1. Main findings and policy recommendations

This chapter presents the report's main findings based on the substantive analysis in Chapters 2 to 10 and offers concrete policy recommendations in three action areas: carbon pricing, technology support, and complementary policies and framework conditions.

Note: a self-standing version of this chapter was published in the *OECD Science, Technology and Industry Policy Paper* series (Anderson et al., 2021[1]).

1.1. The global journey to carbon neutrality

1.1.1. Ambitious climate agendas in the Netherlands and beyond

The Dutch Parliament passed a new Climate Act in May 2019, which mandates the Netherlands to reduce domestic greenhouse gas emissions by 49% by 2030 compared to 1990 levels, and by 95% by 2050. **The National Climate Agreement, adopted in June 2019**, translates the national 2030 target into sectoral objectives. In particular, the Dutch industrial sector has to reduce its emissions by 14.3 Mt of CO_2 equivalent (Mt CO_2-eq) by 2030 compared to a baseline scenario, a reduction of about 59% compared to 1990.

In addition, the Netherlands has been pushing for the European Union (EU) to raise its 2030 emission reduction target from 40% to 55%. As the EU collectively adopted this more ambitious target in December 2020, the Netherlands is considering how best to adapt its reduction goal accordingly.

At the 2050 horizon, the Climate Agreement calls for a carbon-neutral industry: “By 2050, we envisage the Netherlands to be a country with a thriving, circular and globally leading manufacturing industry, where greenhouse gas emissions are almost zero.”

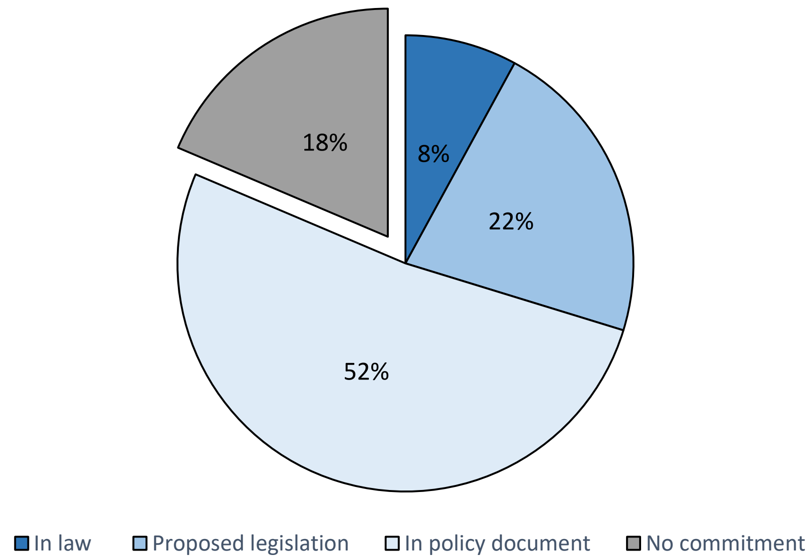
Following the Climate Agreement, and in order to accelerate and support the decarbonisation of industry, **the Dutch government is introducing new policy instruments in 2020 and 2021**, including a carbon levy and enhanced subsidy programmes such as the Sustainable Energy Transition Incentive Scheme (SDE++) in addition to a number of existing policy instruments.

Although a frontrunner, the Netherlands is not alone in this journey to carbon neutrality. An increasing number of countries have announced, or are currently in the process of adopting or discussing climate neutrality targets, and almost all are aiming at the 2050 horizon (Figure 1.1.). The European Parliament is notably examining a European Climate Law that would enact a legally binding target of carbon-neutrality in 2050 in the context of the European Green Deal.

In this context, the objective of the project on “Sustainable transition of the Dutch industry” was to evaluate the consistency, cost-efficiency and comprehensiveness of the toolbox of instruments in place in the Netherlands to reach its long-term decarbonisation objectives *in the manufacturing sector*. The project was carried out by the OECD for the Dutch Ministry of Economic Affairs and Climate Policy and was financially supported by the European Commission’s Structural Reform Support Service (SRSS). The practical aims of that report were to: 1) analyse the energy, production and technological paths consistent with industry’s carbon neutrality by 2050; 2) qualitatively assess the consistency of the existing and new set of policy instruments, including European schemes; and 3) evaluate the need to adjust existing policy instruments and for further measures, in particular innovation incentives focused on some emerging technologies (Box 1.1).

This report as well as the detailed analysis focus on the manufacturing sector. For this reason, some issues, despite being of primary importance for the decarbonisation of the industry, are out of the scope of the project. For instance, dealing with intermittency is critical to ensure a reliable green electricity supply to the industry, but this concerns the energy sector. The same holds to some extent for infrastructure programs and Scope 3 emissions of the manufacturing sector. These aspects are touched upon in this report but would require further consideration.

Figure 1.1. Share of global economy that announced net-zero CO_2 or greenhouse gas emissions by mid-century



Note: In law: Sweden, United Kingdom, France, Denmark, New Zealand and Hungary. Proposed legislation: European Union (part of the EU that does not yet commit to net zero in law, including the Netherlands), Canada, South Korea, Chile and Fiji. In policy document: United States, People's Republic of China (by 2060). South Africa, Japan, Germany, Switzerland, Norway, Costa Rica, Iceland and Marshall Islands. Calculations based on the share of global gross domestic product (GDP) represented by the countries that commit according to the Net Zero Tracker (https://eciu.net/netzerotracker). Share of global GDP calculated based on GDP in 2017 taken from World Bank national accounts data and OECD National Accounts data (2021).
Source: Calculations based on Net Zero Tracker data (https://eciu.net/netzerotracker), World Bank national accounts data and OECD National Accounts data (2021).

1.1.2. General considerations about carbon neutrality policies

Reaching carbon neutrality in 2050 will require a major structural transformation towards the use of green emerging technologies, in the Netherlands as in other countries. In particular, carbon neutrality in industry entails a complete change towards zero-carbon energy sources, and more generally a shift away from fossil feedstock. Not only are large investments needed to adopt existing or close-to-the-market low carbon technologies, but emerging technologies, such as CCS, electrification, green hydrogen and bio-based materials, have to be developed and demonstrated. This requires bringing down the costs and improving the productivity of existing clean technologies, and developing new breakthrough technologies.

Public policies are needed to help trigger these investments, and are justified on the grounds of at least two well-known market failures that hinder decarbonisation. First, carbon emissions constitute an environmental externality, as the costs of the environmental damage from carbon-based production processes are borne by society as a whole rather than internalised by emitting firms. Not internalising the full cost that emissions entail for society leads business to under-invest in low-carbon products, assets and production processes. Second, technological change, which allows reducing the cost of emission abatement over time, is subject to knowledge spillovers at both local and global levels, as firms investing in or implementing a new technology create benefits for others while incurring all costs. These market failures imply that the market produces too many emissions and too little technology innovation related to decarbonisation.

Beyond these two standard externalities, other rationales can justify public action. Learning-by-doing (whereby early producers generate knowledge through the production process) can justify additional demand-pull policies. Well-known imperfections in capital markets make the financing of research and development difficult, particularly for radical or disruptive innovation, which may require public financing, for instance through direct or indirect government-sponsored venture capital. Large investments to decarbonise the industry sometimes also require co-ordination between private stakeholders, and with public stakeholders, because of the existence of network effects. For instance, some carbon-free sources of energy require large infrastructure to be deployed at scale, like hydrogen. Lock-in and path dependence, long lived capital, high upfront costs, imperfect competition in energy markets, behavioural gaps, and regulatory barriers to adoption, are all further examples of additional market failures potentially justifying public intervention.

These policies are all the more necessary as the COVID-19 crisis may jeopardise crucial investments to reduce emissions in the medium to long run. The reduction in emissions due to lockdown measures, and the economic crisis, is likely to be only temporary and will be inconsequential in slowing down climate change, while liquidity challenges, increasing debt burdens and uncertain prospects are likely to weigh on firm investments for the years to come. At a time when many countries are starting to implement recovery packages, the transition to carbon neutrality is often considered as an important dimension of these plans and an opportunity to "build back better".

Policies for the low-carbon transition in the Netherlands, and other economies, should not only focus on reducing emissions towards net-zero but also aim to achieve the transition at the least cost for society. This means reducing emissions where they are cheapest, including considering impacts on productivity, competitiveness and social outcomes. Incorporating these concerns in transition policies and communicating them well can contribute to building broad public support and make the transition politically viable.

Policies should encourage **a cost-effective transition** to carbon-neutral technologies, to preserve productivity as much as possible. Efficient policies will limit the number of losers and make the transition more acceptable.

Policies should limit the impact of the transition on the short run competitiveness of domestic firms, while not compromising on providing an incentive for decarbonisation in the longer run. On the one hand, a loss of competitiveness in the short run could not only affect economic prospects, but also, absent mechanisms to penalise carbon-intensive imports, lessen the efficiency of the low-carbon transition by partly shifting emissions abroad, rather than reducing them (a phenomenon referred to as "carbon leakage"). On the other hand, shielding carbon-intensive production from decarbonisation incentives will harm the long-run competitiveness of the Dutch economy, by slowing down the carbon-neural transition of Dutch industry, thereby leading to stranded assets and jobs.

Policies should **take into account the human side of the transition**. The journey to carbon neutrality, as a sizeable structural change, is not only about greening the existing industry. Some carbon-intensive sectors will downsize, while carbon-free sectors will flourish. Even though the Dutch transition is planned to span 30 years, some workers will be displaced and the set of skills required to thrive in the labour market is likely to evolve. Policies for the green transition need to ensure that green-related skills are accessible in initial curricula and on-the-job training and that workers can smoothly transition to other sectors. Moreover, the provision of green skills will facilitate the deployment and development of green technologies and thereby increase the efficiency of support measures.

1.1.3. The need for a "green industrial policy"

This complex set of market failures and policy objectives calls for a carefully designed strategy relying on a consistent and articulated group of policy instruments, corresponding to the definition of mission-oriented strategies.[1] The objective is not only to foster the development of a decarbonised economy, but also to "re-direct" innovation and deployment from dirty to clean technologies. Such strategy is often referred to as a green industrial policy (Tagliapietra and Veugelers, 2020[2]; Altenburg and Rodrik, 2017[3]; Rodrik, 2014[4]). Green industrial policies typically consist of a three-pronged approach:

- Transforming industry, by supporting not only the deployment of new technologies and innovation, but also affecting the direction of innovation toward green technologies. For this purpose, deployment of carbon pricing and innovation policies are an important component of green industrial policies, in order to bring down the relative cost of green technologies.
- Transforming society, by also inducing changes in producers' and consumers' behaviour, changing skills in the workforce and more generally enabling structural change. For this purpose, strong carbon pricing signals are required to drive behavioural changes, including investment in low-carbon technologies, as well as high-quality framework conditions to allow for an efficient and smooth reallocation of workers and capital.
- Transforming the world by seeking co-ordination, at the European and international level. Co-ordination is a key ingredient of green industrial policies and is needed at the local, national and regional levels (or European level in the case of European countries) to develop the technologies, the infrastructure and standards needed for the transition. This co-ordination is more generally required at the international level as climate change is inherently a global challenge and breakthroughs can benefit the whole world. The existence of integrated markets and global value chains lead to high interconnection of national economies, and result in competitiveness concerns, which require co-ordination as well.

Innovation policy and technology-support combined with strong carbon pricing signals and behavioural changes are, thus, a central feature for a green industrial policy to be successful in the long-term. **Carbon pricing, innovation policy and technology support are not substitutes but instead can be mutually reinforcing**. Technology-specific support can build the case for stronger carbon pricing in the future, by lowering the cost of future green technologies, while strong future carbon prices ensure there will be a demand for new low-carbon technologies developed thanks to technology-specific support.

But as previous waves of industrial policies attest, green industrial policy also raises a number of questions and pitfalls that need to be closely scrutinised. In particular:

- Finding the right level of support can be challenging. As for any other industrial policy, critics have pointed to potential crowding out effects of public investment that might discourage rather than complement private investment. The risk of creating windfall profits to business for activities they would have undertaken anyway is real and needs to be carefully monitored and analysed. Rebound effects (whereby improvements in energy efficiency are compensated by increases in energy consumption) also have to be considered.
- Industrial policies should refrain as much as possible from making bets on specific technologies. Indeed, the techno-neutrality of mission-oriented strategies is one of their major appeals. They are 'problem-led' pathways, rather than 'solution-led'. In fact, nobody exactly knows the exact mix of technologies that will be required to reach carbon neutrality in 2050, even if informed guesses are possible, and desirable. Yet, remaining completely technology-neutral may prove difficult in practice, in particular for green industrial policies.

Selecting which technologies should benefit from government support requires gathering a vast amount of information on the expected returns, risks, spillovers and market failures for each option. Some argue that this information is not available (be it for the government or for any other actor), while others claim that it may be easier for businesses to access than for the government. Due to this potentially asymmetric information between public and private actors, there is a risk of capture and lobbying (Romer, 1993[5]). The ability of governments to stop supporting technologies that prove inadequate (Rodrik, 2008[6]) and the risk of lock-in, have also been questioned.

Box 1.1. Context and objectives of the report

The Dutch Parliament passed a new Climate Act in May 2019, which mandates the Netherlands to reduce domestic greenhouse gas emissions by 49% in 2030 compared to 1990 levels, and by 95% in 2050. By 2050, the electricity sector as well as the industry sector should be climate-neutral. The National Climate Agreement, adopted in June 2019, translates this national target into sectoral objectives. In particular, the Dutch industrial sector has to reduce its emissions by about 59% by 2030. In addition, the Netherlands has been pushing for the European Union to raise its 2030 target for emission reductions from 40% to 55%. As the EU has just collectively adopted this more ambitious target, the Netherlands might now adapt its reduction goal accordingly.

In order to accelerate and support the decarbonisation of industry, the Dutch government is planning to introduce new policy instruments by the end of 2020, including a carbon levy and enhanced subsidy programmes such as the SDE++. The latter was initially introduced to provide subsidies to renewable energy projects but will now be broadened to emission reduction projects in all sectors. These instruments will come in addition to numerous instruments already in place and geared towards industry's decarbonisation, including, for example, existing energy taxes and surcharges, the Energy Investment Allowance (a tax allowance for investments in energy saving assets) or the Long-Term Agreements on Energy Efficiency. They will furthermore interact with other innovation support policies not targeted specifically at low-carbon technologies, such as the R&D tax credit (WBSO) and European climate policies, such as the European Union emissions trading system (EU ETS) or the ETS Innovation Fund.

The targets set by the Dutch government are ambitious and their potential impact on employment and productivity have been vastly debated in the Netherlands. Yet, the Climate Agreement is widely supported, and was designed in collaboration with the relevant sectors, in particular with industry. It is also consistent with the new objectives set out in the EU Green Deal and the EU 2030 Climate Target Plan.

In this context, there is a pressing need to evaluate the consistency, cost-efficiency and comprehensiveness of the toolbox of instruments in place in the Netherlands to reach the long-term decarbonisation objectives. The aim of this project is to: 1) analyse the energy and production paths consistent with industry's carbon neutrality by 2050; 2) qualitatively assess the consistency of the existing and proposed set of instruments, including European schemes; and 3) evaluate the need to adjust existing instruments and for further measures, in particular, innovation incentives focused on some emerging technologies. The assessment of policies is based on their cost-effectiveness in reducing emissions, but it also takes into account their impact on the competitiveness of the Dutch industry and the developments of international markets for hydrogen, electricity and carbon. The project formulates policy recommendations based on these assessments.

The project was funded by the European Commission's SRSS (DG REFORM) with reference SRSS 20NL03 "Sustainable transition of the Dutch industry".

The industrial policy literature, however, points to solutions to overcome these pitfalls. To limit the risk of capture and attenuate information asymmetries, it is necessary to **put an emphasis on the governance of green industrial policies** (Paic and Viros, 2019[7]; Romer, 1993[5]; Warwick, 2013[8]). In particular, it is necessary to:

- Favour their inclusiveness, by ensuring that all the relevant firms, including young and small, are solicited to participate.
- Plan at inception scheduled assessments and evaluations.

- Allow for failure and plan a regular refit of policies. It is even more important when risks or 'wickedness' (i.e. complexity) are high (Cantner and Vannuccini, 2018[9]; Wanzenböck et al., 2019[10]), as is the case for reaching a carbon-neutral industry.

Moreover, to avoid crowding out private investment in productivity-enhancing technologies, green industrial policies need to include instruments to ensure that workers are equipped with the adequate green skills to allow for low-carbon technology deployment and scale-up.

For these reasons, the transition to a green economy requires a systemic approach to get all the relevant institutions in motion. Policy makers should simultaneously consider economic actors, institutions and market failures, working from a clear broadly supported mission target. A transition creates complex co-ordination problems and fundamental uncertainty holds back potential investors. This requires public co-ordination, co-investing and public-private risk sharing, as well as co-operation and co-ordination at the European level (Mazzucato, 2011[11]; Schipper-Tops et al., 2021[12]).

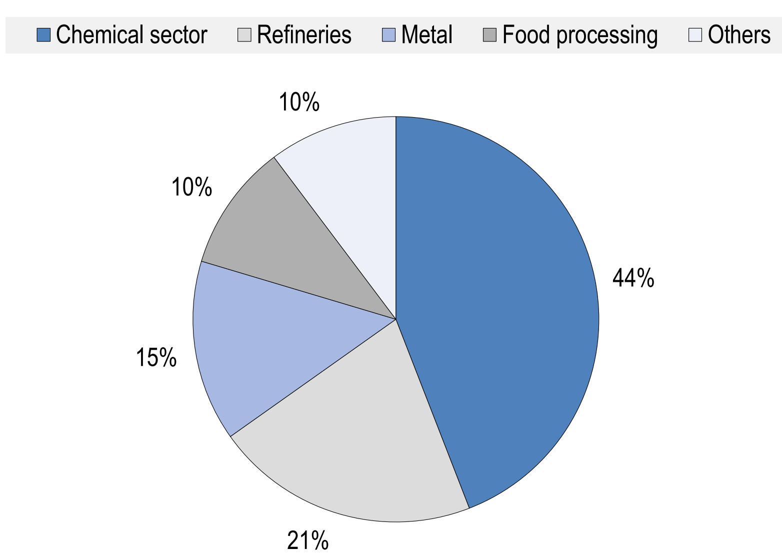
1.2. The Dutch case in practice

1.2.1. Dutch industry: clustered, open and European

The Dutch industry structure features three main characteristics: [2]

- **Four sectors account for 90% of industry's direct (Scope 1) greenhouse gas (GHG) emissions** in 2018: chemicals, refineries, metals (iron and steel, non-ferrous metals) and food processing (Figure 1.2). The heaviest emitter is the chemical sector (notably petrochemical products and nitrogen compounds), representing 44% of industrial emissions. These four sectors also account for a significant share of industry's Scope 2 emissions (i.e. indirect emissions from electricity purchased and used), as they represent 72% of the electricity use of the manufacturing sector.[3]

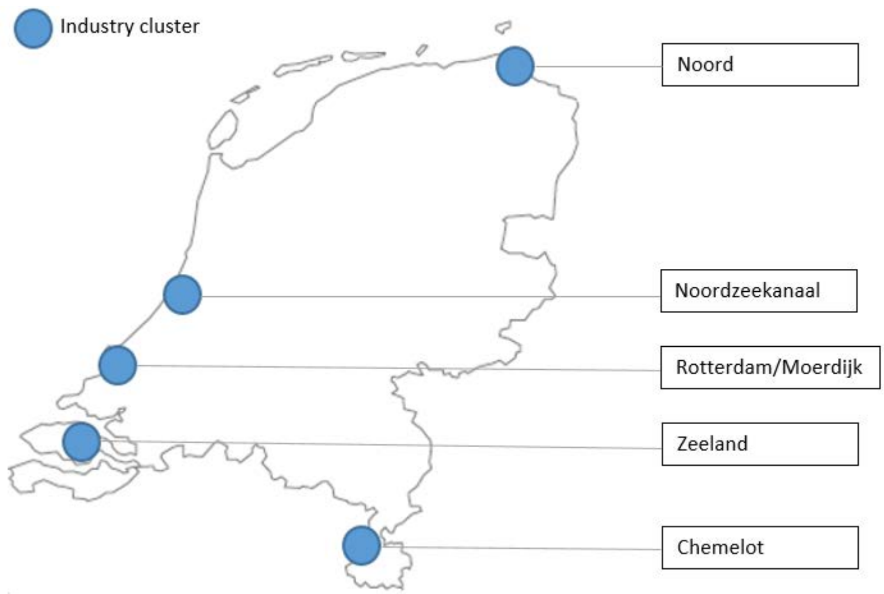
Figure 1.2. Direct GHG emissions of the industry by sub-sector, 2018



Note: This graph only includes direct emissions (Scope 1).
Source: Eurostat (Air emissions accounts by NACE Rev. 2 activity), OECD calculations.

- Dutch emission-intensive industry is very concentrated, with 12 firms accounting for more than 60% of the industrial emissions.[4]
- Five regional clusters include most of the heavy emitters (Figure 1.3): "Rotterdam-Moerdijk"; "Smart Delta Resources" (Zeeland); "Chemelot" (South-Limburg); "Noord Nederland" (Eemshaven, Delfzijl and Emmen) and "Noordzeekanaalgebied" (Amsterdam-IJmuiden).

Figure 1.3. Industry clusters in the Netherlands

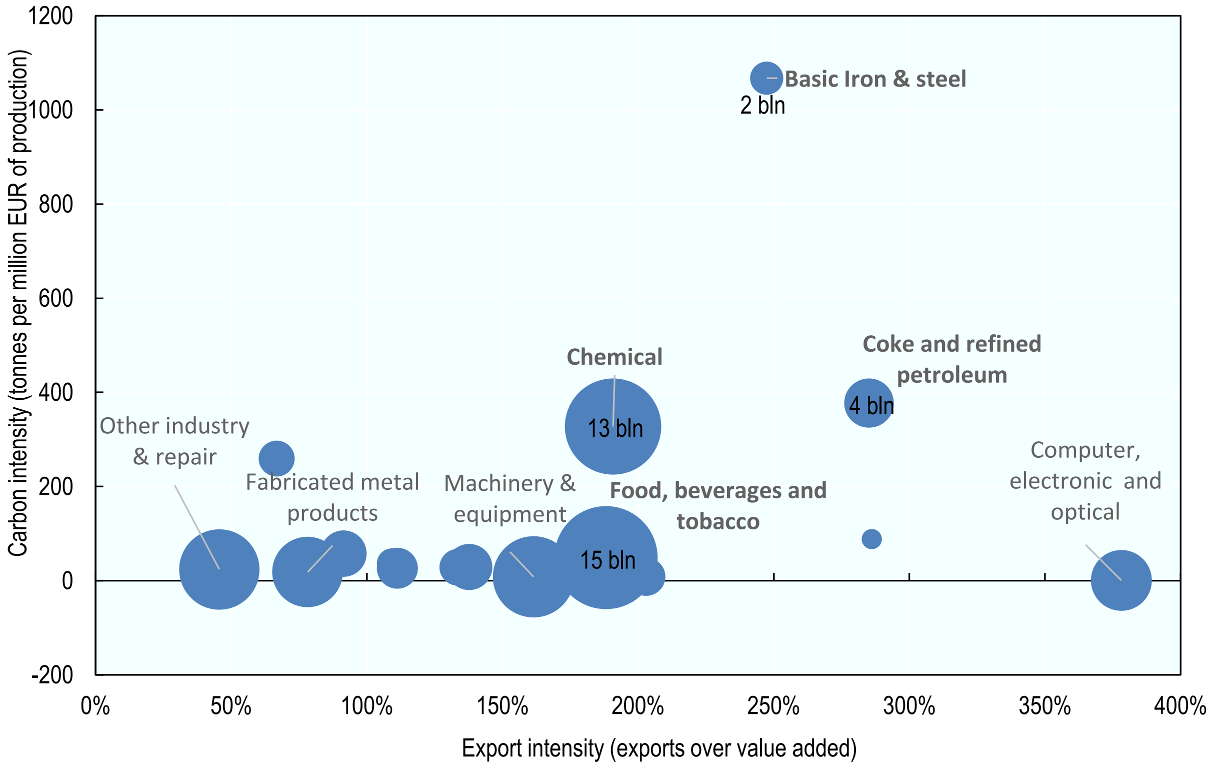


- Moreover, the Netherlands is specialised in products that are both highly traded and carbon-intensive (Figure 1.4). Together, the four main carbon-emitting sectors that this project focused on represent only 2.5% of total employment in the Dutch economy, but account for 10.9% of output and 22.9% of exports. This large export share reflects strong competitiveness in global markets: in comparison, the same four sectors represent 16.1% of exports in Germany and 14.8% in the EU-27 (respectively 8.5% and 9.1% of output).[5]

Given the export intensity of large industrial emitters, their ability to compete in international markets needs to be carefully taken into account. There are many ways to address competitiveness concerns – including subsidies to technology adoption, exemptions from carbon pricing, or adjustments at the border (OECD, 2020[13]) – but not all are compatible with decarbonisation incentives. Preference should be given to instruments that keep decarbonisation incentives in place; a qualification that exemptions from carbon pricing typically do not meet.

Finally, the Netherlands is a member state of the European Union and, as such, must articulate its national decarbonisation policy with European policies, such as EU ETS. The European policy landscape is evolving fast, with the European Green Deal being progressively unveiled. The ambition of the European Green Deal is to transform the European Union into a resource-efficient and competitive economy with no net GHG emissions by 2050. The Green Deal notably aims at proposing a revision of the EU's climate and energy legislation by June 2021, including revisions to the European Energy Tax Directive and the EU ETS Directive. In addition, several mechanisms for a potential carbon border adjustment mechanism are currently being discussed.

Figure 1.4. Carbon intensity and export intensity of manufacturing sectors in the Netherlands in 2015

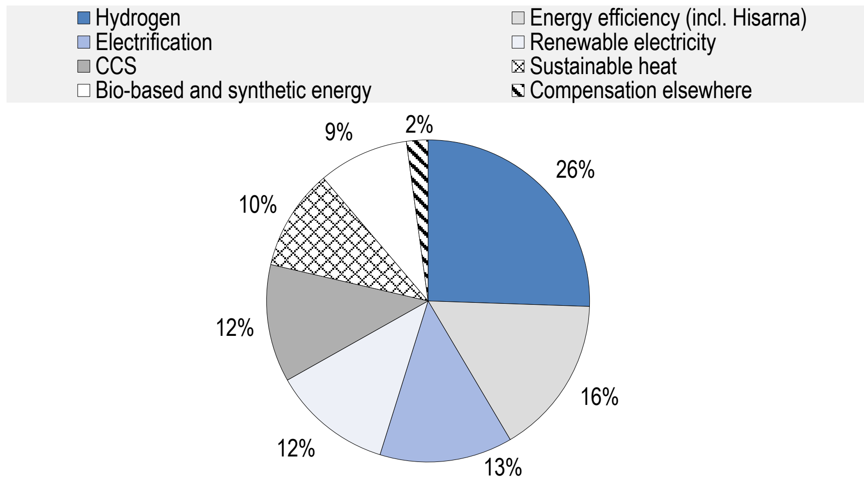


Note: The value added of the industry is presented by the size of the circles. The value added of the four main industries is as follows: 15 billion for the food industry, 13 billion for the chemical industry, 4 billion for the refineries industry and 2 billion for the basic iron and steel industry.
Source: Estimates for CO_2 emissions are based on the OECD Air Emission Accounts and the IEA CO_2 Emissions from Fuel Combustion. The estimates for value added and exports are based on the OECD's Inter-Country Input-Out (ICIO) Database (2018).

1.2.2. A diverse portfolio of low-carbon technologies

The decarbonisation of Dutch industry will rely on a diverse portfolio of technologies, as illustrated by the zero-emission 2050 scenario for the Dutch industry developed with Berenschot (Figure 1.5). At the 2050 horizon, the economic and technological uncertainty is such that this scenario can only be considered as plausible depending on certain assumptions and choices, regarding technologies, policies and the economic environment. Nevertheless, this decarbonisation scenario was designed by carefully taking into consideration the specificities of Dutch industry and its clusters, and was discussed with and validated by industry representatives and experts. Therefore, it can be considered as the most reasonable pathway given current knowledge. The scenario covers the decarbonisation of Scope 1 and 2 emissions, while Scope 3 emissions are not systematically included. Nonetheless, emissions linked to energy carriers that are used as a feedstock (e.g. crude oil in refineries, natural gas in ammonia production and coal in steel production) are considered.[6]

Figure 1.5. Contribution of different technologies in Scope 1 and 2 emission reduction, 2015-50



Note: The scenario covers four manufacturing sectors: chemical, metallurgy, refineries and food-processing. The contribution of "Renewable electricity" corresponds to the abatement of the 2015 Scope 2 emissions, which would be overturned by completely shifting to renewable electricity sources by 2050. The contribution of "Electrification" corresponds to additional electricity needed to reach the carbon neutrality objective in 2050, assuming that this additional electricity is also renewable and carbon-neutral.
Source: Based on Berenschot (2020[14]).

Four main conclusions come from the scenario analysis.

First, the decarbonisation of Dutch industry may significantly rely on technologies that are far from mature today, notably (green) hydrogen, which would replace natural gas in high-temperature processes.

Second, **a massive increase in renewable electricity generation is needed to support the decarbonisation of Dutch industry**. The scenario developed with Berenschot relies heavily on electricity consumption in industry, which doubles between 2015 and 2050, even without including the electricity needed to produce green hydrogen. Electricity is assumed to become fully carbon neutral in the meantime, thereby avoiding Scope 2 emissions.

Third, **CCS would still be needed in 2050**. Although this is nowadays one of the cheapest options to decarbonise industries producing flue gases with high concentration of CO_2 (such as ammonia, iron or hydrogen production from steam methane reforming), the use of CCS may slow down the development of renewable energy sources and maintain a reliance on fossil fuels. The Dutch Climate Agreement emphasises that "CCS should not impede the structural development of alternative climate-neutral technologies or activities for carbon emission reduction".

Finally, **more than half of the decarbonisation hinges on technologies that require the development or the upgrading of infrastructure**, notably to reliably provide (green) hydrogen and renewable electricity and to transport the captured CO_2 to storage locations.

1.2.3. A two-pillar strategy: carbon pricing and technology support

The Dutch government has recently introduced new policy instruments geared at achieving the targets of the Climate Agreement, most notably reducing industry emissions by 14.3 Mt CO_2-eq by 2030. These instruments come in addition to a set of existing tools at the national and European levels, resulting in a large number of instruments supporting the low-carbon transition. This set of instruments can be broken down into two main pillars.

The first pillar aims at delivering a clear carbon pricing signal over the medium term (to 2030) while cushioning the potential negative effects on competitiveness in the short to medium term. In 2021, the

Netherlands implemented a new carbon levy in industry that sets out an ambitious price trajectory until 2030, even if its survival depends on the outcome of the general elections in March 2021. The carbon levy comes on top of several other existing instruments that effectively put a price on Dutch carbon emissions: the EU ETS; energy tax on natural gas; and a sustainable energy surcharge (Opslag Duurzame Energie [ODE]) on natural gas.[7,8] Concerns over competition that domestic energy users may face from firms in countries with less ambitious carbon pricing policies have led the Dutch authorities to grant extensive preferential treatment to energy-intensive users, including generous tax exemptions, regressive energy tax and ODE rates, and freely allocated emission allowances. Providing preferential tax treatment to large energy users still constitutes widespread practice across EU countries. Importantly, beneficiaries in the Netherlands obtain tax relief on the sole criterion of energy use, with no differentiation based on the actual exposure of a sector to international competition. Moreover, proceeds from the ODE are used to finance the main subsidy scheme supporting the deployment of low-carbon technologies (SDE++), with a view to attenuating the potential costs to competitiveness.

The second pillar aims at supporting the uptake of low carbon technologies, focusing on the cost-efficient deployment of a number of emerging and radically new technologies (e.g. blue and green hydrogen, respectively, Box 1.2) through several subsidy programs and tax incentives, with the new SDE++ acting as a spearhead. At earlier stages of technology readiness (R&D and demonstration), the Netherlands mostly relies on horizontal support and EU funding.

To be successful, the two-pillar strategy requires a broader environment that is conducive to the low-carbon transition. This includes implementing complementary policies, including regulatory instruments such as standards, and rapidly deploying public infrastructure, which seems particularly pressing for Dutch industry. Framework conditions are also critical, particularly as regards innovation capabilities, training and firm dynamics. In this respect, firms in the Netherlands enjoy among the most accommodative conditions for doing business across OECD countries, which will likely facilitate the necessary reallocation of labour and capital resources.

Box 1.2. Ways of producing hydrogen: grey, blue, green

Grey hydrogen is produced via steam methane reforming or auto-thermal reforming using natural gas (or coal as in China). Grey hydrogen is the most widely used today, but its production leads to carbon emissions.

Blue hydrogen is the same process as above except the carbon emissions from burning natural gas are captured and stored, or reused. This production process drastically reduces carbon emissions compared to grey hydrogen. However, this process is not carbon neutral either, since the capture rate is usually lower than 100%.

Green hydrogen is produced from electrolysis using renewable energy. This process breaks water down into hydrogen and oxygen. Three main technologies exist today: alkaline electrolysis, proton exchange membrane (PEM), solid oxide electrolysis cells. This process is carbon-neutral.

1.2.4. A bottom-up approach: strengths and weaknesses

Policy design in the Netherlands rests on a bottom-up approach, based on detailed information provided by large firms, sectors and clusters on the availability and cost of selected decarbonisation technologies. The main support instruments, such as the abatement payment SDE++ and the corporate tax allowances, energy investment allowances (EIA) and MIA (*Milieu-InvesteringsAftrek* - environmental investment deduction), rely on lists of eligible technologies to benefit from support. These lists are regularly updated based on firms' suggestions. For SDE++, the Netherlands Environmental Assessment Agency (PBL, Planbureau voor de Leefomgeving) provides a set of parameters for each technology (such as full-load hours, coefficient of performance, etc.), which are used to calculate the subsidy amount. The carbon levy trajectory is also based on a bottom-up approach: the 2030 carbon price was determined as the price needed to reach the 2030 emission reduction objective given an estimated abatement cost curve. This curve is regularly reassessed based on reviews of the engineering literature and on information contained in subsidy requests, in particular to the SDE++.

This strategy is very demanding in terms of information, but this information is easier to obtain than in other countries thanks to the concentrated and clustered structure of Dutch industry, which requires interacting with a smaller number of stakeholders. Clusters and their decarbonisation plans play an important role in informing national policies.

This unique bottom-up approach allows the government to fine-tune support at a granular level and ensure it corresponds to the needs of firms. However, this also makes the need for good governance more acute, and requires flexibility and reactiveness in policy-making. In particular, it is critical to try to ensure that smaller and younger firms, as well as firms outside the clusters, can also participate in the consultation processes. It is also important to maximise the "additionality" of public support, i.e. by avoiding targeting firms that would invest anyway and therefore gain a windfall profit. Regular assessments and evaluations of the policies should be provided for and their results must inform the retrofitting of the schemes in a timely manner. In a rapidly changing technological landscape, support to specific technologies must be reassessed on a regular basis and reallocations should not be considered as a failure, but as a sign of the uncertainty surrounding the maturation of these industrial processes. The trade-off between providing certainty to investors and regularly reconsidering policy targeting needs to be carefully addressed.

1.3. Carbon and electricity pricing: a clear carbon price trajectory, tempered by overlapping competitiveness provisions and uneven rates across firms and sectors

Carbon pricing is a cornerstone of the Dutch policy toolbox for industry decarbonisation. If implemented well, it is a cost-effective means of reducing carbon emissions, and a necessary but likely not sufficient condition for a cost-effective low-carbon industry transition. By raising the cost of carbon-intensive products relative to carbon-free alternatives, well-designed carbon pricing provides a technology-neutral incentive for low-carbon investment and consumption choices.

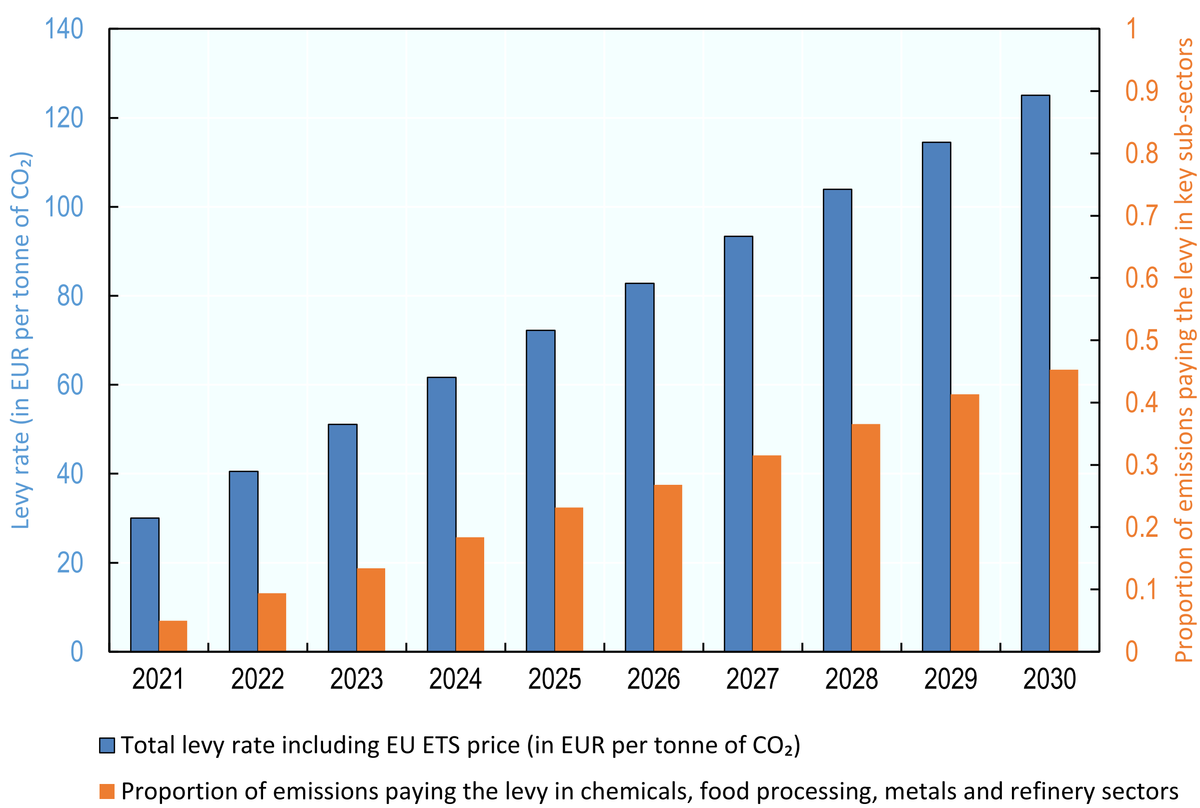
Starting in 2021, the Netherlands has implemented a new carbon levy in industry that sets out an ambitious price trajectory until 2030 (Figure 1.6), providing a clear signal to invest in long-term low-carbon assets and infrastructure. The levy adds a floating contribution on top of the EU ETS allowance price to yield a fixed price on Dutch emissions covered by the system. This price floor provides more certainty over future prices and protects investors against price volatility of the EU ETS allowances. As such, **the carbon levy sends a strong medium-term signal to encourage significant decarbonisation of industry**.

A key feature of the carbon levy is the combination of a pre-defined price trajectory with a levy base that phases-in over time. Initially generous allocation of so-called "dispensation rights" imply that the additional carbon price will effectively kick in only gradually, with the vast majority of emissions not paying the levy initially (Figure 1.6). The government's objective is to avoid immediate threats of carbon leakage. The advantage of this approach is that committing today to future price increases can **create strong incentives for low-carbon investment without immediately burdening businesses with new taxes**. The commitment device is not perfect, however, – changes in political majorities can always roll back previous policies – but the fact that the levy was developed through the widely accepted Climate Agreement has likely widened the acceptability and credibility of the instrument. The drawback of this design feature is that the allocation of dispensation rights largely erodes the carbon pricing signal in the short-run, weakening incentives for low-carbon investment for some users.[9]

Keeping the carbon levy trajectory in place (and potentially extending it to 2050) is critical for a cost-effective technology transformation, i.e. to ensure that incentives through carbon and energy pricing align with decarbonisation objectives. This applies in particular to the further development and deployment of new emerging technologies (such as carbon capture utilisation and storage, electrification of heating, recycling and bio-based materials, which all depend heavily on the relative cost of electricity compared with fossil fuel based alternatives). Providing a clear carbon price path can make these investments worthwhile. Helping these technologies to become profitable will not only stimulate their uptake, but also incentivise R&D activities, which are necessary to reduce their costs. Direct support to R&D can only partially compensate for strong carbon pricing, as investment support alone is not enough to make the business case for investing in low-carbon assets, as illustrated by the relative failure of green recovery packages adopted during the Global Financial Crisis (Agrawala, Dussaux and Monti, 2020[15]).

An important limitation of existing carbon pricing instruments in the long run is that they can in theory drive emissions down to at most zero. Yet, the modelling analyses indicate that negative emissions will likely be necessary to reach the 2050 decarbonisation goal. Questions will therefore arise on whether current policies can provide enough incentives for negative emissions and what role markets could play to stimulate negative emissions.

Figure 1.6. Total levy rate and estimated proportion of emissions paying the levy in the four key sub-sectors, 2021-30



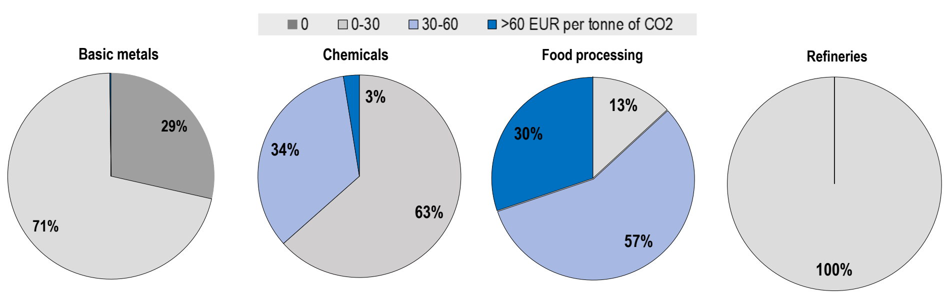
Note: The levy rate includes the floating national contribution and the EU ETS price. The estimated proportion of emissions paying the levy covers only the chemicals, food processing, metals and refinery sectors. It assumes benchmark values follow the draft revision of the EU ETS benchmarks published in December 2020. No behavioural adjustments in the emissions base, i.e. no technological shifts, no energy efficiency improvements or rebound effects compared to 2021 are assumed.
Source: CE Delft (2021[16]).

1.3.1. The Dutch Effective Carbon Rate – a synthetic indicator of carbon pricing in the Netherlands

The carbon levy comes on top of several other existing instruments that effectively put a price on Dutch carbon emissions: the EU ETS, energy taxes and ODE on natural gas.[10] However, competitiveness concerns have motivated the introduction of extensive preferential treatment to energy-intensive users – in particular the chemicals, refineries and basic metals sector – in the form of tax exemptions, regressive tax rates, and freely allocated emissions allowances. Preferential treatment for certain trade-exposed and energy-intensive industrial users are a widespread practice within Europe and the rest of the world. However, the regressive rate structure in the Netherlands provides additional relief to large energy users on the sole criteria of energy-intensity and size, with no differentiation based on the actual exposure of a sector to international competition or the carbon-intensity of energy use.

The concrete application of these instruments including the preferential treatment they entail yields a **very heterogeneous effective carbon rate across energy users within industry**.[11] Figure 1.7 indicates the variation in marginal carbon prices that apply to emissions from fossil fuel energy across the four key industry sectors in 2021. Striking differences appear. In the basic metals sector, a third of emissions are not priced at all and the rest priced at below EUR 30 per tonne. In the refinery sector, all emissions are priced below EUR 30 per tonne, whereas the food processing sector pays EUR 30 per tonne or more on 87% of its emissions. The chemicals sector stands in between and features important within-sector heterogeneity, with 63% of emissions priced below EUR 30 per tonne and 37% above EUR 30.

Figure 1.7. Proportion of CO_2 emissions from fossil fuel energy use in industry at different marginal price intervals in 2021



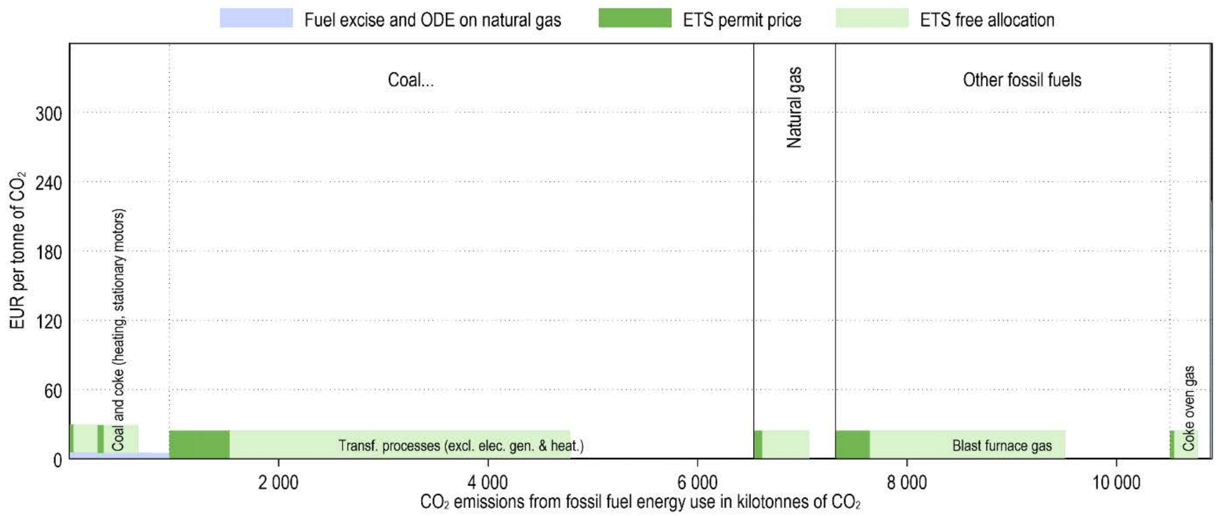
Note: Figures are based on OECD Taxing Energy Use and Effective Carbon Rates methodology (2018[17]; 2019[18]). They include price signals from energy tax and ODE on natural gas (net of exemptions) and the EU ETS permit prices (independent on whether an allowance was allocated for free or not). The national component of the carbon levy is set to zero for 2021 because of the large amount of excess dispensation rights in 2021. CO_2 emissions are calculated based on fossil fuel energy use data adapted from IEA World Energy Statistics and Balances (2020[19]).

The carbon price also varies widely within sectors. For example, in food processing given the regressive rate structure, the largest natural gas consumers pay the lowest available tax and ODE rates. Substantial taxation arises only for small and medium sized consumers of energy.

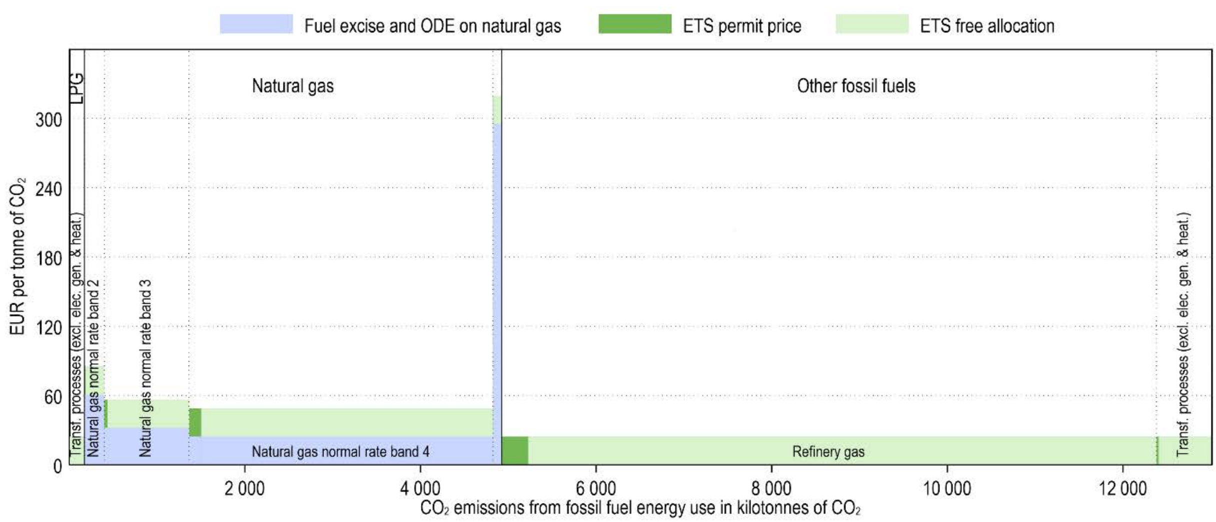
The *marginal* effective carbon rate presented in Figure 1.7 considers energy tax and ODE exemptions, but not the free allocation of EU ETS allowances. It assigns permit prices to the ETS emissions base independently on whether allowances are freely allocated or not.[12] **Accounting for freely allocated emission permits significantly narrows the base of carbon pricing in the chemicals, metals and refinery sectors as shown in** Figure 1.8**.**

Figure 1.8. Effective carbon rates on CO_2 emissions from fossil fuel energy use in key sectors, 2021

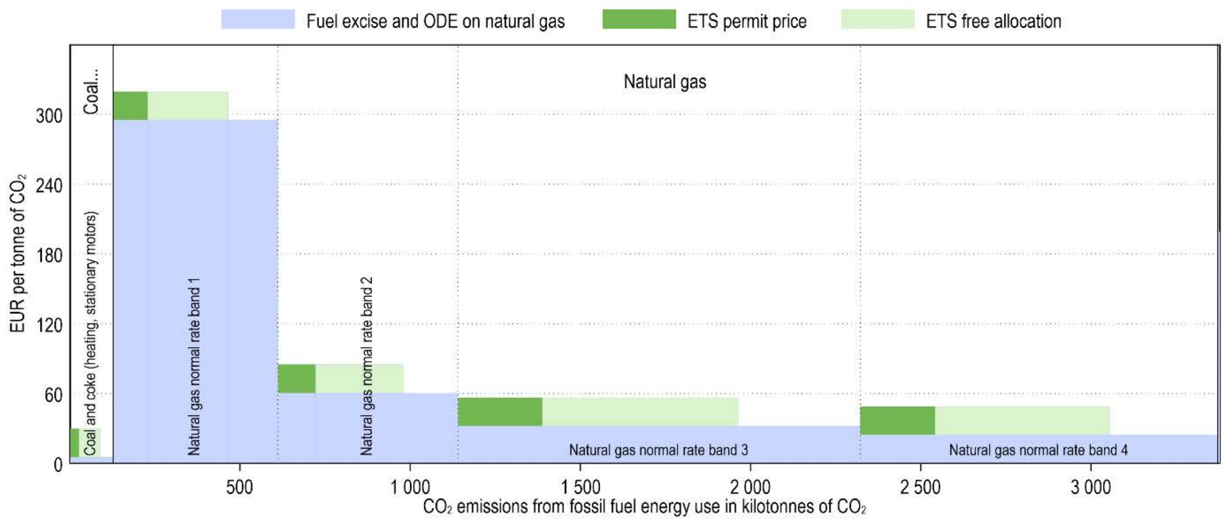
A. Basic Metals



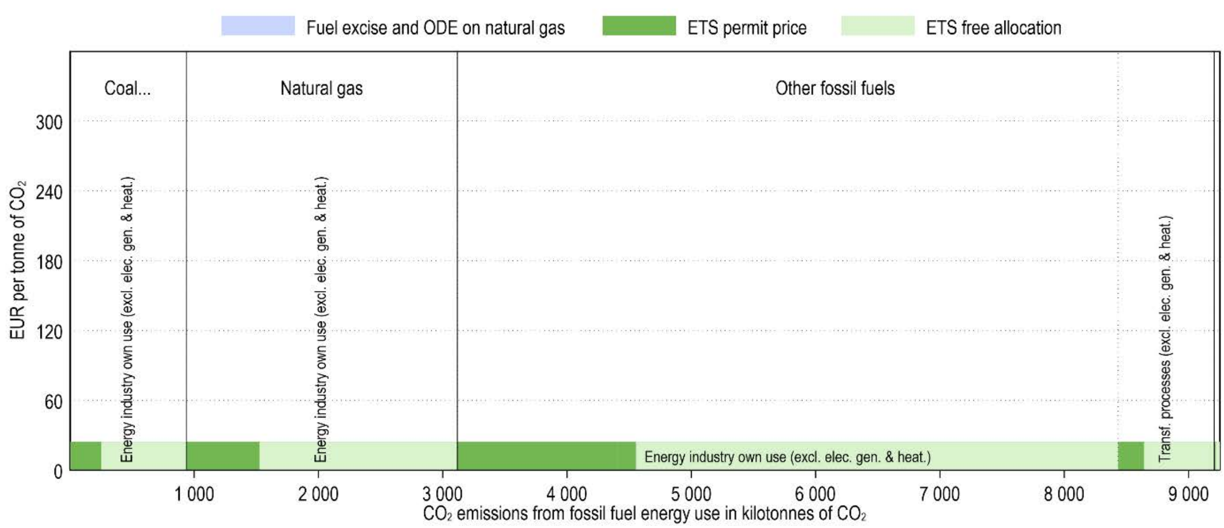
B. Chemicals



C. Food processing



D. Refineries



Note: Figures are based on the OECD Taxing Energy Use and Effective Carbon Rates methodology (2018[17]; 2019[18]). They include energy tax on natural gas ("fuel excise") and ODE rates on natural gas (net of exemptions) and the ETS permit price (accounting for free allocation). The national component of the carbon levy is set to zero for 2021 because of the large amount of excess dispensation rights in 2021. CO_2 emissions are calculated based on fossil fuel energy use data adapted from IEA (2020[19]), World Energy Statistics and Balance.

Taking the free allocation of emission permits in the EU ETS into consideration reveals differences that are even more notable. In 2021, the *average* effective carbon rate is estimated at EUR 76 per tonne for the food processing sector, against an average rate of EUR 13 per tonne in chemicals, EUR 3 per tonne in basic metals and EUR 7 per tonne in refineries. Importantly, applied on the current emissions base, **the carbon levy of EUR 125 per tonne would not change this unequal price signal across sectors, with average effective carbon rates estimated between EUR 24 in basic metals and EUR 92 in the food industry** under such a scenario.

From a pure decarbonisation perspective, the preferential treatment of energy-intensive users adds economic inefficiency to the overall carbon-pricing signal and entails horizontal equity concerns. Uneven prices imply that abatement efforts may not arise where they are cheapest, thereby increasing the total costs from decarbonising the Dutch industry sector. In addition, while minimal price signals reach the energy-intensive users, the less concentrated industries and small energy users pay a relatively high price per tonne of carbon.

Both observations call for **broadening tax bases and gradually removing exemptions and preferential rates**. A future review of the energy tax and the ODE on natural gas could aim to rationalise the design of the tax, establish a uniform rate across users and fuels (including coal and liquid fuels) based on their carbon content and remove exemptions. To start with, energy tax and ODE exemptions are not based on the trade exposure of industrial sectors, but rather on their energy consumption. Phasing-out inefficient and unequal tax and surcharge exemptions should be facilitated through the generous low-carbon technology-specific support for energy-intensive users introduced by the SDE++ and even more so if European trade partners simultaneously strengthen the carbon price signal. In the context of the ongoing discussions on the EU Green Deal, a revision of the Energy Tax Directive provides room for such an approach.

The recommendation to re-evaluate preferential energy tax provisions aiming at preserving the competitiveness of trade-exposed energy-intensive sectors has to be viewed in the context of recent policy developments in the Netherlands and in Europe, which questions the justification for extensive exemptions in the first place. First, **the generous technology-specific abatement payment for industrial users provided by the new SDE++ will likely reduce competitiveness concerns substantially**. Secondly, with the entire EU embarking on an ambitious journey toward carbon neutrality by 2050, competitiveness concerns with respect to other EU Member States are likely to fade away rapidly.

In the case that international competitiveness remains a concern in the future, **alternative mechanisms exist that address competitiveness concerns** of energy-intensive and trade-exposed sectors, while keeping decarbonisation incentives in place through ambitious carbon pricing. Alternative measures can be implemented at different levels of governance, e.g. nationally, at EU level, or internationally. At the European level, the implementation of a carbon border adjustment mechanism would directly reduce competitiveness concerns from firms situated outside the EU countries. Ways to implement a carbon border adjustment are currently being discussed at the European level. At the national level, carbon consumption charges could be used in addition to carbon pricing, e.g. excise taxes on domestic consumption of certain carbon-intensive basic materials, such as steel, cement or aluminium, irrespective of their production process or location.[13] Competitiveness concerns from higher prices would be reduced by passing them on in the value chain, where carbon costs are relatively less important. Carbon consumption charges could also strengthen the incentives to efficiently use, reuse and recycle such materials.

The necessity and suitability of such alternative measures in the Dutch context requires a discussion on their design features and implementation, as all measures entail advantages and have their limitations (OECD, 2020[13]).

1.3.2. Effective price signal on electricity use

An additional concern with the taxation of energy that is unrelated to the carbon pricing signal is the current design of the energy tax and ODE on electricity consumption, which does not directly encourage power producers to shift to cleaner sources of energy, and does not provide direct incentives for the decarbonisation of the power sector. The reason is that the electricity tax is not differentiated by energy source, but applies per unit of electricity used. Therefore, it increases the price on all energy sources used for electricity generation irrespective of their carbon content. Pricing the fossil fuel inputs to electricity generation, e.g. via the Dutch carbon floor price in electricity and the EU ETS, would make them more expensive relative to non-fossil energy sources.

The Dutch electricity tax and ODE also discourage the electrification of some parts of the industry sector, because taxing electricity use makes switching to electricity less profitable for end users. For example, the tax rate in gigajoule (GJ) terms is much higher for electricity than for natural gas use in all but the highest consumption bin (Table 1.1). This favours the use of natural gas over electrification of industrial processes. The total price differential between electricity and natural gas use becomes more pronounced taking pre-tax prices into account: in 2020, pre-tax prices in Dutch industry were EUR 4.7 per GJ for natural gas and EUR 17.2 per GJ for electricity for the typical industrial producer.

As with carbon pricing, the design of electricity pricing in the Netherlands raises equity concerns. Key industrial users of electricity do not pay the Dutch electricity tax and surcharge, or pay only little, either because electricity generation for own use is exempt or because large electricity consumers are subject to the lowest possible rate in the fourth consumption band. **This treatment favours concentrated, large electricity users at the expense of small industrial users as well as residential and commercial users**.

The new carbon price for Dutch power generation, which puts a floor price on emissions from electricity generation in the EU ETS, is a welcome development. Yet, the current rate of the carbon floor price falls well below the EU ETS permit price and therefore does not affect the current overall price signal. **To avoid conflicts between environmental and fiscal objectives, the phasing-down of electricity tax and ODE could be co-ordinated with the phasing-in of an effective carbon floor price in electricity and the removal of energy tax exemptions on natural gas use to generate additional revenue**. Eventually, as the energy system is approaching full decarbonisation, electricity taxes could be reintroduced if so desired (OECD, 2019[18]).

Table 1.1. Energy tax rates for natural gas and electricity in EUR per GJ in 2021

	Band 1	Band 2	Band 3	Band 4
Natural gas	13.31	2.50	0.91	0.49
Electricity	26.19	14.34	3.82	0.16

Note: Conversion follows the methodology set out in (OECD, 2019[18]) based on IEA *World Energy Statistics and Balances*. The GJ value of electricity and gas are not strictly comparable, because they are affected by conversion efficiencies, amongst others. Upstream, the electricity price depends on the fuel- and technology-specific conversion efficiency to transform primary energy into electricity. Downstream, using natural gas as an input in some industrial processes may entail larger energy losses compared to using electricity.

Policy recommendations on carbon and electricity pricing

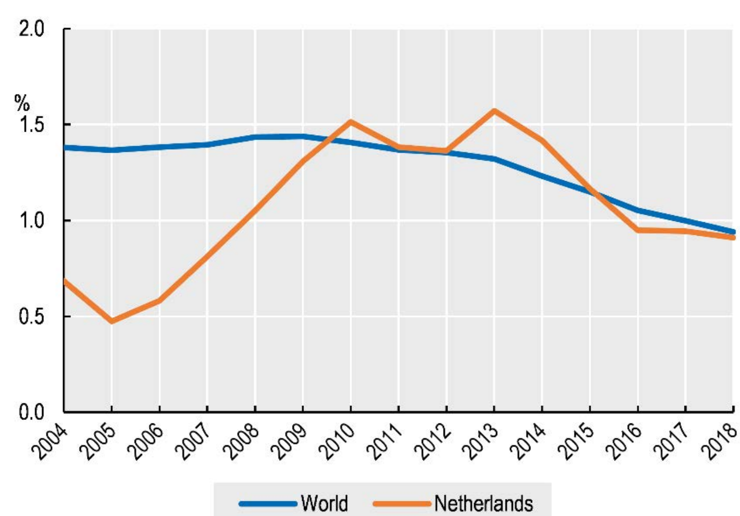
- Maintain the carbon levy trajectory to provide a strong medium-term signal and encourage significant decarbonisation
- Gradually eliminate energy tax and ODE exemptions, as well as regressive rates, to strengthen the efficiency, effectiveness and fairness of the carbon pricing signal
- Engage in a thorough review of electricity taxation to support the country’s need to electrify industrial processes, without burdening small industrial, residential and commercial consumers
- Re-evaluate provisions aiming at preserving the short run competitiveness of trade-exposed energy-intensive sectors in light of policy developments in the Netherlands and beyond

1.4. Innovation and deployment policies: the trade-off between short-term cost efficiency and long-term deep decarbonisation

By complementing carbon pricing with support for technology development and deployment, the Netherlands seeks to achieve two policy goals: the decarbonisation of the industry (which is impaired by knowledge externalities associated with the production of innovation) and the emergence of global leadership in emerging low-carbon technologies. Direct support is intended to bring down the costs of new low-carbon technologies, thereby bridging the gap between these and their carbon-intensive alternatives.

In order to provide empirical insights into Dutch industry's innovation efforts regarding emerging technologies for the low-carbon transition, an analysis of patents filed by inventors located in the Netherlands (as well as patents transferred into the Netherlands by foreign inventors, and exports of Dutch patents) was conducted in five key emerging low-carbon technologies: hydrogen, carbon capture, utilisation and storage (CCUS), electrification of heating processes, biomaterials and recycling. The analysis shows a considerable increase in innovation efforts directed at these emerging low-carbon technologies in the Netherlands between 2004 and 2010: the proportion of patents covering these five technologies in total patenting activity of the Netherlands tripled, from 0.5% to 1.5%. Interestingly, this period corresponded to a significant increase in public support for RD&D in low-carbon technologies, in particular toward CCUS and hydrogen.[14] However, this proportion has decreased since 2013 (Figure 1.9), likely driven by a global decrease in energy prices and a significant drop in domestic public R&D funding following notably the termination of the Economic Structural Strengthening Fund (Fonds Economische Structuurversterking). In 2018, the five emerging low-carbon technologies represented around 1% of total Dutch patenting activity, exactly on par with the global average, suggesting that Dutch inventors are not particularly specialised in low-carbon innovation.

Figure 1.9. Netherlands-based patents in five emerging low-carbon technologies as a share of total patents in all technologies

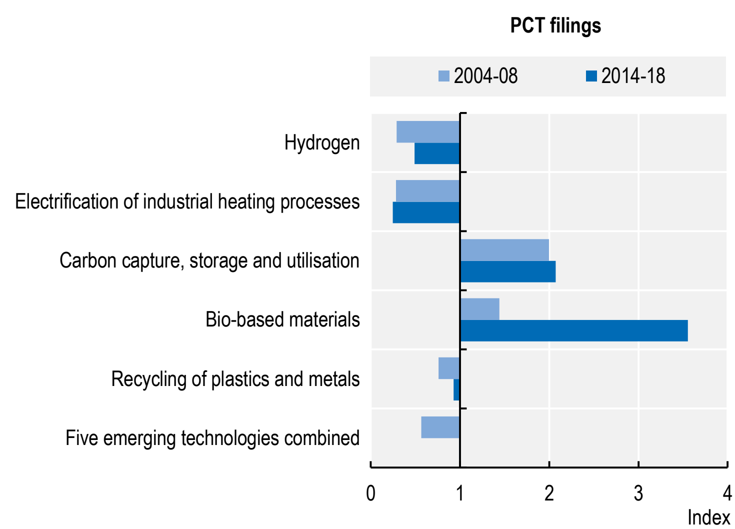


Note: Data refers to patents invented in the five selected low-carbon technologies. Statistics are based on two years moving average.
Source: OECD, STI Micro-data Lab: Intellectual Property Database, http://oe.cd/ipstats, January 2021.

As shown in Figure 1.10, Dutch inventors appear to be specialised in two technologies: CCUS and bio-based materials. These categories are also the ones that have seen the largest increases in recent patenting activity. In bio-based materials in particular, the share of Dutch innovation efforts going into this field is more than three times that of the world average in the most recent period (2014-18). In CCUS, Dutch inventors are twice as specialised as the world's average inventor. In the other three technological fields – namely hydrogen, electrification of industrial heating processes and recycling of plastics and metals – Dutch inventors appear under-specialised compared to the world average.

For a small country like the Netherlands, and given the large fixed costs associated with research into radically new technologies, it might be difficult to promote national champions in all these new technological areas. A possible strategy could be to focus on areas where Dutch inventors seem to possess some comparative advantage, which currently include CCUS and bio-based materials.[15] For other technologies, the Netherlands could rely more on imports from abroad, but adoption of technologies requires absorptive capacities, which also necessitates R&D activity – although not targeted at frontier research.

Figure 1.10. Specialisation of Dutch inventors by technology: a leadership potential in CCS and bio-based materials



Note: The graphs shows the Relative Technological Advantage of inventors located in the Netherlands. The index is computed as the ratio of the share of patents filed for the selected technology by inventors located in the Netherlands to the share of patents in the same technology filed by inventors located in the rest of the world. Data refers to patents invented in the Netherlands for selected low-carbon technologies. Patent counts are based on the filing date.
Source: OECD, STI Micro-data Lab: Intellectual Property Database, http://oe.cd/ipstats, January 2021.

As shown in Figure 1.11, **Dutch support policy for low-carbon technology focuses on the cost-efficient deployment of emerging technologies** through several subsidy programs, spearheaded by the new SDE++. This focus on deployment is specific to the Netherlands – in comparison, Germany, for example, focuses much more on support to fundamental research and development (Chapter 6).

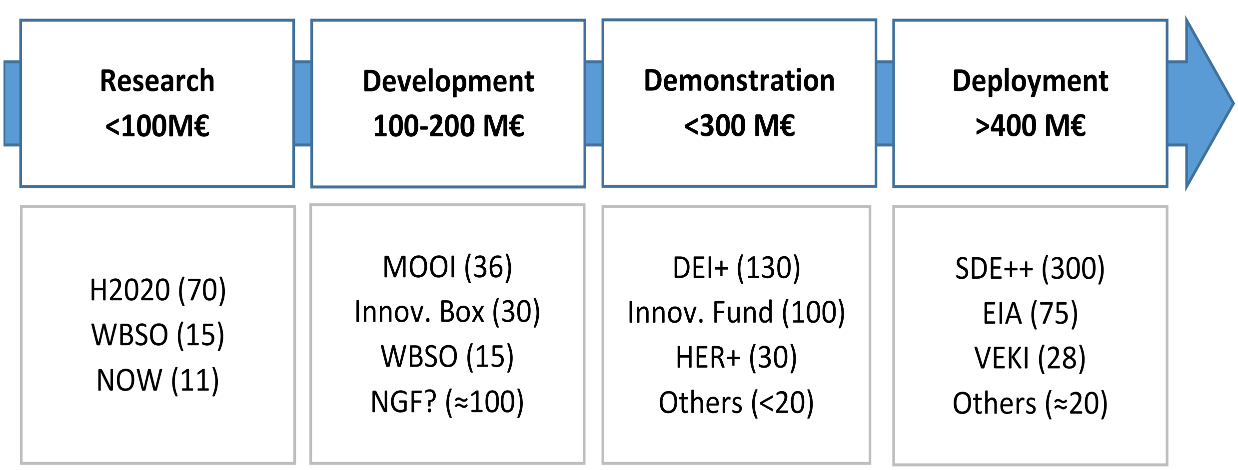
With a future yearly EUR 550 million budget over the long run for the industry sector (and EUR 300 million per year on average until 2030),[16] the SDE++ subsidises the additional costs associated with adopting a low-carbon technology rather than the existing carbon-intensive alternative. SDE++ is the largest support scheme, but other schemes also encourage deployment, including a tax allowance supporting energy efficiency investments (EIA) and tax allowances subsidising capital expenses for low carbon technologies (VEKI and MIA/VAMIL).

Next to deployment, most of the public funding at the national level is focused on demonstration, rather than on research and development. However, many instruments coexist, implying high administrative costs per euro of subsidy and high transaction costs, in particular for young and small firms. This is certainly alleviated by the central role of RVO in the administration of these schemes. Apart from streamlining the innovation package, possibilities to further reduce transaction costs include tailored support to promising firms to help them navigate the different types of subsidies.

In addition, the amount of funding available for demonstration support (less than EUR 300 million per year in total of which EUR 180 million comes from domestic policies, including seven policy instruments with an annual budget below EUR 10 million) is not in line with the typical scale of demonstration projects in the industry (for example, a single 100 MW electrolyser costs around EUR 50-75 million). The current package's apparent funding gap for large-scale demonstration projects contributes to tilting technology towards short-run cost-efficiency. Leveraging either the EU ETS Innovation Fund, the EU IPCEI (Important Projects of Common European Interest – one being hydrogen) or the Dutch National Growth Fund, and re-balancing the innovation policy package to close the funding gap for large-scale demonstration projects, would help breakthrough innovators escape the well-known "valley of death" of clean tech venturing (between research and commercialisation).

For earlier stages of technology readiness (e.g. at the R&D stage), the Netherlands mostly relies on horizontal support (through broad R&D tax credits – WBSO – and the Innovation Box) and on EU funding (in particular H2020). The advantage of horizontal instruments is their technological neutrality, but by construction, they benefit mostly technologies that are closest to the market. The ambitious 2050 objectives and the implied deployment of radically new technologies such as hydrogen might justify a stronger focus on targeted instruments for R&D. As for the reliance on EU funding, this enables benefiting from economies of scale by aligning research programs and co-operation at the European level and makes sense from an economic theory perspective (since knowledge externalities are much larger at the EU level than at the domestic level).

Figure 1.11. Estimated amounts of annual public funding for technology support by stage (in EUR million)



Note: On the estimated SDE++ amount and funding (endnote 16). The average of EUR 300 mln. per year over the 2022-30 period is used.

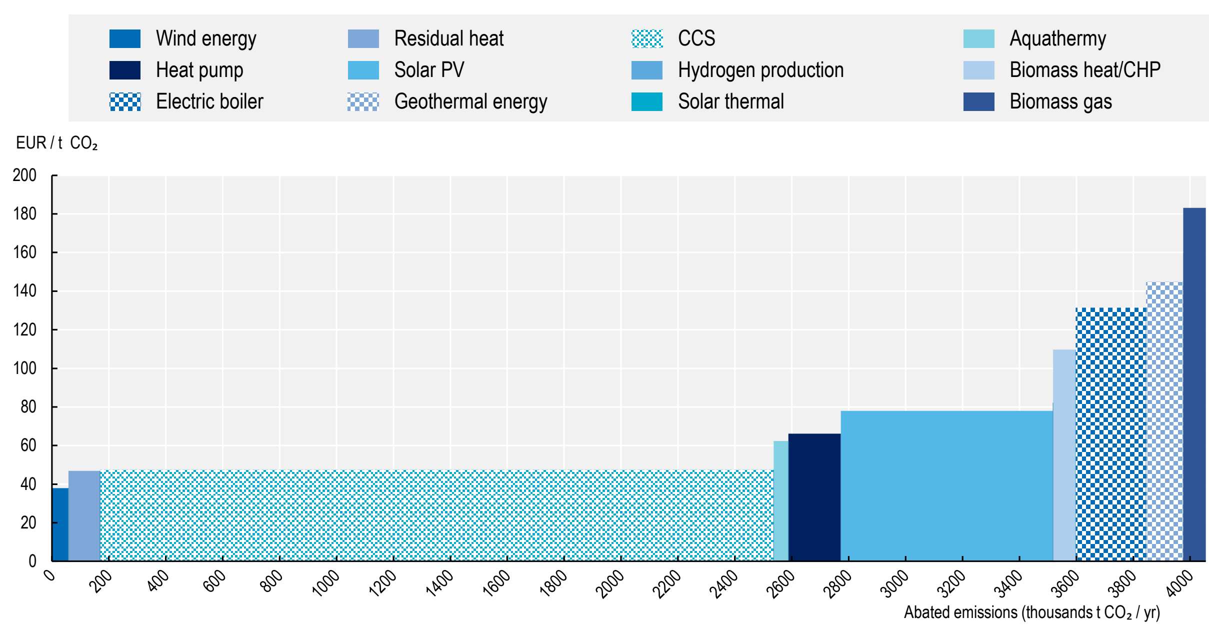
The SDE++ allocates subsidies to project applicants in increasing order of subsidy requirement per tonne of CO_2 reduction in a tender open to a large range of low-carbon technologies, such as CCS, electric boilers, heat pumps, waste heat or green hydrogen production. The abatement payment is defined per unit of avoided CO_2 emissions, i.e. the difference in operating cost (operational expenditures – OPEX) between the low-carbon and the equivalent "standard" technology, factoring in the long-term EU ETS permit price. This gives priority to least-cost options, such as CCS. Therefore, the design of the SDE++ makes the scheme less relevant to support technologies that are still at an earlier stage of development, such as hydrogen. Put differently, the SDE++ currently trades off the promotion of less mature technologies for short-term cost efficiency, thereby potentially compromising long-term cost efficiency.

In principle, SDE++ allocates abatement subsidies on a pure cost-efficiency basis as all subsidy requests are pooled in one single tender, although organised in four phases. This tends to favour close-to-the-market technologies, for which the revenue shortfall with respect to business as usual technologies is small and which can therefore bid at lower costs. Analysis of SDE++ subsidy applications in the first (2020) tender confirms this built-in characteristic: about two thirds of the total amount of requested subsidies in categories that are potentially relevant for industrial applications concern CCS, a technology with lower abatement cost and a technology readiness level (TRL) of 7, i.e. system prototype demonstration in operational environment. By contrast, a negligible share of applications concern green hydrogen, a technology with lower TRL and high operating costs (Figure 1.12).

The very high proportion of CCS applications might end up being specific to the first few tenders, but the priority given to the most mature (and hence most cost-efficient) technologies will remain. Reforming the design of the SDE++ to allow for separate tenders across technologies, production processes or TRL, could promote investment in emerging low-carbon technologies instead of solely favouring low-cost options. The design of the SDE+ (the predecessor of SDE++ aimed at the electricity sector), which provided different tenders at different subsidy levels (linked to distance to the market), could serve as a model in this regard. Such a design change would obviously lower the short-term cost-efficiency of emission reductions, but to the benefit of faster cost reductions in less mature technologies (improving long-term cost efficiency).

Figure 1.12. CCS might crowd out less mature technologies from the SDE++

SDE++ subsidy demand curve in first tender



Note: areas represent the expected subsidy payment based on RVO's long-term prices; actual pay-out will depend on market prices and RVO's grant decision. Category CCS includes "blue hydrogen"; category hydrogen production is "green hydrogen". Amount tendered to categories hydrogen production and solar thermal barely visible. Average subsidy per tonne CO_2 at the technology category level and cumulated abated emissions calculated based on RVO data.
Source: Calculations based on RVO data.

Two case studies of low-carbon alternative to business-as-usual production of hydrogen illustrate the built-in bias of the SDE++ scheme in favour of high-TRL technologies. On one hand, the blue hydrogen alternative (adjunction of CCS on the standard steam-methane reforming production process) is a mature technology with the potential to bridge several chemical and refinery activities to the low-carbon economy. On the other hand, the green hydrogen technology alternative (renewable electricity-based electrolysis) lies at a lower TRL and requires further scale-up and greater cost reductions.

Figure 1.13 shows the cumulative net cash flows associated with the two projects analysed in the case studies: blue hydrogen (black lines) and green hydrogen (blue lines). The net cash flows are calculated by differencing out the business-as-usual (carbon-intensive) alternative. The solid lines correspond to a scenario where no subsidy is received, while the dashed lines show the cumulative cash flows when SDE++ support is granted. All scenarios take into account the savings from the carbon levy, with assumed dispensation rights based on EU benchmarks and counterfactual (business as usual [BAU]) projects' emission intensity.

Looking at the "no subsidy" scenarios, public support appears critical for the viability of both projects, but particularly so in the green hydrogen case. Yet, while both projects are in theory eligible to the SDE++, its design, which favours projects with the lowest abatement cost, implies that the CCS project is very likely to obtain funding while the green hydrogen project is very unlikely to receive the subsidy.

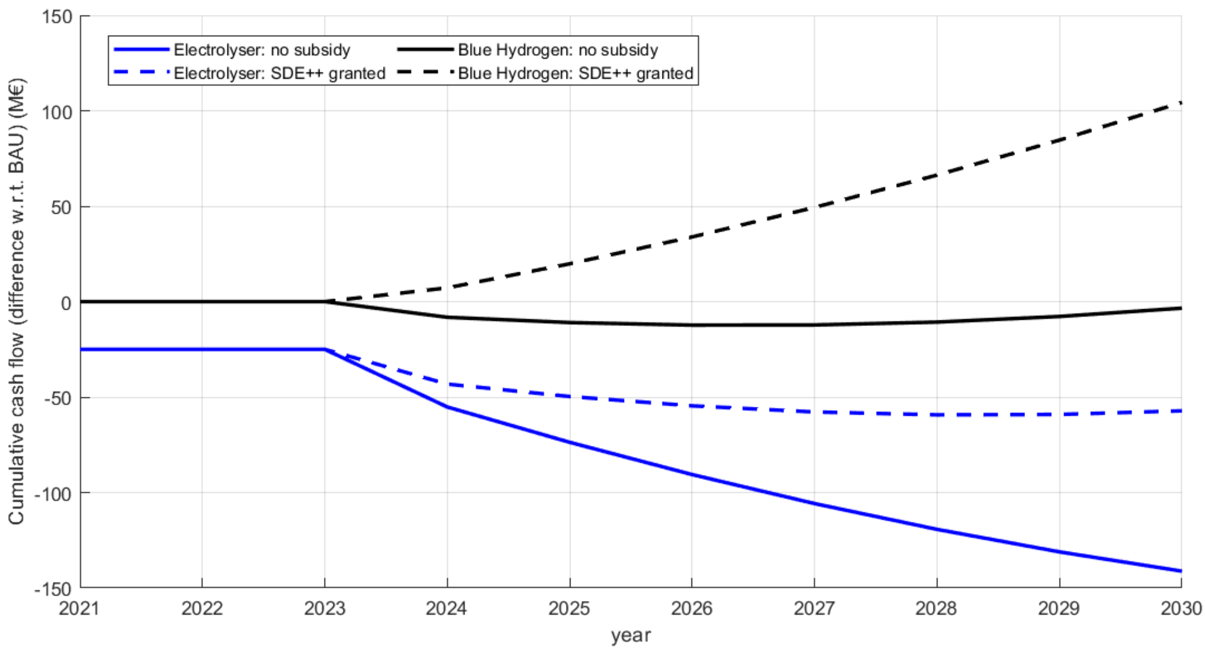
Moreover, the other key feature of the SDE++, which does not take into account savings from the carbon levy to determine the subsidy rate but only the EU ETS price, implies that the CCS project gets "overcompensated" for its emission reductions. Thus, the two case studies also illustrate the interplay of the carbon levy and the SDE++. For the blue hydrogen project, the cost savings on the carbon levy partially make up for the additional cost of CCS and the SDE++ subsidy is large enough to make the project immediately profitable. Under more favourable energy and/or carbon transportation prices, the blue hydrogen project would not even need the SDE++ subsidy to break even. By contrast, the cost savings on the carbon levy are largely insufficient to make up for the investment cost in the case of the green hydrogen project and the SDE++ subsidy – if granted, which is unlikely given the cost-efficiency allocation criterion – fails to make up for the revenue shortfall. If electricity prices remained low, the SDE++ could however make the green hydrogen project break even.

Since the carbon levy is not accounted for in the SDE++ scheme, the savings from the carbon levy therefore appear as a "free lunch" when the SDE++ is granted. It would make sense to consider ways to account for carbon levy savings when determining the SDE++ subsidy rate, just as the savings from EU ETS allowances are already accounted for. This would have the advantage of freeing up some resources for less mature technologies while maintaining the cost-effectiveness criterion.

Stronger support through demonstration-oriented instruments (DEI+ and HER+) could also help to bring about the necessary cost reductions in green hydrogen. However, further cost reductions can only be expected through scaling-up and learning-by-doing. In the absence of other available instruments to support the scaling up of green hydrogen, holding tenders by technology with dedicated budgets or accounting for carbon levy savings could help ensure that the SDE++ also supports emerging technologies in the near future.

Figure 1.13. Accounting for carbon levy savings, CCS requires less support than green hydrogen

Cumulative net cash flows for a blue hydrogen project (CCS on steam methane reformer) and a green hydrogen project, with and without SDE++ support



Note: high electricity prices scenario. Carbon transportation costs are taken as the mean of the PBL estimate and the Gasunie/Energie Beheer Nederland (EBN) estimate. Feasibility study cost incurred in 2021. Capital investment incurred in 2024. Savings from the carbon levy account for dispensation rights based on EU benchmarks and counterfactual (BAU) projects' emission intensity.

Policy recommendations on technology support

- Ensure greater support for technologies that are still far from the market as part of a more balanced approach to technology support across levels of technology maturity
- Consider changes in the design of the SDE++, in particular holding different tenders by technology or production process, and at least partially accounting for the savings from the carbon levy
- Ensure adequate support at all RD&D stages in areas where Dutch inventors have (or potentially have) a comparative advantage – including CCUS and biomaterials – to enable technological leadership, and boost absorptive capacity in the others
- Streamline the innovation support package, particularly at the demonstration stage, in order to improve administration cost efficiency and reduce transaction costs for young firms and SMEs

1.5. Complementary policies and framework conditions

Industry decarbonisation takes place in a broader environment, which includes regulatory frameworks, public infrastructure, competition policies, skills provision and the availability of capital. The characteristics of these framework conditions are also critical for the shift towards a low-carbon economy.

1.5.1. Standards and other regulatory instruments

An important and cost-effective way for the Dutch government to increase the necessary investments in the different green technologies can be achieved through reducing regulatory uncertainty and defining regulatory standards. Reducing uncertainty is particularly important for CCS, where project developers currently run the risk of being held liable for carbon leaks outside of storage facilities or other environmental damage. **Defining liabilities would allow investors in CCS to more accurately price and potentially insure this risk**. The industry, the financial sector and the different levels of government could work together to explore potential risk-sharing solutions should such liabilities create a barrier to market development.

Setting regulatory standards is another important complementary policy. For green hydrogen, this includes standardisation on guarantees of origin, for example if hydrogen is blue or green, but also on hydrogen purity, the design of liquefaction/conversion and regasification/reconversion facilities, for equipment specifications and for blending hydrogen into the gas grid. Standardisation would strongly promote the diffusion of technologies with network externalities. **Hydrogen-related standards would be best defined at the EU level.**

A harmonisation of standards and regulations related to the use of recycled products is necessary to promote the circular economy and, ultimately, address Scope 3 emissions. This is of particular importance in the steel industry, where **relabelling by-products of steel production at the European level (e.g. slag and fly ash) from 'waste' to 'product'** with all due care to avoid pollution hazard would reduce the administrative burden associated with purchasing scrap for companies and increase imports opportunities.

Minimum content requirements, public procurement and removal of fossil fuel subsidies are critical to help create markets for recycled products and synthetic and bio-based feedstock. While such policy efforts would be ideally implemented at the EU level, national minimum content standards and public procurement could already give a necessary boost to the recycling and bio-based industry.

1.5.2. Infrastructure

As the scenario analysis clearly shows, infrastructure needs are extremely important for the decarbonisation of Dutch industry. In particular, the transition to a low-carbon industry requires infrastructure regarding renewable electricity production and distribution, the heat network, hydrogen production and distribution, and carbon transportation (potentially using the existing gas pipeline infrastructure). These infrastructure needs were established by the Taskforce Infrastructure Climate Agreement Industry (TIKI) and the Multi-year Program Infrastructure Energy and Climate (MIEK), and the Ministry of Economic Affairs and Climate has recently announced the creation of a national Infrastructure Programme for a Sustainable Industry (PIDI).

Visibility over future infrastructure plans appear key for industrial firms to undertake investments in low-carbon technologies. **In view of the infrastructure needs implied by the modelling analysis conducted for this project, bringing more clarity and co-ordination at the national, regional and local levels seems pressing for the timely rollout of the necessary low-carbon infrastructure.** The National Growth Fund may contribute to financing infrastructure projects following PIDI's recommendations. Therefore, making PIDI operational should be a priority so that investments can take place. It is crucial that PIDI collaborates with the Exploration of Landing Wind at Sea (VAWOZ) programme, the Energy Main Structure (PEH) programme as well as with neighbouring countries, in particular Germany and Belgium. The Porthos project, which will build and operate a CO_2 transport network between the ports of Rotterdam, Antwerp and the North Sea Port is an example of such cross-country infrastructure planning, with significant financing by the Connecting Europe Facility (CEF) of the European Commission. The Athos project, which is less advanced, is planning to transport CO_2 from the Amsterdam region to the North Sea.

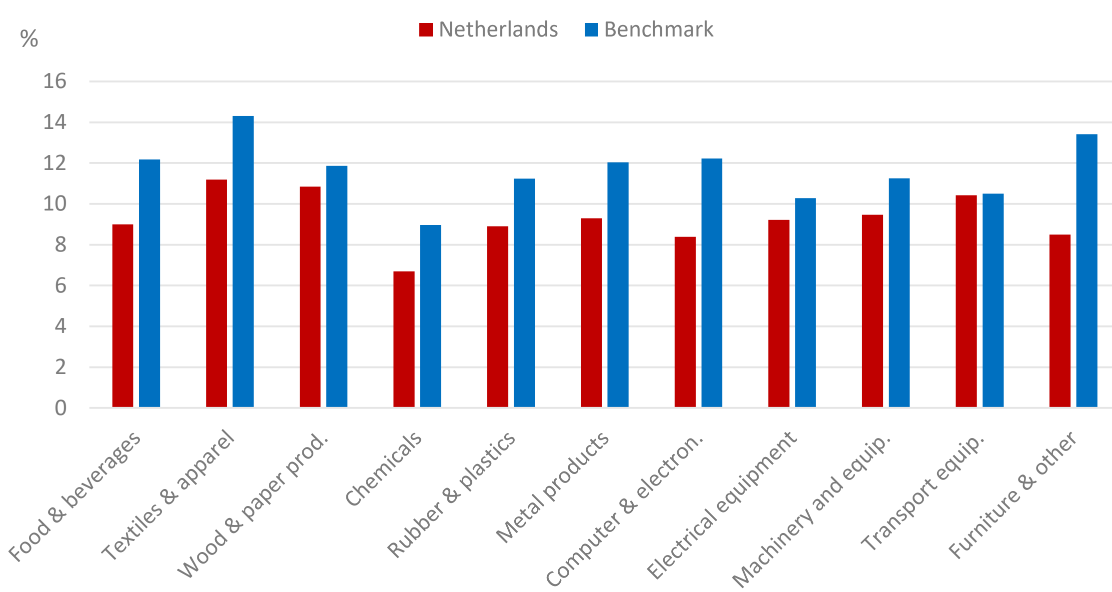
Infrastructure investment and management pose two key challenges, which should be carefully addressed. First, dynamic cost efficiency should be considered, particularly the risk of following too many technology routes that may prove unnecessary or even mutually exclusive, at great cost for public finance. Second, pricing the use of this monopoly infrastructure should be designed to take into account the pricing of externalities such as the integration of more renewables into the grid or demand schedule pricing allowing for intermittencies.

1.5.3. Business dynamism

The reliance on infrastructure for achieving decarbonisation is a consequence of the geographic structure of Dutch industry around highly integrated clusters. This cluster structure contributes to the cost-efficiency of decarbonisation as it promotes the internalisation of scale economies and knowledge spillovers, e.g. the efficient provision of energy carriers and the exploitation of synergies. However, it may also contribute to **locking in sectoral and geographical allocation of resources at the expense of efficiency-enhancing dynamism, therefore coming at a cost in terms of flexibility and adaptability in the longer run** – potentially a major issue at the 2050 horizon, given the uncertainty regarding the technologies that will eventually emerge in the low-carbon transition.

Figure 1.14. Relatively low business dynamism

Job reallocation rate among incumbent firms



Note: churning rates of incumbents defined as the sum of the job creation rates and job destruction rates of incumbent firms, reported by SNA A38 as averages over the period of 2012-15. Benchmark countries include Austria, Belgium, Brazil, Canada, Costa Rica, Finland, France, Hungary, Italy, Japan, Portugal, the Netherlands, New Zealand, Norway, Spain, Sweden and Turkey.
Source: Calculations based on DynEmp3 Database (August 2019).

The Dutch clusters typically harbour a few large players that considerably contribute to international competitiveness. However, **young firms and start-ups are also key to foster innovation and enable the emergence of the next generation of technological leaders**. Therefore, maintaining a sufficient level of business dynamism is key to minimise the downsides of the cluster structure. First, competition should be sufficient *inside* the clusters, so that new firms can effectively enter into these structures, compete and eventually challenge large incumbents. Enabling the reallocation of production factors can have an indirect positive effect on both challengers' and incumbents' incentives to innovate. Second, resource reallocation should be enabled *between* the clusters and the rest of the country, to allow and foster the emergence of alternative decarbonisation options that do not rely on large infrastructure and can be implemented for scattered industries when relevant. This reinforces the need to **ensure that the cost of carbon emissions is the same across sectors and across small (new) and large (incumbent) firms.**

Relatively low worker churn rates across incumbent firms in Dutch manufacturing industries (including metallurgy, food processing and chemical industry) suggest a lack of business dynamism compared to other OECD countries (Figure 1.14). **Enhancing business dynamism through facilitating entry and the reallocation of outputs and inputs across firms towards their highest-valued use would contribute to enabling innovative clean tech companies to emerge**.

1.5.4. Skills for the green economy

Decarbonisation and the transition to the net-zero emission economy will affect both labour supply and demand in the industry. On one hand, skilled installation and maintenance workers are already in short supply in industry (Climate Agreement, 2019) and will be increasingly demanded in the low-carbon economy. On the other hand, decarbonisation will bring about labour reallocation of economic activity, with for example the capacity of refineries projected to decrease by (at least) 40% between 2020 and 2050.

Adequate green skills supply is particularly important for firms engaging in low-carbon technology deployment and scale-up, and likely to promote investment. More generally, it contributes to the overall absorptive capability of Dutch industry, which is a necessary condition for reaping the benefits of supra-national (mostly European) R&D and translate it into local deployment. **Re-skilling and up-skilling displaced workers with green skills through active labour market policies and adult training is immediately necessary to both address social concerns and contribute to reducing skill shortages in the future low-carbon industries.** Cross-sector training programmes can ease labour market transitions from surplus to shortage sectors. Timely and transparent information on sectoral labour markets can help workers to anticipate future labour needs and policy makers to monitor and accompany the changes. With a view to the longer run, education programmes need to incorporate new material and competences in curricula, so that the next cohort of workers can cope with the low carbon transition in the workplace.

1.5.5. Venture capital

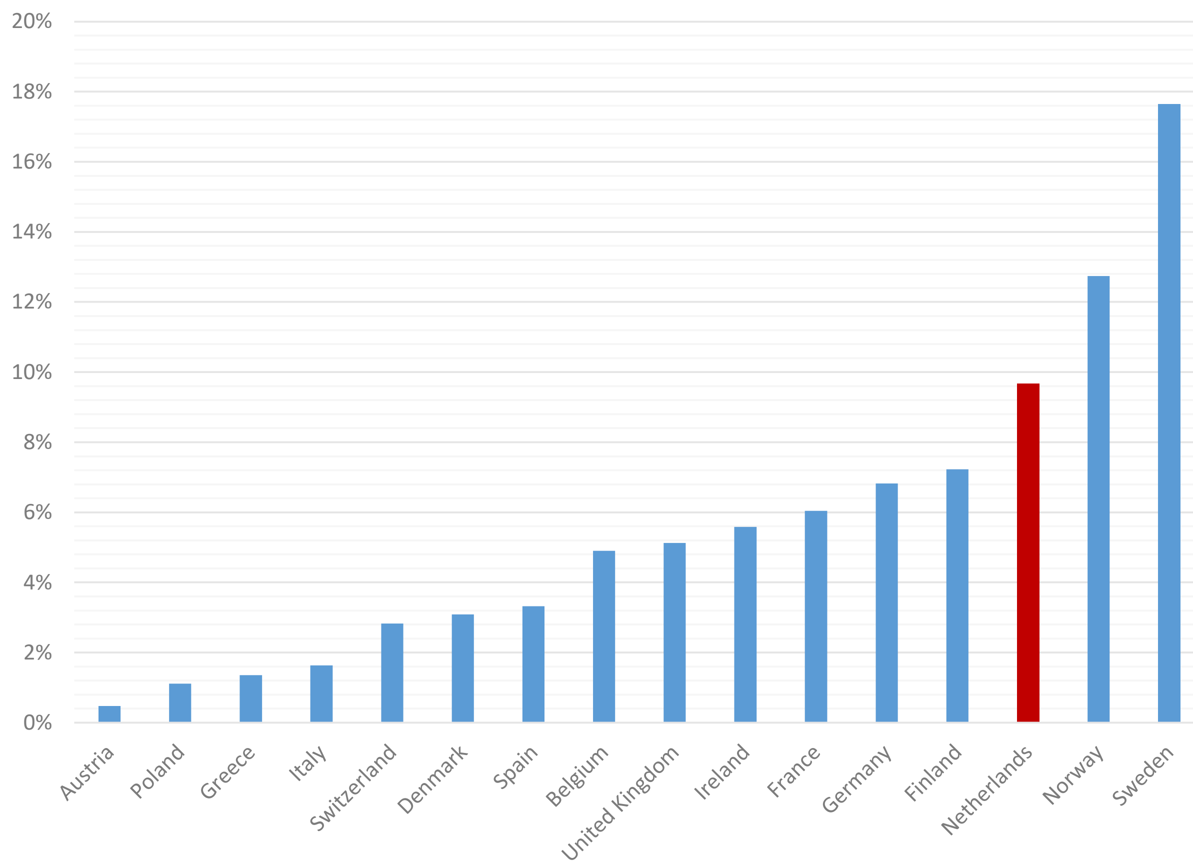
Venture capital (VC) is instrumental in funding, supporting and scaling up young firms developing market-ready technologies. VC is a key complement to government support for technology, as it helps entrepreneurs through the “valley of death” by financing pilots and demonstrations of innovative ideas and prospective technologies, which are often the output of government-funded R&D. More generally, it allows to diversify the sources of funding for new ventures. VC is also important for small companies to move beyond an initial niche market. Moreover, it contributes to knowledge transfer across venture capitalists’ portfolios. In the Netherlands, total VC investments are comparable with the OECD median. The government is very involved in providing VC funding, with half of venture capital invested in the Netherlands related to a government entity.

Importantly, a relatively large share of VC investments focuses on low-carbon technologies in the Netherlands. Data on VC deals suggest that in 2020 about 10% of total VC investments in the Netherlands concern sustainable energy technology firms, which is greater than most other European countries (Figure 1.15). This performance is remarkable given the global decrease in the share of global VC deals accounted for by clean energy since 2012 (IEA, 2020[20]).

The launch of Invest-NL is expected to further improve the Dutch VC landscape, in particular its ability to identify and fund industry decarbonisation. By launching a government-owned national investment fund with a strong focus on low-carbon technologies, the Dutch government signals that VC will be key in funding the transition to the net-zero emission economy and provides the necessary strike force for complementing its technology support policies. VC will bring capital market discipline within the bottom-up, cluster-based overall decarbonisation strategy. Against this background, both **VC investments and the needs of green tech start-ups should be monitored to ensure that Invest-NL contributes to developing a strong green VC ecosystem and promoting industry decarbonisation**.

Figure 1.15. VC investment in sustainable energy technologies across European countries

Share of total VC investment, 2016-20 or available years



Note: share of VC investment in sustainable energy technologies as a share of total VC investment. VC investment in sustainable energy technologies in a given country is the value of all VC deals classified as "affordable and clean energy" by the data provider. Total VC investment is the total value of VC deals taking place in that country.
Source: Calculations based on DealRoom data.

Policy recommendations on complementary policies and framework conditions

- Update the regulatory framework for decarbonisation technologies (particularly CCS) and ensure standardisation (especially for hydrogen and recycling), if possible at the European level.
- Encourage the creation of markets for the circular and bio-based economy in order to address Scope 3 emissions by setting minimum content standards for recycled plastics and bio-based products, and re-labelling by-products of steel production from "waste" to "product" to ease scrap purchase.

- Provide visibility on the infrastructure programmes related to the transportation of hydrogen, electricity, heat and captured carbon, and clarify the role of the National Growth Fund in funding the low-carbon industrial infrastructure.
- Foster competition within and between clusters, ensuring a level playing field for young firms and SMEs and an adequate supply of green skills.
- Ensure sufficient funding for green start-ups, in particular through VC.

1.6. Lessons beyond the Netherlands for a green recovery

The "Sustainable transition of the Dutch industry" project provides a comprehensive evaluation of the toolbox of policy instruments in place in the Netherlands to reach its long-term decarbonisation objectives in the manufacturing sector. Many countries around the world have similarly recently committed to achieve net zero carbon emissions by 2050 as part of the global effort to slow global warming and meet the goals of the Paris Agreement on climate change, and are in the process of designing the set of policy instruments needed to reach this objective. As they embark on this journey, countries can benefit from learning from each other and exchanging knowledge and experience on their different roads towards carbon neutrality.

Dutch industry has some clear specificities – a concentration of industrial emissions in four main sectors, an industrial organisation centred around large firms and geographical clusters – and some of the policy recommendations coming out of this analysis focus on the particular design of domestic policy instruments. Yet, the four main sectors in the Netherlands share many characteristics with sectors in a large number of countries, particularly in Europe: being highly competitive, specialised in products that are highly traded internationally and responsible for significant GHG emissions, closely integrated in global value chains and in the European free trade area, relying on a highly skilled workforce, a dynamic venture capital market, etc. As such, the Netherlands faces similar challenges to many other nations around the world: achieving the low-carbon transition of industry while preserving competitiveness, avoiding carbon leakage, limiting the distributional impacts of climate policies, and promoting the emergence of future leaders in green technologies. The Netherlands, like many other countries, does not start from a blank page, but has long experience in carbon pricing and technology support. The challenge ahead is to retrofit this extensive policy package to ensure that it will effectively put industry on the path to carbon neutrality.

In this respect, what lessons can be drawn from the Dutch case for other countries? First, the Netherlands can serve as a good example of the necessity of a two-sided approach that combines ambitious technology support with a strong commitment to raising carbon pricing, developed in consultation with the relevant stakeholders. Investment support is not sufficient and needs to be accompanied by clear trajectories of gradually increasing carbon prices over the next decades, to establish a level playing field and make the business case for a low-carbon transition. The design of the Dutch carbon levy is particularly interesting in the context of the ongoing COVID-19 pandemic, with the new carbon pricing mechanism imposed in practice only well into the recovery period due to the increasing price path and a levy base that phases in gradually over time. Such a design can provide forward guidance to investors and reduce uncertainty without immediately imposing new taxes on businesses in a context of high uncertainty over short- and medium-term demand and liquidity (OECD, 2020[21]).

In this context, forthcoming post-COVID stimulus packages may orient investment towards sectors and technologies that accelerate the low-carbon transition, and improve resilience to future shocks from climate change, but they will be much more effective if accompanied by a well-designed carbon price. Carbon pricing will also direct investment towards low-carbon options resulting from stimulus packages that are conditional on green objectives, (OECD, 2020[21]).

The way in which the Climate Agreement was designed – in close co-operation with stakeholders, including industry – can also serve as a model insofar as it increases acceptability of politically difficult carbon price reform and, therefore, the credibility of the policy package. This close co-operation with stakeholders may be relatively easy in a small country like the Netherlands, with an industrial organisation centred on large firms and geographical clusters, but might also work at the regional level for larger countries.

Second, the design of the Dutch technology support policy toolbox clearly reveals the fundamental trade-off between short-run cost-efficiency and the need to switch in the longer run to radically new technologies, such as hydrogen. Technology neutrality and competitive tenders for carbon abatement projects are economically efficient and can ensure least-cost decarbonisation in the short run, but they favour technologies that are close to the market and, in the particular case of CCS, risk locking the industry into high-carbon processes rather than inducing the switch to more radical carbon-free alternatives. This calls for a balanced approach, whereby both emerging and mature technologies are supported. Mature technologies should not crowd out emerging technologies from public support, and the support to mature technologies should be regularly reassessed and removed as soon as they are competitive with fossil fuel-based alternatives. In this respect, carbon pricing helps mature technologies become cost-competitive more rapidly and enables focusing public support on technologies that are further away from market. For emerging technologies, framework conditions (such as reactive regulation, market creation, etc) are effective complements to public support.

Third, **the Dutch policy landscape perfectly illustrates the pervasiveness of competitiveness concerns related to carbon pricing**. All carbon pricing instruments (carbon levy, European carbon market, energy tax and energy surcharge) include competitiveness provisions which grant extensive preferential treatment to energy-intensive users – particularly in the chemicals, refineries and basic metals sectors. They take the form of tax exemptions, regressive tax rates, levy dispensation rights, and freely allocated emission allowances. This naturally erodes the carbon pricing signal, reduces the cost-effectiveness of the policy instrument and generates equity concerns as small firms typically face much higher energy and carbon prices than large incumbents. **Strong financial support for low-carbon technology adoption should be seen as an alternative, not a complement, to providing generous exemptions to energy-intensive industry, and allow governments to gradually remove such preferential treatments that are standing in the way of long-term decarbonisation**. The convergence of climate policy ambitions at EU level and beyond – notably among large emitters from the developed and developing world alike – is another justification for removing these exemptions. With all eyes now on COP26, the Dutch case study is a reminder of the importance of setting mutually agreed and convergent ambitious climate targets that alleviate short-run competitiveness concerns and get the industry sector ready to compete in the long run, net-zero carbon world.

Fourth, the Dutch situation underlines the value added of supra-national co-ordination and investments, in particular at the European level. This is particularly relevant for infrastructure critical to ensure transportation of hydrogen (e.g. standards are required on the origin and purity), captured carbon, and electricity across borders, notably within Europe. Beyond the cross-border issues related to carbon pricing and infrastructure, the global nature of climate change and the significant investments that it requires call for a mutualisation of the effort. For instance, the scale of investment needed and the size of typical retrofitting and demonstration projects imply that the green transition of industry can best be tackled at the European Union level, through the mobilisation of large financial resources, permitted for example by IPCEIs or the Recovery Plan for Europe (EUR 1.8 trillion, approximately one third of which is dedicated to the fight against climate change).

Finally, the Netherlands' case is a reminder that, as a structural transformation, the low-carbon transition requires the alignment of policy frameworks well beyond the core climate policy toolbox. Fit-for-purpose and reactive regulation, able to adapt swiftly to new technology developments, is a necessary pre-condition for the creation of a zero-carbon, circular and resource-efficient economy. Competition and entrepreneurship policies play a critical role to encourage business dynamism, the creation of new innovative firms and the reallocation of resources toward the most resource-efficient firms. Education, skills and science policy are necessary to make sure that industry can rely on the right set of skills and that new research into low-carbon technologies does not have to come at the expense of the development of other productivity-enhancing innovations. Investment and finance policy can support the transition by ensuring that financial resources flow to start-up businesses that can offer solutions for the decarbonisation. An efficient and cost-effective shift to a low-carbon economy thus requires the engagement of many parts of government beyond those traditionally mobilised in the development of climate change policies, possibly through a mission-oriented strategy.

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Notes

[1] Mission-oriented strategies are defined as a "co-ordinated package of […] measures tailored specifically to address well-defined objectives related to a societal challenge, in a defined timeframe. These measures possibly span different stages of the innovation cycle from research to demonstration and market deployment, mix supply-push and demand-pull instruments, and cut across various policy fields, sectors and disciplines." (Larrue, 2020[23]).

[2] In this report, the industry corresponds to the manufacturing sectors (NACE Rev. 2 10-33).

[3] Source: Eurostat, energy supply and use by NACE Rev. 2 activity.

[4] These include Tata Steel, Shell Refinery, Shell Chemistry, BP, Zeeland Refinery, Chemelot Site Permit, Esso, Dow, Yara Sluiskil, Air Liquide, and ExxonMobil.

[5] The manufacturing sector as a whole represents 22.9% of output and 44.2% of exports in the Netherlands. In Germany, the numbers are respectively 33.0% and 69.9%. In the EU-27, 27.3% and 59.6%.

[6] Scope 3 emissions are currently not taken into account in climate policies (in the Netherlands or elsewhere), and need to be addressed internationally as part of ongoing climate negotiations.

[7] The terms ODE and surcharge are used interchangeably.

[8] Pricing instruments that are fuel specific (e.g. energy tax and surcharge on natural gas) or that target emissions directly (e.g. EU ETS) effectively put a price on carbon emissions. However, the Dutch electricity tax and the surcharge on electricity do *not* differentiate by type of fuel and their carbon content but apply on kWh electricity consumed. The latter are therefore not considered a carbon-pricing instrument and not taken into account in effective carbon rates. They are instead discussed under effective electricity pricing.

[9] Dispensation rights are allocated to carbon-efficient facilities defined on the basis of EU ETS benchmarks. Although some relatively inefficient firms will be short of dispensation rights early in the process, they can most likely acquire those rights at negligible costs due to the large amount of excess dispensation rights in early years that are not bankable, thereby losing their value for future trading periods. Eventually, only few of the most carbon-inefficient facilities will be exposed to a significant price in early years.

[10] An energy tax and ODE also applies on electricity use in the Netherlands. These are not considered a carbon price, because rates are not differentiated by energy source, but apply per unit of electricity used. Therefore, they increase the price on all energy sources used for electricity generation irrespective of their carbon content. Both are discussed below under electricity pricing.

[11] The OECD Effective Carbon Rate estimates the total price that applies to carbon emissions from fuel use as a result of market-based policy instruments: carbon taxes, specific taxes on fuel use (primarily excise taxes) and emissions trading systems (OECD, 2018[17]).

[12] The latter approach is rooted in the idea that freely allocated allowances retain CO_2 abatement incentives at the margin due to the opportunity cost (the allowance price) that they entail.

[13] For example, Neuhoff et al. (2016[22]) propose to combine an ETS and free allocation with excise taxes on carbon intensive products, where the excise taxes rate is derived from the product benchmark. The idea is that permit prices provide a marginal incentive to improve the carbon efficiency of existing products and that the excise taxes encourage the consumption of more carbon efficient goods.

[14] Average annual public RD&D support to CCUS and hydrogen was respectively EUR 15.5 million and EUR 4 million over 2004-10, against EUR 1.8 million and EUR 1.9 million over 2011-18. There was no public funding for either technology before 2004 (IEA, 2021[24]).

[15] These two technologies, however, are also those that generate the highest political resistance.

[16] The maximum budgeted expense on SDE++ subsidy for CO_2 reduction in industry increases from EUR 50 million in 2022 to EUR 550 million in 2030 for a total of EUR 2.675 billion over the 2022-30 period, or about EUR 300 million per year on average. Whether these amounts are structural remains subject to uncertainty due to current discussions regarding ODE reforms, and the need to fund more expensive abatement in other sectors in the long run.

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