Chapter 11. THE FUTURE OF NORDIC CLIMATE AND ENERGY

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The need for energy management is clear. It sets the basic conditions across the globe for societal well-being and defines the parameters for economic growth. This, combined with global attention on climate change in the wake of COP21 and the continuing challenge of maintaining energy security, has placed energy at the forefront of the global political agenda. The Nordic Region has emerged as a global leader in combining ambitious climate and energy policy with steady economic growth. Despite this, room for improvement remains, particularly with respect to the transport and building sectors and in terms of the potential benefits of further Nordic cooperation. This chapter begins by outlining both the current position and the path that is already laid out for us as regards our energy and climate goals. An overview is then provided of a select number of dimensions with respect to the energy sector viewed from a Nordic spatial perspective, including energy production and consumption, with a focus on low-carbon energy. We conclude by exploring the Nordic electricity trade, as well as a number of future developments set to deliver us towards a low carbon energy future.

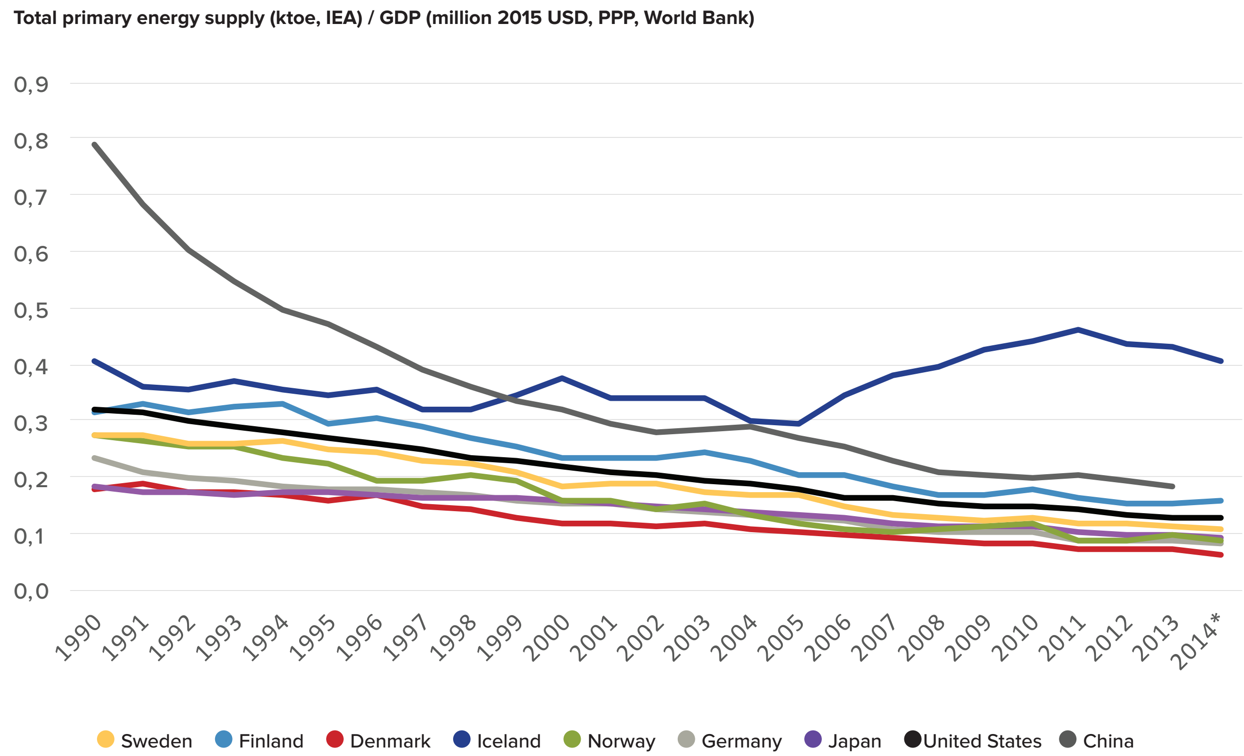
Is a fossil free future possible?

Figure 11.1 reflects a long-term trend across the Nordic countries - steady growth in GDP combined with flat growth in energy consumption, resulting in a reduction in the energy intensity of the economy. For instance, Denmark has a low ratio in both Figure 11.1 and 11.2 due to its proactive energy efficiency measures, lack of energy intensive industries and increased use of wind and biomass in electricity and heat production. Iceland is the exception here as it uses its abundant geothermal energy for heating and has little need for energy efficiency measures. As such, its growing energy intensity over the last decade reflects the increasingly dominant role of energy intensive industries such as aluminium smelting in its small economy. Given, however, that all of the country's electricity and 81% of its energy supply is renewable, an energy intensive industry is a smart approach for exporting its plentiful clean energy resources. At the same time, this model is currently under scrutiny as negotiations for a high capacity grid connection to the UK have recently gathered momentum.

The Nordic Region has emerged as a global leader in combining ambitious climate and energy policy with steady economic growth.

In terms of the measure of carbon intensity with respect to electricity production, the Nordic Region is effectively 25 years ahead of the global trend – measured in CO2 emissions per unit of electricity generated. This is crucial assuming that if the 2-degree reduction target is achieved, the global carbon intensity rate in relation to electricity will reach the current Nordic level in 2039

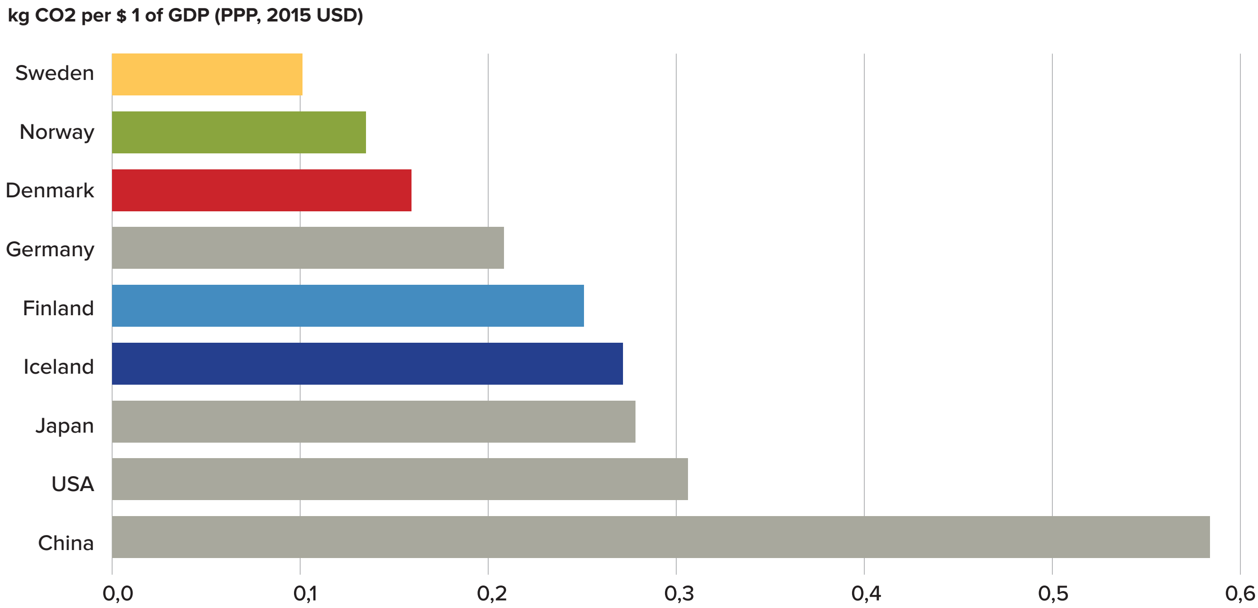
Figure 11.1: **Energy Intensity of GDP**



Data source: Nordic Energy Research, IEA (TPES) and World Bank (GDP). Note: Finland: Includes Åland. Greenland and Faroe Islands: No data. *Preliminary data for TPES in 2014

Energy Intensity of GDP: energy intensity is a measure of the energy efficiency of economic output, in this case shown by the total primary energy supply (in kilotons of oil equivalent) per million USD GDP (in 2015 USD, using Purchasing Power Parity). Most Nordic countries have achieved gradual improvements in energy intensity while retaining energy-intensive industries.

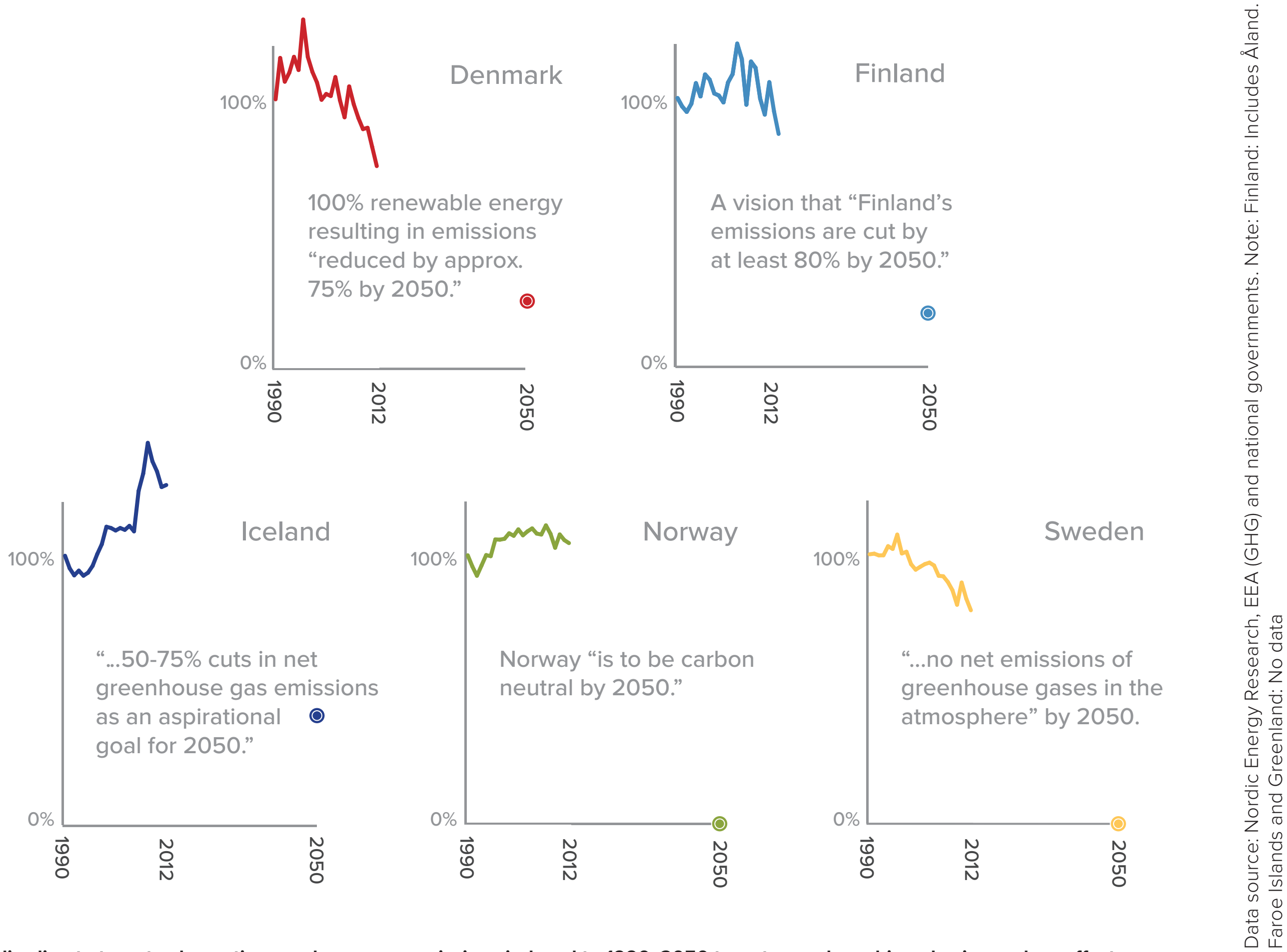
Figure 11.2: **CO2 intensity of GDP 2014**



Data source: Nordic Energy Research, European Commission / EDGAR (CO2) and World Bank (GDP). Note: Finland: Includes Åland. Greenland and Faroe Islands: No data

2014: the CO2 intensity of GDP is a measure of the CO2 emitted from fossil fuel use and industrial processes for every dollar of GDP. Despite a heavy reliance on energy-intensive industries, the CO2 intensity of the Nordic economies is generally lower than the major OECD economies. This is primarily due to low shares of fossil fuels in the energy mix. Iceland's intensity is highest in the region due to process emissions from aluminium production.

Figure 11.3: **Nordic climate targets**



Nordic climate targets: domestic greenhouse gas emissions indexed to 1990. 2050 targets may be achieved using carbon offsets.

(IEA, 2014). Similarly, Figure 11.2 shows the CO2 intensity of selected national economies, providing a useful measure of their economic-environmental efficiency. The strong position of the Nordic countries compared to others such as China and the United States reflects, in part, their use of hydropower and nuclear power, recent additions to the energy mix, such as bioenergy and wind power.

The carbon intensity of electricity production or the fossil fuel intensity of the economy does not however tell the whole story. For example, measures of energy or CO2 intensity do not reflect our globalised economies with their significant levels of trade in goods and services, labour, energy and capital. This means that the connection between a country's economy and its energy system can be seen to be weakening when in fact energy consumption now takes place internationally rather than domestically. Countries that consume the metals refined using energy intensive processes in Iceland are a perfect example of this. In addition, as can be seen below, sectors such as transport, building and industry have high consumption levels, particularly of non-renewable energy. This means that considerable progress is required if we hope to reach our exemplary energy and climate goals set out in Figure 11.3. Only by making sustained progress towards these goals will we be able to consider ourselves as global leaders across the spectrum of aspects that truly define energy and climate progress

In short, fossil fuels still make up 45% of Nordic total primary energy supply. Meeting our collective goals by 2050 will require the reduction of this number to just 16% (IEA/NER, 2013). This is possible, but only through comprehensive demand management and by increasing the share of renewables. The high level of energy demand from the industrial sector in the Nordic Region also presents a substantial challenge. Currently, industry makes up 38% of the Nordic energy demand. This is well above the OECD average and constitutes the bulk of large Nordic point source emissions of CO2 (see Figure 11.4). For example, Figure 11.5 shows that, in sharp con-

Figure 11.4: **Large CO2 point sources, 2011**

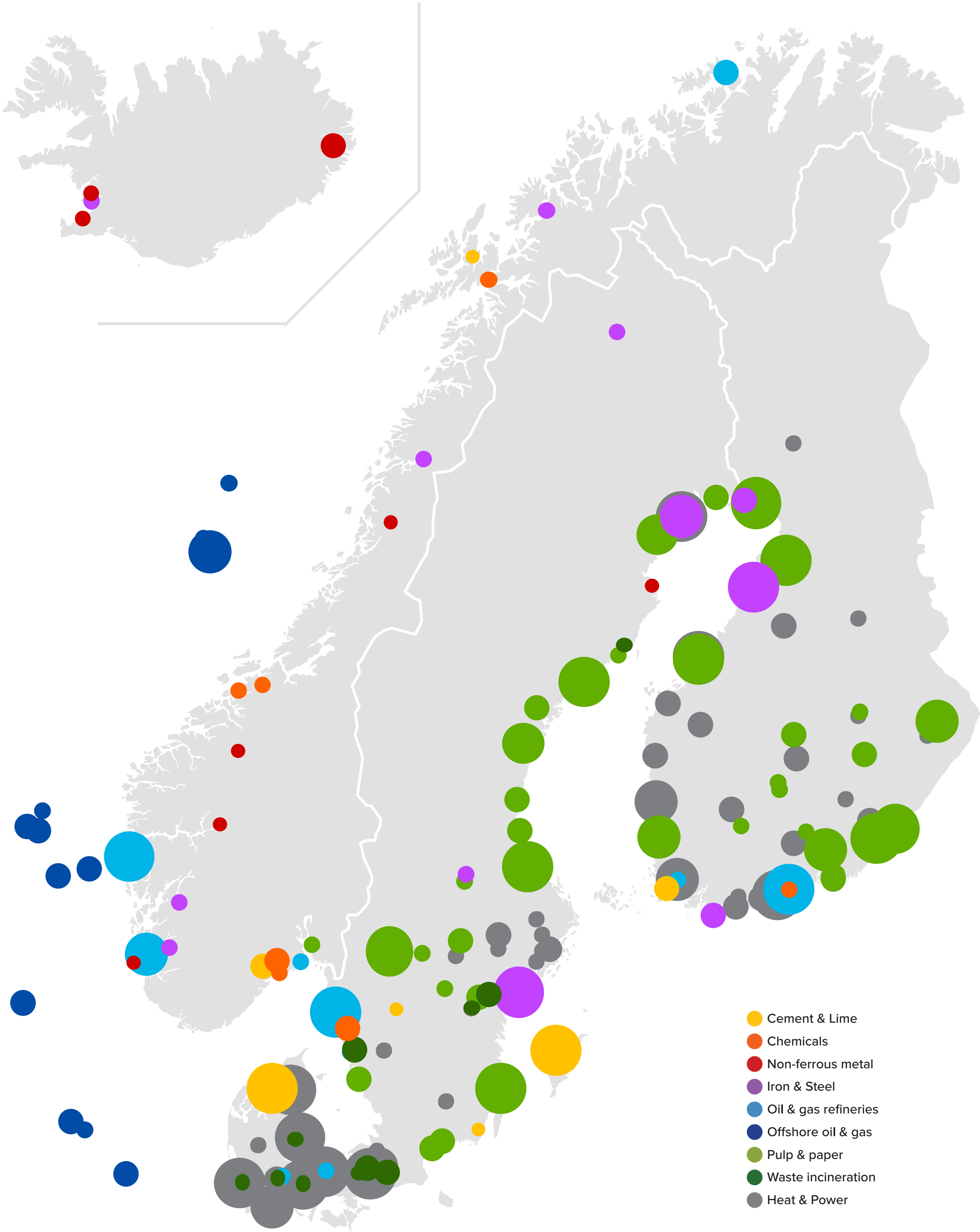
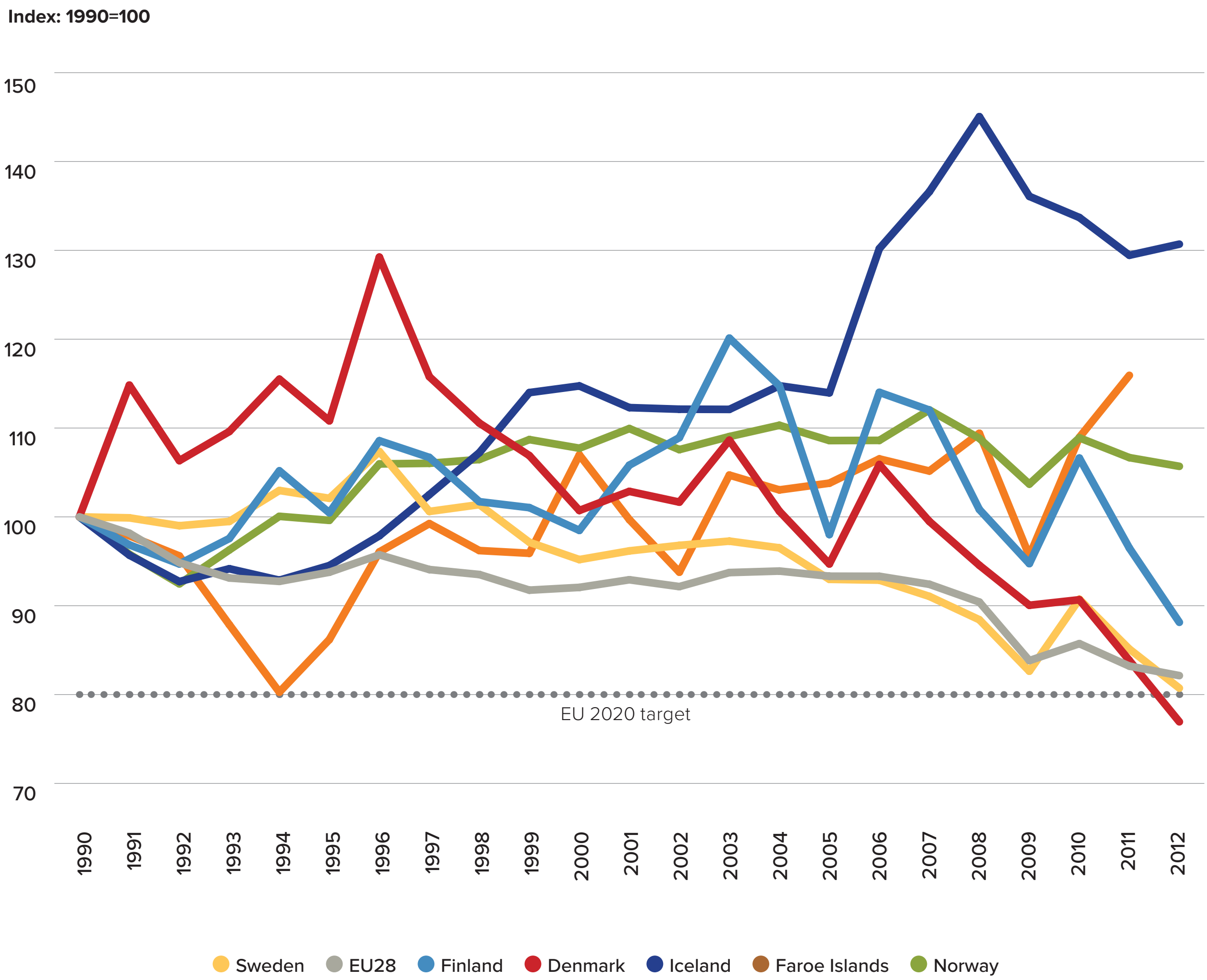


Figure 11.4: Large CO2 point sources, 2011: sources of CO2 emissions from selected large scale industries.

Figure 11.5: **Percent change in greenhouse gas emissions since 1990**



Percent change in greenhouse gas emissions since 1990: the EU 2020 target calls for a 20% reduction in European greenhouse gas emissions from 1990 levels.

Data source: Eurostat and Nordic Statbank. Note: Finland: Includes Åland. Faroe Islands: No data

trast to falling emission levels in Finland, Denmark and Sweden, Norway's emissions have actually increased since 1990. A large share of this growth can likely be accounted for by Norway's oil and gas industry (shown in Figure 11.4). As can be seen in Figure 11.4, other large industrial emitters include iron and steel in Sweden and Finland, non-ferrous metal such as aluminium in Iceland and Norway, chemicals in Norway, Sweden and Finland, and cement across the region. Maintaining these industries, while still meeting the ambitious 2050 climate goals laid out in Figure 11.3, will therefore require further research and development on, and eventually widespread deployment of carbon capture and storage.

The three faces of energy: consumption, production & trade

Energy has three fundamental dimensions: consumption, production and trade (i.e. transmission/distribution). Consumption describes the energy that is supplied and the purpose of its demand. Production describes the amount of energy created, regardless of where it is consumed. It can be thought of in economic terms value added, or quantity (in oil equivalence). And trade through transmission networks such as wires, pipelines, shipping or rail alleviates spatial imbalances between production and consumption.

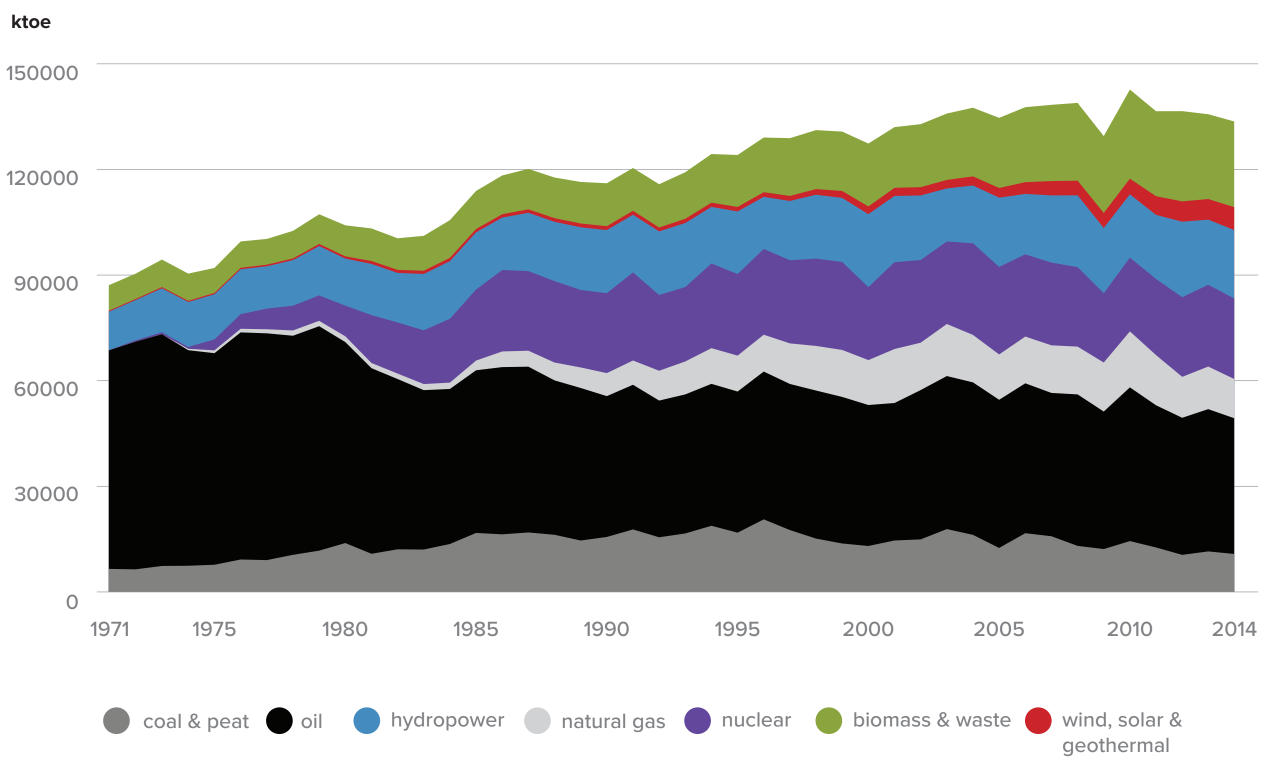
Consumption: growing demand in key sectors

Total Primary Energy Supply (TPES) is the sum of production and imports subtracting exports and storage changes. It therefore accounts for the total energy that is demanded by a given area. Figure 11.6 outlines the trends of Nordic TPES since the oil crises of the 1970s, showing a move away from oil towards alternative energy sources. Of particular note here is the rise of nuclear energy in Sweden and Finland, as well as a rise in the use of coal in Finland and Denmark. At the same time, the past forty years have seen a steady growth in renewable energy sources like biomass and wind, as well as geothermal energy in Iceland. These are used to generate electricity, heat and transport fuels especially in Sweden, Finland and Denmark. As Figure 11.7 demonstrates, electricity produced from renewable sources is also generated from hydropower in Norway, as well as a growing amount of wind power, particularly in Denmark and Sweden. Geothermal heat and power production is the most important energy source in Iceland. With nuclear power in Sweden and Finland, over half of the region's energy is CO2-free and, overall, 38% of the Nordic Region's total energy supply comes from renewable sources.

Despite these positive developments, oil is still the largest single energy source and the only one common to all five Nordic countries. This is due to its central role as a transport fuel. Also, despite the increases in both renewable and nuclear energy, the absolute demand for fossil fuels is roughly the same as it was 1971. This is due to an increase in the absolute demand for energy and an increase in fossil fuel use in transport and industry. In short, we see that the higher generation of low-carbon energy described above has come in addition to, not instead of, fossil fuels.

This growing demand for energy is largely explained by population growth, a higher share of single person households and by ongoing economic growth more generally. Figure 11.8 shows electricity consumption patterns across the Nordic Region, including a breakdown by main sector branches. Electricity demand for buildings generally represents a higher share of total

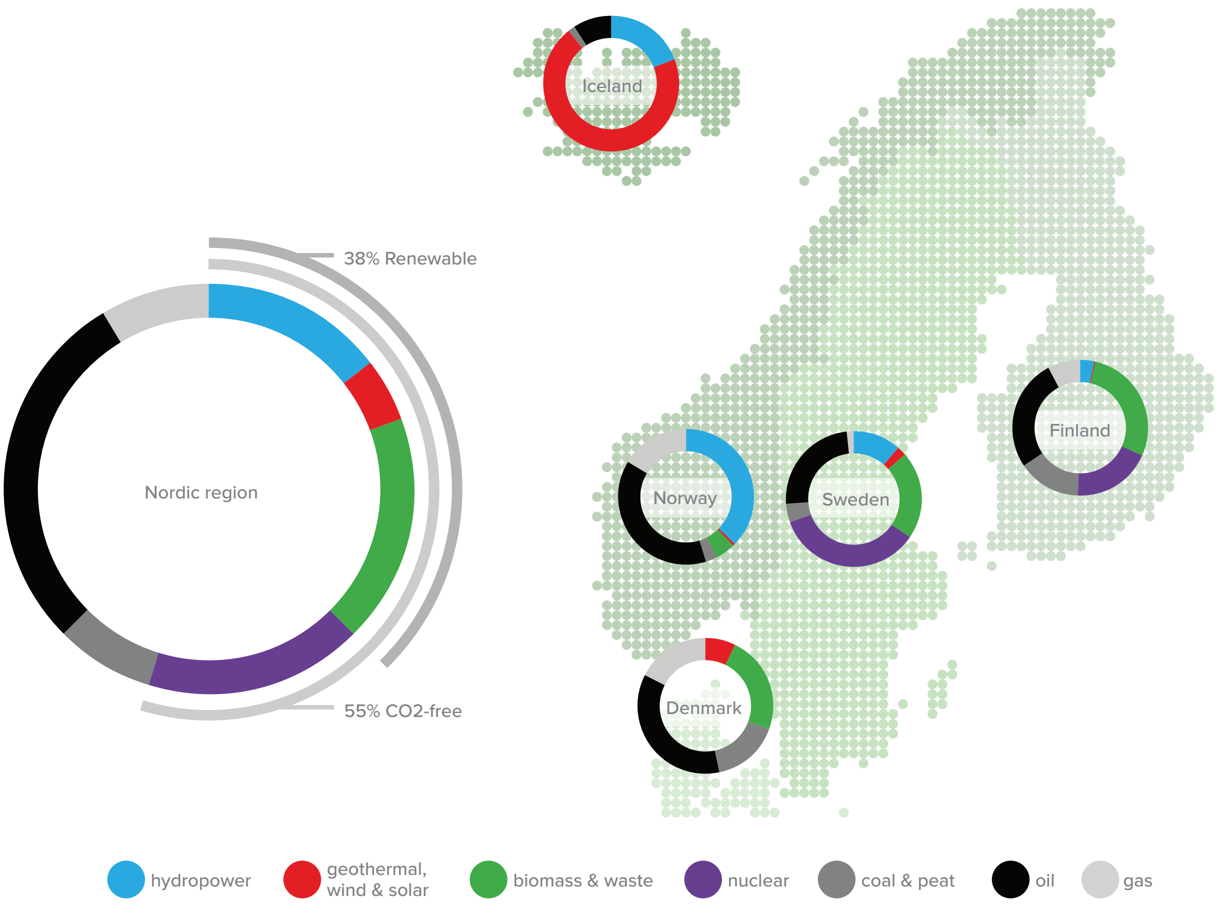
Figure 11.6: **Nordic total primary energy supply, 1971-2014**



Data source: Nordic Energy Research and IEA.

Nordic total primary energy supply, 1971-2014: trends in Nordic total primary energy supply by source. Reductions in the share of oil have been compensated by an increase in nuclear and biomass.

Figure 11.7: **Total primary energy supply mix for selected Nordic countries in 2014**



Data source: Nordic Energy Research and IEA. Note: Finland: Includes Åland. Faroe Islands and Greenland: No data

energy demand in urbanised regions, where overall energy demand is the highest but per capita energy use is lowest. Electricity and heating in buildings therefore represents a central intervention area for reducing absolute energy demand. This is illustrated in Figure 11.9, where buildings represent the largest single sector for energy consumption.

Looking ahead, overall improvements in CO2 emission levels must be met in large part by the demand sectors. Together with transport and industry, the building sector must play a central role here. Building codes and policies supporting energy efficiency measures in both new and existing buildings support a shift towards the creation of a greener building stock in the Nordic Region. Given that over 70% of today's existing building stock will be standing in 2050 however, a significant ramping up of deep renovation efforts is required in order to meet energy and climate targets (IEA/NER, 2013). Authorities at all levels need to take more action in this regard. Local governments are mainly responsible for governing the improvement of the building stock through investment and thus need to lead by example. At the same time, national government can provide significant support through policy investments that provide direct support for energy efficiency improvements in private buildings.

Production: towards renewable energy

Our energy and climate goals can only be met through a comprehensive approach that includes the widespread development of renewable energy. The European Commission's recent Renewable Energy Progress Report (EC, 2015) highlighted that Sweden, Finland and Denmark have not only already achieved their 2020 renewable energy targets, but have surpassed them by the three widest margins in Europe.

The steady progress of Nordic renewable energy deployment is evident in Figure 11.10. Denmark and Sweden's development is particularly notable, largely due to

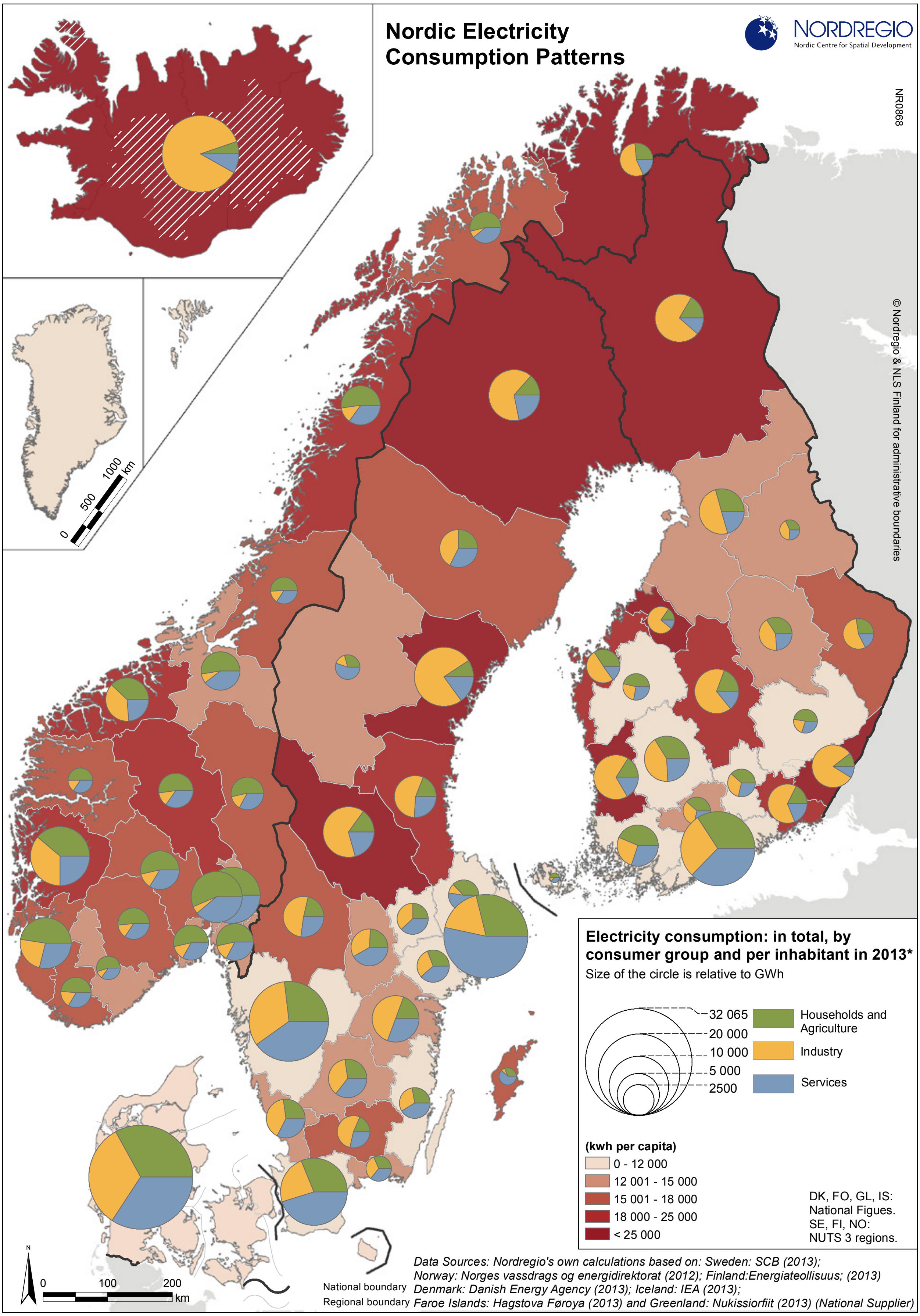


Figure 11.8: Nordic electricity consumption patterns: consumption by consumer group and per capita in 2013

their progress in the wind sector. At the same time, Figure 11.11 shows significant room for improvement with respect to renewable energy consumption in the transport sector. This is consistent with the increase in CO2 emissions from transport in recent decades. IEA projections show significant growth in demand for transport services in the Nordic Region between 2015 and 2050 – passenger by over 30% and freight by well over 20% (IEA/NER, 2013). As a result, urgent action is required to tackle Nordic transport emissions. Considering our expansive area in a European perspective, this must include improving the efficiency of long-haul transport technologies and shifting modes away from road freight and air traffic to rail and maritime shipping. Fuel-switching to biofuels is an ideal way to reduce emissions from long-haul road freight, aviation and shipping. Unfortunately however, other higher value uses for Nordic biomass such as paper and pulp, limits their availability for biofuels. Even if half of all road freight growth to 2050 is shifted to electric trains, biofuel demand may be so high that the Nordic Region is a net importer in 2050 (IEA/NER, 2013).

With respect to passenger transportation, policies and investments that promote the use of electric cars and public transportation powered by renewable energy sources will be crucial for meeting our energy and climate targets. Cities are the key drivers of this development through effective planning and policy instruments that promote the rapid roll-out of electric cars and support modal shifts toward public transit, cycling and walking. The Nordic Energy Technologies Perspectives 2013 report projected a reduction from today's 80Mt of Nordic transport CO2 emissions to just 10Mt in 2050 in order to meet Nordic climate targets (IEA/NER, 2013). Cities can lead this reduction as their larger populations, higher population densities, and shorter commuting distances make them well suited to key technologies such as EV charging infrastructure and public transport systems. In 2050, according to the report's 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.

Figure 11.12 shows the spatial distribution of Nordic energy production per capita, by volume and by source type. A number of issues and patterns are evident. First and foremost, we see the high amount of electricity being produced for the five nuclear facilities in the Nordic Region. While Finland pushes ahead with new reactors, Sweden recently announced the early closure of certain reactors due to high costs and low power prices, painting an uncertain picture for the nuclear sector going forward. Second, a substantial volume of hydro-electricity is produced in southern Norway, throughout Iceland, Northern Sweden and Northern Finland. As a result, over half of Nordic electricity is produced from hydropower. With limited potential for the further development of hydropower however, wind represents a more likely area of future potential for the Nordic Region. Figure 11.12 shows some impressive results in terms of the production of wind power at the regional level. Regional wind power production has been strengthened in the past three years

Figure 11.9: **Nordic energy consumption by sector in 2012**

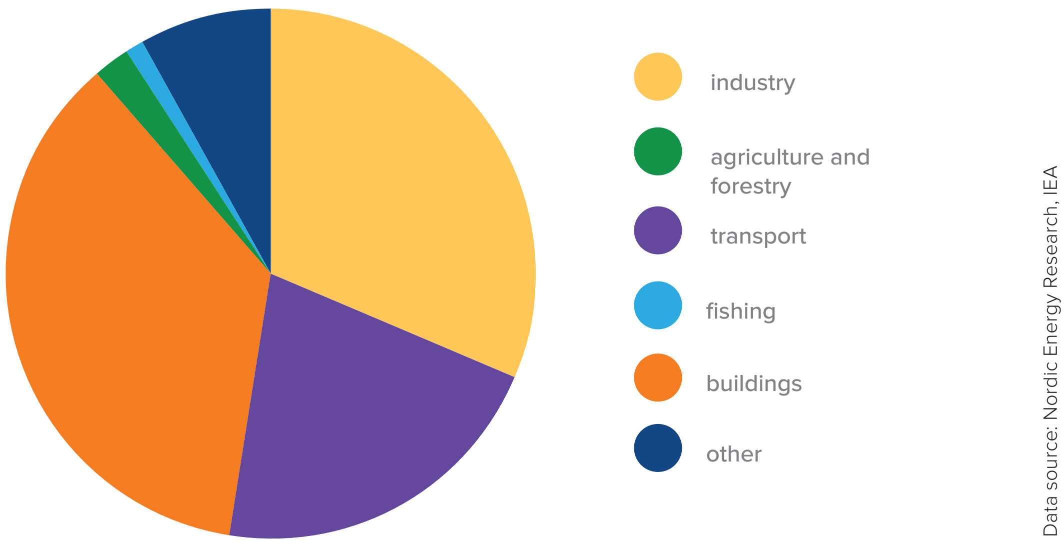
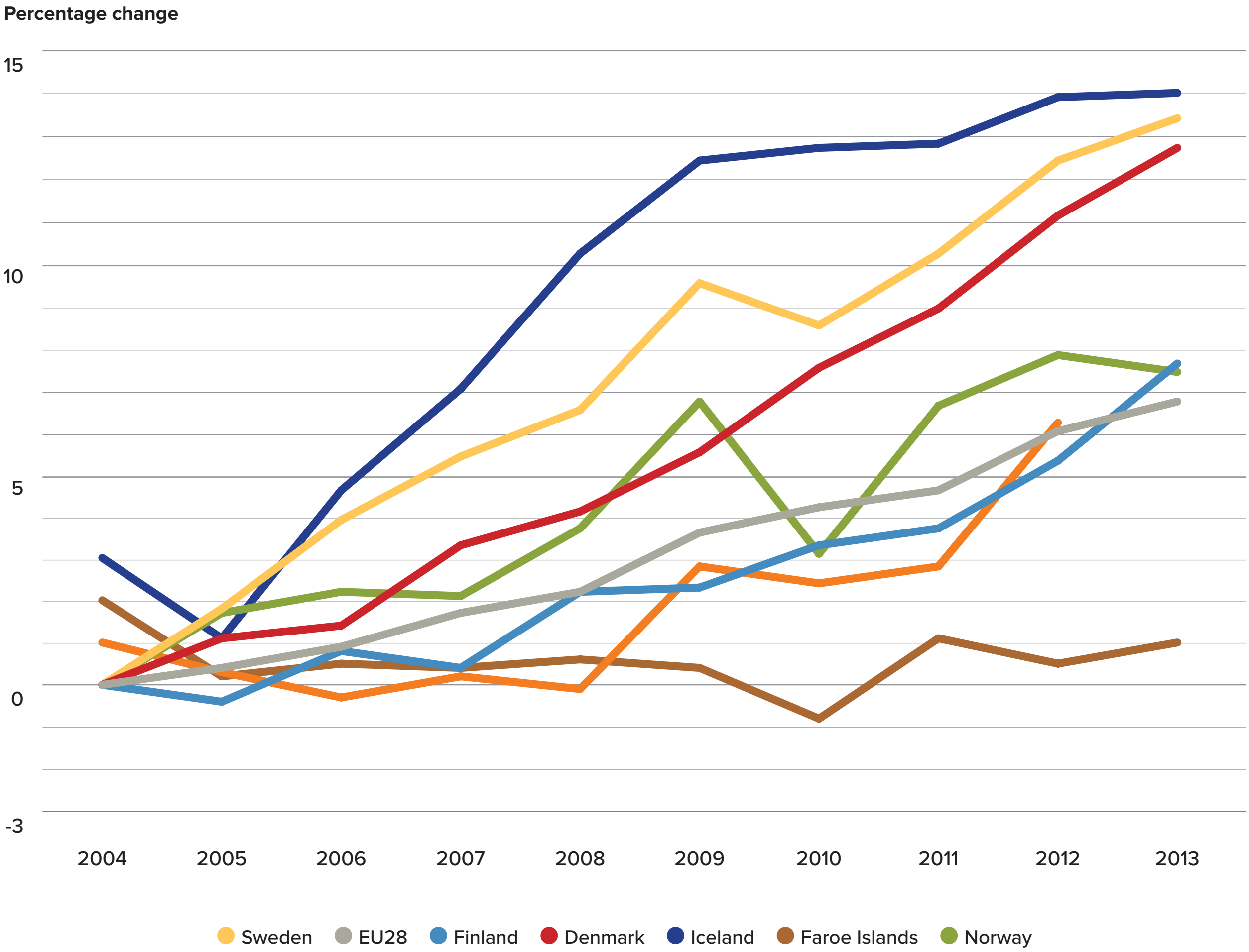


Figure 11.10: Trends in the share of renewable energy in final energy consumption, 2004-2013



Data source: Eurostat, NSI's and Jarðfeingi. Note: Finland: Includes Åland. Faroe Islands: energy use for international transport not included

throughout much of Denmark, Sweden, and to a lesser extent in Norway and Finland. Low power prices have however significantly impacted the wind sector too, leading to a slowing of deployment across the region in 2015.

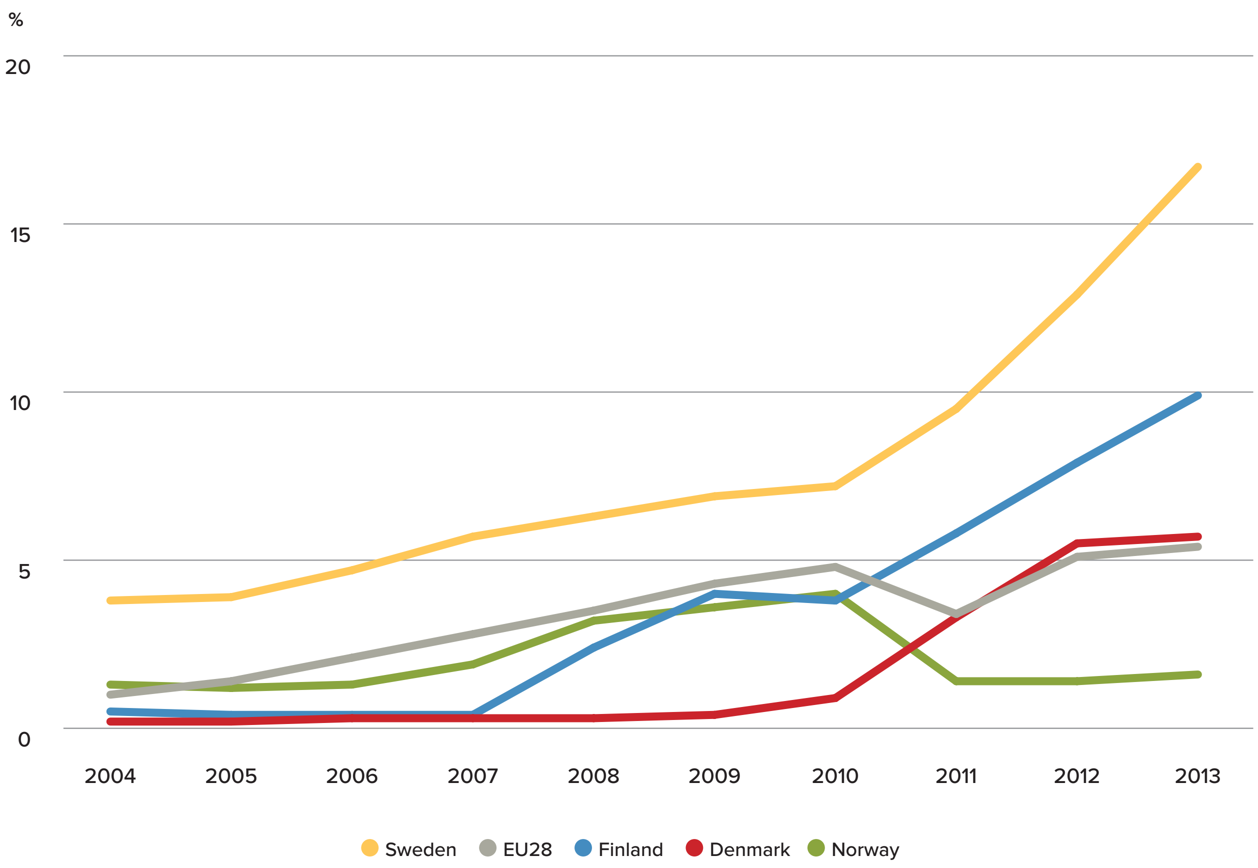
Despite the current lull in wind power investment, Nordic wind energy potential is undeniably significant. Nordic Energy Research has recently produced a new map that combines different data sources for each technology to indicate the areas of the Nordic Region that have the highest theoretical potential for various renewable energy sources. Figure 11.13 shows the potential for off-shore wind energy development throughout much of the coastal areas of the Nordic Region, and that the best solar resources are in Denmark and the capital regions of Sweden and Finland.

Trade: Nordic countries rely on each other

Significant electricity trade flows are evident between all Nordic countries with especially large flows between Norway, Sweden and Finland in 2014. Figure 11.14 shows the flow of electricity between trading regions in 2014, with hydropower transmitted from the west coast of Norway to Oslo in the east, and from central Sweden south to Stockholm. The Nordic Region is also a net exporter of electricity southwards to the European continent. The figure also shows the relatively small role that Russia plays in the Nordic electricity market compared to previous years, as Finland now imports less from Russia and depends more on trading with Sweden. From 2016 a new cable between Sweden and Lithuania will begin operation, and new cables from Norway to Germany and the UK are expected to come online in 2018 and 2020 respectively. If interconnection infrastructure is built out further, Nordic exports of clean electricity to the continent could increase significantly towards 2050.

In the Nordic Region we have wide differences, with some regions or countries being heavy net importers of energy to meet their demand (Denmark for instance), while others export a large share of their produced energy on international markets (e.g. Norway). Iceland,

Figure 11.11: **RES development in transport in selected Nordic Countries**



Data source: Eurostat. Note: Finland: Includes Åland. Faroe Islands, Greenland and Iceland: No data. Data missing and assumed for Finland in 2011 and 2012

with its energy-intensive refining of foreign raw materials into immediately exported goods can also be seen as a heavy exporter of energy, even though it may not appear this way in the statistics.

The Nordic Region has the world's most integrated international electricity market, enabling the optimisation of each country's diverse resources. Nordic electricity grid integration also provides security of supply against uncertainties. These uncertainties include annual variation in precipitation affecting hydropower reservoirs, unusually cold winters leading to increased heating demand, maintenance of 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 the construction of its newest 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.

Market integration through a well-developed network also allows for the region to benefit from its significant variable renewable energy sources, where production is dictated by short-term changes in the weather. Figure 11.15 shows the share of gross electricity production coming from wind, solar and ocean power for selected countries. Denmark's high share of wind is evident, covering upwards of one third of its electricity production. Germany's deployment of wind and solar options gives it a total of around 15% for variable renewables, while Sweden and the UK have seen recent surges in wind power.

The higher the share of variable renewables, the greater the need for flexibility in the electricity system. Denmark is connected to Norway and Sweden by subsea interconnector. Under windy conditions, Denmark exports to Norway and Sweden. Under calm conditions, Denmark imports hydropower from these countries. Without this flexibility, the cost of wind power integration in Denmark would have been higher and the system less efficient.

The Nordic Region can further capitalise on its potential to supply clean electricity to Europe by making the common Nordic grid even stronger and more flexible. For example, the significant wind build-out expected in the Nordic Region will require additional infrastructure

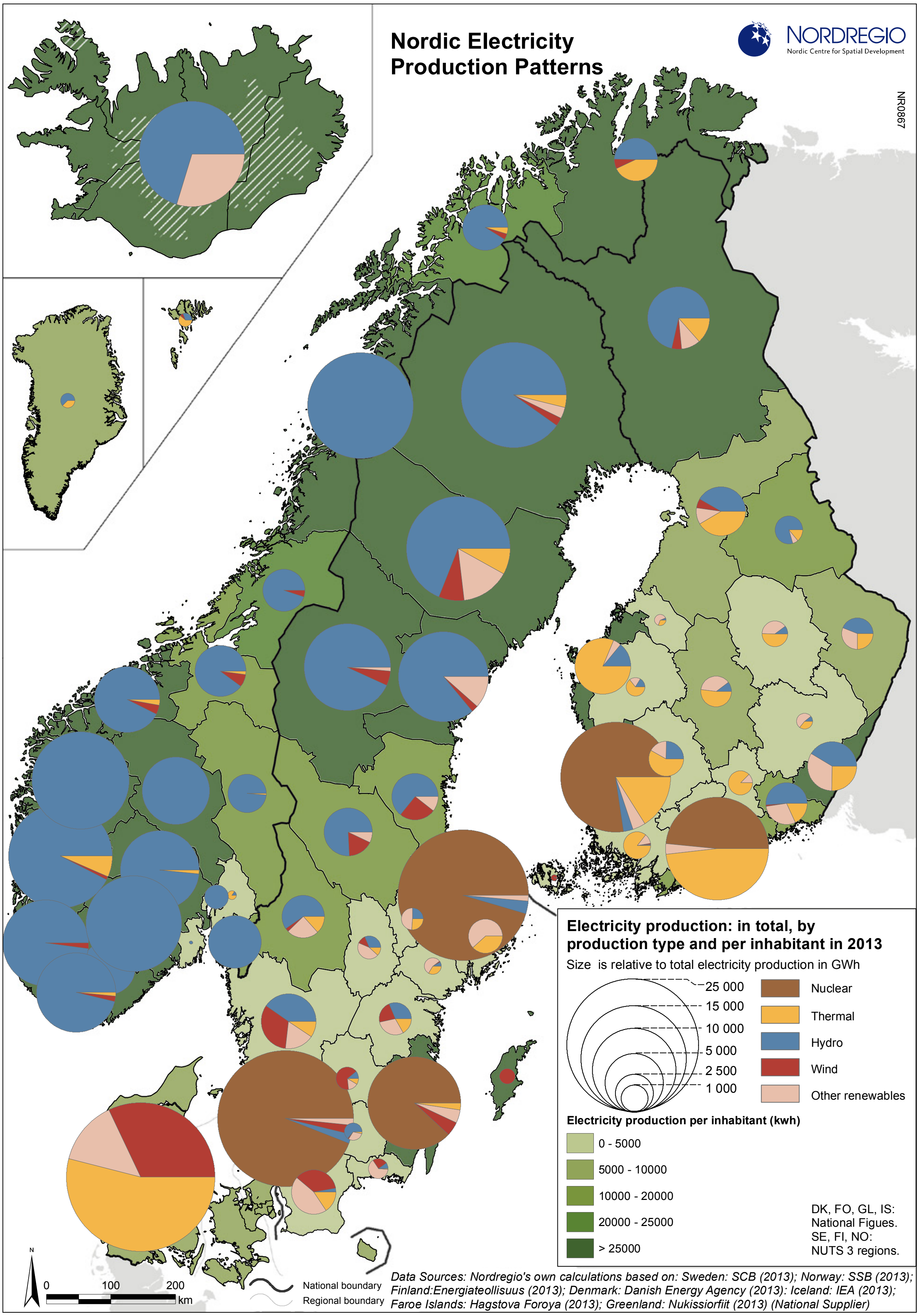


Figure 11.12: Nordic electricity production pattern: by volume (per capita) and by source groups in 2013

Figure 11.13: **Nordic Renewable energy potential**

SOLAR

The yellow coloured triangles on the renewable energy map indicate areas with a relatively high solar irradiation for the Nordic region – specifically a yearly sum of global irradation above 1150 kWh/m², measured at an optimal fixed inclination.

- EC. 2012. PVGIS. RE.JRC.EC.EUROPA.EU/PVGIS

GEOTHERMAL

The red coloured triangles on the renewable energy map indicate areas with high geothermal potential. This is defined as a heat flow density above 80 mW/m²

- EC. 2002. ATLAS OF GEOTHERMAL RESOURCES IN EUROPE. GOO.GL/BTKDC6 GOO.GL/96GVVO

WIND

The blue colour indicates areas with an average wind speed above 6 m/s at hub height. This is averaged over the period 2000-2005, at 80 m above ground level for onshore and 120 m for offshore, and corrected for orography and local roughness. Data for offshore areas is incomplete. A seperate dataset was used for Iceland, with measurements at 100 m above ground level.

- EEA. 2009. EUROPE'S ONSHORE AND OFFSHORE WIND ENERGY POTENTIAL. P.14. GOO.GL/JC9HFR
- IMO. 2013. THE WIND ENERGY POTENTIAL OF ICELAND. P.27. GOO.GL/XTNYBK

HYDROPOWER

Politically, the greatest potential for increased hydropower generation in the Nordic region is through the upgrading of existing infrastrucutre.

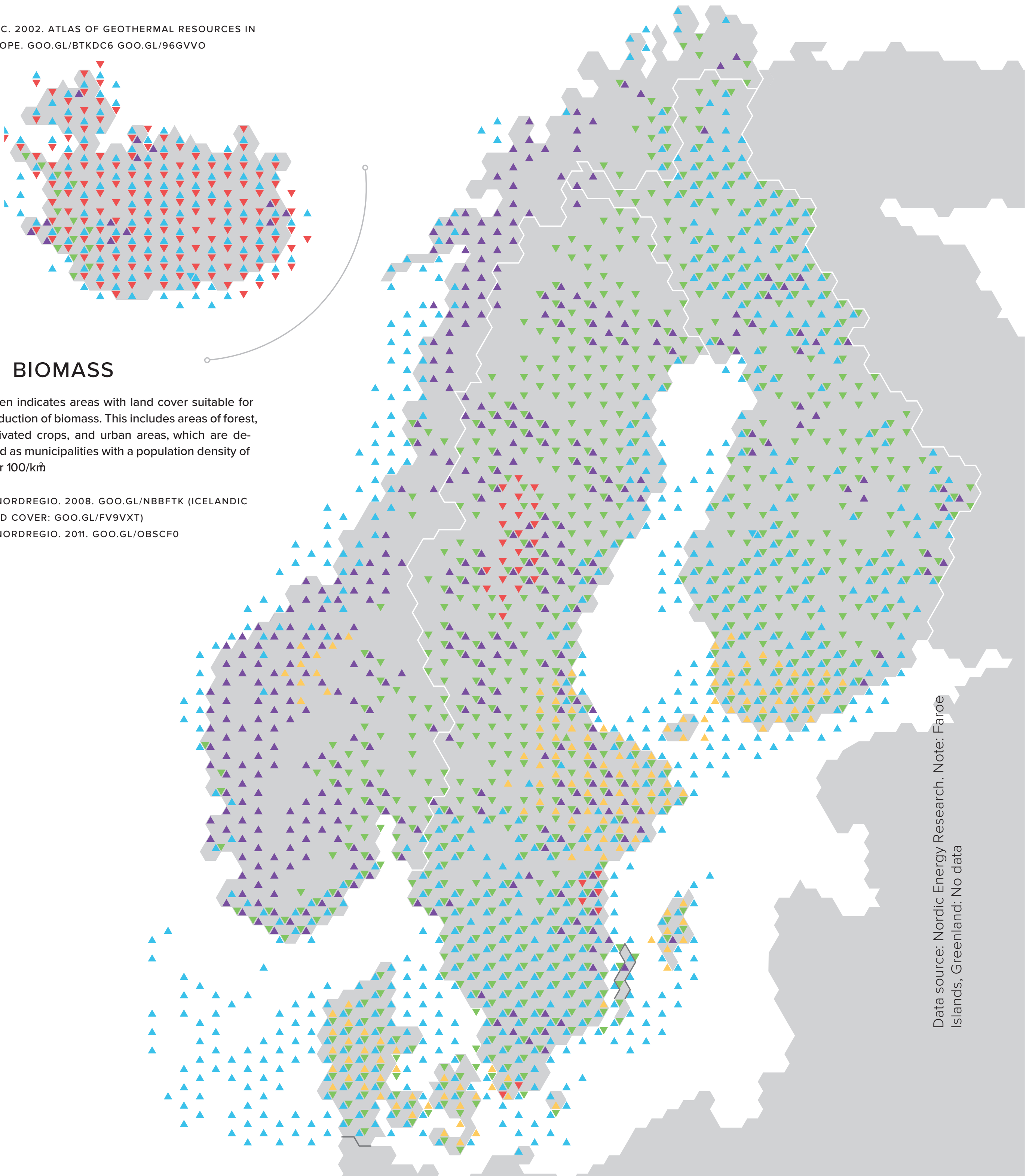
The purple coloured triangles on the above map are indicating areas with existing hydropower installa tions in 2005 over 0,1 MW.

- LEHNER ET AL. 2005. THE IMPACT OF GLOBAL CHANGE ON THE HYDROPOWER POTENTIAL OF EUROPE. ENERGY POLICY. P.839-855. GOO.GL/UE2B5L

BIOMASS

Green indicates areas with land cover suitable for production of biomass. This includes areas of forest, cultivated crops, and urban areas, which are defined as municipalities with a population density of over 100/km²

- NORDREGIO. 2008. GOO.GL/NBBFTK (ICELANDIC LAND COVER: GOO.GL/FV9VXT)
- NORDREGIO. 2011. GOO.GL/OBSCF0



Data source: Nordic Energy Research. Note: Faroe Islands, Greenland: No data

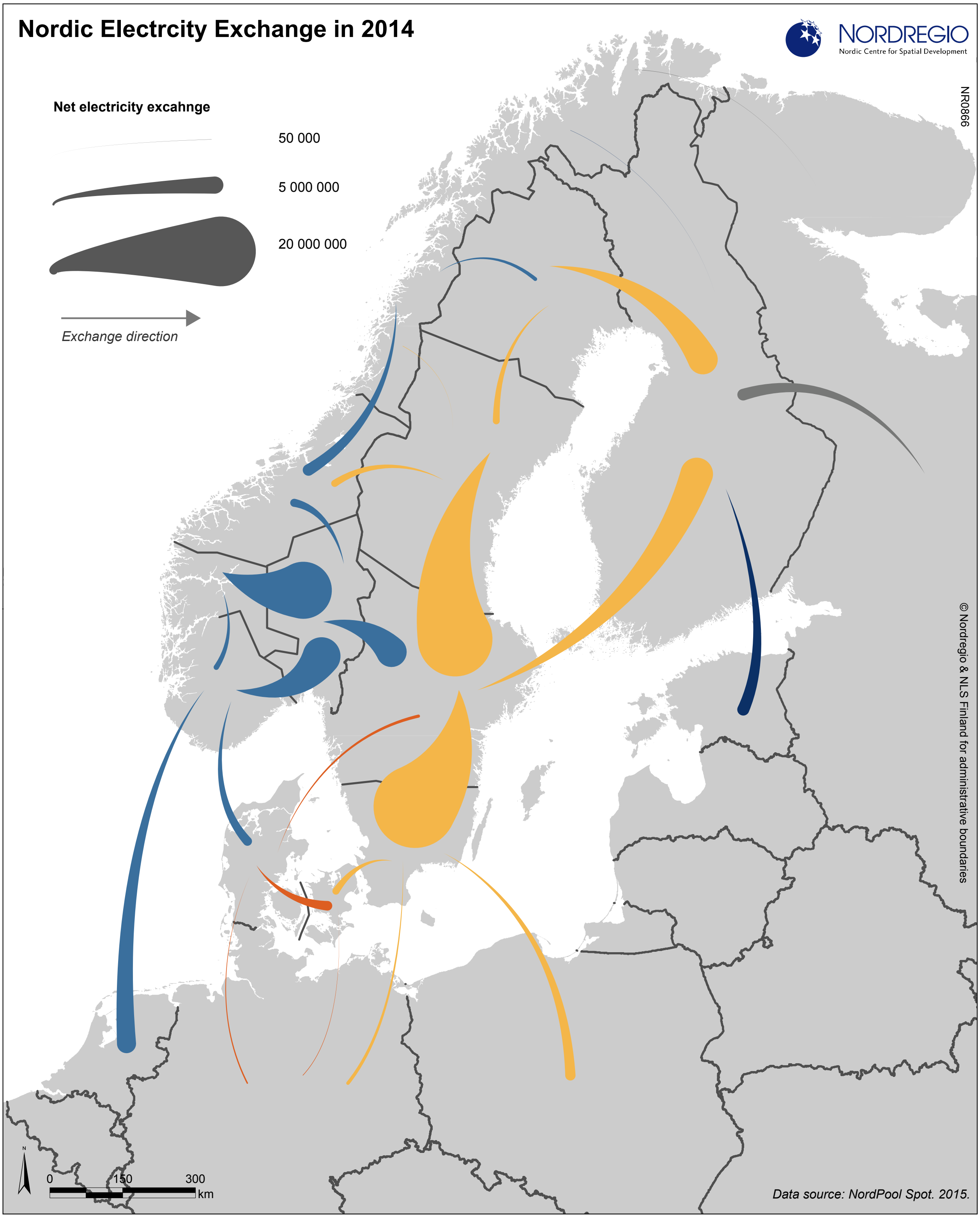
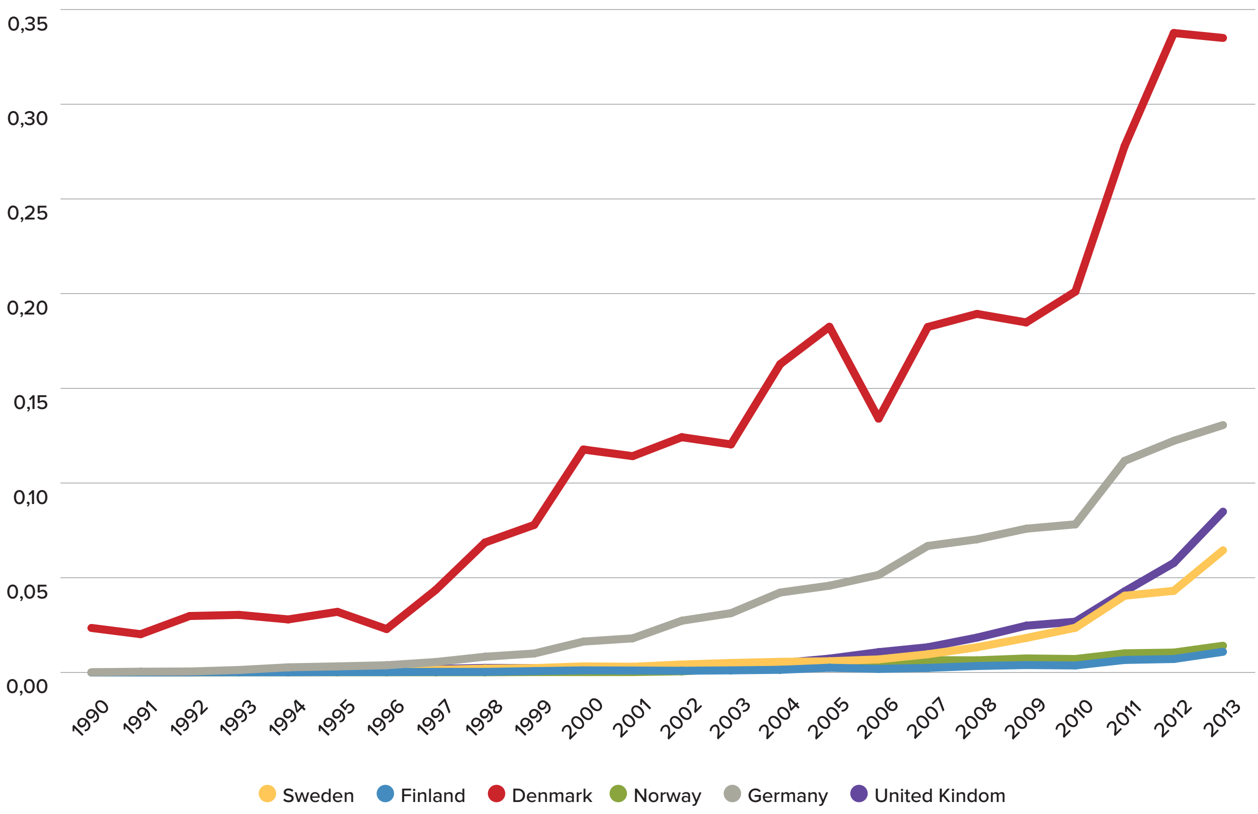


Figure 11.14: Nordic electricity exchange in 2014: net annual electricity trade flows between price zones in the Nordic Region and adjacent countries for 2014. The Nordic countries were net exporters in 2014, but much greater flows are evident within the Nordic countries, moving hydroelectric power from mountainous regions to major cities Note: Faroe Islands and Greenland: No data

Figure 11.15: **Share of variable renewables in gross electricity production**



Data source: Eurostat. Note: Finland: Includes Åland; Iceland, Greenland and Faroe Islands: No data

Share of variable renewables in gross electricity production: electricity production from variable renewables (wind, PV solar, ocean) as a share of gross production. Denmark's large share of wind power and Germany's wind and PV solar have necessitated measures in those countries to balance the weather-dependent production output from these technologies.

in order to be integrated efficiently. 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 forthcoming second edition of Nordic Energy Technology Perspectives 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).

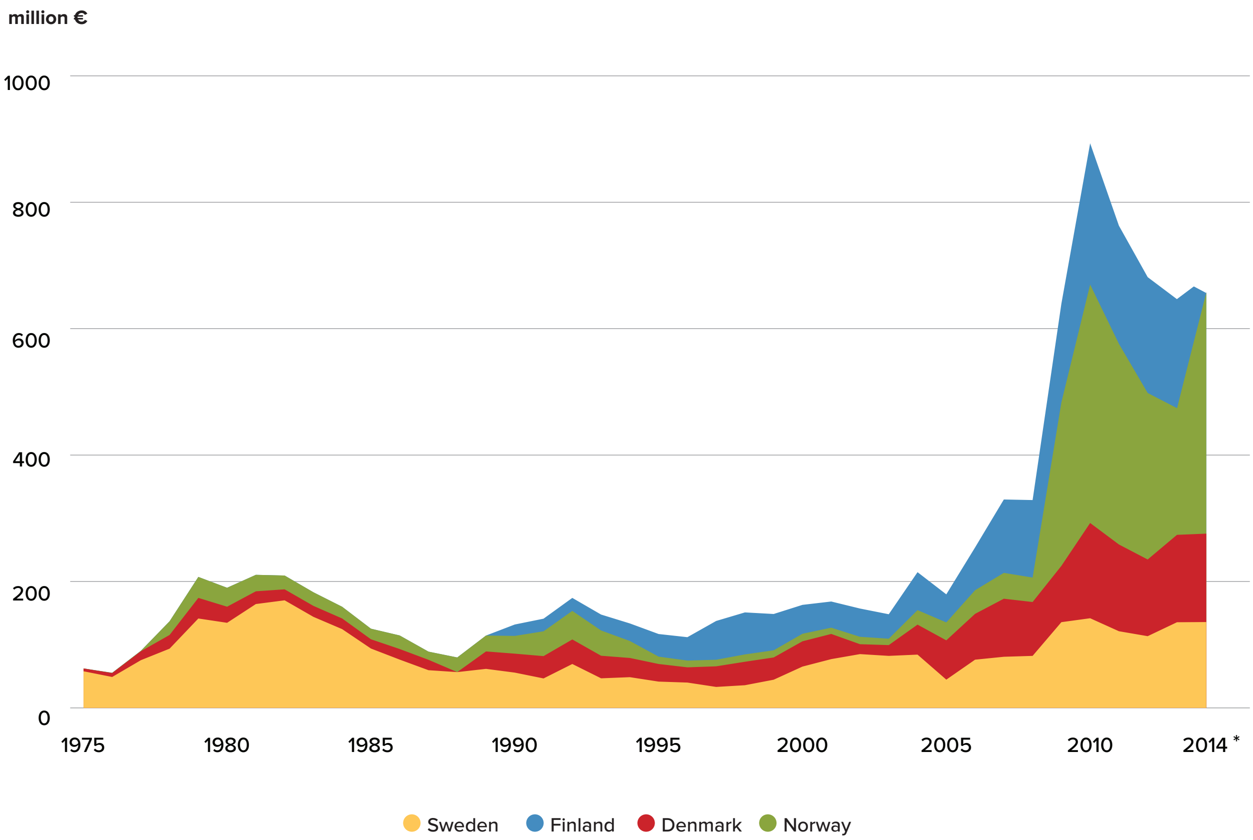
Funding strong for clean energy solutions

Public funding for non-nuclear low-carbon Research, Development and Demonstration (RD&D) in the Nordic countries has increased dramatically in the last decade. While these statistics are affected by allocation issues and do not account for private investment in RD&D, they paint a clear picture of the focus of Nordic governments on accelerating clean energy technology development. After decades of support at levels below its neighbours, Norway has emerged as the largest funder of low-carbon RD&D in recent years due in the main to two very large demonstration projects in CCS and aluminium smelting. The technology areas currently receiving the most support across the Nordic Region are energy efficiency and bioenergy.

Nordic cooperation is key to future energy development

The Nordic Region has emerged as a leader in many aspects of the global transition to cleaner energy systems. While 2014 may have seen the first global decoupling of GDP from energy-related CO2 emissions (IEA, 2015), the Nordic Region has exhibited a steady decoupling for almost 20 years.

Figure 11.16: **Public research and development investment budgets in low carbon energy sources**



Public research and development investment budgets in low carbon energy sources. Norway's significant increases in the last decade stem mainly from support of CCS technologies.

A strong Nordic electricity market and grid integration enhances efficiency and security of supply. This has allowed, for example, Denmark to integrate the world's highest share of variable renewables into its electricity system in an efficient manner.

Ambitious, long-term and stable policy frameworks have been the key to achieving this leading position. All five Nordic countries have used policy frameworks actively to decouple GDP from CO2, with carbon taxes and renewable energy incentives among the most effective examples.

However, there are a number of opportunities to further decarbonise the Nordic energy system. 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 more flexible. The significant wind build-out expected in the Nordic Region will require additional infrastructure in order to be integrated efficiently.

CO2 emissions from transport must be decoupled from rising demand for transport services if climate targets are to be met. 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 road, sea and air transport.

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.

Lastly, Nordic cooperation can reduce the cost of achieving national climate targets. According to the IEA (IEA/NER, 2013), the potential for cooperation is high in RD&D, infrastructure and policy development. Technologies with high cooperation potential include offshore wind, biofuels, CCS and the electricity grid.