
In the NETP 2016 CNS, the main transition from fossil fuels is driven by a **five-fold increase in wind generation** by 2050, mainly onshore, which also displaces nuclear power. Given the sharp drop in PV prices observed since 2016, it is likely that solar power could also provide a considerable and cost-effective contribution.

Nordic **hydropower** and **flexible operation of thermal generation** will be increasingly valuable for regulating the North European power system.

Electrification of the heating and transport sectors along with flexible demand from industry, represent key demand response measures in the CNS.

The major potential for wind power creates opportunities for the Nordic region to become **exporters of low-cost low-carbon electricity** to continental Europe.

Fig 3.1: Development of Nordic power generation. Statistics for 2013 and 2016 and CSN projections for 2030 and 2050



Progress indicators

Fig 3.2: Share of RE in electricity

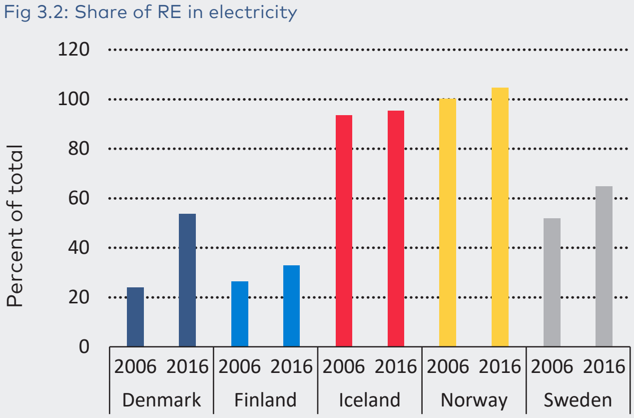
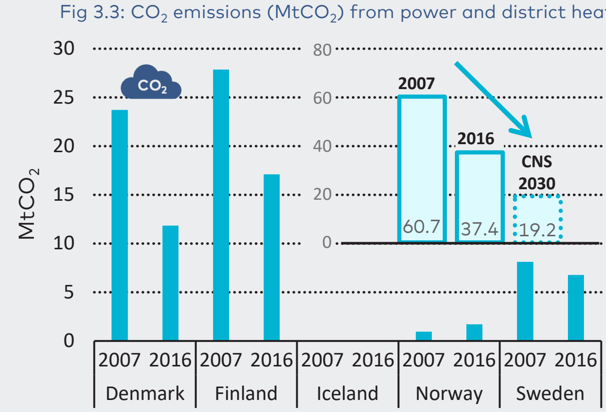


Fig 3.3: CO_2 emissions ($MtCO_2$) from power and district heat



The Nordic RE share of electricity consumption increased from 63% in 2005 to 71% in 2016.

CO_2 emissions from power and heat generation in the Nordic countries fell from 60.7 $MtCO_2$ in 2007 to 37.4 in 2016, in line with the CNS 2030 target of 19.2 $MtCO_2$.

Did you know that...

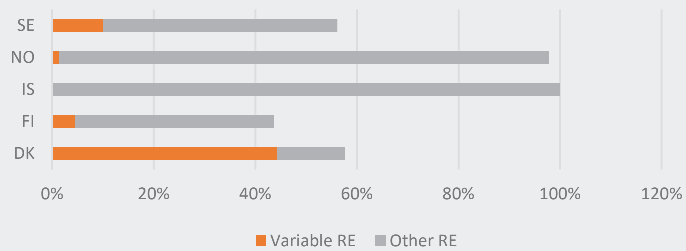
...The Finnish parliament has proposed banning the use of coal to produce energy from 1 May 2029. After that date, coal could only be used in an emergency situation.

Did you know that...

...Ørsted, the largest Danish power producer, has decided to phase out coal fired power production by 2023.

...Denmark has committed to phasing out the use of coal for electricity generation by 2030.

Fig 3.4: RE share of gross final energy consumption in 2016 i.e. excluding conversion losses in connection with activities such as the production of electricity and district heating



Renewable energy shares per country

Norway and Iceland have the highest shares of renewable power in their power systems. In some years, renewable energy generation has even exceeded demand in Norway, with subsequent exports resulting in RE shares above 100%.

Denmark displays the highest share of variable renewable electricity (VRE) within power consumption, but in terms of installed GW wind and solar capacity, Sweden has overtaken Denmark.

Onshore wind capacity 83% of VRE

The Nordic countries have seen a **massive expansion of VRE generation capacity** over the last ten years. The installed capacity of VRE generation has more than tripled from 4.8 GW in 2008 to 16.6 GW in 2017. In comparison, the CNS foresees a total need for approximately 30 GW wind and 1 GW solar power generation in the Nordic countries in 2030.

Solar PV is a recent arrival that now accounts for 7% of total installed variable renewable electricity capacity.

Iceland has very limited capacity of solar and wind power, whereas the country's installed hydropower capacity is close to 2 GW and geothermal power more than 700 MW.

Fig 3.5: Development in variable renewable energy capacity (GW)

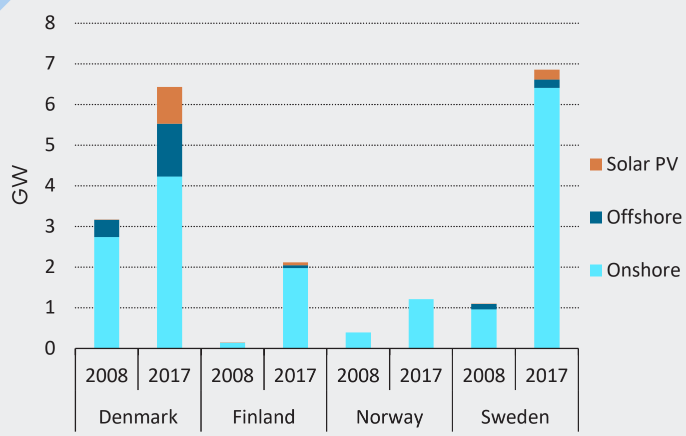
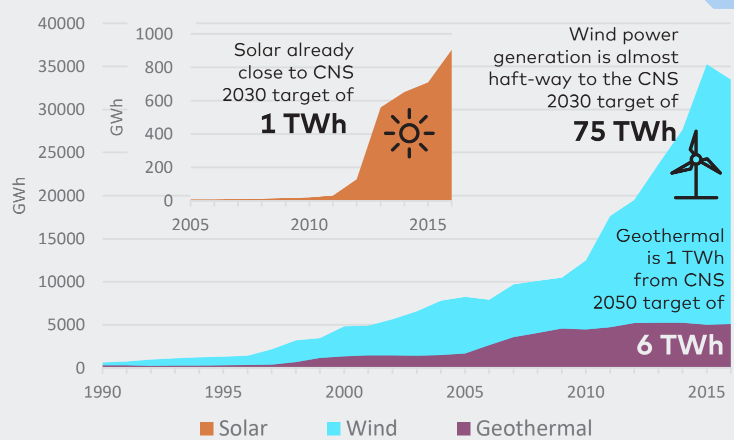


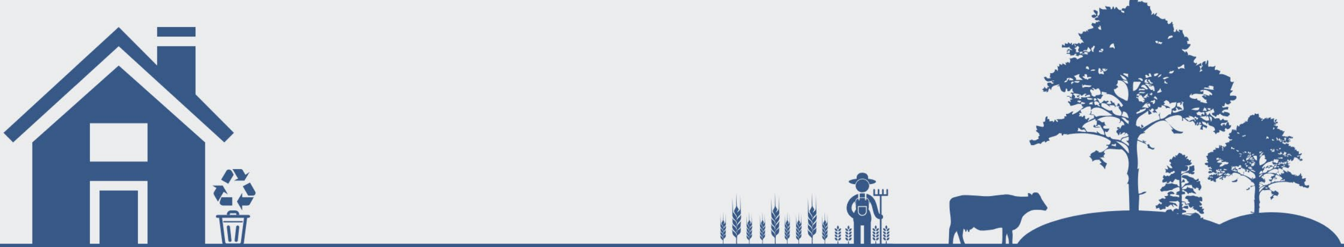
Fig 3.6: Nordic renewable electricity generation (excl. hydro) (GWh)



Variable RE increasing

Deployment of wind and solar power has nearly tripled since 2010. **Wind power** generation has been significantly increasing since the mid-90s, bringing total Nordic wind power generation to 33 TWh in 2016 – almost half-way to the CNS target for 2030 of 75 TWh. **Solar power** has seen a rapid expansion since 2010. The power generated from solar energy is already nearing the CNS 2030 target of 1 TWh. Electricity generation from **geothermal energy** has stabilised at just above 5 TWh, very close to the CNS 2050 target of 6 TWh. The use of **hydropower** for electricity generation (not shown in the figure) fluctuates from one year to the next depending on precipitation levels. On average, generation has been stable over the years with a slight increase in 2016 (235 TWh).

/ BOOSTING BIOENERGY



KEY MESSAGE: Intelligent use of bioenergy is a must

Bioenergy production is increasing and is expected to be the single largest energy carrier in 2050. The Nordics are experienced users of traditional bioenergy for energy production, but innovation within policy and technology will be required to satisfy demand – in particular, within the transport and industrial sectors.

Political synergies can deliver leverage that benefits the energy transition.

Nevertheless, RD&D must find **new solutions** and help avoid import dependency and price vulnerability. Clear long-term political ambitions and guidelines that establish the framework for the required developments will play a vital role in creating the environment needed for significant technological and market development. Robustness through **diversity of suppliers and technologies** will be pivotal to limiting potential negative impacts of bioenergy imports.

The way ahead

In the CNS, Nordic primary energy supply decreases by 25% in 2050 compared to 2013 (excluding the net electricity export). **Bioenergy surpasses oil** as the largest energy carrier with a total supply of over 1,600 PJ in 2050.

Biofuels for the transport sector is alone expected to reach about 470 PJ in 2050.

Fig 4.1: Nordic primary energy supply (PJ)

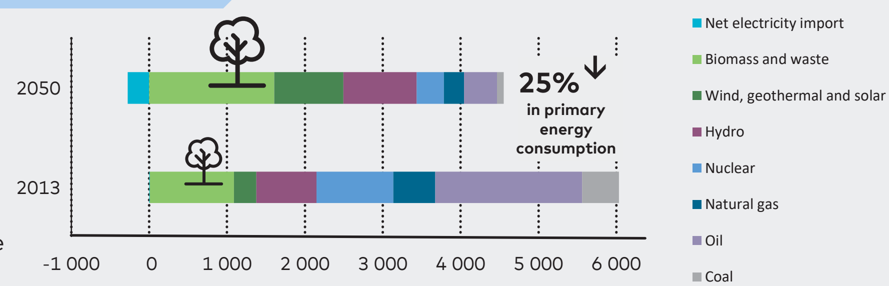
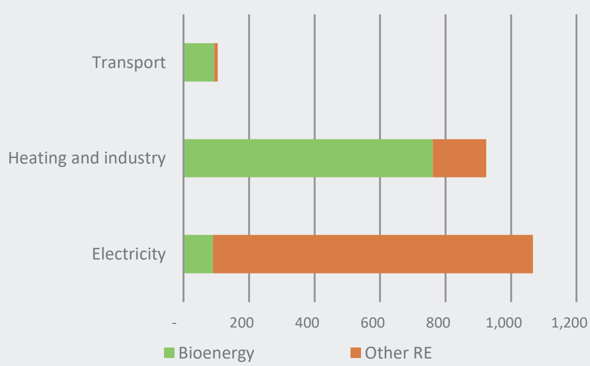


Fig 4.2: Gross RE consumption (PJ) across all sectors of the economy 2016



Progress indicators

Overall gross consumption of bioenergy has gradually increased in the Nordic countries, reaching more than 940 PJ in 2016.

The largest increase can be seen within transport. Here, gross bio energy consumption more than doubled in the period 2011–2016 alone to reach 90 PJ – particularly due to large demand in Sweden. Hydro and wind power are the dominating RE technologies for power generation with bioenergy only contributing 5%, a situation that has changed only little since 2011. In heating and industry, the opposite is true – here bioenergy accounts for more than 80% of the RE share.

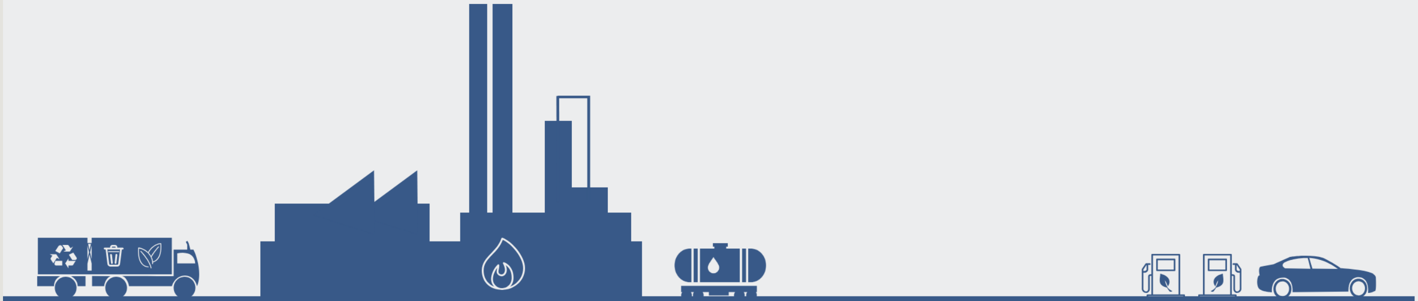
Landfill gas in Iceland

In Álfsnes, Iceland, **landfill gas is a significant contributor to biofuel production**. The site produces methane from organic waste and production exceeds 1,500,000 Nm^3 per year. This energy is used to power 20 waste trucks, two city buses and multiple light duty vehicles and passenger vehicles.

Left unexploited, landfills emit a GHG that has approximately 21 times greater impact than carbon dioxide. Exploiting the landfill gas at Álfsnes for vehicle fuel therefore benefits the climate both directly and indirectly. The methane produced at Álfsnes is high-grade, 125-130 octane biomethane fuel with up to 98% purity.

A biogas plant is also currently being built in the Reykjavík area to exploit local organic waste. The plant is scheduled to start operation in February 2020.

Photo credit: Visme_**Dan** Gold / Unsplash



Within centralised heat production efficiency, **improvements are key**, while within transport, the challenge is (a) to produce biofuels at prices that can compete with imported biofuels and (b) to ensure **robustness through diversity of supply**.

Within industry, the focus of development is on new biofuels and innovative modification of production technologies and processes suited for bioenergy.

Sustainable and politically acceptable **sourcing** of bioenergy will be paramount. About 16% of total Nordic biomass demand across all sectors will need to be met by imports in 2050, according to CNS.

The net import share of domestic bioenergy use in 2013 (including waste but excluding peat), was 9% for Sweden and 32% for Denmark, while Norway had a net export of 5% and Iceland and Finland had a neutral balance.

Picture: 6 MW modular WoodRoll plant at Höganäs AB

Woodroll technology for steel industry

High temperatures and fuels that do not contaminate the product are required for iron and steel production. In June 2018, the **world's first biogas and biocoke plant** for the iron and steel industry was commissioned with a syngas capacity of 6 MW. Höganäs AB, a metal powder manufacturer, and Cortus Energy AB, a biomass gasification technology developer, test the WoodRoll technology under real-life conditions and adjust the process to the demands of the metal powder production.

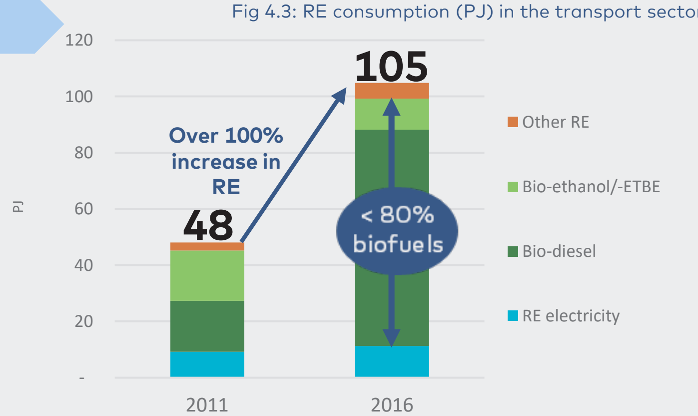
"Biocoke" is produced as a by-product that could potentially replace some of the fossil coke currently used as a reduction agent in the production of sponge iron powder.

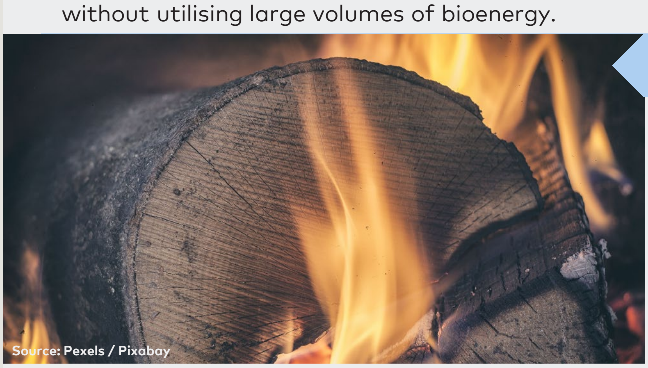
Renewables in the transport sector

Nordic consumption of RE within the transport sector more than doubled in the period 2011–2016 reaching more than 105 PJ in 2016. **Bio-diesel consumption has increased fourfold** and was together with bio-ethanol responsible for more than 80% of total consumption in 2016.

Decarbonising the transport sector, however, remains a major challenge, especially within heavy and long-distance transport. Electrification holds big potentials within short-distance transport, whereas it will be challenging to decarbonise long-distance modes and heavy transport without utilising large volumes of bioenergy.

Fig 4.3: RE consumption (PJ) in the transport sector




Source: Pexels / Pixabay

Exodraft's chimney fan ensures an instant and consistent chimney draught while reducing particle emissions in living rooms by 80% and by 20% outside near the chimney.

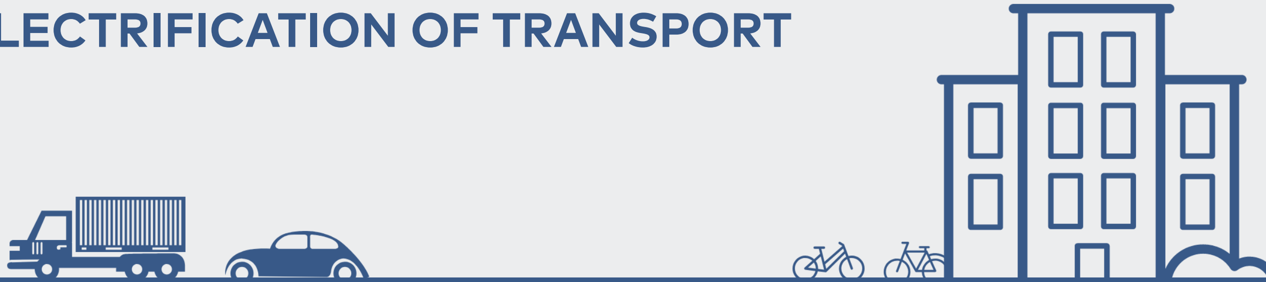
Synergising political agendas

Biomass and waste resources are limited. Smarter and more efficient use of biomass and waste will therefore be critical to achieving the Nordic region's green development targets.

Cascading – whereby material use, re-use, and recycling of materials such as wood are prioritised ahead of burning the wood for energy – **can help maximise the effectiveness of resource exploitation**.

A holistic perspective taking account of political non-energy agendas can be harnessed as drivers to develop or improve the economic viability of different solutions. Initiatives to reduce air pollution and improve the indoor climate in residential buildings could also help improve the energy efficiency of stoves.

/ ELECTRIFICATION OF TRANSPORT



KEY MESSAGE: We are at the beginning of an electrification journey

Electrification is likely to become **the single-most important measure** in the long-term transition of the transport sector to renewable energy. **Electric vehicles (EV) are expected to dominate the light-duty vehicle stock** in the decades to come and in recent years we have seen indications that electric vehicles may also play a significant role within certain types of heavy transport. Many Nordic cities are already purchasing electric buses, and several truck manufacturers are in the **early stages of marketing electric trucks**. Norway is currently leading the market for electric vehicles. In 2018, electric vehicles and plug-in electric vehicles (PHEV) accounted for approx. 48% of total sales of passenger vehicles, and in the first quarter of 2019, this figure rose to a remarkable 60%. At a Nordic level, EV sales are significantly lower, 14% in 2018, and the share of the total stock is even lower, just 2.6% in 2018.

The way ahead

In the NETP 2016 CNS alternative, powertrains such as hybrids (HEV), plug-in hybrids (PHEV), and battery-electrics (BEV) start to account for substantial and increasing stock shares from around 2025.

Virtually full phasing-out of conventional ICE vehicles by 2050 will be necessary to achieve the decarbonisation targets. The share of new registrations of EVs for passenger light-duty vehicles reaches nearly 70% in 2050. Consequently, in the CNS by the middle of the century BEVs account for the majority (60%) of vehicles operating across the Nordic countries.

Recent sales statistics from Norway suggest that the Nordic countries may be capable of an even faster and more widespread deployment of EVs.

Fig 5.1: Share of electric vehicles in light-duty vehicle stock (CNS) and "zoom in" on the actual Nordic share from 2010-2018 in relation to CNS targets

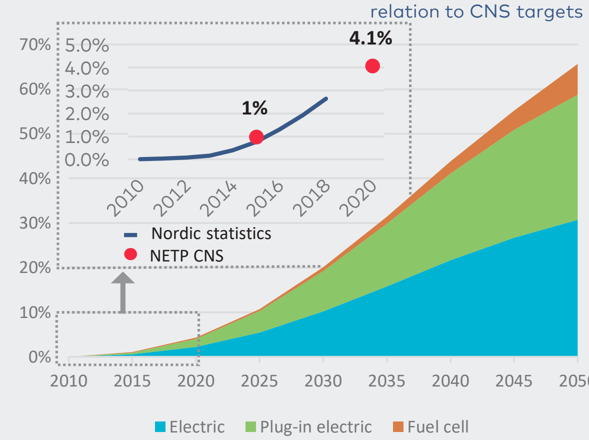
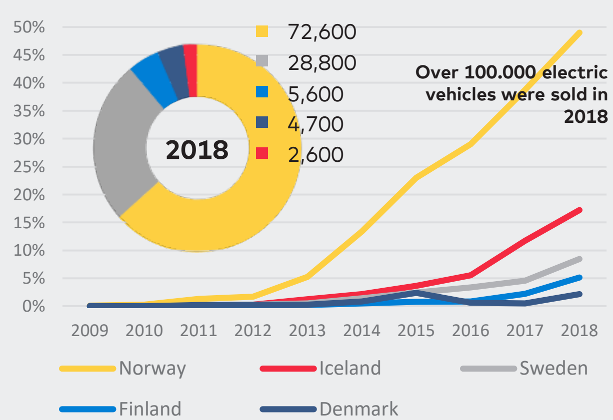


Fig 5.2: Battery and plug-in hybrid electric vehicles share of new passenger vehicle sales. Piechart: Number of new passenger vehicle sales (BEV and PHEV) in 2018



Progress indicators

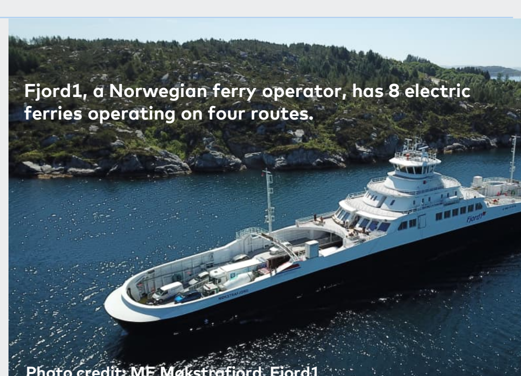
New passenger EV registrations are increasing each year in the Nordic region – and accounted for 14% of new passenger sales in 2018. Plug-in hybrids generated about half of these sales.

Norway has the highest share of EVs in the world. In the first quarter of 2019, battery electric vehicles and plug-in hybrids accounted for 60% of total sales of passenger cars in the country. Only 20% of these vehicles were plug-in hybrids. Exemptions from Norway's high registration taxes, VAT and roll tolls – in addition to non-financial measures such as giving access to bus lanes – have been a key driver of high EV sales shares.

With a rate of 17%, Iceland demonstrated the second highest share of EV sale in the world in 2018.

Leading by example – Electric ferries

The Nordic countries are also starting to tackle carbon emissions from sea-faring vessels. In Norway, for example, **16 electric car ferries** are in operation, and a further 39 are expected to enter operation by the end of 2020. This includes Ampere, the first all-electric car ferry launched in 2014. Compared to a traditional diesel-powered ferry, costs have been reduced by 60% and emissions by 95%. Scandlines' ferry Princess Benedicte which sails the Puttgarden-Rødby route was refitted in 2013 to become the **world's first hybrid** in its class with a 1.6 MWh electric storage system. All-electric and hybrid solutions for fishing fleets and other industrial and commercial vessels are also being launched.



Fjord1, a Norwegian ferry operator, has 8 electric ferries operating on four routes.

Photo credit: MF Møkstrafjord, Fjord1

Did you know that...

...Sweden has set a goal of reducing emissions from domestic transport, except for domestic flights, by at least 70% compared to 2010 by no later than 2030.

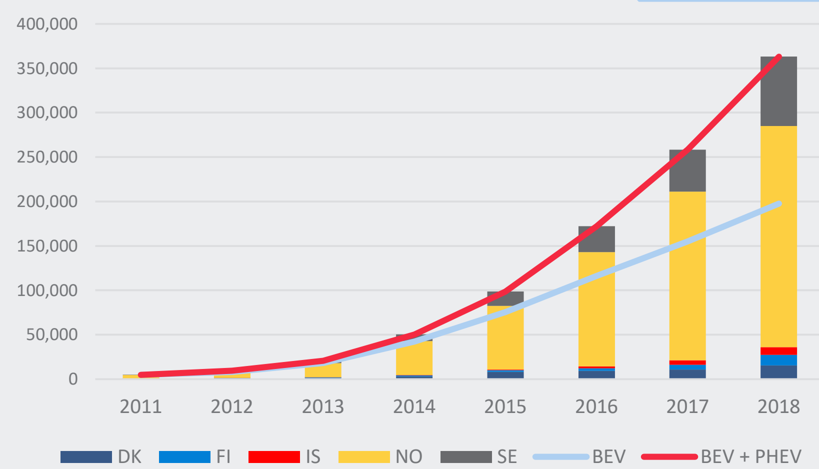
...Some Norwegian counties require bidders to deliver lower or no-emission vessels to tender to operate ferry routes.

Did you know that...

...Norway will phase out the sale of all fossil fuel-based cars by 2025.

...Norway has more than 550 fast public charging stations per 100 km highway.

Fig 5.3: Stock of Nordic passenger electric vehicles



Electrified stock of passenger vehicles

The fleet of passenger EVs is gradually growing in all the Nordic countries.

Norway leads the way with almost 250,000 passenger EVs in 2018, followed by Sweden (78,200), Denmark (15,400), Finland (11,700), and Iceland (8,700). Battery-driven electric vehicles (BEV) make up 54% of the total EV stock with plug-in hybrids (PHEV) accounting for the remainder.

The total increase in the Nordic stock of passenger EVs from 2017 to 2018 was more than 40% and exceeded 1 per 100 capita. Norway leads with 6 passenger EVs per 100 capita.

Nordic cities opting for electric buses

Zero direct CO_2 emissions, cleaner air, and less noise – just three reasons why Nordic cities are increasingly choosing electric buses over their diesel counterparts. Just a few years ago electric buses were still experimental technology, but today they are a **commercial option that is gaining an increasing market share.**

In Reykjavik, there are currently 14 electric buses in operation. This represents an impressive 10% of the total fleet. In Stockholm, 100% of today's bus fleet runs on either biodiesel, biogas or ethanol. Electric buses are being tested on selected routes.

Other cities are following suit:

- **Copenhagen** – 41 electric buses will be in operation by the end of 2019. The last diesel-powered bus in the city is due to be replaced by an electric bus no later than 2025.
- **Helsinki** – 30 electric buses will enter service during 2019.
- **Oslo** – 110 electric buses will be added to the public transportation fleet in 2019.
- **Gothenburg** – 45 electric buses will be deployed by 2020.

Photo credit: eRoadArlanda

Charging as you go

In April 2018, the **world's first electrified road** for recharging car and truck batteries opened in Sweden. About 2 km of electric rail has been embedded in a public road near Stockholm.

In 2016, 2 km of Swedish motorway was equipped with similar technology, in this case overhead power lines for lorries.

/ ELECTRIFICATION OF HEAT SUPPLY

KEY MESSAGE: Biomass remains important despite electrification

In the Nordic climate, heating is obviously **an important energy end-use**. Electric heating, biomass, and district heating (to a large extent produced from biomass) provide the bulk of heat supplied in the Nordic region today.

In the future, the heating sector will need to adapt to the requirements of the rest of the energy system. This will involve **improving the energy efficiency** of heat production, for example, by replacing direct electric heating with heat pumps and **using surplus heating from industry** and other large energy consumers to generate district heating. Since biomass is expected to become a scarce resource in the future – with a higher value in other sectors – **electric heat pumps should take market shares from biomass**, both for individual heating and in the district heating sector.

The way ahead

Electricity consumption for heating is expected to grow and account for almost half of the heat in district heating networks in 2050, through utility-scale heat pumps and electric boilers – both of which provide important flexibility for the integration of variable renewables.

Heat pumps will replace the vast majority of oil burners, gas boilers, and direct electric resistance heating systems used to heat private homes.

Fig 6.1: Nordic district heat generation (TWh) in the CNS

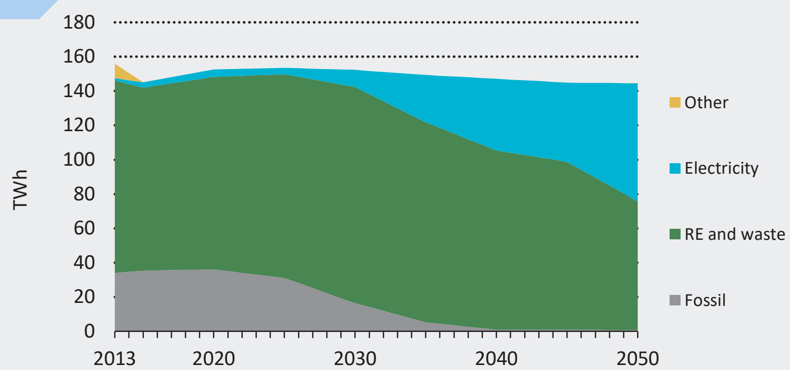
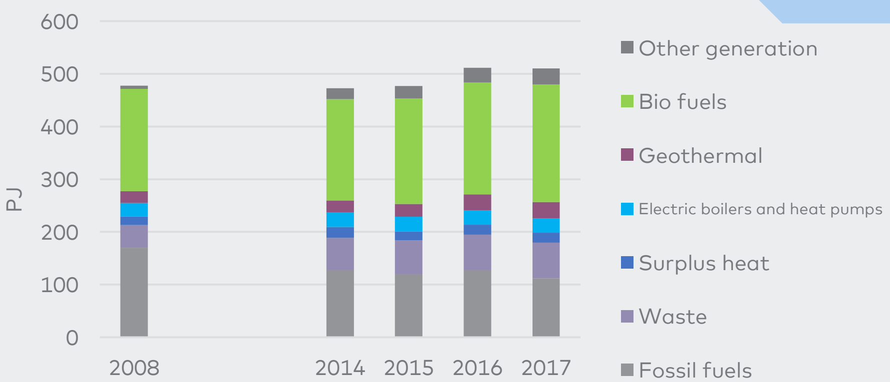


Fig 6.2: Nordic district heat generation (PJ) by fuel



Progress indicators

During the last ten years, district heating generated from fossil fuels has been reduced by about one-third, despite an overall increase in demand for district heating of around 7%. **Fossil fuels have mainly been replaced by biofuels and waste fuels** (which also include a fossil portion). Electric boilers and heat pumps still play a small role in district heating, accounting for about 7% of total supplies in 2017.

The world's largest seawater heat pump

Several large-scale heat pumps were installed in Swedish district heating systems during the 1980s, utilising long-standing national electricity surpluses from new nuclear power. Stockholm is home to the **largest seawater heat pump facility in the world**, with a capacity of 180 MW. However, since 2004, heat production from heat pumps in Sweden has almost halved and today heat pumps account for 7% of total district heating generation. The photo to the right shows the building containing six heat pump units at the Värtan Ropsten plants in Stockholm. Two seawater intake pipes are connected to each unit.

In Denmark, 33 heat pump projects in district heating systems have been granted financial support from the Danish Energy Agency in the period 2017–2019 – jointly more than 54 MW capacity. In addition, large cities such as Aarhus and Aalborg are considering investing in geothermal heat. In Iceland, a 10.4 MW heat pump using seawater was installed in June 2019 on the island of Vestmannaeyjar.

Photo credit: © Friotherm

Fortunately, there are **major opportunities for better system integration** between electricity and heating systems. Electricity for heat generation provides a flexible source of supply, which is valuable for balancing fluctuating renewable energy sources in the power system – while low-cost heat storage offers a cost-efficient means of indirect electricity storage.

Did you know that...

...as the first country in the world, the Norwegian government has plans of banning the use of fossil-based oil to heat buildings from 2020 onwards.

Stable sales of heat pumps

Fig 6.3: Number of heat pumps sold

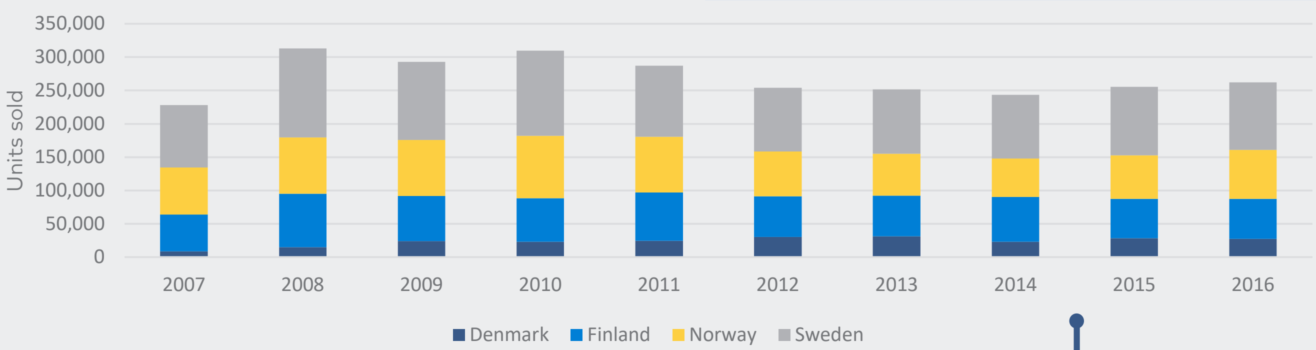
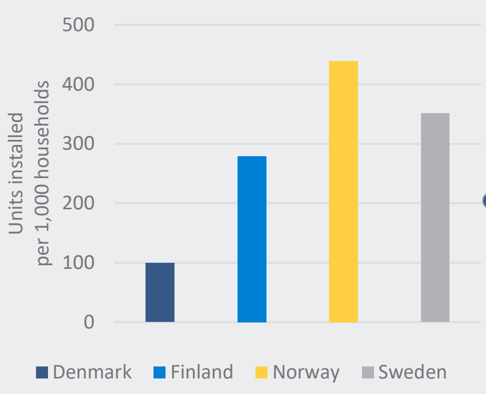


Fig 6.4: Number of heat pumps installed per 1,000 households in 2016



While the sale of heat pumps has been relatively stable in most Nordic countries during the last seven years, the amount of square metres heated by heat pumps has been gradually increasing. This reflects the fact that the installed **heat pumps have largely replaced other heat sources** such as oil burners, which have significantly reduced in number, and replaced direct electric heating.

Denmark has the lowest share of heat pumps of all the Nordic countries. However, sales have increased in the recent years and heat pumps are expected to play a key role in the future Danish heat supply, replacing boilers using oil, biomass, and natural gas.

Note: The statistics cover all types of heat pumps, i.e. air-air, air-water and ground-water. (No statistical data regarding heat pumps is available for Iceland).

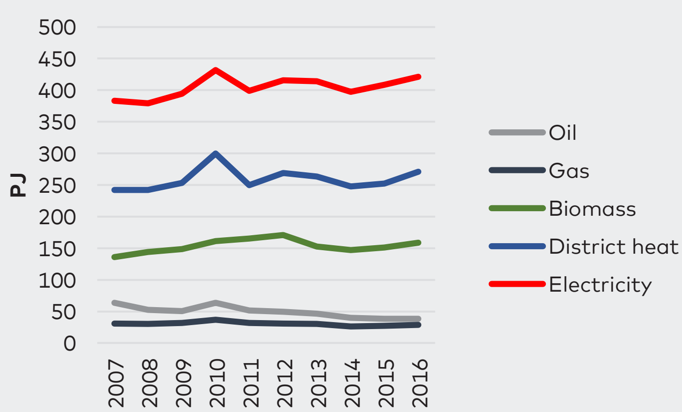
Replacing oil burners

Overall energy consumption for the residential sector increased by about 7% between 2007 and 2016. **Electricity is the most important source of energy** – and even though heat pumps are gradually replacing direct electric heating, electricity demand has been increasing over the last 10 years. On the positive side, oil demand has fallen 40% over 10 years and gas demand 5%.

The peak in demand in 2010 was due to a particularly cold winter in the Nordic countries.

Note: The use of coal, peat and geothermal heat (less than 2 PJ) is not depicted on the graph.

Fig 6.5: Final energy consumption (PJ) in the Nordic residential sector



/ DECARBONISATION OF INDUSTRY

KEY MESSAGE: Decarbonisation of industry requires technological innovation

The Nordic energy-intensive sector is a mature industry and is **already relatively energy- and material-efficient**. Further incremental energy efficiency measures may be more challenging and will require technological innovation. Technological developments for replacing fossil fuels, especially in steel manufacturing and chemical industries will be needed to promote further decarbonisation.

In the CNS, the total final Nordic **industrial energy consumption in 2050 is reduced by 9% and the CO_2 intensity by 60%,** both compared to 2013 levels. This will require 1) further fuel and feedstock switching to low-carbon sources, 2) maximisation of material efficiency techniques, 3) more rapid commercial-scale demonstration, and 4) wider deployment of innovative sustainable processes.

Furthermore, carbon capture and storage plays a major role from 2025.

The way ahead

In the CNS, assumes four key levers to a green transformation of the industrial sector:

1. Energy efficiency
2. Electrification
3. Bioenergy
4. Carbon capture and storage

Industry has the slowest rate of decarbonisation due to process-related emissions and competitiveness issues for globally traded commodities; industry accounts for almost half of remaining emissions in 2050 in the CNS.

Fig 7.1: Industrial energy use (PJ) and aggregated direct CO_2 intensity (tCO_2/TJ)

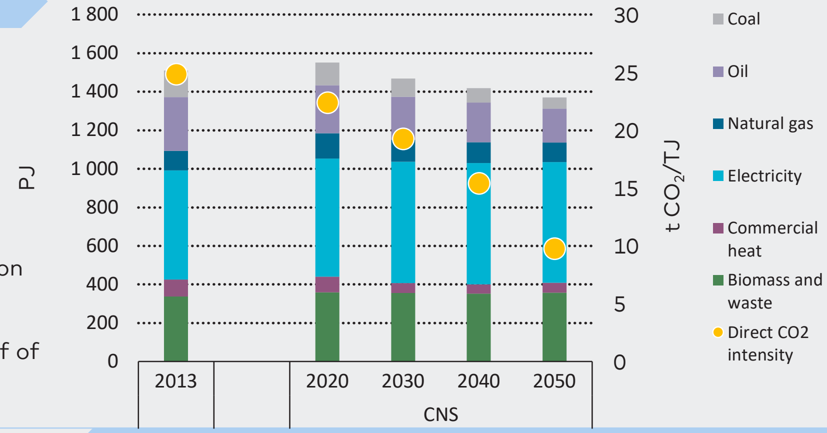
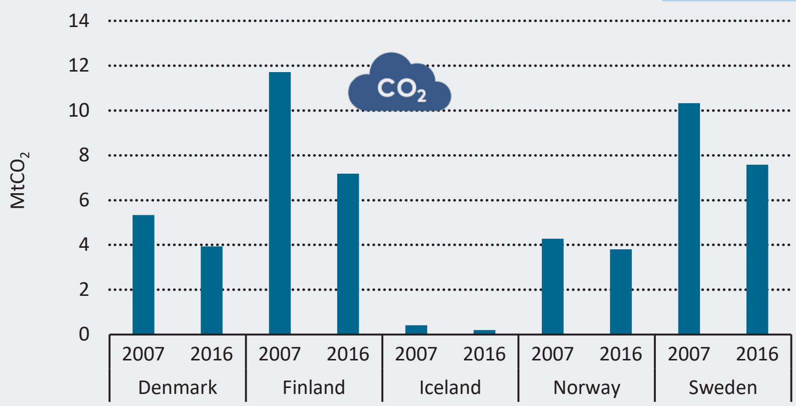


Fig 7.2: CO_2 emissions ($MtCO_2$) in the industrial sector by country



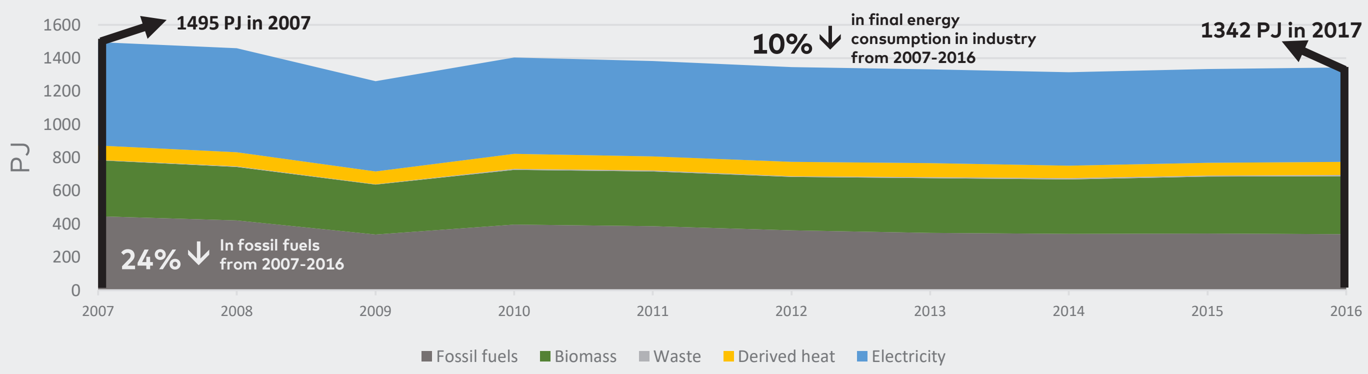
Progress indicators

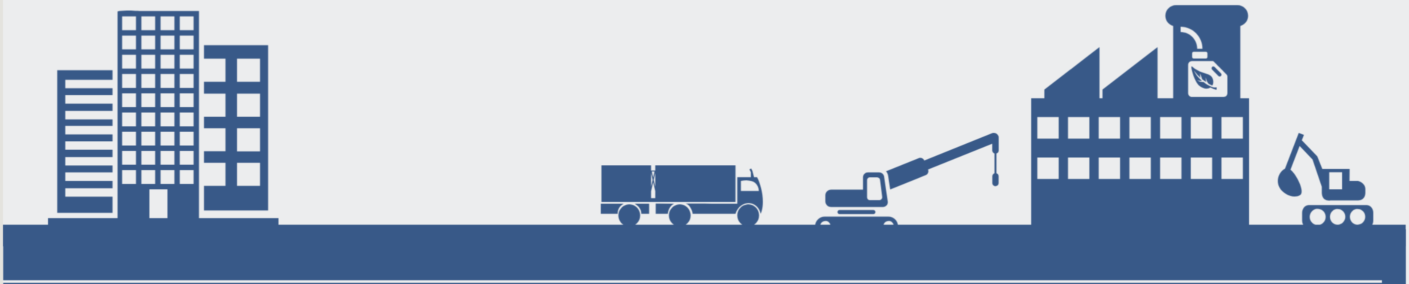
The last 10 years have seen industrial demand for energy decrease by about 10%. Demand took a dip after the financial crisis, since when it has remained more or less stable. CO_2 emissions have decreased by around 25% from 2007 to 2016, in particular due to a 33% reduction in oil consumption, while the use of natural gas has only decreased by 13%.

Electrification is already high, especially in Norway and Iceland, and is higher than the average in OECD countries.

Biomass also plays a key role in Nordic industrial energy supply, particularly in Sweden and Finland.

Fig 7.3: Final energy consumption (PJ) in industry



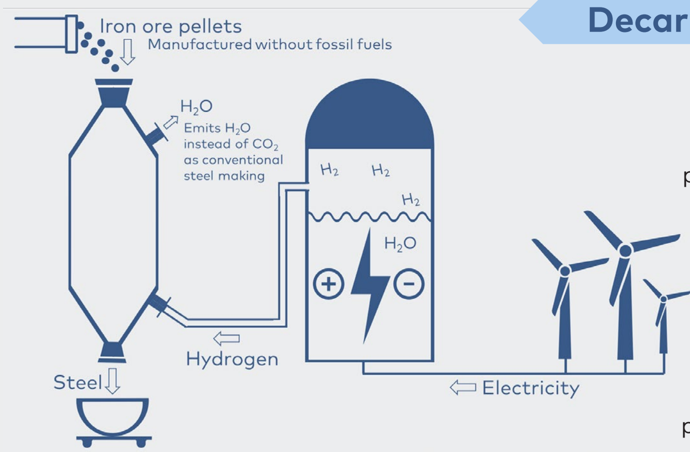


The Nordic energy-intensive industry is relatively energy- and material-efficient, which has been key to the sector's competitiveness. Maintaining Nordic industrial capacity, at the same time as decarbonising the industry sector, represents a major technological and policy challenge.

Circular economy initiatives and use of residual heat in industrial parks and other resource efficiency measures are being developed in several industrial parks in the Nordic area.

Residual heat from industries is currently a relatively unutilised resource that can be exploited for e.g. district heating and has the potential to reduce emissions across sectors.

Decarbonising steel industry an opportunity



The iron- and steel-making industry is currently the biggest user of coal in the Nordic industrial sector. In the CNS, the industrial sector is expected to contribute 39% of the total projected emissions reductions. Major technological advances are needed to decarbonise this sector.

In 2016, SSAB, LKAB and Vattenfall joined forces to create HYBRIT – an initiative to replace coking coal, which is traditionally needed for ore-based steel making, with hydrogen. The result will be the world's first fossil-free steel-making technology, with virtually no carbon footprint. The production of CO_2 could fall up to 25 kgCO_2/ton steel produced. Full-scale demonstration of a production facility by LKAB and SSAB is expected by 2035.

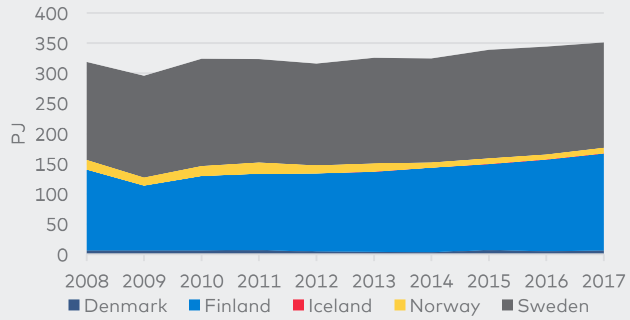
Slow large-scale CCS technology deployment

In the CNS, **carbon capture storage (CCS)** is expected to contribute to decarbonisation of industrial sectors where fossil fuel reduction is proving particularly challenging – starting from about 2025.

At present, the deployment of large-scale CCS solutions is progressing slowly. Norway has test sites for CCS and a governmental strategy that aims to develop CCS technologies. The Norwegian continental shelf is suited for CO_2 storage and is already used to store CO_2 from the Gudrun, Sleipner, and Snøhvit gas fields.

Photo credit: Michal Jarmoluk/ Pixabay

Fig 7.4: Bioenergy use (PJ) for energy in industry



Biofuel use on the increase

The pulp and paper industry is a major energy consumer, in particular in Sweden and Finland. This industry is already less carbon-intensive than similar industries in other OECD countries due to the extensive use of biofuels and electricity as well as a management focus on energy efficiency improvements.

Biofuels are increasingly being used in other industrial sub-sectors as well. The figure to the left indicates a slight growth of bioenergy use for energy production in industry. Here, the only question that remains is how much forest-based biomass use can increase without adversely impacting carbon sinks.

/ ENERGY EFFICIENT AND SMART BUILDINGS

KEY MESSAGE: We have most of the tools but there is still a long way to go

The Nordic countries have progressively reduced the role of fossil fuels in their respective buildings sectors, while the overall energy efficiency of buildings has improved marginally over the last 25 years. With Nordic **urban areas expected to grow** at twice the rate of previous decades, an opportunity exists to transition to efficient low-carbon systems. **Building codes** continue to be an important tool for the green transition. However, the low turnover of the building stock means that emphasis should also be given to retrofitting older buildings. Fossil fuels only play a marginal role in today's Nordic heat supply and in the CNS, the intensity falls to zero in 2045, as both the electricity and heat supply become carbon-free. Yet efficiency gains **may provide multiple benefits for the green transition and hold significant economic potential**. Improving building efficiency can unlock biomass to substitute fossil fuels in transport, avoid grid infrastructure investments, facilitate electricity exports, and enable deployment of new technologies such as low-temperature district heating/cooling.

The way ahead

Buildings account for 1/3 of final energy demand in the Nordic countries, with **space heating being the largest end-use** (nearly 60% of total building final energy consumption). The average energy intensity is envisioned to drop from 213 kWh today to 126 kWh/m² in 2050.

In the CNS, building sector energy consumption decreases by 27% in 2050 compared to 2013, with space heating being the main contributor through a 45% reduction. Lighting consumption is forecast to halve. In the residential sector, **energy efficiency** is the main contributor to CO_2 emissions reductions. The CNS requires residential energy intensity to fall to 89 kWh/m² by 2050.

At present, long payback periods under low energy prices and split incentives in rental situations are hampering efforts to accelerate energy efficiency investments.

Electricity, alongside district heating and cooling, will dominate the future in heat supply of both residential and services buildings.

Fig 8.1: Final energy consumption (PJ)

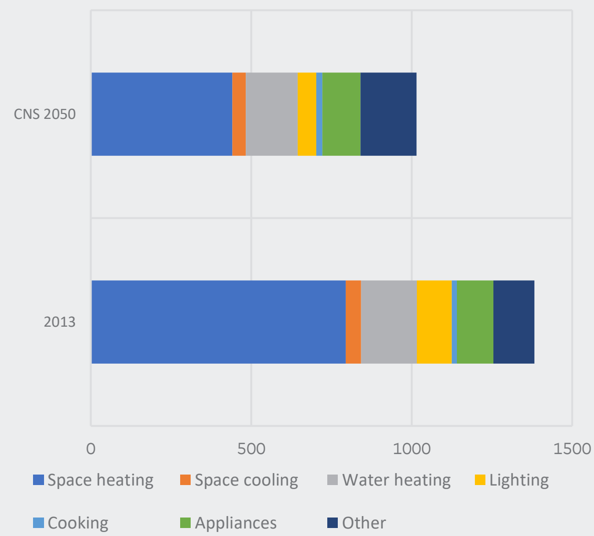
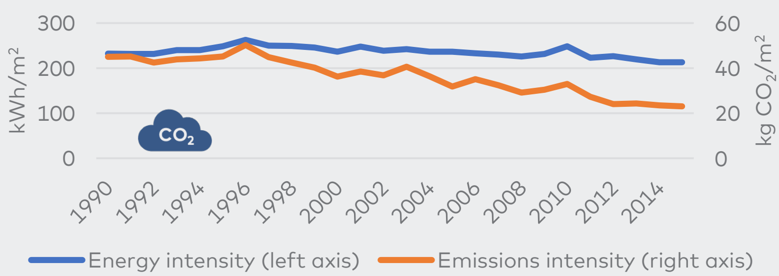


Fig 8.2: Energy intensity (kWh/m²) and CO_2 emissions intensity ($kgCO_2/m^2$) in the buildings sector



Progress indicators

Energy intensity reached 213 kWh/m² in 2016 and carbon emissions 23 $kgCO_2/m^2$.

Energy intensity and carbon intensity in the buildings sector is declining – the latter more than the former. This indicates that decarbonisation of the production of heating, cooling and electricity is progressing more rapidly than the energy efficiency improvements.

Cities are taking action

Cities are increasingly taking action to limit the climate implications of urban planning choices for the benefit of their citizens and local economy.

In 2008, the City of Porvoo, Finland, launched an initiative to improve energy efficiency in the built environment and in people's everyday lives – the Skaftskärr urban development project. This project had three core objectives: 1) To afford greater prominence to energy efficiency in the city and energy planning processes; 2) To create a Living Lab exploiting real-time information on consumption to encourage people to think about energy efficiency in their homes; and 3) To develop business models for public energy companies that support the low energy and passive buildings of the future.

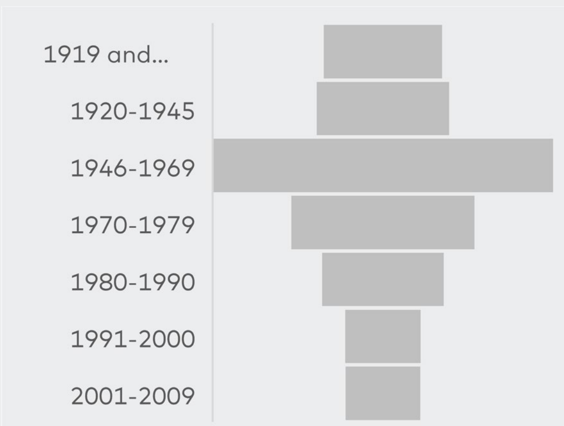
The roll-out of **smart meters** offers new opportunities for load management and modern, differentiated customer tariff structures.

Mechanical ventilation is widely used in buildings, while cooling is the "new kid on the block" with regard to residential buildings. Care should be taken to limit the need for cooling and to provide **efficient cooling solutions** on both the demand and supply side.

Good design combined with control systems can help ensure energy efficiency as well as adequate temperature control and air quality.

Achieving an efficient, low-carbon buildings sector by 2050 is a formidable challenge. While the technical solutions already exist, the speed of change lags behind. One major question is how to motivate building owners to embrace deep renovation?

Fig 8.3: Nordic residential building stock 2009 (Iceland not included)



Building codes stimulating innovation

The majority of residential buildings date from before the oil crisis in the 1970s. Refurbishment of existing dwellings therefore offers significant opportunities for efficiency improvements. Building codes are key to progress in this area. However, ever-stricter building codes might demand new solutions.

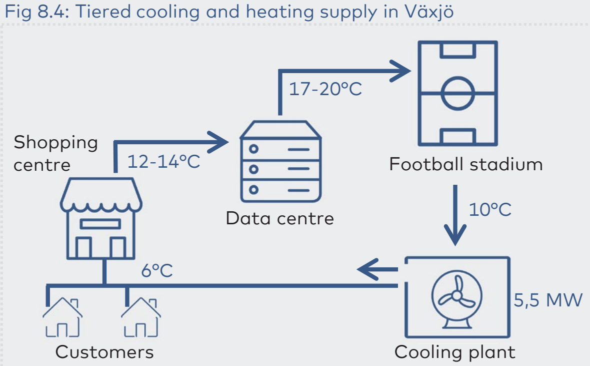
One approach to stimulating new solutions is **technology procurement**. A study by BeSmå, a Swedish innovation cluster and purchasing group for improved energy performance in both existing and new single-family houses, identified a need for a compact, combined system for heating and ventilation using exhaust and supply air and heat recovery for low-energy single-family houses in the Nordic climate in order to meet the new energy requirements. Through technology procurement, co-financed by the Swedish Energy Agency, a market launch of an efficient and cost-effective product is now imminent.

Smart meter opportunities

Finland and Sweden have long been front runners in the roll-out of smart meters in Europe. Norway and Denmark expect to complete roll-out by 2019 and 2020, respectively. Iceland is following close behind. Smart metering can offer new opportunities for aligning demand and supply cost-effectively. On the demand side, it can be used for **sensitising consumers** to greater energy awareness and targeting investment and behaviour campaigns better. On the supply side, smart meter data facilitates better and closer **real-time optimisation** of production operation. **New tariff structures** are also being trialled. Its is no longer just a matter of reducing energy consumption: It could be that a higher consumption but a smaller load at certain times of the day will enable a higher share of renewable energy, at a lower cost.

Photo credit: Landis+Gyr, Electricity Meter E350

Fig 8.4: Tiered cooling and heating supply in Växjö



Efficient district cooling and heating

Areas of high population and activity density can facilitate efficient use of district heating and cooling in buildings – in some cases through the use of excess heat.

In Växjö, Sweden, the district heating company VEAB provides cooling using **a tiered approach** whereby three large consumers with differing temperature requirements are served by the same supply. After first cooling a shopping centre and then a data centre, the return district cooling passes by a football stadium where heat is extracted for the grass pitch before coming full circle back to the cooling plant.

/ GREEN MOBILITY

KEY MESSAGE: Multiple measures needed to curb transport CO_2 emissions

Three different measures are required for the decarbonisation of the transport sector:

1) **Reducing transport demand or shifting** to cleaner types of transport (so-called modal shift)
2) Improving the **efficiency of transport** means
3) Switching to **low carbon fuels**.

The NETP CNS expects **low-carbon fuels** to become the primary means to reduce the transport sector's climate footprint. However, the potential of additional levers should not be discounted offhand; it is still possible that **disruptive technologies** such as autonomous vehicles or shared mobility services may deliver significant impact in the longer term.

The way ahead

In all Nordic countries except Iceland, **modal shifts to rail transport** from cars and aviation in passenger transport and from trucks in freight transport are contributing to CO_2 reductions. However, the **share of energy reduction due to these shifts is relatively small** compared to the contributions from vehicle efficiency and low-carbon fuels.

Further **shifts from cars to non-motorised travel (walking and cycling) and public transit** will require further investments in what are in many Nordic cities already world-class transit and non-motorised systems and infrastructure.

Fig 9.1: Transport GHG emission reductions ($MtCO_2$) in the CNS, by mode.

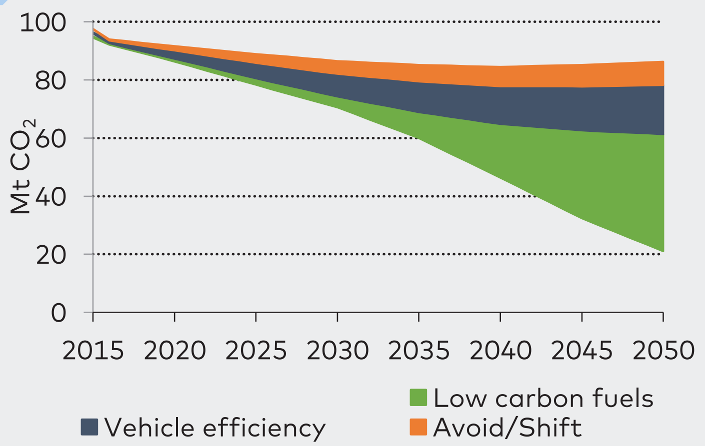
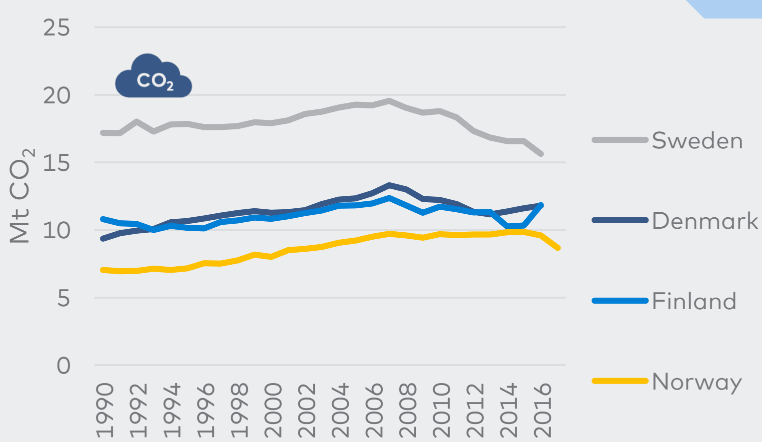


Fig 9.2: CO_2 emissions ($MtCO_2$) from road transport



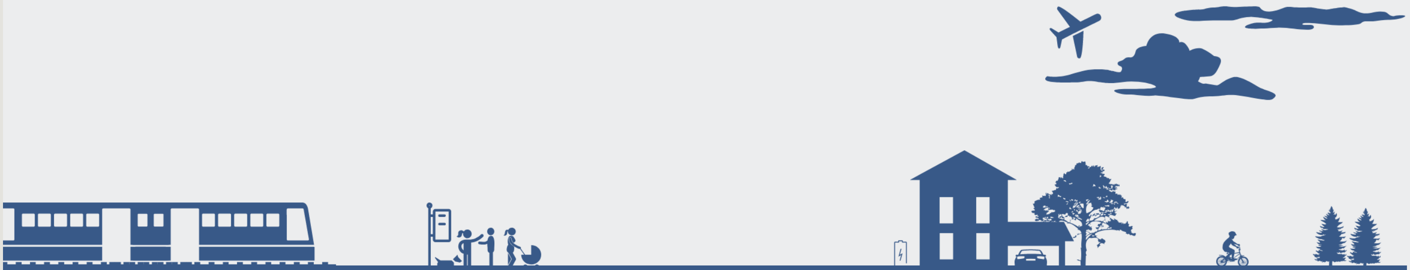
Progress indicators

Until 2007, CO_2 emissions from road transport increased in all Nordic countries. Since then emissions have dropped or stagnated. The reduction in emissions is attributable to multiple factors; an economic downturn following the financial crisis, more fuel-efficient vehicles, biofuel requirements and recently, the uptake of electric vehicles, particularly in Norway. In Sweden, energy demand for road transport has been more or less constant since 2007, meaning that the considerable drop in CO_2 emissions is primarily attributable to the rising share of biofuels.

Photo credit: Max grayson / Unsplash

41%...

...of all journeys to work and study to/from Copenhagen are made by bike and **62% of Copenhagen residents choose to bike to work and study** in the Danish capital. Bikes feature less prominently in the other Nordic capitals, but there are ambitions to increase the popularity of cycling. In Oslo, for example, the goal is that 16% of daily journeys be made by bicycle by 2025.

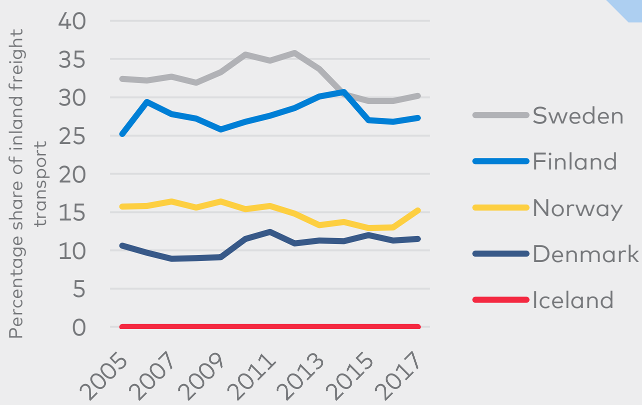


The Nordic countries already widely implement many of the key policies designed to limit the growth of car ownership. In addition to **high national fuel and vehicle taxes across the Nordic region** (vehicle taxes are particularly high in Norway and Denmark), many regions and municipalities in the Nordic countries have implemented **road pricing, road tolls and access restrictions in city centres**. Despite these initiatives, cars are still responsible for somewhere between 80-90% of all inland passenger transport.

Did you know that...

...passenger air transport alone accounted for 15% of all transport related energy consumption in 2016?

Fig 9.3: Rail-share of inland freight transport.



Focus on freight

On a Nordic level, freight-related energy consumption is responsible for 43% of the transport sector's energy demand. Sea-bound transport (19% of total transport energy demand) and heavy road transport (18%) are the two most important energy end-uses. Compared to transportation of goods by truck, railways provide an energy efficient and low-carbon option.

It appears from the figure to the left that the rail share of inland freight transport varies substantially between the Nordic countries. This may (partly) be due to differences in industry structure. Unfortunately, the Nordic countries have not managed to significantly increase their rail shares during the last ten years.

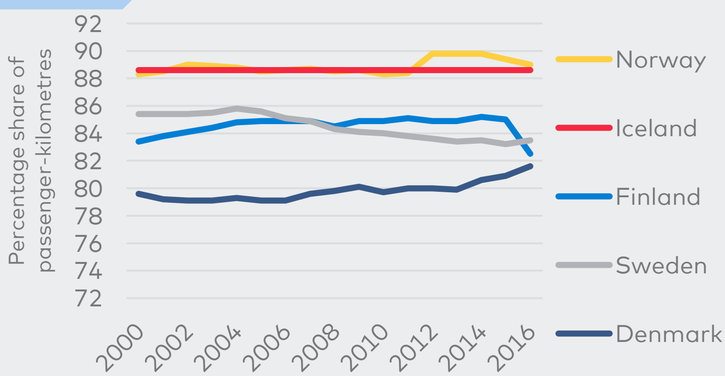
Cars still the preferred transport mode

Cars are responsible for the bulk of inland passenger transport in all Nordic countries – a trend that has persisted throughout the last 15 years.

Norway has the highest share of inland passenger transport by car. At 9% in 2016, Sweden has the highest share of rail-based passenger transport, while Finland has the highest bus share, namely 12%.

Sweden has managed to slightly reduce its share of passenger transport by car over the last ten years, while the opposite is the case in Denmark.

Fig 9.4: Share of inland passenger transport by car.



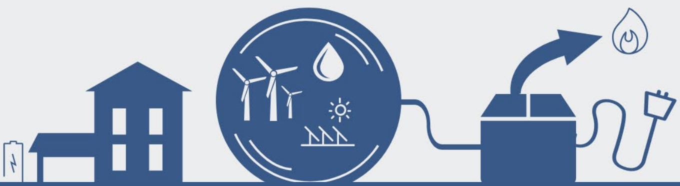
Mobility as a Service

Digitalised mobility solutions, whether multimodal Mobility-as-a-Service (MaaS) applications or separate services such as car sharing, provide the customers with an alternative to private vehicle ownership and use.

Nordic households that replace a private car with car sharing can reduce their kilometres travelled by vehicle by approximately 30-45%, and their greenhouse gas emissions by 130-980 kg CO_2 per year.

Helsinki is often cited as the first city in the world to offer a comprehensive Mobility-as-a-Service package.

/ ENERGY STORAGE



KEY MESSAGE: Storage systems augment flexibility and efficiency

Heat and gas are relatively cheap to store while electricity storage is rather expensive. Chemical storage in particular can be used to link different energy carriers in the system.

The projected **high shares of variable** renewable energy technologies in the power system will place **new demands on operation of the electricity system** and organisation of the joint Nordic electricity market.

Providing cost-efficient storage will become key to balancing the power system.

Currently, the cheapest methods of energy storage are **hydro reservoirs and large-scale heat storage** (water tanks or pits); however, batteries, large-scale demand response and conversion of electricity to hydrogen, methane, or liquid fuels are likely to become more relevant in the future.

Hydropower flexibility

Hydropower storage has for many years contributed to a flexible Nordic electricity system. As wind and solar gains significance, **hydropower flexibility becomes ever more valuable**.
The research project **HydroFlex**, supported by EU Horizon2020, with academic and commercial partners from Norway and Sweden, aims to develop new technology that facilitates highly flexible operation of hydropower stations, such as high ramping rates, frequent start-stops, and the option to provide a wide range of system services. One example of such technology are new turbine designs that can operate with very high flexibility and at higher efficiency.

Photo credit: SorbyPhoto

Photo credit: PlanEnergi

Large scale thermal heat storage

In recent years, a number of **large-scale thermal heat pit storages** have been commissioned in Denmark. The role of these plants are mainly to store and integrate heat production from solar thermal plants at district heating plants.

A newly planned pit storage at Høje Taastrup will be connected to the Copenhagen district heating system, and is expected to be used very intensively, i.e. with a target of **25-30 loading cycles a year**. The Høje Taastrup storage will allow the combined heat and power units to produce **more flexibly** and reduce the need for heat peak units. The consumer-owned district heating company Vojens Fjernvarme is currently the world's largest solar heating plant (70,000 m^2) and has the world's largest underground thermal storage pit (200,000 m^3).

Chemical storage

A testbed and competence centre can help accelerate the development and deployment of hydrogen technology across multiple industries and in society. Planning of the **hydrogen testbed** in Luleå, Sweden, started in 2017. Work will commence in 2021 with expected full testbed platform operation in the autumn of 2022.

The testbed will be an open and neutral arena where stakeholders can test and evaluate both individual components and entire value chains for a wide range of different hydrogen applications. This may include energy storage, production of biofuels and green chemicals, or hydrogen applications in the metallurgical industry.

Photo credit: Swedish Hydrogen Development Center

/ CARBON CAPTURE AND STORAGE

Carbon capture and storage (CCS) presents a conceptually different storage opportunity compared to energy storage, and CCS plays an important role in the NETP CNS.

Even with very aggressive action to increase energy efficiency, to switch to low-carbon fuel and feedstock, and to increase recycling, the CNS requires **wide application of CCS** in cement, iron & steel, and chemical industries.

There are also promising opportunities for bioenergy CCS in Nordic industry, or in waste incineration plants that can produce negative emissions.

Proving new concepts and technologies is critical to market penetration.

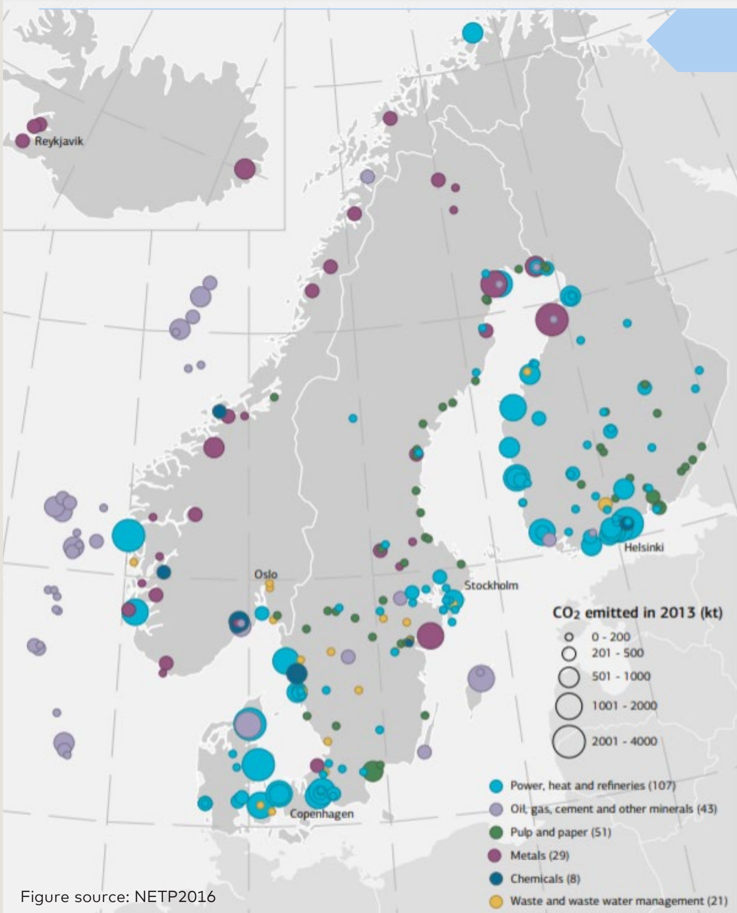


Figure source: NETP2016

Industrial stationary CO_2 sources

Sweden and Finland are responsible for the largest industrial CO_2 emissions in the Nordic region, while Norway and Denmark offer significant offshore storage capacities.

*"**Carbon capture and storage is one area where Nordic collaboration could prove particularly valuable.** The size and risk involved in investments, the need for a joint legal framework and the potential benefit of CCS in the future Nordic energy system support a collaborative approach – for instance, to finance demonstration and market establishment of CCS."* – NETP 2016.

In June 2019, a Letter of Intent regarding exploitation of the CarbFix method for large emitters in Iceland was signed by the Prime Minister of Iceland, Reykjavík Energy, the Aluminium and Silicon Industry in Iceland, and three ministries. CarbFix is a process that captures CO_2 and other acid gases in water, injects this water into the subsurface where the gases are stored as stable minerals. Work developing this process began in 2006. About 200 tons of CO_2 were injected into subsurface basalts in 2012 at the Hellisheiði Geothermal Power Plant and within two years fixed as stable carbonate minerals.

Since then the approach has been scaled up at Hellisheiði and ongoing research is applying this approach at other sites across Europe. These types of technology are of major interest to large CO_2 emitters.

Testing CCS technologies

The Norwegian Government has set a goal of realising a cost-effective solution for full-scale CO_2 management in Norway. The government strategy aims to identify measures to promote technology development and to reduce the costs of CCS. Any such technologies could hold a potential for international application.

Technology Centre Mongstad is the world's largest facility for development and testing carbon capture technologies. Located at the Mongstad oil refinery, the centre has access to flue gas from the natural gas combined heat and power plant, as well as from the refinery cracker, which provides a unique opportunity to investigate capture technologies relevant for coal and gas fuel power plants, along with other industrial applications.

Photo credit: Technology Centre Mongstad, July 2013

The green energy transition of the Nordic countries started back in the 1970s as a consequence of the global oil crisis. Major improvements in the energy profile of the Nordic countries have since been realised as a result of political courage and initiatives – jointly and individually.

The uniquely high penetration of renewable energy sources in the energy mix and the energy efficiency improvements in industry and buildings could not have been achieved without political determination and public interest.

We have come a long way but still have far to go. Key drivers for change to a carbon neutral energy system have been identified. Many promising new initiatives have been launched in recent years, although their impact is not yet fully visible. However, we are still some way from achieving the needed significant impact.

This publication provides an overview of recent achievements and where we need to be in 2030 and 2050.