

Nordic Energy Technology Perspectives 2016 (preview)

Pathways to a carbon-neutral Nordic energy system, coming May 2016

Mid-term preview of insights from the project:

- Decarbonising urban buildings and transport
- Integration of variable renewables
- Nordic decoupling experiences in the context of COP21

Decarbonising urban transport and buildings

The coming NETP 2016 report¹ will have a special focus on the role of urban energy systems in meeting the climate targets of the Nordic countries, with in-depth case studies of both Helsinki and Oslo.

Nordic urban areas account for the majority of non-industrial energy use and are growing strongly through urbanisation. Urban areas are home to most of the Nordic population, over half of energy used in buildings and almost half of energy used in transport. After over three decades of approximately 0.5% annual urban growth, Nordic urban areas are expected to grow at over three times this rate during the coming decades. This presents a significant opportunity to improve urban energy efficiency and decrease emissions.

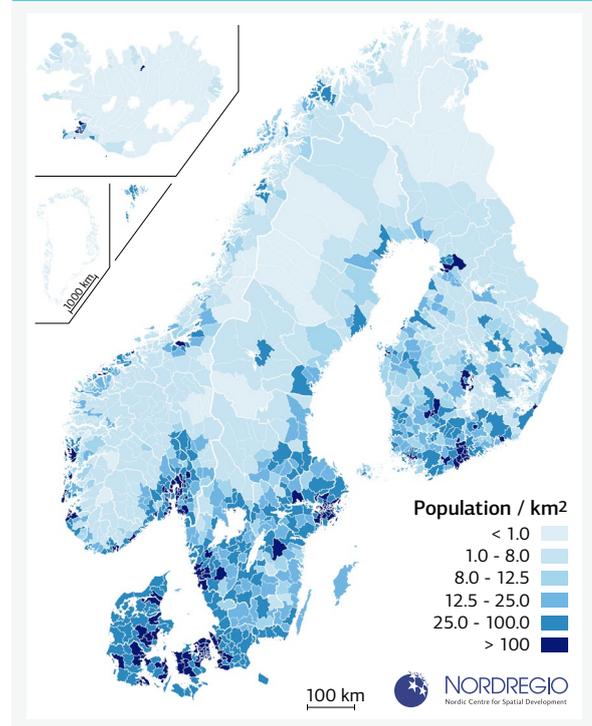
Urban areas are well positioned to adopt smart and highly efficient technologies. Nordic urban areas use significantly less energy per person than rural areas. Their larger populations, higher densities and shorter commuting distances make them ideal for solutions such as electric vehicle charging infrastructure, public transport systems, cycling, utilisation of waste heat, and district heating and cooling. Urban areas could even balance variable

renewable energy production in rural areas through advanced district heating and cooling networks, distributed storage, smart demand load shifting, and transmission and energy system control. The urban definition covers a wide range of population densities, resulting in varying applicability of technologies even within urban areas.

Urban areas are leading national decarbonisation efforts. 108 Nordic cities are signatories to the Covenant of Mayors, entailing ambitious local energy and climate targets. All five Nordic capitals have targets to become carbon-neutral. Policy design at the national level must consider the growing role of urban areas and regions, while avoiding sub-optimisation of energy priorities at different levels of government.

Figure A

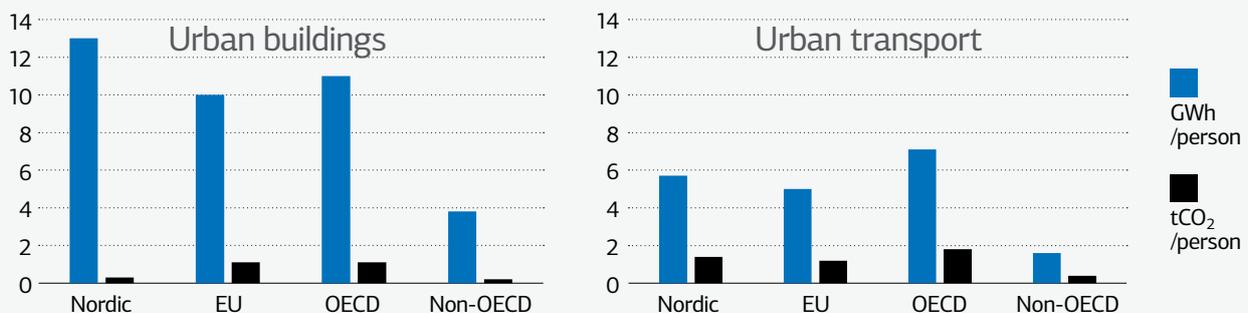
Nordic population density in 2011



Key point: The Nordic population is increasingly concentrated in urban areas.

Figure B

Estimated per capita energy use and CO₂ emissions from urban buildings and transport in 2013



Key point

Estimates of per capita energy use in Nordic urban buildings are higher than the EU or OECD, while CO₂ emissions are lower. For urban transport, Nordic per capita energy use and CO₂ emissions are higher than the EU due to higher car ownership and use.

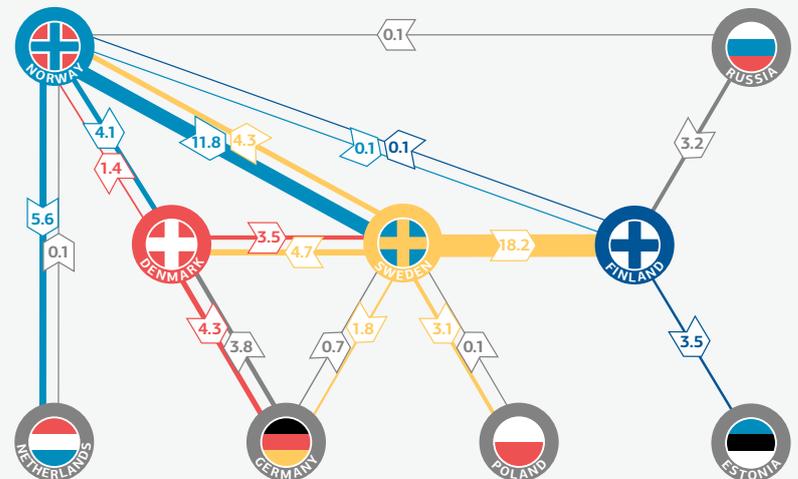
¹) The NETP project develops scenario-based analysis on how technology can assist the Nordic countries in meeting their climate targets. It is a cooperation between the International Energy Agency (IEA), Nordic Energy Research, IVL Swedish Environmental Research Institute, VTT Technical Research Centre of Finland, Danish Technical University (DTU), Institute for Energy Technology (IFE), University of Iceland, EA Energy Analysis and Profu AB. The first NETP report was published in 2013. Unless specified, the NETP project is the source of all data and figures. The sole responsibility for the accuracy of the content of this November 2015 preview lies with the author, Nordic Energy Research.

Integration of variable renewables

The coming NETP 2016 report will have a secondary special focus on how sufficient flexibility can be achieved to integrate further variable renewables in the Nordic grid. The analysis will look specifically at the buildout of wind power, based on the significant potential in the Nordic region. Four technological options for flexibility will be analysed: Flexible consumption, flexible production, storage, and electricity trade. In addition, the analysis will offer insight into the interplay between Nordic and European power systems, as well as the interaction between smart and efficient future cities and the future Nordic grid.

Figure C

Nordic electricity exchange in 2014 (TWh)



Note: Compiled from hourly data. Source: NordPool Spot

Key point

Electricity exchange changes year by year, balancing both long and short-term variations in the Nordic power system.

Nordic decoupling experiences in the context of COP21

Five Nordic achievements in decoupling GDP and CO₂

1. The Nordic region decoupled GDP from energy-related CO₂ emissions two decades ago. The IEA observes that 2014 may have seen the first global decoupling, while the Nordic region has exhibited a steady decoupling for almost 20 years.
2. The IEA projects that global electricity demand and power sector CO₂ will be decoupled if national pledges to COP21 are fulfilled. If Intended Nationally Determined Contributions (INDCs) are achieved, growth in global power sector CO₂ emissions will slow to a near stop. Nordic power sector emissions are already decoupled from electricity demand, and are dropping rapidly despite only 13% of electricity being generated from fossil fuels in 2014.
3. The Nordic electricity mix is 25 years ahead of the rest of the world in terms of carbon intensity. Nordic CO₂ emissions per unit of electricity produced are one fifth of the global average in 2015. The world will reach this level in 2040 if it follows the IEA 2-degree scenario.
4. Tight Nordic electricity market and grid integration enhances efficiency and security of supply. Danish electricity trade with Norwegian and Swedish hydropower facilitates the efficient integration of wind power – the world's highest at 39% in 2014. Nordic grid integration provides security of supply against uncertainties such as dry hydropower years, offline nuclear capacity, or changes to electricity market access outside the region.
5. Ambitious, long-term and stable policy frameworks have been the key to decoupling. All five countries have used policy frameworks actively in decoupling GDP from CO₂, with carbon taxes and renewable energy incentives among the most effective examples.

Five challenges for further decoupling

1. The Nordic region can capitalise on its potential to supply clean electricity and balancing services to Europe by making the common Nordic grid stronger and electricity markets more flexible. The significant wind build-out expected in the Nordic region will require additional infrastructure in order to be integrated efficiently.
2. CO₂ emissions from transport are not yet decoupled from rising demand for transport services. Nordic cooperation in transport infrastructure and policy can accelerate this decoupling. Urban transportation can lead the uptake of electric vehicles and modal shifts to public transport, while a large-scale transition to sustainable biofuels can decarbonise long distance transport on roads, seas and airways.
3. Carbon Capture and Storage (CCS) is needed to decouple heavy industry output from emissions in sectors such as cement, steel and chemicals. Nordic cooperation on CCS RD&D and infrastructure can accelerate its implementation. CCS in industry can complement efforts in energy efficiency use and renewable energy.
4. Nordic cities are more energy efficient than rural areas and can deploy a wider range of technology options. District heating, electric vehicles and public transport systems are more efficient and economical in densely populated areas. Knowledge sharing between Nordic cities can identify best practices in urban energy systems.
5. Nordic cooperation can reduce the cost of achieving national climate targets. Potential for cooperation is especially high in RD&D, infrastructure and policy development. Technologies with high cooperation potential include offshore wind, biofuels, CCS and the electricity grid, amongst other areas.

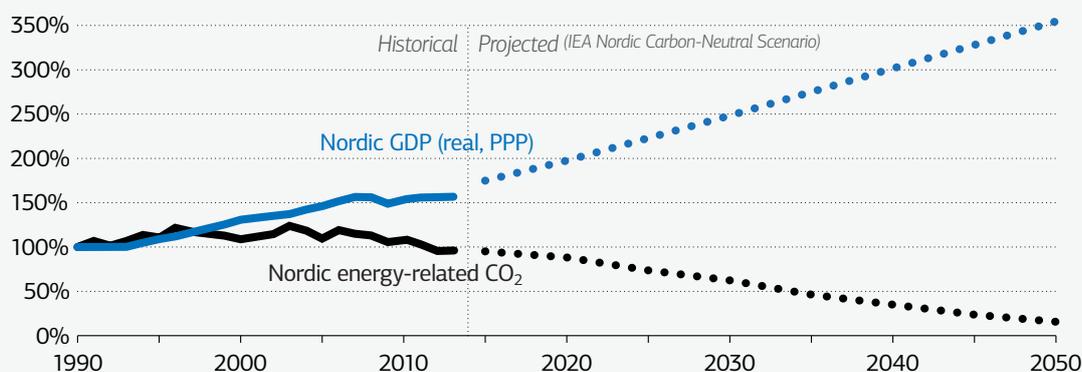
Decoupling GDP and energy-related CO₂ emissions

2014 may have been the first year where growth of the global economy decoupled from energy-related CO₂. In June 2015 the IEA reported that for the first time in 40 years there was an annual halt or reduction in global CO₂ emissions that was not tied to an economic downturn. Recent revisions of Chinese emission data may alter the global picture and it remains to be seen if this single-year result will become a long-term trend.

The Nordic region decoupled GDP from energy-related CO₂ emissions from around 1997. Gradual emission reductions have been sustained in the following 17 years while GDP has grown. Together, the Nordic

Figure D

Nordic GDP and Energy-related CO₂ emissions



Key point

Nordic GDP decoupled from energy-related CO₂ around 1997, beginning the sustained decoupling required to achieve the Nordic Carbon-Neutral Scenario.²

² Statistics and projections from the IEA Nordic Carbon-Neutral Scenario come from the NETP project. The scenario is more ambitious than the 2-degree scenario, with an 85% reduction in domestic emissions from 1990 levels, including process emissions and international transport, with 15% emissions offset internationally. GDP assumptions used by the NETP project are consistent with the projections used in the IEA World Energy Outlook. Variation in historical emissions are due to wet and dry hydropower years, amongst other factors.

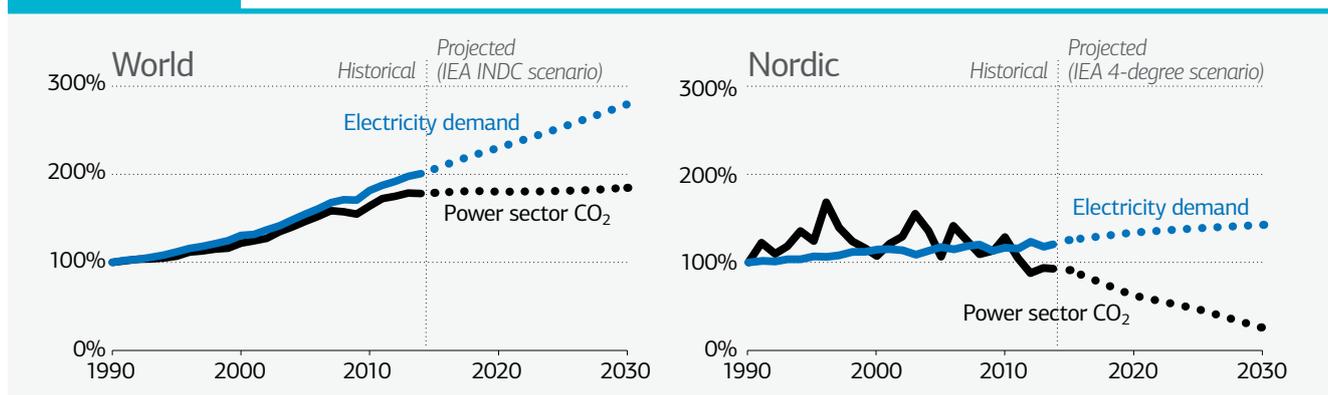
region would constitute the world's 12th largest economy, proving the feasibility of sustained decoupling for a medium-sized developed economy.

The decoupling effect is likely reduced if consumption-based emission accounting is used. UNFCCC emission accounting is production-based and includes emissions within the country's territorial borders. Reliable and comparable data for an alternative consumption-based approach is limited, but individual studies of national carbon footprints point to Nordic consumption-based emissions being higher than official production-based emissions.³ This is due partly to the import of goods formerly produced within the region, but especially due to increasing imports and exports in all sectors, which tie Nordic consumption-based emissions closer to global levels.

With a largely decarbonised heat and power supply, the Nordic region can look to sectors such as transport and industry to achieve further decoupling. Most countries in the world have significant low-hanging fruit in decarbonising their fossil-fuel-based electricity systems. This is evident in Figure E, which projects a global decoupling of electricity demand and power sector CO₂, assuming that national Intended Nationally Determined Contributions (INDCs) submitted in advance of COP21 are fulfilled. Nordic power sector emissions are already decoupled from growth in electricity demand, and are declining despite being only 13% fossil-fuel based in 2014. The greatest potential for further progress towards the ambitious climate targets⁴ of the Nordic countries lies in other sectors.

Figure E

Electricity demand and Power sector CO₂ emissions



Key point

If INDCs are fulfilled, global power sector emissions will level out, while electricity demand continues to rise. This decoupling was evident in the Nordic region in the late 1990s, despite a largely decarbonised electricity supply at the start of the period.⁵

The integrated, low-carbon Nordic electricity system

The carbon intensity of the Nordic electricity mix is where the rest of the world needs to be in 2040 according to the IEA's 2-degree scenario. The low Nordic carbon intensity of around 100 gCO₂ per kWh is largely thanks to hydropower and nuclear power, but wind power and bioenergy are lowering the carbon intensity further. However, as shown in Figure F, emissions from heat and power represent only 30% of total Nordic energy-related CO₂.

The common Nordic electricity market is the world's most integrated, synthesising the diverse electricity systems of the region. The world's first international subsea interconnector was laid a century ago in 1915 between Sweden and Denmark. Since then the grids of Denmark, Finland, Norway and Sweden

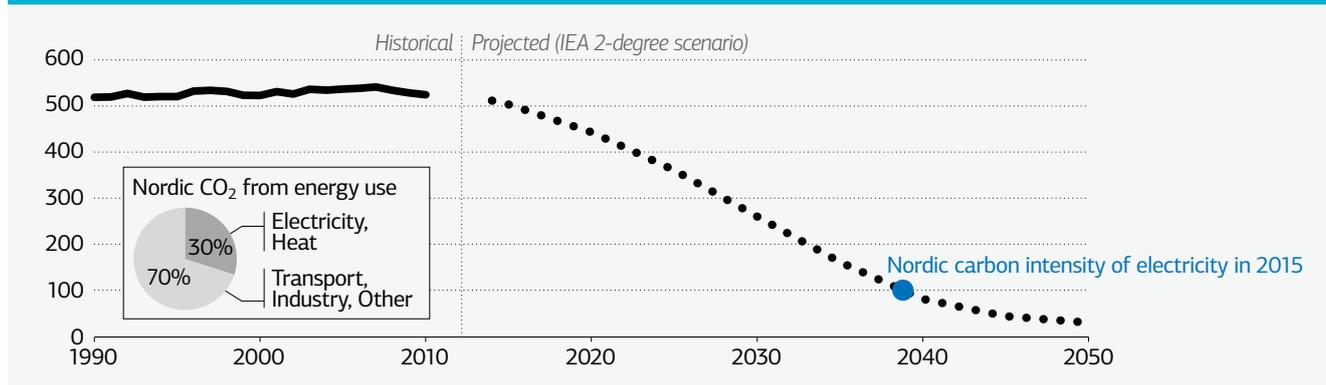
3) See: Peters, G. and Solli, C., 2010, Global carbon footprints

4) Nordic climate targets: The EU's Intended Nationally Determined Contribution (INDC) submitted in advance of COP21 outlines a 2030 target of 40% from 1990 levels. The collective delivery of this target covers member states Denmark, Finland and Sweden. Non-members Norway and Iceland have both submitted INDCs with the same 2030 target and with intentions to fulfil the target under the EU's collective delivery. National targets for 2050 range from Denmark's 100% renewable energy system, to Finland's vision of an 80% GHG reduction, to Iceland's aspirational goal of 50-75% net GHG reduction, to Norway's carbon-neutrality, to Sweden's zero net GHG emissions.

5) World figure adapted from IEA Special Briefing for COP21. Nordic figure based on IEA databases for historical data and NETP project for projections. Nordic projections in the IEAs 4-degree scenario are used as the closest available Nordic substitute for the IEA's global INDC scenario. Fluctuations in Nordic power sector CO₂ are due to the effect of annual variations in precipitation on hydropower production, amongst other factors.

have become increasingly interconnected. Market integration began between Norway and Sweden in 1993, and by the year 2000 the common Nordic spot market covered all market areas of the four continental Nordic countries. Integration enables an optimisation of each country's diverse resources. While 99% of electricity production in Norway is hydropower, Denmark has a mixture of primarily coal, wind, gas and biomass, Sweden has primarily nuclear, hydropower, wind and biomass, while Finland has primarily nuclear, biomass, hydropower, coal and gas. Iceland has hydropower and geothermal power but is not currently connected to any continental electricity system.

Figure F

Global carbon intensity of electricity production (gCO₂/kWh)

Key point

Nordic CO₂ emissions per unit of electricity produced are one fifth of the global average in 2015. The world will reach this level in 25 years if it follows the IEA's 2-degree scenario.

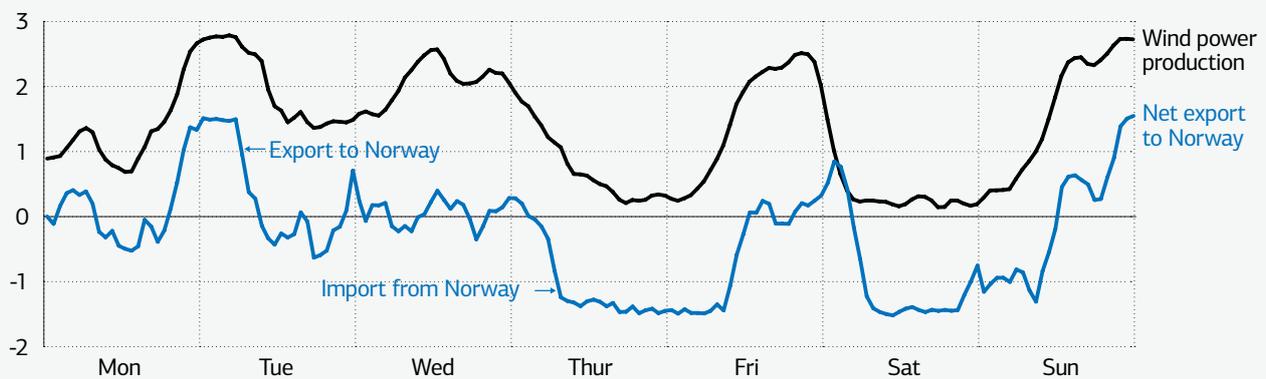
Security of supply is ensured through tight integration of grids and markets. National electricity systems in the region are affected by various long-term uncertainties. These include annual variation in precipitation affecting hydropower reservoirs, unusually cold winters leading to increased heating demand, maintenance on nuclear power plants, and changes in access to electricity markets outside the Nordic region. This was exemplified in 2014 when Finland – already experiencing a delay in construction of a nuclear power plant – was unable to continue the large net import of electricity from Russia that it had relied on in previous years. Finland therefore imported over 60% more electricity from Sweden in 2014 than in 2013, making that connection the largest cross-border flow of electricity in the region, as shown in Figure C.

High penetrations of variable renewables are efficiently integrated through the common grid and market. In 2014, 39% of Danish electricity consumption was covered by wind power – a world record. Much of this was generated in West Denmark, which is connected to Norway, Sweden, Germany and East Denmark through interconnectors. Simply put, under windy conditions Denmark exports to the hydropower-rich systems of Norway and Sweden. Under calm conditions, Denmark imports from these systems. Without this flexibility, the cost of wind power integration in Denmark would have been higher and the system less efficient. The correlation in Figure G illustrates this interaction during a week in February 2015.

A stronger Nordic grid and more flexible markets can capitalise on the potential to supply clean electricity and balancing services to Europe. The Nordic region can take advantage of its significant renewable energy potential in wind power and continental Europe's expected need for balancing services due to a high penetration of variable renewables there. This can be facilitated through internal grid strengthening within and between the Nordic countries, through expansions in interconnector capacity to Europe, and through other interrelated flexibility measures. The NETP 2016 report will offer a special focus on the flexibility measures available to better integrate large amounts of new Nordic wind generation. In addition to grid integration with Europe, these include storage (such as pumped hydropower or battery electric vehicles), flexible supply (such as capacity mechanisms or dispatchable hydropower) and flexible demand (such as demand response, power-to-heat, or power-to-fuels).

Figure G

Wind power production in West Denmark and electricity trade with Norway (GWh) for one week in February 2015 (22.02 – 28.02)



Key point

The correlation between wind power production and electricity trade illustrates the role of hydropower in balancing variable wind power through grid interconnection.⁶

Ambitious, long-term and stable policy frameworks

Ambitious and long-term policies have been pivotal to attract the necessary investment in low-carbon technologies. All five Nordic countries have long-term policies on the taxation of both carbon emissions and energy. The Swedish carbon tax was established in 1991 and has since gradually increased three-fold to reach 119 EUR/t in 2015. This is 15 times the current European Emission Allowance price, which is recognised as being too low to be effective. The Swedish carbon tax has been instrumental in bringing about the transition of district heating from fossil fuels to predominantly biomass. In 2003, Sweden introduced a green certificate scheme for renewables expected at the time to last until 2030. Combined with other incentives, this policy has helped Sweden's surge in wind power from 2 GW in 2010 to almost 5.5 GW in 2014. Norway joined the scheme in 2012, making it Europe's only bilateral incentive mechanism for renewables.

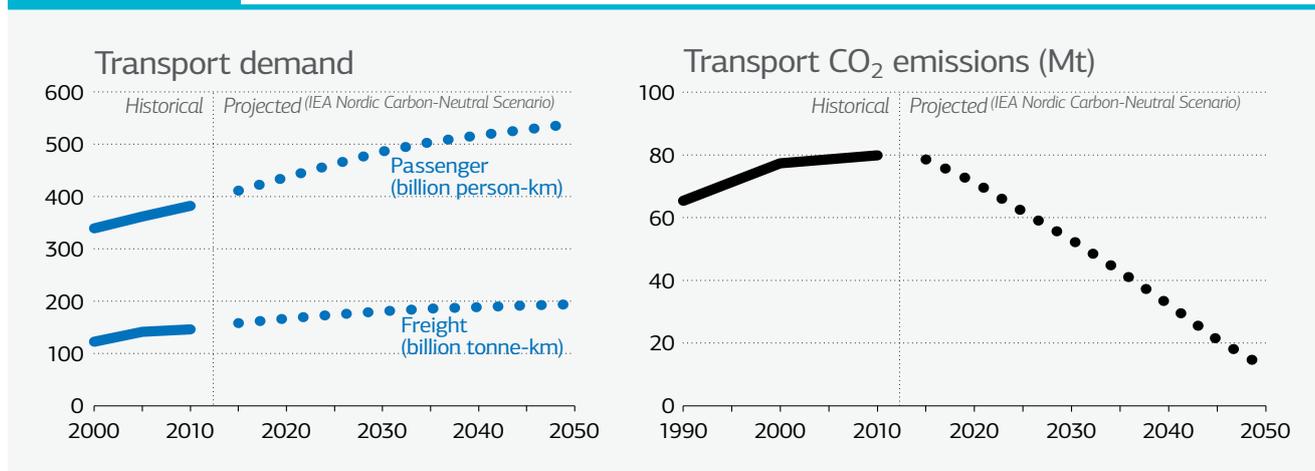
Beyond heat and power, Norway's support schemes for electric vehicles (EVs) have resulted in the country of just 5 million inhabitants accounting for a third of all EVs sold in Europe in 2014. Norway has the world's highest number of EVs per capita, with 17% of all new cars sold during the first three quarters of 2015 being electric. The key to this rapid technology penetration has been a strong and relatively stable policy consisting of exemptions from a high vehicle registration tax and a 25% VAT, as well as free municipal parking, charging and bus lane use, amongst other user benefits. The policy's success necessitated a revision to the incentives in 2015, however, the main incentives were retained and sales are expected to continue to grow. Despite the cost of this support, there is broad political agreement to kick-start the rollout of zero-emission vehicles in the country.

Opportunities to decouple emissions in demand sectors

Demand for transport services in the Nordic region have grown in recent decades and are expected to continue to grow. CO₂ emissions from transport have also seen significant growth in recent decades. The NETP project outlines a reduction from today's 80 Mt of Nordic transport CO₂ emissions to just 10 Mt in 2050 in order to meet national climate targets. Nordic transport emissions can be decoupled from transport demand by improving the efficiency of transport technologies, shifting fuel sources, and by shifting modes away from private cars, road freight and air traffic, on to public transport, rail and sea. In 2050, according to the Nordic Carbon-Neutral Scenario, 4% of passenger transport could be avoided through better urban planning, 20% shifted from cars to public transport, and 90% of all new car sales could be EVs.

6) Note to Figure G: Hourly data from Nordpoolspot. The West Denmark electricity market area covers Jutland and Funen. It also has interconnectors to East Denmark, Sweden and Germany, but their role in balancing wind power are not as significant and are not shown in the figure.

Figure H

Projected Nordic transport demand and CO₂ emissions**Key point**

Decoupling Nordic transport emissions from rising transport demand will require a combination of shifting modes, fuels and improving efficiency.

A sustainable biofuel supply for long distance transport is key. Long-haul road freight, aviation and shipping will likely remain dependent on high energy density liquid fuels even in 2050, with biofuels being the most feasible candidate. Biofuels compete with other higher value uses for Nordic biomass such as paper and pulp, limiting their availability. Even if half of all road freight growth to 2050 is shifted to electric trains, biofuel demand may be sufficiently high that the Nordic region becomes a net importer in 2050.

Carbon Capture and Storage (CCS) is needed to fully decouple industrial output from emissions.

Heavy industry accounts for a third of Nordic energy demand compared to a fifth in other developed countries. The NETP project suggests that in addition to extensive energy efficiency improvements and a halving of the fossil-fuel share of energy used in industry, CCS is implemented on half of cement plants and a third of iron, steel and chemical plants by 2050.

Accelerated energy efficient retrofits are needed to decouple building energy use from floor area.

Most buildings in the Nordic region will still be standing in 2050, meaning an accelerated retrofit rate for the existing building stock is pivotal.

Decoupling can be cheaper if done in cooperation with other Nordic countries. According to the NETP project, there is significant potential for increased Nordic cooperation in the following three areas: Research in immature technologies, such as advanced biofuels, offshore wind and CCS; Coordination of infrastructure for electricity grids and CCS; and Policy coordination for both clean transport and carbon pricing.

To find out more about the Nordic Energy Technology Perspectives project, visit www.nordicetp.org.

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