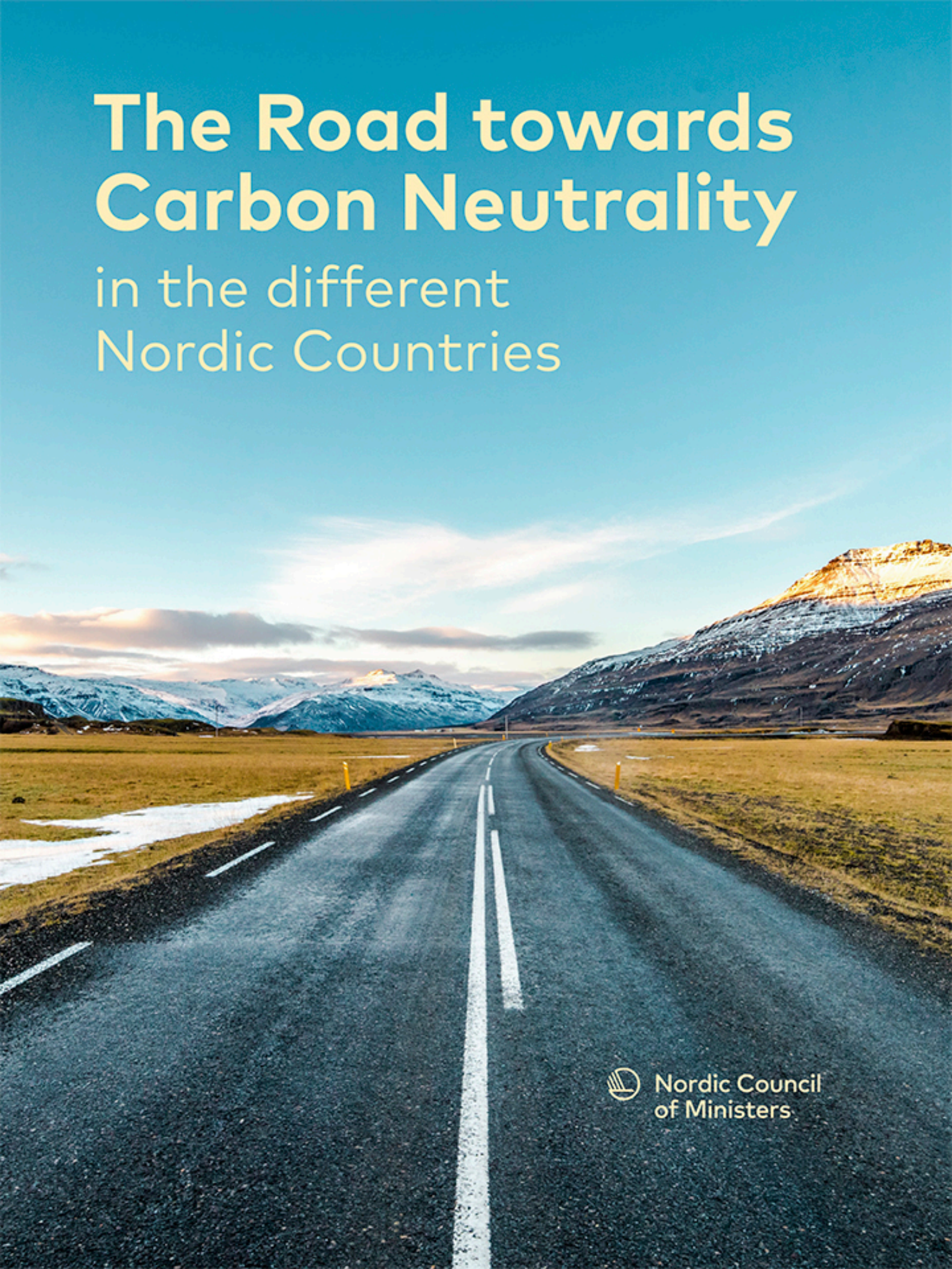
# The Road towards Carbon Neutrality

## in the different Nordic Countries



Nordic Council of Ministers

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# PREFACE

The Nordic countries have agreed to an ambitious vision for 2030 for the Nordic Region; that the Nordic region will become the most sustainable and integrated region in the world by 2030.

All of the five Nordic countries, Denmark, Sweden, Norway, Finland and Iceland, have set national goals for carbon neutrality before or by mid-century. In 2020, under the Helsinki Declaration on Carbon Neutrality, the Nordic countries committed themselves to assessing the scenarios for how to achieve their respective carbon neutrality goals. This report contributes to making this assessment possible and to highlight areas where Nordic cooperation and initiatives can support the road towards carbon neutrality in the Nordic countries.

The project was launched in February 2020 and data collection ended in April 2020. The project has been undertaken by Ramboll Management Consulting, Gaia Consulting and Environice in close dialogue with the Nordic Working Group for Climate and Air (NKL).

Project activities include stakeholder interviews and workshops with a variety of sector representatives and public stakeholders across the five countries. This has benefitted the insights on existing and planned sector efforts in the different Nordic countries.

It should be emphasized that this report has largely been produced during the outbreak of the COVID-19 crisis. Therefore, it has not been possible to integrate this impact in the report. The Nordic business communities have, at the time of writing, not adjusted their sector roadmaps, nor has the impact in terms of reductions in GHG emissions across sectors been assessed. All Nordic governments have, however, declared in various contexts to incorporate thinking about green transition as an engine of recovery.

The outcome of this project is expected to provide knowledge on where Nordic cooperation could support mutual efforts on further GHG reductions, enhancing carbon sinks and omission of GHGs from the atmosphere.

The Nordic Council of Ministers will assess the recommendations outlined in this report and discuss how they could be addressed going forward towards Nordic Carbon Neutrality, contributing to the vision of a Green Nordic region.

In parallel to this report, Nordic Energy Research is undertaking a project Nordic Clean energy Scenarios 2020. It will provide scenarios for how the Nordic energy sector can reach carbon neutrality in compliance with the goals established by the Paris Agreement.

August 2020

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# EXECUTIVE SUMMARY

This study identifies joint challenges in reaching carbon neutrality in the Nordic countries and highlights sectors and potential activities where enhanced Nordic cooperation could contribute to the fulfilment of the carbon neutrality goals, in line with the Nordic prime ministers' 2019 Declaration on Nordic Carbon Neutrality.

The results have been reached through a combination of desk reviews, expert analyses as well as stakeholder consultations of existing and planned national efforts to reduce greenhouse gas emissions (GHG emissions) in each Nordic country. The data collection ended in April 2020. Taking into account different starting points and framework conditions, the study has identified a number of best practices and common challenges, where a strengthened Nordic cooperation could support mutual efforts towards further reductions of greenhouse gas emissions.

Each Nordic country has or is in the process of defining roadmaps as input for their national plans. In Norway, new sector roadmap proposals have been published in January 2020. In Denmark and Sweden, new sector roadmap proposals have been published in March 2020. Finland will publish comprehensive sector roadmaps in June 2020. Iceland has established a cooperation platform, but not published specific sector roadmaps.

The contents of the roadmaps as well as the definitions of carbon neutrality vary. While Norway aims at achieving climate neutrality in 2030, Finland is planning to reach carbon neutrality in 2035, Iceland in 2040 and Sweden in 2045. Denmark aims to reach net zero emissions by 2050, but with ambitious reduction targets of 70% in 2030. Rather than indicating different levels of ambitions, the targets reflect the individual methods in accounting GHG emissions. For example, for some of the countries, carbon neutrality is defined as reductions within own territory, while others allow for the use of international mechanisms in offsetting the country-specific emissions. However, regardless of the choice of method, comparison of sector efforts is highly valuable and fruitful from the perspective of sharing good practices and enabling joint Nordic learning.

The study identifies challenges and opportunities for joint activities in key national sectors[1], including energy, transport, mineral and metals, waste, forest and agriculture and construction. The study recognizes a plethora of overlapping efforts across Nordic sectors, many of which would gain from increased Nordic collaboration. Also, the interviews and workshops held show a high degree of interest in working closer together at a Nordic level. This is especially by increasing collaboration on research and development, knowledge sharing and establishing new working groups on specific themes.

By clustering the most promising joint activities in terms of contribution to the sector carbon neutrality efforts, the recommendations for joint Nordic actions are the following:

1. Rather than following the common reporting form (CRF) (as used by the UNFCCC), the sectors are following a pragmatic division, reflecting the economic sectors and business roadmaps across the Nordics.

**Nordic platform on sustainable transportation solutions**

Sustainable and advanced liquid biofuels for transportation has long been a focus of Nordic Energy Research and other Nordic working groups. However, a higher degree of joint activities with the private sector across the Nordics would benefit the collaboration and ensure a better cross-Nordic dissemination of the results.

Besides development of biofuels, other joint collaboration potentials within sustainable transportation exists. This includes cross-Nordic sector collaboration on inter alia sustainable freight solutions, intermodal solutions and electric charging infrastructure. Furthermore, a cross-Nordic dialogue could contribute to a revision of the funding selection criteria of the Nordic funding mechanisms.

Policy recommendations for joint collaboration:

- NCM should support the development of a cross-Nordic sector collaboration on sustainable biofuel production in close collaboration with Nordic Energy Research. This could be implemented by:
    - Establishing a Nordic sector platform with participation from relevant sectors, including energy, agriculture, forestry and transportation. The platform should cluster collaboration on specific themes, including inter alia sustainable freight solutions, intermodal solutions and electric charging infrastructure.
    - Identifying studies, support pilot projects and disseminate knowledge from second generation biofuels and the development of electro fuels.

**Nordic public/private sector platform on Power-to-X**

Nordics have a great opportunity for collaborating on common solutions and standards, including collaboration on R&D and testing plants for Power-to-X (PtX) technologies.

Policy recommendations for joint collaboration:

- NCM should support the collection and dissemination of new knowledge and best practices on PtX technologies in close collaboration with Nordic Energy Research. This could be implemented by:
    - Establishing a Nordic public/private sector platform with participation from relevant sectors (including energy and transportation).
    - Identifying and supporting new studies focusing on PtX solutions and operation strategies.
    - Organising sector dialogue meetings on new promising solutions for PtX.
- Follow-up on the ongoing study by Nordic Energy Research that identify PtX sites, by identifying resources that can enhance R&D and demonstration of PtX solutions. Priority should be given to solutions matching the national plans for expansion of renewable electricity production, including new offshore technologies such as floating technology hubs for wind.
- Encourage national governments to provide additional funding for Nordic participation and knowledge dissemination on international PtX projects outside Norden.

**Nordic public/private sector platform on CCUS technologies**

Nordic collaboration could support the Nordic energy and construction sectors by ensuring that the newly (in 2020) established Nordic Networking group on Carbon Capture, Use and Storage (NGCCUS) focus on facilitating collaboration on joint infrastructure, including the establishment of a Nordic CO2-storage hub and sector-driven taskforces on CCUS and BECCS technologies in the respective sectors.

Policy recommendations for joint collaboration:

- Nordic Networking group on Carbon Capture, Use and Storage (NGCCUS) and Nordic Energy Research should establish a cross-Nordic public/private sector initiative to:
  - Develop recommendations for the establishment of aligned national framework conditions for CCS infrastructure, research and funding across the Nordics. This includes the identification of regulatory solutions for international shipping of captured CO2.
  - Explore possibilities for developing Nordic auction for negative emissions.
  - Collaborate internationally for emission allowance corresponding to the negative emission of CCS on fossil-free fuels.

**Joint initiative on removal of emissions from peatlands**

GHG emissions from peatland is one of the most important steps for the agricultural sector in reaching carbon neutrality. The agricultural sector would gain from Nordic collaboration on research. More specifically this should be on the effects of rewetting, the dissemination of results regarding soil emission factors, and the identification of the right conditions for transforming agricultural land into alternative land use.

Policy recommendations for joint collaboration:

- NCM is recommended to convene a workshop in collaboration with the Nordic agriculture sector to establish a forum for exchanging and disseminating knowledge regarding:
  - rewetting and conserving peatlands.
  - economic perspectives of alternative land use and soil emission factors.

**Enhance research and development**

Many other research initiatives are already identified in various Nordic working groups. For example, Nordic Energy Research has identified priorities for joint Nordic research based on thorough engagement with stakeholders. Some of these are also mentioned in this study.

During the research for this study, construction sector representatives have explicitly requested assistance for the development of alternative climate neutral building and packaging materials, including the innovation of biocement and bioplastics. One way to support this is creating a better data foundation. Additionally, research collaboration on smart controlling technologies would also create much value added. Furthermore, the energy and waste industries need increased R&D on heat solutions to enhance the utilization of waste in district heating.

Policy recommendations for joint collaboration:

- Convene a meeting with key Nordic institutions and working groups (e.g. Nordic Working Group on Climate and Clean Air, Nordic Working Group for Environment and Economy, Nordic Working Group for Green Growth, Nordic Energy Research), to identify measures for supporting the cross-Nordic research and development of new technologies with a high impact on GHG emission reductions. The meeting should inter alia explore and clarify possibilities for mobilizing funding and establishing networks to support the development of alternative climate neutral construction and packaging materials, including the innovation of biocement and bioplastics. In addition, the meeting should support the development of heat solutions to enhance the utilization of waste in district heating and research collaboration on different electrification technologies within the construction sector.
- Organise a cross-Nordic workshop for core stakeholders in the Nordic construction sector exploring the possibilities for establishing/aggregating a joint Nordic database with comparable inventory data on the CO2 footprint of materials available on the Nordic market.
- Establish a Nordic sector platform to help the food industry to design recyclable and low carbon efficient packaging, including dairy packaging. The platform should focus on solutions to replace plastics in the food industry, and support to research, development and testing of new promising packaging materials.

**Perspectivation**

Besides the immediate recommendations, the following observations can be made from the study:

1. The national roadmaps and partnerships with the sectors are cornerstones for the Nordics to reach carbon neutrality.
2. There is a lack of awareness and knowledge on Nordic best practices, and past and current sector efforts, amongst sector representatives across the Nordic sectors.
3. Common ambitions and partnerships are windows of opportunity for Nordic-wide sector collaborations and dialogues on carbon neutrality.

The study has been produced during the outbreak of the COVID-19 crisis, between February to June 2020. It has not been possible to include an analysis of the impact of this crisis on the countries' road towards carbon neutrality, as the impact on sector efforts has yet to be assessed. The Nordic governments have however indicated that low carbon development is likely to be part of the engine of recovery.[2] This could indicate a need for Nordic collaboration to explore activities that identify the impacts of the COVID-19 on the carbon neutrality pathway.

2. See for example: https://www.norden.org/en/news/nordic-ministers-call-post-corona-synergies-between-economic-recovery-and-green-transition

# 1. NATIONAL ROADS TOWARDS CARBON NEUTRALITY

Across the Nordic countries, overall targets for carbon neutrality vary. Norway aims to achieve climate neutrality in 2030, Finland aims for zero net emissions in 2035, Sweden in 2045 and Denmark in 2050. Iceland aims for carbon neutrality in 2040. These targets include various sub goals. Most central are that Denmark aims for 70% reduction in GHG emissions in 2030 compared to 1990 levels, Sweden 63%[3], Finland 55%, Norway 50 towards 55% (NDC), and Iceland 40%.[4] All Nordic countries seek cooperation with or are part of the EU and participate in the European Union Emissions Trading System (EU ETS).

Each of the Nordic countries has a unique definition and interpretation of "carbon neutrality". For some of the countries, carbon neutrality is defined as reductions on own territory, while others allow for the use of international mechanisms in offsetting national emissions.

The Land Use, Land Use Change and Forestry (LULUCF) sector may also affect the Nordic carbon neutrality targets. LULUCF exerts strong impacts on national GHG emissions, since land resources and activities, such as forestry and land use change, can add or remove significant amounts of GHG emissions. LULUCF is a major net sequester of carbon in Sweden, Norway and Finland, primarily due to extensive forest land, while augmenting total GHG emissions in Denmark and Iceland. Due to complex accounting methodologies and national differences regarding of LULUCF, the following overview presents the national GHG emissions without LULUCF.

Table (1) below provides an overview of the overall GHG emission targets, total GHG emissions without LULUCF, the countries' GHG mitigation commitments and the status of the reduction efforts relative to the 1990 level.

3. By 2030, emissions in Sweden within the sectors covered by the EU Effort Sharing Regulation should be at least 63% lower than in 1990.
4. By 2030, emissions in Iceland within the sectors covered by the EU Effort Sharing Regulation should be at least 40% lower than in 1990.

**Table 1 National roads towards carbon neutrality**[5]

| Denmark | Sweden | Norway | Finland | Iceland |
|---|---|---|---|---|
| 2050: Zero net emissions<br><br>2030: Gross GHG emissions shall decrease 70% relative to 1990<br><br>The reductions must be made on Danish territory<br><br>Total GHG emissions 2018 without LULUCF: 48.2 Mt CO2eq | 2045: Zero net emissions<br><br>2040: GHG emissions shall decrease at least 75% relative to 1990<br><br>2030: Gross GHG emissions shall decrease at least 63% relative to 1990<br><br>GHG emissions covered by the EU ETS are not included in the intermediate targets<br><br>Total GHG emissions 2018 without LULUCF: 51.8 Mt CO2eq | 2030: Climate neutrality<br><br>2030: GHG emissions shall decrease 50 towards 55% relative to 1990<br><br>From 2030 onwards Norwegian GHG emission surpluses shall be compensated by GHG mitigations in other countries through flexible mechanisms and the EU ETS<br><br>Total GHG emissions 2018 without LULUCF: 52 Mt CO2eq | 2035: Zero net emissions<br><br>2030: Gross GHG emissions shall decrease at least 55% relative to 1990<br><br>The 2035 carbon neutrality target is expected to be achieved by national measures only, as a balance of GHG emissions and carbon sinks without the use of international offsets<br><br>Total GHG emissions 2018 without LULUCF: 56.4 Mt CO2eq | 2040: Carbon neutrality<br><br>2030: Gross GHG emissions shall decrease 40% relative to 1990<br><br>Total GHG emissions 2018 without LULUCF: 4.9 Mt CO2eq |

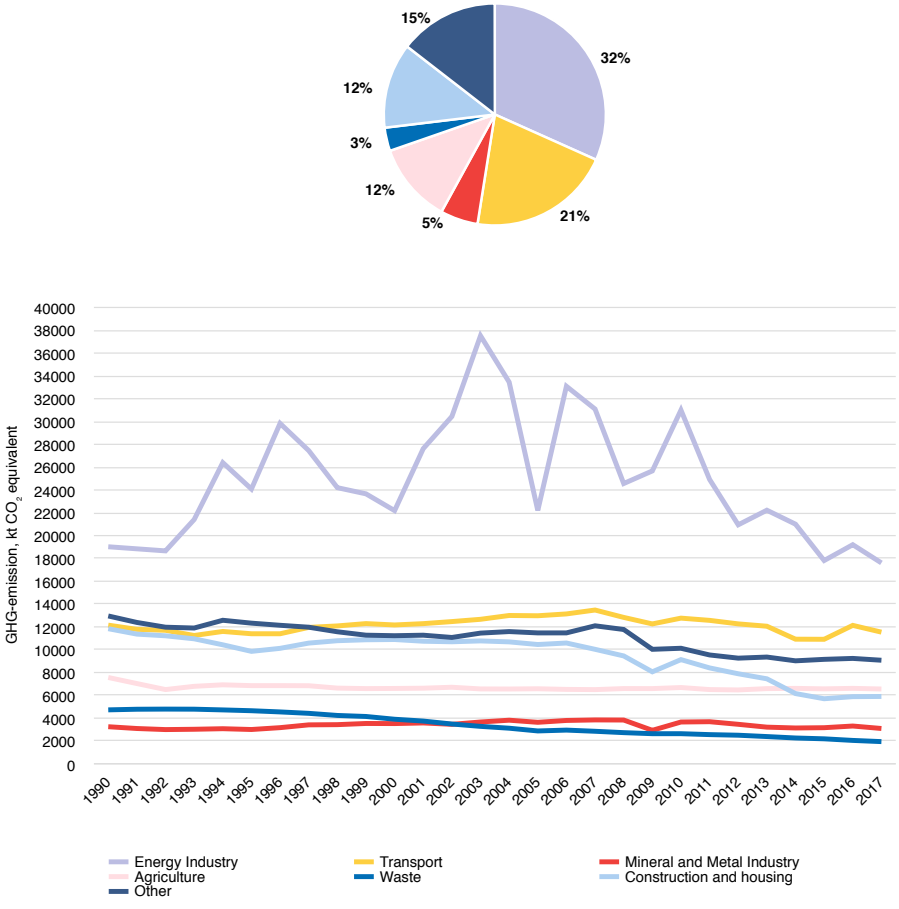
The following five subsections provide a brief overview of each of the national long-term climate strategies as well as governmental goals and plans for the reduction of GHG emissions.

5. Based on National Inventory Reports (NIR) 2020.

## 1.1 Finland

Since 1990, annual Finnish GHG emissions have decreased from 71.1 Mt to 56.4 Mt CO2eq in 2018, corresponding to a 21%[6] reduction. The decrease is mainly caused by reductions in the energy industries which was 7.8% lower compared to 1990. Furthermore, since 1990 emissions from the agricultural sector and the transport sector have remained stable, while emissions from the manufacturing, construction and waste industries have declined. By including LULUCF, national emissions are reduced to 46.1 Mt CO2eq in 2018, lowering the emissions by more than 10 Mt.[7]

**Figure 1. GHG emissions in CO2eq distributed on main sectors for 2017 (excluding LULUCF and indirect CO2) and time series for 1990 to 2017 (UNFCC's GHG emissions by sector). 'Other' cover GHG emissions from UNFCCC subcategories of 'Energy' and 'Industrial Processes and Product Use'.**




According to the 2019 Finnish Governmental Programme, Finland aims to achieve carbon neutrality in 2035 and to be carbon negative soon after that. Carbon neutrality will be achieved by accelerating emission reduction efforts and strengthening carbon sinks. The carbon neutrality target is expected to be achieved by means of national measures only, as a balance of GHG emissions and carbon sinks in 2035, without the use of international offsets. However, the carbon

6. (Statistics Finland, 2020).
7. (Statistics Finland, 2020).

neutrality target will be assessed in 2025, including the potential role of international offsets.  In Finnish legislation, the current Climate Change Act (609/2015) of Finland sets the national long-term GHG emission reduction target at least -80% from 1990 levels by 2050. The long-term target is being reassessed as part of Climate Act amendment.

Also under the Climate Change Act, the Government shall each calendar year submit to Parliament an annual climate report on the trends in emissions and the achievement of emissions reduction targets included in the medium-term plan for climate change policy.[8]

The Finnish Climate Change Panel[9] has calculated that the targeted carbon sinks and also the targeted GHG emissions of Finland could be approximately 21.4 Mt CO2eq in 2035. For reference, Finland's emissions were 56.5 Mt CO2eq in 2018. Therefore, the need for additional emission reductions is approximately -62% or 35 Mt CO2eq from the current level by 2035.

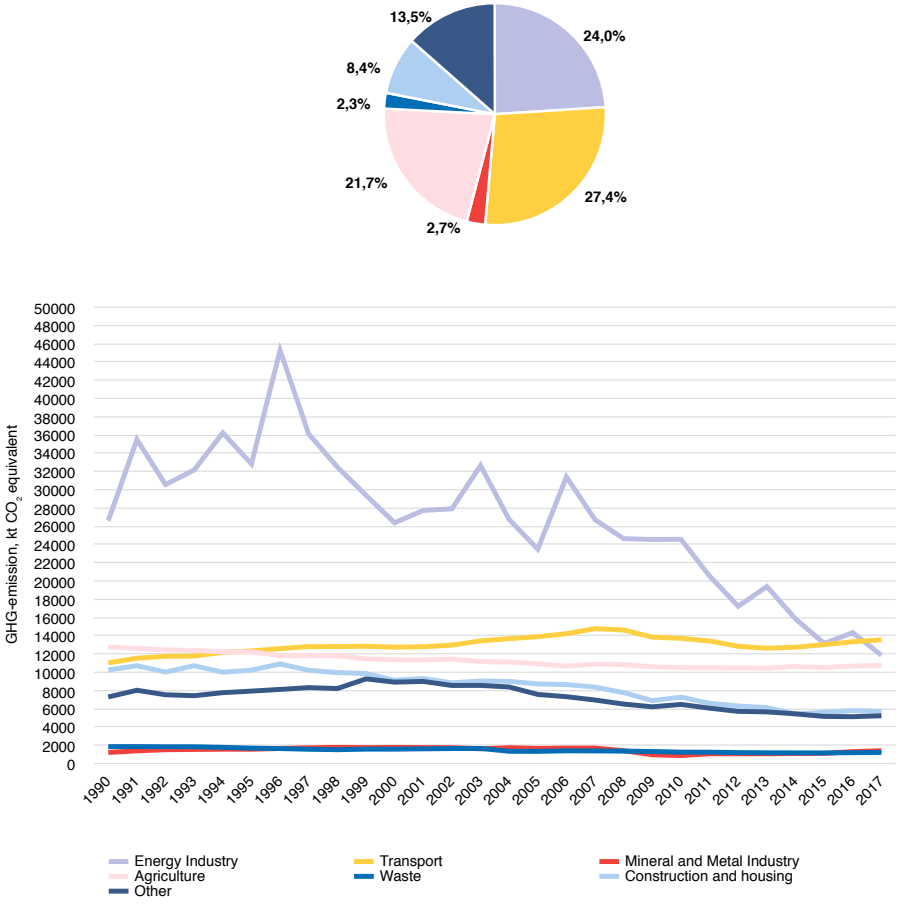
In order to reach the ambitious 2035 carbon neutrality target, The Government of Finland has started the process of amending the current Climate Change Act (609/2015) to update the targets for 2030, 2040 and 2050 and to include the land use sector and enhance carbon sinks into the Act. Also, as set in the Governmental Programme of Finland, all major and important sectors must formulate their own carbon neutrality roadmaps by June 2020.[10]

8. (Ympäristöministeriön, 2020).
9. (Suomen Ilmastopaneeli 2019).
10. (Ministry of Economic Affairs and Employment of Finland 2020).

## 1.2 Denmark

Since 1990, annual Danish GHG emissions have decreased from 75.2 to 48.2 Mt CO2eq in 2018, corresponding to a 32% reduction.[11] Energy industries account for the majority of this decrease, having reduced their emissions with 19 Mt C02eq since 1990 by means of increased use of renewable sources, especially wind. Without additional initiatives it is expected that emissions will drop to 41.5 Mt CO2eq in 2030. In 2020, Denmark expects to fulfil its national EU goal of reducing non-ETS emissions by 20% relative to 2005 and to surpass the annual subgoals, amounting to more than 15 Mt CO2eq in the period.[12] Including LULUCF total GHG emissions increase with app. 6%, primarily due to cropland.[13]

**Figure 2. GHG emissions in CO2eq distributed on main sectors for 2017 (excluding LULUCF and indirect CO2) and time series for 1990 to 2017 (UNFCC's GHG emissions by sector). 'Other' cover GHG emissions from UNFCCC subcategories of 'Energy' and 'Industrial Processes and Product Use'.**




11. (Danish Centre for Environment and Energy, 2020).
12. (Klima- Energi- og Forsyningsministeriet., 2019).
13. (UNFCC 2020).

In December 2019, Denmark adopted a new political agreement that aims to cut emissions with 70% in 2030 relative to 1990 and to reach net zero emissions by 2050 at the latest. Together with the climate act agreement, 13 climate partnerships (Klimapartnerskaber) have been established. The 13 climate partnerships are a collaboration between the Danish government and the Danish business community to realize green transition of society and cut carbon reductions across business sectors. In March 2020, the 13 climate partnerships published their sector roadmaps towards carbon neutrality. In the time of writing, the Danish government is developing Climate Action Plans that will outline concrete policies to reduce sector emissions.

The climate act includes milestone targets based on a five-year cycle. The milestone targets should be specified according to the Paris Agreement, the evolution in climate science, the long-term goal of becoming climate neutral no later than 2050, the 1.5-degree goal and inclusion of the Danish Council on Climate Change (Klimarådet). Every intermediate milestone target goal must be no less ambitious than the previous one, in accordance with the principle of the Paris Agreement regarding no backsliding.[14] In the 2020 Finance Law Agreement, the government and supporting parties agreed to create a DKK 25 billion Green Future Fund. The fund must contribute to both national and global green transition, including development and dissemination of new technologies, conversion to renewable energy and promoting global exports of green energy, especially wind.[15]

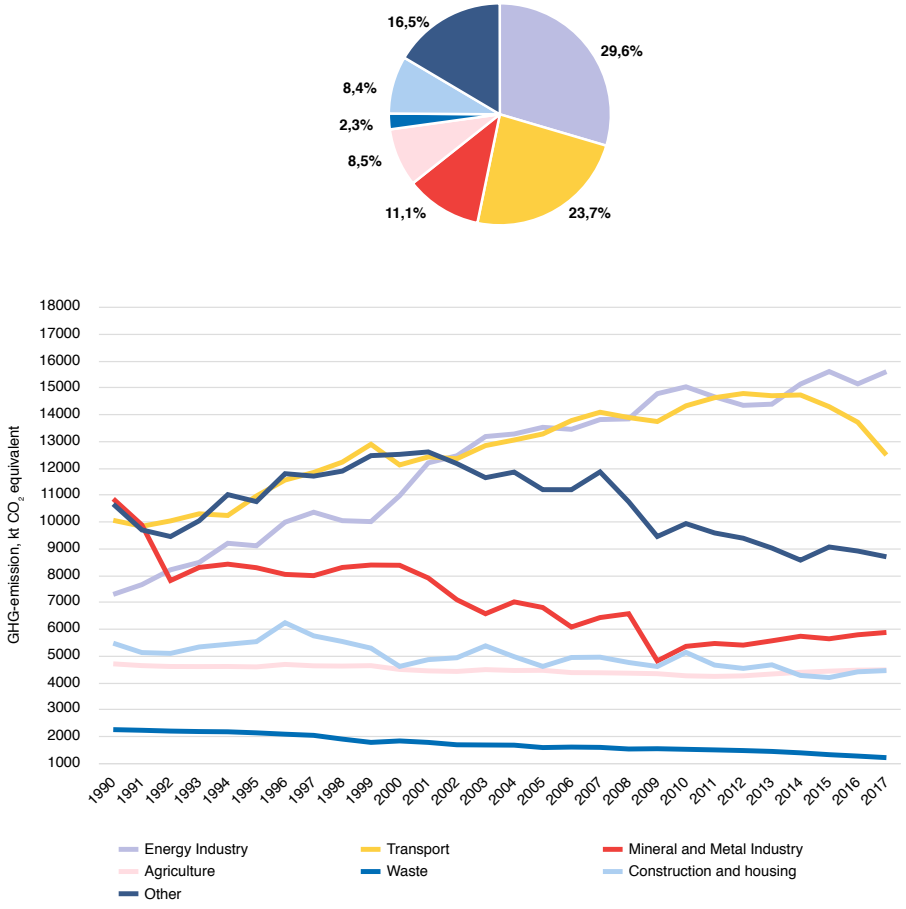
14. (The Danish Parliament, 2019).
15. To ensure a quick initiation and realisation of climate effects, it is proposed that the fund should be established on the framework of existing and proven schemes. The total framework of DKK 25 billion include strengthening of the Export Credit Fund (EKF) with DKK 14 billion, the Growth Fund with DKK 4 billion, Denmark's Green Investment fund (DGIF) with DKK 6 billion and the Investment Fund for Developing Countries (IFU) with DKK 1 billion.

## 1.3 Norway

The Norwegian total GHG emissions were about 1% higher in 2018 than in 1990, corresponding to an increase from 51.2 to 52 Mt C02eq.[16] The main reasons for GHG emissions staying above 1990 level through 2018, are increased transport and petroleum production. Today, over 80% of the Norwegian GHG emissions are covered by the cross-sector economic instruments taxes and the EU ETS, and close to 70% of the emissions (non-EU-ETS) are regulated by adding tax.

Including the LULUCF, total GHG emissions in Norway is greatly reduced, from 52 to 28,4 Mt CO2eq in 2018. The recent vast net sequestration is due to Norway's forestry practices over the last century. Net sequestration in the LULUCF sector has equaled more than 20 Mt CO2eq for two decades now.

**Figure 3. GHG emissions in CO2eq distributed on main sectors for 2017 (excluding LULUCF and indirect CO2) and time series for 1990 to 2017 (UNFCC's GHG emissions by sector). 'Other' cover GHG emissions from UNFCCC subcategories of 'Energy' and 'Industrial Processes and Product Use'.**




16. (Norwegian Environmental Agency, 2020).

In 2016, a parliamentary decision set Norway's climate neutrality target to 2030.[17] The NDC target aim for a reduction in GHG emissions of 50 towards 55% by 2030[18] relative to 1990, and the remaining GHG emissions shall be compensated by GHG mitigations in other countries through flexible mechanisms; the EU ETS and international cooperation on GHG emission reductions.[19] The target for 2050 is to become a low-emission society[20], as stated in the Norwegian Climate Act[21], and the target will represent an emission reduction of 90 – 95% from the reference year.[22]

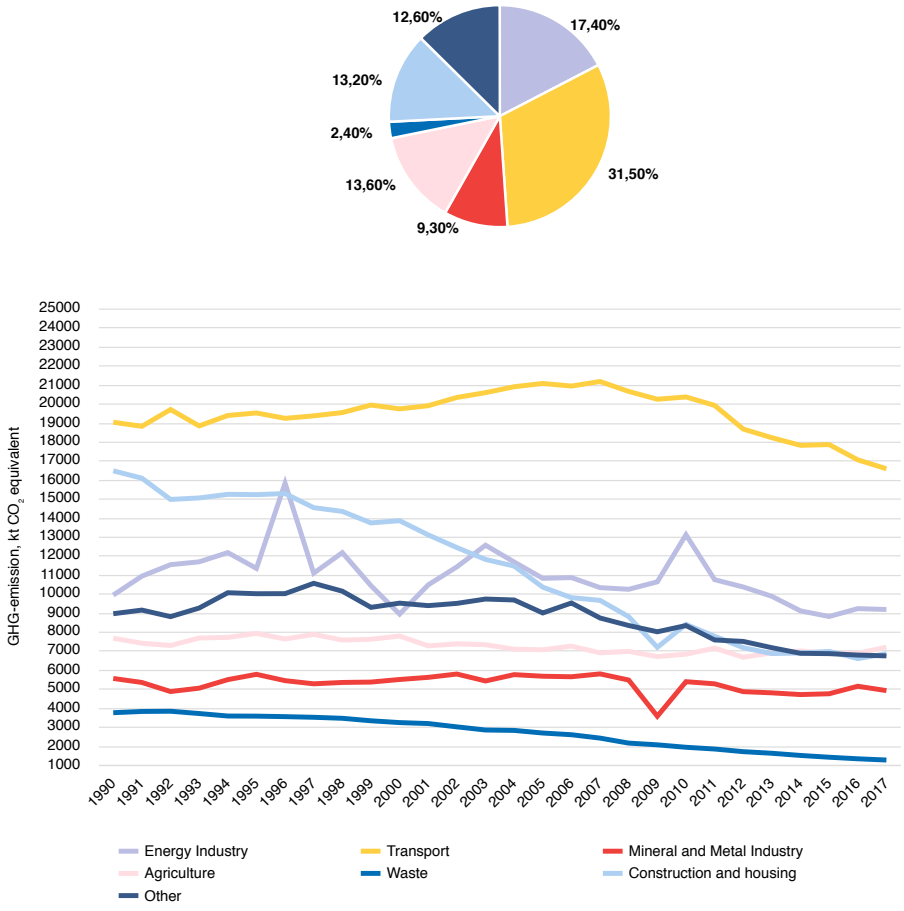
In order to promote the shift towards a low-emission society, the present government will submit updated targets on GHG reductions to the parliament starting in 2020 and then every fifth year.[23] GHG emissions, reduction projections and progress towards the targets are reported annually to the parliament.

17. (Stortinget, 2016).
18. (Regjeringen 2016).
19. (Miljødirektoratet 2020).
20. A low-emission society means one where GHG emissions, based on the best available scientific knowledge, global emission trends and national circumstances have been reduced in order to avert adverse impacts of global warming, as described in Article 2 1.(a) of the Paris Agreement of 12 December 2015.
21. (Ministry of Climate and Environment 2017).
22. (Regjeringen, 2019).
23. (Ministry of Climate and Environment 2017).

## 1.4 Sweden

Since 1990, Swedish GHG emissions have decreased from 71.3 to 51.8 Mt CO2eq in 2018, corresponding to a 26,2% reduction.[24] All sectors have reduced GHG emissions since 1990, with domestic transport, manufacturing and construction and waste industries accounting for the largest reductions. By including LULUCF, the GHG emissions are reduced to 9,8 Mt CO2eq for 2018.[25]

**Figure 4. GHG emissions in CO2eq distributed on main sectors for 2017 (excluding LULUCF and indirect CO2) and time series for 1990 to 2017 (UNFCC's GHG emissions by sector). 'Other' cover GHG emissions from UNFCCC subcategories of 'Energy' and 'Industrial Processes and Product Use'.**




24. (Naturvårdsverket, 2020).
25. (Naturvårdsverket, 2020).

In June 2017, the Swedish Parliament (Riksdag) adopted a climate policy framework with a Climate Act for Sweden.[26] The long-term goal of the climate act is to have zero net GHG emissions by 2045 and negative emissions thereafter. Additionally, this is complemented by intermediate goals for 2030 and 2040. The gross GHG emissions in 2045 shall be at least 85% lower compared to 1990, and the remaining 15% can be achieved by supplementary measures.[27] The supplementary measures can consist of increased uptake of carbon dioxide by forests as a result of additional measures; verified GHG emission reductions carried out outside the Swedish borders; and/or carbon capture and storage based on the combustion of biomass (bio-CCS).

The climate policy framework enforces a long-term responsibility on the Swedish government to pursue climate policy that corresponds with the climate targets and to evaluate the progress of this work. It is built on three pillars: climate targets (mentioned above), a Climate Act and an independent climate policy council. The Climate Act entered into force on 1 January 2018. The Act addresses the Government's obligation to present a climate report in the Budget Bill every year, this report must include: (1) a description of emissions trends; (2) a description of the most important climate policy decisions during the year and the possible effects of these decisions on greenhouse gas emissions trends; and (3) an assessment of whether further measures are needed and, if so, when and how any decisions on such measures may be taken.

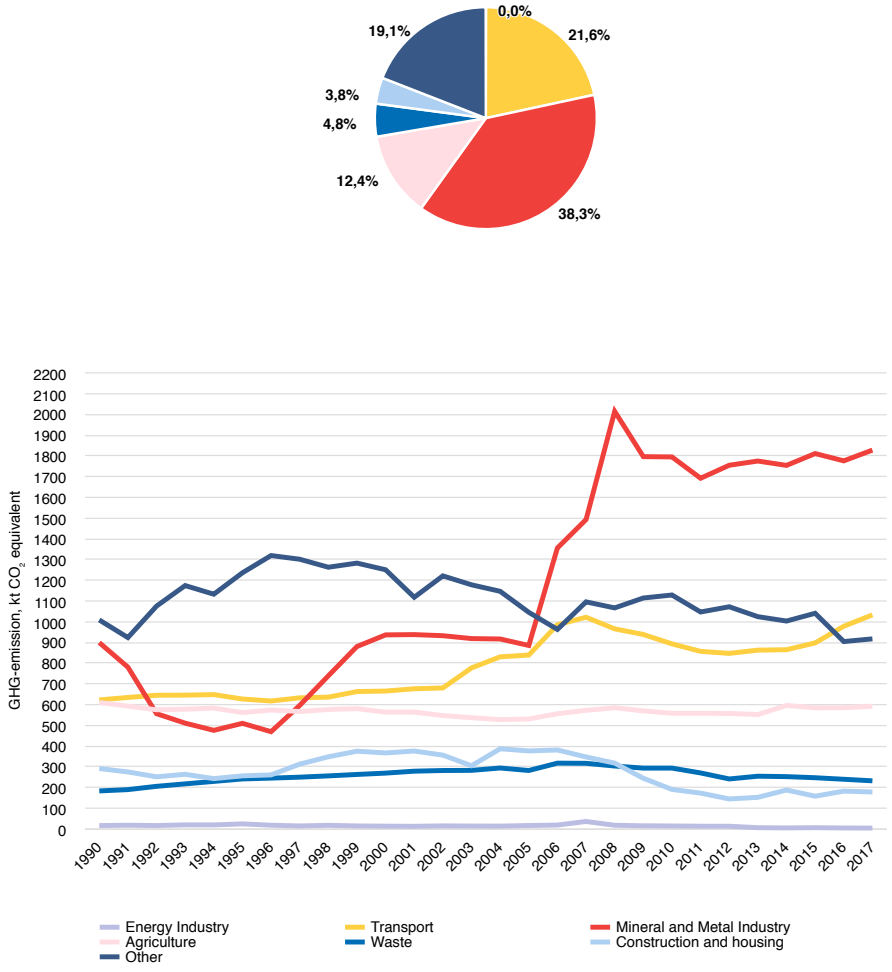
Before the 2015 Climate Conference in Paris, the Swedish government established the initiative Fossil-Free Sweden (Fossilfritt Sverige) to coordinate the development of sector-specific roadmaps describing ways forward and challenges towards carbon neutrality in 2045.

26. (Ministry of the Environment and Energy, 2018).
27. Emission reductions by 2030 and 2040 can be achieved through supplementary measures by a maximum of 8% and 2%[2] respectively.

## 1.5 Iceland

Since 1990, annual Icelandic GHG emissions have increased from 3,6 to 4,9 Mt CO2eq in 2018, corresponding to a 7% increase.[28] The increase is due to the more than doubling in GHG emissions in the metal industry, based on the expansion of three aluminium plants. The transport sector has also increased emissions throughout the period, while emissions in the agricultural sector, waste sector and energy industries have remained stable. If included, the LULUCF sector would increase the total national emission to 13,9 Mt CO2eq in 2018, primarily due to cropland, grasslands and wetlands.

**Figure 5. GHG emissions in CO2eq distributed on main sectors for 2017 (excluding LULUCF and indirect CO2) and time series for 1990 to (UNFCC's GHG emissions by sector). 'Other' cover GHG emissions from UNFCCC subcategories of 'Energy' and 'Industrial Processes and Product Use'.**




28. (Environment Agency of Iceland 2020).

According to a report from the Icelandic Environmental Agency, the total GHG emissions are projected to increase until they reach a peak in 2021, after which they will begin to decrease.[29] Emissions are projected to be higher in 2035 than in 1990, but below 2017 levels.

Iceland aims at being carbon neutral in 2040. The national Climate Council (Loftslagsráð), established in spring 2018, was mandated to develop a report on carbon neutrality. In April 2020 the Climate Council published a short report on carbon neutrality, which contains general reflections on carbon neutrality, but does not mark the way to Iceland's carbon neutrality.

In September 2018, the Icelandic government published a new Climate Change Action Plan.[30] The action plan focuses on non-ETS emissions and has two main goals; achieving the emission reductions of the Paris Agreement for 2030 and reaching carbon neutrality for Iceland in 2040. To reach these goals, the action plan has set forth 34 actions which mostly focus on clean energy transfer in the energy sector (and in particular electrification of the transport sector) and increased efforts in afforestation, revegetation and wetland restoration. Other actions include enhancing information to the public and education in schools, climate strategies for governmental agencies, phasing out Hydrofluorocarbons (HFC), and introducing taxes on waste.

29. (Environment Agency of Iceland 2019).
30. (Umhverfis- og auðlindaráðuneytið 2018).

# 2. STATUS OF SECTOR INVOLVEMENT

All Nordic countries are seeking input from business communities in the form of roadmaps as contributions to national plans on carbon neutrality and GHG reductions. The most recent roadmaps from Norway are from February 2020. In Denmark and Sweden, new sector roadmap proposals were published in March 2020. Finland is expecting similar roadmaps in June 2020, and Iceland has established a cooperation platform, but not published specific sector roadmaps.

In Denmark the climate partnerships have been established across 13 business sectors. The climate partnerships are continuously monitored in a newly formed Green Business Forum made up of representatives from the government as well as chairmen of the climate partnerships, representatives of businesses, trade union movements and independent experts.[31] In March 2020 all sectors published their roadmaps stipulating recommendations for the government as well as presenting their own sector-specific initiatives. Most roadmaps include specified cost and climate calculations for all suggested efforts. The roadmaps are used as part of vital input to the government and the parliament for the development of the national climate plans.

In Sweden the government established the initiative Fossil-Free Sweden (Fossilfritt Sverige) before COP21 in Paris in 2015. The committee coordinates the development of the 21 sector-specific roadmaps, which exist as of now[32], describing the way forward and the challenges towards carbon neutrality in 2045. The roadmaps describe when and how the sectors will be fossil-free, technological solutions needed to be developed, investments needed to be made and obstacles needed to be removed. The roadmaps also include emission reduction pledges from stakeholders and proposals of political solutions.[33]

In Norway the government has established the Expert Committee for Green Competitiveness, which works in close dialogue with the business and industry sectors. In 2017, the committee challenged the Norwegian business community to develop carbon neutrality roadmaps, which included economic value creation and new jobs.[34] As a result of this process, 18 carbon neutrality roadmaps were developed by 2018 and by 2020 a few more have been added. The roadmaps serve as input for the Norwegian government's strategy for green competitiveness.

In Finland, a Finnish Government Programme has been initiated requiring all major sectors to formulate their own carbon neutrality roadmaps by June 2020. Other important sectors for Finland, but minor in terms of emissions, will also produce roadmaps. The roadmaps will be produced by consultants selected by industry associations but coordinated by relevant Finnish Ministries. Input from the private sectors are used in the formulation of national policies and will feed into the National Climate and Energy Strategy and the climate change policy plan (KAISU).

31. (Regeringens Klimapartnerskaber 2019).
32. More sector roadmaps are expected in Sweden.
33. (Fossilfritt Sverige 2016).
34. (Regjeringen 2020).

In Iceland, Green By Iceland (Grænvangur) was established in 2019 and is a cooperation platform for climate issues and green solutions between the government and the business community. The purpose of the forum is to strengthen cooperation between the industry and the government in reducing GHG emissions as well as mapping green solutions and support the goal of a carbon neutral Iceland in 2040. Several sectors have established initiatives and commitments to reach carbon neutrality, such as sheep farmers, the energy production and the distribution sector.[3536]

*The following chapters provide an overview of sector pathways and measures to reach carbon neutrality, including challenges and opportunities for joint activities at Nordic level. The selected measures are selected by expected impact and relevance for joint Nordic activities.*

35. (Landssamtaka sauðfjárbænda (2017).
36. (Samorka 2018).

# 3. ENERGY INDUSTRY

The Nordic countries have already decarbonized large aspects of their energy systems and have successfully been decoupling GHG emissions from GDP growth. However, a carbon neutral energy production system does require a significant change in the composition of the energy supply. Furthermore, this must be coupled with energy efficiency policies that substantially reduce demand for energy based on fossil fuels.

In Finland, the energy sector has a high attention on the ban of the use of coal by 2029 and changes in the electricity systems. The use of peat in energy production has diminished in Finland and will continue to do so in future years. Main challenges in emission reductions of the sector are related to the electricity infrastructure, caused by fluctuating electricity from the many renewable energy forms. In the upcoming roadmap, which will be launched in June 2020, the sector is expected to identify new flexibility mechanisms, regarding both the timing and scheduling of energy demand, and flexibility in the utilization of different energy forms.

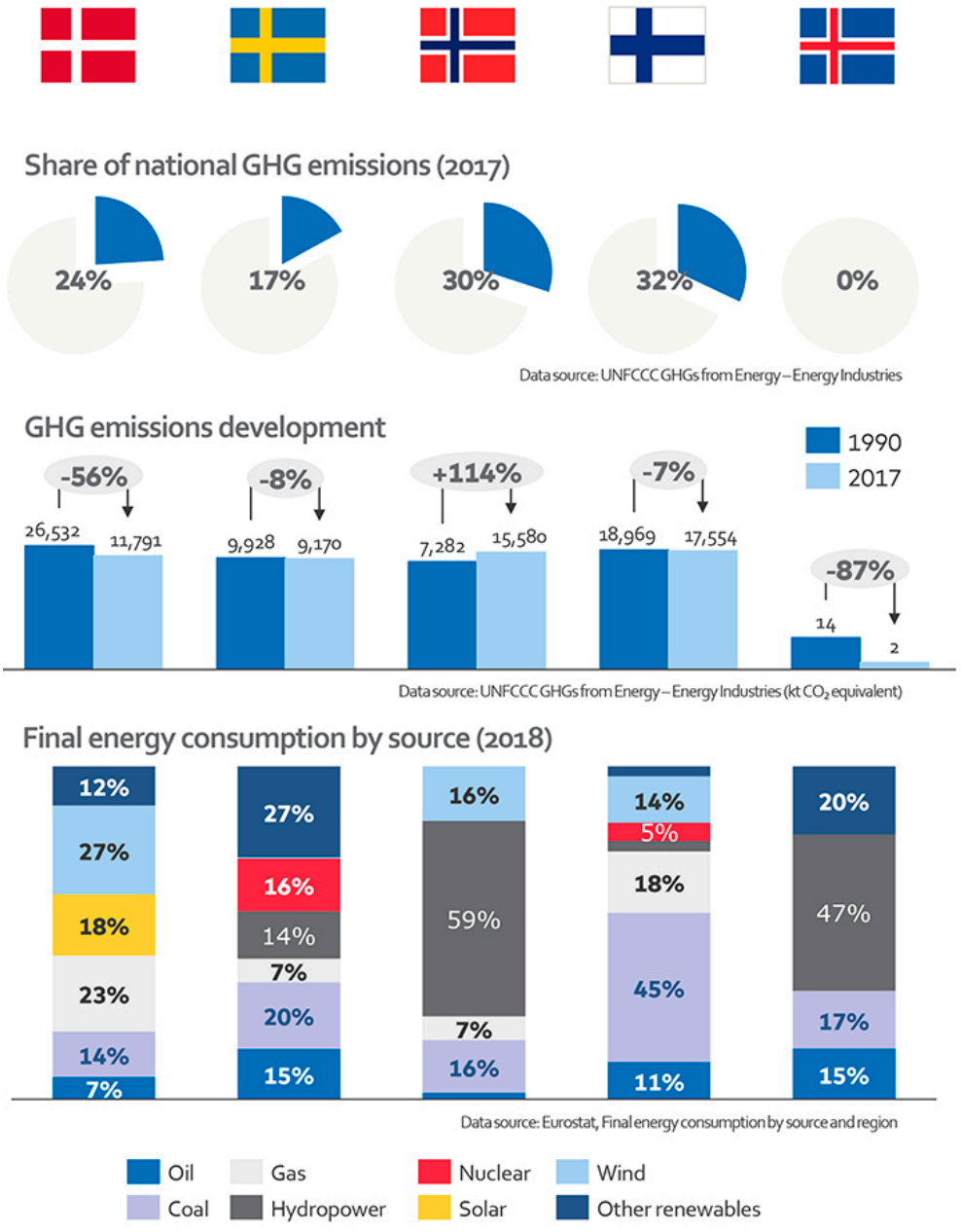
Iceland has extensively used renewable energy sources for electricity and heat production in the past few decades. The emissions from energy industries are therefore lower than for most other countries that utilize a higher share of fossil fuels. Iceland's two largest energy companies aim to become carbon neutral in 2025 (the National Power Company of Iceland) and 2030 (Reykjavík Energy). Besides, the sector is especially focusing on methods to capture GHGs from geothermal power plants and store it permanently in rocks. Further utilisation of this method is being explored by Icelandic power companies.

In Denmark, the main sector initiatives in energy are focusing on phasing out the remaining coal in the power plants and natural gas for district heating production, phasing out natural gas and oil in individual heating. Conversely, Denmark is expanding the production of offshore wind energy to cover the increasing electricity demand following the electrification of heating, transport and industrial processes. The government is also looking into CCS at large point gates, reducing plastic in waste energy and reducing natural gas consumption for energy production in the North Sea. According to the Danish roadmap, the energy and utilities sector expect to contribute to approximately half of the total required Danish reductions from 2019 to 2030 cf. the national 70% reduction target, by reducing emissions from 13 to 1 Mt CO2eq.

Sweden has a low share of fossil fuels in its primary energy supply, and Sweden has become the largest producer of wind power among the Nordic countries. Sweden has been successful in its energy transformation through market-based policies that focus on energy efficiency and renewable energy, which has helped drive decarbonisation across several sectors. The key policies and measures influencing GHG emissions in Sweden are energy tax, carbon tax, electricity certificates systems and the EU ETS. In the roadmap for electricity and heating, focus is on phasing out the use of remaining fossil fuels by means of district heating based on recycled energy, increased sorting of plastic waste and on new heat pumps and biofuel boilers. Conversely, the roadmap for gasoline, biofuels and gas emphasize increased production of renewable gas and digitalisation.

Norway has access to vast amounts of renewable energy through hydropower and an increasing share of onshore wind power. Norwegian energy initiatives focus on lower emissions associated with power and heat supply for oil installations, reduced emissions of short-lived climate drivers such as methane, increased energy efficiency at field and area level and reductions in emissions related to drilling operations from mobile rigs.

**Figure 6. Infographic with energy industry sector characteristics**



Energy industry cover emissions from public electricity and heat production, petroleum refining and manufacture of solid fuels and other energy industries. Energy industries account for between 0 and 32% of national GHG emissions across the Nordics. The GHG emission development has increased in Norway and decreased in the four other countries. Final energy consumption[37] by source varies between the countries. Hydropower is the main source in Norway and Iceland, whereas it is wind in Denmark, other renewables in Sweden (primarily bioenergy) and coal in Finland. Other renewables cover bioenergy, thermal energy, ethanol, hydrogen and heat pumps.

## 3.1 Enhancing offshore wind

The energy sectors in Sweden, Norway, Denmark and Finland have a high focus on increasing wind power by establishing new offshore windfarms. The Danish government is already far in the construction plans for increasing offshore wind capacity, and between 2020 and 2023 tenders for two new windfarms with an estimated capacity of 800 to 1000 MW will be announced. Also, Denmark is planning the construction of two "energy islands" (in the North Sea and at Bornholm in the Baltic Sea), with a capacity of respectively 3 and 2 GW. In Norway efforts are undergoing to electrify oil rigs through floating offshore wind turbines. Norway holds a global leading position within floating offshore wind turbines, and two ground-breaking initiatives, the Rogaland Project and the Hywind Tampen wind farm, are under development. The expectation is that 40% of offshore petroleum exploration is electrified in 2025. The sectors in Sweden and Finland are more focused on creating the right preconditions for new investments, including the development and knowledge dissemination of wind power technology and attracting enough investments.

The sectors face a combination of technical and governance challenges, where joint activities on a Nordic level could add value to the national net transition.

A central challenge in the Nordics is dealing with ice conditions, such as forecasting, ice sensoring, ice tracking and removing and icing of wind turbines. This is especially a focus in Finland, Sweden and Norway. Dealing with offshore ice conditions is not a new area of expertise and all countries have advanced knowledge from the maritime and mining, oil and gas industries. Best practices are likely to be found in Finland, Norway and Denmark. Finland is a global leader in icebreaker design, polar shipbuilding, ice technology and fleet operation[38], and in Denmark and Norway the large maritime sectors also have world leading capacity developing ice technologies.

Another challenge is the establishment of procurement and pricing models. The issue is to get a price that attracts additional funding and to assist the governments in the planning and tender processes. All countries are developing their own approaches to ensure alignment with the future energy markets. A common Nordic approach would further enhance the sector's ability to attract new international

37. "Final energy consumption" covers only the energy consumed by end-users, such as industry, transport, households, services and agriculture; it excludes energy consumption of the energy sector itself and losses occurring during transformation and distribution of energy.
38. Finnish companies have designed about 80 percent of the world's icebreakers, and about 60 percent of them have been built by Finnish shipyards.

funding and bidders for future projects.

Finally, all countries are facing the complicated and time-consuming public planning processes for offshore wind farm locations. These involve intense and often politized dialogues with sectors and citizens on regulation and location of sites. Denmark is often referred to as being in the forefront of streamlining these processes, and The Danish Energy Agency has developed toolkits and is disseminating Danish knowledge and experience.

**Joint Nordic opportunities:**

- Establish forum for sector collaboration on ice technologies.
- Develop toolkits for procurement and pricing models.
- Conduct further analyses on procurement and pricing models.
- Establish coordination and joint planning of offshore locations and related power infrastructure.
- Support the research and development of floating offshore technology including the development of operation strategies and demonstration.

## 3.2 Preparing for more renewable energy in national grids

The increase of especially wind power will decentralize and re-locate the energy production, and the transmission infrastructure must be able to meet the challenges from fluctuating energy sources.

Enhancing wind power and other renewable energy sources in the national electricity systems are already challenging the traditional grid infrastructure.

The new grids call for adjustments to governance structures, energy pricing systems, revenue models and market arrangements. This is necessary in order to ensure a significantly more distributed, interconnected and flexible energy-only power market than today.

The challenge for all the Nordic countries is the need to upgrade the transmission and distribution grid. This involves significant investments in infrastructure and increased support for innovation in technologies and services to meet the flexibility of the Nordic energy systems.

An example of enhancing investments and innovation is the North Sea Energy Hub consortium. In the consortium Denmark and Norway are collaborating with other North Sea partners to develop new energy-islands that integrate large-scale offshore wind energy into the energy system. As mentioned above, in May 2020, the Danish government announced the ambition to construct two "energy islands", one in the North Sea and one at Bornholm in the Baltic Sea. The energy islands need efficient utilisation of international, cross-border transmission infrastructure. The collaboration calls for cross-border coordination in spatial planning and collaboration across the industries, fisheries and shipping.

**Joint Nordic opportunities:**

- Support enhanced co-operation within grid infrastructure and electricity

markets.
- Create incentives for investment and innovation within technologies and services that increase the flexibility of the Nordic energy system.

## 3.3 Exploring Power-to-X technologies

Part of the effort to identify green fuels for transportation is to explore the yet immature technologies involved in the production and usage of Power-to-X-based fuels (PtX). PtX technologies could be a potential solution to reduce greenhouse gas emissions in hard-to-abate sectors such as aviation, shipping and heavy transport and industries such as chemicals and cement. It may also stabilize power prices and provide balancing to an energy system with increased amounts of fluctuating wind and solar power. This is because of its ability to store renewable energy that cannot be fed into the grid, by producing carbon neutral gasses via electrolysis. A great advantage is that it can be easily transported through existing pipelines and used in gas-powered engines. However, a penetration of e-fuels for road transport would stress the renewable electricity generation capacity due to significant conversion losses. Also, the need for grid balancing might not be high enough to make the PtX process sufficiently cost-efficient.

Despite lack of viable business cases, the Nordic sectors foresee PtX technologies to become a significant part of the solution towards carbon neutrality. Already, the Danish sectors are actively leading three demo-projects[39] on these technologies, and leading Danish companies have joined forces to develop an industrial scale facility by 2030 with a total electrolyze capacity of 1.3 gigawatts, which would likely make it one of the world's largest facilities of its kind. Swedish SBB is involved in demonstration of hydrogen-to-fossil-free steel. Denmark has also established a partnership with the Netherlands on PtX, that will secure funding to new large-scale PtX facilities in Denmark (approx. 100 MW electrolysis).

Many challenges are yet to be solved before PtX can become a realistic energy alternative. Common challenges are lack of efficient technologies, large energy conversion losses and business cases that can ensure the right market design with commercially driven incentives. PtX technologies have yet to show its commercial value and is therefore connected to great risks for investors. Furthermore, future demand is very sensitive to the development on international markets.

**Joint Nordic opportunities:**

- Support data collection and studies focusing on Nordic green transition.
- Support collaboration on R&D and testing.
- Support dissemination of best practices in business cases.

39. See e.g. financed technology projects, the so-called EUDP programme, at Danish Energy Agency. https://ens.dk/ansvarsomraader/forskning-udvikling/eudp

## 3.4 Phasing out oil, gas and coal in individual and district heating

In Denmark and Finland, and to a lesser degree Norway and Sweden, the widespread district heating systems in urban areas still use combustion of fossil fuels and peat. The main part of the GHG-emissions from combustion for district heating in Sweden comes from waste incineration. Iceland has pioneered the use of geothermal energy for local and district heating and approximately 90% of homes are heated geothermally. In the four other countries, plans are to phase out oil and natural gas boilers for individual and district heating, mainly by replacing natural gas in decentralized district heating production by means of a strong expansion of collective heat pumps, solar heat, biogas and energy recovery of waste. Utility-scale heat pumps and electric boilers will facilitate the integration of renewable electricity and according to scenario calculations, they will account for almost half of the heat in district heating networks in 2050.

A common Nordic challenge in the shift to a more decentralized electricity system is that the business case for cogeneration of heat and power in district heating is worsening due to the growing electricity production from renewables. This is lowering the incentives for the transition to a more energy efficient energy production system. Another central Nordic challenge is lack of support in terms of research, development and demonstration of new heat. There is a need to support research, development and demonstration of new technologies such as bio-coal, solar heat, seasonal heat and cold storage, combined heat and power production with higher electricity exchange, small-scale combined heat and power technology and recycling refinery for plastic waste.

**Joint Nordic opportunities:**

- Support research and knowledge sharing on waste heat solutions (from industry to district heating).

## 3.5 Increased bioenergy with carbon capture and storage (BECCS)

Bioenergy with carbon capture and storage holds great potential across the Nordics. In the roadmap of the Swedish heating sector, with voluntary targets, BECCS is an important element in making the heating sector a carbon sink that will decrease the total amount of greenhouse gas emissions. The heating sector roadmap involves a BECCS demonstration plant in 2025, a fully operational plant in 2035 and a long-term goal of 5 Mt GHGs annually sink capacity in 2045.[40] Likewise, the Danish energy and utilities sector aim for the construction of two new CCS plants with BECCS according to their roadmap. These should be located at a large waste power plant and a CHP plant using biomass. The two plants will have a combined reduction of 1.3 Mt CO2eq of which 0.8 Mt CO2eq will be negative emissions.

Like Sweden, Finland has a high proportion of biofuels with around 40% of their

40. The plan is well underway, and in December 2019 the country's first BECCS pilot plant for testing was launched in the Värtan biomass-fired combined heat and power (CHP) plant in Stockholm.

GHG emissions stemming from biogenic origins[41], thus posing a high potential for BECCS. Norway is at an advanced development stage in developing a full-scale CCS project. The project can be fully operating in 2023-2024, capturing 800,000 tpa. of CO2, given a positive investment decision by the Norwegian government by the end of 2020. The project has the potential of being one of few global CCS projects with large scale BEECS integration. The Full-scale CCS Project with BECCS integration will involve Heidelberg Norcem cement factory and Fortum Oslo Varme waste-to-energy plant in Oslo.

The main challenges are immature technology and lack of financial incentives for negative emissions.[42] Further Nordic cooperation could be to explore the possibilities for establishing a cross-Nordic auction for predetermined volumes of negative emissions where the player offering BECCS at the lowest price wins. The Nordic countries could also collaborate with respect to establishment of emission allowance corresponding to the negative emission of CCS on fossil-free fuels (biogenic waste and sustainable biomass). This could materialize through EU or international agreements on calculation and payment rules for CCS.

**Joint Nordic opportunities:**

- Collaboration within research and development resources for BECCS.
- Explore possibilities for developing Nordic auction for negative emissions.
- Explore the possibilities for introducing emission allowance corresponding to the negative emission of CCS on fossil-free fuels.

41. (SINTEF, 2013).
42. Other challenges that are still to be balanced by regulation, although not exclusively associated with Bio-CCUS, include seismic risks, potential CO2 leakage and conflicting sub-surface land usage such as extraction of drinking water and geothermal energy (IEA Bioenergy, 2018).

**Nordic countries are establishing first mover advantages in CCS technologies**

The Nordic CCS technology development holds promising potential for international application, yet some countries are further in development than others.

Norway is the Nordic frontrunner on CCS technology development. This is best exemplified through the Technology Centre Mongstad. Technology Centre Mongstad is the world's largest facility for research, development and demonstration of CCS technologies. The centre has access to energy and industrial emissions, which provides a unique opportunity to investigate various relevant applications of CCS technologies.

In Iceland, a new technology has been developed, Carbfix, that turns CO2 from GHG emissions to stone underground in less than two years. The method has been used with good results at Reykjavik Energy´s geothermal power plant. Further development is undergoing, and the Icelandic metal industry is looking into the possibilities to adopt this method. The solution could play an important role in making the energy and industrial sectors climate neutral.

The other Nordic capitals are, however, supporting development of CCS technologies. An alliance of cities (Helsinki, Oslo, Stockholm and Copenhagen) has recently joined forces to demonstrate CCS technologies at power plants in HELEN (Helsinki), Klemetsrud (Oslo), Exergy (Stockholm), and Amagerverket (Copenhagen) (Nordic Council of Ministers, 2020).

# 4. DOMESTIC TRANSPORT

The share of GHG emissions from land-based transport, relative to other sectors, are increasing despite increased use of biofuels and electrification of personal vehicles in the Nordics. Furthermore, replacing fossil fuels remain challenging, and current research suggests that existing and planned policies do not result in enough GHG emission reductions in the light of the 2030 climate objectives.[43] Increased joint Nordic efforts are therefore needed in a number of areas simultaneously if 2030 objectives are to be achieved.

Emission reduction goals in the transport sector are very ambitious across the Nordics. Sweden aims to reduce emissions in the transport sector with 70% by 2030, compared to 2010. Likewise, Norway[44] and Finland aim for 50% reduction of emissions in the transport sector by 2030, with reference to 2005. Furthermore, Iceland's national plan hinges significantly on the transition to renewable fuels in the transport sector. Taking it one step further, Norway plans that all new passenger cars and light duty vans shall be zero emission vehicles in 2025[45], and Finland aims for fossil-free transport by 2045.[46] These goals are, however, very ambitious and contingent on technological maturity, why strong measures are needed if the Nordic transport sector are to deliver on these.

There are also ambitious voluntary reduction goals in the maritime and air transport business communities. In Sweden, the sector has the ambition that all domestic flights shall be fossil-free by 2030, and flights originating from Sweden by 2045. Likewise, the Danish aviation sector association has a declared target that Danish aviation aims to be CO2 neutral no later than 2050. In shipping, the Norwegian government has the ambition to halve emissions from domestic sea transport and fishing by 2030, relative to 2005.

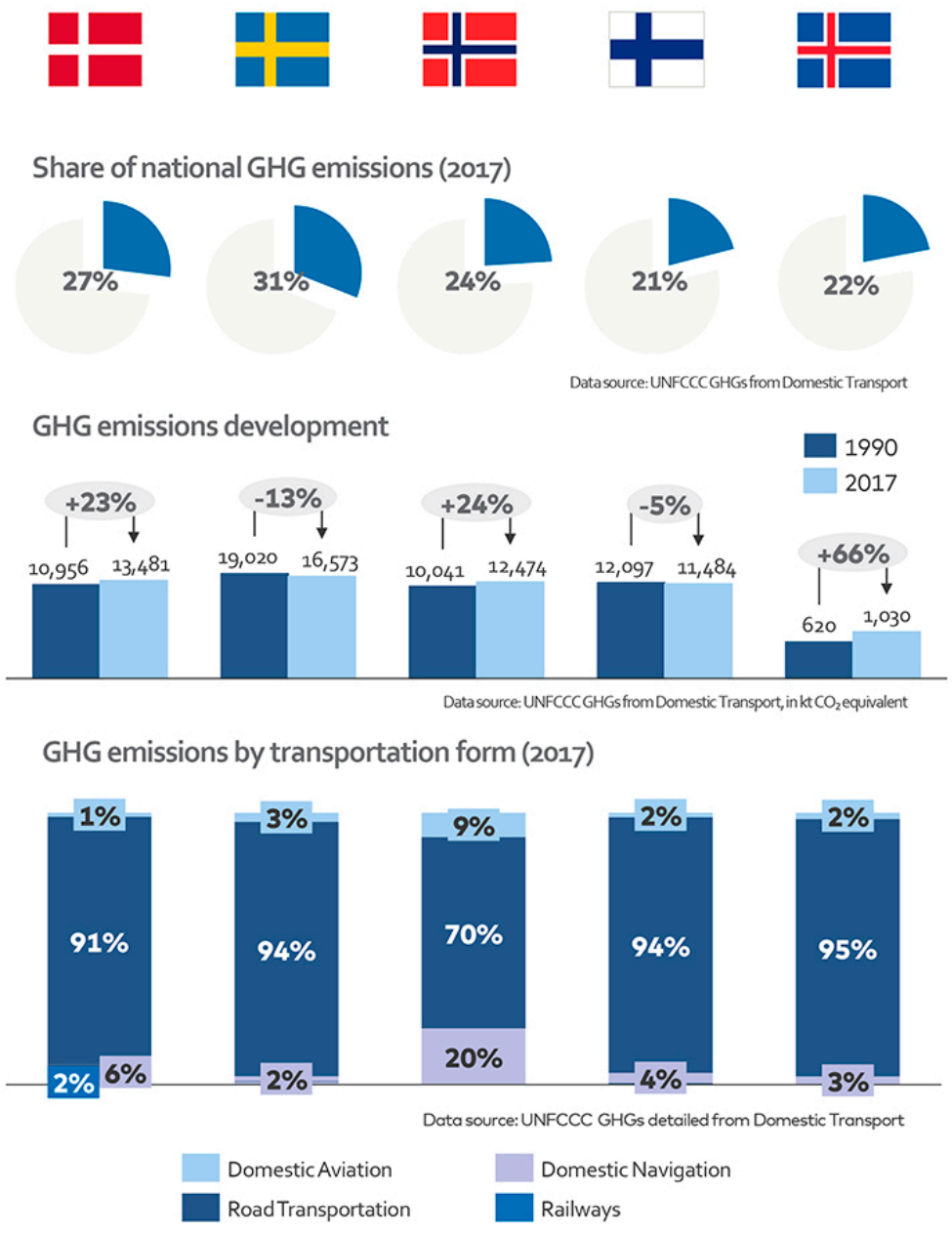
To reach these targets, there is an urgent need for alternative fuels, propulsion technologies and vehicles. The main arenas for reducing GHG emissions can be grouped into five areas; reducing transport demand, increasing transport system efficiency, stimulating modal shift of freight, and switching to new low carbon fuels and transportation technologies. The three first, i.e. reducing transport demand, improving efficiency of transport modes and stimulating modal shift of freight, will, however, only contribute to limited emission reductions, why alternative fuels, propulsion technologies and new low carbon vehicles are strongly needed.

This is reflected in national adopted or planned sector strategies which all emphasize the importance of biofuels, biogas, hydrogen and electrification. Accordingly, Nordic governments focus, to varying extent, on increasing purchase subsidies for electric and gas-powered cars, busses and trucks, expansion and support of electrical and hydrogen charging infrastructure, combined CO2/NOX taxes on fuel, and reduced biofuel taxes.

43. (Norden, 2019a).
44. This target was set in the Norwegian government's most recent political platform (Granavolden platform) (Norwegian Environmental Agency, 2020).
45. The term "zero emission" refers to the use of electricity and hydrogen as energy source in batteries or fuel cells, which do not release greenhouse gases when being used.
46. (Valtioneuvosto 2019).

There are, however, distinctive national focus areas. Norway and Iceland have strong focus on electrification of land transport as well as ports and ships, Sweden and Finland on biogas and biofuels based also on methanol and bio-methanol in maritime use, and Denmark on electro fuels from Power-to-X technologies.

**Figure 7. Infographic with domestic transport sector characteristics**



Domestic transport cover emissions from fuel combustion from domestic aviation, road transportation, railways, domestic navigation and other transport. Fuel combustions from domestic transport accounts for between 21% and 31% of national domestic GHG emissions. The GHG emissions' development varies amongst the five countries. Sweden and Finland have reduced emissions, while Denmark, Norway and Iceland have increased emissions. Across all countries domestic transport GHG emissions stem primarily from road transportation. Norway is a minor exemption with almost 1/3 of GHG emissions coming from domestic aviation and navigation, whereas the other countries have less than 10% from these two sources.

## 4.1 Maturing of new, less carbon-intensive fuels

The increased use of alternative fuels such as biofuels, hydrogen and electro fuels are a top priority across the Nordics, especially in the heavy road haulage, the maritime and the aviation sector. These sectors are struggling to electrify, and existing fleets are costly to replace. Especially heavy road haulage is important with regard to domestic emissions, as this accounts for the large majority of road freight across the Nordic countries and is almost entirely based on diesel.[47] The new less carbon intensive fuels are, however, at an immature state, why further technological development and efforts are needed. Despite country differences in alternative fuel prioritizations, there are some key areas where the Nordics could benefit from more cooperation.

Biofuels and biogas are key to short-term carbon reductions in the Nordic transport sector. Biofuel usage can be ramped up quickly, but it can become a challenge to source enough raw materials. Projections show that the Nordics will become net importers of biomass, if they are to live up to the carbon neutral scenario.[48] Accordingly, the Nordics need to increase production of biomass for first- and second-generation biofuels. Sweden and Finland already cover 11.9% and 9.3% of their transport energy use with biofuels, and best practices with regard to production are to be found here.[49] Thus, Nordic cooperation should focus on supporting increased production of sustainable biofuels by sharing best practices, supporting pilot projects and disseminating knowledge from second generation biofuels.

Hydrogen is a central medium-term alternative to fossil fuels in the Nordic heavy road haulage sector. It does, however, require dedicated vehicles which are more expensive than conventional trucks, and they must be fuelled by dedicated tank infrastructure. Currently, hydrogen is also more expensive than diesel. Work to develop a Nordic hydrogen corridor has been ongoing for more than a decade in the "Scandinavian Hydrogen Pathway Partnership", yet infrastructure and recharging

47. Norway: 92% in 2015 (Næringslivets transporter, 2016), Denmark: 93% in 2020 (Regeringens Klimapartnerskaber, 2020b), Sweden: 97% in 2019 (Bil Sweden, 2019).
48. (Nordic Council of Ministers, 2020).
49. Between 2010-2016, the use of HVO (hydrated vegetable oil) in Sweden, a synthetic renewable diesel that requires no change in engines or infrastructure, accounted for emission reductions of 25% in heavy road haulage, despite an increase in tonne kilometres. The Finnish company Neste is responsible for most of the total renewable diesel production globally.

possibilities for heavy road haulage remain limited, why a common Nordic roadmap would create much value.

Electro fuels are an important long-term alternative to fossil and biofuels in the Nordics, in both the land, aviation and maritime transport sector.[50] Electro fuels are based on Power-to-X technologies where renewable energy is converted to hydrogen through electrolysis. The technology is, however, still at an experimental stage, and it is relatively expensive compared to e.g. e-roads, biogas or hydrogen. Accordingly, if the Nordics are to be frontrunners on Power-to-X technologies, there is a need for enhanced cooperation on development of Power-to-X technologies. Best practices are to be found in Iceland where $CO_2$ electro fuel has been produced since 2012.

**Joint Nordic opportunities:**

- Support development of regional sustainable biofuel production.
- Support pilot projects and disseminate knowledge from second generation biofuels.
- Support technology development of electro fuels.

## 4.2 Electrification of private vehicles

The Nordic stock of electric cars has been expanding steadily since 2010, and the region has one of the highest ratios of electric cars per capita in the world. New passenger EV registrations accounted for 16% of new passenger car sales across the Nordics in 2019, with Norway as the absolute frontrunner with 56%, that is more than half of the regions share of EVs. The main drivers of this increased EV adoption are EU CO2 emission standards in combination with national policy measures. All Nordic countries provide purchase incentives for electric cars, primarily having the form of differentiated registration taxes based on CO2 emissions or fuel economy ratings, along with subsidies for electric charging infrastructure.

By 2030, it is projected that 4 million electric cars will be on the road in the region, implying more than a 15-fold growth of the electric car stock from 2017 volumes.[51] This requires increased consumer demand and an extensive expansion of charging infrastructure. Albeit consumer demand is driven by national policy measures, the Nordic countries could benefit from increased dissemination of Norwegian best practices on subsidies and other support instruments.

More important from a Nordic perspective is cooperation on EV infrastructure, as expansion of EV infrastructure is imperative for increase in EVs. Norway, under the auspices of the public enterprise ENOVA, has developed a nationwide infrastructure for fast charging of batteries and is an at advanced state of developing a countrywide grid with filling stations for hydrogen cars. Knowledge from this process should be used by the other Nordic countries, who are not at the same stage. Nordic cooperation should focus on supporting the development of a roadmap for cross

50. The hydrogen can, together with nitrogen from e.g. biomaterial and CO2 from carbon capture, be transformed into a sustainable synthetic liquid or gaseous fuel. The fuel can be in the form of e.g. e-gasoline, e-diesel, e-gas, jet fuel and methanol.
51. (International & Agency, 2018).

Nordic EV infrastructure as this would stipulate consumer demand and producer security.

**Joint Nordic opportunities:**

- Collaboration with regard to charging network for cross-Nordic transport and EV infrastructure.

## 4.3 Electrification of freight vehicles

A large share of light and heavy road freight vehicles will have to be electrified if the Nordic countries are to decarbonize their transport sectors. Whereas policy measures have started to decrease emissions from passenger cars, this has yet to happen within freight transport. At the same time demand for freight transport in the Nordic countries is expected to increase, particularly by road. Challenges related to light and heavy freight are, however, different. Whereas light freight EVs have reached a commercially viable level, heavy freight EVs for e.g. waste collection, manufacturing and distribution are costly and with insufficient range and capabilities.

Electrification of heavy freight is at an early stage, why continuously knowledge dissemination from pilot projects and technology development is crucial. A relevant pilot project is the Norwegian wholesaler ASKO who deployed it's two first battery-electric Scania distribution trucks in its operations in Oslo, Norway. In 2018, the Norwegian Public Roads Administration also concluded the project ELinGo (Electrical Infrastructure for Freight Traffic).[52] Together with Norwegian industry and Norwegian research environments, the project developed five working packages on infrastructure requirements and framework conditions for national transition. In the other Nordic countries increased dissemination of knowledge from this study together with Norwegian experience could create much more value.

Increased Nordic cooperation on battery technology is also key to make heavy freight EVs a viable alternative. A new study evaluating experience gained from battery-electric truck users in Norway conclude that battery-electric trucks could, to some extent, replace typical use of Norwegian trucks.[53] The study did, however, also show that EV trucks will only become competitive with "normal" Internal Combustion Engine (ICE) trucks when technology reaches mass production and battery technology matures. E-trucks simply cannot compete with the costs of ICE-based vehicles except for when mileages are set unrealistically high, considering the driving range set by current battery technology.

Battery technology is top of agenda across universities in the Nordics, why strong cooperation and knowledge sharing is important, and increased Nordic university cooperation is imperative for Nordic progress on battery technology for heavy freight vehicles. It would create much value to integrate Nordic companies, but due to strong competition it is important that collaboration is anchored at university level.

52. Sintef (2016).
53. (Hovi, Pinchasik, Figenbaum, & Thorne, 2019).

**Joint Nordic opportunities:**

- Increase knowledge dissemination and sharing of best practices on electrification of heavy freight.
- Support research partnerships on battery production and technology.

## 4.4 Electrification of maritime transport and port infrastructure

Electrification of maritime transport has great potential for reducing carbon emissions in the Nordic region. Accordingly, national maritime sectors in all countries have electrification of ships and ports as one of their main initiatives to reduce emissions. Norway, which has the highest emissions from the domestic maritime sector across the Nordics, aim for 40% low or zero emission ships, including biofuels, by 2030, and overall emission reductions from maritime transport and fisheries by 50%. Likewise, the Danish shipping company Mærsk has pledged to make carbon neutral vessels viable by 2030 and to have fully carbon neutral operations by 2050.[54]

In recent years, the Nordic maritime sector has begun to electrify domestic ferries and short-haul passenger vessels. The first electric ferries were Ampere in Norway (2015) and Elektra in Finland (2017). The ferries decreased emissions by 95% and costs by 80% (compared to standard ferries), and across the Nordics more operators either have or will purchase electric ferries and short-haul passenger vehicles. Electrification of domestic ferries and short-haul vessels is an important first step, next is fishing vessels and ferries between the Nordic countries.

There are two mutual challenges to electrification of Nordic maritime transport and port infrastructure: limited battery technology and insufficient charging infrastructure. For electrification of e.g. fishing vessels and ferries between the Nordics, considerable technology development is needed for battery technology to mature sufficiently. Furthermore, electrification of maritime transport demands additional investments in charging infrastructure. If the electricity grid in the harbour holds inadequate charging speed, which is often the case, the grid must be fortified, or additional battery buffers installed at the harbour.

Increased Nordic cooperation on maritime electric charging infrastructure has strong potential. As the different countries plan expansion of national electricity grids to accommodate electric ships, it is important that best practices and knowledge is disseminated. Best practice is to be found in the port of Kristiansand in Norway, where advanced port electrical charging infrastructure is in place. Regarding battery development, room for increased Nordic cooperation in this area is limited. Strong competencies on battery development for the maritime industry are already found in Finland, Norway and Denmark, and Nordic cooperation on battery development already exist in the form of "Nordbatt" (Nordic Battery Conference).[55]

54. (Mærsk, 2018).
55. Nordbatt is a bi-annual conference organised by the Danish Battery Society. The two-day conference covers topics from materials development to battery applications, providing a Nordic platform for representatives of academia and industry to communicate new findings and solutions for batteries and energy storage applications. See http://nordbatt.org/

One way to realize cooperation on maritime charging infrastructure could be a Nordic forum with focus on standardizing Nordic tax systems for charging as well as on knowledge dissemination. A standardized taxing system for charging ships in the Nordic harbours would add much value, and it would be an important first step in a plug-n-play electric charging system across the Nordics. Such a forum should involve leading transport buyers, harbours, academic institutions, marine technology companies, shipyards, energy suppliers, authorities, politicians and shipowners and operators. The forum could take inspiration from "Nordic Green Shipping", a forum establishing new partnerships between Danish shipowners and leading Finnish suppliers.

**Joint Nordic opportunities:**

- Support a Nordic forum with focus on standardizing Nordic tax systems for charging of maritime transport.
- Support dissemination of knowledge on charging and grid infrastructure for increased electrification of maritime transport.

## 4.5 Increasing intelligent multi-modal transport systems

In order to reduce emissions, the Nordic countries have to transfer greater proportion of long-distance goods from road to rail – and sea transport. In general, rail and sea transport are more energy efficient and result in lower emissions per tonne and kilometres than road transport. However, conveying goods by truck has logistical advantages as goods can be taken from door to door, while trains and boats usually require transhipment.

Multi-modality has been in the loop more than a decade, and it is still a key focus area across the Nordics. For instance, in Denmark, where the land transport sector – in their roadmap – emphasizes the importance of a national strategy for multi-modal freight and terminal infrastructure that can strengthen the link between road, sea and rail transport.

The main mutual challenge for increasing multi-modality is lack of economic incentives for commercial operators. Accordingly, higher utilization of inter-modal freight transport requires joint political initiatives across national borders to make the most efficient and green transport form more possible**.** Nordic cooperation on multi-modality is already in the "Nordic Smart Mobility and Connectivity innovation" programme[56] and also bilaterally between neighbouring countries, but a common Nordic strategy for multi-modal transport would create much value.

Much knowledge exists at national level. For instance, the Swedish National Road and Transport Research Institute, VTI, is one of the main contributors to the international FALCON "Freight and Logistics in a Multimodal Context" project. Within the auspices of this project, Sweden contributed, alongside Norway, to a manual aimed at national road transport authorities and other infrastructure actors

56. The programme "Nordic Smart Mobility and Connectivity innovation" programme is running from 2018-2021. One project is the newly launched "Nordic Innovation Mobility Mission: Sea Meets Land" that supports collaboration initiatives seeking to develop solutions to decarbonize multi-modal transport activities in the transition between land and sea. (Nordic Innovation 2018)

and operators within the freight transport sector.[57]

Adding Nordic value could be a comprehensive Nordic freight flow analysis. Based on this overall freight flow analysis, the Nordics could develop a comprehensive strategy for Nordic multi-modal freight transport, which could strengthen the link between road, sea and rail transport. The work should be coupled with ongoing EU work under the Combined Transport Directive as well as involvement of the private sector.

**Joint Nordic opportunities:**

- Nordic cooperation on freight flow analysis with associated strategy for multi-modal freight and terminal infrastructure.

57. (Vierth et al., 2017).

# 5. MINERAL AND METAL INDUSTRY

The mineral and metal industry, in a Nordic carbon emission context, involves extraction/mining and processing of steel, non-ferrous metals, mineral, cement and concrete – with the steel and cement industries being the two primary emitters. Energy efficiency measures have generated overall carbon reductions related to the industries in Sweden, Norway and Finland, whereas Denmark and Iceland have experienced increase in emissions. The road towards carbon neutrality is much dependent upon new processing technology, biomass/biogas and the development of CCS solutions for those parts that are difficult to decarbonize.

The Icelandic metal and mineral industry account for approx. 38% of national GHG emissions, with GHG emissions from metal production accounting for the largest share of emissions. To bring down emissions, the Icelandic government is implementing new carbon taxes, trading with ETS systems and is phasing out fluorinated gases. Furthermore, the metal industry will explore the feasibility of using CarbFix, which is a new CCS technology that turns GHGs from emissions to stone underground in less than two years.

In Norway, the metal and mineral industry has almost halved emissions since 1990, from approx. 10.8 to 5.8 Mt CO2eq, primarily through process efficiency gains within aluminium and fertilizer[58], use of biomass for cement production and end of pipe solutions. The largest reductions since 1990 have occurred within aluminium and fertilizers. The focus of the industry going forward is new process technology and efficiency measures. To reach carbon neutrality the sector emphasizes the importance of technology development within CCS and carbon-free processing, increased use of biomass, hydrogen as a reducing agent and energy carrier and side streams for new products.

The Swedish metal and mineral industry account for approx. 9% of national GHG emissions, with the steel sector accounting for the largest share. Within the cement and concrete sector, initiatives focus on electrification, increased use of biofuels in the production process, circular material flows, increased use of life cycle analysis (LCA) and carbon capture storage (CCS). The mining and mineral sector has made significant progress in switching from diesel to electricity-powered technologies. For reducing emissions further, the sector focuses on new processing technologies, biomass, increased electrification and CCS. In the steel sector, direct emissions emanate primarily from the use of coal when iron ore is reduced to iron (85%), and fuel to heat and processing the steel (12%). For carbon reductions, the sector focuses on new hydrogen process techniques, biocoke for reduction of iron ore and more use of biogas.

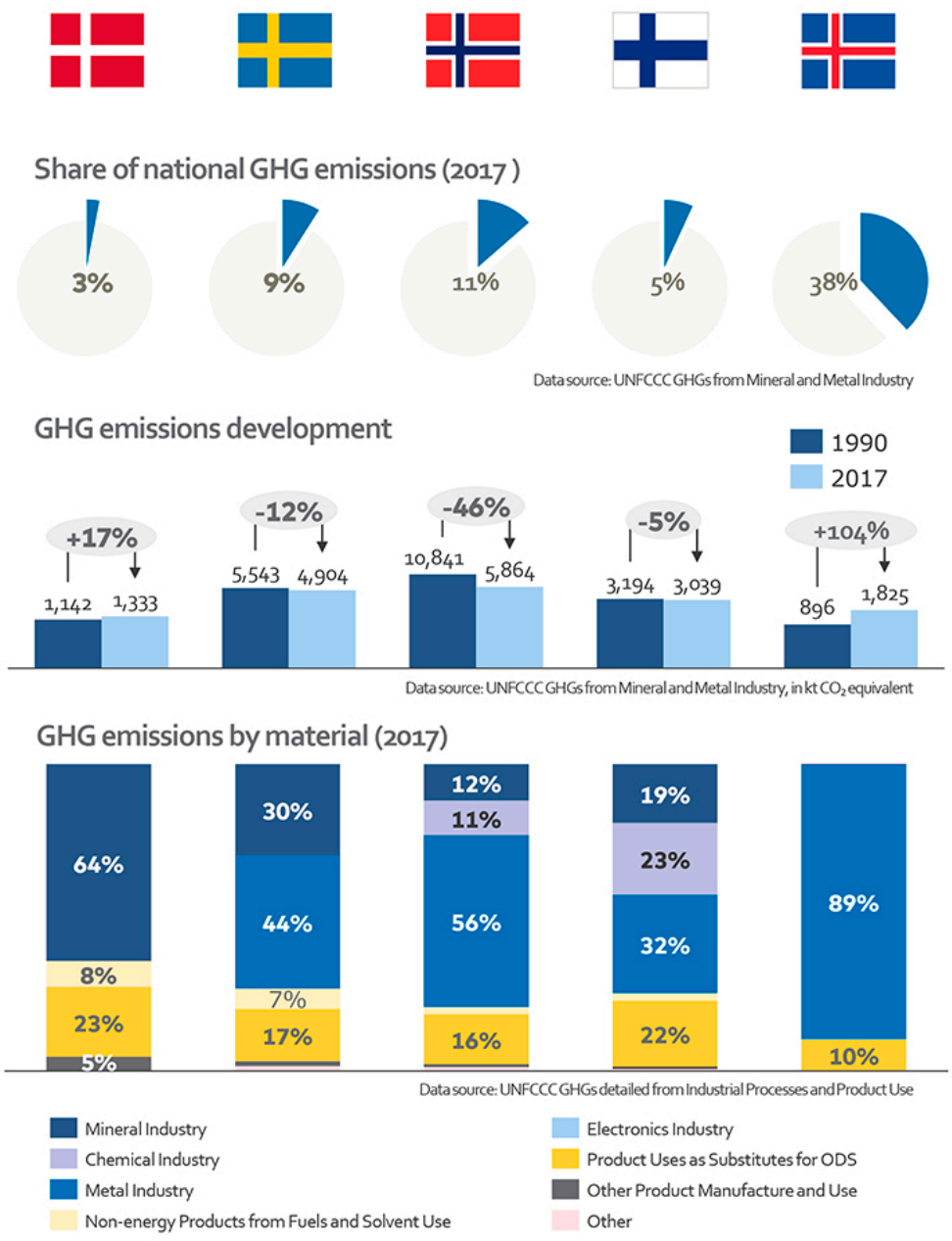
The Danish mineral and metal industry account for approx. 3% of national emissions, with cement as the largest emitter. The sector aims to reduce emissions through

58. Most of reduction from fertilizer production is because of scrubbing

increased energy efficiency, increased use of alternative fuels (e.g. biomass and waste) and changes in the products themselves (e.g. cement with lower chalk content). Also, efforts for replacing coal and natural gas with biogas, electrifying processes and utilizing CCS are the biggest emitters.

In Finland direct emissions of the mineral and metal sector cover approx. 5% of Finland's total emissions. Over 90% of sector-related emissions come from the steel industry, and less than 10% from the mining industry. The steel sector is focusing on the development of new HYBRIT technology that aims to replace coking coal, traditionally needed for ore-based steelmaking, with hydrogen. The efforts could reduce Finland's total emissions by 7% in 2045. Other important initiatives for emission reductions are low carbon raw materials for metal processing, e.g. biomass as an alternative to coke, electrification of mining machines, CCS/CCU, utilization of side streams and manufacturing of synthetic fuels.

**Figure 8. Infographic with mineral and metal industry sector characteristics**



The mineral industry covers emissions from production of cement, lime, glass, whereas the metal industry covers emissions from iron and steel, ferroalloys, aluminium, lead, zinc, copper, nickel and other metal production. Emissions from the mineral and metal industry ranges from 3% to 38% of national GHG emissions. In Sweden, Norway and Finland, GHG emission development has decreased, whereas emissions have increased in Denmark and Iceland. GHG emissions by material display how, on a Nordic level, the metal and mineral industry are the two largest sources of emissions in the UNFCCC category "Industrial Processes and Product Use".

## 5.1 Electrification in the mining and metal industry

Electrification of machinery and extraction transportation is a key priority across countries within cement, mining and minerals industries. In 2013 the Nordic industrial sector accounted for 36% of the total final energy use.[59] The potential for electrification is great, and both in Norway and Sweden total reductions of the processing industry have been brought down primarily due to increased energy efficiency and electrification. In Sweden and Finland, electrification of the mining process is a central focus, and in Sweden and Denmark electrifying cement production is an important component in making the sector CO2 neutral.

The main challenge is Low Technology Readiness Level (TRL) of electrification technologies in both processing and transport systems. Electrification in the processing industries is cumbersome, since both knowledge and technology are lacking. To ramp up technology development to advance decarbonisation of the industrial sector, many pilot projects have been launched across countries and industries. Best practices are found in Sweden, where many of the industry's processes and technologies already are fossil-free, especially in mining operations. Also, in Sweden the company Cementa has launched the initiative Cem-Zero to investigate the conditions for electrifying cement production and GHG emissions. Best practices with regard to electrification of mining transport is found in Sweden and Finland. The mining and smelting company Boliden has invested heavily to expand electrified transportation at Aitik, northern Sweden, and to implement corresponding technology in Kevitsa, Finland.[60]

**Joint Nordic opportunities:**

- Joint research and sharing of experience from different electrification technologies (e.g. induction, plasma or microwave for cement production).
- Exchange of experience between Nordic countries of the use of electrified vehicles for mining and transportation of waste and produced materials.

59. (International Energy Agency, 2016).
60. (Creamer Media Report 2019)

## 5.2 Maturing hydrogen-based steelmaking

In the steel industry further technological developments for replacing fossil fuels are needed to promote further decarbonisation. Accordingly, steelmakers across Sweden, Finland, Island and Norway are working towards using renewable hydrogen, as a reducing agent and energy carrier, to decarbonize their industrial steel processes. Most prominent is the joint initiative HYBRIT involving SSAB[61] (SE/FI), LKAB[62] (SE) and Vattenfall[63] (SE). The initiative aims to replace coking coal, traditionally needed for ore-based steelmaking, with fossil-free energy and hydrogen. The initiative will potentially reduce Sweden's carbon dioxide emissions by 10% and Finland's by 7%[64] and has been presented as one of the most ambitious and most transformative initiatives to tackle climate change at the UN Climate Summit in 2019 (Lead IT). At Luleå in northern Sweden, HYBRIT is now building the world's first pilot plant based on direct reduction of iron ore with hydrogen, which will be ready in 2020. SSAB's goal is a market launch of the first fossil-free steel products in 2026 and produce fossil-free steel by 2035.[65]

Investing in ground-breaking technology such as HYBRIT is often risky, time-consuming and associated with major investments. From a Nordic perspective it is important that all steel and metal producing countries contribute to and benefit from the HYBRIT project. HYBRIT is anchored in SSAB, a Swedish/Finnish company, why knowledge dissemination to the steel industries in Norway and Iceland is central. Knowledge dissemination could, however, also flow from e.g. the Norwegian company TiZir, supported by ENOVA, that plan to replace coal with hydrogen as a reducing agent in the production of titanium slag and pure iron. Or the Norwegian chemical industry, where the company Reinertsen, with the support of Gassnova, plans to establish a pilot project to test new technology to produce pure hydrogen at Tjeldbergodden.[66]

**Joint Nordic opportunities:**

- Collaboration and joint research on the use of hydrogen steelmaking processes.
- Knowledge dissemination from Sweden and Finland to the steel industries in Norway and Iceland

## 5.3 Carbon Capture and Storage in cement, iron and steel

A widespread roll-out of Carbon Capture and Storage (CCS) and carbon capture and utilization (CCU) solutions could be the main driver of Nordic emission reductions between 2030 and 2050. Accordingly, CCS may be an important component for carbon neutrality in Nordic roadmaps in both energy production, waste and biofuels, industrial sectors such as cement and limestone, iron and steel production and petrochemical industries. CCS will be necessary for industrial

61. SSAB AB, earlier Svenskt Stål AB, is a Swedish-Finnish company formed in 1978 and specialised in processing raw material to steel.
62. Luossavaara-Kiirunavaara Aktiebolag is a Swedish mining company.
63. Vattenfall is a Swedish multinational power company owned by the Government of Sweden.
64. (Hybrit 2019).
65. (Hybrit 2019).
66. NorskIndustri, 2016).

emissions that cannot otherwise be avoided. Even with very aggressive action to increase energy efficiency, low-carbon fuel and feedstock, and increased recycling, IEA scenarios indicate the need for wide application of CCS in cement, iron and steel, which cumulatively accounts for almost 30% of total direct industrial GHG emission reduction over the period 2020-50.[67]

In Sweden the ambition is to develop full-scale CCS facilities for carbon capture at a number of refineries. In Denmark, the process industry aims to establish a public-private CCUS lighthouse project centered at Aalborg Portland cement factory, which can be used to test technology and develop competencies. In Norway, the process industry will scale up CCS efforts, with the long-term goal of 5.5 Mt annual CO2eq reductions in 2050. In addition to the full chain CCS plant at Norcem Cement plant, Norwegian efforts until 2030-2035 will focus on establishment of transport and storage systems. From that point and until 2050, efforts will be focused on extending the current CCS system. In Finland, the industrial sector is also looking to introduce CCS at a cement plant after 2035, and the overall goal is to make the cement production carbon neutral before 2050. In Iceland the power intensive industry is assessing the feasibility of using the CCS technology "CarbFix" to reduce emissions.

In general, there are great advantages to gain from a Nordic collaboration on development of new industrial CCS plants and enhanced storage capabilities. Both with regard to the test and research level, and with the actual capture, storage and use of CO2. Much could be gained from further[68] knowledge sharing and dissemination from Norway and Iceland to the remaining Nordic countries. Norway is one of the world's leading nations in terms of CCS development and technology, and Iceland has a remarkable negative emissions CCS plant "Hellisheidi" that uses the innovative CarbFix technology.

There are two central and mutual challenges where increased Nordic cooperation could add much more value for all countries. The first is challenges related to transport and storage of CO2, while the other is lack of long-term framework conditions creating uncertainty with respect to investments, infrastructure, research and funding. The transport and storage challenge both involve geospatial conditions, lack of knowledge and regulatory barriers. Improving the business case of CCS projects is key to accelerating the deployment of carbon capture in industrial applications. Clustering industrial CO2 emissions sources, identifying adequate storage capacities and strategically designing transport infrastructure would enable economies of scale.

As for geospatial conditions, there are large CO2 point sources across the Nordics, complemented by large storage capacity off the coasts of Norway and Denmark. The development of large-scale Nordic projects utilizing joint CO2 hubs and storage sites could therefore benefit from economies of scale. This is underlined by the very high construction and operational costs with a high risk and long-term perspective characterizing CCS. Norwegian companies have about 25 years of experience with storaging in sandstone reservoirs at a depth of 3000 meters off the Norwegian coast. Currently, the Norwegian "Northern Lights" project comprises the transport

67. (International Energy Agency, 2016).
68. Nordic collaboration on CCS has already taken place. Most important has been the NordiCCS - Nordic CCS Competence Centre. This was a Top-level Research Initiative (TRI) which existed from 2011 to 2015. Amongst other the project resulted in a Nordic CCS Roadmap- For publication see: https://www.sintef.no/globalassets/project/nordiccs/nordiccs-bok---web_utg2.pdf

and storage scope of the Norwegian Full-Scale CCS Project, and there should be ongoing Nordic learning, and in best case contribution, from and to this project.

Regarding transport, ETS legislation is currently not adapted to a situation where CO2 is captured at a point source, then transported by ship across national borders to the storage site. This is a problem, for instance in the Skagerrak area, because Nordic CCS projects may require CO2 to be shipped from sources in Sweden and Finland across national borders for offshore storage in Denmark and Norway. There is a need for adapted regulatory conditions for transport of captured CO2, and Nordic cooperation could focus on establishing Measurement Reporting Guideline (MRG) for shipping of CO2.

A cross-Nordic sector involvement to develop Nordic framework conditions for CCS infrastructure, research and funding could add much more value. Nordic Energy Research together with the newly established Nordic networking group on Carbon Capture, Use and Storage (NGCCUS) are already involved in developing this. Amongst other things, the framework conditions should focus on supporting Nordic CCS research and mitigating the financial risk of CCS projects. The technology for CCS exists, but the costs are still too high for a single company to take on in a competitive market. In general, financing the technological leap is a key issue to be addressed by the Nordic countries in collaboration.

Lack of funding operation for Nordic CCS projects must be addressed at a Nordic level since the financial risk is significant. This could be done within the realm of NiB (the Nordic Investment Bank), which could provide capital for a new common Nordic CCS project.

**Joint Nordic opportunities:**

- Encourage knowledge dissemination from Norway and Iceland on CCS research and development.
- Call for collaboration on establishment of Measurement Reporting Guideline (MRG) for shipping of CO2 for adapted regulatory conditions for transport of captured CO2.
- Enhance framework conditions across the Nordic countries for improved CCS infrastructure, research and funding.

# 6. CONSTRUCTION AND HOUSING

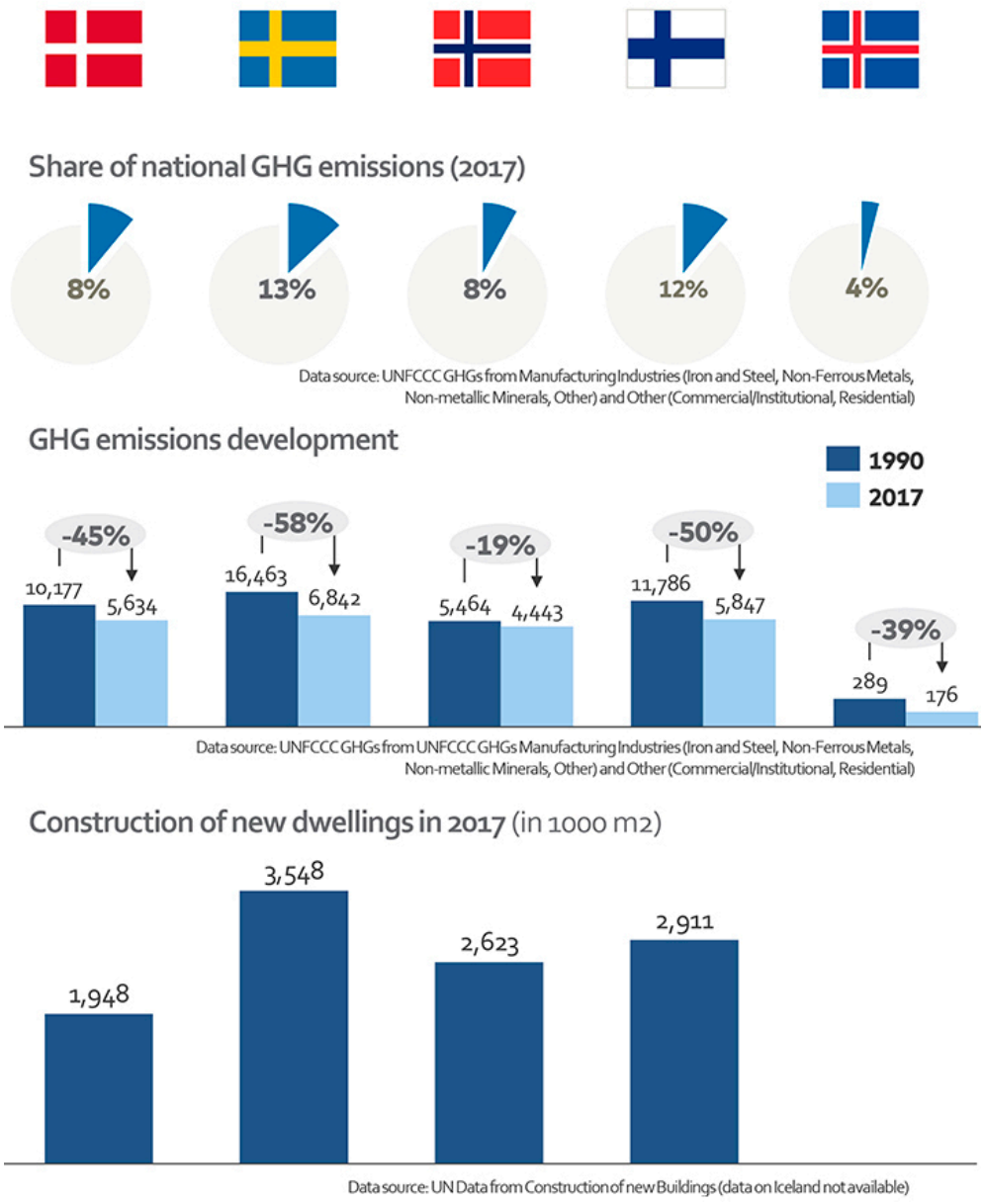
For decades, the construction and housing sector in the Nordics has undertaken measures to reduce environmental footprints and, related with this, in particular carbon footprints, for instance via lower heating and cooling-related energy requirements in buildings. This was enabled mainly through more insulation and improvements in energy efficiency of building. This tendency has been initiated and propelled to a high degree by regulation and by industry-driven improvements in technologies and materials, focusing on e.g. insulation of the building shell.

Across the Nordics, current focus on efforts is extended from professional sector buildings, e.g. office buildings, to also include private/residential housing. Means and depth of implementation differ though, as national building codes (i.e. the nationally implemented regulatory requirements) differ regarding carbon performance requirements. Energy labelling of buildings has become an obligatory documentation in relation to real estate trading in most Nordic countries due to EU regulation (e.g. the Energy Performance of Buildings Directive).

Nevertheless, today significant shares of total domestic GHG emissions in the Nordic countries still relate to buildings, making the sector a substantial contributor to climate impact in the Nordics. Following the sector separation of this report, GHG emissions from construction and housing equal between 4% and 13% of total national emissions. This number would, however, be higher if emissions from e.g. heating and cement production, were included. In this report they are however in energy industry and mineral and metal industry. Construction and housing has a very important position in carbon roadmaps in all Nordic countries – displayed in the form of dedicated sector roadmaps in e.g. Sweden, Norway, Finland and Denmark.

Additionally, the sector overlaps with all five other sectors analysed in this study, since energy, transport, and materials – such as steel, cement, concrete, wood as well as waste, all are key themes when aiming at improving the life cycle-wide GHG performance of buildings. This interdependency yields opportunities of potential win-win effects, since e.g. improvements in the energy sector in a country may lead to reduced energy-related GHG emissions in the construction and housing sector.

**Figure 9. Infographic with construction and housing sector characteristics**[69]




69. The GHG emissions data in Figure 9 cover GHG emissions from Manufacturing Industries (Iron and Steel, Non-Ferrous Metals, Non-metallic, Mineral), in addition to GHG emissions from fuel combustion of Commercial/Institutional and Residential Housing. GHG emissions from Manufacturing Industries are not directly relate to housing, yet they have been included in this figure as they are indirectly related. In general, the UNFCCC data used for the infographics does not mirror the six categories of this report 1 to 1.

Construction and housing cover emissions from fuel combustion from manufacturing industries and construction (iron and steel, non-ferrous metals, non-metallic minerals and other) and fuel combustion from residential and commercial/ institutional housing. This account for between 4 and 13% of national C02 emissions. The GHG emission development has decreased in all countries ranging from 19% in Norway to a 58% decrease in Sweden. In between are Iceland with 39%, Denmark with 45% and Finland with 50% decrease.

## 6.1 Fossil-free construction sites

Most of the carbon neutrality roadmaps across the Nordic sectors address to some extent the potential of reducing – or entirely eliminating – GHG emissions taking place at construction sites from machinery and equipment using internal combustion engines.

The sectors face especially two challenges in this context. Firstly, there is a lack of availability of fossil-free fuels in required quantity and quality (either biofuels or, on longer term, e.g. PtX technologies – both being part of energy sector efforts as well). Such fossil-free fuels would represent the easy way, as machinery would not have to be changed substantially, keeping investment costs low.

Secondly, there is a lack of available market solutions for fossil-free driven machinery and equipment. This is especially due to a low demand from the construction sector on electric machinery, e.g. cranes and excavators. Regulation plays an important role in setting up the right incentives for the producers and providers. For this, the private and public sector across the Nordics could gain from collaboration on identifying common characteristics for regulatory instruments to boost the market for electric equipment for the construction sites.

**Joint Nordic opportunities:**

- Explore regulatory barriers and opportunities for boosting the market for low-carbon solutions on the construction sites, including electric machinery and equipment.

## 6.2 Reduction of embodied carbon

Traditionally, focus on carbon reduction efforts in construction and housing has especially been on energy efficiency in building deployment. While substantial improvements in energy efficiency have been reached in the last decades, further reductions still need to be achieved. Today, focus is thus extended to also reduce the embodied carbon, i.e. the GHG emissions related to the construction materials. This include emissions taking place during production, usage and disposal (this also feeds into the international agenda towards circular economy[70]). Current international efforts, including European standardisation in the field cover both operational carbon and embodied carbon, thus comprising the entire life cycle of a

70. (European Comission 2020).

building.[71,72] Sweden and Finland have incorporated GHG emission targets in their national roadmaps. In Denmark, suggestions for such sector goals have been developed and solutions are being explored. Norway integrates disassembly of buildings in the sector's roadmap.

In order to have the full overview of a building's life cycle, carbon performance, databases on carbon intensity of construction materials and processes are required. In addition, these databases need to be built up in a similar consistent way to ensure comparability, with respect to, for instance, geographical and technical scope. Such databases partially exist at national levels but not at Nordic, European or global levels (although efforts are ongoing, e.g. in the context of EPD schemes (Environmental Product Declarations) and the EU Product Environmental Footprint (PEF).

**Joint Nordic opportunities:**

- Explore the potentials of establishing/aggregating a joint Nordic database with comparable inventory data on CO2 footprint of materials available on the Nordic market, taking into account existing efforts at European level.

## 6.3 Intensified focus on energy efficiency and smart controlling

Energy efficiency is the by far the most common instrument to drive carbon reductions in construction and housing, and it comprises e.g. insulation to reduce demand, but also active electronic ("smart") controlling of consumption. However, increased focus on supply of renewable energy for buildings might turn focus away from this field, challenging its relevance. Thus, it seems relevant to underline the continued high relevance of energy efficiency as an instrument in reaching Nordic carbon targets (as pointed out e.g. in the Danish national roadmap and demonstrated in recent Danish legislation). A special role can be seen in releasing the unused high potential to reduce operational carbon[73] of existing building mass, especially in private housing, which represents a vast opportunity in all Nordic countries.

**Joint Nordic opportunities:**

- Establish a cross-Nordic collaboration with public and private stakeholders on smart controlling technologies with a potential focus on existing buildings, including residential housing. This include strengthen Nordic research efforts, provide experience for regulation and strengthen the related technical equipment industry.

71. (NSAI 2011).
72. (World Green Building Council 2019).
73. Operational carbon describes the emissions of carbon dioxide during the operational or in-use phase of a building, such as use of energy to heat and power a building.

## 6.4 Introduction of greenhouse gas accounting broadly

Any monitoring of developments towards reaching a target requires measuring mechanisms. The instrument of GHG accounting is, however, only relatively sparsely applied in the sector. To be used effectively, several accounting conditions should be defined, e.g. types of buildings to cover (e.g. professional and/or residential, new build and/or existing), life cycle stages, who does the accounting, what data sources are used (which relates to the recommendation in section a. of this sector chapter), definition of assurance mechanisms etc. Since several international standards and schemes exist in this field, especially in the Nordics, inspiration could be drawn from here.

For this purpose, the NCM established the Nordic Climate Forum for Construction. The work is still in progress.

**Joint Nordic opportunities:**

- In close collaboration with the Nordic Climate Forum for Construction, identify the potential of establishing common Nordic guidelines and regulation (e.g. private/residential and professional buildings/infrastructure for existing and new build) for GHG accounting in the entire construction and housing sector.

## 6.5 Expansion of energy labelling to all building types

Requirements in some Nordic countries towards mandatory energy labelling of buildings have proven to be powerful instruments to drive market interest towards low-energy buildings. Yet, this instrument is not necessarily applied to all building types, i.e. it may only cover parts of the sector (e.g. professional buildings, to lesser extent existing private buildings). Furthermore, if applied, it is typically only used when buildings are newly constructed or traded, i.e. at frequencies of many years, maybe decades, rather than e.g. every other year. Thus, incentives to improve energy and GHG performance of buildings may be very limited for existing owners. This could be improved through expanded Nordic labelling schemes for buildings.

**Joint Nordic opportunities:**

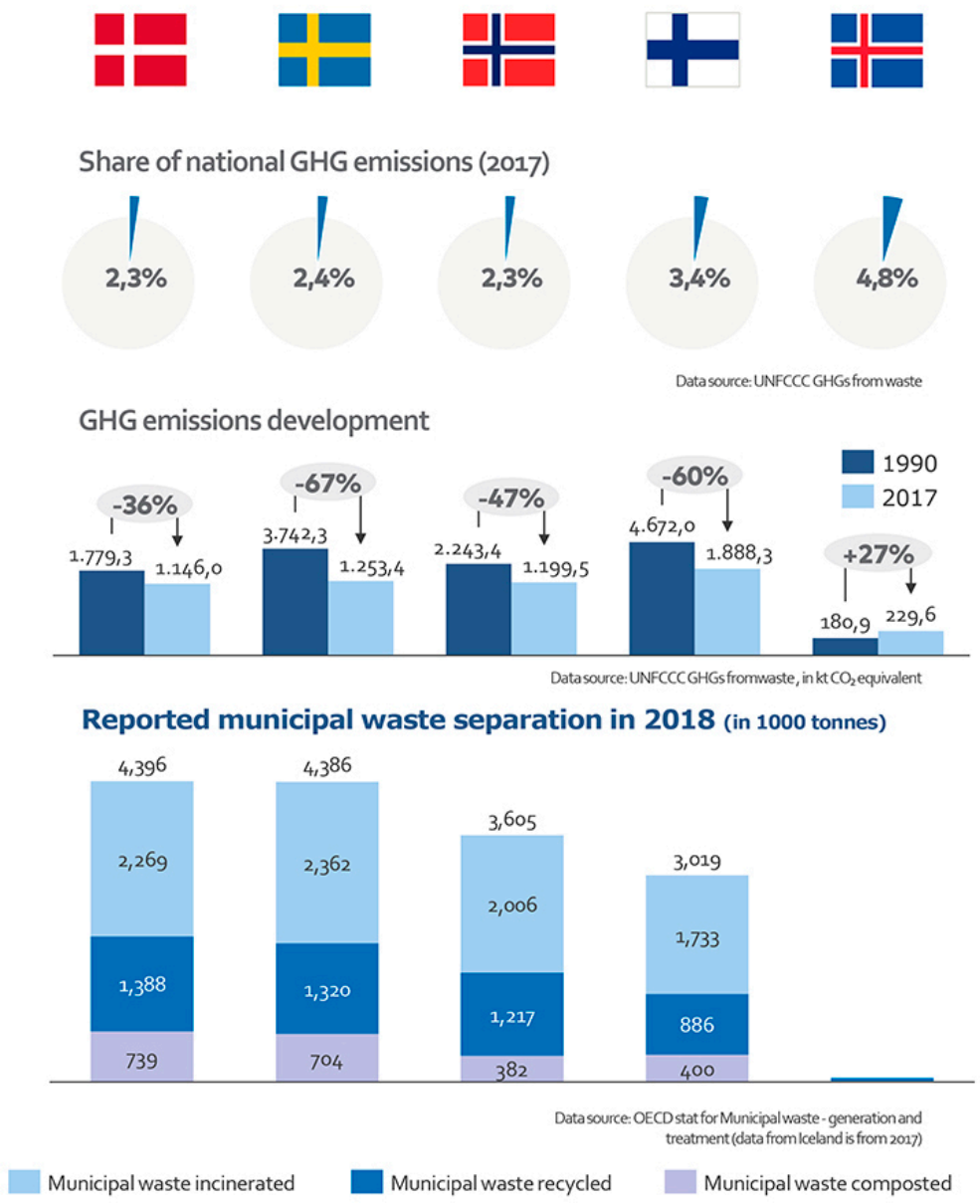
- Investigation into the potential of common Nordic labelling schemes for buildings to drive energy and GHG reductions. A potential expansion of existing labelling schemes, potentially in steps of expanding scope, tightening thresholds etc.

# 7. WASTE MANAGEMENT

For a long time, the Nordic countries have been market leading within waste management systems, using incineration with energy recovery to reduce emissions from the industry. The sector emissions primarily stem from methane from solid waste disposal at landfills and biological treatment from solid waste. Also, methane and nitrous oxide emissions from wastewater treatment and discharge are in focus. Composting and biogas plants are increasing but are still a minor source to methane emissions. Besides, the plants produce products replacing fossil products, thereby representing a greenhouse gas emission reduction.

The emission potential is limited looking isolated at direct emissions stemming from waste, but more significant in the intersection between waste and other sectors such as mining and minerals, production, construction and housing and trade. In the past few years, Nordic national waste strategies have increasingly focused on circular conversion to less climate-damaging materials. This has resulted in new business models placing resource efficiency, waste prevention and recycling at the heart of production and consumption across sectors. Also, the countries have focus on enhancing the efficiency of waste-to-energy, reducing waste through recycling materials, extending product lifetimes and the development of new bio-based materials to substitute undesirable chemistry.

**Figure 10. Infographic with waste management sector characteristics**



Waste management cover emissions from solid waste disposal, biological treatment of solid waste, incineration and open burning of waste, wastewater treatment and discharge and other. The sector covers between 2.3% to 4.8% of Nordic GHG emissions. In Denmark, Sweden, Norway and Finland GHG emissions from this sector has decreased with 36% and 67% between 1990 and 2017. The reported municipal waste separation displays a high level of incineration relative to recycling and composting across the Nordics.

## 7.1 Improved separation and recycling of plastics

Improved separation of plastic prevents emissions from incineration, and separation and recycling of plastics have the potential to reduce emissions from waste energy plants significantly. Accordingly, the EU has set a target that 55% of all plastic packaging is to be recycled in 2030. To fulfil this, a significant increase in recycling of plastic is needed across the Nordics. This is reflected in national waste strategies and sector roadmaps. In Norway, a dedicated sector roadmap for circular plastic has been developed in 2019, and the Swedish food retail sector aims for all plastic packaging to be based on recyclable or renewable raw materials by 2030.[74]

The main barrier for increased separation of plastic is the current technology for mechanical fine separation. Whereas the recycling market for metals has matured over many years – the market and technologies for plastic is still in its infancy. As a result, the Nordic countries focus on developing technologies for removing plastic from incineration. The energy and waste sectors are, however, challenged by the cost of separating plastic in waste plants, and improved separation technologies are needed. The Nordic waste sectors could benefit from increased collaboration on separation technologies.

Another central challenge is limited incentives for separating and recycling plastic in industries and households. Public campaigns have increased separation of plastic in households and companies, and dissemination from these campaigns and national incentive structures could create value.

**Joint Nordic opportunities:**

- Enhanced collaboration on plastic separation and recycling technologies.
- Dissemination of best practices on incentive structures for plastic recycling.

## 7.2 Increased use of recycled materials

Increased recycling of materials is a key focus for all the Nordic countries. In some sectors, such as the metal industry, markets for recycling are well developed, whereas others, such as building material and plastics, are less developed.

74. (Ministry of the Environment, 2018)

A central challenge for the Nordic sector is standardisation of the development of new materials. Nordic cooperation within product standardisation would add value to and support the development of a well-functioning market for i.e. recycled building materials. As an example, the Nordic construction and housing sector would benefit from a common Nordic approach to the EU commission's work on product standards in their "Circular Economy Action Plan". A central part is that product standards should incorporate directions on how recycling can create new products. Such new product standards would be the cornerstone of a market for recycled materials that goes beyond what is already happening in the field, and it is important the Nordic countries has a unified approach to the directives.

**Joint Nordic opportunities:**

- Support the development of a unified approach to the EU Commission's work on product standards.
- Cross-Nordic pooling of recycled waste materials.

## 7.3 Combatting food waste

Following the full production chain, emissions from food production have become a growing concern with consumers in the Nordic countries. Therefore, the sectors have had an increasing focus on combatting food waste. Also, the circular economy agenda in the Nordic countries as in EU emphasises the fight against food waste and food loss by establishing platforms. Food waste refers to decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers, and food loss refers to food being discarded, incinerated or otherwise disposed of along the food supply chain, excluding the retail level. Also, public awareness campaigns to minimize food loss are launched, and some countries have allowed for distributing food after the sell-by period.

The cross-cutting theme of food waste calls to bridge efforts across the food industry and waste management sectors. However, as the sectors are still experiencing lack of economic incentives for reducing food waste in large scale, the efforts are yet to grow in large scale.

**Joint Nordic opportunities:**

- Systematic approach to organise campaigns and collaboration with civil society.
- Encourage broad collaboration between representatives and the Nordic Working Group for Circular Economy (NCE) on cutting the volumes of waste.
- Enhanced knowledge on behaviour.

## 7.4 Enhance eco-design in production

Although the Nordics have long paved the way for circular economy approaches by promoting eco-design, clean production, eco-innovation and sustainable consumption, waste production is still among the highest in Europe. Technical issues on embodying the eco-design in the product development line are still a key challenge. Also, the sector faces lack of risk-willing capital for development projects

and knowledge on how to increase longevity and reutilization of products.

Design plays a crucial role in the transition to circular economy and is the catalyst for efforts. Through design thinking, companies will be able to ensure longer product lifetimes, increased focus on recycling, changed material use and less waste.

A driver for enhancing the eco-design is the EU revisions of the Waste Framework Directive and Packaging and Packaging Waste Directive. These revisions may lead to a reform on producer responsibility systems which may lead to an increase in recycling rates and reduced volumes of waste.

**Joint Nordic opportunities:**

- Collaborate on promoting and utilizing the leading expertise in the Nordics.
- Collaborate on sustainable product design, in both academia and industry.
- Identifying financial sources and enable a Nordic fund.
- Identifying regulatory tools, e.g. extending warranties, for encouraging producers to make products more durable and recyclable.
- Nordic strategy on extended producer responsibility.

# 8. AGRICULTURE AND FORESTRY

The forestry and agricultural sectors have a central role in the Nordic strategy towards carbon neutrality. The sectors are an emitter from land use, producer of energy crops and biomass and carbon storage. The emissions are roughly divided into three main categories: enteric fermentation, manure management and agricultural soils, with minor emissions from other sources.

While emissions from forest has been reduced over the last decades, agriculture has been more challenged and is only expected to see a minor reduction alongside the current development. The main challenge is to reduce emissions from agriculture without comprising an international competitive farming and food producing sector. The main areas of reduction of emissions from agriculture are animals and agricultural soils. Also, a more resource effective food production industry is in focus, together with increased carbon capture, for example through afforestation, a sustainable food consumption and avoidance of food waste.

In Denmark, the farming and food producing sector can half emissions before 2050 with current technology. The sector focus is a mixture of incorporating existing technology and new methods and technology that might be invented in the future. National efforts focus on restoring peatlands, reducing the use of fertilizer and a forest foundation for forestation. The latter including afforestation and buyup of carbon rich farmland.

In Finland, the direct emissions from the agriculture and forestry is about 12% of total greenhouse gas emissions. The largest emission source is nitrous oxide from soils, which is mainly due to fertilization in agriculture. Future efforts include changing land use, increasing carbon capture in soils and forest, increasing renewable energy production, electrification. Focus is also on investment in low-emission technologies, strengthened framework conditions to prevent carbon leakage from the industry, improving energy and material efficiency and new solutions for circular economy as well as supporting the industry in developing products that replace fossil, non-renewable materials and meet the demands of environmentally conscious consumers.

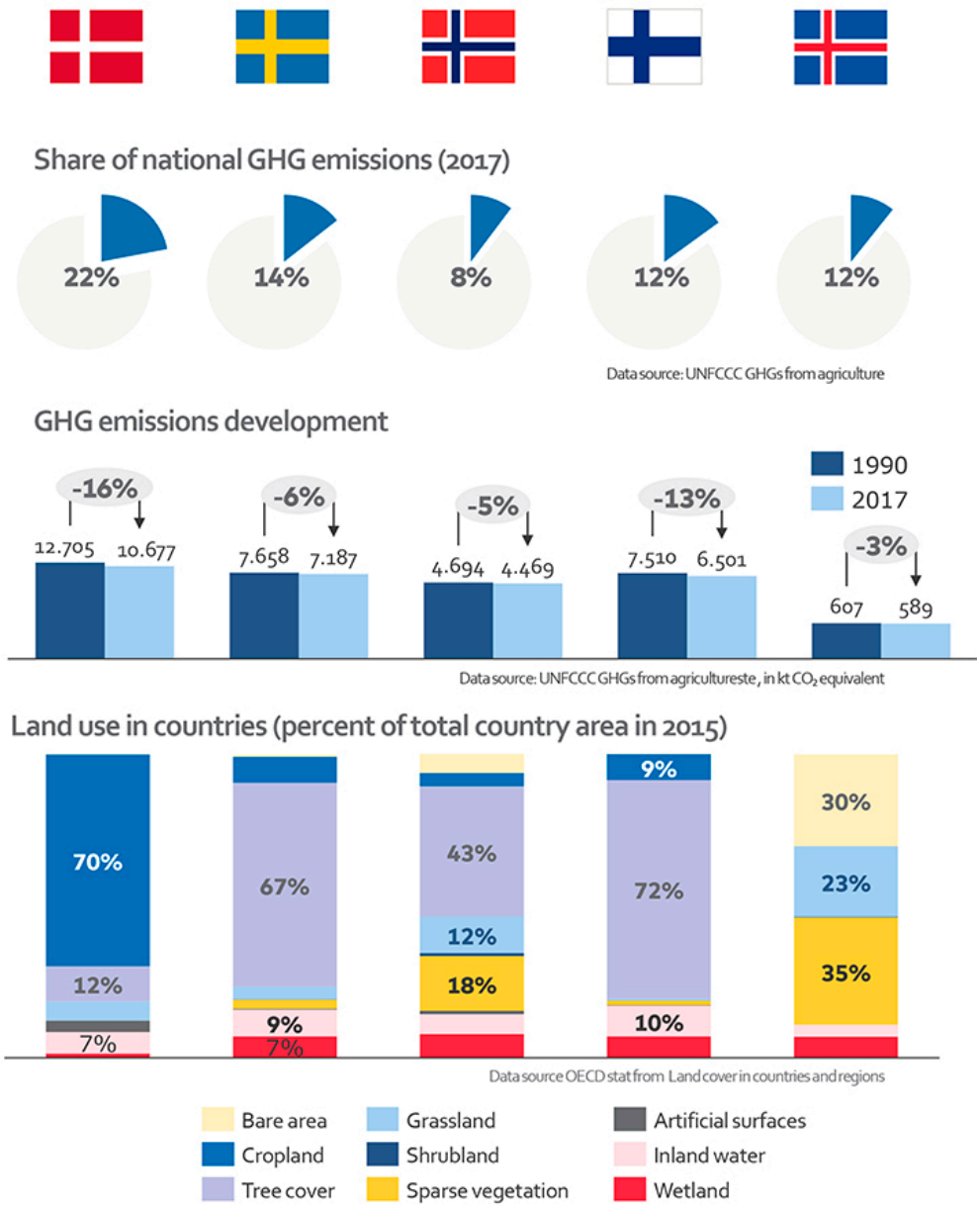
In Sweden, agriculture and forestry accounts for about 15% of national emissions. The main part of emissions in the sector origins from cattle and land use. In the agricultural sector, the Swedish agriculture cooperative Lantmännen is in the forefront of developing knowledge, technologies and methods for farming. Forward focus is on improving efficiency of transportation, electrification as well as investments in research and innovation.

In Norway, the emissions related to the agriculture sector was 4.5 mill. ton CO2eq, corresponding to 8.4% of the total Norwegian greenhouse gas emissions. Characteristic for the Norwegian agriculture sector is small scale farms and long transport routes. The sector is especially focusing on climate efficient production and collaboration with other sectors on usage of bioresources.

The agriculture sector in Iceland account for about 12% of the emissions and has

only decreased slightly since 1990. Iceland is self-sufficient in all major livestock products, such as meat, milk, and eggs. Traditional livestock production is grassland-based, and most farm animals are native breeds. In Iceland, the focus of the sector is to reduced use of synthetic fertilizers, improve manure management, carbon efficient cattle and sheep farming and increase the biofuel production from plants and waste.

**Figure 11. Infographic with agriculture sector characteristics**



Agriculture cover GHG emissions from UNFCCC reporting category agriculture only excluding LULUCF. Share of national GHG emissions from agriculture range from 8% in Norway to 22% in Denmark. GHG emissions from agriculture have decreased across all countries, with Denmark accounting for the largest decrease. Land use differ across the Nordic countries. In Sweden, Norway, and Finland, most land use is forest. In Denmark it is cropland, and in Iceland it is sparse vegetation.

## 8.1 Land restauration, reforestation and peatland rewetting

Land restauration, reforestation and peatland rewetting are central efforts to reduce carbon emissions in agriculture and forestry, as drainage and cultivation of soil with a high content of organic carbon is a significant source of greenhouse gas emissions. Peatlands are an important natural terrestrial carbon reservoir, and drained peatlands reduce soil respiration and lead to substantial amounts of GHG emissions. The challenging process of conversion of peatland calls for knowledge sharing on best practices with optimal climate effects. There is lack of knowledge on which lands to convert and optimal alternative land utilization. Furthermore, at an institutional level, lack of positive business cases for converting the lands are found, which again removes the economic incentives for the landowners.

Best practice is to be found in the Danish agriculture sector, where the agricultural sector is heavily investing in the removal of emissions from low-lying organic lands.

Furthermore, there is a need for increased incentives for reforestation and land restauration.  Best practices for these efforts are found across all the Nordic countries. One example is Iceland where increased state support is prioritized. Also, NGOs and foundations in Finland and Denmark have developed projects where people can buy relatively small forest areas for protection use.

**Joint Nordic opportunities:**

- Collaboration on research regarding peatlands and the effects of rewetting.
- Disseminate knowledge on economic perspectives of alternative land use and soil emission factor.

## 8.2 Increased production of biofuels

Biomass that is suitable for energy sources represent about 90% of all biomasses available in the Nordic countries. Sweden and Finland have the largest supply of forest biomass, and Sweden and Denmark of biomass from agriculture.

Agro-biomass, suitable as an energy source, consist of energy crops, straw, husk, grasses, and manure.  According to a recent analysis[75], the amount of agro-biomass is expected to increase in Finland and Denmark. Norway and Iceland will stay the same, and a decrease is predicted in Sweden due to a decline in straw (caused by a decline in cereal production) and husk. Biomass from waste is expected to increase in all countries due to population and economic growth. There is, however, ongoing

75. See Pöyry Management Consulting Oy (2019c). *Potential for Bioenergy in the Nordics.*

political pressure to reduce and separate biowaste, which will reduce the availability of waste biomass as an energy source.

A main challenge related to increasing the production of biomass is the complexity of developing sustainable biofuel without adverse effects on the environment and biodiversity. Also, challenges include poor profitability of biofuel production investments, uncertainty on future demand for biofuel and general lack of funding.

**Joint Nordic opportunities:**

- Development of Nordic framework conditions for sustainable biofuel production.
- Knowledge dissemination of different Nordic biofuel trajectories.
- Knowledge dissemination and R&D on biofuels, including genetics, among others.
- Nordic study on understanding the biological processes and measuring the emission factor and storage capabilities.

## 8.3 Reducing fossil-based dairy packaging

The Nordic dairy industry plan to reduce emissions by reducing fossil-based dairy packaging. The reduction may occur through increased recycling, reuse or replacement of conventional plastics with biogenic plastics. An example is the Scandinavian multinational cooperative Arla, aiming to make 600 million milk cartons 100% recyclable and emit 25% less GHG with a conversion from fossil plastics to bio-based plastics in production.[76]

Such ambitious initiatives prompt the need for Nordic collaboration on logistics and having consumers accept new forms of packaging.

Even though some of the world leading companies in the field of dairy packaging are in the Nordic countries, the sector is challenged by lack of efficient and cost-effective solutions to fossil-free packaging. The EU directives on extended producer responsibility, will stipulate sustainable transformation. The Nordic companies face increasing cost of compliance, which is likely to lead to greater system integration. The sector, however, needs assistance on increasing competencies, tools and materials for designing recyclable and resource efficient dairy packaging.

Many initiatives involve focusing on circular economy and the out phasing of fossil-based plastics in food packing. This also includes initiatives of collecting and reusing plastics. This calls for collaboration across the sector and with consumers in order to handle logistics and accepting new forms of packaging. The sector is also challenged by lack of knowledge on efficient and cost-effective production of fossil-free packaging.

**Joint Nordic opportunities:**

- Collaboration on increasing competencies, tools and materials for designing

76. (Regeringens Klimapartnerskaber, 2020a)

recyclable and resource efficient dairy packaging.

- Joint test facilities for recyclable materials to replace conventional plastic packages.

# 9. POLICY RECOMMENDATIONS ON JOINT ACTIVITIES WITH NORDIC ADDED VALUE

The partnerships between the Nordic governments and business communities demonstrate that public as well as private stakeholders are committed to closing the gap between carbon neutrality efforts and the ambitious national GHG emissions targets. It is evident that the Nordic business communities share a common interest in replacing fossil-based solutions with carbon neutral solutions.

Chapter 3 to 8 have focused on planned carbon reducing efforts and mutual Nordic challenges in reaching these. Focus has been on sectors with the highest potential for ensuring the fulfilment of the carbon neutrality goals.

The interviews and workshops conducted during the project have revealed a high degree of interest from the business communities in working closer together at a Nordic level. Especially within increased collaboration on research and development, knowledge sharing and establishing new working groups on specific themes.

Based on the identified sector challenges for reaching carbon neutrality, different joint Nordic opportunities for action have been highlighted. These opportunities all have the potential of contributing to the sectors' realization of their roadmaps. In the following sections, we clustered these opportunities for action into recommendations for a Nordic collaboration. It should be noted that not all opportunities for joint actions are included. Instead the recommendations reflect those activities that according to our analyses would bring most added value to the carbon neutrality agenda.

## Nordic platform on sustainable transportation solutions

Sustainable and advanced liquid biofuels for transportation has long been the focus of Nordic Energy Research and other Nordic working groups. However, a higher degree of involvement of the private sector would benefit the collaboration and ensure a better cross-Nordic dissemination of the results. Such collaboration could focus on the major challenges of using biofuels, including the competing utilization of biofuels for aviation, shipping and road-based heavy freight transportation. Furthermore, a cross-Nordic sector collaboration may also contribute to meeting the challenges regarding regulatory uncertainty related to sustainability certification and biofuel producers.

Apart from the development of biofuels, other collaboration potentials within sustainable transportation exists. This includes cross-Nordic sector collaboration on inter alia sustainable freight solutions, intermodal solutions and EV charging infrastructure.

Furthermore, a cross-Nordic dialogue could contribute to a revision of the funding selection criteria of the Nordic funding mechanisms. This could favour solutions for

sustainable transportation, including second generation biofuels and technological development on synthetic fuels for the transportation sector and pilot projects in this field.

**Policy recommendations for Nordic collaboration:**

NCM could, in close collaboration with Nordic Energy Research, support cross-Nordic sector collaboration on sustainable biofuel production. NCM could:

- Establish a Nordic sector platform with participation from relevant sectors, including energy industries, agriculture, forestry and transportation. The platform should cluster collaboration on specific themes, including inter alia sustainable freight solutions, intermodal solutions and EV charging infrastructure.
- Identify studies, support pilot projects and disseminate knowledge from second generation biofuels and the development of electrofuels.

## Nordic public/private sector platform on PtX

PtX solutions are still in their infancy and viable business cases have yet to be seen. The technologies are, however, increasingly becoming a core part of the Nordic countries' way to reduce GHG emissions in hard-to-abate sectors, especially transport, and to balance the increasing level of renewables in the energy systems. The Nordic energy sectors are also increasingly focusing on PtX and are requesting financial support for increased research and development of PtX solutions. This common interest, and the need for cooperation on R&D, represent a great opportunity for Nordic public/private collaboration. Collaboration should focus on common solutions and standards, R&D, as well as testing plants for PtX technologies. Selection criteria for Nordic funding mechanisms also present an opportunity for collaboration.

**Policy recommendations for Nordic collaboration:**

NCM could, in close collaborate with Nordic Energy Research, support the collection and dissemination of new knowledge and best practices on PtX technologies, by:

- Establishing a Nordic public/private sector platform with participation from relevant sectors (including energy and transportation).
- Identifying and supporting new studies focusing on PtX solutions and operation strategies.
- Organising sector dialogue meetings on new promising solutions for PtX.

NCM could also follow up on the ongoing study by Nordic Energy Research that identified PtX sites, by pinpointing resources that can enhance R&D and demonstration of PtX solutions. Priority should be given to solutions matching national plans for expansion of renewable electricity production, including new offshore wind technologies such as floating hubs.

NCM could also encourage national governments to provide additional funding for Nordic participation in, and knowledge dissemination on international PtX projects outside Norden.

## Nordic public/private sector platform on CCS technologies

Across the Nordics, the energy and construction sectors are increasingly involved in a widespread roll-out of Carbon Capture and Storage (CCS) and Carbon Capture and Utilization (CCU) solutions. In 2019, a Nordic networking group on Carbon Capture, Use and Storage (NGCCUS) was launched to exchange information on CCUS in the Nordic countries.

There are two central Nordic CCUS challenges where increased Nordic cooperation could add more value for all countries. The first is challenges related to transport and storage of CO2, while the other is lack of long-term framework conditions that creates uncertainty with respect to investments, infrastructure, research and funding. The transport and storage challenge both involve geospatial conditions, lack of knowledge and regulatory barriers.

Regarding BECCS technology, the primary challenges are immature technology and lack of financial incentives for negative emissions. Further Nordic cooperation could be to explore the possibilities for establishing a cross-Nordic auction for predetermined volumes of negative emissions where the player who can offer BECCS at the lowest price wins. The Nordic countries could also collaborate for the establishment of emission allowance corresponding to the negative emission of CCS on fossil-free fuels (biogenic waste and sustainable biomass). This could materialize through EU or international agreements on calculation and payment rules for CCS.

**Policy recommendations for Nordic collaboration:**

Nordic Networking group on Carbon Capture, Use and Storage (NGCCUS) and Nordic Energy Research should establish a cross-Nordic public/private sector initiative to:

- Develop recommendations for the establishment of aligned national framework conditions for CCS infrastructure, research and funding across the Nordics. This include identification of regulatory solutions for international shipping of captured GHG.
- Explore possibilities for developing a Nordic auction for negative emissions.
- Collaborate internationally for emission allowance corresponding to the negative emission of CCS on fossil-free fuels.

This networking group could also focus on facilitating collaboration on common Nordic CCS/CCU infrastructure, including the establishment of a Nordic GHG storage hub as well as sector-driven taskforces on CCU and BECC technologies within the energy and construction sectors.

## Joint initiative on removal of emissions from peatlands

Reducing GHG emissions from peatland is one of the most important steps for the agricultural sector in order to reach carbon neutrality. This include drainage and cultivation of soil with a high content of organic carbon, since it is a significant

source of GHG emissions. The sector would gain from a Nordic collaboration on research with respect to the effects of rewetting, dissemination of results regarding soil emission factors and the identification of the right technical conditions for transforming agricultural land into alternative land use.

**Policy recommendations for Nordic collaboration:**

NCM should convene a workshop in collaboration with the Nordic agriculture sector to establish a forum for exchanging and disseminating knowledge on two main areas:

1. Rewetting and conserving peatlands.
2. Economic perspectives of alternative land use and soil emission factors.

## Enhance research and development on materials and heat and electrification solutions

The Nordic region has a strong tradition of collaborating in R&D, and many organisational groups have been formed to organise this collaboration. R&D is a continuing topic across all sectors for reaching carbon neutrality.

Many R&D initiatives exist across various Nordic working groups. For example, Nordic Energy Research has identified six priorities for joint Nordic energy research collaborations.[77] These recommendations were based on thorough engagement with stakeholders, some of these are also mentioned in this study.

During the research for this study, some sectors have, however, explicitly requested assistance for R&D. The housing and construction sector would like R&D support in the development of alternative climate neutral construction and packaging materials, including the innovation of bio-cement and bioplastics. The energy sector call for R&D support for heat solutions to enhance the utilization of waste in district heating, as well as research collaboration on electrification technologies within the construction sector.

Considering the high level of demand for new technologies to reach carbon neutrality, it should be stressed that the selected themes are not the only ones in need for increased R&D support. Furthermore, a systematic list of prioritized research themes is beyond the scope of this study.

**Policy recommendations for Nordic collaboration:**

NCM could convene a general meeting with key Nordic institutions and working groups to identify measures for supporting a cross-Nordic R&D of new technologies with a high impact on GHG emission reductions, leading to a prioritization of R&D support. The meeting could inter alia explore and clarify possibilities for mobilizing funding and establishing networks to support the development of alternative climate neutral building and packaging materials, including the innovation of bio-cement and bioplastics. Likewise, the meeting could look at how to support both the

77. 1) Digitalisation of the electricity grid, 2) The Nordic energy market, 3) Energy storage, 4) Sea, air and road transport, 5) Bioenergy, 6) Carbon capture and value creation.

development of heat solutions to enhance the utilization of waste in district heating and research collaboration on different electrification technologies within the construction sector.

NCM could also organise a Nordic workshop for central stakeholders in the Nordic construction sector to explore the possibilities for establishing a common Nordic database with comparable inventory data on the CO2 footprint of materials available on the Nordic market.

NCM could furthermore establish a Nordic sector platform to help the food industry to design recyclable and low carbon efficient packaging, including dairy packaging. The platform should focus on solutions to replace plastics from the food industry, and support to research, development and testing of new promising packaging materials.

# 10. CONCLUDING REMARKS AND WAY FORWARD

The purpose of this study is to identify how a Nordic cooperation can contribute to the fulfilment of the Nordic carbon neutrality goals, focusing on the areas identified in the Helsinki Declaration. Accordingly, the study has identified Nordic opportunities for cooperation to overcome challenges related to realizing carbon reducing efforts across Nordic key sectors.

The results have been identified by going through existing and planned efforts to reduce GHG emissions in each of the Nordic countries. Considering different starting points and framework conditions, the study has identified best practices and common challenges, where a strengthened Nordic cooperation could support mutual efforts to spur further reductions of GHG emissions.

The following extracts can be made:

1. Sector partnerships and roadmaps are cornerstones for the Nordics to reach carbon neutrality.

   The governments in all the Nordic countries have established partnerships with various sectors, which have developed roadmaps in close coordination with public authorities. The roadmaps provide a prioritized list of sector efforts intended to remove the gap between current baselines and carbon neutrality targets. The partnerships play a critical role ensuring sector action and commitment to identify the most effective roadmaps.

2. Limited knowledge exists within sectors on best practices in the other Nordic countries. This also includes past and current Nordic policy initiatives. In addition, common, aggregated Nordic energy and climate related data and statistics are not present.

   Joint Nordic efforts are likely to play a key role in increasing knowledge transfer on legislation, data and R&D. Interviews and dialogue with sector representatives indicate a need for increased knowledge sharing, as local industries are often unaware of relevant sector efforts outside their own networks. If the sectors are engaged in cross-border knowledge sharing, attention is often directed towards larger EU members states and the USA rather than looking for best practices in the Nordics.

3. Common ambitions and partnerships are windows of opportunity for Nordic-wide sector dialogues on carbon neutrality.

   2020 marks the year where Nordic business communities are becoming increasingly engaged in national roadmaps and international commitments toward carbon neutrality. The ink from the Danish and Swedish sector roadmaps is hardly dry at the time of writing, and the final roadmaps in Finland

are expected to be published in summer 2020. This, together with the ambitions following ratchet mechanism in the Paris Agreement (the in-built design to steadily increase ambition over time) and, more generally, the international awareness of mitigation efforts, further increases the motivation for the Nordics to share best practices.

Our study has shown that there are plenty of overlapping sector efforts across the Nordic countries, many of which would gain from an increased Nordic collaboration. As summarized in the policy recommendations, such collaboration could happen on specific research themes, through e.g. CCS and PtX, or by sharing experience through e.g. joint test and pilot projects. Opportunities for scaling carbon neutrality efforts in the Nordic countries have never been greater.

As mentioned in the preface, the study has been produced during the outbreak of the COVID-19 crisis, between February to June 2020. It has not been possible to include an analysis of the impact of this crisis on the countries' road towards carbon neutrality, as the impact on sector efforts has yet to be assessed. All Nordic governments have indicated that low carbon development is likely to be part of the engine of recovery.[78] This could indicate a need for Nordic collaboration to explore activities that identify the impacts of the COVID-19 on the carbon neutrality pathway.

78. See for example: https://www.norden.org/en/news/nordic-ministers-call-post-corona-synergies-between-economic-recovery-and-green-transition

# METHODOLOGY

This study is the result of a Nordic project, undertaken by Ramboll Management Consulting in collaboration with Gaia Consulting, and developed in dialogue with the Nordic Working Group for Climate and Air (NKL).

The data for the study has been collected from February to April 2020. There have however been specific data modifications up to the final report in June 2020. Activities have included:

- Five national desk studies on national and business roadmaps and initiatives in each Nordic country.
- Stakeholder interviews on existing and planned goals and sector-wide efforts in key emission sectors in each of the five countries.
- National and cross-Nordic workshops to verify the findings and involve dialogues on identifying joint Nordic challenges and opportunities.

Following the data collection, a three-step analysis was carried out. First a **country mapping**, to provide an overview of the landscape of carbon neutrality definitions used in the five Nordic countries. The mapping also identified the national long-term climate strategies as well as governmental goals and plans for reduction of GHG emissions. The second step involved a **comparative cross-country analysis** to identify national commonalities and differences, where knowledge sharing could enhance the green transition. Finally, an **action identification analysis** was produced. This analysis level focused on common and mutual challenges and highlight areas of Nordic-added value to initiatives for joint action.

It should be noted that the data and analyses were largely produced during the outbreak of the COVID-19 crisis. As a consequence, some of the originally planned workshops were held as e-conferences, and others were converted into stakeholder interviews. It is the assessment of the authors that this adaption did not influence the conclusions and recommendations of the report.

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# About this publication

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ISBN 978-92-893-6755-4 (PDF)
ISBN 978-92-893-6756-1 (ONLINE)
http://dx.doi.org/10.6027/temanord2020-527

TemaNord 2020:527
ISSN 0908-6692



### Disclaimer

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