

DECARBONISATION OF THE NORDICS

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EXECUTIVE SUMMARY

All the Nordic countries have ambitious targets for decarbonisation of their economy.

Moreover, the Nordic Council of Ministers has a vision for a decarbonised Nordic region, signed by all heads of state.¹ We identify **four key results that a successful decarbonisation strategy** needs to deliver and propose a **roadmap** for the coming years. Further, we propose **a set of concrete policy actions** at the national, regional and international level needed to bring about a cost-effective path for decarbonisation of the region.

The four results to be delivered

First, progress for decarbonisation must be speeded up for heavy transport, including shipping and aviation and large parts of heavy industries, as energy use in these sectors is still largely relying on fossil fuels.

Second, the technologies to potentially decarbonise these sectors will have to be developed to industrial scale. While there is a portfolio of proven and promising technologies with large potential, they are still too costly to deploy.

Third, incentives to deploy such technologies must be improved. The deployment of more costly technologies is notably constrained by the fact that prospective users are very much exposed to international competition. In other words, if firms producing in the Nordic region are forced to purchase expensive alternatives to fossil fuels, then global emissions will not decline, as the energy intensive activities risk moving out of the region.

Fourth, and related to the third challenge, the global community must step up with more firm measures to reduce GHG-emissions consistent with the Paris Agreement. This is particularly important as Nordic decarbonisation targets are also more ambitious than the decarbonisation targets for the EU and the international community. Hence, the risks of carbon leakage will be increasing in sectors with international competition, also within the EU.

The proposed policy roadmap has three main components that can help the Nordic region deliver on its ambitious decarbonisation targets. Highlights of these are summarised below while 13 specific recommendations are included in our policy chapter.

First component: establish a credible carbon pricing framework

- *Streamline current tax and subsidy schemes* related to energy use. Over time, carbon emissions should ideally be taxed at the same rate for all uses of energy. This should replace the current patchwork of highly varying levels of taxation of CO₂ at both national and EU level coupled with a multitude of subsidy schemes for renewable energy. This would encourage a more cost-effective path for decarbonisation, notably by creating incentives that are more technology neutral. As an example, taxation of electricity at end user level becomes increasingly counterproductive from a climate policy perspective since inputs in generation are increasingly non-fossil based, and since electricity will be a key driver for decarbonisation in the wider economy.

¹ Norden (2019), Our Vision 2030. Available at <https://www.norden.org/en/declaration/our-vision-2030>

- *For internationally exposed industries, focus firstly on the EU level and secondly on the national level.* Given expected technology costs, higher carbon prices are needed for the energy-intensive industries to deliver on decarbonisation. On the EU level, the effort should be focused on strengthening the Emission Trading System (ETS), introducing a carbon price floor both in the ETS and in the Energy Tax Directive. We see a higher ETS price as an absolute no-regret policy option, as the carbon price within the ETS sector is orders of magnitude lower than the implicit carbon prices outside the ETS as a result of (higher) national taxes on fossil fuels. Should EU measures be insufficiently stringent to deliver Nordic decarbonisation targets, we recommend introducing a regional or national carbon price floor both for the ETS and the non-ETS sector.
- *Combine a more effective carbon pricing with a compensation mechanism to address carbon leakage.* Such a system is already in place for ETS but also needs to be implemented at the national level. This can for example be done by compensating industries at risk of carbon leakage through direct transfers to the relevant industries. This should be in place as long as carbon prices in the Nordic region exceed EU and international levels for industries exposed to leakage.

Second component: Targeted support for promising technologies

- *Increase government support to develop critical low-emission technologies* and mature these to an industrial scale over the coming decade. This can be done through smart blended finance where the government absorbs a substantial part of the downside risks associated with these technologies. Further, a portfolio approach is useful to ensure that government funding is not too narrowly targeting specific technologies (to avoid a ‘pick the winner’ policy) and encourages competition for scarce innovation funding.
- *Optimising the division of labour in risk management between the private and public sector.* Private sector stakeholders can hedge risk by engaging in long-term contracts across the entire value chain (‘Power and Fuel Purchase Agreements’, PPAs and FPAs). This can both de-risk the investment and lower the costs of renewable energy. At the same time, *Policy* initiatives such as blended financing should focus on bearing some of the risks associated with developing new technologies and ensure carbon pricing support, helping to de-risk both PPAs and FPAs.
- *Support for standards through the value chain.* Governments have a role in supporting more common standards in the use of PPAs and potentially also FPAs. Moreover, the implementation of EU standards for reporting climate footprints for products and activities will allow consumers and businesses to identify and purchase products with low emissions throughout the value chain and potentially pay a premium for such products. This will provide additional revenues for upstream industries, such as airlines, truck operators and shipping companies, when choosing more costly low carbon technologies that are not yet competitive.

Third component: Integration of power markets and better regulation models for TSOs/DSOs

- *Develop further the regulation of the electricity grid.* Electrification of the wider economy will require substantial investments in the grid system and will benefit from a better functioning power market in the Nordic region. Regulation of Transmission and Distribution System Operators (TSOs and DSOs) should be changed to a more forward-looking approach, clearly focused on the needs of customers and encourage the uptake of new technologies and market mechanisms that support more flexibility of demand and supply in the electricity system. In turn, that would alleviate some of the pressure for more grid investments to the benefit of consumers.

Chapter 1

DECARBONISATION IN THE NORDICS: STATUS AND TARGETS

In this chapter we look at the historical reductions in emissions of greenhouse gases (GHGs) in the Nordics and necessary future reductions to reach decarbonisation targets. First, we provide a simple overview of the status of decarbonisation in the Nordics (1.1). Second, it is shown that national decarbonisation targets in the Nordics warrant a higher pace in reductions than in the past while also being ambitious in an international context (1.2). Lastly, we provide an overview of the projected reductions from current and planned measures and argue that these are insufficient to reach the nationally stated targets (1.3).

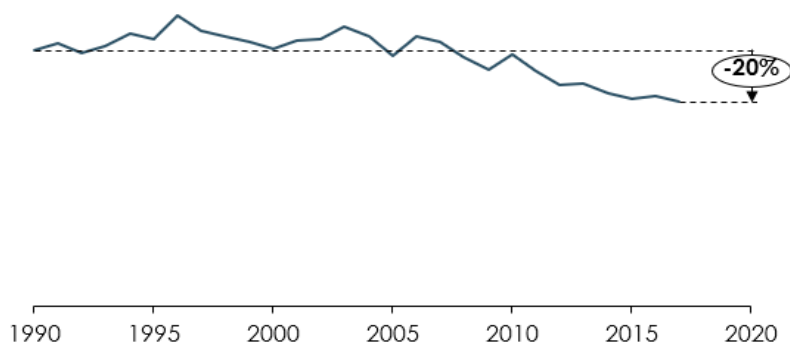
1.1 STATUS ON DECARBONISATION IN THE NORDICS

There has been an increasing focus on reducing GHG emissions in the Nordic countries. This is paralleled by an increased understanding of the potential risks of climate change and the need for decarbonisation across the globe. The focus is also reflected in actual reductions in GHG emissions since 2010 of about 20% while overall emissions remained largely stable from 1990 to 2010, see Figure 1.

Figure 1

Emissions of greenhouse gases in the Nordics, 1990-2017

Emissions of CO₂ equivalent in the Nordics, tonnes, index with 1990=100



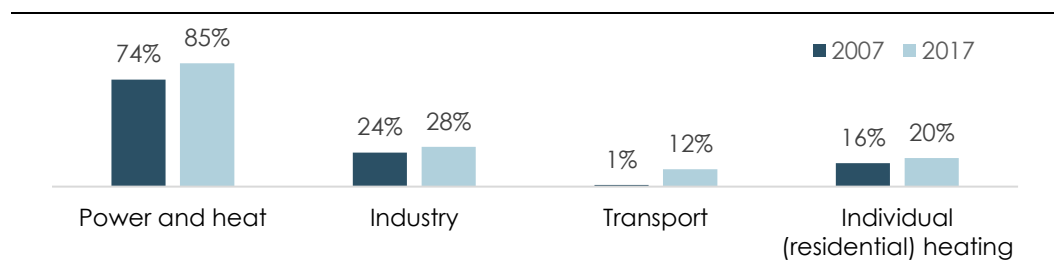
Note: National total GHG emissions for the five Nordic countries excluding international aviation and LULUCF.

Source: EEA greenhouse gas – Data viewer.

Power production and district heating have achieved by far the highest rates of non-fossil fuels in the production of energy, cf. Figure 2. The key sources of fossil-free energy are hydro, nuclear, biomass, geothermal, wind and solar energy, as well as ambient energy recovered by heat pumps.² The shares are much lower in the rest of economy. However, over the last 20 years the *increase* in the shares of non-fossil fuels have been roughly equal for the transport sector and the power production/district heating industry.

² Burning of biomass is physically associated with emission of CO₂ to nearly the same extent as coal. However, if the stock of biomass is held constant through replantation, the process can be viewed as carbon neutral as new trees will capture the same amount of emissions as emitted in the burning process.

Figure 2
Fossil-free energy share per sector, 1990-2017
Pct.



Source: Eurostat, Eurostat (nrg_bal_sd) and Eurostat (nrg_bal_peh)

1.2 STRICTER DECARBONISATION TARGETS IN THE COMING DECADES

Going a step further, all Nordic countries have ambitious decarbonisation targets. Denmark, Finland, Iceland and Sweden have set a target year for carbon neutrality somewhere between 2035 and 2050. Norway aims at transitioning to a low-emission society by 2050.³ These targets have been signed into law or are expected to be so in 2020 for all Nordic countries except Iceland, see Table 1.

Table 1
National decarbonisation targets in the Nordics

	Denmark	Finland	Iceland	Norway	Sweden
Carbon neutrality	2050	2035	2040	2050 (reduction of 80-95%)	2045
Milestones	2030 (75%)	No	No	2030 (50-55%)	2030 (63%)** 2040 (75%)**
Offsetting	No	No	No	2030	No
Binding by law	Yes*	Expected to be implemented by law in 2020	No	Yes	Yes

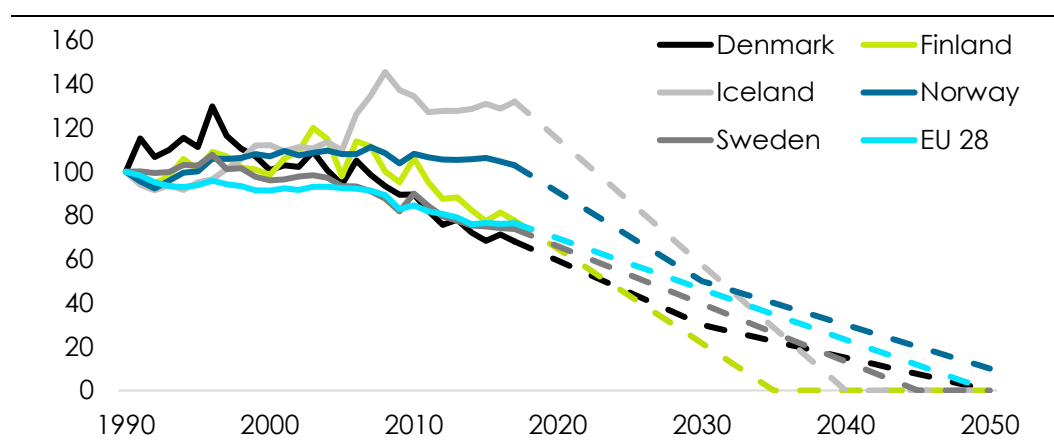
Note: *A political agreement has been achieved which is currently undergoing the parliamentary legislation process. **Non-ETS only

Source: Ministry of Economic Affairs and Employment (2019), Finland's Integrated Energy and Climate Plan, page 11. / Government Offices of Sweden (2019), Sweden's Integrated National Energy and Climate Plan, page 5. / Danish Ministry of Climate Energy and Utilities (2019), Denmark's Integrated National Energy and Climate Plan, page 8. / Norwegian Ministry of Climate and Environment (2019), Norway's National Plan, page 5. / <https://www.regjeringen.no/no/tema/klima-og-miljo/klima/id1307/> / Ministry for the Environment and Natural Resources (2018), Iceland's Climate Action Plan for 2018-2030, page 2 and 5-8.

The ambitious targets set out by the Nordic countries demand continued and even steeper reductions than delivered in the past, see Figure 3. It is also clear that the pace of reductions needed is higher than in the EU as a whole (EU28) with Norway as the exception.

³ Reduction of emissions by 80-95%.

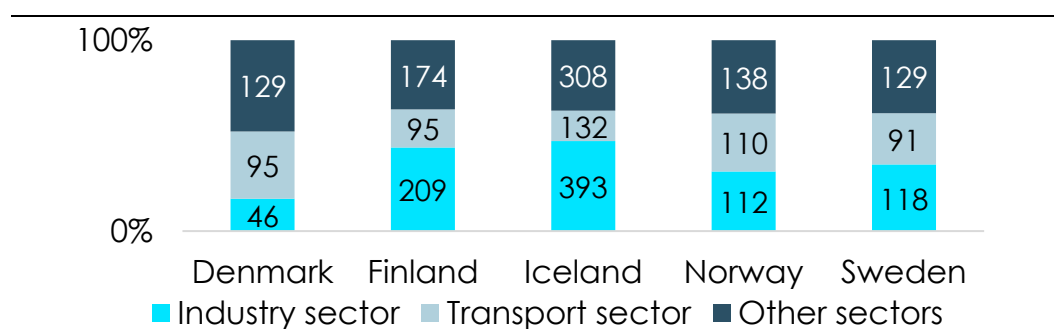
Figure 3
Recent reductions in emissions and required reductions to reach national targets
 Index 1990=100



Note: Projections in the period 2017-2050 based on national targets. Norway's target assumed to be 90%. National total emissions (including international aviation but excluding LULUCF). The year 2035 carbon-neutrality target in Finland allows some GHG emissions in 2035 if they are compensated for by carbon sinks.
 Source: EEA greenhouse gas – Data viewer and national energy and climate plans

The focus areas for more effective decarbonisation will differ somewhat due to considerable variations in industrial structure within the Nordic region. Energy intensive industries such as heavy industry, like mining and quarrying, paper and pulp, aluminium, steel and cement production play a large role in Finland, Iceland, Norway and Sweden. Especially Finland and Iceland have a significantly higher share of energy consumption in their industry. This can be explained by cheap electricity in Iceland which has attracted energy-intensive industries. While in Finland the paper and pulp industry is responsible for 62% of the industrial energy use. By contrast, the life science industry, with a relatively low energy intensity, plays a much larger role in Denmark. As a result, the share of manufacturing in overall energy consumption varies a lot between the Nordic countries, reflecting the underlying differences in the composition of manufacturing within the countries, see Figure 4.

Figure 4
Consumption of energy within sectors in the Nordics, 2017
 Final consumption, MJ pr. Capita



Note: Final consumption of energy across all fuel types.
 Source: Eurostat (nrg_bal_sd).

1.3 CURRENT POLICIES INSUFFICIENT TO REACH TARGETS

National projections of carbon emissions under current policies reveal that the current and planned measures will not be enough to reach the decarbonisation targets. Following the trend from historical reductions and the projected reductions under current measures and policies, new measures and instruments will be required to reach the decarbonisation targets. Projections of estimated reductions with current policies show a fall in reductions in 2030 from 1990 levels in the range of 10 to 50%, see Table 2. This should be compared with targets that require (nearly) full decarbonisation by 2050, at the latest, leading to a reduction gap equivalent to 45-70% of 1990 emissions.

Table 2
Difference between projected reductions with current policies and Nordic targets
 Reductions as share of emissions of CO₂ equivalents in 1990

	Denmark	Finland	Iceland	Norway	Sweden
Current policies, effect 2030	46%	39%	53%	12%	35%
Targets (2035-2050)	100%	100%	100%	80-95%	100%
Gap	54%	61%	47%	68%	65%

Note: Calculated by using expected emissions with current policy measures in each individual country. Projections based on current policies are for 2030 while targets are for individual years between 2035-2050. However, current policies are not expected to reduce emissions significantly after 2030.

Source: EEA greenhouse gas – Data viewer. Ministry of Economic Affairs and Employment(2019), Finland's Integrated Energy and Climate Plan, page 138. Government Offices of Sweden(2019), Sweden's Integrated National Energy and Climate Plan (Swedish), page 145. Denmark: Danish Ministry of Climate Energy and Utilities(2019), Denmark's Integrated National Energy and Climate Plan, page 135. Norwegian Ministry of Climate and Environment (2019), Norway's National Plan, page 21. Ministry for the Environment and Natural Resources (2018), Iceland's Seventh National Communication and Third Biennial Report, page 94.

The Nordics have stricter decarbonisation targets than other parts of the EU, especially eastern and south-eastern member states. In a global comparison, this is even more true, with the US having left the Paris Agreement and posing an important example of a country without a national decarbonisation target⁴. This makes it harder and relatively more expensive for the Nordics to reach their relatively strict decarbonisation targets, as they cannot rely solely on international or intra-EU instruments to solve the problem. On that basis, national or regional instruments most likely need to be added on top of international and intra-EU measures.

⁴ Several US states have targets, and this will likely be instrumental in reducing emissions of GHG in the US. However, it can't fully compensate for the lack of a federal commitment notably with respect to US support for international measures and agreements.

CHAPTER 2

A PATH FOR DECARBONISATION ACROSS SECTORS

In this chapter, we examine the potential for decarbonisation across four sectors, i.e. power and district heating, industry, heavy transport and residential heating, and create a roadmap for decarbonisation. To begin with, we discuss the key technology options to decarbonise the Nordic economies and their expected contribution across sectors (2.1) and suggest when the technologies could be mature enough to be rolled out in scale (2.2). Most technology options for decarbonisation are dependent on electricity either directly or indirectly, we therefore discuss how much new capacity is needed and what this also implies for grid investments (2.3). Finally, we discuss what is needed to turn promising technologies to viable investments for private investors and society (2.4). This last section is also the bridge to chapter 3 on the “Policy Roadmap”.

2.1 KEY AVAILABLE DECARBONATION TECHNOLOGIES AND OPTIONS ACROSS INDUSTRIES

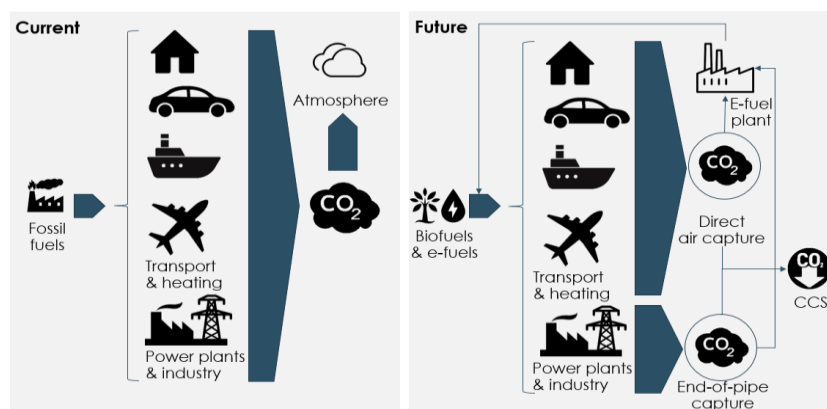
The decarbonisation of power and district heating has come a long way and is expected to be completed by 2030 or by the latest in 2035. The key technologies to deliver on this is a combination of energy sources such as wind and solar power as well as bioenergy combined with continued uses of nuclear and hydro as important sources of fossil-free energy.

For road transport, individual district heating and service industries we see *direct electrification* as a prime driver: (1) Electrical cars (plug-in or fully electric) for the light duty segment of road transport (2) heat pumps for individual residential heating notably in areas with limited access to district heating and (3) wider electrification of energy use in the service industry.

To deliver on decarbonisation in the sectors that are difficult to electrify directly – long distance transport and heavy industry – a range of technologies can be deployed in the coming decades. This includes e-fuels, biofuels and introduction of Carbon Capture and Storage (CCS). A primer on these technologies is provided below.

Carbon is currently extracted from the ground in the form of fossil fuels. After the combustion of these fossil fuels, the carbon content is released as CO₂ to the atmosphere. Commercialisation of e-fuels and biofuels will change this process to one where carbon from a point source or directly from the air is captured and repurposed in e-fuels. This will render e-fuels carbon neutral, since the carbon stems from atmospheric CO₂. Likewise, the use of CCS will be based on the same processes of carbon capture, but instead of being repurposed, the carbon will be stored in the ground, see Figure 4.

Figure 4
Illustration of current and future carbon flows



Source: Gardarsdottir et al. (2019). "Comparison of technologies for CO₂ capture from cement production—Part 2: Cost analysis". *Energies*, 12(3), 542. Available at: <https://www.mdpi.com/1996-1073/12/3/542/pdf>

E-fuels in this report should be interpreted as a wide range of fuels, all of which use electricity as the main input. All e-fuels are based on the production of hydrogen through electrolysis, which splits water into hydrogen and oxygen. Using hydrogen as a fuel therefore only releases water and energy⁵.

CCS is the process where the carbon is sourced from the capturing of CO₂, either from end-of-pipe or direct air capture, and the carbon is used to produce e-fuels. We foresee that CCS will have a role in the further decarbonisation, especially as a solution to non-energy related emissions. However, some issues might arise in relation to CCS in the decarbonisation of the Nordics. Firstly, there is a public concern about the lifespan of CO₂ storage in underground reserves, though this might be unproblematic in reality. Secondly, the IPCC foresees that if we fail to vastly reduce global GHG emissions within a few years, we need significant net-negative emissions (i.e. sinks) after 2050 to keep the temperature increase within the +1.5 degrees Celsius as agreed upon in the Paris Agreement⁶.

Though we do foresee that both CCS and bio-energy CCS (BECCS) can play a significant role, the process is currently costly. BECCS prices lie in the range of 50-60 EUR/tonne and CCS in the range of 43-88 EUR/tonne⁷. These options are relevant for single point emitters as power production, district heating and potential large-scale industries but not distributed emissions such as heavy transport.

The above cost estimates are based on end-of-pipe carbon capture. This can be done at large single-point emitters, primarily industries and power and district heating plants. However, both power and

⁵ More complex e-fuels can also be produced by combining hydrogen with a catalyst, of which two (main) types exist: (1) Carbon free, i.e. ammonia (NH₃) by introducing nitrogen (2) Carbon-based e-fuels, i.e. methanol by introducing carbon from biomass, end-of-pipe or direct air capture of CO₂.

⁶ IPCC (2018), *Global Warming of 1.5°C*, page 17.

⁷ The low-cost estimate for CCS is for oxy-fuel combustion processes, where the only known full-scale project was planned at the White Rose power plant in the UK, and it was never fully developed (see Gardarsdottir et al. (2019). "Comparison of technologies for CO₂ capture from cement production—Part 2: Cost analysis"). (For cost estimates of bio-energy CCS, see Restrepo-Valencia and Walter (2019), *Techno-Economic Assessment of Bio-Energy with Carbon Capture and Storage Systems in a Typical Sugarcane Mill in Brazil*).

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district heating are assumed to be fossil-free in a foreseeable future and thus not a relevant source for end-of-pipe CCS. However, this does not rule out BECCS for plants converted to biomass. Furthermore, end-of-pipe CCS can only be used in larger, heavy industries, also for process emissions that cannot be decarbonised through fuel-shifting. CCS can also rely on direct air capture of CO₂ which is more costly than end-of-pipe CCS⁸.

Adding to this, carbon capture – either end-of-pipe or direct air capture – is a necessity for carbon-based e-fuel production. This means that a large share of the costs of e-fuels will be linked to the same costs related to CCS, namely the carbon capture. Therefore, the discussion will revolve around whether it is most efficient to use the captured carbon to produce carbon-based e-fuels or to simply continue the use of fossil fuels and CCS to offset emissions.

2.2 TIMING OF DECARBONISATION ACROSS INDUSTRIES

The optimal speed of decarbonisation across industries is linked to the maturity of technologies needed. By maturity, we mean how costly it is to deploy the technology in scale – so-called levelized cost of energy (LCOE) – and how far we are from having scalable technologies. However, also other challenges are identified as discussed in the following sections.

Early movers (2020 onwards)

The early movers are direct electrification *of light duty vehicles, the service sector as well as full decarbonization of power production and districting heating*, see Figure 5. The remaining CO₂ emissions from district heating can be decarbonised through further penetration and expansion of waste-to-heat and a continued shift away from fossil-based district heating to biomass-based, also in combined heat and power plants (CHP). Furthermore, heat pumps can play a role in some countries and are expected to play a crucial role in the future district heating system, especially in Denmark.

Another early mover is individual residential heating. It is to a large degree electrified in Nordic countries, except in Denmark. We expect that direct electrification through heat pumps will continue to be the most cost-efficient way of decarbonising individual residential heating⁹.

In the transport sector, the decarbonisation of light duty vehicles is expected to be achieved through increased use of electric vehicles (EVs), which seems the most promising low-emissions technology for light-duty vehicles. Furthermore, EVs are expected to outperform conventional fossil fuel vehicles (ICEs) in relation to the total costs of owning and using the vehicles from around 2025 and onwards, even without tax incentives.¹⁰ The timing of the phasing out of ICEs should take into account that a car has a technical lifespan of about 15-30 years¹¹, with Finland having by far the oldest car stock with an average lifespan of above 25 years, whereas the same figure for Denmark is less than 16 years. For heavy transport, e-fuels are expected to play a role in the longer run. The technology of e-fuels is less

⁸ CCS, with or without direct air capture, might still play a role for decarbonisation. It seems to be the only viable technology to decarbonise process emissions from industry not linked to energy use and emissions from agriculture (mainly methane) through offsetting. Thus, we see the technology as a potential, firstly, to offset emissions from agricultural methane emissions and non-energy related industrial processes, and secondly, to obtain needed negative sinks in the future.

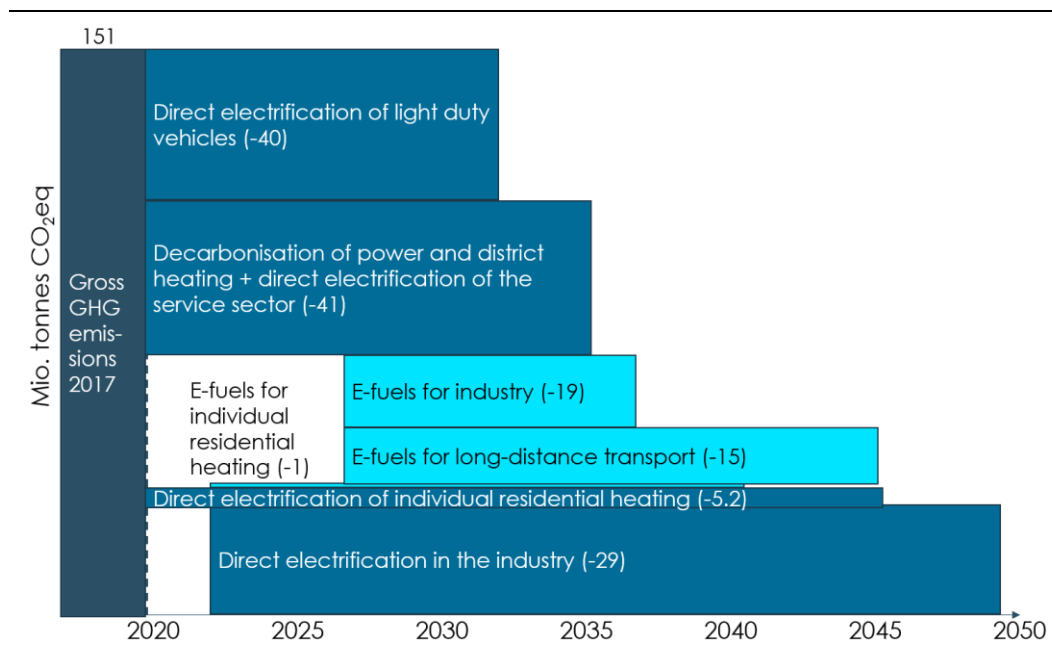
⁹ We expect that a minor share of individual residential heating will be based on boilers with the input of e-fuels. Even though heat pumps can be used in cold weather, the efficiency is low in the coldest regions of the Nordics. We make the simplifying assumption that 80% of current fossil fuel use for individual residential heating will be decarbonised by using heat pumps while the remaining 20% will be decarbonised by replacing fossil fuel-based boilers with e-fuel-fired boilers.

¹⁰ ICCT (2019), Update on electric vehicle costs in the United States through 2030, p. 10.

¹¹ Based on age of passenger car stock in Nordic Countries, Eurostat (road_eqs_carage).

mature, and costs are currently too high to compete with fossil fuels.¹² To get costs down to a tolerable level and for generation capacity to reach the needed scale, we are looking many years into the future.

Figure 5
Roadmap for decarbonisation across the Nordics
 Million tonnes CO₂ equivalents



Note: The figure is illustrative in the sense that Finland has a target of complete decarbonisation by 2035. As such, the illustrated transition will need to move faster in Finland than in the remaining Nordic countries. The time span for each technology indicates the expected options for initiating deployment. National governments can then "choose" the timing for deployment of each technology based on their individual targets for decarbonisation. GHG emissions from waste management are included in power and district heating due to increased focus on waste-to-heat. Excluding LULUCF and international aviation.

Source: Illustration by Copenhagen Economics

Later starters

Direct electrification of industry can to a large extent be done through both existing, cost-efficient technologies and through the introduction of new high-temperature heat pumps. However, the technological and economical lifespan of industrial investments are relatively long. New investments typically have a lifespan of 5-10 years for smaller investments and up to 50 years for larger investments. This implies that direct electrification will have a longer time span.

Latest starters

We expect the introduction of *e-fuels in the industrial sector and long-distance transport* to start in larger scale only towards 2030. Industrial processes are more fine-tuned and dependent on more precise standards for energy density and viscosity than transport equipment is. However, the transition from fossil fuels to e-fuels can be expected to be easier and quicker than direct electrification

¹² ICCT (2018), Decarbonization potential of e-fuels in the EU, page 3. The Royal Society (2019), Sustainable synthetic carbon based fuels for transport, page 4-5. LBST and dena (2017), The potential of electricity based fuels for low-emission transport in the EU, page 10.

when sufficient volumes and standards for e-fuels become available. Finally, these sectors are also characterized as having assets with very long asset lives, often to be counted in decades for example for ships and airplanes.¹³

2.3 ELECTRICIFICATION REQUIRES MASSIVE EXPANSION OF NON-FOSSIL POWER

Both direct and indirect electrification will lead to increased electricity demand in the Nordics. Large investments in generation capacity are needed to meet the additional electricity demand, and achieve the decarbonisation targets in the Nordics, based on a path of direct and indirect electrification.

To deliver on decarbonisation, direct and indirect electrification needs to rely on fossil-free energy. Currently, the power production in the Nordics relies *partly* on renewable (wind and solar PV) and other fossil-free (hydro and nuclear) energy sources and partly on the combustion of carbon-based fuels. A full transition to a power system based on fossil-free energy sources requires installation of both new renewable generation capacity and replacement of carbon-based generation capacity as it is decommissioned.

Additional demand will depend on the efficiency and shares of direct and indirect electrification within sectors. The size of this additional demand will depend on the efficiency of transforming produced electricity into the final form of energy used in each sector. A lower efficiency will imply a bigger loss and thus more electricity generation is required to meet the final energy use in each sector.

Indirect electrification increases electricity demand due to conversion losses. The role for e-fuels in the decarbonisation of the Nordics is based on the ability of e-fuels to substitute fossil fuels in difficult-to-electrify sectors. This is primarily due to the fact that e-fuels can provide the high-energy density as well as other properties that current fossil fuels deliver. However, in the production of e-fuels, there will be a conversion loss which lowers the energy content in the final product compared to the electricity input. In other words, more electricity is therefore needed to use e-fuels in electrification of heating, transport and industry than if the electricity is used directly.¹⁴

Heat pumps and electric vehicles reduce final energy use due to high efficiencies compared to fossil fuel-based alternatives. Heat pumps are efficient since they utilise the heat in the outside air or other sources rather than using electricity to heat it.¹⁵ Correspondingly, electric vehicles require less energy than conventional cars, mainly since they do not have the thermal heat loss that the internal combustion engine of a conventional car has. Efficiencies of heat pumps are about 150-300% compared to a fossil-based boiler (in the cold Nordic regions), and electric vehicles are about 300-400% more efficient than fossil fuel-based alternatives.¹⁶

¹³ ETC (2018) Mission Possible, Sectoral Focus –Shipping, Boeing (2013) Key Findings on Airplane Economic Life

¹⁴ Hydrogen has the highest efficiency, namely 65%, while other e-fuels which are carriers of hydrogen will have lower efficiencies. Among these are ammonia with an efficiency of 55% (see IRENA (2019), Hydrogen: A renewable energy perspective) and methanol with an efficiency of 58% (see Danish Energy Agency (2017), Technology data for renewable fuels, page 190). However, efficiencies are likely to increase as electrolyser technology (for production of hydrogen) is advanced to full scale. Part of this efficiency increase will stem from heat recovery in the production process. As such, the efficiencies of e-fuels are in the range of 50-60%. Our analysis shows that indirect electrification will make up between 20-30% of final energy use in residential, transport and industry sectors on the road to decarbonisation.

¹⁵ Even very cold air contains heat energy; however, the efficiency drops with outside air temperature, but never below 100%.

¹⁶ <https://sparenergi.dk/forbruger/varme/varmepumpe/fakta-om-varmepumper> and Danish Energy Agency (2015), Teknologivurdering af alternative drivmidler til transportsektoren.

Based on current LCOE estimates, including grid and system costs, we expect that the bulk of the net expansion in capacity to meet the additional electricity demand for decarbonisation will be through renewable energy in the form of offshore and onshore wind and solar PV.

Here it is important to note that a substantial part of additional grid costs to facilitate increased electricity consumption will be independent of the source from which the electricity is produced.

To keep the required additional capacity at a minimum, it is crucial that existing fossil-free power production, especially nuclear and hydro, is maintained for its technical lifespan and is re-invested to increase lifespan if economically viable. This will serve both to cover existing power demand and as baseload and backup for new renewable generation capacity. Moreover, installing a large amount of renewable power generation capacity is both costly and takes a long time. Utilising current power generation capacity from nuclear and hydro plants, with possible lifespan extensions and planned new units under construction can postpone the timing for installing some of this new capacity. Moreover, nuclear and hydro will continue to play a role for the baseload of existing electricity demand, with hydro also serving as flexible backup capacity as discussed below.

The required expansion of power production in the Nordic areas will also depend on the extent to which new fuels for the difficult-to-electrify industries will be produced within or close to the region. If all fuels were to be produced “locally”, it would require an expansion of capacity equal to a five-fold increase in wind and solar power capacity in the Nordics.¹⁷

Using a split between direct and indirect electrification for individual sectors and using efficiencies of e-fuels and heat pumps, we estimate that the additional demand to reach full decarbonisation of the residential, transport and industry sectors could be about 290 TWh (113 TWh for direct and 177 TWh for indirect electrification), see Table 3.

Table 3
Additional electricity generation needed to decarbonise residential heating, transport and industry

	FOSSIL FUEL TO BE CON- VERTED	PJ DI- RECTLY ELECTRI- FIED	PJ INDI- RECTLY ELECTRI- FIED	TWh USED FOR DIRECT ELECTRIFI- CATION	TWh USED FOR INDI- RECT ELEC- TRIFICATION
	PJ	PJ	PJ	TWh	TWh
Residential heating	65	20	25	5 (263%)	7 (53%)
Transport	768	128	433	41 (374%)	120 (50%)
Industry	345	239	178	66 (105%)	49 (53%)
Total	1,178	406	636	113 (210%)	177 (51%)

Note: Electrification efficiency in parenthesis.

Source: Eurostat (nrg_bal_sd). Danish Energy Agency (2015), Kortlægning af energiforbrug i virksomheder.

We have estimated that the 290 TWh could represent an expansion of generation capacity of about 83GW, see Table 4. This is based on a scenario where onshore wind, offshore wind and solar power

¹⁷ Wind Europe (2018), Annual Statistics 2018, page 10. SolarPower Europe (2019), EU Market Outlook 2019-2023, page 19.

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account for 70%, 20% og 10% of the expansion respectively.¹⁸ Of this, 33GW will be needed for direct electrification, and the remaining 50GW will be needed for e-fuel production.

Our estimate is, *firstly*, based on capacity potential in the Nordics and, *secondly*, based on the projected costs of new fossil-free power generation capacity. New technologies could come into play, such as ‘small modular nuclear reactors’ (SMRs). However, such technologies are yet to be proven and scaled up, and, as such, costs are expected to be high in the beginning, following traditional learning curves for new technology. Therefore, we do not include those in our calculations. However, it can be expected that new generation capacity in reality will come from a broad portfolio of technologies with the need of keeping existing hydro and nuclear in operation.

The estimated additional fossil-free power generation capacity is based on the additional demand from decarbonisation through direct and indirect electrification.

Table 4
Additional RE generation capacity needed to decarbonise residential heating, transport and industry

	Generation capacity*, GW	Capacity factor	Additional generation need, direct electrification, TWh	Additional generation need, indirect electrification, TWh
Onshore wind	58 (70%)	39%	79	124
Offshore wind	17 (20%)	51%	30	46
Solar	8 (10%)	15%	4	7
Total	83 (100%)		113	177

Note: * Share of each renewable energy source in parenthesis.

Source: Eurostat (nrg_bal_sd). Danish Energy Agency, technology catalogue - Power and heat production data, updated January 2020.

E-fuel production for indirect electrification can be placed globally wherever renewable energy costs are lowest. As such, the best low-cost options within the Nordic or EU area will compete against installations in for example Texas, Australia or Northern Africa (taking the transport costs of e-fuels into account). In our rough estimates, a total of 61% of the additional electricity production needed stems from indirect electrification and can thus be placed outside the Nordics or even the EU.

Locational choice for e-fuel production will mainly be driven by two factors: 1) what is the cost of producing green power and 2) how strong is the infrastructure all the way from producing green power to producing and distributing the fuels. One idea is to use the cost-efficient North Sea wind power in the area around Rotterdam, which has a strong infrastructure and has moved forward with hydrogen-based solutions. Also, North Sea wind power could be transported to the Norwegian petrochemical industry sites. Another option is to use the large wind resources in the Baltic sea and appropriate geographical locations for e-fuel production, e.g. Bornholm, which is located near an abundance of Nordic and Baltic area shipping routes. Furthermore, a Baltic Sea hydrogen grid could be installed to harvest additional benefits from the wind energy resources in the Baltic Sea.

Need for hedging revenue for backup plants

¹⁸ See for instance IRENA (2019), Future of Wind, page 25 and 43, for split of expected on- and offshore wind in 2050.

Flexible power generation is valuable to provide electricity in tandem with wind and solar power. Renewable energy from wind and solar is very inflexible since the wind does not always blow and the sun does not always shine. In periods when neither of these sources can produce enough power to meet demand, it is necessary to have flexible power generation, storage or demand/response capacity or power imports to close the gap. Though there is an increased interconnection on the Nordic power market in combination with Germany and the UK, there will still be a need for flexible power and baseload to serve the existing electricity demand.

This can efficiently be supplied from both nuclear and hydro power in combination with central heating and power plants (CHP) using biomass or e-fuels as fuel. Nuclear, hydro and combined CHP plants will therefore still play an important role in the future power market. Further need of backup can efficiently be based on gas turbines, fuelled by either biogas, synthetic natural gas or, alternatively, on hydrogen.

2.4 FROM POTENTIAL TECHNOLOGIES TO VIABLE INVESTMENTS

Investments needed for the roadmap are massive, and the question is whether returns are sufficiently high and predictable to attract the necessary investments. This should be seen in the context of the fact that investments often have very long lead times with asset lives typically being measured in decades rather than years. We suggest that we need actions on at least three fronts to ensure that the new technologies are viable in the marketplace to be deployed in scale.

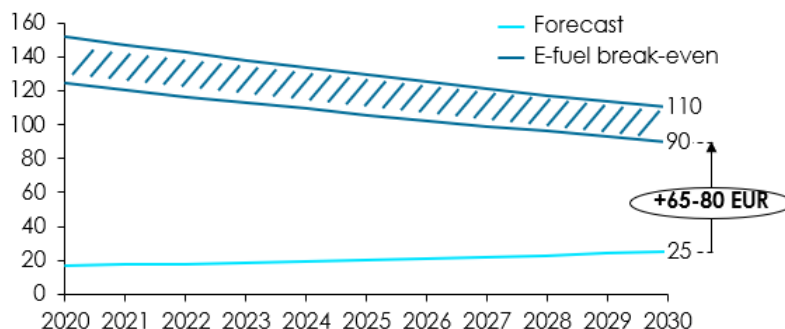
First, we need to take proven technology/demonstration concept to industrial scale. This requires building installations in smaller scale to start with and reap “learning” benefits to progressively reduce costs. When costs reach a break-even with conventional technologies, they become competitive.

A key driver for speeding up this process is policy instruments that divide the technology risks between the public and private sector in a manner that reflects the substantial positive spill-over effects associated with such efforts, e.g. the fact that private investments and deployment of new technologies will have positive effects on the cost reductions of the technology on an economy-wide scale.

Second, we need stronger incentives to deploy the new low carbon technologies. The projected costs of new technologies, even if supported by technology tools, will still for a long period be too expensive to compete against fossil fuels in the absence of some form of carbon pricing. As an example, we estimate that carbon prices in the range of 90-110 EUR/tonne by 2030 will be needed for making e-fuels competitive against fossil fuels (effectively same carbon prices needed for both ammonia for shipping and methanol to be competitive). The required carbon price is not only dependent on the price of the new technology but just as much on the costs of electricity to be used as an input in production. This requires a further increase in the carbon price of about 65-80 EUR/tonne by 2030 compared to the carbon price of about 21 EUR/tonne in week 11 of 2020 in the ETS¹⁹, see Figure 5.

¹⁹ Before the comprehensive economy lockdown due to Covid-19, EUA futures for December 2022 were priced at 24.3 EUR/tonnes (as from week 11, 2020), a small decline compared to the previous three-month average. Therefore, the current ETS price is a reasonable predictor for future prices, extrapolating to 2030. See <https://www.theice.com/products/197/EUA-Futures/data?marketId=5115275&span=1>.

Figure 5
Necessary CO₂-price increase to make e-fuels competitive with fossil fuels by 2030
 EUR per tonne



Note: A span for the e-fuel break-even price has been used to illustrate the uncertainty in the forecasted e-fuel price in 2030. An approx. 10% uncertainty in the e-fuel production cost was used to calculate the span.

Source: Energy Transition Commission (2018), "Mission Possible", Irena (2019, Hydrogen: A renewable energy perspective and current ETS market prices, extrapolated with a 2.2% increase in real annual ETS prices. Reference oil price at 60 USD/ton, see Department for Business, Energy & Industrial Strategy (2020), "BEIS 2019 Fossil Fuel Price Assumptions" (figure 5, policies aligned with Paris Agreement)

Third, investments need to be de-risked across the value chain. Power purchase agreements (PPAs) and fuel purchase agreements (FPAs) can play a crucial role in de-risking investment in the needed renewable electricity capacity and e-fuel production units. A PPA is an agreement of the exchange of power at a fixed price and amount for a fixed period of time (e.g. ten years).²⁰ PPAs for renewable energy installation have been on the rise across the globe in the last 5-10 years due to their ability to de-risk investments in wind and solar installations.²¹

Likewise, we see a need for FPAs to be introduced to de-risk future investments in e-fuels production facilities. Corresponding to a PPA, an FPA could be introduced as an agreement for exchange of e-fuels at a fixed price and amount. There are two main arguments for FPAs:

- the needed quantities are very large, and it is uncertain if anyone is willing to take the risk for large installations if there is not a secured, firm demand, which can be secured by FPAs.
- while the fixed costs of e-fuel production capacity are a lower share than in RE generation capacity²², there are still arguments for entering into FPAs. As an example, demand for e-fuels is heavily dependent on the future costs of carbon. In the case that ETS plays a major role in carbon pricing, there are large carbon-pricing risks associated with investment in e-fuel production capacity, which calls for signing FPAs.

PPAs and FPAs are market-based instruments but are both complicated. Differences in how PPAs are regulated in different energy markets are the reason for the difference between countries in the PPA penetration rate. Thus, there is a political and a market signal to make PPA and FPA regulation more standardised and the handling of such contracts less complex.

²⁰ The most common type of PPA, though one advantage is the flexibility in structure and terms which allows for tailoring of each PPA to the specific circumstances for the two parties involved.

²¹ Copenhagen Economics (2020), Changed trading behaviour in long-term power trading

²² Fixed costs are about 15-20% of total costs for e-fuels generation capacity. (see Danish Energy Agency (2017), Technology data for renewable fuels, page 198)

CHAPTER 3

POLICY ROADMAP FOR DECARBONISATION

In the previous chapter, we have shown a path towards decarbonisation. It has been shown that it is possible but requires vast investment in new fossil-free power production capacity, e-fuel production capacity and power market interconnections.

To reach this, outcome targeted policies and measures need to be implemented to support a staged approach where wider electrification of the economy in conjunction with deployment of new low-emission technologies being rolled out in scale as they become increasingly mature and cost-effective. Hence, we need a set of policy priorities to ensure a smooth and cost-effective transition to a decarbonised future.

It is our recommendation that the policy roadmap should focus on three sets of initiatives which are crucial for delivering a trajectory for decarbonisation in the Nordic region:

- Firstly, we argue that investor uncertainty and costs of the green transformation can be reduced by moving towards a more consistent carbon-pricing framework, and, bearing in mind that difficult-to-electrify sectors are exposed to global competition, we argue that international cooperation and mitigation of carbon leakage risk is required (3.1).
- Secondly, we argue that increased public support for maturing key technologies, including direct public funding linked to very high technology risks, is required for full decarbonisation. The focus should be on de-risking investments across the value chain (3.2).
- Thirdly, we argue that an increased focus on the huge investment needs in grid infrastructure following from the gradual electrification of the whole economy is needed as well as better functioning power markets. This includes better functioning markets for PPAs to de-risk notably investments both in intermittent energy power sources as well as the new fuels types requiring vast amounts of electricity as input (“e-fuels”) (3.3).

3.1 CREDIBLE CARBON-PRICING FRAMEWORK

The climate challenge is a global problem and will not be solved unless decisive action is taken at a global level. This calls for a global CO₂ tax as a first-best solution. We see more systematic use of a carbon price to drive decarbonisation as a precondition for a cost-effective approach to replace the present use of a variety of support schemes, regulations and the large variation of effective carbon prices both within and even more so between countries.

However, reaching an agreement at this level seems unrealistic.

For the Nordic countries, this leaves the EU as the major instrument through which they can attempt to affect favourable global outcomes. The EU is directly important through the role it plays in the decarbonisation efforts in the Nordic countries but is also the most natural instrument to influence global agreements, e.g. at the UN level.

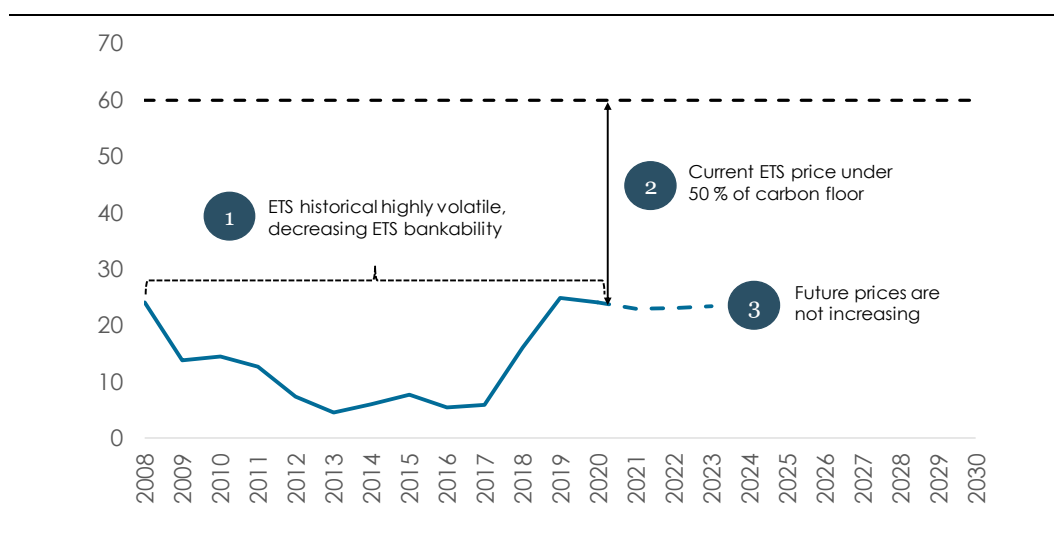
Consequently, we will, under the three different priorities, discuss the respective roles for different levels of government and what might have to be done at national level if international cooperation fails to deliver the required support for the long-term decarbonisation plans in the Nordics.

Role of the EU

The EU has put in place an instrument that to a very large extent covers the sectors that have huge potential for direct or indirect electrification, namely the ETS. All carbon in power production in the EU is priced through the ETS, which currently covers power and combustion installations above 20MW, intra-EU aviation and energy-intensive industries.

The problem is that the ETS has not fully served as the investment signal it was designed to be. It has in periods served for fuel shifting from coal to gas in power production, but this is not sufficient to say that the ETS functions as a proper investment signal (as fuel shifting has only affected existing power plants). The system failures have manifested themselves in two clear weaknesses. *Firstly*, the price has been very low for a long period and is still not at a level high enough to make e-fuels and other green energy sources competitive by itself. *Secondly*, the ETS price has been volatile which increases uncertainty of the value of an investment. It therefore has a low value as a stable long-term anchor²³, see Figure 6.

Figure 6
ETS price, historical and future prices and illustrative carbon floor
 EUR/ton



Note: Carbon floor is illustrative and based on estimates of the needed carbon price to make green investments, including e-fuels, competitive in the long run.

Source: EEX and Thelce, ETS EUA future market prices.

Furthermore, we see little risk that increasing ETS prices will lead to any significant increase in electricity prices, undermining the electrification potential. The very substantial decarbonisation of power production in the North-western European countries will imply that power prices will be less and less affected by the ETS price. Indeed, power market prices are increasingly being determined by

²³ See Copenhagen Economics (2012). "Reform of the EU ETS system" for a comprehensive review of these barriers for the ETS to work as an investment signal. The recent negative demand-side shock due to the outbreak of Covid-19 has further weakened the investment signal. However, such demand side shocks will always continue to be present.

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the costs of producing renewable power which is getting close to being fully competitive with power based on coal and gas even without the support from the ETS.²⁴

By contrast a higher ETS price could be the driver for the decarbonisation of energy intensive industries within the ETS that constitute a substantial share of the difficult-to-electrify sectors. In other words, a higher ETS price could be a key component in the indirect electrification process required to reach decarbonisation targets.

We see a carbon floor as a no-regret option ensuring both more equal carbon pricing across the wider EU economy and as a needed spur to motivate the decarbonisation of a wider EU economy.

Recommendation 1

We propose a firming of the EU ETS price for all ETS-covered installations and sectors through the implementation of a carbon price floor within the ETS.

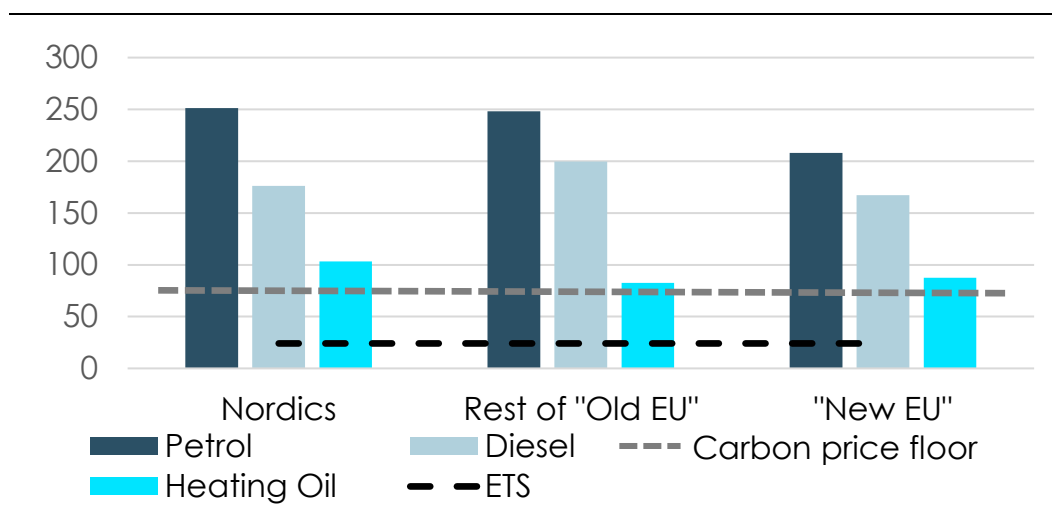
A possible alternative to a full-scale EU solution would be to go for regional alliances. The idea goes under the name ‘coalition of the willing’, where an alliance of countries act together to strengthen the carbon price by holding back ETS allowances (effectively cancelling them from auctioning, and as such affecting the entire ETS supply and price). This could have significant effects, if the coalition of the willing is large enough. However, there could be a drawback if other countries with less stringent decarbonisation targets counter this action by demanding a slower reduction in the ETS cap (e.g. effectively reducing the decline in ETS allowances versus business-as-usual, leaving the effects from the coalition of the willing less effective).

In addition to the above, it should be noted that the electrification of the wider economy by itself will – all other things being equal – boost the ETS price in the coming years, as energy demand is shifted from fossil fuels outside the ETS system to demand for power inside the ETS system.

Even with such a firming of the ETS system, the de facto carbon pricing of most other sectors would be substantially higher across the EU, see Figure 7. As such, a carbon price floor would not affect the carbon price outside the ETS for non-business use.

²⁴ For similar arguments, see Danish Energy Association (2019), “Electricity price outlook 2019”, page 4. Downlift describes the consequence that a large share of intermittent energy (e.g. wind power) which produces in the same hours will lead these intermittent energy producers to receive a lower than average power price for their produced power.

Figure 7
De facto carbon tax on different products compared to current ETS price
EUR/ton



Note: 'Old EU' refers to EU Member States in the EU before 1 January 2004. 'New EU' refers to new entrants after 1 January 2004.

Source: EEX and Thelce, ETS EUA future market prices.

The firming of the CO₂ price, through an ETS carbon price floor would increase the risk of carbon leakage for sectors exposed to international competition, e.g. the risk that production moves to other jurisdictions with lower carbon taxation. In these sectors, the carbon price floor should still apply, but the risk of carbon leakage should be mitigated by giving free allowances to industries within the ETS deemed at risk of carbon leakage.

Recommendation 2

For industries at risk of carbon leakage and within the ETS, give free allowances to mitigate the risk of carbon leakage, with a decline of free allowances to follow the trajectory for national decarbonisation targets.

The recommendation is relevant as long as international agreements do not ensure equal treatment of internationally competing industries. The free allowances should be given to sectors deemed at high risk of leakage, based on historical emissions and changes in production volumes in line with the current principles of the ETS. This is effectively a lump-sum transfer to these industries. The same mechanism should apply to national CO₂ tax credits. The level of compensation should optimally reflect the risk of carbon leakage. If the industry is at high risk of carbon leakage, there should be a very large compensation of the higher CO₂ cost in their production²⁵. The logic is explained in Box 1 below. Targeted use of such a mechanism could replace the current system in place in EU countries where

²⁵ For similar arguments, see Copenhagen Economics (2019), Carbon leakage in the Nordic countries

tax rates for energy use for industries exposed to international competition is generally well below rates for other users.

Box 1 Example of using free allowances to avoid carbon leakage while ensuring incentive to reduce emissions

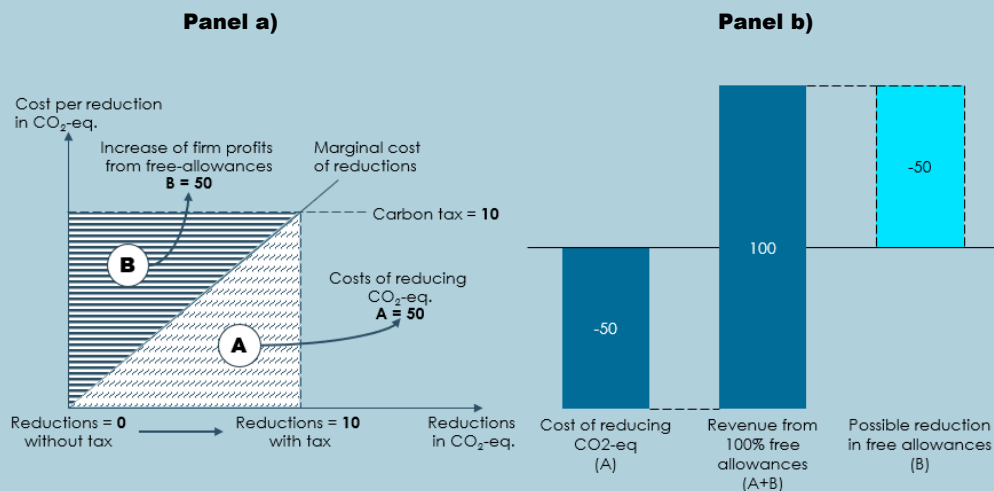
A simple example of using free allowances to avoid carbon leakage under a carbon tax while keeping in place the incentive to reduce emissions can be explained in two steps related to the illustration in panel a) and b):

1. Introducing a carbon tax to incentivise reductions in emissions

- Imposing a carbon tax will incentivise a firm to invest in low carbon solutions
- These investments have a cost per reduction called the marginal cost of reductions (see Panel a)
- With a carbon tax of €10 and linearly increasing marginal costs of reduction, this leads in the example to 10 units of reductions of carbon and total costs € 50 (area A in Panel a)

2. Avoiding carbon leakage by using targeted compensation

- To avoid carbon leakage from the firm moving abroad, we give free allowances to firms exposed to international competition to compensate for increased costs (area B in Panel a)
- Hence, we give the firm compensation/free allowances worth €50 (see Panel b)
- The net result is that the net profits of the company is the same as before the implementation of carbon tax and it cannot all other things equal increase profits by moving to another jurisdiction (see Panel b)



Source: Illustrative example by Copenhagen Economics

By letting the industry pay the carbon price but compensating them through free allowances or direct transfers, they will still have the incentive to reduce their CO₂ emissions on the margin. This means that businesses that produce with a CO₂ intensity in line with the decarbonisation trajectory will not see a competitive disadvantage, as their bottom line will not be affected. Thus, the ETS price and national CO₂ taxes will only affect industries that do not decarbonise in line with the trajectory of the decarbonisation targets. Furthermore, businesses that decarbonise faster than the national decarbonisation trajectories will receive a lump-sum transfer to the benefit of their bottom line, either through excess ETS quotas that they can sell on the market or through excess national CO₂ tax credits.

We also suggest that the use of free allowances/direct compensation is a more manageable instrument than penalising imports into the EU through carbon border taxes for example on imports of energy intensive goods into the EU. This is a type of measure that has often been discussed as an instrument to ensure that EU industries are not being penalised when competing against countries with less stringent climate policy targets²⁶. A possible exception is the imports of power from neighbouring countries. We could see a system working whereby providers of power to final consumers would be obliged to add a surcharge on the electricity bill corresponding to the estimated costs of producing coal based power unless providers could present a certificate that the imported power was produced by fossil-free energy sources.

There are also discussions about extending the ETS to other sectors. Some of the proposals we see as having more merit than others:

- **Road transport and individual heating:** Existing tax rates on these sources of energy use are already much higher than the price of ETS. Hence, including transport in the ETS will lead to lower carbon taxation for transport and less incentives for decarbonisation. At least, that would be the result unless national taxes were wholly or partly maintained and that would somehow remove the argumentation for the integration into the EU ETS. In other words, absorbing these sectors into the ETS would de facto require a substantial EU harmonisation of national energy taxes if the aim was to ensure an EU wide common CO₂ price for the sectors covered in an enlarged ETS. It would also require that the ETS was changed from the current system: instead of holding the direct emitters accountable for emissions, it should be changed to an upstream system focusing on the providers of fossil fuels to final consumers for example refineries etc. This follows from the basic fact that inclusion of hundreds of millions of car and house owners in the current compliance set-up is not in practice feasible.
- **External aviation:** Inclusion into ETS is EU's aim²⁷, but depend on EUs ability to convince international partners to agree. Alternatively, the EU tax directive could be changed to allow member states to include external aviation in the ETS and over time force them to do it.
- **Shipping:** Is difficult in practice given very high risk of leakage. Most shipping companies have the freedom to decide to register their ships with the 'flag state' of their choice including those which, under the current Kyoto Protocol, are not Annex I nations. Measures to deliver meaningful emission reductions from international shipping are thus much more likely to be achieved by instruments developed by governments at IMO".²⁸

Further, it should be noted that both road transport and individual heating will all by itself to an increasing extend be covered by the ETS, through their electrification as power production is within the ETS.

²⁶ The issue is discussed in inter alia in Mehling et al (2019), Porterfield(2019), Krenek(2020). A key challenge identified in all papers is how a potential tax on for example steel imports can be modified so that it reflects the de facto carbon content in the entire value chain of the imported product before it enters EU soil. If such a system cannot be applied, then it would tax imported steel at the same rate irrespective of the costs that steel exporters into the EU market have faced to decarbonise steel production. The operation of such a system is challenging from both a WTO and a practical example. In the European Council Conclusions (2020) from July 2020, it is states that the EU Commission will put forward a proposal with effect at the latest from 1. January 2023.

²⁷ As also confirmed by the European Council that invites the EU Commission to present a proposal for a "revised ETS, possible extending it aviation and maritime".

²⁸ The Clean Shipping Portal (2018), *COP 18 DOHA paper*, page 3. and IMO (2019), Reduction of GHG emissions from ships, page 3. Se also the footnote linked to external aviation.

Recommendation 3

Revise the energy tax directive to focus on minimum tax level on carbon and set the minimum tax rate equal to the carbon floor price within the ETS. Focus on international efforts to decarbonise aviation and shipping.

National

Should the EU fail to deliver on both a firm and sufficiently high ETS-price and minimum carbon tax in the Energy Tax Directive, we propose that Nordic countries implement energy tax reforms with the focus fully on the needs for decarbonisation. This proposal is based on two arguments:

Firstly, it is not clear that cooperation at the EU, regional or global level can deliver on reforms quickly enough to provide carbon pricing signals consistent with the ambitious decarbonisation targets in the Nordic areas. This applies both to the price level of ETS allowances and extension carbon pricing for international aviation and shipping.

Secondly, the current energy tax structure both on fossil fuels as well as electricity does not support a cost-effective solution, i.e. as is also clear from Figure 7 above, the implicit taxation of CO₂ is very different for different fuel types and the taxation of electricity is also very high which is inefficient since electricity is increasingly only supplied by non-fossil sources. However, a large share of the national taxes on fossil fuels are energy taxes which makes them ineffective for fuel-shifting to less carbon-intensive fuels.

Thirdly, Nordic countries have more ambitious and stricter medium-term targets for decarbonisation than the rest of the EU on average. Hence, Nordic countries may need higher levels of CO₂ taxes than other countries in the EU to ensure decarbonisation.

However, we urge some caution here with respect to two concerns. Firstly, having levels of taxes that significantly exceed levels in other EU countries will make schemes to compensate for leakage difficult to manage in practice. Secondly, if we have credible long term options for decarbonisation that are economically viable for example at a carbon price of 100 €/tonne or less from 2030 or 2035, we suggest that the Nordic countries should be conscious not to aim for carbon taxes far higher than this level in the years to come and then later reverse them as the technologies mature and costs go down.

Recommendation 4

Restructure national taxes from a focus on energy taxes to CO₂ taxes based on CO₂ equivalents and on a trajectory to a common price consistent with the climate goals thus increasing incentives to shift to low-emission fuels and technologies.

The CO₂ tax should be differentiated between sectors, depending on whether they are covered by the ETS or not. This means that national CO₂ taxes should be reduced by the ETS price, such that CO₂ is priced equally inside and outside the ETS. Furthermore, the CO₂ tax should apply to the entire economy, both for business and non-business use, but also in respect to the EU Energy Tax Directive. Such

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national tax reform would not imply that countries with high carbon taxes across the economy, e.g. Sweden, will need to lower their carbon tax.

The firming of the CO₂ price through national taxes, would also increase the risk of carbon leakage for sectors exposed to international competition, e.g. the risk that production moves to other jurisdictions with lower carbon taxation.

As goes for the ETS, the national carbon price floor should still apply to all sectors, but the risk of carbon leakage should be mitigated by giving tax credits to industries deemed at risk of carbon leakage as explained above and illustrated with the example in Box 1.

Recommendation 5

For industries at risk of carbon leakage, give tax credits based on production-adjusted carbon emissions to mitigate the risk of carbon leakage, with a decline of CO₂ tax credits to follow the trajectory for national decarbonisation targets.

Emissions from domestic transportation and residential heating primarily stems from cars, where the leakage risk is small, taking into account that neighbouring countries also have high fossil fuel taxes for transportation. The same argument is true for residential heating. Furthermore, domestic shipping and domestic aviation is at low or no risk of leakage. Thus, leakage risks are manageable within local and Nordic-oriented transport and residential heating.

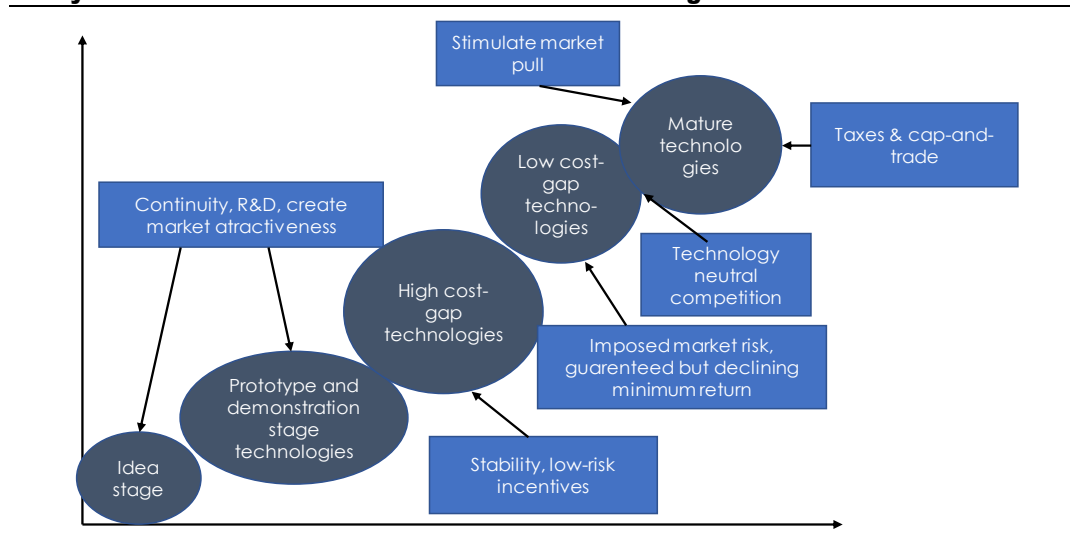
Recommendation 6

Domestic transport and residential heating should not receive CO₂ tax credits, as they are not at risk of carbon leakage.

3.2 TARGETED SUPPORT FOR PROMISING TECHNOLOGIES

Well-established innovation policy guidelines have a useful framework for thinking about advancing promising technologies all the way from the lab to industrial scale. These guidelines point to different policies being efficient for technologies at different maturity levels, see Figure 8.

Figure 8
Policy recommendations from R&D to mature technologies



Source: Copenhagen Economics (2013), Efficient strategy to support renewable energy, page 44

Right now, we recommend that focus should be on promoting promising and proven technologies that need to be taken to an industrial scale such as advanced biofuels and e-fuels, to mature them through continuity and stability with low-risk incentives. The aim should be to have industrial-scale technologies that can be rolled out from around 2030 if sufficiently supported by a more effective carbon pricing policy.

Instruments include blended finance where the government co-finance investments all the way from prototype to late stage technologies. As a technology matures, the rate of government financing lowers since the private sector increasingly assumes a larger share of the risk of taking the technology closer to the market. As a counterpart to the government financing, the public investor could reserve a right to a part of the revenues deriving from the exploitation of the technologies that will ultimately be successful in the marketplace. This could for example take the form of a co-ownership of intellectual property rights (IPR).

Recommendation 7

Policy focus over the coming decade should be on promoting promising technologies that need to be taken to an industrial scale, notably advanced biofuels and e-fuels, to mature them through continuity and stability with low risk.

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In the end of 2019, the EU Commission presented the **European Green Deal**. The **European Green Deal** sets an ambitious target to make Europe the first carbon neutral continent by 2050. This calls for massive investments in R&D but also a mobilisation of the industry towards an economy which can provide clean, cheap and secure energy. The deal is planned to be implemented in stages from spring 2020 to the end of 2021. As part of **European Green Deal**, the EU has prepared the *Sustainable Europe Investment Plan* which is a plan to make green investments of 1,000 billion EUR between 2021 and 2027. Around 50% of this is expected to come from the EU Budget.

The European Council at its meeting in July 2020 adopted measures that would de facto strengthen climate policy as priorities both in the EU “ordinary” budget and in the funds allocated to speed up the recovery of the EU in the context of the Covid crisis²⁹.

Recommendation 8

Within the scope of the ordinary EU Budget (MFF) as well as the specific measures to speed up the recovery of the EU (NGEU), should support promising technologies, i.e. technologies for direct electrification, flexible electricity demand and the maturing of technologies, storage and use of e-fuels.

Finally, more support for developing and deploying advanced biofuels and e-fuels could help to decarbonise difficult-to-electrify sectors. From a Nordic perspective, this could include joint schemes for the use of green fuels for transport within the Nordic region, notably ships and aviation.

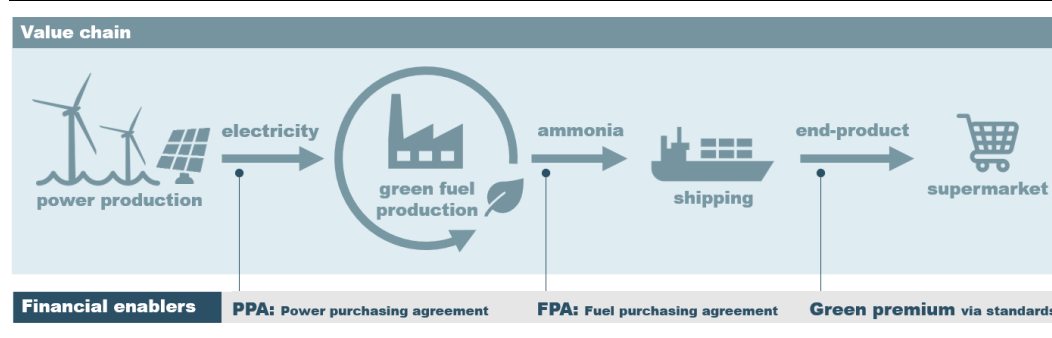
Recommendation 9

Develop and implement joint systems for the use of green fuels for international transport within the Nordic region.

De-risking the investments in new low carbon technologies can be assisted by more use of long term PPAs and FPAs. As noted earlier, a lack of standardisation with respect to PPAs may restrain use this mechanism. We also see a need for development of FPAs, as there might also be benefits from developing standard mechanisms for agreements between for example a fuel producer and an airline cf. Figure 9.

²⁹ European Council (2020)

Figure 9
Value chain illustration and financial enablers,
Example: Green ammonia and shipping fuel



Source: Copenhagen Economics

In addition to de-risking investments in fuel plants directly, very transparent and verifiable agreements may in turn be used by international transport companies to prove to end customers such as retail stores that they are engaged in a long-term decarbonisation plan. This is linked to the EUs development of a taxonomy for classifying ‘green’ economic activities throughout the value chain ultimately dictating the share of a portfolio of assets, that can be classified as ‘green’. The first part of the taxonomy is expected to be implemented throughout 2021 and will lay the foundation for creating standards and transparency around green activities and investments.³⁰ In turn, this might provide an additional revenue stream for the green transformation. As such, end business customers are increasingly put under pressure by financial investors such as pensions funds and banks that they are supporting the climate agenda and will hence be willing to pay a premium for an energy supply that becomes more carbon neutral over time.

Recommendation 10

Encourage regulation and development of industry standards that strengthen the adoption and effectiveness of PPAs and FPAs and support procurement of products and services with a small carbon footprint.

3.3 Integration of the Nordic power market

The Nordic power market is already very integrated. There exist interconnectors between all neighbouring countries. However, as an example, Eastern Denmark is the region with the lowest transmission capacity to other Nordic countries and neighbours, see Table 5.

³⁰ See e.g. <https://www.consilium.europa.eu/da/press/press-releases/2019/12/18/sustainable-finance-eu-reaches-political-agreement-on-a-unified-eu-classification-system/>

Table 5
Existing interconnection capacity in the Nordic and neighbouring countries

NTC MW

=> / <=	SE	NO	FI	DK1	DK2	Neighbours	TOTAL EX-PORT
SE	-	3,995	2,400	680	1,300	1,915	10,290
NO	3,695	-	0	1,640	0	2,100	7,435
FI	2,300	0	-	0	0	1,700	4,000
DK1	740	1,640	0	-	590	1,780	4,750
DK2	1,700	0	0	600	-	985	3,285
Neighbours	1,915	2,100	1,016	2,200	1,000	-	8,231
Total Import	10,350	7,735	3,416	5,120	2,890	8,480	37,991

Source: ENTSOe(2017), Regional Investment Plan 2017 - Group Baltic Sea and North sea, ENTSOe(2018), Ten-Year Network Development Plan (TYNDP) 2018.

The Nordic countries have highly integrated power markets as evidenced by relatively uniform power prices, but further measures could be taken to strengthen integration. Variations in regulation of grid tariffs and different systems for supporting renewables can distort competition among producers and distort the location of renewable generation capacity. The European TSO organisation, ENTSO-E, assesses that there is a significant need and a market for additional transmission capacity in the future. This is a sign both that the existing transmission capacity is already being used, and, as ENTSO-E assesses, that there are economic gains from further integration. This would in turn indicate that a single Nordic power market today is constrained by limited transmission capacity.

Indeed, ENTSO-E's ten-year network development plan (TYNDP) shows significant economic gains from increased interconnections. The TYNDP for 2040³¹ indicates a need for increased interconnection capacity across the Nordics in the order more than 19GW (+51%), see Table 6. In addition to further interconnection capacity, there are examples of congestion in the internal grid in several of the Nordic countries. To be able to adapt a single Nordic power market, such internal congestions should be managed through internal grid investment, to a degree where internal grids are not a barrier for a single Nordic power market.

³¹ The name 'ten-year network development plans' is a bit misleading, as the network development plans reach further into the future than ten years.

Table 6
Expected interconnection capacity in the Nordic and neighbouring countries, 2040

NTC MW

=> / <=	SE	NO	FI	DK1	DK2	Neighbours	Total
SE	-	3,995	4,100	680	1,300	3,115	13,190
NO	3,695	-	0	2,140	0	4,500	10,335
FI	4,100	0	-	0	0	1,000	5,100
DK1	740	2,140	0	-	1,090	5,100	9,070
DK2	1,700	0	0	1,100	-	1,500	4,300
Neighbours	3,115	4,500	1,016	5,100	1,500	-	15,231
Total	13,350	10,635	5,116	9,020	3,890	15,215	57,226

Source: ENTSOe(2017), Regional Investment Plan 2017 - Group Baltic Sea and North sea, ENTSOe(2018), Ten-Year Network Development Plan (TYNDP) 2018.

Measures supporting a single Nordic power market can also reduce the costs of decarbonisation. The reason for this is that interconnectors in combination with a single Nordic power market can ensure that the access to the cheapest and most suitable renewable energy resources can be fully harvested and distributed and transmitted among countries to meet national and regional demand.

Furthermore, it is crucial both that DSOs work together with national TSOs and that national TSOs work together on a cross-Nordic basis, on top of looking strictly to optimise interconnector capacity on a national basis:

- Both DSOs and TSOs should in their day-to-day operations and cooperation be more forward-looking in relation to future needs, which are rapidly changing, also as a result of the huge electrification that will be needed.
- TSO and DSO companies should be given greater freedom to choose the most efficient technical solutions with the lowest costs to customers and society notably by encouraging market mechanisms that encourage higher degree of flexibility in the supply and demand of power in the grid as a substitute to invest in grid capacity.
- The DSOs should in this respect be more customer-oriented in relation to differentiated preferences and needs and especially ensure delivery of the needed capacity for clients with a large increase in electricity demand.

Recommendation 11 and 12

National TSO's and DSO's should co-work and co-plan to optimize on a cross-Nordic basis.

TSO and DSOs should be more forward-looking and customer-oriented in their operations.

On top of the above, in relation to more regional and national measures for integration of the Nordic power market, the EU Clean Energy Package (2016) contains a number of measures and instruments to ensure an efficient and well-functioning power market. This includes adaption to the power market design, with the focus to allow electricity to move freely to where it is most needed. The argument is that the society will increasingly benefit from cross-border trade and competition, that can drive

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the investments necessary to provide security of supply while also decarbonising the European energy system.³²

Recommendation 13

Implement measures from the EU Clean Energy Package, including alignment of rules for cross-border trade, management of DSO as well as TSO grid congestions, alignment of grid-connections tariffs in the TSO and DSO grid, including requirement of cost true tariffs and creation and implementation of Regional Operation Centres (ROCs), to ensure efficient regional grid operations.

³² See European Union (2019), Clean Energy for all Europeans, The Electricity Directive (2009/72/EC) and Electricity Regulation (No 714/2009). Available at: https://ec.europa.eu/energy/topics/markets-and-consumers/market-legislation/electricity-market-design_en?redir=1

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Table 7
Summary of recommendations from the policy roadmap for decarbonisation

FOCUS	EU LEVEL	NATIONAL LEVEL	REGIONAL LEVEL
Credible carbon-pricing framework	Recommendation 1: We propose a firming of the EU ETS price for all ETS-covered installations and sectors through the implementation of a carbon price floor within the ETS.	Recommendation 4: Restructure national taxes from a focus on energy taxes to CO2 taxes based on CO2 equivalents and on a trajectory to a common price consistent with the climate goals thus increasing incentives to shift to low-emission fuels and technologies.	
	Recommendation 2: For industries at risk of carbon leakage and within the ETS, give free allowances to mitigate the risk of carbon leakage, with a decline of free allowances to follow the trajectory for national decarbonisation targets.	Recommendation 5: For industries at risk of carbon leakage, give tax credits based on production-adjusted carbon emissions to mitigate the risk of carbon leakage, with a decline of CO2 tax credits to follow the trajectory for national decarbonisation targets.	
	Recommendation 3: Revise the energy tax directive to focus on minimum tax level on carbon and set the minimum tax rate equal to the carbon floor price within the ETS. Focus on international efforts to decarbonise aviation and shipping.	Recommendation 6: Domestic transport and residential heating should not receive CO2 tax credits, as they are not at risk of carbon leakage.	

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Targeted support for promising technologies	Recommendation 7: Policy focus over the coming decade should be on promoting promising technologies that need to be taken to an industrial scale, notably advanced biofuels and e-fuels, to mature them through continuity and stability with low risk.	
	Recommendation 8: The EU budget, and the European Green Deal, should support promising technologies, i.e. technologies for direct electrification, flexible electricity demand and the maturing of technologies, storage and use of e-fuels.	Recommendation 9: Develop and implement joint systems for the use of green fuels for international transport within the Nordic region.
	Recommendation 10: Encourage regulation and development of industry standards that strengthen the adoption and effectiveness of PPAs and FPAs and support procurement of products and services with a small carbon footprint.	
	Recommendation 11: National TSO's and DSO's should co-work and co-plan to optimize on a cross-Nordic basis.	
Integration of the Nordic power market	Recommendation 12: TSO and DSOs should be more forward-looking and customer-oriented in their operations.	
	Recommendation 13: Implement measures from the EU Clean Energy Package, including alignment of rules for cross-border trade, management of DSO as well as TSO grid congestions, alignment of grid-connection tariffs in the TSO and DSO grid, including requirement of cost true tariffs and creation and implementation of Regional Operation Centres (ROCs), to ensure efficient regional grid operations.	

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