OECD Economics Department Working Papers No. 1705

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Andrew Barker,

Hélène Blake,

Filippo Maria D'Arcangelo,

Patrick Lenain

https://dx.doi.org/10.1787/5b40df8f-en

OECD

Organisation for Economic Co-operation and Development

ECO/WKP(2022)6

Unclassified English - Or. English

28 March 2022

ECONOMICS DEPARTMENT

TOWARDS NET ZERO EMISSIONS IN DENMARK

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JT03492207

ABSTRACT/RÉSUMÉ

Towards net zero emissions in Denmark

Denmark has been a frontrunner in policies that reduce greenhouse gas emissions and now plans to cut emissions by 70% by 2030 from 1990 levels and to achieve carbon neutrality by 2050. Such ambition induces halving emissions from 2019 levels and making the same emission abatement effort in ten years than the past thirty years. Cutting emissions at such fast pace will be challenging with substantial disruptions and macroeconomic consequences. A balanced mix of pricing policies, public investment, regulation and enabling policies should allow smoothing the potential economic and social shocks and accompanying the reallocation of resources.

This paper investigates further sectoral climate strategies in Denmark. In the energy sector (electricity and district heating), past progress made to ramp up clean technologies provides a good blueprint to achieve further decarbonisation, but the focus will need to be put soon on lowering reliance on woody biomass. In the transport sector, emissions have continued to increase despite the shift to more fuel-efficient vehicles, highlighting the need for more transformative policies to expand alternatives to individual car uses. In agriculture, little has been done so far to cut emissions, especially from livestock. The sector is subject to leakage risks, but nonetheless should be encouraged to transform its practices. Helping farmers to monitor their GHG emissions should be combined with more stringent regulation.

Key words: Denmark, Climate change mitigation, Climate change adaptation, Public policy, Climate strategy, Environmental taxation, Energy, Transport, Agriculture

JEL codes: H21, H23, H50, H54, Q52, Q53, Q54, Q55, Q56, Q15, Q42, Q43, Q48, R48

This Working Paper relates to the 2021 Economic Survey of Denmark
https://www.oecd.org/economy/denmark-economic-snapshot/

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Vers la neutralité climat au Danemark

Les politiques de réduction des gaz à effet de serres du Danemark ont été jusqu'ici exemplaires et le pays cherche aujourd'hui à réduire ses émissions de 70% à l'horizon 2030 par rapport au niveau de 1990, et d'atteindre la neutralité des émissions en 2050. Cette ambition suppose de diminuer par deux son niveau actuel d'émission et de réaliser le même niveau d'effort en dix ans que durant les trente dernières années. La baisse drastique des émissions sera délicate, amenant son lot de perturbations et de conséquences macroéconomiques. Un mélange équilibré de mesures prix, de régulation, d'investissement public et de mesures habilitantes devrait permettre de limiter les chocs économiques et sociaux, ainsi que d'accompagner la réallocation des ressources qu'implique la transition.

Cet article se propose dans un second temps d'étudier plus en profondeurs des stratégies climatiques sectorielles au Danemark. Dans le secteur de l'énergie (électricité et chauffage urbain), les progrès déjà réalisés dans le déploiement des énergies renouvelables ouvrent la voie pour plus de décarbonation. Toutefois, une attention particulière devra être portée à la réduction de la dépendance du secteur à la biomasse. Dans le secteur du transport, les émissions continuent d'augmenter malgré l'adoption de véhicules plus verts. Cela appelle à la mise en place de politiques transformatrices, favorisant les alternatives aux véhicules particuliers. Très peu a été fait pour réduire les émissions de l'agriculture, et en particulier de l'élevage. Le secteur est exposé au risque de fuite de ses émissions, mais il n'en faut pas moins encourager la transformation de ses pratiques. Il conviendrait notamment d'aider les agriculteurs à suivre leurs émissions et de renforcer les exigences règlementaires.

Mots clés: Danemark, Atténuation du changement climatique, Adaptation au changement climatique, Politique publique, Stratégie climatique, Fiscalité environnementale, Énergie, Transport, Agriculture

Codes: H21, H23, H50, H54, Q52, Q53, Q54, Q55, Q56, Q15, Q42, Q43, Q48, R48

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Towards net zero emissions in Denmark

By Andrew Barker, Hélène Blake and Patrick Lenain[1]

Denmark has been a frontrunner in policies that reduce greenhouse gas emissions and now plans to achieve carbon neutrality by 2050. Emissions of greenhouse gases peaked in the mid-1990s and have since declined by about 47 million tonnes. Achieving carbon neutrality will require additional cuts of a similar amount. Denmark plans to frontload this effort and more than halve its emissions by 2030. Achieving these ambitious targets would contribute to global efforts to control climate change, but the transition towards carbon neutrality will have large macroeconomic consequences and entail significant financial risks. Rapid changes in consumer behaviour, large amounts of private and public investments, and a reallocation of labour across sectors will be required. The impact of climate policy on public debt will be increased by unavoidable spending to protect the country from changing weather patterns. This makes it crucial to adopt well-designed policies that contain both types of costs and promote the benefits of adaptation to climate change. This chapter outlines a cost-effective, inclusive and comprehensive strategy to decarbonise the Danish economy. It reviews progress so far, discusses macroeconomic consequences of climate policies, and recommends a package of policies.

This chapter discusses an effective, inclusive and comprehensive strategy to cut Denmark's greenhouse gas (GHG) emissions by 70% by 2030 from 1990 and reach carbon neutrality in 2050, as currently planned.[2] First, it assesses the current situation, including the exposure of Denmark to climate risks and its strategy to cut emissions (section 2.1). Second, it discusses the economic and employment consequences of rapid cuts in carbon emissions (section 2.2). Finally, it proposes various policy options and their associated risks (section 2.3). Following this analysis, Chapter 3 will delve into the details of three specific sectors. The two chapters follow the framework discussed by the Working Party No.1 of the Economic Policy Committee in March 2021 (ECO/CPE/WP1(2021)9).

The climate strategy in Denmark

Denmark is at the forefront of efforts to reduce greenhouse gas (GHG) emissions. The country succeeded by 2019 in cutting its emissions by 36% relative to 1990 and now has adopted the ambition to halve emissions from their current levels by 2030 and then progress further towards carbon neutrality in 2050. Reflecting its ambition to be a global leader and provide an example of how emission cuts can be achieved, Denmark does not plan to meet its goals through offsets from funding emission cuts abroad even though this could offer cheaper abatement opportunities. Denmark's targets imply that the pace of carbon cuts needs to accelerate from progress achieved so far – a considerable endeavour with large macroeconomic and financial consequences.

[1] The authors are from the OECD Economics Department (ECO). They would like to thank Filippo Maria D'Arcangelo. The paper has also benefitted from comments by Laurence Boone, Alvaro Pereira, Isabell Koske, Tomasz Kozluk, Douglas Sutherland, Mauro Pisu, Tobias Kruse, Geoff Barnard, Kurt Van Dender, Jonas Teusch, Luisa Dressler, Antoine Dechezleprêtre, Stefano Piano, Stefan Thewissen, Enrico Botta, Guillame Gruère and Grégoire Garsou. Special thanks go to Isabelle Luong, Mathilde Sonne and Karimatou Diallo

[2] Accounted in carbon dioxide equivalent (CO_2e), measuring CO_2 and non-CO_2 greenhouse gas emissions based on their global warming potential.

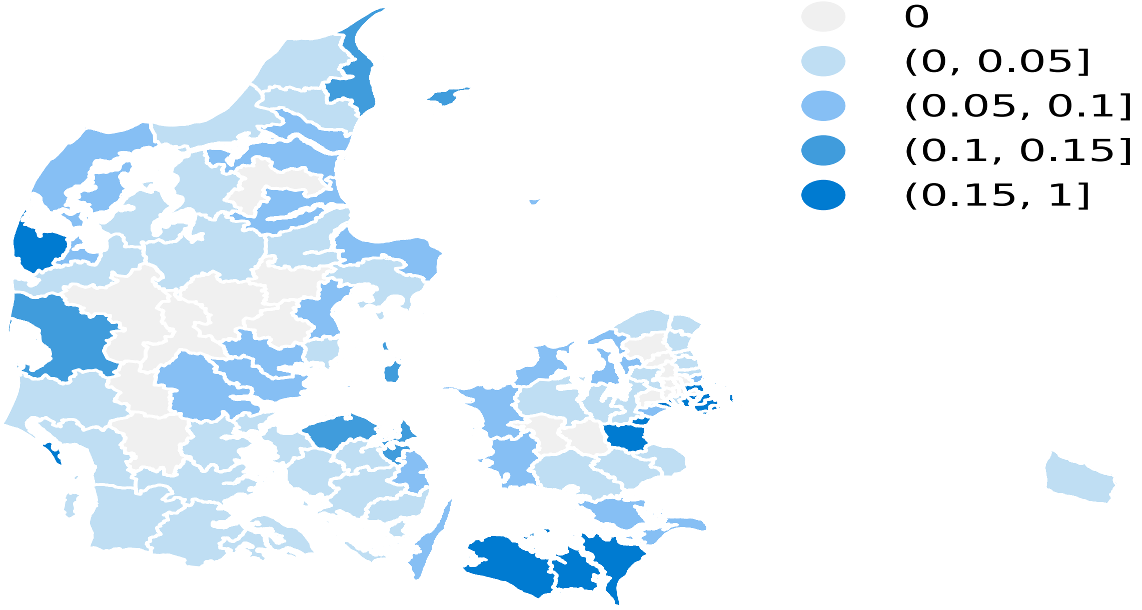
Denmark is exposed directly and indirectly to the impacts of climate change

Despite its location in the temperate zone, climate change is likely to have a negative impact on Denmark, and catastrophic events could occur in extreme scenarios. The country is not expected to suffer substantially from new drought episodes (IPCC, 2014[1]) (World Bank Group, n.d.[2]), but rain episodes will be more concentrated and heavier in the winter season by the end of the century (Danmarks Klimacenter, 2014[3]). The frequency of extreme weather events (storms, long and heavy rains) will increase in the coming decades (World Bank Group, n.d.[2]), as in the rest of Northern Europe, with possible catastrophic losses of lives and properties. A collapse of the Gulf Stream and its effect on northern Europe's climate could trigger more extreme weather, including colder winters and more intense storms (Jackson et al., 2015[4]) that could increase domestic energy demand. There is medium confidence that the Gulf Stream will weaken this century, but it is not expected to change much or shut down totally (IPCC, 2021[5]).

A sharp worsening of climate change could hit Denmark severely. Its geography consists of the Jutland peninsula with a highest point of 170m above sea level and more than 400 islands, which makes it particularly vulnerable to flooding and erosion from rising sea levels due to melting glaciers and ice sheets. Vulnerability is concentrated in areas of high asset values around Copenhagen (Figure 1). Partly reflecting high asset values and insurance coverage, Denmark has already been particularly exposed to extreme events such as storms and flooding: although losses in Denmark have been small in aggregate (EUR 50 per capita per year), on the basis of information from insurance associations and local informers they were estimated to be among the highest per capita in the European Union between 1980 and 2019 (European Environment Agency, 2021[6]). Rising seas, extreme events and floods could threaten the provision of basic goods and service by damaging or destroying water and transport infrastructure (OECD, 2018[7]), and would undermine activity in ports and coastal areas (Danish Ministry of Energy, 2017[8]). Crops could be more exposed to flooding and farmers may have to cope with heavier rains and adjust their pesticide and fertiliser use to reflect a higher risk of run-off. Drier summers might affect the availability of groundwater, used for agriculture and household consumption.

Global warming will also have indirect effects on Denmark and its trade-dependent economy. There is little doubt that increasing temperatures will threaten ecosystems and cause more frequent and serious wildfires and drought globally, particularly in subtropical areas (IPCC, 2014[1]). Although food production might increase in certain areas, including in Denmark, climate change is projected to undermine global food security, decreasing wheat, rice and maize production in tropical and temperate regions (IPCC, 2014[1]). Migration and the tensions on resources that might emerge (Danish Ministry of Climate, 2020[9]) can undermine trade and access to some commodities. Danish agriculture, with a major livestock sector, might have to cope with higher and more variable feed prices.

Figure 1. Much of Denmark is exposed to flood risk, particularly the greater Copenhagen area



Note: The map shows the share of exposures collateralised by real estate at risk of flooding in proportion to the total number of exposures collateralised by real estate. The exposures are by the end of 2020. The shares are by municipality. Based on the worst-case scenario in 2071-2100.
Source: Danmarks NationalBank (2021),"Flood Risk Can Potentially Affect a Large Share of Credit Institutions' Exposures", Analysis No.13.

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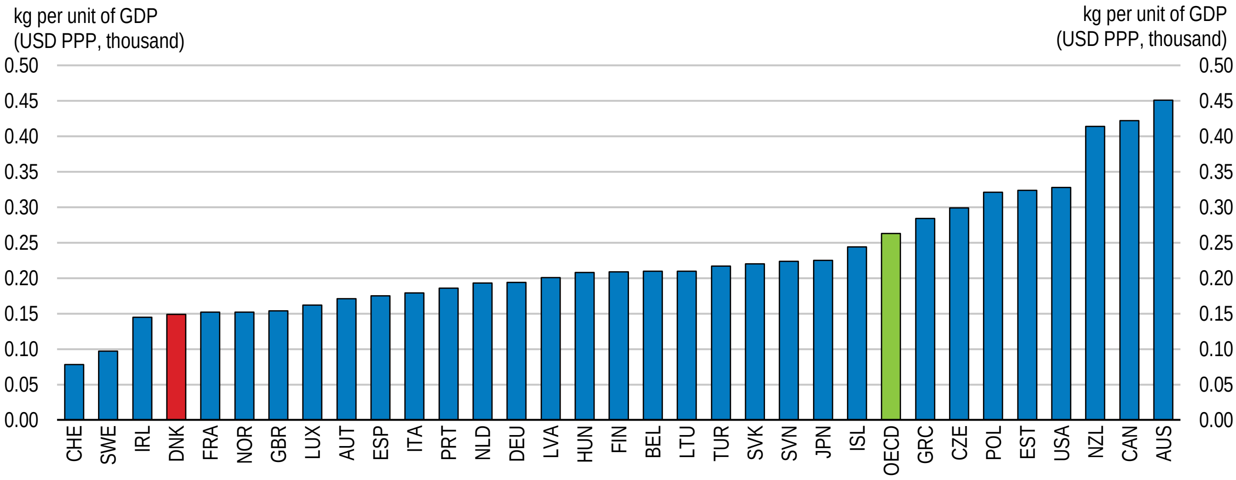
Adaptation of the economy and society to climate change is critical to manage the socioeconomic effects. Costs of adaptation are highly uncertain, centring around 0.1% to 0.5% of GDP for developed countries (Stern (2006[10]); UNEP (2021[11]); Agrawala et al (2010[12])) but potentially higher in the near-term if retrofitting and coastal protection is brought forward (IMF, 2021[13]). There are important roles for government to embed climate considerations in risk management (including spatial planning), protect the vulnerable, provide localised information and ensure sufficient flexibility in regulatory settings to allow households and firms to manage risks. There are opportunities to adapt while also reducing emissions, such as restoration of wetlands that reduce exposure to flood risks, but also trade-offs such as higher energy use in buildings to maintain comfort levels in a changing climate (OECD, 2021[14]). Denmark in 2008 launched its strategy for adaptation and followed up with an action plan for a climate-proof Denmark in 2012. An update to incorporate the latest climate science and risk assessment would be timely.

Denmark has reduced its GHG emissions and set ambitious new targets

Danish GHG emissions have consistently decreased since 1996. The electricity generation sector has been driving the trend, reducing its GHG emissions by two thirds between 1990 and 2019, thanks to a fast-growing use of renewables. As a result, emission intensity is among the lowest in OECD countries (Figure 2). Most energy use is for transport and residential purposes and emissions from the transport sector are now higher than those from electricity generation (29% vs. 19% in 2019). Importantly, Denmark has reduced its energy intensity (the total energy supply per unit of GDP) by a quarter over the last decade, contributing further to the transition of the economy towards climate neutrality. Renewables account for a relatively high share of total energy supply, particularly biofuels and wind power (Figure 3). Denmark's high levels of consumption and low emissions-intensity in production contribute to larger demand-based emissions – which include emissions embodied in imports – than production-based emissions, though demand-based emissions have consistently declined over the past fifteen years (Figure 4).

Figure 2. Denmark has among the lowest emission intensities in OECD countries

Green house gas emission intensity, 2019 data



Note: GHG emission intensity is calculated as total gross greenhouse gases excluding land use, land use change and forestry per unit of GDP expressed in thousand 2015 USD PPP. Emission accountings also exclude international transport, although they substantially contribute to GDP (transport and trade being responsible for 20% of the total net value added in Denmark in 2020 according to Statistics Denmark).
Source: OECD, Environment Statistics (Air and Climate) - GHG emissions database.

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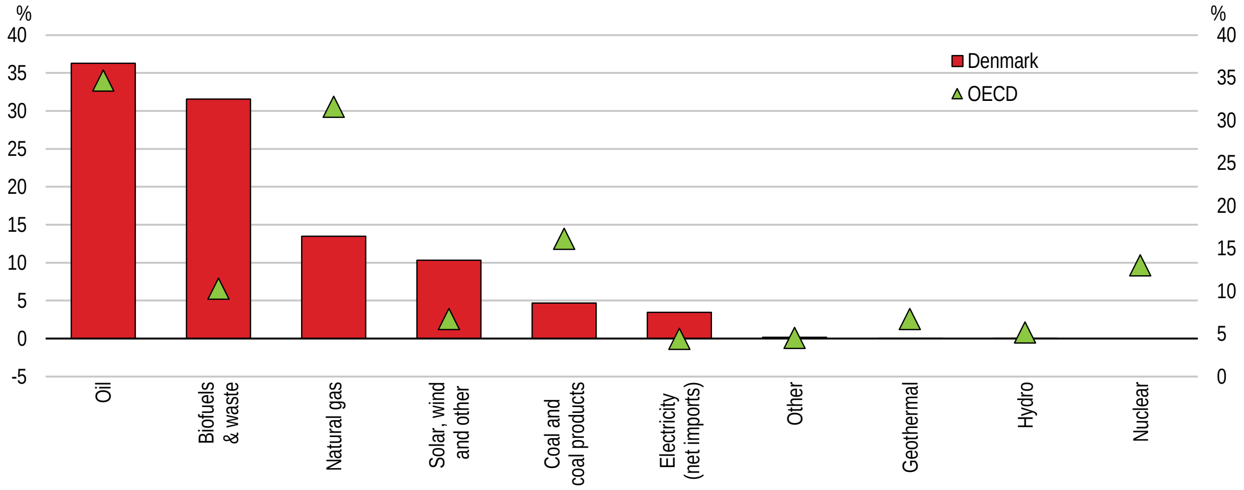
Consistent with evidence from other OECD countries, emission cuts have not derailed economic growth or employment. Denmark is one of many OECD countries to have decoupled its GHG emissions from economic growth during the last three decades (Figure 5). OECD-wide evidence indicates that implementing stringent environmental policies has had little aggregate effect on economic performance so far despite achieving significant environmental benefits (OECD, 2021[15]). For Denmark, the highest environmental policy stringency in the OECD has not prevented one of the highest employment rates of 75% of the working age population (Botta and Koźluk, 2014[16]; OECD, 2021[17]). However, environmental policies generate winners and losers and trigger a reallocation of capital and labour from high-emission to low-emission industries and firms. For example in Denmark, employment in fossil-fuel fired electricity generation has contracted over the past two decades while employment in renewable generation, especially wind, has grown. Employment in renewable energy production grew by 4.6% annually between 2012 and 2018, well above the EU average of 0.4% per year (Eurostat, 2021[18]).

The steep reduction of GHG emissions, particularly in electricity-generation and district-heating, is the result of a strong and consistent political will over many years, targeted support and a long history of co-operation between public and private actors for innovation. Both domestic targets and international commitments, particularly at the EU level, are driving this action. The European Union committed in December 2020 to reduce its emissions by at least 55% by 2030, compared to 1990, in order to achieve climate neutrality by 2050 (European Union, 2020[19]). The climate mitigation policy of Denmark is embedded in the EU Emissions Trading System (ETS), the European carbon market for large emitters, covering more than 10 000 installations and 40% of emissions of the European Union, Iceland, Liechtenstein and Norway. Denmark's mitigation commitments frequently exceed EU averages, for instance a -39% reduction between 2005 and 2030 in GHG emissions that are not covered by the EU ETS (mainly transport, residential, agriculture and waste), exceeding the EU-wide target of -30%.

Figure 3. Renewables, including biofuels, are relatively important sources of energy in Denmark

As a percentage of total energy supply, 2020 data



Note: OECD is the average of 37 member countries excluding Costa Rica. Other includes heat, oil shale and oil sands, and peat and peat products. The shares of "Other", geothermal, hydro and nuclear are negligible or nil for Denmark.
Source: IEA, World Energy Balances database.

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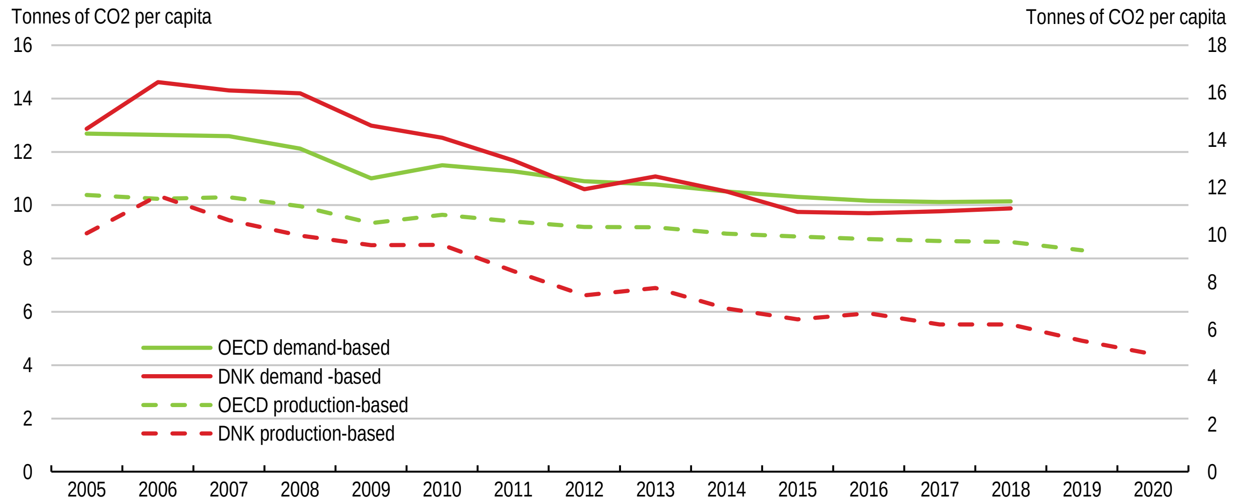
Figure 4. Carbon emissions based on Danish consumption are much higher, but also declining



Note: Based on CO_2 emissions from energy use, excluding indirect effects and net emissions from land use, land use change and forestry.
Source: OECD, Green Growth Indicators database.

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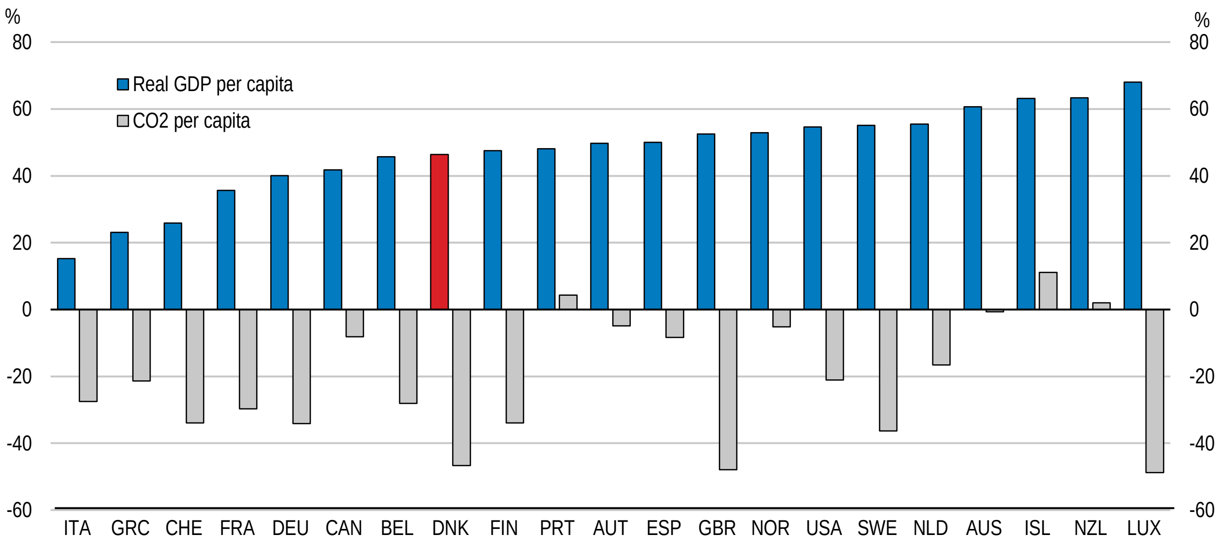
Figure 5. Carbon emission cuts have not prevented strong economic growth in a number of OECD countries

Total growth over the period 1990-2019



Note: 1991-2019 for Germany. CO_2 emissions exclude land use, land use change and forestry and are consumption-based: emissions caused in the production of imported goods are included while emissions embedded in exports are excluded.
Source: OECD, Economic Outlook database; Our World in Data.

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The new Danish Climate Law, voted in June 2020, steps up ambitions through a legal commitment to climate neutrality by 2050 and a 70% reduction of GHG emissions in 2030 relative to 1990 levels. In May 2021, a trans-partisan agreement was made on setting a 50-54% intermediate target for 2025. Moreover, the Danish Parliament agreed to phase-out oil and gas extraction in the North Sea by 2050. The Climate Law provides a strong supporting framework: targets should be revised every 5 years for a 10-year horizon. Furthermore, the government is required to define a climate programme yearly, including an assessment of whether current policies are consistent with official targets. Actions are categorised into a near-term "implementation track" and a longer term "development track" (Danish Ministry of Climate, 2020[9]).

Strong engagement of stakeholders is at the heart of the Danish climate strategy. The Climate Act defines four guiding principles for climate effort[3], including maintaining "a strong welfare society, where cohesion and social balance are secured". In order to build its climate strategy, the government launched Climate partnerships in thirteen sectors and a "Green Business Forum" to identify challenges and opportunities with the support of businesses and trade unions. Specific partnerships are also made with big GHG emitters such as the cement producer Aalborg Portland (Box 4 below). An advisory citizen assembly with 99 randomly chosen members will be involved in the strategy. This approach is similar to the French *Convention Citoyenne pour le Climat*, but with a more limited mandate, as the Danish assembly will focus on how citizens can contribute to climate action and will discuss the dilemmas they face in the transition.

Accounting for 0.1% of global emissions, Denmark aims to mitigate climate change also using international diplomacy with its own success as an example. The country takes an active role in climate talks and partnerships, including under the UN Framework Convention on Climate Change (UNFCCC) and

[3] These guiding principles are: 1) being a leading nation in the international climate effort; 2) realising climate targets as cost-effectively as possible; 3) maintaining a strong welfare society; 4) ensuring that domestic measures do not simply relocate all of the GHG emissions outside Denmark's borders.

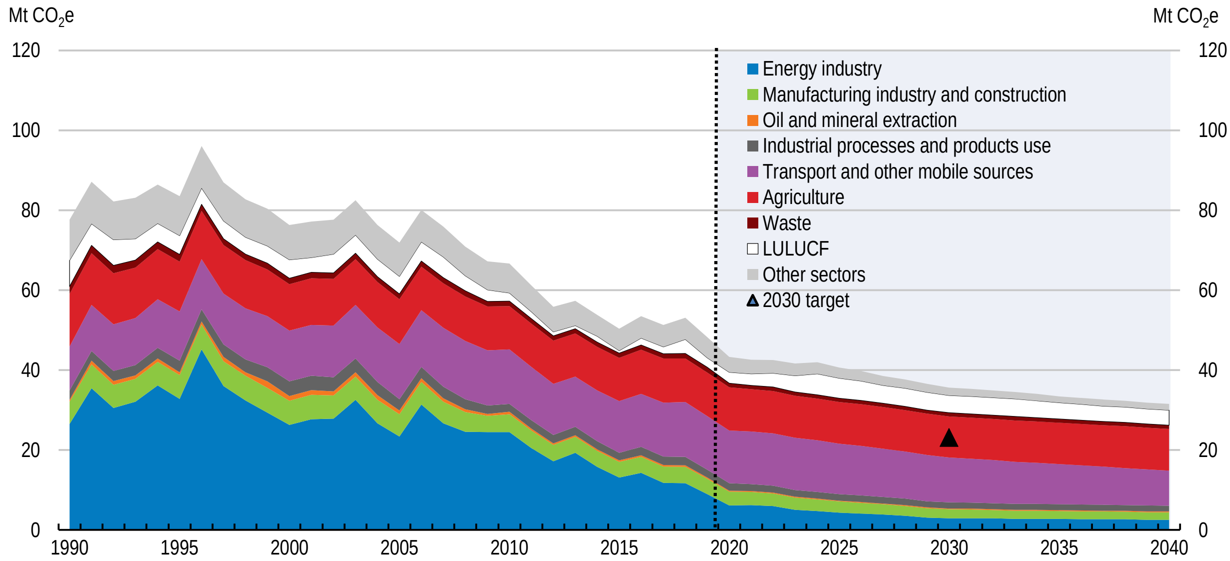
Conference of the Parties (COP). In 2009, Denmark hosted COP15, which led to the Copenhagen Accord with a long-term goal to limit average temperature increase below 2°C, together with a call to consider limiting it to 1.5°C. Being "a leading nation in the international climate effort" is a guiding principle for the country's climate action. In 2018, Denmark signed the Helsinki's principles together with 26 other countries, to highlight the role of fiscal policy and the use of public finance. A total of DKK 2.9 billion has been allocated to climate and environmental efforts in developing countries in 2021, and 36.8% of Denmark's bilateral aid supported the environment in 2019 (OECD, 2021[20]). In March 2020, Denmark initiated a concerted call with 11 other EU countries for more ambitious emission reduction targets within the union.

Climate targets call for accelerated action, but this will have socio-economic impacts

Reaching the 2030 target requires a faster pace of emission cuts than achieved so far. Under policies currently implemented and agreed upon, emissions will decline by 55% in 2030, not enough to achieve the government's goal of -70% (Danish Climate Council, 2021[21]) (Danish Ministry of Climate, 20121[22]), which will jeopardise the goal of carbon neutrality in 2050. Hence, Denmark's climate policy needs to become more ambitious. Further investment in renewable energy will help, but this will not suffice. The sectors of transport, buildings, agriculture, non-ETS industry and waste will need to accelerate also their decarbonisation to meet the 2030 target (Figure 6), as noted by the European Commission (2020[23]).

Figure 6. Denmark will miss its carbon targets under unchanged policies

Greenhouse gas emissions



Note: The GHG emissions include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. The latest historic year is 2019 which forms the basis of the projection. The emissions are projected to 2040 using a scenario which includes the estimated effects of policies and measures implemented or decided by May 2020 on Denmark's GHG emissions based on unchanged policies. Oil and mineral extraction covers fugitive emissions from fuels. Other sectors include combustion in commercial/institutional, residential and agricultural plants. The 2030 target reflects a 70% reduction of the 1990 emission level. LULUCF stands for land use, land use change and forestry.

Source: UNFCCC, GHG Data Interface (1990-2019); Danish Centre for Environment and Energy, Projection of greenhouse gas emissions - 2020 to 2040 data.

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Faster decarbonisation to meet Denmark's ambitious carbon targets will have macroeconomic and financial consequences. Long-term costs depend crucially on the efficiency of policy and availability of new technologies (Box 1). During the transition, large changes in consumer behaviour will be required to reduce the use of fossil fuels, as well as significant household spending on new vehicles and energy efficient appliances. Sufficient resources will need to be allocated to finance new investments in low-carbon capital assets, some equipment will lose economic value and some plants will have to close (Pisani-Ferry, 2021[24]). Retirement of carbon-intensive capital before the end of its productive economic life will entail stranded assets and consequent financial risks. Labour will need to be reallocated between sectors, with risks that workers will be left behind. Further public spending can address these issues, but potentially at the cost of inflating government debt.

A strategy to mitigate macroeconomic and financial consequences

The exposure of households and firms to the economic consequences of emission abatement will vary according to their capacity to adapt to the new policy environment. Higher costs of emission-intensive goods and services will not impact all households in the same manner, depending on their capacity to invest in new vehicles, appliances or energy efficiency. The consequences of higher costs for firms will vary depending on their initial conditions – notably their financial strength, their dependence on emission-intensive inputs and their capacity to pass on price increases. Higher costs from more stringent climate policy could damage international competitiveness of some Danish firms.

Although some firms will be put under pressure, others will benefit from this rapid transformation, as Denmark already experienced with the emergence of thriving firms that have become world-leaders in offshore wind. The Porter Hypothesis posits that a redesign of production processes or reallocation of resources within firms could trigger productivity increases. Empirical evidence indicates that larger, more productive, low-emission and well-managed firms are better equipped to respond to more stringent policies and are thus able to raise their productivity and gain higher market shares, while other firms can suffer negative effects (Albrizio, Kozluk and Zipperer, 2017[25]; Dechezleprêtre et al., 2019[26]). As a result, the climate strategy will continue to have winners and losers: creating opportunities for some firms (such as those building green infrastructure) while others carry disproportionate adjustment costs.

Framework conditions allowing "creative destruction" processes to operate are important to allow innovative firms to bring low-carbon technologies to the market and displace high-carbon firms. This includes policies to improve the business environment, reduce entry barriers for new firms, strengthen competition, and enable the exit of loss-making firms. Denmark's legislation generally underpins a competitive business environment that facilitates market entries (OECD, 2018[27]) but key sectors for climate can be opened further to new entrants. More specifically, the passenger rail system is dominated by a state-owned company and the EU Commission highlighted in June 2021 the country's limited effort to transpose the EU directive for a European railway area (European Commission, 2021[28]). Recent reforms to provide greater power to the competition authority are welcome and outcomes should be monitored (Chapter 1).

Box 1. Welfare implications of climate policy: model simulations

Assuming that Denmark's policies are cost-efficient, holding policies constant in other countries, the Danish Economic Councils (2021[29]) estimates that reaching a 70% cut in GHG emissions in 2030 would entail a modest annual welfare cost of DKK 4 billion in 2030 (0.15% of GDP). Gross value added is estimated to decline by DKK 7 billion as it becomes more expensive to produce emissions-intensive goods in Denmark, reducing real household income and consumption to a similar extent. This is partly offset by DKK 2 billion in benefits from reduced air pollution and DKK 1 billion from reduced nitrogen discharges. Benefits from reducing climate damages, traffic congestion, noise and other agricultural pollution are excluded, as are the transition costs from the path to a new equilibrium.

The actual costs of the transition are highly uncertain and will depend critically on the efficiency of policy and the availability of low-emission technologies. The Climate Council (2020[30]) has estimated a somewhat higher cost of 0.7-1% of GDP to meet the 2030 target, in part from assuming lower availability of abatement technologies. Past trends show a rapid reduction in the costs of renewables that reduced the costs of cutting energy emissions (IRENA, 2020[31]), but future costs will depend on whether this progress is maintained and broadened to other sectors and technologies, including carbon capture use and storage. Welfare costs could be three times higher if the agriculture sector was excluded from action, or higher again if subsidies were the principal policy tool (Danish Economic Councils, 2021[29]).

Curbing labour market adjustment costs

Effects on employment are also expected to be very heterogeneous, reflecting differences in the capacity of firms and sectors to adapt to a low-emissions economy. Various studies suggest that, with the right policy mix, the overall employment impact of a policy package leading to a 70% emission cut by 2030 can be very small. However, climate policy will generate movement within the labour market with shifts between jobs and between sectors. As many as one in four jobs could be lost in agriculture (-3.1% per year) and almost one in ten in the food industry (-1.3% per year) (Table 1), although these sectors amount for a small share of overall employment. Job losses are also likely to affect specific parts of broader industries where emissions are concentrated among a small number of firms, such as in cement production (Box 2), sugar and oil refining. More disaggregated modelling is needed to better understand the scale and location of these effects (section 2.3.7). Job losses are likely to entail losses of income. Historically more than one displaced worker in three has faced an earnings loss of at least 10% in the year following displacement and Danish agricultural workers are particularly vulnerable as they have lower re-employment prospects than workers from other sectors (OECD, 2016[32]). At the same time, adjustment in agriculture will be enabled by the high share of geographically mobile foreign workers.

The extent of job losses in broad industries is not expected to be exceptional by historical comparison: agriculture (-2.4% per year) and food (-3.1%) also contracted substantially between 2000 and 2010 (Danish Economic Councils, 2021[29]). In addition, the number of “green jobs”, such as those in renewable energy and building renovations, has potential to increase by tens of thousands in coming decades with an ongoing commitment to supportive policy, technological development and training (CONCITO, 2019[33]) (Cedefop, 2018[34]). In 2016, the number of environmental jobs in Denmark amounted to 71,000 (Statistics Denmark, 2018[35]). Managing the implications for gender equality in the labour market by ensuring there are real opportunities for women will be important: men are more affected by shrinking extractive industries, but also more likely to work in green construction (ILO, 2019[36]).

Table 1. Estimated effect of climate mitigation policy on employment by sector

	Change in employment in 2030 vs baseline		Average annual growth in employment 2019-2030 (%)	
	Number of person-years	%	*Without mitigation*	*With mitigation*
Agriculture	-14 500	-25	-0.5	-3.1
Food industry	-4 500	-9	-0.4	-1.3
Supply	600	1.9	1.6	1.8
Industry	3 200	1.3	0.3	0.4
Private services	9 600	0.6	0.2	0.2
Others	4 500	0.4	0.8	0.8
Total	-1 000	-0.0	0.4	0.4

Note: Based on a scenario where existing energy taxes are phased out, financed by a uniform greenhouse tax to achieve the 70% target. The changes in employment in 2030 in the first two columns are relative to the level of employment in the baseline scenario in 2030. The agriculture sector also covers horticulture. Food industry covers the food, beverage and tobacco industry. Supply covers North Sea production, oil refineries, electricity, gas, heat and water supply as well as waste incineration. Industry covers other industry and processing, and "other" covers forestry, fishing, construction and public services. The total in the first column does not sum precisely due to rounding.
Source: Danish Economic Council (2021).

Box 2. Reducing emissions from cement production in Denmark

The Danish cement industry consists of a single producer, Aalborg Portland, which is the world's largest exporter of white cement. The company has just over 350 employees in Denmark, mostly located in and around Aalborg, Denmark's third largest city. As the only cement producer, Aalborg Portland has strong specific skill needs and internal training, with the highest share of apprentices per employee among Danish process companies.

Aalborg Portland is by far the largest single emitter of CO_2 in Denmark, responsible for more than 4% of national emissions in 2018 (2.2 million tonnes). Industrial process emissions from cement production are subject to emission pricing under the EU ETS. The government has entered into a cooperation agreement with Aalborg Portland that secures greenhouse gas emission reductions of 0.5 million tonnes of CO_2e by 2030. Rather than reducing production, the emphasis is on replacing fossil fuels, using clay instead of chalk to reduce process emissions and using excess heat for district heating of homes in Aalborg. More expensive technologies, notably carbon capture, may be needed to make further cuts.

Source: (Danish Economic Councils, 2021[29]); (Danish Economic Councils, 2019[37]); (DI Business, 2020[38]); (Aalborg Portland, 2021[39])

Apart from agriculture, regional employment effects of climate policy are not likely to be as severe in Denmark as in countries with a strong geographical concentration of emission-intensive activity. Denmark does not have regions reliant on coal mining activity as in Germany, for example. The phase out of oil and gas activity will be gradual, and workers often have skills that can be used in offshore wind. A survey of the UK oil and gas workforce found that more than half would be interested in retraining in offshore wind (Windpower Monthly, 2020[40]). In agriculture, job losses will be concentrated in key livestock provinces of South and West Jutland, where there are less alternative employment opportunities than in the major cities. However, the contraction in agricultural employment in the decade to 2010 was managed without pushing unemployment rates in these provinces above the national average. Historical experience suggests new green jobs are also likely to be concentrated in South and West Jutland (and more broadly in Southern and Central Denmark) (CONCITO, 2019[33]). Nonetheless, the potential for job losses to be regionally-concentrated in agriculture increases the importance of removing barriers to labour mobility, such as reducing housing market inefficiencies.

Denmark has a strong policy starting point to facilitate the deep structural transformation needed to reach net zero emissions. The Danish framework of "flexicurity", which is based on ensuring mobility between jobs while providing a comprehensive safety net for the unemployed and strong active labour market policy, should help to promote a smooth reallocation of labour in the context of the green transition. A recent example of large-scale restructuring was the manufacturing industry during the 2008 financial crisis, when its share of Danish employment fell from 13% to 11% over two years as foreign demand collapsed. Displacement rates in manufacturing tripled from 1.8% to 5.7% and laid-off workers faced lower re-employment prospects than those from most other sectors (OECD, 2016[32]). While unemployment spiked, a sustained increase in structural unemployment was avoided as the flexicurity system enabled a large proportion of the jobless to find employment relatively quickly (Eriksson, 2012[41]) and further strengthening of activation policies made the system more robust (OECD, 2016[32]).

Skill formation and a social safety net that protects people rather than jobs will become increasingly important. International experience shows that workers in the construction sector, once reskilled, are well-suited to working in renewable energy and energy efficiency renovations (Kane and Shivaram, 2020[42]; NABTU, 2020[43]). Construction employment fell substantially in Denmark during the 2008 financial crisis, but it has been one of the first industries to show signs of skill shortages during the recovery from the COVID-19 crisis, in part due to government support for energy efficiency renovations.

The strong involvement of trade unions and the private sector in skill development in Denmark is an asset for supporting workers' transition to a low-carbon economy. Social partners hold a key role in vocational training centres and can help anticipate future needs. Vocational training will become increasingly important, as green activities in Denmark employ 10% more vocationally trained staff than the country-wide average (CONCITO, 2019[33]). This is consistent with experience in the EU that climate policies benefit technician jobs at the expense of manual workers (Marin and Vona, 2019[44]). The Green Business Forum has set up a collaboration on green skills to help ensure the availability of skills required for green initiatives. Several vocational education programmes have been overhauled to meet the demand for green skills, such as qualifications for environmental technologists, "energy-plumbers" and wind turbine operators (Cedefop, 2018[45]). However, there is no skill development strategy clearly related to the environmental and climate strategies and the need for green jobs is poorly assessed (Cedefop, 2018[46]). As most green activities in Denmark are concentrated in the energy sector, assessing the skills needed in other sectors could enahance their contribution to the transition (such as land management, and carbon capture and storage (CCS)).

The risk of emission leakage through international trade will have to be assessed and curbed to allow for an effective domestic strategy

Being a frontrunner towards carbon neutrality, with more ambitious targets than its trading partners, Denmark is exposed to the risk of losing international competitiveness if its firms have to bear the burden of higher energy costs. Production and emissions could shift to foreign countries as a result of increasing climate policy stringency. Emission leakage reduces the global effectiveness of climate policies and, through the threat of job and competitiveness losses, undermines political support.

Most empirical evidence based on past experience point at small emission leakage effects resulting from pricing emissions (Aldy and Pizer, 2015[47]; Sato and Dechezleprêtre, 2015[48]; Naegele and Zaklan, 2019[49]; Borghesi, Franco and Marin, 2019[50])). However, Denmark's ambitious reforms and the openness of its economy increase the concern of large emission leakage and call for policy intervention. Recent modelling results from the Danish Economic Councils (2021[29]) show that an uncompensated carbon tax would cause a 21% leakage rate, with differences across industries. The most affected industries are expected to be those more exposed to European and international competition, such as agriculture and the food industry, and those in which relocation is easier.

To minimise carbon leakage, Denmark should continue engaging at the EU level, for example supporting the strengthening of the EU ETS, and globally, encouraging the adoption of ambitious climate policies elsewhere. When designing unilateral climate measures, the government should take into account existing European policies, including measures to reduce carbon leakage. An ambitious Danish policy, such as more stringent standards or a carbon price floor in the industries covered by the EU ETS, would reduce domestic emissions and thus reduce demand for EU ETS allowances, spreading the excess elsewhere in Europe. This effect can be partially limited via the EU ETS market stability reserve, or by cancelling allowances proportional to reductions in electricity generation capacity (electricity production is about one third of Danish EU ETS emissions). A more broad-based but fiscally costly solution would be for the government to purchase and hold allowances equal to the reduction caused by domestic policies.

Denmark can choose among several unilateral instruments to reduce emission leakage, with different trade-offs (Table 2). Rebates on domestic emission pricing, delinked from emissions, can be designed to shield industries from competitiveness loss but calculating them based on vintage or historic criteria (e.g. past emissions or past output) provides unfair advantages to incumbent firms and those firms able to pass-through carbon costs to consumers (Branger and Quirion, 2013[51]). Rebates calculated on current production ("output-based rebates") provide a lower incentive to reduce output and thus to decarbonise (Sterner and Muller, 2007[52]). Such rebates provide stronger abatement incentives than preferential (lower) emission tax rates, as even under output-based rebates firms maintain a strong incentive to reduce emissions per unit produced. Unilateral border carbon adjustments seek to make the price of imported products reflect the costs they would have incurred had they been regulated under the destination market's greenhouse gas emission regime (Cosbey et al., 2012[53]). While border carbon adjustments could minimise carbon leakage and favour the mitigation of GHG emissions, they are not a good unilateral option, as they could evoke risk of "green protectionism", encountering retaliation from trade partners and possibly insurmountable legal hurdles within the EU and WTO rules (OECD, 2020[54]).

For Denmark, output-based rebates calculated on the basis of current production are likely to strike the best overall balance between protecting competitiveness and maintaining abatement incentives. Output-based rebates dull incentives to reduce output of emissions-intensive goods but this output reduction, concentrated in export-exposed sectors in a small open economy, would translate almost entirely into carbon leakage. A commitment to progressively phase-out compensation will strengthen the incentive to reduce production of emissions-intensive goods, while giving firms enough time to adjust.

A precise assessment of leakage risk, using clear criteria, is needed to calibrate rebates. The results from the Danish Economic Councils (2021[29]) improve significantly on earlier studies (Danish Economic Councils, 2019[37]), but cannot be used to calibrate product-specific compensations as they do not overcome common methodological shortcomings, including the sensitivity to the model parametrisation (Alexeeva-Talebi et al., 2012[55]) and insufficient industry disaggregation (Fowlie and Reguant, 2018[56]). The government should also commit to regularly update leakage rate estimates, which is necessary to take into account changes in trading partners' efforts to reduce emissions and international policy conditions.

The Danish Economic Councils also proposes an excise tax on final and intermediate goods in industries benefiting from rebates. Such a tax would be levied on domestic production and imports but, if allowed by WTO and EU regulation (Fischer and Fox, 2012[57]), not on exports. An excise tax on carbon-intensive goods, in addition to emission pricing and the output-based rebates, can restore mitigation incentives (Böhringer, Rosendahl and Storrøsten, 2017[58]; Neuhoff et al., 2016[59]). Its main disadvantage is that, because such a tax would be levied at the consumption stage, it requires keeping track of all the materials used in the value chain, including imported ones (Neuhoff et al., 2016[59]). This would pose further administrative costs and data requirements, especially in heterogeneous and finished goods.

Table 2. Policy options to reduce emission leakage: strengths and weaknesses of selected instruments

Instrument		Strengths	Weaknesses
Output-based rebates[1] (OBR)	Product-specific OBR	- Minimum risk of over/undercompensating	- Difficult to calibrate rates - Low incentive to replace GHG-intensive products
	Industry-specific OBR	- Reduced risk of over/undercompensating	- Moderately difficult to calibrate rates - Low incentive to reduce GHG-intensity at the industry level, but encourages more substitution of goods within the industry - Cannot be computed on volumes
	OBR + excise tax	As above plus: - Stronger incentives to replace GHG-intensive products - Helps to avoid overcompensation if OBR is homogeneous	- Very difficult to calibrate rates in non-homogeneous or downstream goods
	Flat OBR only for EITE industries[2]	- No need to calibrate rates	- High risk of over/undercompensating - Subsidy to consumption of emission-intensive goods can be very high (depending on rebate rates)
Rebates on historical performance (e.g. past emissions or "grandfathering"; past production or "benchmarking")		- Easy to calibrate rates - Do not reduce mitigation incentives	- Higher risk of under/overcompensating than OBR - Need corrections to avoid favouring incumbents
Preferential rates			- Substantially reduce abatement incentives - Very high administrative cost to calibrate the rates and apply them
Unilateral border carbon adjustments		- No risk of under/overcompensating firms	- Not WTO-compatible (especially export rebates) and EU-compatible - Raises risk of retaliation

1. Output-based rebates are rebates on the emission pricing proportional to the firm's share in domestic production. 2. Providing a flat rebate, not calibrated on leakage rates, only to Emission Intensive and Trade Exposed (EITE) industries.

Key policy instruments for a net-zero economy

Accelerating the pace of decarbonisation will require an ambitious package of new policy measures. This section argues that emission pricing should remain a keystone of climate policy. However, public resistance and adverse income distribution effects limit what can be done in the short term. Hence, flanking measures will continue to be needed to complement carbon pricing such as regulation, public investment, innovation incentives, and other institutional reforms.

The policy instruments that are specified in this section can be used for curbing either the supply or the demand for emission-intensive goods. Although policies affecting demand would have a smaller impact on direct emissions and domestic objectives, they will contribute to decrease the emission footprint of Denmark (Figure 6 above) and reduce the risk of carbon leakage. Leveraging the demand for emission-intensive goods, notably by providing sustainable alternatives, can contribute significantly to reaching the global objectives of the Paris agreement and offers synergies with other sustainable development goals such as food security and air quality (Allen et al., 2018[60]). Sectoral examples of such policies are presented in Chapter 3 in energy, transport and agriculture.

Aligning emission pricing to accelerate the transition

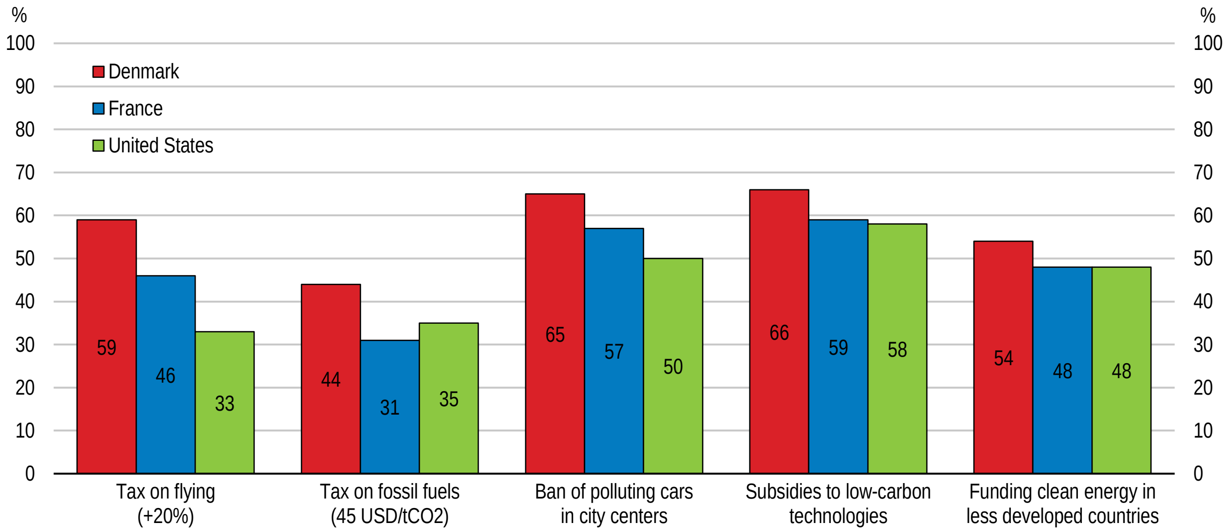
Denmark has been a pioneer in environmental taxation and first implemented carbon pricing in 1992. This carbon tax now amounts to DKK 178.5 per tonne of CO_2 (EUR 24/tCO_2) and is applied to sales of transport fuel and non-district heating. Other carbon pricing mechanisms include the excise taxes on fuels and EU ETS. The government intends to retain carbon pricing as a keystone of its decarbonisation strategy. The Energy and Industry Agreement of June 2020 between government and other parties contains a proposal for green tax reform. The first phase of the reform consists of an increased tax rate on fossil fuels used in industries' processes as soon as 2023, along with compensation measures. The second phase will consist of a uniform carbon tax. An expert group on carbon pricing convened by the government will publish the first part of its recommendations for uniform CO_2e taxation by the end of 2021, before a final report in 2022, so a decision on coverage and the future pathway of emission taxation cannot be expected before 2022 at the earliest.

Keeping carbon pricing as a key instrument of decarbonisation is welcome and all the more efficient if the strategy is clarified soon enough for actors to adjust. Putting a price on emissions discourages the production and consumption of goods with strong carbon content. It also provides a clear signal to investors about the interest of investing in low-carbon technologies and encourages innovations that reduce GHG emissions (OECD, 2021[61]). Experience has shown that a strong carbon price effectively reduces carbon emissions. After the United Kingdom added a Carbon Price Floor to EU ETS prices in the electricity sector in 2013, emissions decreased by 53% by 2018 and the share of coal in generation went from 37% to 2% (Hirst and Keep, 2018[62]; IEA, 2021[63]). Making the carbon price uniform across energy sources and sectors is particularly important: it makes the instrument technologically neutral and does not require supervision to determine or anticipate which technology or process is the most effective – it leaves firms to innovate and determine the best approach in their own context. Carbon pricing also provides revenue that can be used to reduce other taxes or compensate those worst affected, at least temporarily before success in reducing emissions erodes the tax base.

However, while emission pricing is the most cost-effective tool in theory (OECD, 2019[64]), it creates both winners and losers and there can be resistance to such policies, compromising the efforts to cut GHG emissions (OECD, 2019[65]). Even though the notion of a uniform emission tax is supported by a large part of the population (FH, 2020[66]), its concrete application can face opposition. A new international OECD survey of over 2 000 respondents in Denmark in several countries investigates the public acceptability of carbon pricing and other mitigation policies (Figure 7 and Box 3). Similar to other countries studied, a large majority in Denmark (81%) considers that climate change is an important problem and that it is their country's responsibility to fight it (77%). Danes are more prone to accept stringent measures, such as taxes and regulation on polluting goods or service and more than half of them are willing to pay up to USD 300 a year for climate action. However, the implementation of a USD 45/tCO_2 tax on fossil fuel is supported by only a minority of Danes (44%), while the population is rather supportive of a tax on flying or local ban for polluting cars.

Figure 7. Denmark's population is rather supportive of climate policies, except a fossil fuel tax

Proportion of people supporting the following measures, 2021 data



Source: Boone, L., Dechezleprêtre, A., Fabre, A., Kruse, T., Planterose, B., Sanchez-Chico, A., and Stantcheva, S. (forthcoming), Understanding public acceptability of climate change mitigation policies across OECD and non-OECD countries, OECD publishing, Paris.

StatLink https://stat.link/hacilx

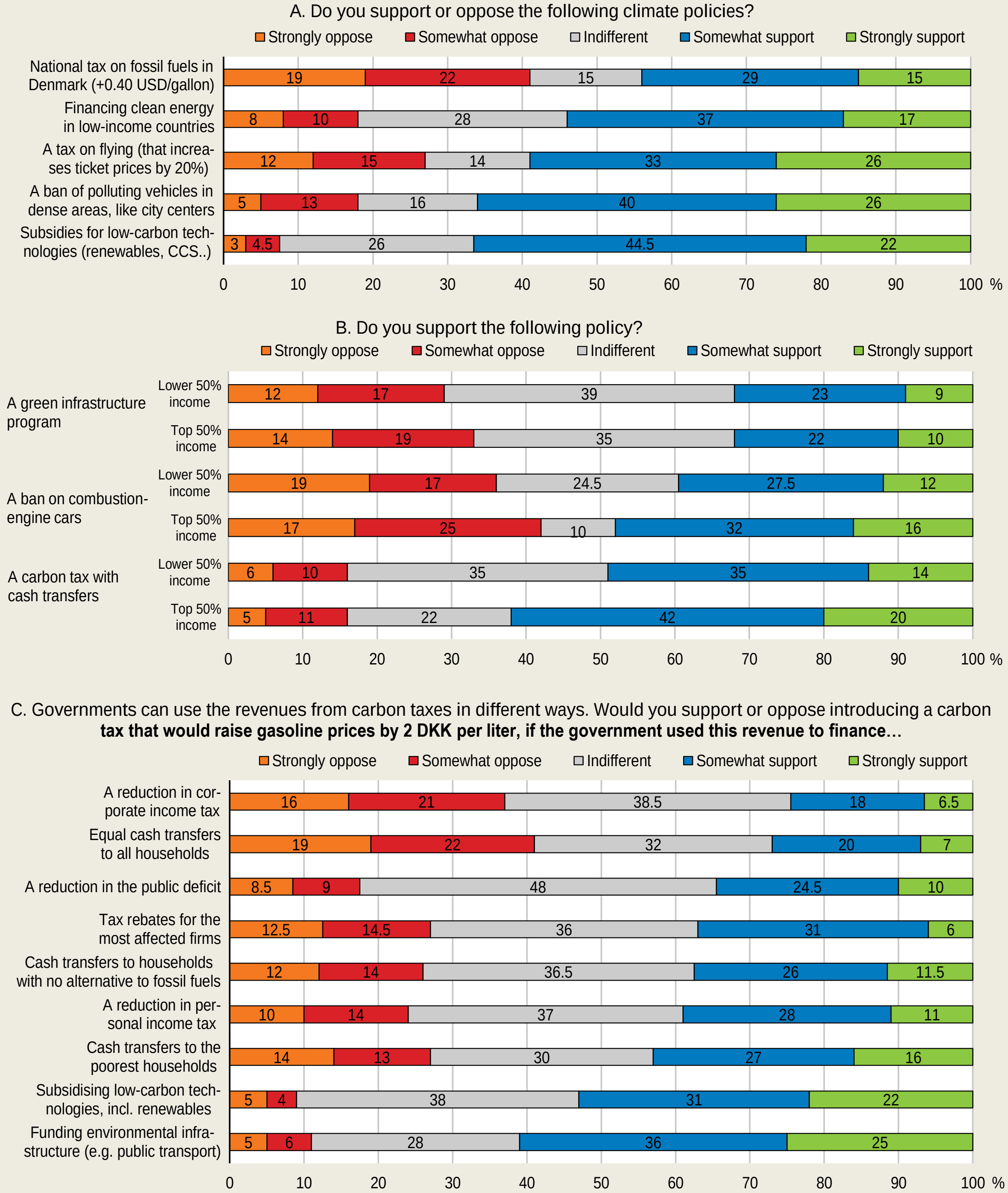
Box 3. Acceptability of climate change mitigation policy instruments in Denmark

The OECD led a survey on the acceptability of climate policies in Denmark, France and the United States. In Denmark, it was made on a sample of 2 011 respondents, representative along gender, age, income, region and rural/urban dimensions.

Survey results indicate that fewer Danes support a tax on fossil fuels than other climate policies presented, and this opposition varies little with the level of income. Other types of climate policies are generally better supported by high income groups. Support for carbon taxation is higher when revenue is used for targeted investment and support for green technologies. When Danish survey participants were provided with information on the local impacts of climate change and the effect of climate policies, they tended to be more supportive of climate policies, particularly a carbon tax with transfers.

Figure 8. Stated support to climate policies

Denmark, 2021 data



Source: Boone, L., Dechezleprêtre, A., Fabre, A., Kruse, T., Planterose, B., Sanchez-Chico, A., and Stantcheva, S. (forthcoming), Understanding public acceptability of climate change mitigation policies across OECD and non-OECD countries, OECD publishing, Paris.

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Box 4. Building acceptability for carbon pricing: the case of Switzerland

Switzerland's carbon intensity is the lowest in Europe and OECD countries due to low energy intensity and a large share of energy from hydro and nuclear power. In order to meet its annual carbon target, the country implemented in 2008 strong carbon pricing on heating fuels, which has been set at CHF 96/tCO_2 (about EUR 88/tCO_2) since 2018. In that year, 75% of CO_2 emissions from energy used were priced and 69% of them at a rate exceeding EUR 60/tCO_2 (OECD, 2019[64]).

This policy raised distributional and competitiveness concerns, which the federal government addressed through a transparent processes and accountability. Eligible firms can be exempted if they commit to undertake specific abatement measures or targets. About two-thirds of the tax revenue was redistributed through a lump-sum rebate of social security contributions of around EUR 80 per person and reimbursement of firms proportional to their wage bill. The remaining third of tax revenue is earmarked for retrofitting works and the development of sustainable heating fuels.

The level of the carbon tax depends on the country's climate performance and its success in meeting annual objectives, adding another incentive for abatement. In June 2021, a federal vote rejected increasing the maximum tax rate up to CHF 210/tCO_2 (EUR 194/tCO_2) and broadening the tax base.

Broad support for climate policies and emission pricing can be ensured in Denmark with transparent use of new tax revenue during the transition and education measures. A large share of Danes would oppose a carbon tax used for reducing corporate taxes, but the share of people opposed would fall by more than two-thirds if it was used to fund green technologies and infrastructure (Figure 8 above). Moreover, providing information on climate change and the effectiveness of policies substantially increases public support for these policies (Boone et al., forthcoming[67]).

Policy design is therefore crucial. Popular support could be boosted by involving stakeholders in the design of policy measures. Past experience in British Columbia showed that negotiations with businesses prior to the launch of the measure and strong political leadership can help public support to gain momentum over time (Harrison, 2013[68]; Murray and Rivers, 2015[69]). Clear communication and transparency on climate targets and the tools to reach them are also key. Transparent use of revenues from emission pricing can restrict government choices, but also contribute to a broad endorsement of tax measures. A study across 40 countries showed that a large majority of emission pricing revenues are subject to constraints on their use (Marten and van Dender, 2019[70]). Switzerland offers a good example of an effective carbon tax that gained public support through transparent revenue use and flexibility (Box 4 above).

While gaining public acceptance for strong measures can be a challenge, Denmark has scope to catch up with countries that implement emission pricing more effectively. The OECD indicator on Effective Carbon Rates show that many emissions are priced in Denmark at low levels by international comparison (Figure 9), particularly compared with other European countries. Neighbouring countries such as Germany (Box 5), the Netherlands (Box 6) and the United Kingdom have plans to implement carbon pricing more effectively. Indeed, countries with the most effective carbon pricing (in terms of level and coverage) have the lowest carbon intensity (OECD, 2021[61]) (Figure 9).

As noted, emission pricing needs to be uniform to be technologically neutral and provide incentives to all actors. Gases other than CO_2, such as methane (CH_4) and nitrous oxide (N_2O), are key for the future of climate (Allen et al., 2018[60]), and cuts in methane emissions are particularly important to meet medium-term international climate targets (UNEP - UN Environment Programme, 2021[71]). Uniform pricing of GHG emissions also means that negative emissions, and therefore CCS (from cogeneration plants, waste incineration, cement, etc), are supported through a subsidy at the same price. Such support would greatly accelerate the development of Danish CCS technologies, which could contribute up to a third of total abatement by 2030 according to the Danish Economic Councils (2021[29]). While there are no CCS projects in full-scale operation in Denmark as yet, pilot projects are underway and the technology is being deployed in other countries such as Norway and the United States. Delivery of CCS and other technological solutions to reduce emissions without reducing output could reduce the risk of emissions leakage through international trade. Subsidies for negative emissions would also pave the way for accelerated carbon capture in restored land in the longer term.

Box 5. Increasing emissions pricing in non-EU ETS sectors: the case of Germany

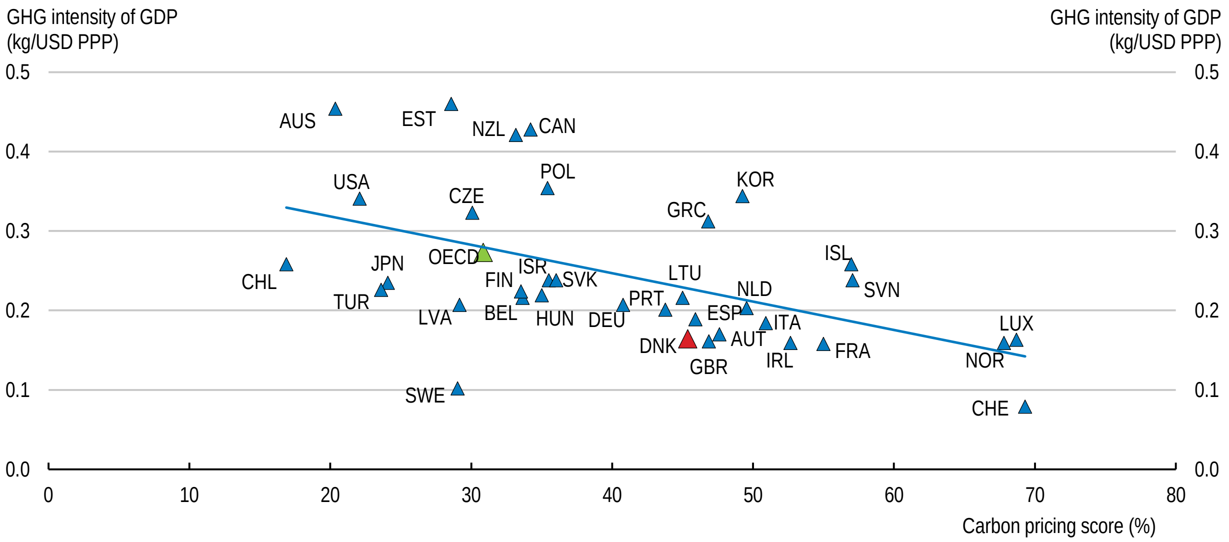
Germany's Climate Action Plan 2030 includes a carbon pricing system in transport and heating that became operational in January 2021. It operates in parallel to the EU ETS and covers the bulk of emissions not included in the EU ETS. During the initial phase (2021-2025) emissions allowances have a fixed price (equivalent to a tax), starting at EUR 25/tCO_2 in 2021 and increasing to EUR 55/tCO_2 in 2025. In 2026, emission permits will be auctioned with a price range of EUR 55 to 65/tCO_2, transitioning to a market price with an option for price corridors from 2027.

The government expects the system to generate revenue of EUR 40 billion from 2021 to 2024, which will be used to lower the renewables surcharge on electricity, for other relief measures and to support climate action. The government adopted a regulation in March 2021 to reduce leakage by providing compensation in emissions-intensive trade-exposed industries, under the proviso that companies undertake emission reduction measures and invest at least 50% (from 2023) to 80% (from 2025) of compensation payments from the previous year in economically-viable energy-efficiency measures. Compensation payments are scaled between 65% and 95% depending on emissions intensity, with subsidy levels set by benchmarking against the 10% best-performing plants in the sector.

Source: (Clean Energy Wire, 2020[72]; Clean Energy Wire, 2021[73])

Figure 9. Emission intensity is negatively correlated with coverage of carbon pricing

2018 data



Note: The GHG emissions include non-CO_2 emissions such as methane and nitrous oxyde but exclude LULUCF. The effective carbon rate is the sum of taxes and tradeable permits that put a price on carbon emissions. The carbon pricing score answers the question how close countries are to price carbon in line with carbon costs. In this chart, the carbon pricing score refers to the EUR 60 per tonne of CO_2.
Source: OECD, Environment database and Effective Carbon Rates (ECR).

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Box 6. Increasing emissions pricing in EU ETS sectors: the case of the Netherlands

The Netherlands has the ambition of reducing its GHG emissions by 49% by 2030 and 95% by 2050 relative to 1990, while reducing industry emissions by 59% by 2050. The country is heavily reliant on fossil fuels, with a concentration of emission-intensive industries. Energy, manufacturing and construction are responsible for 46% of GHG emissions. Like Denmark, it is a small country, open to international trade and embedded in the EU climate policy.

The first pillar of the Dutch strategy is a carbon levy on industrial emissions which applies if EU ETS prices fall under a certain level. In this case, emitters pay the differential to the floor price. Implemented in 2021 with a clear pathway, it is expected to reach a total of EUR 125 per tCO_2 in 2030 (including EU ETS prices) adding some certainty to sectors subject to variable prices under the EU ETS. In order to avoid carbon leakage and loss of competitiveness, the government has granted tax exemptions, in the form of regressive energy tax and emission allowances to energy-intensive industries. This erodes the carbon pricing signal and advantages large incumbents over small firms, which typically face much higher energy and carbon prices. Generous allocation of "dispensation rights" based on EU ETS benchmarks mean that less than 10% of emissions in key sectors are subject to the carbon levy in 2021, but long-term incentives are stronger as this ramps up to 45% by 2030.

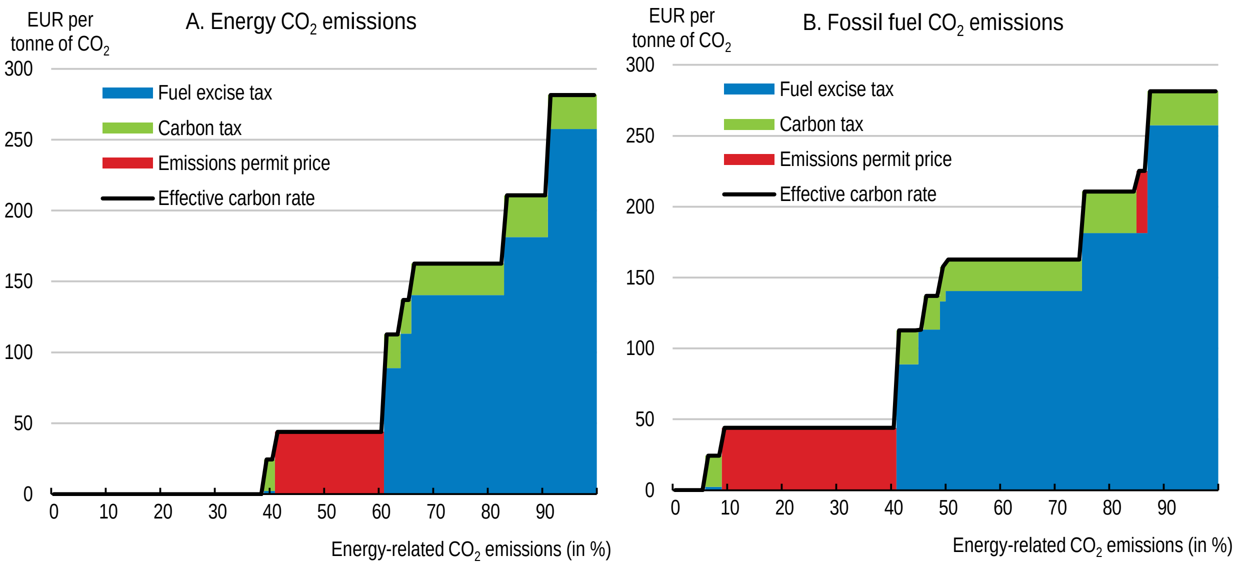
The second pillar of the strategy is support to new technology development for mitigation. Public tenders of the main support programme are allocated on the basis of least-cost abatement, to ensure an efficient distribution of subsidies. The development of markets for low-carbon hydrogen is a key issue, with the potential to partly replace natural gas and fuels in hard to abate sectors (such as international transport).

Source: (Anderson et al., 2021[74]), (IEA, 2020[75])

However, Denmark fails to apply a uniform carbon price, creating a pricing gap between sectors and industries (Figure 10). In 2021, 61% of carbon emissions from energy use are priced, but rates are relatively low and heterogeneous. Only 39% of carbon emissions from energy use were priced above EUR 60 per tonne of CO_2, which is a midpoint estimate of the carbon price in 2020 that would be consistent with the Paris Agreement, and a low-end estimate for 2030 (OECD, 2021[61]). Road transport produces most of the priced emissions, which have an average effective carbon price (through excise taxes and carbon pricing) of EUR 197.7 per tonne of CO_2. This is lower than in most neighbouring countries (OECD, 2019[64]) and excise taxes, not based on a fuel's carbon content, constitute a very large majority.

Eliminating the carbon pricing gap by pricing all emissions at a minimum of EUR 60/tonne would provide more consistent price signals and thus contribute to cost-effective abatement. Government revenue would be increased by 1.2 billion (almost DKK 9 billion), more than half from the pricing of agricultural emissions (Table 3). Without behavioural adjustment, this would have the biggest effect on energy emissions in industry, as well as on electricity production. Behavioural adjustment would reduce government revenue, with a smaller reduction in costs for firms as substitution to lower emissions technologies will generally carry costs. The tax burden for biomass, now poorly priced, would exceed 40% of the increased tax revenue (EUR 550 million) in the energy sector if it is priced according to its average life-cycle CO_2 emissions. Burning biomass emits CO_2, but where it is harvested from forests that are managed sustainably then regrowth offsets these emissions, with the precise environmental effects dependent on the type and source of biomass (Chapter 3). Implementing a minimum price on all GHG emissions would entail a significant cost for agriculture, responsible for both CO_2 and non-CO_2 emissions. The risk of leakage from the expansion of emission pricing to traded sectors should be addressed directly via temporary rebates (section 2.2.2).

Figure 10. Effective carbon rates are heterogeneous in Denmark in 2021



Note: Effective carbon rates are the sum of fuel excise, carbon taxes, and emissions permit prices. The figure shows the effective carbon rates across all energy-related (respectively fossil fuel) CO_2 emissions, sorted from lowest to highest rates by total emission percentile (some emissions where they account for less than 1% of total emissions therefore do not appear). Tax rates are those applicable on 1 April 2021, the emissions permit price is the average EU ETS price for the first half of 2021. Emissions are calculated based on energy use data for 2018. For panel A, emissions from the combustion of biomass and biofuels, are included, whereas these are excluded under the IPCC Guidelines for emissions from energy use and in panel B.
Source: OECD (work in progress), Taxing Energy Use 2022.

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Table 3. Budgetary impact of a uniform GHG emission price of EUR 60 per tCO_2e

	Proportion of emissions with increased pricing (per cent)	Average emission price increase for emissions with increased pricing (EUR/tCO_2)	Government revenue (million EUR)
All energy emissions	56	19	550
Energy emissions by sector :			
Agriculture and fishery	99	38	63
Electricity	98	16	116
Industry	66	19	254
Offroad transport	85	51	39
Commercial and residential	65	15	79
Road transport	0	0	0
Energy emissions from solid biomass	100	15	228
Non-energy emissions from agriculture	100	60	665

Note: The reference EU ETS price amounts to 43.96 EUR as the average futures daily close price in December 2020. Emissions from solid biomass are priced according to the 25% midpoint of the emission saving requirement for biomass from the EU 2018 Renewable Energy Directive, based on most of the gross emissions being offset by forest regrowth. Direct emissions from solid biomass are therefore here subject to a minimum EUR $15/tCO_2$ price. Energy emissions from municipal waste and biogas are not covered by the increase in pricing.
Source: OECD calculations from OECD data on effective carbon rate for energy emissions (year 2021) and on domestic emissions for non-energy emissions (year 2018)

EU ETS permit prices are more than twice as high as the Danish carbon tax, creating different price signals across sectors. Broadening the application of a minimum emission price of EUR 60/tonne would be roughly consistent with the prevailing EU ETS permit price in the third quarter of 2021, thus increasing efficiency through greater uniformity in prices across sectors and facilities within and outside the system. The EU ETS is now in its fourth phase, during which the reduction of free allocations and reinforcement of the market stability reserve should support a price on emissions that is broadly consistent with Denmark's climate ambitions. The proposal made by the European Commission in July 2021 to lower emission caps further and phase out free allowances for aviation confirms the intent to strengthen the EU ETS (Box 7). Cooperating to strengthen the EU ETS should be Denmark's priority, as the EU-wide system also alleviates the risk of leakage between neighbouring countries in key sectors.

Denmark is a strong advocate of reforming support to fossil fuels, and, since 2010, has been an active member of the informal group of countries "Friends of Fossil Fuel Subsidy Reform". Support to fossil fuels is a common tool worldwide to reduce costs for energy users, at the expense of climate targets, blurring price signals to the benefit of technologies with high emissions. Although Denmark's support measures are relatively weak, total public fossil fuel support amounted to DNK 1.6 billion in 2019, most of which (1.3 billion) consisted of a reduced diesel tax rate for buses, lorries and tractors (OECD, 2021[76]). This sectoral support can be shifted to more efficient types of subsidies that do not encourage the use of and investment in technologies that are detrimental to climate objectives.

As prices of goods and services will be affected, the distributional impacts of increased pricing should be anticipated and offset. Government revenues from carbon pricing might provide some fiscal space to implement such compensatory measures, including direct transfers or accompanying measures, even if only temporarily. These measures should not blur the carbon price signal by subsidising current emissions or long-term unprofitable activities. Targeted support to households rather than sectors can be viable options, as well as temporary measures helping with the transition, depending on the sector and populations affected. For instance, carbon pricing on energy products affects all households throughout the income distribution and households can be compensated on the basis of their income. By contrast, climate measures in agriculture might be detrimental to farmers, but also rural regions dependent on farming. Temporary accompanying measures and subsidies for carbon sequestration would support mitigation actions and avoid widespread bankruptcies of firms that would otherwise be profitable.

Redistributing proceeds and continuing to reduce electricity taxation can avoid negative distributional effects from emission pricing. Households with low incomes are likely to carry a disproportionate burden, because of the higher share of goods with a high climate impact (transport, heating, food) in their consumption or disposable income. Using the revenue to reduce electricity taxes (Chapter 3) and provide a climate bonus to every citizen would reverse the distributional outcome, with the possibility for households in the first two deciles to benefit overall (Kraka and Deloitte, 2020[77]).

Even with measures to attenuate the social impact of higher carbon prices, it may be difficult politically to raise carbon prices rapidly to the levels estimated by the Danish Economic Council as needed to meet the 2030 target levels (EUR 135 to 160 per tonne of CO_2 uniformly). Alternatively, gradual increases in emission pricing could be complemented by other instruments that are available in Denmark (Table 4) to form an inclusive and acceptable climate strategy.

Table 4. Impact assessment criteria and the Danish implementation of climate policy tools

Tool	Cost-efficiency	Administration costs/required information	Reallocation, fiscal and distributional concerns	Acceptability	Current implementation in Denmark
GHG emission tax.	High Encourages innovation Ensures reaching climate targets with minimum welfare cost.	Potentially high as pricing requires monitoring emissions.	Potential leakage related to the openness to international trade. Distributional concerns related to job loss and the share in lower-income households' consumption Increased fiscal revenue.	Low to moderate.	Carbon pricing on heating and fuels since 1992. Amounts for a small share of overall energy prices.
Cap-and-trade permit system.	High Encourages innovation. Ensures reaching climate targets with minimum welfare cost.	Potentially high as pricing requires monitoring emissions.	Potential leakage related to the openness to international trade. Distributional concerns related to job loss and the share in lower-income households' consumption. Increased fiscal revenue when permits are auctioned.	Moderate.	Denmark is in the EU ETS for energy generation, energy-intensive industry sectors, commercial aviation within the European Economic Area, nitrous oxide (N_2O) from production of nitric, adipic and glyoxylic acids and glyoxal, perfluorocarbons from the production of aluminium.
Environmental regulation.	Moderate, with small encouragement to innovation.	High, with strong monitoring required to identify the most effective actions.	Concerns of regressivity if compliance is costly. No fiscal revenue raised.	Moderate.	Current applied at the domestic and the EU level (e.g. fuel performance).
Subsidies for climate change mitigation actions.	High if subsidies cover carbon sequestration. Lower if they cover actions for carbon sequestration (rather than outcomes). Low to moderate when subsidies cover emissions cut, at the risk of over-compensating efforts of firms with high baseline emissions.	Potentially high if subsidies aim to directly support GHG mitigation. Lower where actions instead of outcomes are subsidised (at the expense of efficiency).	Concerns of regressivity (biggest firms and emitters are probably able to receive more) and fiscal balance.	High.	Subsidies are used in the agriculture and land-use sectors to support actions sequestrating carbon into soils and preventing nitrogen leakage in the environment.
Active technology-support policies (e.g. government infrastructure spending and incentives for R&D).	Low to moderate: fails to address directly the negative environment externality and can lead to low-cost abatement options being overlooked, but can increase market size and unleash benefits from learning-by-doing. High incentives to invest in research and development of new technologies.	Moderate.	Concerns of regressivity if new technology is only available to wealthier households (e.g. electric cars) and fiscal balance.	High.	Technology support is at the core of the Danish success in renewable energies and, more particularly wind energy.
Green financial policy, including updating policy to reflect systemic risks and strengthening disclosure requirements.	High to the extent that unpriced financial uncertainty is reduced and investors can act on preferences for green investment. Effectiveness constrained by lack of capacity to internalise climate externalities or influence all financial flows.	Potentially high to achieve broad monitoring and reporting of emissions, as well as linking emissions and physical climate exposures of firms back to credit providers.	Low by enabling investors to act on their own preferences. However, potential distributional and effectiveness concerns if restrictions and disclosure around emissions-intensive investments can be avoided by some sources of capital, such as private equity or foreign investors.	High.	Disclosure is enhanced by the EU taxonomy of environmentally sustainable economic activities. The Danish Central Bank undertook a first climate stress test to highlight transition risks in the banking sector in 2020. The Danish Government is in 2021 working towards issuing its first green bonds.

Source: Adapted from (D'Arcangelo et al., 2022[78]).

Box 7. Cutting EU emissions by 55%: an ambitious package from the European Commission

In July 2021, the European Commission (EC) launched a package of proposals for the EU to reduce its GHG emissions by at least 55% by 2030 compared to 1990 levels and reach climate neutrality by 2050. Although the 2030 target at the EU level is less stringent than the 70% target in Denmark, specific measures in the EU package, and more particularly in the transport sector imply faster action than expected so far. An EU-wide package, by defining a coordinated action between countries can also reduce the risk of leakage and facilitate the implementation of bold domestic strategies.

The Commission's plan includes stronger and more efficient carbon pricing and more stringent regulations, with a major focus on transport emissions. According to this proposal:

- The EU ETS will be strengthened through the broadening of its scope to emissions from the maritime sector, the decrease of the annual cap of emissions and phasing-out free allowances. Revenues from ETS will be used for climate and energy-related projects.
- Strengthened emission reduction targets will be assigned to member states in sectors currently not covered by the EU ETS through the Effort Sharing Regulation.
- Emissions from road transport and buildings will be priced from 2026 through the creation of a separate emission trading system based on fuel distribution in these sectors, leading to a 43% reduction of targeted emissions in 2030 relative to 2005.
- A Carbon Border Adjustment Mechanism will apply to a selection of carbon-intensive products. This will apply from 2026, after a three-year transition, and should be consistent with WTO rules.
- The Energy Taxation Directive will be updated to set minimum energy tax rates that encourage energy efficiency and sustainable fuels. Fuel tax exemptions and reductions will be phased out.
- New ambitious targets include carbon removal (including a plan for planting 3 billion trees), the share of renewable energy and energy efficiency (energy saving targets being nearly doubled).
- More stringent standards for fuel emissions will be applied in the transport sector to pave the way for zero-carbon standards from 2035. This will be accompanied by new requirements for member states to provide adequate electric charging and sustainable fuel provision points. More stringent requirements and easier access to sustainable fuels will also apply to the aviation and maritime sectors.
- A "Social Climate Fund" will support vulnerable households and micro-enterprises in the transition, partially financed by new revenue from the ETS in the transport and building sectors.

Most of these proposals from the European Commission will be discussed with the EU Parliament and the Council of the EU, under the ordinary legislative procedure. This entails that both institutions should agree on a text on the basis of the EC's proposal and the overall process could well exceed a year.

Source: (European Commission, 2021[79]), (European Commission, 2021[80])

Regulation can be a valuable part of the policy mix where cost-effective measures are targeted

Substantial mitigation benefits can be reaped through a clear and predictable regulatory environment (i.e. rules and norms making mitigation actions mandatory) that can directly reduce emissions, but also enhance the effect of pricing measures if well-tailored. The Danish Climate Council recommends a broad set of regulatory measures to reach the 70% target, including a ban on burning coal for electricity or heating by 2025, a ban on conventional-engine vehicles, low-carbon zones in cities, requirements for energy renovation or emissions standards for biogas plants (Danish Climate Council, 2020[81]). Regulation has proven effective to reduce emissions by restricting outright emissions-intensive activity and is mostly more supported by the public than pricing (Box 3 above). For instance, stringent regulation and monitoring of fertiliser use and soil management allowed for a 16% reduction of nitrous oxide emissions over two decades in Denmark, though the main objective was the reduction of nitrate in the environment (Section 3.3.).

However, there is a significant risk that the emissions cuts brought by standards and norms entail much larger socioeconomic compliance costs than under a pricing mechanism. Complying to standards and rules may entail substantive abatement costs and fail to target the cheapest emission cuts: for example, studies show that implementing fuel standards may be very expensive, at up to USD 2 900/tCO_2 (Gillingham and Stock, 2018[82]). A number of studies indicate that average costs per unit emission reduction via regulations are about double those for a price intervention (Goulder and Parry, 2008[83]). Regulation can also have negative distributive impacts where compliance costs are higher for vulnerable households and firms. These effects are unclear and poorly documented so far, requiring further research (OECD, 2021[84]). Nevertheless, where price responses are muted due to imperfect information or behavioural limitations, such as for household appliances, building insulation, land clearing and waste disposal, regulation can be a valuable part of an overall policy package (Freebairn, 2020[85]).

Regulation should be tailored and updated to facilitate mitigation actions with minimum costs. The first condition is to curb the potential regulatory barriers to mitigation actions. In France, heavy administrative constraints for solar power tenders might have hampered the development of this renewable energy (OECD, 2021[86]). In Denmark, as CCS is a key element of the government's climate strategy, legislation needs to clarify the safety conditions, liabilities in case of leakage, adapt and potentially remove barriers to storage (Danish Climate Council, 2020[30]), for instance by facilitating the storage from multiple sources in order to harness economies of scale when security is ensured. Regulation should also be reformed to facilitate the phasing out of households' boilers from the natural gas network (Danish Climate Council, 2020[81]). Making the legislative environment predictable is a second condition for effective actions. It also has to be regularly updated to exploit opportunities from cutting-edge technologies. In order to keep incentives for the lowest carbon-emitting technology and maintain tax revenues, Israel, for instance, updates the categories of vehicles that are eligible to lower taxation every two years according to a pre-agreed procedure (OECD, 2016[87]).

Private investment is key for meeting climate targets

Investment in low carbon technologies in all sectors is crucial for the transition to a net-zero economy and climate outcomes in the long term. Supporting public and private investment flows in such technologies could accelerate the transition and complement carbon pricing by providing alternatives to emission-intensive technologies. The recent action plan for the financial sector estimates that DKK 600 billion of investment will be needed by 2030 to cut emissions by 70% (Pedersen, 2020[88]), which is three times the capital of the government-supported Danish Green Investment Fund and just over 2% of GDP for the next decade. Illustrating the considerable uncertainty around investment needs, the Trade Union Confederation estimates that financing needs amount to the lower range of DKK 330-440 billion (2020[89]).

Green investment benefits climate stability, but also economic growth and employment. It can be a substantial lever for job creation, particularly in the energy sector (Moszoro, 2021[90]). In the context of unprecedented recovery packages following the COVID-19 crisis, green investment measures such as infrastructure or energy efficiency renovations are among the most effective to support economic growth and climate in high-income countries (Hepburn et al., 2020[91]). Accordingly, the Danish plan for recovery includes substantial support (DKK 3 900 million) for research and development of green technologies (OECD, 2021[92]). While there are upfront costs from reducing consumption to fund investment (Pisani-Ferry, 2021[24]), some funding can come from redirecting investment away from emissions-intensive activities and a large share of green investments will carry long-term welfare and economic benefits: for example, there are large upfront costs from investing in wind generation, but longer-term benefits from savings in fuel costs.

Government action is crucial to accelerate investment in low-carbon or net-zero technologies by supporting private sector investment, direct public investment or regulation. Denmark has led the way by substantially decreasing the cost of renewable energy, particularly offshore wind, through sustained support including feed-in tariffs, spatial planning and ambitious quantitative targets (Chapter 3). A clear and predictable GHG pricing system should make such investments profitable and bring forth liquidity. However, the *Green Tax Reform* announced by the Danish Government will take some time to be clarified and implemented, while today's investment choices will affect the country's capacity to cut GHG emissions by 2030 and 2050. Furthermore, even with significant and predictable carbon pricing, market imperfections might hamper investment. Development of a sound definition of what constitutes "green" investment would facilitate better disclosure and provide new market opportunities, while financial supervision should be updated to reflect systemic physical and transition risks associated with climate change (Section 2.3.5).

The Danish government supports private investment for climate using different tools, including research and development funding, streamlined planning processes, subsidies and ambitious national targets for renewables. Public finance institutions also use co-investment in equity funds to reduce the financial risks for institutional investors in green infrastructure (OECD, 2021[93]). The Green recovery plan, decided in 2020 for the country to overcome the COVID-19 crisis and built from the past agreements on the green transitions of road transportation, on stimulus and green recovery and from the Green tax reform, will constitute a third of the emission cuts from measures decided so far by the current government to reach the 70 percent target (The Danish Government, 2021[94]). It includes tax cuts and up to DKK 700 million grants for investment in green technologies (OECD, 2021[92]). In September 2020, a trans-partisan agreement between the Danish Government and other parties allocated DKK 6 billion to the Danish Green Investment Fund, an independent state loan fund that offers risk capital to promote a green transition. It has the ambition to develop technologies and ecosystems for green innovation and to scale them up in five areas: food and agriculture, energy and utilities, building and infrastructure, materials and resources, transport and mobility. The government also encourages green financial investment and requirements through partnerships with the private sector and investments from its pension funds (see below).

Public support for investment needs to be well targeted to sectors with untapped climate potential and address a specific market imperfection. As technologies become more profitable for private actors, as for much renewable energy, uncertainty decreases and public support should be phased-out gradually, without compromising continued development. Good monitoring of green investment projects and their costs is therefore key. Moreover, when possible, and when the information is available, the abatement cost of projects (the cost of one unit of abated GHG emission) should be one of the criteria used to prioritise. This is the approach already taken by the government when comparing different climate change mitigation measures at the national level (Danish Ministry of Climate, 2020[9]). On the contrary, in Norway, the lack of consideration for economic efficiency throughout the process for transport infrastructure often leads to sub-optimal choices with high early costs and low benefit-cost ratios (OECD, 2017[95]).

Well-targeted public investment needs to play a role

Public investment, possibly paired with the private sector, will be a cost-effective option in some cases, even alongside other mitigation policies. Public money can be spent to cover other externalities that are not included in carbon pricing. This is the case for instance for land restoration that benefits a large number of environmental outcomes (biodiversity, water regulation), or natural monopoly public transport infrastructure that facilitates overall mobility. The choice of one technology over another depends not only on its relative cost, but also on its physical accessibility (for example, the access to a charging station or to the grid), which private markets cannot always provide because of high fixed costs.

The quality of infrastructure is overall high in Denmark, but more public investment is needed to expand electricity networks and access to electrified rail and heating. The definition of a clear strategy for infrastructure in June 2021 for a 2035 horizon for DKK 160 billion (including for a total decarbonisation of train traffic by 2035) also has the benefit of providing some certainty to firms and consumers willing to invest in certain sectors (e.g. Transport or energy). The overall quality of infrastructure is judged to be in the dozen best among OECD countries, but below the OECD average for railroad infrastructure (World Economic Forum, 2018[96]). There is low efficiency of train services and a low share of electrified rail, with delays in plans for electrification (European Commission, 2020[97]). The electricity network will need to expand to accommodate plans to further increase renewables, while investment is also needed to convert district heat generation from biomass combustion to electric heat pumps (Chapter 3). The infrastructure agreement between the government and a broad majority of the parliament released in June 2021 includes more than DKK 86 billion for public transport and DKK 3 billion for new bicycle infrastructure by 2035. Infrastructure planning processes should be improved to prioritise projects according to cost–benefit analysis, particularly at municipal level where there are no long-term strategic plans (Chapter 1; (Vammalle and Bambalaite, 2021[98])).

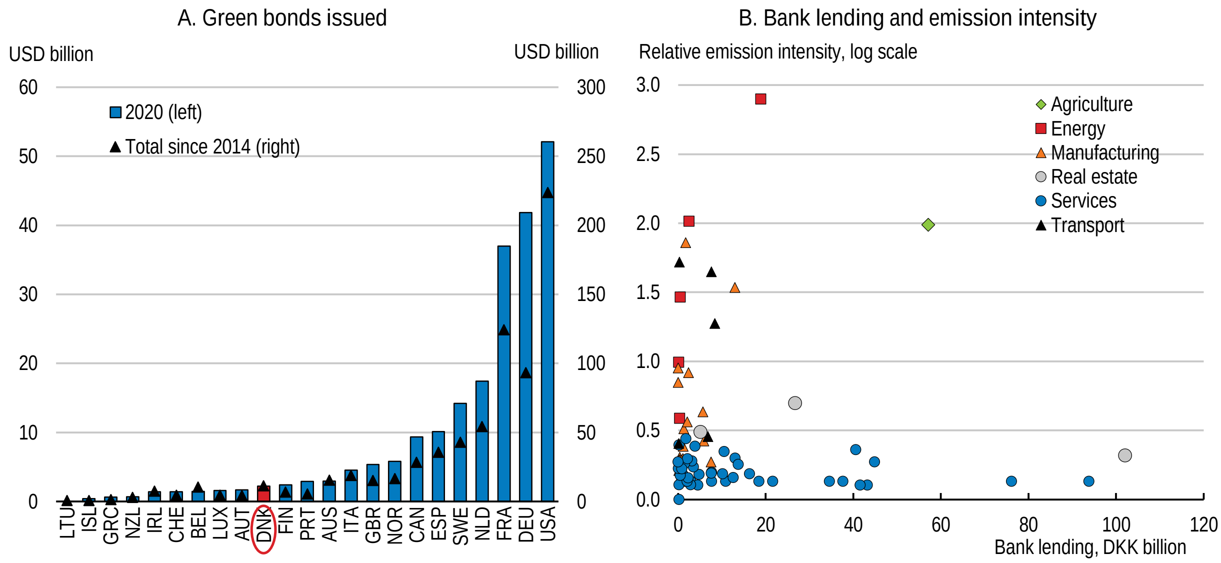
Integration of a significant emission price in public projects has the capacity to enhance investments for climate change mitigation. It should be included in cost-benefit assessments for public projects, ensuring they do not undermine climate objectives and allowing public authorities to choose between different options. Similarly, emission pricing at a level that is aligned with Danish climate ambitions should be a component of green procurement processes, as DKK 300 million is spent each year for public procurement. Central government nudges local governments for greener processes through guidance and events, but it can go further, for instance by providing a simple carbon footprint calculator for different projects, or by including climate requirements for green procurement in local climate strategies. Such policies are relatively easy to implement and would send a clear signal to private investors.

The green transition has important implications for the finance sector

More information on a credible, consistent and comparable basis is necessary for financial institutions and investors to assess climate-related risks. Financial frictions and asymmetric information in financial markets reduce financial institutions' ability to correctly price climate risks in investments, limiting opportunities for private low-carbon investments (Battiston et al., 2017[99]). Policies that strengthen the informational tools of banks and institutional investors are critical, such as Environmental, Social and corporate Governance (ESG) indicators for financial assets and the EU's new taxonomy of environmentally sustainable economic activities. Mandatory disclosure for listed companies and simplified labelling of the climate exposure of financial products, consistent with the EU taxonomy, would help retail investors in particular to make better-informed choices. This information facilitates the flow of capital towards investments consistent with an orderly transition to a low-emissions economy, while better enabling management of climate-related financial stability risks by investors, banks and regulators (Bailey, 2021[100]). Better disclosure will enhance benefits from the plans of Danish pension funds to invest EUR 46 billion in clean energy and climate between 2020 and 2030. Since 2019, EUR 8 billion has already been invested, exceeding expectations. Specific training may be needed in banking, coupled with incentives to overcome short-term biases that impede the reaction to long-term climate risks.

The central bank and financial regulators need to take climate-related risks into account in their operations. Updating financial regulation to reflect the systemic risks associated with climate change can reduce (unpriced) financial uncertainty and foster decarbonisation. Climate stress testing is important to gauge the systemic importance of climate-related risks, though methodological limitations remain important: financial institutions have difficulty assessing market risk over such a long time horizon, the mechanisms for transmitting climate shocks to the real and financial economy are not yet well understood and the exercise remains sensitive to the choice of different scenarios (OECD, 2021 forthcoming France survey). As an alternative to a fully-developed climate stress test, the Danish central bank investigated a number of sensitivities, finding that Danish banks are well-equipped to handle risks from the transition to a low-emissions economy, but that a drastic transition over a short time frame could result in a capital shortfall (Danmarks Nationalbank, 2020[101]), with greatest exposures in key industries of agriculture, energy, manufacturing and transport (Figure 11, Panel A). Stress testing by the Banque de France showed that insurance companies are particularly exposed to physical risks: the cost of claims could rise by a factor of 5 to 6 in certain French departments between 2020 and 2050. Development of new, scenario-based modelling approaches is necessary to better understand climate-related risks (Svartzman et al., 2020[102]). Central banks cannot entirely substitute for other policies that are lacking. For example, the Danish central bank (2021[103]) has stated that a specific and credible carbon tax will support financial stability by preventing lock-in of unprofitable investments, and by reducing the uncertainty surrounding the transition and thus supporting the pricing of climate-related risks in financial markets.

Figure 11. Green bonds are still developing, while lending to high-emissions activities varies considerably by industry



Note: In Panel B, each dot represents one sub-industry within the named industry groupings.
Source: Danmarks Nationalbank (2020), "A Gradual Green Transition Supports Financial Stability", Analysis - Climate, No. 21; Climate Bonds Initiative database.

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The Danish government is working towards joining nineteen other countries by issuing its first green bonds. Several models are being considered, including a unique proposal for the issue of separable conventional bonds and green certificates. The bonds and certificates would be sold together at green auctions, but could then be traded separately (Danmarks Nationalbank, 2021[104]). The aim is to support liquidity in the conventional bond market (Bongaerts and Schoenmaker, 2020[105]), but the enduring value of the green certificates is unclear, as these would have no financial commitments (coupons or redemption value) attached. If this adversely affected demand for green bonds at auction it would undermine an important mechanism to fund green investments. An alternative being pursued by Germany is a “twin bond” first issued in September 2020, whereby green bonds can be freely swapped with a conventional bond with the same maturity and coupon. This underpins liquidity while still allowing green bonds to be sold at a premium on the secondary market. The best model for Denmark needs to be chosen after due consultation with primary dealers and investors to establish demand and preferred design features. Improving the credibility of green investment labelling will be important to increase demand for green bonds, including those issued privately, which are a small but growing source of finance (Figure 11 above, Panel B). The European green bond standard proposed in July 2021 is an important tool to improve information disclosure, verification and standardisation.

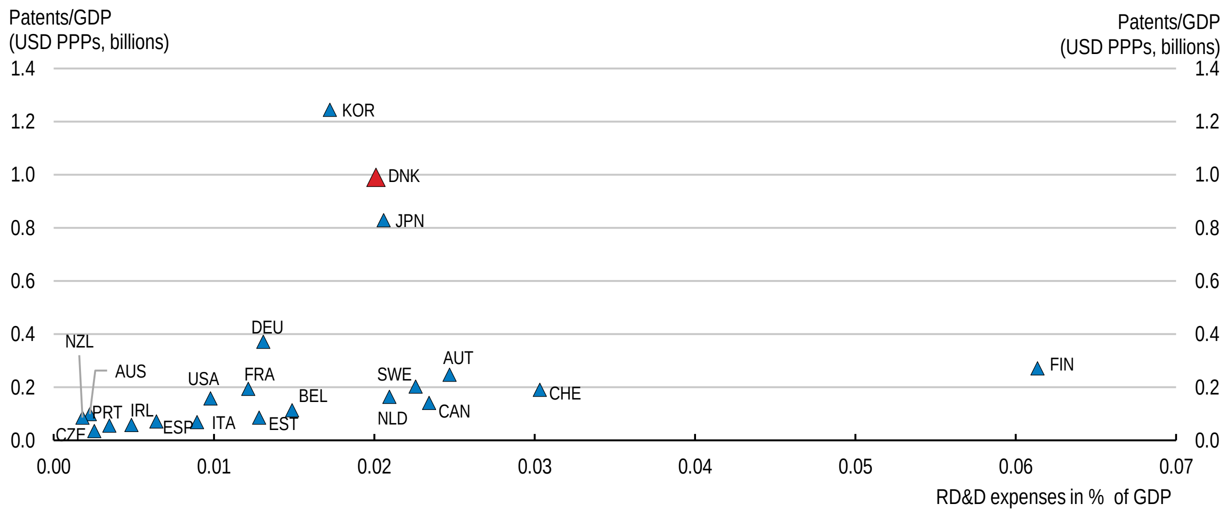
Research and development plays a major role in the Danish climate mitigation strategy

The current climate programme relies on technological advances for two thirds of abatement by 2030. This calls for measures in areas with acknowledged mitigation impacts, but also highlights the need for a significant contribution from innovation, research and development (Danish Climate Council, 2021[21]). Investment in research and development can also benefit employment and job creation, more effectively than direct public investment if this research is done in higher education and the private sector (Moszoro, 2021[90]). The green research strategy is focused on four missions: 1) carbon capture, utilisation and storage, 2) power-to-X (Chapter 3), 3) climate and eco-friendly agriculture and food production, 4) recycling and reduction of plastic waste (Danish Ministry of Climate, 2020[9]).

Research and development for climate and the environment is particularly effective in Denmark. Experience shows that it is a key factor for successful climate change mitigation strategies: economies with a higher share of R&D spending per unit of GDP are also the most innovative for climate (Figure 12). The share of GDP allocated to research and development is relatively high in Denmark (3%), and 5% of non-business research and development (accounting for 35% of total R&D) is specifically allocated to energy and the environment. Denmark ranks particularly high among European countries in terms of environmentally-related patents, which accounted for 23% of new patents from Denmark in 2018. Moreover, Denmark ranks particularly high in international comparisons of the number of climate-related patents per unit of GDP (Figure 12). As a small country, Denmark's access to new technology will also depend crucially on innovation in other countries, heightening the important of international collaboration on research that can drive emission reductions.

Figure 12. High R&D expenses are correlated with many environmentally-related patents

Climate change mitigation technology patents relative to RD&D expenses



Note: RD&D expenses cover the expenses on energy efficiency (group 1) and renewable energy sources (group 3). Both RD&D expenses and GDP are measured in 2019 USD PPP for 2019. The number of patents is the 2015-2018 average of climate change mitigation technologies related to energy generation, transmission or distribution (family size two and greater), weighted by the 2015-2018 average of the GDP expressed in 2015 USD PPPs billions.

Source: OECD, Environment (Innovation in environment-related technologies - Technology Development) database; OECD, National Accounts database; and IEA, Energy (Energy Technology R&D - RD&D Budget) database.

StatLink https://stat.link/1dnahz

Strong support for R&D should be broadened to sectors other than energy. Innovation for climate and the environment has been focused so far on the renewable energy sector (61% of environmentally-related patents in 2018), mostly in wind energy. In contrast, a smaller share of environmentally-related patents apply to production processes (15%) or buildings (8%). Carbon capture and sequestration only accounts for 0.5% of innovations in Denmark (against 0.74% in all OECD countries). The current plan for climate research, opening areas of research outside the energy sector, is therefore welcome, all the more because it provides a strong focus on areas with high potential for climate change mitigation.

Enhancing good governance to improve coordination and monitoring

Ensuring good governance of institutions enhances the chances of success of any policy plan, particularly in the case of a climate strategy, where local action should align with national and international objectives. The institutions of Denmark and the fact that the Climate Law builds on political agreements and shared objectives facilitate inter-ministerial coordination. Ambition in non-energy sectors and policy alignment can be further improved by the formation of a ministry of climate or another governmental entity dedicated to climate that is independent from the energy sector, clarifying the crucial role of other sectors like transport or agriculture as the energy sector decarbonises. This cross-sectoral entity might be better suited to address competing priorities in other ministries and sectors.

Local governments have a strong role to play in the transition to carbon neutrality, but it is not their specific responsibility in Denmark. Climate action is covered at the national level and the central government can provide municipalities with wind turbines or biogas plants to reduce their carbon footprints. However, municipalities have some levers for action. They hold relatively high autonomy, with their expenses accounting for 35% of Danish GDP and 28% of public investment (OECD, 2016[106]). Danish municipalities hold some responsibilities regarding crucial tools for climate change mitigation, such as transport, land use planning, waste and district heating. The city of Copenhagen has a plan to reach climate neutrality by 2025 through measures encompassing mobility, energy consumption, and energy production. Alignment of actions between neighbouring municipalities should be enhanced and facilitated as collective action can be more effective, for example in regulating land use or to reduce tensions between a city and peripheral areas transport planning. This can be done by providing independent funding to intermediate authorities (such as regions or metropolitan areas) or building specific projects (OECD, 2009[107]).

Denmark has built a strong framework to monitor the implementation and effectiveness of its climate policy. Regular impact assessment both *ex-ante* and *ex-post* is crucial in this strategy, where success relies on uncertain technologies. Policy tools will therefore need to be regularly updated and adjusted according to their results and the evolution of national GHG emissions. *Ex-ante* monitoring is used to identify and calibrate policy tools, for example modelling work by the Danish Economic Councils. *Ex-post* assessment provides information on the relative effectiveness of different tools and informs adjustments. As an example, policies aiming at accelerating the roll-out of electric cars, which are among the most expensive measures, should be carefully monitored. The recent Climate Law, which includes the requirement of a yearly climate programme and the revision of targets every five years, paves the way for strong and regular monitoring. It also builds on sound impact assessments by independent advisory bodies such as the Danish Economic Councils or the Danish Climate Council. The development of a new macroeconomic model, GreenReform, will support this approach by providing more disaggregated and dynamic information on the environmental and climate effects of economic policies, as well as the socioeconomic effects of environmental, energy and climate policies. The GreenReform model consists of a main dynamic computable general equilibrium model fully integrated with sub-models covering key sectors including energy, transportation, agriculture and waste management. The project group developing the model is comprised of 15-20 people, supported by a government grant of DKK 14.3 million and DKK 6.55 million in funding from other sources. However, how this model will be used in policy is still unclear and implementation might take some time.

Main findings	Recommendations (key recommendations in bold)
Climate change is likely to have a negative impact on Denmark, and it is particularly exposed to long-term impacts from sea level rise. Denmark's adaptation strategy was launched in 2008 and has not been recently updated.	Update the adaptation strategy to incorporate the latest climate science and risk assessment.
Denmark's ambitious domestic climate targets will be challenging to achieve, making complementary structural reforms important. The measures decided so far fall short of reducing GHG emissions by 70% by 2030, with most abatement reliant on unclear measures and uncertain technologies.	Continue the implementation of a well-balanced policy mix of pricing, regulatory measures, investment and structural reforms to cut domestic emissions.
The scope and level of carbon pricing is not aligned with climate targets. Its evolution is still to be defined and will not be implemented before 2023, delaying action and thus increasing costs to meet targets.	Clarify and communicate the climate strategy at an early stage, so as to reduce policy uncertainty and encourage firms and households to prepare for upcoming changes. Make emission pricing outside the EU Emissions Trading System more uniform by implementing a minimum price that reflects the evolution of prices in the EU Emissions Trading System.
Denmark's business-friendly regulatory settings, labour market flexibility and reskilling policies will help unleash private investment and reallocation needed for the transition to net zero emissions.	Continue to undertake regulatory reform to facilitate market entry, competition and skill formation, such as for carbon capture and storage, passenger rail and district heating.
Acceptability of climate mitigation policies can be hindered by fear of adverse distributional consequences. Distributional consequences from emission pricing can be offset by reducing high energy taxes.	Offset unwanted consequences of climate policy in a transparent manner via reduced taxation of renewable energy, means-tested transfers, support for green investment and support to labour-market reallocation.
Investment in green technologies will be critical to meet abatement goals and needs to be broadened to sectors outside energy to remain cost-effective.	Optimise supports to green innovation through technology-neutral subsidies that prioritise areas with high potential for climate change mitigation at lowest cost.
Physical and transition risks from climate change could threaten financial stability but information on exposures and transmission mechanisms are lacking.	Strengthen disclosure requirements for listed companies based on the EU taxonomy of environmentally sustainable economic activities. Update monetary and macroprudential policy to reflect unpriced systemic risks associated with climate change.
The Danish government is working towards issuing green bonds. One proposal is to issue separable conventional bonds and green certificates as a means to underpin liquidity in the bond market.	Consult further with dealers and investors on the best model for green bonds, including the possibility of allowing swaps with equivalent conventional bonds.
The threat of carbon leakage can hinder action in some sectors and reduce policy effectiveness. Any compensation for affected firms should be delinked from their emissions to maintain incentives to reduce emissions per unit of production.	Provide time-limited rebates of emission pricing based on production levels in emissions-intensive trade-exposed industries, informed by an institutionalised assessment of leakage rates. A second-best solution could be to provide time-limited subsidies for investment in abatement technologies, such as carbon capture and storage. Commit to the progressive phase-out of rebates and offset them with a consumption tax where administratively feasible. Establish a formal mechanism to review domestic leakage policies if an EU-wide border carbon adjustment is implemented.
Evidence on the socio-economic impact of climate policies lacks detail. Economic models have been recently developed to assess future policies, but their use in the policy process is still unclear.	Continue to accelerate the development of impact assessment modelling, including social and spatial dimensions, and optimise its role in decision making while providing greater transparency on likely costs and their distribution.
The power of local governments is high but there is little room for coordination between them.	Allow for devolution for local climate action at the metropolitan or regional level with specific responsibilities and consistent funding sources allocated to local governments and intermediate authorities.

Denmark's energy, transport and agriculture sectors are responsible for a large share of the country's greenhouse gas emissions. Fast decarbonisation of these sectors will require radical transformations of business plans, large public and private investments, and a reskilling of the workforce. In the energy sector (electricity and district heating), past progress made to ramp up clean technologies provides a good blueprint to achieve further decarbonisation, but the focus will need to be put soon on lowering reliance on woody biomass. In the transport sector, emissions have continued to increase despite the shift to more fuel-efficient vehicles, highlighting the need for more transformative policies to expand alternatives to individual car uses. In agriculture, little has been done so far to cut emissions, especially from livestock. The sector is subject to leakage risks, but nonetheless should be encouraged to transform its practices. Helping farmers to monitor their GHG emissions should be combined with more stringent regulation.

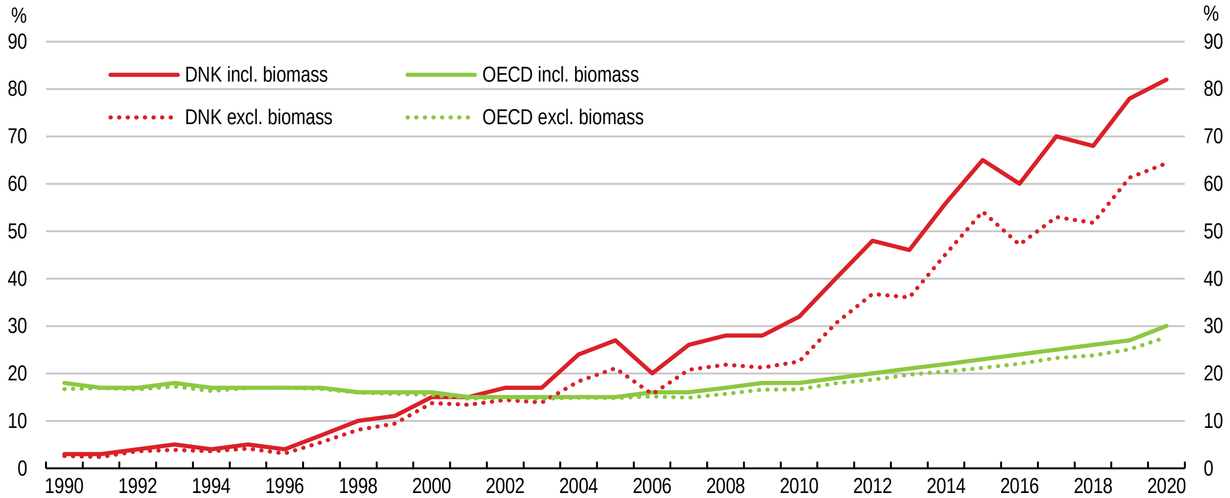
This chapter sets out priorities in three sectors that are responsible for a large share of Denmark's emissions of greenhouse gases: energy (19% of 2019 emissions, excluding emissions from land use, land use change and forestry (LULUCF)), transport (29%) and agriculture (24%). Other important sectors are manufacturing and construction (8%), industrial processes and product use (4%), waste (3%) and residential and other (11%) (OECD, 2022[108]). In all these sectors, achieving rapid decarbonisation will require transformative policies, both in the short and medium terms.

Maintaining progress in the energy sector

Denmark has made considerable progress in reducing GHG emissions from electricity generation (Figure 13). While coal was the main source of energy in the 1990s, renewable sources now account for over 80% of electricity generation. The 57% wind share of total electricity generation is the highest of any country (IEA, 2021[109]). Renewable power is expected to account for 97% of electricity generation in 2030, leaving heat generation as the main source of sectoral emissions. Production process emissions from oil and gas exploration and production in the North Sea also contribute. In December 2020, parliament brought an immediate end to new oil and gas exploration as part of a plan to phase out production by 2050.

Figure 13. Renewable generation has grown fast

Share of renewable sources in electricity generation



Source: IEA, World Energy Balances and World Energy Statistics databases.

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Policy measures have contributed to the falling cost of renewables

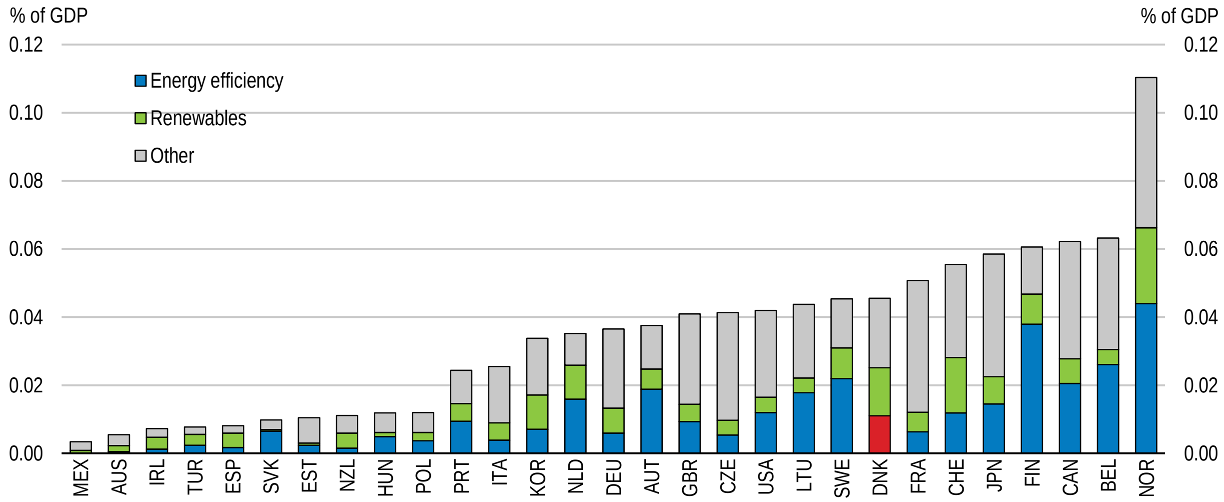
Support for renewable energy generation through a complementary combination of research and development funding, streamlined planning processes, subsidies and national targets has driven down costs through learning-by-doing and economies of scale. This is particularly the case in offshore wind where it took decades of sustained support to bring down high installation costs (Box 8). Key initiatives to incentivise deployment included first feed-in-tariffs, complemented by the introduction of a carbon tax in 1992, then an environmental premium added to the market price and finally tenders for new renewable capacity. This approach has seen risk gradually shift from the government and electricity consumers to investors. A range of renewable technologies are now competitive with fossil fuel generation (Figure 15), particularly after taking into account a mid-range estimate of the cost of carbon consistent with the Paris Agreement (OECD, 2021[61]). While sunk capital reduces the economic cost of existing plant, renewable energy facilities are still set to be installed without subsidies in the decade ahead (Energinet, 2019[110]). Denmark's lead in wind energy has contributed to the development of a sophisticated export industry. The manufacture of wind turbines embodies a continuous accumulation of sophisticated knowledge, with the technological advantage of a few leading companies growing over time (Garsous and Worack, 2021[111]).

Support for energy research, development and deployment is currently unexceptional by international comparison (Figure 14) and further increases are likely to be needed given the scale of ambition on electrification, carbon capture and storage, and power-to-X (conversion of electricity to sustainable fuels such as hydrogen, methane or ammonia that can be used in other sectors). Major energy-related research and development programmes include the Energy Technology Development and Demonstration Programme (EUDP), the Innovation Fund and ELForsk, which mainly provide support to projects implemented in public-private partnerships. Support stepped up in 2020 and is tilted towards new and emerging technologies: for example, of DKK 543 million in new EUDP grants in the second half of 2021, more than DKK 200 million is for carbon capture and storage as well as power-to-X projects.

The intermittence of weather-dependent variable renewable electricity has been managed via effective grid management, gas peaking plants and baseload biomass combined heat and power, as well as interconnection with the Nordic electricity market and Germany. Interconnection with the hydroelectricity-rich Swedish and Norwegian systems has been a key factor in the Danish power system remaining one of the most reliable in Europe as renewable penetration increased, underlining the importance of further increasing interconnector capacity and aligning renewable policies in the Nordic region (IEA, 2017[112]). There have also been steps taken to ensure system-friendly deployment of renewables through optimising locations, generation profiles and integrated resource planning. There are nevertheless some costs that tend to increase with penetration of variable renewable electricity related to balancing and the time profile of production (NEA, 2019[113]). Denmark-specific estimates of these costs are highly uncertain, but central estimates indicate they are manageable relative to the overall advantage over fossil fuel generation (Figure 15). System-wide grid costs may also increase with renewable deployment but these are highly location- and context-specific. For example, concentrated wind development far from demand increases grid costs, while solar power close to consumers reduces costs.

Figure 14. Public support for energy research, development and deployment is moderately high

Government expenditure on R&D, 2020 or latest year available



Note: "Other" includes spending on fossil fuels, nuclear, hydrogen and fuel cells, other power and storage technologies, other cross-cutting technologies/research, and unallocated spending.
Source: IEA, Energy Technology RD&D Budgets database.

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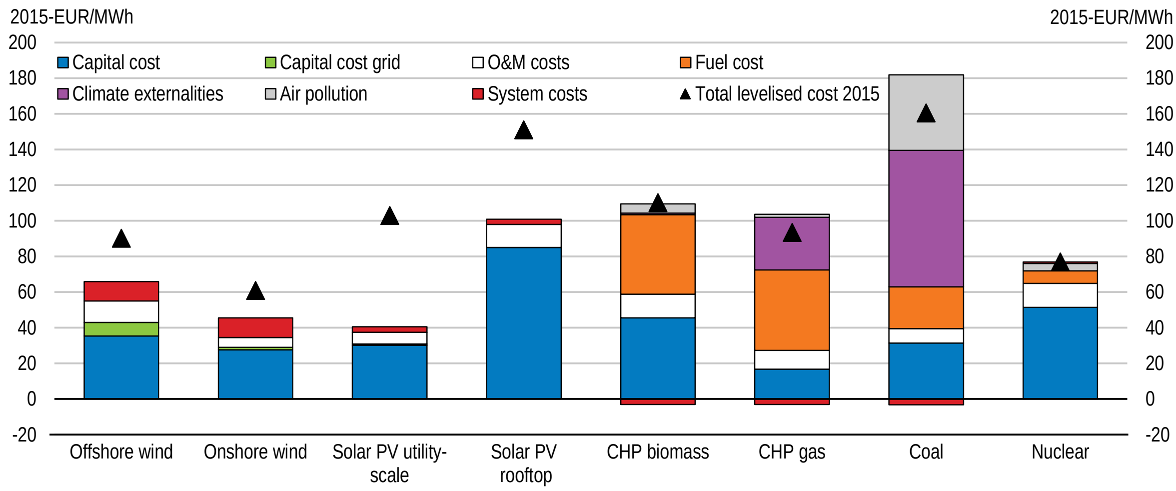
Figure 15. Wind and solar are now the cheapest source of electricity after including environmental costs

Levelised cost of electricity generation, 2020 and 2015



Note: Levelised cost is the average net present cost of producing one unit of electricity, including capital, operating and maintenance (O&M) and environmental costs. Coal and nuclear are based on international estimates from the IEA, other technologies are Denmark-specific. Costs extend from the start of construction preparation to the end of dismantling, including waste management. CHP biomass is the cheapest of four biomass options. For nuclear, air pollution costs represent an estimate of the social cost of radioactivity. System cost estimates include balancing and profile costs based on the Danish Energy Agency Levelized Cost of Electricity manual, but have significant uncertainty and will vary with the generation mix and transmission network. The carbon price schedule is based on mid-range cost of carbon estimates from OECD (2021[61]), with linear interpolation up to 2030 and real price growth of 0.6% thereafter. The discount rate used is 7%, the central rate in IEA projections. A higher discount rate increases the cost of all technologies with the greatest increase for long-lived assets with low fuel costs. The ranking of technologies is maintained under sensitivity analysis of the discount rate, except that nuclear becomes more expensive than gas-fired CHP, and rooftop PV more expensive than biomass CHP at a 10% discount rate, while rooftop PV becomes cheaper than gas-fired CHP at a 3% rate.
Source: OECD estimates using Danish Energy Agency (2020), Levelized Cost of Energy Calculator; IEA and NEA (2020), Projected Costs of Generating Electricity; and OECD, Effective Carbon Rates database.

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Challenges from security of supply will increase over the next decade as wind penetration continues to grow and baseload biomass generation is reduced. Outages are projected to remain at or below an average of 30 minutes per year until 2027, which is lower than currently in most western European countries, but step up to a more typical 65 minutes per year by 2030 (Energinet, 2021[114]). Strategies employed to date will need to be ramped up, along with increasing interconnector capacity and maximising flexibility of the non-renewable fleet, for example through gas peaking plants. Electricity storage, such as large-scale batteries, could also be part of the solution but is not yet cost efficient compared with the use of hydro storage through interconnection with Norway and Sweden. Nuclear power holds benefits in some situations as a low-emissions source of baseload power, but does not have the same capacity as gas-fired generation to quickly vary production to meet demand. For the Nordic region it is likely to cost less to transition to a more distributed electricity supply with a high share of wind than a system reliant on centralised nuclear and thermal generation (IEA/Nordic Council of Ministers, 2016[115]).

Demand-side flexibility to use electricity when wind power is readily available will become increasingly important. In the short-term, this means ensuring consumers have sufficient temporal price signals to use renewable power when it is cheap (charging electric vehicles overnight, for example). Making household electricity prices more cost reflective by reducing taxes (see below) is a key step to benefit from an early rollout of smart meters and hourly billing for end users, as well as the information available from the DataHub repository of electricity consumer data. Over a longer period, technologies such as power-to-X (Box 9) can use electricity when available, provided prices are sufficiently low when supply is plentiful.

Box 8. Government-supported innovation in offshore wind

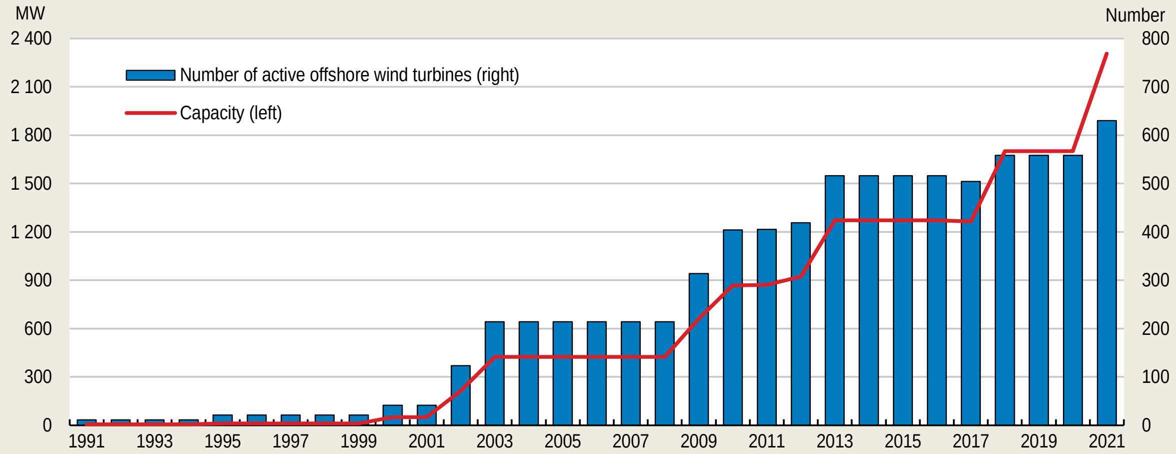
The world's first offshore wind farm was commissioned in Denmark in 1991, but it took two decades of sustained support to get to the point where it met 18% of Danish electricity demand in 2019 (Figure 16). Policy measures have been central in increasing deployment and bringing down costs.

- Sustained support for wind research, development and deployment, with significant subsidies in the late 1970s and 1980s and increasing funding throughout the 2000s, peaking at DKK 618 million in 2013.
- Quantitative targets for wind energy in energy plans for 2000, 2005 and 2020, all exceeded.
- A spatial planning committee for offshore wind was established in 1995 to ensure coordinated development. Grid connection for large offshore wind farms is planned, procured, operated and paid for by the transmission system operator and can contribute to the broader network and interconnection.
- The Danish Energy Agency is the single body responsible for issuing all required licenses. The average consent processing time of 16 months is considerably shorter than in the Netherlands, Spain or Germany.
- Feed-in tariffs determined by competitive tender, which peaked at DKK 1.05/kWh for the Anholt wind farm in 2013, falling to DKK 0.372/kWh for the Kriegers Flak project scheduled to be operational in 2021.
- Development sites for government-run tenders are de-risked: prior to tender there is a fully approved Environmental Impact Assessment of the offshore area and possible grid solutions.

Despite higher costs, offshore wind may still offer greater development opportunity than onshore wind by facing less local resistance, scarcity of good sites and planning problems. The cost of offshore wind developments globally increased in the early 2000s as projects moved further from shore and into deeper waters and key commodity prices increased, but have been on a consistent decline since 2014 as construction costs have fallen while scale and capacity factors increased. Denmark had the lowest levelised cost of offshore wind for projects commissioned in 2019, reflecting experience in offshore developments as well as projects located relatively close to shore and in shallow water.

Figure 16. Offshore wind capacity has increased rapidly over the past two decades

Cumulative number of turbines and generation capacity



Note: 2021 data are as of end-September 2021.

Source: Danish Energy Agency, Oversigtstabel over vindkraftanlæg (ultimo 09 2021).

Source: (IEA, 2021[116]); (IEA, 2017[112]); (Danish Energy Agency, 2015[117]); (IRENA, 2013[118]); (Salvador, Gimeno and Sanz Larruga, 2018[119]).

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Box 9. Wind energy islands and power-to-X

The Danish government is planning to develop two wind energy islands, an artificial island in the North Sea and the Baltic island of Bornholm, to provide renewable electricity, sustainable fuels and interconnection with other countries. The first stage of the North Sea project carries an estimated cost of EUR 29 billion, making it the largest construction project ever in Denmark. The projects will be developed as public-private partnerships, with a target to deliver the first 5GW of capacity by 2033. The lifetime cost of power from the energy islands has been estimated at EUR 62-66/MWh, comparable to the current cost of offshore wind power.

Energy island investments carry considerable risk in advance of the development of commercially viable technology to convert electricity to sustainable fuels such as hydrogen, methane or ammonia (power-to-X). Producing such fuels using renewable electricity offers potential to cut emissions from hard-to-decarbonise sectors that cannot use the electricity directly, such as aviation, heavy road haulage, shipping and industrial processes, as well as a flexible demand source that can use electricity when there is excess wind supply. Several Power-to-X demonstration projects are in progress or operating.

- Copenhagen Infrastructure Partners is working with agricultural and shipping companies to establish Europe's largest production CO_2-free ammonia using wind power in Esbjerg.
- A consortium of energy users and renewable energy companies plan to produce sustainable fuels close to Copenhagen from late 2021 under the H2RES project.
- The city of Aarhus in 2015 added an an electric heat pump to an existing combined heat and power plant to create heat from excess wind generation in western Denmark in winter.

Sources: (Cowi, 2020[120]); (International Renewable Energy Agency, 2019[121]); (Ørsted, 2021[122]).

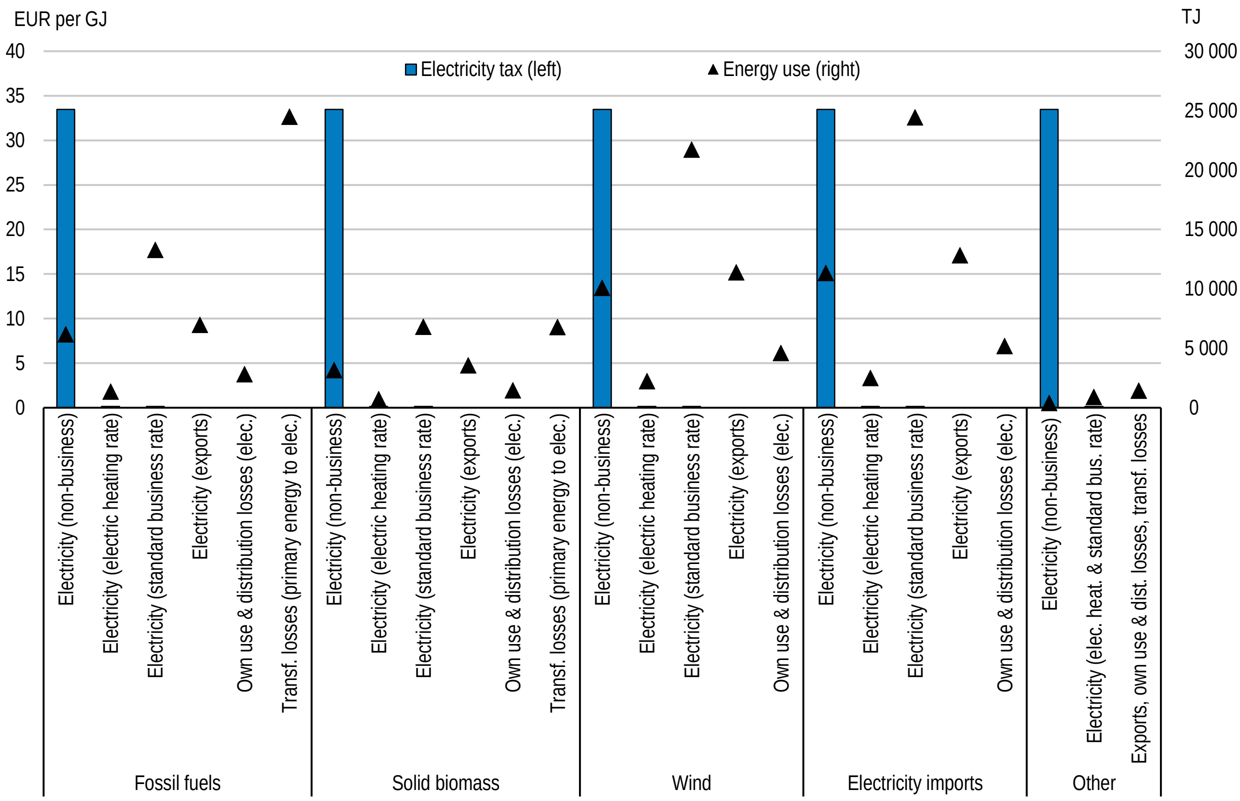
Electricity taxes unrelated to environmental effects should be reduced

Electricity taxation is concentrated on households and is the same whether electricity comes from renewables or fossil fuels (Figure 17). Exemptions for businesses that use electricity in production processes protect their competitiveness but increase the burden on households (Figure 18). Only a small fraction of electricity taxation is used to support renewables: the Public Service Obligation (PSO) used to fund renewables is being phased out by 2022 but before the phase-out began had only accounted for 20% of taxation of electricity for a typical household (Secretariat for Energy Tax and Subsidy Analysis, 2018[123]).

High taxation of electricity has curtailed abatement outside the energy sector via electrification, such as the use of electricity in electric heat pumps and electric vehicles. Measures have been taken to reduce the tax on specific uses of electricity, notably electric heating once a household's annual consumption goes above 4 000kWh and charging electric vehicles through a business service. These schemes are ad hoc and create perverse incentives, for example by providing bigger benefits from shifting to electric heating for households that use more electricity. A comprehensive electrification strategy would help reduce emissions in other sectors by driving the transition to widespread use of renewable electricity.

Figure 17. Electricity taxes are concentrated on households

Effective tax rates on energy use in the electricity sector, 2021



Note: Energy use refers to the quantity of electricity used in Denmark for each type of fuel and usage.
Source: OECD (forthcoming), Taxing Energy Use 2022.

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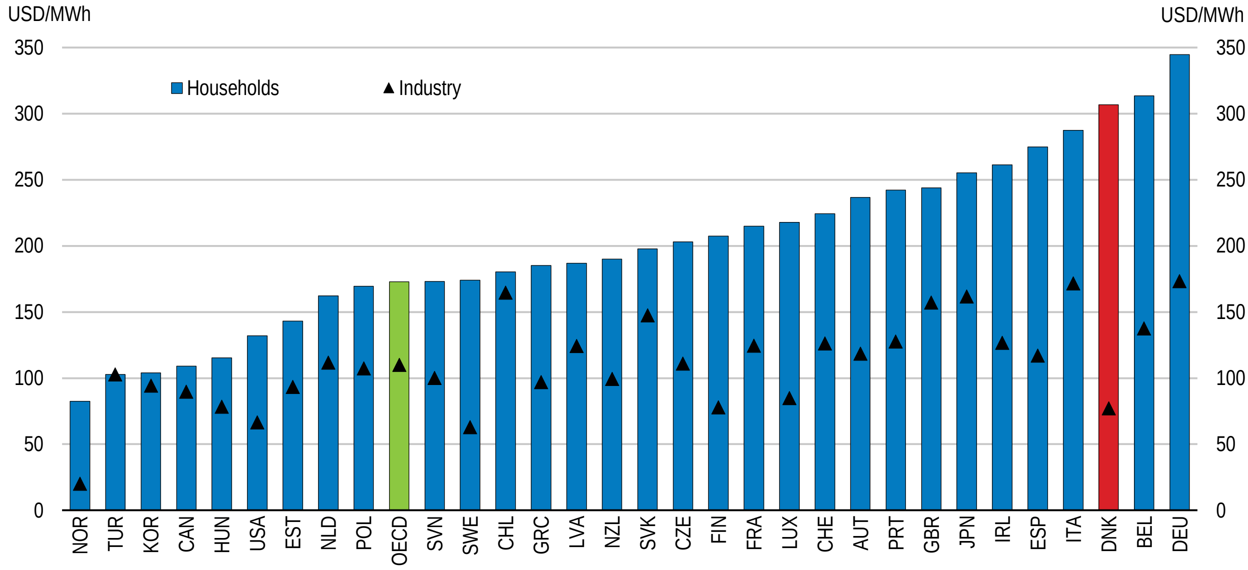
Electricity taxes, which apply to electricity from renewables as well as from fossil fuels, should be gradually reduced as GHG emission pricing ramps up. Removing non-transport energy taxes has been estimated to halve the economic welfare cost of meeting the 2030 emissions target (Danish Economic Councils, 2021[124]). Electricity taxes do not directly encourage power producers to shift to cleaner sources and may decrease the effectiveness of carbon taxes by discouraging electrification (OECD, 2019[125]). In addition, Danish electricity taxes are highly regressive: lowest income decile households spend on average almost 2% of their disposable income on electiricy taxation, compared with less than 0.5% for the the top decile (Ministry of Taxation, 2020[126]). Consequently, using 55% of the revenue from emission pricing to reduce non-transport energy taxes (predominantly electricity taxes) can make the overall income distribution more equal, with no welfare losses for the bottom four income deciles and a loss of approximately 0.5% of consumption for deciles 7 to 9 (Kraka and Deloitte, 2020[77]). Outcomes should be monitored to ensure that lower electricity prices do not trigger a fall in energy efficiency and jeopardise compliance with the EU Energy Saving Directive, though current electricity taxation of DKK 900/MWh is far above the EU minimum of DKK 7.4/MWh (EUR 1/MWh). Energy taxes on heating oil, coal and gas should also be reviewed to ensure these are aligned with non-climate environmental costs, such as local air pollution, as GHG prices increase.

Figure 18. Electricity prices for households are among the highest in the OECD

2020 or latest available year



Note: Industry refers to large business users of electricity in the highest consumption bands.
Source: IEA, Energy Prices and Taxes database.

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Reliance on biomass for heat and power needs to be reduced

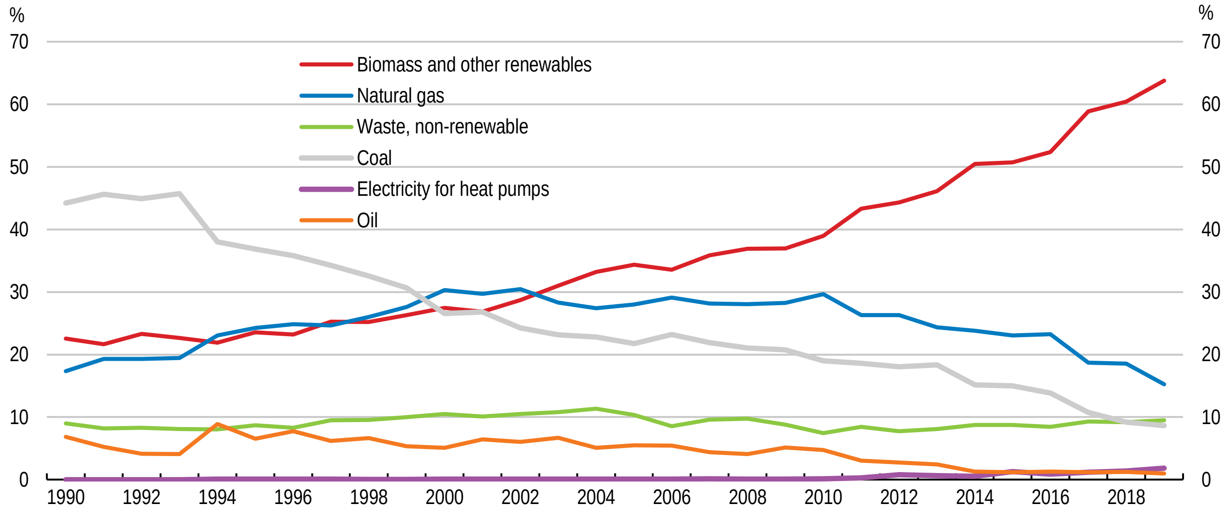
Biomass has played an increasing role in Danish energy supply, particularly woody biomass used for district heating. District heating accounts for the highest share of residential energy consumption among OECD countries (IEA, 2019[127]). Biomass is now the dominant fuel for district heating (Figure 19) and its share of electricity generation has gone from 1% to 18% (Danish Energy Agency, 2020[128]). In total, over half of Denmark's end use of renewable energy comes from solid biomass in the form of wood pellets, wood chips, firewood and straw. The shift to biomass has been incentivised by an exemption for otherwise high energy taxes on the basis that biomass is a renewable energy source. Electricity produced using biomass-fired combined heat and power plants with capital costs that have not been fully written-off also receive an add-on to the market price of EUR 20/MWh.

Tax exemption and subsidies for using woody biomass for heat and power are inconsistent with the environmental costs. Burning biomass emits gross CO_2 roughly equivalent to burning fossil fuels, but where it is harvested from forests that are managed sustainably then regrowth offsets these emissions. While there are climate benefits from shifting from fossil fuels to biomass, there can also be emissions from land use change and the assumption that biomass is carbon neutral from a lifecycle perspective has increasingly been challenged in the scientific literature (OECD, 2018[129]; Booth, 2018[130]; Searchinger et al., 2018[131]). Median international estimates of lifecycle GHG emissions from biomass-fired electricity are more than a quarter of those from coal and half those from gas, which is an order of magnitude higher than other renewables such as wind and solar (Schlömer et al., 2014[132]). For Denmark specifically, CO_2 emissions from transporting, drying and processing biomass are estimated to be between 5% and 25% of those from fossil energy (Danish Energy Agency, 2020[133]). There are also negative local air pollution effects from burning biomass and harvesting can be detrimental for the use of land as carbon sinks, for biodiversity and soil quality. Pursued at scale, biomass production can have negative consequences for land conversion. Woody biomass sourced from residue and waste has limited detrimental effects, but supply is limited, particularly in Europe. Woody biomass carries the greatest environmental and land use trade-offs, whereas other forms of biomass such as agricultural waste (also used extensively in Denmark) can provide energy without impinging much on land use (Catuti et al., 2020[134]).

Denmark consumes much more biomass per capita than would be sustainable on a global scale (Danish Council on Climate Change, 2018[135]) and imports a greater share of its solid biomass use than any other OECD country (Figure 20.). The high share of imports, predominantly from Estonia, Latvia, the United States and Russia, makes it more difficult to ensure forests are managed sustainably. If extraction of biomass for energy leads to a decline in the forest carbon stock or carbon sink strength, this should be accounted for in the emissions accounting of the exporting country, but not all countries supplying Denmark have binding and adequate mitigation targets that include all sectors correctly (Danish Energy Agency, 2020[133]). The EU Renewable Energy Directive II requires that forest biomass is sourced only from locations where legislation at national/subnational level, or management systems at the forest sourcing area, ensure that forests are regenerated and that carbon stocks and sink levels in the forest are maintained or strengthened over the long term. Denmark has recently approved stringent new sustainability criteria that build on an earlier voluntary programme and go beyond EU requirements, but these criteria do not take into account indirect effects on land use change.

Figure 19. Biomass use has grown and now powers the majority of district heating output

Fuel sources as a percentage of total production of district heating



Note: Biomass and other renewables include a small minority of other renewables, mostly solar.
Source: Danish Energy Agency, Energy Statistics 2019.

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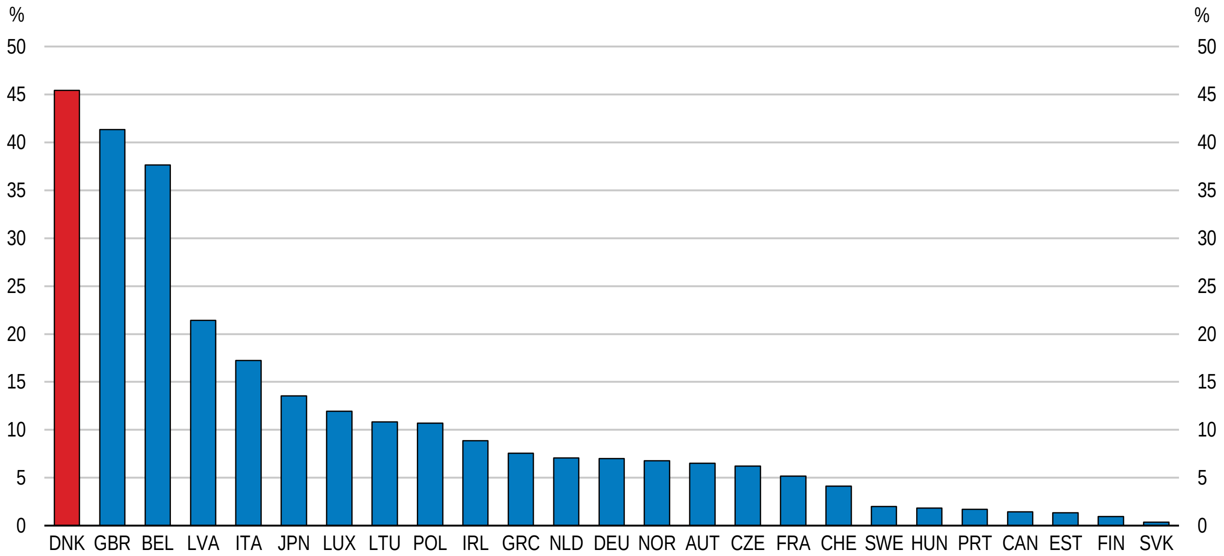
While steps taken to ensure sustainable supply of biomass are laudable, the scale of Denmark's reliance on biomass for heat and power is a problem. There is a limited supply of truly sustainable woody biomass, and greater use increases the risk of environmental costs. In the longer term, scarce sustainable biomass is likely to be most valuable in applications where the substitution of carbon-based fuels is particularly difficult, such as aviation and long-distance shipping. Combining bioenergy with carbon capture and storage is one of the most promising options for achieving negative emissions, as long as the bioenergy is sourced sustainably.

Figure 20. Biomass imports are a large share of Denmark's energy supply

Share of imports of primary solid biofuels in total energy supply, 2019 or latest year available



Source: IEA, World Energy Balances database.

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Denmark should gradually shift away from using scarce woody biomass for heat and power, and incentives to use biomass should be better aligned with the environmental effects from net carbon emissions, local air pollution and damage to biodiversity and soil when harvesting. International GHG accounting standards stipulate that lifecycle emissions from biomass should be accounted for in land use, land use change and forestry and any pricing of lifecycle emissions should follow this classification in order to avoid the risk of double taxation. At present, however, emissions from the land use, land use change and forestry sector are either not priced (as in Denmark), or not subject to binding and adequate mitigation targets (as in some countries supplying biomass to Denmark), which undermines incentives to shift away from woody biomass. While a range of technological solutions should be considered to underpin the shift, the most promising is a move to large capacity electric heat pumps that will provide opportunities to act as an energy store and be a flexible source of electricity demand (EnergiKommissionen, 2017[136]; Heat Pump Centre, 2019[137]). District heating in Sweden already relies on large capacity heat pumps to a substantial degree. Recent government initiatives have gone in the right direction by supporting large capacity heat pumps, reducing taxation of electric heating and removing fuel restrictions. While biomass was valuable as a transition fuel to reduce emissions from burning coal, and combined heat and power provided efficiency gains, further policy steps are needed to access environmental benefits from the reduced costs and increased efficiency of electric heat pumps, wind and solar generation.

Reforms to promote competition in district heating generation have the potential to drive down costs of the transition away from biomass through innovation and private investment. Throughout Europe, based on EU legislation and competition policy, district heating generation is increasingly managed separately from the distribution network (European Commission, 2020[138]). In Denmark, however, competition in the heat market is weak with incumbents protected by a lack of third party access to the network. Denmark should move towards greater competition as in Sweden, where liberalisation led to significant investment and a greener system (EA Energy Analyse, Deloitte and Konveks, 2017[139]).

The rate of renovations should be increased to meet energy efficiency goals

There is a need to accelerate the rate of renovations to improve the energy efficiency of existing buildings and reduce energy use, as existing buildings will form around 85% of the building stock in 2050. Final energy consumption for heating has declined by 45% since 1975, but energy consumption by Danish households increased between 2000 and 2017 as growth in the number and size of dwellings outweighed efficiency improvements (Odyssee-Mure, 2021[140]). Energy use for space and water heating per dwelling is higher than in Germany, the Netherlands and Sweden (European Environmental Agency, 2019[141]). The Danish Climate Council (2017[142]) has identified energy renovation of buildings as a relatively cheap source of abatement, after taking into account reduced local air pollution, when it occurs at the same time as other maintenance and renovation activity. However, the rate of energy renovation lags the EU average, which itself is insufficient to meet long-term energy use and GHG emissions targets (European Commission, 2019[143]). There also remain opportunities where the cost of energy savings in commercial buildings is well below the cost of generating and distributing more electricity. Examples include improving office ventilation, energy-efficient industrial electrical motors and pumps (Danish Energy Agency, 2018[144]). The high and increasing share of renewable electricity reduces the emission reductions from energy efficiency improvements, with household and business use of electricity, district and space heating forecast to be responsible for only around 2 million tonnes of CO_2 emissions in 2030, down from over 10 million tonnes in 2018 (Danish Energy Agency, 2020[145]). However, energy efficiency can still serve to reduce energy demand, freeing up renewable electricity and biomass for other uses.

Denmark has strict minimum standards for new buildings and renovations that must be verified by an independent expert under the Building Code, which is updated at least every five years, though a building class consistent with near zero energy buildings under the EU Buildings Directive remains voluntary. Other positive aspects of Danish regulation include initiatives supporting installation of electric heat pumps, energy saving measures for government-owned buildings, grants to owners who can demonstrate the lowest costs of energy savings, the Better House scheme that provides advice on reducing all forms of energy consumption and access to qualified contractors, and energy labelling. Energy labelling requires owners to pay a trained consultant to review their building’s energy efficiency, with results available to potential buyers and renters, and deliver a plan to improve efficiency (though this could be made more specific (Bjørneboe, Svendsen and Heller, 2018[146]). Several studies indicate a positive correlation between the labelling grade and the market price of the dwelling (IEA, 2017[112]). As elsewhere, energy renovations of private rental properties are more problematic because of the split-incentives problem whereby landlords pay for renovation while tenants benefit from lower energy bills. Almost half (47%) of Danish households are renters, with social rentals comprising 21% of all dwellings (OECD, 2021[147]). The capacity of owners to pass on the costs to tenants varies by type of rental, but schemes are typically based on costs rather than energy savings (European Commission, 2021[148]). Allowable rent increases should instead be better tied to the reduction in energy bills from energy-efficient renovations. Mandating minimum energy performance for rental properties can be a powerful measure to force upgragrades of the most inefficient buildings, as in the UK (Economidou and Bertoldi, 2015[149]).

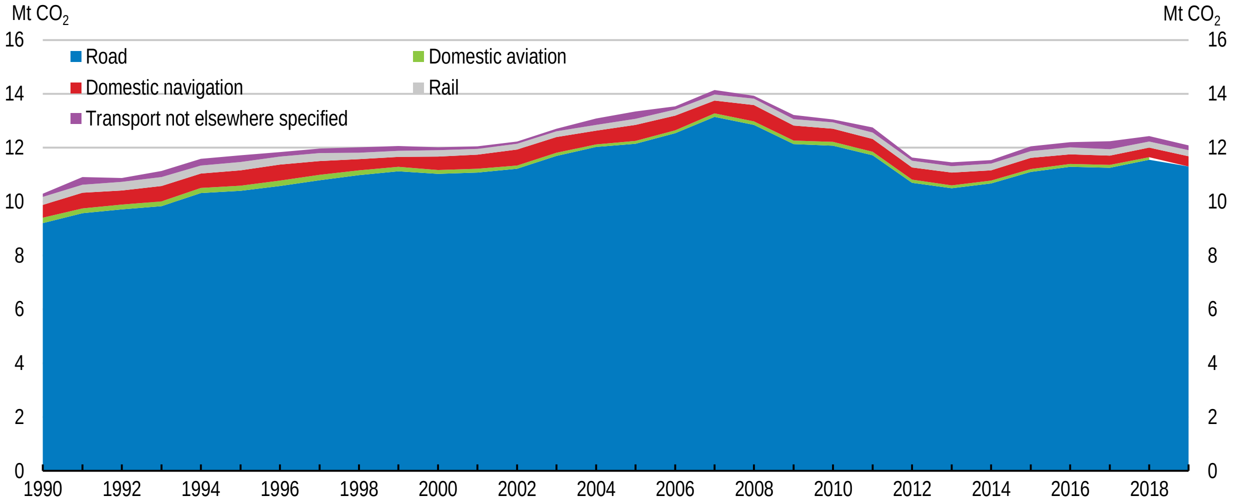
The housing-job scheme (*BoligJobordningen*) provides tax deductions for the costs of energy saving renovations of private homes, but annual caps mean that it does not cover major energy renovations, support is linked to the type of renovation rather than energy saved, and owners of rental properties are ineligible. The housing-job scheme should be reformed to focus on renovation that offers the most cost-effective energy savings without increasing overall funding, as there is little spare construction industry capacity at present. Excluding other house-work such as cleaning and gardening services that do not provide broader societal benefits while prioritising credit-constrained households, as recommended in the 2016 *Economic Survey*, would better target the scheme towards cost-effective energy savings. Consideration should be given to merging with a new scheme taking effect in 2020 (*Bygningspuljen*), which is available to landlords and targeted at dwellings with the greatest scope for energy efficiency improvements. The heating allowance for pensioners (*varmetillæg*) works against energy efficiency by subsidising heating costs of up to DKK 22 500 per year at an annual cost exceeding DKK 300 million. It should be replaced with targeted support that is independent of the quantity of energy used.

Reversing the increase in GHG emissions in the transport sector

The transport sector has become the largest emitter of GHGs

Emissions from the transport sector have increased since 2013, despite a small drop in 2019 (-2%), driven by road transport (Figure 21). The number of vehicles per inhabitants is relatively low, with an average of 565 road vehicles per thousand inhabitants in Denmark, 689 in Germany, 789 in Norway, 592 in the United Kingdom and 655 in the Netherlands. Emission intensity of vehicles has been regularly decreasing and requirements for blending biofuels, which emit less GHGs than conventional fuels, have been particularly stringent. However, due to more intensive use of vehicles, transport emissions per inhabitant are higher than most OECD countries (2.2 tonnes of CO_2 emissions per thousand inhabitants against 1.9 tCO_2 in Germany, 1.8 in the Netherlands and the United Kingdom and 1.6 in Sweden). There are thus likely to be opportunities to cut emissions by emulating best practices in other countries.

Figure 21. CO_2 emissions from transport have been increasing after a fall in the late 2000s



Note: The CO_2 emissions include the total of all emissions from fuel combustion, i.e. coal, peat, oil shale, oil products, natural gas and industrial and non-renewable municipal waste.
Source: IEA, CO_2 Emissions from Fuel Combustion (detailed estimates) database.

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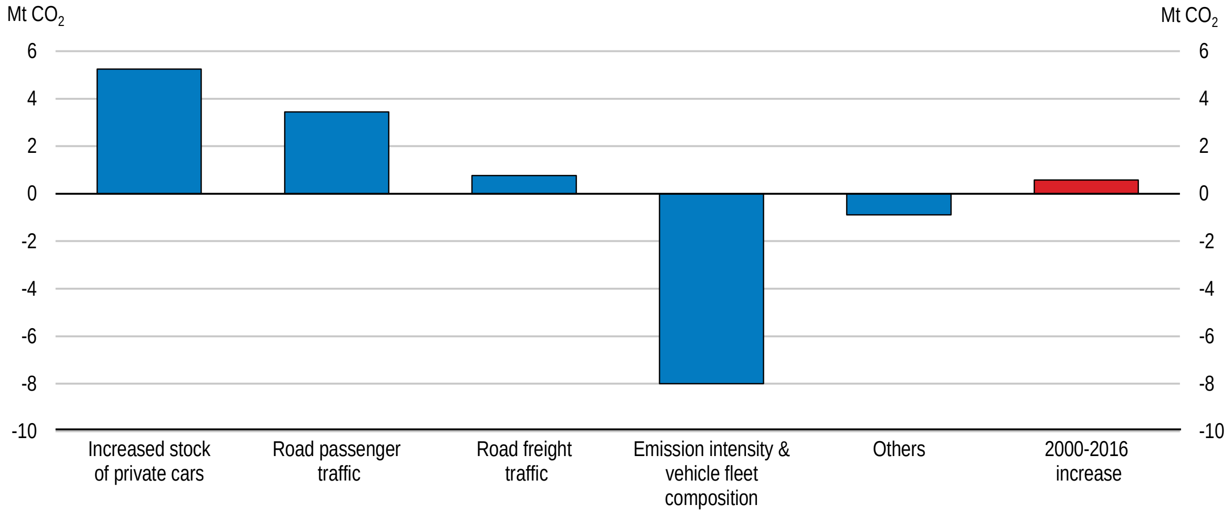
International transport by Danish companies is also responsible for a large part of emissions, but are not accounted in domestic emission accounts and climate targets. Globally, aviation is responsible for 2.8% of CO_2 emissions (adding to short-lived non-CO_2 GHG emissions such as NOx, which can double this impact (Lee et al., 2021[150])). International shipping accounted for around 2% of global energy-related CO_2 emissions in 2019 (IEA, 2020[151]). In Denmark, fuel use for international aviation accounts for 9.5% of fuel use CO_2 emissions and international marine for 5.8%. The high risk of leakage in the international transport sector calls for international coordination. Denmark's action to reduce its emissions from the international maritime sector are in the context of the European Union or the International Maritime Organisation, which adopted in 2018 an initial strategy for the reduction of GHG emissions from ships by 70% by 2050 (Danish

Maritime Authority, n.d.[152]). As for other EU countries, emissions from intra-EU international aviation are included in the EU ETS; they have also been subject to the GHG emission regulation mechanism CORSIA from this year. The shipping industry in Denmark has played an active role in climate mitigation policies by setting a target of carbon neutrality by 2050 (without emission offset), proposing policies and building partnerships for research and development. Margins for action lie in energy efficiency gains and low-carbon fuels, as well as the electrification of short-distance shipping. The establishment of a carbon pricing mechanism at the international level would encourage further actions (ITF, 2020[153]).

The increased use of private cars has driven most of the recent rebound in CO_2 emissions from transport in Denmark, together with a small rebound in road freight traffic since 2008 (Figure 22). Road passenger use has increased by 30% between 1999 and 2019 and private cars now account for 82% of inland passenger traffic. A shift to less emissions-intensive vehicles and the smaller share of gasoline-fuelled cars in the private fleet (from 95% in 1994 to 68% in 2020) partially offset the climate impact of increased use of road vehicles. This is related to higher fuel efficiency and more stringent regulation on vehicles' CO_2 efficiency for manufacturers at the EU level.

Figure 22. The increasing number of private cars and traffic outweighs greener vehicles

Estimation of drivers of CO_2 emissions evolution in the transport sector over the period 2000-2016



Note: OECD estimation is based on an ordinary least square regression with data on private car ownership and vehicle fleet composition from Statistics Denmark (BIL10 and BIL11), data on road passenger and freight traffic from ITF and data on emission intensity from EEA. "Others" include control variables and residuals.
Source: EEA; Statistics Denmark; ITF, Performance Indicators database; and OECD estimation.

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The transport sector is one of the hardest and most expensive to abate in terms of the cost per tonne of GHG (Danish Ministry of Climate, 2020[9]). This is first due to path-related dependency on private vehicle use and ownership, as the recourse to private vehicles in transport has been increasing for more than 30 years. Motor vehicles constituting medium term investments for households and firms and the renewal of the whole fleet takes 15 years on average, a reversal of trend is likely to be difficult in the short term. Fossil fuel consumption for transport and their related GHG emissions respond poorly in the short term to policy incentives such as emission pricing and are therefore likely to make only a small contribution to the 2030 target. Regulation and further incentives for the procurement of zero-carbon vehicles could increase this contribution, but also calls for a full deployment of charging and fuelling stations throughout the country well before 2030, entailing substantial costs for consumers or the public budget. Conversely, a sharp decrease in transport GHG emissions is required for 2050 climate neutrality and current action can initiate this potential. Putting a clear and strong signal on future prices of fossil fuels will accelerate the immediate change in the vehicle fleet.

Reducing vehicles' carbon intensity is the focus of government policy

Decarbonisation of the vehicle fleet is at the centre of the government's strategy. In the short term, the government aims to promote biofuels, though the margins for action are very limited. It proposes to integrate a CO_2 displacement requirement to fuel producers instead of a blending requirement. This will allow consideration of the climate impact of biofuels, but the technical capacity of blending remains limited. Hydrotreated Vegetable Oil (HVO) has the ability of fully replacing diesel without a technical blending limit or change of motor, but the resources required can be very large (estimated at DKK 2.1 billion for 10% use of HVO (Danish Ministry of Climate, 2020[9])). This suggests that the timing for adjusting production might be too long for such a transitional measure. Moreover, the potentially substantial carbon component of biofuels (OECD, 2019[154]) can be better taken in consideration by increasing the carbon component of fuel prices (currently null for biofuels).

The Green Transportation Agreement, reached in Parliament in December 2020, is expected to reach the target of 775 000 zero- and low-carbon emission cars in 2030 (with an ambition of 1 million vehicles). The penetration of zero or low-carbon vehicles in the private fleet has been growing rapidly, accounting for 31% of new sales from January to August 2021, up from 5% in 2019 (De Danske Bilimportører, 2021[155]). However, these vehicles are still more expensive than conventional cars, particularly for the most affordable micro and small car categories (Danish Ministry of Climate, 2020[9]). The speed of charging, the limited availability of charging stations or hydrogen fuel and the small range of model choices in these car categories are other barriers to more widespread adoption of non-conventional cars. Historically, policy uncertainty regarding infrastructure and pricing has hampered a significant roll-out of electric vehicles. The 2020 agreement and the Infrastructure Plan 2025 (agreed in June 2021), which sets aside DKK 500 million for 2022-2030 to support charging services both provide multi-year horizons, and are therefore welcome. Domestic legislation can also be adapted to the proposal by the European Commission in its July 2021 climate package, which includes requirements for the distribution of charging points and sustainable fuels (Box 7, above).

Current measures in Denmark for green vehicles are generous and will be ramped up by future reforms. A central measure is a heavily reduced registration tax on zero and low-carbon vehicles in order to make them more competitive with conventional cars. This tax accounts for a very large part of the final price of conventional vehicles and depends on the pre-tax value of the car, with a progressive tax rate (85% up to a threshold of DKK 197,700 in 2020 and 150% thereafter). It can be reduced on the basis of fuel efficiency criteria, and carbon emissions. As a result, the registration tax that applies to electric vehicles is very low, or even zero for some models (Danish Automobile Commission, 2020[156]). The Green Transportation Agreement of December 2020 will restructure the registration tax, which will be based on the taxable value and emissions per km driven (which will be progressive with the value). This will maintain strong incentives for electric vehicles and extend them to other types of low-carbon vehicles, without technological bias. However, these incentives will be higher for more expensive vehicles, which means that the purchase of cheap low-carbon vehicles will be encouraged less than expensive ones.

Access to charging is also crucial for the development of electric vehicles, whether provided privately or publicly. Electricity for charging is taxed at a significantly lower rate if the charging takes place through a business service (at home or elsewhere), but this scheme still needs further development. Facilitating charging at home can contribute to the use of electricity when supply is plentiful, as charging is more likely to happen overnight.. Households with an electric car benefit from a cut in electricity taxation when they reach a certain level of energy consumption (Section 3.1), if the household where the electric car is charged is registered with electric heating as the primary heating source. However, generally, electricity taxation entails that the tax on energy is much higher for electric vehicles than for motor-fuelled ones (DKK 248/GJ against DKK 133/GJ for petrol and DKK 78/GJ for diesel (Danish Automobile Commission, 2021[157])). Energy taxation is also not aligned with the climate cost of fuel use as an electricity-driven kilometre incurs an average DKK 0.17 of taxation (against DKK 0.26 for petrol and DKK 0.15 for diesel), although its climate impact is about one fifth (Danish Automobile Commission, 2020[156]). Implementing an electricity tax cut for households with electric cars, as for households with electric heating, can be a first temporary step to reduce this disincentive to electric vehicles (Danish Automobile Commission, 2021[157]), until electricity taxes are substantially reduced (Chapter 2 and Section 3.1).

In parallel, the government plans to accelerate the roll-out of charging infrastructure. A 10 years funding program for fast chargers on the trunk road network was part of the Infrastructure Plan 2035 agreed in June 2021. The government has announced a change in the regulation of charging infrastructure for electric cars which has the aim to increase competition among charging infrastructure operators and to adapt the regulation for municipalities so that they can take a larger role in the local roll out of charging infrastructure. On top of that an industry agreement with the Danish Electric Car Alliance includes the installation of 23 000 charging stations by 2025 (against 3 000 in 2021). These plans aim to make the use of electric vehicles easier, including for long journeys.

In the longer term, the development of alternative fuels like advanced biofuels or fuels generated by power-to-X can also allow the decarbonisation of heavy vehicles, planes and ships, which are very difficult to electrify. The green research strategy contains a large component for green fuels and Power-to-X in industry and transport and the abatement potential is relatively large, even for 2030 (from 0.5 to 3.5 $MtCO_2$ (Danish Ministry of Climate, 2020[9])). As an example, Ørsted recently unveiled a plan to combine carbon capture and carbon-neutral fuel generation (Ørsted, 2021[158]). A clear strategy on the carbon taxation of fuels in all sectors, at the domestic and international level, would accelerate the realisation of this potential, foster private research and support the future roll-out of these fuels.

Although there is a strong potential for the deployment of clean vehicles in Denmark, their deployment will provide a small contribution to the 2030 climate objectives and might create a public finance risk if targets are exceeded. Past experience in Norway has shown that ambitious policy packages (including tax cuts, carbon pricing and reduced urban tolls for green vehicles) can substantially increase the recourse to electric vehicles to the point that they account for a majority of new car sales (54.3% of new car purchases in 2020). However, Norway has been leading such policy for decades, putting a heavy burden on public finance, as abatement costs amount to hundreds euros per tonne of CO_2, with regressive effects (Eskeland and Yan, 2021[159]). Similarly, short-term effects in Denmark will be hard and expensive to get. Reaching 775 000 zero or low-carbon vehicles in 2030 would have little climate impact in 2030 (-0.41 $MtCO_2$ relative to 2020 and -1.1 $MtCO_2$ relative to a 2030 base scenario) (see scenarios 1 and 2 in Table 5), relative to the 30$MtCO_2$e cut needed between 2020 and 2030 to meet official targets, although it will be particularly expensive for public finance (the registration tax reform will cost a total of DKK 7 billion between 2021 and 2030 (The Danish Government, 2021[160])). The generalisation of tax cuts and the decrease of fuel use would also generate a substantial tax revenue drop, as the vehicle registration tax amounts to more than DKK 20 billion and 1.9% of total fiscal revenues in 2019 and fuel taxation (excluding carbon taxation) DKK 17,6 billion (1.6% of tax revenue). As a result, the Danish Automobile Commission estimated that the social cost of registrations tax cuts to reach 750 000 electric vehicles in 2030 will amount to DKK 3,400 per tonne of reduced CO_2 (Danish Automobile Commission, 2020[156]). This shadow price is likely to be much higher, as the tax cut also benefits hybrid vehicles, which have a higher climate impact when powered using conventional fuels, and make up two-third of low-carbon vehicle sales so far in 2021 (De Danske Bilimportører, 2021[155]).

A general reduction in car taxation due to an increase of low-carbon car purchases might also improve the attractiveness of car ownership and increase the damages caused by car traffic through accidents, congestion and air pollution caused by non-exhaust emissions (Danish Automobile Commission, 2020[156]) (OECD, 2020[161]) without a strong climate impact (see scenario 3 in Table). In Israel, a drop in car registration taxes aiming to green the vehicle fleet led to a large increase in car ownership (+17% between 2013 and 2016), which exacerbated congestion and its related nuisance (time loss, noise, pollution) (OECD, 2016[162]). In Denmark, while electric cars might benefit air quality, further use of vehicles might worsen congestion and the quality of road infrastructure. Average air quality is relatively good (Figure 23) but the concentration of particulate matter is beyond WHO recommendations in urban areas and particularly in Copenhagen. Furthermore, the increased purchase of vehicles will increase the material impact of Denmark's consumption, as alternative fuel vehicles have a higher material footprint than conventional ones, especially due to the impact of battery manufacturing (Sen et al., 2019[163]).

Table 5. The direct climate impact of electric and low-carbon vehicles strongly depends on their capacity to substitute for conventional cars

Projection scenarios based on the evolution of the car fleet and its composition by 2030.

	2030 base	2030 scenario 1	2030 scenario 2	2030 Scenario 3
Car fleet	3.2 M	3.2 M	3.2 M	3.5 M
of which electric and low-carbon vehicles	500 000	775 000	1 000 000	775 000
Evolution of emissions from private vehicles relative to 2020	7%	-4%	-13%	6%
in $MtCO_2$	0.70	-0.41	-1.31	0.60
Evolution of emissions from private vehicles relative to base scenario	-	-10%	-18%	61%
in $MtCO_2$	-	-1.1	-2.0	60.1

How to read: scenario 1 is based on the hypothesis that in 2030 there will be 3.2 million vehicles, of which 775 000 will be electric and low-carbon vehicles. This results in a decrease in GHG emissions from private vehicles by 4% (i.e. 0.41 $MtCO_2$) relative to 2020 and by 10% (i.e. 1.1 $MtCO_2$) relative to the 2030 base scenario.
Note: The 2030 base scenario is built on current evolution of the overall car fleet and non-conventional cars. Scenarios 1 and 2 estimate that a change of the registration tax increases the recourse to electric and low-carbon vehicles up to respectively 775 000 and 1 million without changing the trend of car ownership. Scenario 3 considers that a change of the registration tax increases the recourse to zero and low-carbon vehicles up to 775 000 and these vehicles add to current trends, accelerating overall car ownership.
Source: Author calculation considering a fixed emission factor of conventional vehicles, similar scenarios were made in the *Danish Automobile Commission (2020), Interim report 1: Roads to a Green Taxation*, also considering socio economic impacts.

Shifting the tax burden to encourage sustainable use of transport in a cost-effective way

Emissions rather than the number of low-carbon vehicles is what matters for the climate and non-climate externalities of car use should also be taken into account in policy making. While revenues from the registration tax are being decreased (due to recent reforms and the increasing uptake of low or zero-carbon vehicles), shifting part of the fiscal burden from vehicle purchase to vehicle use and emissions would make the transition to net-zero more cost-effective, mitigate the drop in fiscal revenue and discourage the use of polluting fuels and vehicles. Petrol and diesel are estimated to become around 20% more expensive under a uniform carbon price consistent with meeting Denmark's 2030 abatement target (Danish Economic Councils, 2021[124]), which is a similar magnitude to cyclical price changes such as between mid-2014 and the start of 2015 (decrease) or between November 2020 and September 2021 (increase) (EC, 2021[164])

Well-tailored road pricing could improve the integration of the social costs of car use in people's behaviours. While purchase taxes on conventional vehicles are already high, the recurrent social costs of car use are not fully priced through taxation. It is estimated that the annual social cost[4] of a conventional car on average amounts to DKK 8,100 and that for an electric car to DKK 6,100, compared to an annual taxation (including energy taxes but excluding purchase taxes) of respectively DKK 6,700 and DKK 4,900 (Danish Automobile Commission, 2020[156]). Road pricing could help to fill that gap and could compensate part of the potential erosion of revenue from other taxes related to the deployment of zero and low-carbon vehicles. Past experience in big cities showed that such policy successfully reduced externalities related to traffic and enhanced the shift to public transport (Croci, 2016[165]).

A first step, which could contribute to 2030 climate objectives and is currently under study, would be to replace the current heavy vehicle toll by a distance-based toll, applying to all heavy vehicles. A carbon component would incentivise the choice of trucks with lower emission intensity and reduce the risk of users purchasing fuel abroad. This could have a direct impact on emissions in a sector that is hard to decarbonise while fossil fuel alternatives are still difficult to deploy at scale.

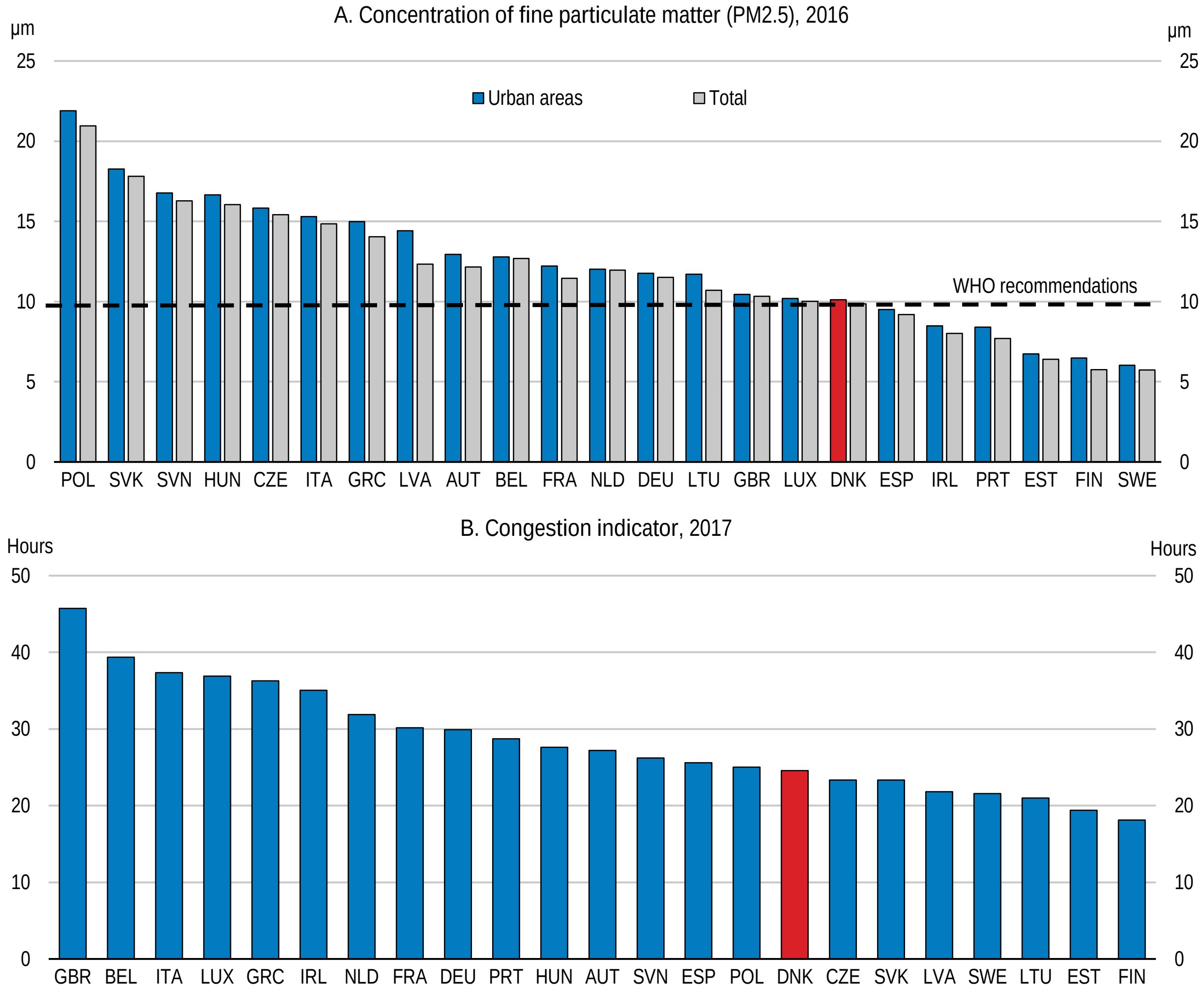
[4] Including the costs of CO_2 emissions, air pollution, noise, congestion, accidents, wear and tear.

A broad development of zero and low-carbon passenger cars and the erosion of fuel and registration tax revenues would justify the extension of a distance-based toll to car passengers in the medium to long term. Denmark has already taken a first step by defining environment zone schemes in Copenhagen, Frederiksberg, Aarhus, Odense and Aalborg, with environmental requirements for lorries, buses and vans (Danish Automobile Commission, 2021[157]). Extension to the whole territory and to a distance-based toll in the longer term should be considered to establish a stable tax base, whereby targeted extra-charges can be an efficient way to fight against congestion (van Dender, 2019[166]). The implementation of a toll-ring road in Copenhagen would, for instance, reduce traffic by 18% and related CO_2 emissions by 12% (OECD/ITF, 2018[167]). A more recent study showed the potential of time-based tolls that increase in rush hours to reduce congestion at limited additional cost for users (Danish Automobile Commission, 2021[157]).

This approach calls for broad complementary measures and infrastructure investment to avoid disproportionate costs for vulnerable households in remote areas. Low-carbon vehicles are significantly more expensive than conventional ones for small and medium models, even when accounting for tax exemptions (Danish Automobile Commission, 2020[156]). The temporary increase in the scrapping premium for old diesel cars, included in the 2020 plan, could help address this issue while accelerating the phasing out of diesel vehicles. Moreover, depending on the charge structure and rates, road pricing could be particularly costly for commuting households living outside city centres and market rigidities will not allow housing prices to adjust accordingly. In order to avoid putting a disproportionate cost on households living in remote areas and to ensure public acceptability, it is important that, in parallel, alternatives to individual cars are offered. An OECD-led survey showed that people are more amenable to limiting driving or paying for climate action when they have available public transport (Box 3, above). Accessibility to goods, services and opportunities are more limited in commuting areas and should not be further impeded, in order to ensure the social acceptability of reforms and promote people's well-being (OECD, 2019[65]). An in-depth survey on these distributional impacts by income groups and territories should anticipate such issues. However, targeted subsidies for households contingent on their living in remote areas should be avoided, as they encourage urban sprawl. For this reason, the current tax cut for commuters, which increases with daily commute distance, needs to be revised and separated from housing choices or scrapped.

Solutions to reduce car use and car dependency should be implemented, focusing on commuting areas outside city centres. They include improved public transport, renovated road spaces that ensure the security of active mobility or land-use projects ensuring an easy access to basic goods and services. Big cities like Copenhagen have successfully launched ambitious policies to decarbonise through public transport and encouraging walking and biking (OECD, 2012[168]). The 2020 recovery plan includes DKK 1 billion in investments for 2021-2024 aiming to foster and secure bicycle use, including electric bicycles, with bike paths, specific charging stations and subsidies (The Danish Government, 2021[160]). The use of public transport (train, bus and coaches) as a share of inland passengers has been stable for the last 40 years in Denmark (around 18% of passenger-kilometres), despite an increase of population density in all regions, particularly in the Copenhagen area. Densified areas offer opportunity for the development of transport stops and measures promoting modal shift could improve the uptake to public transport in areas that are poorly served, more particularly outside city centres. Opening passenger rail to competition could help to make this transport mode more attractive for commuters (chapter 2). Finally, land-use projects promoting inter-modal transport use for commuters and fostering accessibility should be prioritised, for instance mixed-use urban development within close proximity (walking distance) to mass transit facilities (ITF-OECD, 2017[169]). The use of precise local indicators on accessibility to goods, services and opportunities, like the Public Transport Accessibility Level used in London, could help target areas and people that are the most in need, to adjust the transport system, but also land use policies (OECD, 2019[65]).

Figure 23. **Denmark's urban areas are slightly over**-exposed to air pollution, while congestion is relatively low



Note: The congestion indicator is measured as hours spent in road congestion annually by an average driver with two 30km trips per day and for 220 working days.
Source: WHO, Modelled exposure to particulate matter air pollution; European Commission, EU Transport Scoreboard.

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Ramping up mitigation in agriculture

Agriculture and land use are key sectors in the long-term climate strategy of Denmark for their capacity to both reduce GHG emissions and sequester carbon from the atmosphere in soils and plants. Agricultural production covers 62% of land in Denmark but comprises a relatively small part of the Danish economy: agriculture, forestry and land use accounting for 1.6% of the Danish gross value added and 1.9% of total employment (European Commission, 2021[170]). However, agriculture and land use respectively account for 23% and 5% of emissions, (including LULUCF), which makes them the most GHG intensive sectors in Denmark relative to their output. Emissions come primarily from the animal sector which produces 61% of sectoral economic output and 77% of GHG emissions (Figure 24.). Without additional measures, emissions from agriculture are expected to grow and reach 16 $MtCO_2e$ in 2030 (Danish Ministry of Climate, 2020[9]). Failing to reduce agricultural emissions while keeping the objective of cutting overall emissions by 70% would entail larger welfare cost for other sectors and households (Danish Economic Councils, 2021[124]).

Climate mitigation in the agriculture sector often can also help reduce other environmental damages from agricultural production. Fertiliser use and animals' waste are potential sources for the leaking of nutrients, particularly nitrogen, into the environment, degrading water and air quality. Denmark's nutrient balance (the quantity of nutrient inputs not removed by crop and pasture production) is high, exceeding the OECD average by 70% for nitrogen (OECD, 2021[171]). However, nutrient balances in Denmark have consistently fallen since the 1990s even as agricultural production has grown, with the nitrogen balance falling by more than 50% since 1990. As in other countries, biodiversity has been declining (-28% from 2000 to 2019, as measured with farmland birds population (OECD, 2021[171])). A large number of climate change mitigation measures also benefit the local environment and these synergies should be enhanced. Reducing fertiliser use, for instance mitigates nitrous oxide emissions (N_2O) and overall nitrogen leaching (OECD, 2018[172]). Land restoration can enhance carbon sequestration, while providing habitat for on-farm biodiversity (OECD, 2019[65]).

Agriculture offers clear opportunities for substantial, cost-effective abatement. Emissions from the agriculture sector are among the cheapest to reduce, with abatement costs of a number of GHG mitigation actions estimated to be well below the cost of action in other sectors such as transport (Danish Economic Councils, 2021[124]). Furthermore, taking into account benefits other than climate (water, soil and air quality) the overall improvements in welfare caused by some of the mitigation measures make the net abatement cost negative. This is the case for measures reducing nitrogen fertiliser load by optimising practices, which reduces farmers' input costs and improves the environment without compromising competitiveness or productivity. However, actions that offer the highest mitigation potential for 2030 and would reduce emissions from enteric fermentation are the most expensive (estimated at DKK 1,300 /tCO_2e) (Table 6).

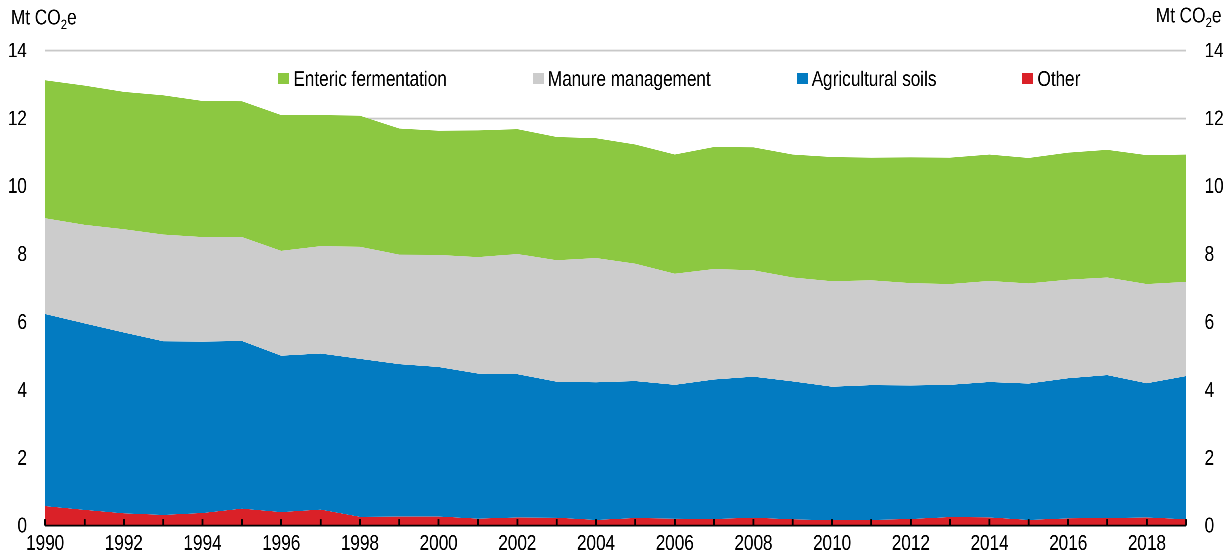
Ramping up ambitions in agriculture is technically feasible now, for medium to longer term results (2030 and climate neutrality in 2050) and with limited cost for society, particularly by improving nutrient management, reducing enteric fermentation and restoring peatlands (Arneth et al., 2019[173]). There are solutions available to improve the climate efficiency of feed provided to dairy cattle (by breeding animals with lower feed requirements, feed quality improvements, and additives that inhibit enteric methane), rationalise the application of nitrogen fertilisers and improve manure management (Searchinger et al., 2021[174]). The restoration of carbon-rich lands, and particularly peatlands also offer a great potential with limited cost and environmental benefits that could only be fully reached in the longer term, but should be initiated now. Several of these opportunities have been prioritised in an October 2021 political agreement on the green transition of Danish agriculture (Box 10). Increasing abatement in agriculture is consistent with the approach taken by the EU Commission in its 2021 proposal for climate (Box 7, above) which pushes for climate neutrality in the EU land use, forestry and agriculture sectors by 2035.

Danish agriculture is open to international trade and potentially vulnerable to GHG emission leakage if unilateral measures increase production cost

Danish agriculture is strongly embedded in international trade and the European single market, which frames the policy options. Food and agriculture account for 16.7% of all Danish exports and 16.0% of exports to the European Union. Reciprocally, food accounts for 14.5% of imports from the European Union (European Commission, 2021[170]).

EU regulation has an important role in shaping Danish agricultural policies, as Denmark belongs to the EU common market and policies are operating under the Common Agricultural Policy (CAP). The EU Nitrate Directive (1991) and, more broadly, the Water Framework Directive (2000) set restrictive standards for water quality and nutrient loads, encouraging a reduction in nitrate leaching and nitrous oxide emissions (a large part of which comes from the leaching of nitrogen from fertilisers). The CAP also frames agricultural subsidies in Denmark as in other member states and CAP subsidies account for 37% of agriculture income nationally. The share of CAP subsidies for climate action is very small, as they mainly consist of direct payments (83,2%), depending on land area (European Commission, 2021[170]). This framework allows EU countries sharing a large market with common ground for regulation in order to enhance their competiveness. It also limits the margin of action for individual member states in the short term, until the new CAP is applied in 2023.

Figure 24. GHG emissions from agriculture in Denmark mainly come from the livestock sector



Note: GHG emissions exclude Land Use, Land Use Change and Forestry. Emissions from agriculture soils cover N_2O emissions from managed soils and fertiliser application (urea application and other carbon-containing fertilisers). Other includes field burning of agricultural residues, liming and other. Enteric fermentation is the anaerobic fermentation process that naturally occurs in the digestive system of domesticated and wild ruminants, resulting in the emission of methane (as well as hydrogen and carbon dioxide).
Source: United Nations Framework Convention on Climate Change (UNFCCC), Greenhouse Gas Inventory data.

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Table 6. Costs and climate impact of mitigation measures in agriculture

	Reduction		Costs	Shadow price	Shadow price
	Million tonnes CO2e /year		DKK million	DKK per tCO2e	DKK per tCO2e
	2025	2030	Annual average to 2030	(without side effects)	(with side-effects)
Increased proportion of fat in feed for conventional dairy cows and heifers	0.17	0.16	146	1 170	1 170
Frequent slurry flushing from pig housing	0.15	0.17	31	250	250
Increased state afforestation	0.002	0.01	25	800	300
Additional state afforestation	0.01	0.06	196	1 300	800
Current effort in targeted nitrogen regulation (3,500 t N abatement)	0.29	0.29	200	1 500	Negative
Collective nitrogen measures (1,500 t N abatement)	0.02	0.1	450	230 to 556 000	Negative to 500 200

How to read: Increased state afforestation has the potential to reduce GHG emissions by 0.002 million tonnes CO_2e per year in 2025 and 0.01 million tonnes CO_2e per year in 2030, for an annual average cost of DKK 25 million. This is equivalent to gross spending of DKK 800/tCO_2e and, after accounting for the welfare benefits of the measures (biodiversity, water retention, etc.) to a net welfare cost of DKK 300/tCO_2e. Each measure is here assessed independently, taking a bottom-up cost-engineering approach as described in (MacLeod et al., 2015[175]).
Source: (Danish Ministry of Climate, 2020[9]).

Box 10. Agreement on the Green Transition of Danish Agriculture

On 4 October 2021, the Danish Government and most of the parties in the Danish parliament entered an agreement that runs until 2030 regarding the green transition of Danish agriculture and forestry. The agreement contains a binding reduction target of 55% to 65% in 2030 compared with 1990, a reduction of approximately 6-8 million tonnes CO_2e. The agreement will use the Common Agricultural Policy actively through financing and regulation schemes.

Measures covered by the agreement are estimated to reduce GHG emissions by 7.4 million tonnes CO_2e by 2030. Of that, measures already agreed will reduce emissions by 0.5 million tonnes and implementation of existing technologies is anticipated to reduce emissions by a further 1.9 million tonnes. The remaining 5 million tonnes is the potential from technologies currently under development, including biochar, more efficient handling of manure, fodder additives for livestock, increased organic farming and peatland restoration.

A cornerstone in the agreement is the rewetting and restoration of natural hydrology on drained agricultural soils with an organic carbon content of more than 6% (mostly peatlands). The scheme is voluntary, whereby project owners (such as municipalities or farmers) can apply for grants for project expenses. Along with previous agreements, 50 500 hectares of agricultural land is expected to be restored, with an additional 38 000 hectares planned as part of an eco-scheme under the Common Agricultural Policy. Towards 2030, the goal of the agreement is to restore at least 100 000 hectares of carbon-rich land.

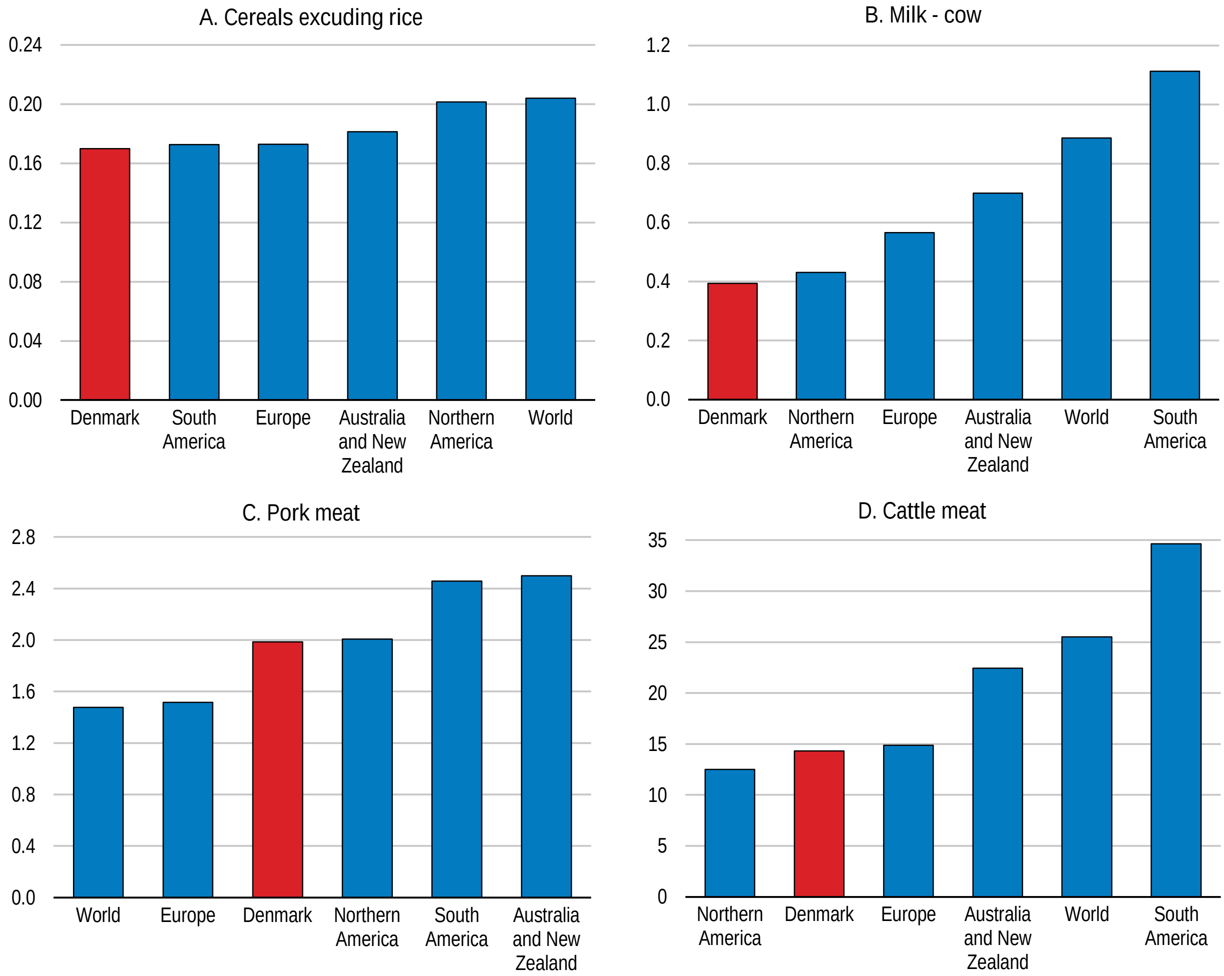
The agreement commits the parties to take measures to reach the 2027 goal set by the EU Water Framework Directive through measures to reduce the loss of nitrogen to the marine environment. The agreement specifies concrete measures to reduce nitrogen emissions by around 10 800 tonnes in 2027. This includes voluntary collective measures, such as mini-wetlands, which farmers can apply for funding to establish locally. The current targeted regulation, which delivers additional nitrogen efforts in relevant catchment areas, will remain in place until a new, more cost-efficient regulation can be phased in.

The openness of Danish trade creates some risk for the acceptability and the overall effectiveness of climate actions in agriculture, whether implemented *via* a tax or regulatory measures. If the cost of climate change mitigation actions is reflected in decreased productivity or increased costs, Danish farmers may lose shares of international and domestic markets. The first risk is that stringent measures for climate generate revenue and job losses in the agriculture and food sector. The Danish Economic Councils (2021[124]) estimated that the implementation of a CO_2eq tax of DKK 1 200/tCO_2e would destroy about 25% of current jobs in agriculture and 9% in the food sector (Chapter 2, Table 2.1).

The carbon leakage of the potential drop of agricultural production that could result from an emission price is hard to estimate, but calls for a careful implementation of climate policies in agriculture. In comparison to other countries, Denmark has low emissions-intensity in agriculture, excluding emissions from land use change (Figure 25). Using a lifecycle approach (including the production of fodder and emissions from land use change), Denmark is also among the most climate efficient countries, a position shared with other Northern European countries (Searchinger et al., 2021[174]). As the global demand for food and particularly animal products is growing (OECD/FAO, 2021[176]) (Searchinger et al., 2021[174]), reducing production solely in Denmark might give market shares to competitors and goods with higher climate impact. There is therefore a risk that reducing emissions from Danish agriculture might trigger an increase of GHG emissions from other countries. This depends very much on the climate policy of other countries. So far, the risk is subdued as overall leakage (the share of emission cuts that would be shifted abroad) has been estimated at 35% for Danish agriculture under a DKK 1 200/tCO_2e emission tax (Danish Economic Councils, 2021[177]).

Figure 25. Emissions intensity of main agricultural products in Denmark is in many cases lower than non-European countries

Kg CO_2e per kg product, 2017



Note: The GHG emissions comprise emissions generated within the farm gate. Additional emissions from upstream and downstream production as well as consumption processes and trade are excluded.
Source: Food and Agriculture Organization, Corporate Statistical Database, Agri-Environmental Indicators, Emissions Intensities data.

StatLink https://stat.link/xp5o2e

An ambitious policy mix of regulation and subsidies for carbon sequestration can enhance climate change mitigation in agriculture

Denmark succeeded in reducing its nitrous oxide emissions from fertilisers using a policy mix of regulation and subsidies to improve water quality. Compliance with water-related legislation, particularly EU Directives, entailed a set of requirements, with costs borne by farmers, for initiatives such as fertiliser accounting, mandatory catch crops, the period for manure application and restriction of fertiliser use in certain areas. In parallel, farmers can be supported when they implement measures mitigating nutrient leaching in the environment. As a result, nitrogen fertiliser use decreased by 0.81% in a decade (against a 0.66% increase in the OECD) and strongly improved the efficiency of nitrogen use for fertilisers (+33% between 2004 and 2014) (OECD, 2021[171]). As a result, the emissions intensity of crops has strongly declined in the last decade. In parallel, the milk sector has benefitted from highly digestible feed leading contributing further to the decrease of the overall agricultural GHG emissions intensity However, the emissions intensity of meat production has increased and pig meat production in Denmark is particularly emissions-intensive relative to other European countries (Figure 25. above).

These efforts fall short of reducing GHG emissions and the environmental damages of agricultural production. The agreement on the green transition of agriculture (Box 10 above) is a significant step forward in developing a strategy for agriculture that is consistent with Denmark's 2030 climate target. However, the bulk of emission savings under the agreement rely on technologies that are not yet mature and further policy measures will be needed to deliver the associated emission reductions.

The 70% target calls for implementing promptly a clear strategy in the agriculture sector to offer rapid results and provide time for sectoral actors to adapt to future policy conditions. The second phase of the Green Tax Reform will determine the framework for a uniform carbon tax across the economy, including for agriculture. Although a specific carbon price is politically hard to implement in this sector and might generate leakage, this strategy should aim at pricing the negative outcomes of agricultural production and encouraging the most efficient actions for climate change mitigation. The current mix of strong regulation and voluntary subsidies are an acceptable short-term option, but should be reinforced and made more efficient to align with the government's high climate ambitions. Increasing requirements for well-known mitigation practices together with monetary sanctions proportional to their cost would unlock the potential of the government plan for agriculture (Danish Government, 2021[178]). This can take the form of stronger environmental and climate requirements for CAP payments or other types of requirement. The Netherlands have restricted since 2019 the installation of nitrogen-intensive projects with more stringent regulations and requirement near protected (OECD, 2021[179]). Ramping up practices enhancing carbon sequestration (such as land restoration and forestry) in soils through subsidies (funded by CAP supports and central budget) could substantially contribute to 2030 targets.

Carbon sequetration using biochar also has high potential, but further research, development and demonstration is required. In the longer term, research and development can contribute to provide alternatives to GHG intensive practices and therefore abate emissions with limited leakage effects (Henderson and Verma, 2021[180]). Research is also needed to improve monitoring of emissions at the farm-level, which would aid monitoring and make the direct pricing of emissions practically feasible. The new CAP that will be implemented from 2023 to 2027 provides broad scope of action to National Strategic Plans while increasing mandatory funding of environmental programmes and the stringency of climate and environmental requirements. Furthermore, European Commission aims at building a climate neutral land use, forestry and agriculture sector by 2035 (European Commission, 2021[79]). EU-wide policies offer opportunity to Member States for bold climate and environmental policies in the sector without weighing on its competitiveness.

Regulating or pricing emissions requires strong monitoring of agriculture emissions at the farm level. In the medium-term, improved monitoring of farm emissions, as planned by the government, should help to individualise regulatory requirements and make enforcement easier. It could also allow pricing or regulation of GHG emissions and other environmental damage of agriculture production, instead of regulating actions or inputs as currently. This would provide more margin for farmers to innovate and reduce their impact in a cost-effective way.

Strengthening regulation and monitoring in the short term should be targeted so as to trigger the most cost-effective actions with current technology. Denmark has been developing spatially-targeted nitrogen regulation, and should continue following this path. Limiting the propagation of nitrogen in the environment is all the more beneficial as it would allow meeting EU requirements for water quality and improve soil and air quality. Reducing methane emissions will affect climate change in the short term (UNEP - UN Environment Programme, 2021[71]) and actions such as improving feed intakes and improving manure management are both feasible and cost-effective. Stronger requirement for fertiliser, manure and building management should therefore bring rapid results with limited costs.

Reciprocally, actions improving carbon capture and sequestration should be encouraged at the level of the generated benefits, accounting for other environmental services such as improvement of biodiversity or water quality. For this, current subsidy patterns such as the Agro-environmental measures of the CAP or the new government plan for land restoration could be made more cost- effective. CAP funding has so far had a small impact on EU emissions, due to poor targeting of measures (European Court of Auditors, 2021[181]). First, payments are based on actions instead of environmental and climate outcomes. Experience has shown that increasing payment for measures with multiple benefits (e.g. water quality and carbon sequestration), substantially improves uptake and general environmental outcomes (Lankoski et al., 2015[182]). Moreover, until now, these measures have been capped, which prevents any action over budget even though they can be cost-effective.

In the longer term, Denmark is set to play an active role in EU talks for aligning member states' policies for a climate-friendly CAP and henceforth reducing its risk of GHG leakage. These talks will shape the agriculture sector from 2027 onward and then define the role of EU agriculture in climate change strategies. Shifting CAP payments, currently mostly based on land ownership, to payment for ecosystem services is crucial. The current EU framework is particularly expensive related to the services provided and the damages agriculture causes to the environment. Phasing out this inefficient scheme and paying farmers for the improvement of climate and environmental performance would accelerate climate action in agriculture in a cost- effective way in the perspective of a carbon neutral economy for 2050. A first step has been taken from the 2014 CAP that includes a mandatory share of direct payments for eco-schemes (30% from 2014 to 2022 and 25% in the next period) and the new 2023-2027 CAP tightens the green requirements related to payments (such as set-aside land and wetland protection). However, this is a mild effort relative to what is needed to reach climate targets. Conversely, while leaving the European Union, the United Kingdom undertook a similar path and decided to phase out direct payments and to pay farmers for "producing public goods" based on environmental and animal welfare outcomes (Defra, 2020[183]).

However, this shift of subsidies should be implemented gradually and in a predictable way, with accompanying measures for farmers, as CAP subsidies account for a large part of agricultural income. 28% of Danes live in rural areas and massive bankruptcies could have dramatic social and local impacts, more particularly as livestock production, likely the most impacted sector, is concentrated in provinces with smaller alternative job opportunities (chapter 2). A close cooperation with farmers, the food industry and rural stakeholders could help identify the most efficient actions for climate and build a plan that would gain endorsement from population in charge of its implementation. This is for instance the way New Zealand chose to reduce the climate impact of its agriculture and work towards pricing the emissions of the sector (Box 11).

Temporary measures could be considered to build new skills, in order to mitigate drops of individual incomes and facilitate transitions. The Danish government has taken specific measures to support generational change and a green transition through financial supports and a reform of agricultural leases, adding to the EU subsidies to young farmers (Danish Government, 2021[178]). Temporary tax rebates based on past outputs of the land property might be an option, provided they are temporary and do not exceed the cost of the monetary sanction (or the emission pricing cost in the longer term). Tying eligibility to these rebates to land ownership or management would avoid penalising new generations of farmers.

Box 11. Case study: mitigating emissions from agriculture in New Zealand – building a pricing scheme in agriculture with the cooperation of stakeholders

The agriculture sector plays a major role in New Zealand's economy, accounting for 5.8% of its GDP in 2017 and employing 48 000 people across the country (around 3% of total employment). The dairy industry is the country's largest export earner. Agriculture is also the main contributor of GHG emissions (48% of national emissions, including 23% dairy cattle).

The Interim Climate Change Committee (ICCC), an independent ministerial advisory committee projects that, in order for New Zealand to meet its climate objectives for 2050, dairy and sheep and beef animal numbers should be each reduced by around 15% from 2018 levels by 2030, cutting emissions by 8-10% relative to current policies (Climate Change Commission, 2021[184]).

In November 2019, the Climate Change Response Amendment Act passed into law with a cross-party consensus a specific target for biogenic methane emissions (10% less than 2017 level by 2030 and 24-47% by 2050),as other GHG emissions should reach net zero by 2050. It also states that, from 2025, agricultural emissions will be priced at the farm level. Pricing emissions is consistent with New Zealand's Emissions Trading Scheme (NZ ETS), which now covers a large part of the economy, including transport fuels, electricity production, synthetic gases, waste and industrial processes. Currently under the NZ ETS, agricultural processors, e.g. meat and dairy processors, nitrogen fertiliser manufacturers and importers, are required to report on their agricultural emissions but do not pay for these.

Primary industry organisations and Maori representatives developed their own proposal called He Waka Eke Noa (He Waka Eke Noa, 2019[185]), which was adopted by government. The ICCC will review its progress in 2022.

Through He Waka Eke Noa, the development of a pricing scheme for agriculture emissions by 2025 will be undertaken in close cooperation with the farm industry and iwi/ Māori representatives and will involve building on-farm capacity to manage and mitigate emissions at the farm-level.

This process is flexible and the pricing mechanism still needs to be defined by the primary sector and then proposed to the Government by 2022, when the ICCC will review progresses. If progress is deemed insufficient to develop a mechanism to price agricultural emissions at the farm level, legislation includes a default provision that the pricing of agricultural emissions will be applied at the processor level under the NZ ETS before 2025 and at the farm level after 2025.

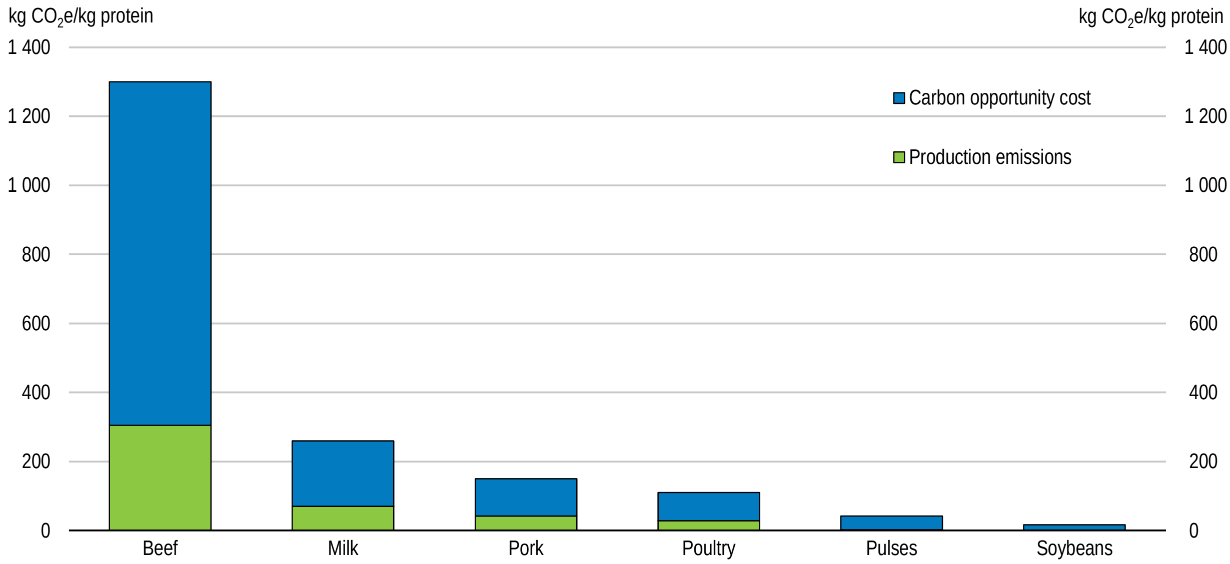
Source: (OECD, 2021[186])

Complementing with steps to encourage sustainable consumption

Changes in food consumption patterns in Denmark could further reduce global GHG emissions by 3 $GtCO_2$ in 2050 (Searchinger et al., 2021[174]), but the way to achieve this potential is still unclear. This effect will not be reflected totally in Denmark's emissions, because of the share of imports in food consumption, but the country's ambition to act at the international level and to lead the way for climate action justifies that this potential is not overlooked.

A first way to reduce the climate impact of food consumption in Denmark is to improve the climate efficiency of diets. This could reduce the carbon footprint of Denmark by 2.6 $GtCO_2e$ a year in 2050. Partly shifting protein intake from animal to plant sources would not only benefit climate and the environment (Figure 26), but also people's health. The consumption of milk, animal fat, eggs, poultry and beef in Denmark far exceeds the planet's boundaries, but also nutrition recommendations (Searchinger et al., 2018[187])). Beef consumption has the largest climate impact per protein intake. In contrast, the average consumption of vegetable oils is below requirement and could be increased to partly replace animal-sourced nutrients. However, this change is hard to impose on citizens: only 33% of Danes are willing to reduce their beef consumption (against 36% of French people and 38% of Americans), according to a recent OECD survey (Boone et al., forthcoming[67]) and the experience of campaigns for healthy diets showed that only a tailored policy mix is able to successfully shift diets, as shown by an OECD report on obesity prevention policies (OECD, 2019[188]). The government's release of official dietary guidelines integrating health and climate issues is commendable. The city of Copenhagen showed the way by implementing the Organic Conversion policy through the training of kitchen staff in catering, increased use of seasonal fruits and vegetables, and the reduction of food loss and waste (Copenhagen House of Food, n.d.[189]).

Figure 26. Animal proteins, and particularly beef meat, have huge carbon footprint relative to plant proteins



Note: A carbon opportunity measure integrates costs attributable to Denmark's land area footprint both for agricultural production and for feeds imported from abroad.
Source: Searchinger, T. et al. (2021), "A Pathway to Carbon Neutral Agriculture in Denmark", World Resources Institute.

StatLink https://stat.link/b1i8vd

Reducing food loss and waste is also an option to reduce the carbon and environmental footprint of Danish food consumption and has a global mitigation potential of 1.4 $GtCO_2e$ in 2050 (Searchinger et al., 2021[174]) In Denmark, as in most developed countries, consumers are the biggest source of food loss, but the food industry is a major source of avoidable food loss and waste. Governments have implemented policy packages that reduced substantially food loss and waste during the last decade. A collective agreement with major food companies to reduce waste was also signed in 2020 to reduce their food loss by 50% (Searchinger et al., 2021[174]). An integrated strategy along the food chain with all stakeholders, including consumers and municipalities, could accelerate the current trend.

Main findings	Recommendations (key recommendations in bold)
Maintaining progress in the energy sector	
Government support has contributed to significant reductions in the cost of wind and solar generation, but supply will need to expand further to meet increasing demand. Emerging technologies will be needed to meet targets and maintain security of electricity supply.	Continue to shift energy research, development and deployment support from mature to emerging technologies with substantial long-term potential in Denmark and abroad.
High taxation of household electricity use has impeded electrification and ad hoc exemptions for specific uses are inefficient, favouring some electricity uses over others and households with high base usage.	Gradually reduce electricity taxes as GHG pricing ramps up, while monitoring effects on energy efficiency. Remove ad hoc measures for specific uses as general electricity taxation declines.
Heavy reliance on woody biomass, for district heating in particular, reduces availability of scarce biomass for other uses.	Better align incentives for woody biomass use with its climate and environmental impact. Ease regulation of district heating to allow private investment to drive a shift towards new technologies, such as large capacity heat pumps.
The rate of renovation to improve building energy efficiency is too low to meet long-term targets. Energy renovations of rental properties are particularly challenging because landlords pay while tenants benefit from lower bills, yet tax deductions for energy saving renovations under the housing-job scheme are not available to landlords.	Reorient the housing-job scheme (*BoligJobordningen*) to support renovations to improve building energy efficiency, including by landlords, rather than other housework such as cleaning and gardening. Mandate minimum energy performance standards in rental properties. Replace the heating allowance for pensioners (*varmetillæg*) with targeted support that does not reduce incentives for energy efficiency.
Reversing the increase in GHG emissions in the transport sector	
An accelerated uptake of low-carbon vehicles would substantially contribute to carbon neutrality.	Ensure the provision of charging stations and low-carbon fuels in rural areas and social housing, using public tenders and potentially subsidies in order to cover remote areas
Transport emissions remain high, in part because replacing the stock of conventional vehicles takes decades. Private car use has been increasing, with associated costs from high local air pollution.	Continue to encourage the shift towards low and zero-carbon vehicles, including with incentives to invest in recharging stations particularly in remote areas. Carefully anticipate and potentially compensate distributional effects. Provide and encourage the development of user-friendly and low-carbon alternatives to private car use, particularly outside city centres, by making active mobility, public transport, low-carbon shared mobility more attractive and adapt land management in order to reduce the need for private car use.
Ramping up mitigation in agriculture	
Emissions from agriculture are disproportionally high relative to the share of the sector in the economy and are among the most cost-effective to reduce.	In the short term, maintain and step up ambitions for environmental and climate standards, improvement of emission monitoring towards farm-level assessment and restoration of carbon-rich lands. Build an ambitious national agriculture strategy making the most of the margins provided by the new EU Common Agricultural Policy (CAP) to enhance payments for ecosystem services.
The agriculture sector is embedded in an international and EU trade system and therefore particularly exposed to leakage.	Prioritise action at the EU level and support further reform of the Common Agricultural Policy to include ambitious climate (and environmental) measures, and more particularly a large shift of EU subsidies from agricultural land to ecosystem services. If needed, avoid emission leakage by temporarily providing rebates based on past outputs.
Postponing action in the agriculture sector would make climate objectives harder to reach in the longer term and increase the abatement burden for other sectors.	Accelerate action and discussions with stakeholders to reduce emissions in the short term through the agricultural national strategy due in 2021, with a focus on reducing N_2O and land restoration. Set up a pathway towards GHG emission pricing in the medium term by approving a plan with specified milestone and a clear time horizon, built together with stakeholders.
Dietary choices and the mitigation of food loss and waste are critical for mitigating global emissions.	Engage discussions with a broad range of stakeholders on means to reduce emissions, including labelling, school-based education, setting examples in public catering, agreements between local authorities and producers for food provision or waste management.

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